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**TRAINING ENHANCEMENT FOR COMPLEX
MILITARY INFORMATION TECHNOLOGY SYSTEMS
THROUGH ARCHITECTURE REVIEW**

by

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September 2018

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TECHNOLOGY SYSTEMS THROUGH ARCHITECTURE REVIEW**

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ABSTRACT

Technological advances bring an increased need for training. Military programs have difficulty providing adequately for increased training in a cost-effective manner via traditional methods. This research examines if improvement in military training is possible through identification of commonalities in complex information technology system architecture. Geographic Information Systems are used as a representative example of a complex system. An architecture review is conducted for physical and functional comparison, and a qualitative review of training success factors is applied to an extrapolated common architecture. This research indicates that training to a common architecture framework does not significantly depart from training to individual Geographic Information Systems with respect to knowledge retention, but it does allow for more flexibility in development and deployment. Continuing research with a quantitative analysis and exploring the applicability of this concept to other complex systems is recommended.

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LIST OF ACRONYMS AND ABBREVIATIONS

ADDIE	Analyze, Design, Develop, Implement, and Evaluate
CAD	Computer Aided Design
DoD	Department of Defense
ESRI	Environmental Systems Research Institute
GIS	Geographic Information System
ID	Instructional Design
ISD	Instructional Systems Design

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EXECUTIVE SUMMARY

Along with technological advances comes an increased need for training, and military programs may have difficulty providing this training adequately in a cost-effective manner. This research examines if identification of commonalities in complex information technology system architecture could result in improvement in military training. Geographic Information Systems are used as a representative example of a complex system.

This research indicates that training to a common architecture framework does not significantly depart from training to individual Geographic Information Systems with respect to knowledge retention but does allow for more flexibility in development and deployment. Training to a common architecture framework supports a new approach to information system training delivery with generalized training preceding shorter, application-specific training. This approach supports more exposure to stakeholders due to the decreased time for delivery of generalized training and decreased requirement for stakeholder expertise within the generalized session. With this knowledge, concluding that cost would be reduced is reasonable due to the shortened length of training and lack of duplication of effort in developing training for common information across multiple complex systems. Continuing research with a quantitative analysis and exploring the applicability of this concept to other complex systems is recommended. Results are obtained through a structured approach of architecture review following by a qualitative training applicability review.

An architecture review is conducted for physical and functional comparison. The architecture review begins with an effort to scope what this research will consider Geographic Information Systems. Concepts gained from literature and tool applicability lead to a definition of Geographic Information Systems of a capability which allows users to import, conceptualize and manipulate location-based data to transform it into exportable information products to answer specific questions. The physical and functional architectures for four candidate Geographic Information Systems are compared to the definition, leading to the expulsion of one candidate because it did not fully support the

definition. The physical and functional architectures of the three remaining Geographic Information Systems, along with process for critical functionality, were compared and a common architecture framework was developed. Commonality is high within the functional architecture, but less so with the physical architecture. As a result, only portions of the physical architecture could be included in the common architecture framework developed. All four critical processes show sufficient similarity to constitute inclusion the common architecture framework.

A qualitative review of training success factors is applied to the extrapolated common architecture framework. The concepts of Instructional Design, training motivation factors, and similarity paradigm are evaluated as part of the qualitative review. The common architecture framework for Geographic Information Systems supports the Instructional Design methodology with a structured and linear approach to training package development. Motivational factors for common architecture framework are lacking but do not vary widely from training to specific applications. The high degree of similarity of inputs and responses in the Geographic Information Systems common architecture framework to that of the individual candidate Geographic Information Systems candidates leads to an expectation of a high degree of knowledge transfer and retention in the areas where those similarities exist.

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I. INTRODUCTION

A. BACKGROUND

Technology continues to advance rapidly as it has since the development of the computer. Computing devices continue to become smaller and increasingly more complex. Military systems are required to adapt and incorporate complex software and firmware to maintain technological relevance. The President of the United States is leaning forward on technological advances, publishing the following in the National Security Strategy, “To maintain our competitive advantage, the United States will prioritize emerging technologies critical to economic growth and security, such as data science, encryption, autonomous technologies, gene editing, new materials, nanotechnology, advanced computing technologies, and artificial intelligence” (Trump 2017, 20). To incorporate emergent technologies in a fiscally responsible manner, the Department of Defense (DoD) must develop mature methods for generating and maintaining increasingly complex systems.

Sustainment of complex systems includes continued development and procurement efforts. Aging systems must maintain relevance, be secure, and provide training efforts to maintain user proficiency. This research will focus on training efforts necessary for proficient user operation. With increased complexity, additional user training is required to ensure proper understanding of system operation. This concept of additional training is not new; previous research into implementation of technological advancements indicates that “it does little good to invest in computers, numerically controlled machines, tools, or other sophisticated devices if a skilled work force is not available to operate and maintain them” (Swanson 1987, 7). The need for more robust training is apparent; however, DoD programs experience difficulty in adequately responding to this need due to schedule and budgetary constraints. The revelation that “there are gaps in training” (Department of the Navy 2017, 1–2) has renewed focus on the development and implementation of training. A Navy budget brief highlights an initiative with pilot programs, which began in 2017, “to create a new way of training our Sailors through mobile, modularized learning, re-engineering content, and a distributed Learning Continuum IT infrastructure” (Department

of the Navy 2017, 2–2). The identified goal of this pilot program is to “increase the tempo and efficiency” and “adapt our processes to be receptive to innovation and creativity for the individual, the team, and the institution” (Department of the Navy 2017, 2–2).

Complex naval systems are required to operate in the arenas of air, land, and sea. Each deployment arena brings different system environmental and information requirements. The functions of processing and acting on acquired information are implemented differently for different domains. For example, a pilot receives information from a dashboard of electronics, visual input from the surrounding area, and auditory input through a headset. More complex aircraft will require the pilot to process an increasing number of inputs. The training method of simulation is used in a pilot-type scenario (Strachan 2011). Highlights from the Fiscal Year 2018 Department of the Navy Budget directs “improvements to training will include employing gaming technology, simulation environments, virtual reality, modular training, and mobile environmental training” (Department of the Navy 2017, 2–2). Virtual reality and gaming simulation methods are applicable to systems such as aircraft, but they may not be applicable for systems that require operators to sit at a computer terminal and convolve and analyze data. Training structures and methods applicable to information technology systems will be reviewed in this research to determine if efficiencies can be gained from training to a common functional architecture.

B. ARCHITECTURE STUDY APPROACH

In this research, information technology systems are defined as systems that require operators to obtain and review information inputs from numerous sources, convolve and analyze the data, and provide a report. Information technology systems can contain multiple suites of software tailored to specific mission requirements. While software use differs based on mission requirements, similar functions performing in similar software applications on disparate systems is anticipated. In addition, these similar software applications having a set of common functions that are used to perform mission requirements, irrespective of the mission is probable. Construction of separate training programs for each software application that shares functionality with other applications is

inefficient. This research examined if common functions and workflows were identifiable in similar software applications. A functional decomposition was performed on multiple similar software applications. Where similarities exist, a decomposed view of common functions was developed, and an evaluation was performed to determine if this common architecture could improve training efficiency. The concept behind this approach to training efficiency was for trainers to develop introductory instruction at the common functional architecture level, with tailored, mission-specific and application-specific training conducted as needed with a subset of personnel. For success of this approach, individual application physical architecture had to have associations to the common functional architecture. As an example, a common architecture could identify an “Export” function while an individual software application could have a “Send” button to accomplish that function. A common functional architecture was included in this research where obtained.

To scope this research, the Geographic Information System (GIS) construct was used as a representative example of a complex system. A comprehensive definition of a GIS was developed to guide criteria for inclusion of applications in this evaluation. Multiple GIS definitions were reviewed to determine common elements of a GIS application. Once a definition was determined, it was used to develop the IDEF-0, or top functional model, for the GIS application. In this IDEF-0 diagram, inputs, outputs, controls and mechanisms were identified. The IDEF-0 model was used as the basis for evaluation of applications to ensure that they met the basic requirements of a GIS application prior to further analysis.

Multiple candidate GIS applications were reviewed to identify if common functions and processes exist. The physical architecture of each GIS application was documented. A functional diagram was extrapolated from the physical architecture of each application. The functional components identified in the functional architecture were used to develop action diagrams detailing the process for completing basic activities in each application. Once functional and action diagrams were defined for each GIS application, they were compared to determine where common elements existed for construction of a common functional architecture. A common functional architecture was developed where possible.

C. TRAINING APPLICABILITY REVIEW

Where a common functional architecture was constructed, an evaluation of training applicability was conducted. The evaluation of training applicability began with a review of basic learning theories. An overlay of learning theories on the common functional architecture supported evaluation of transfer of training, and inevitability, a retention of knowledge. A training environment that is like the actual-use environment is critical for knowledge retention (Osgood 1949). The further training departs from the real-world physical environment, the less effective the training (Human Systems Integration Program Naval Postgraduate School 2014; Osgood 1949). The Instructional Systems Design (ISD) model was used to determine if the developed common functional architecture is sufficiently robust to meet user needs. This research did not include construction and delivery of training, but only a qualitative review of attributes for the training methods and potential course content. The output of the ISD research consisted of information which was used to determine how closely the common architecture training mirrored the real-world environment. The correlation to the real-world environment was used to generate similarity factors which were used to support a transfer of training evaluation. In addition, motivational factors were assessed. Following the assessment, the common architecture training approach cost and schedule implications were summarized.

D. RESEARCH STRUCTURE

This research is organized into four chapters in addition to this introductory chapter. The second chapter consists of scope definition and an architecture review. The scope of a GIS is defined through evaluation of literature, context development, and functional decomposition. The following architecture review evaluates GIS physical and functional architectures and processes to determine if the applications referenced meet the determined scope requirements. At the close of the second chapter a common GIS framework consisting of physical and functional architectures and processes is provided. The third chapter consists of an evaluation of the suitability of training the common GIS framework developed in the second chapter. Within the third chapter training development methods are considered, as well as motivational factors and transfer of training. The close of this

chapter identifies the degree of knowledge retention expected to be associated with the common GIS framework developed in the second chapter. The fourth chapter is a review of the results of architecture research and training research and provides a recommendation for the approach of common GIS framework training. The fifth chapter identifies potential areas for future research.

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II. GIS ARCHITECTURE REVIEW

A. GIS SCOPE

1. Literature Review

The first step in evaluating Geographic Information System (GIS) commonality is to develop a comprehensive definition of a GIS. Prior to analysis, candidate GISs will be evaluated against the definition to confirm that they are, in fact, GISs. GISs have applicability to several industries (Tomlinson 2013; Galati 2006), and as a result, there is little consensus on a comprehensive GIS definition.

A quick Internet search for “what is GIS?” provides a multitude of different responses. In one instance, a GIS is described as “a system designed to capture, store, manipulate, analyze, manage, and present all types of geographic data” (Board of Regents of the University of Wisconsin System 2018). In another, a GIS is “a system that collects, displays, manages and analyzes geographic information” (GIS Geography 2018). Other results from the basic Internet search which are more abstract describe a GIS as “merely a tool” which “allows you to visualize your data as a map” and “allow us to ask complex questions—or ‘queries’” (MangoMap Limited 2017). Additional definitions offered by manufacturers of GISs denote a GIS “is designed to store, retrieve, manage, display, and analyze all types of geographic and spatial data” (Caliper Corporation 2018) and Galati references the Environmental Systems Research Institute’s (ESRI’s) definition of a GIS as “a collection of computer hardware, software, and geographic data for capturing, storing, updating, manipulating, analyzing, and displaying all forms of geographically referenced information” (Galati 2006, xx). In reviewing these definitions, similarities are apparent, but commonality is not.

There is also disparity in definitions among scholarly sources. In one instance, a GIS is defined as “a central repository of and analytical tool for geographic data collection from various sources” in which users can “overlay the information from these various sources by means of themes and layers, perform comprehensive analysis of the data, and portray it graphically for the user” (Galati 2006, xx). With this definition, the stated end

goal is that “geographic data are transformed into geographic information” (Galati 2006, 3). Previous research acknowledges that “modern GIS technology has transformed spatial data-handling capabilities” and that a GIS is focused on “information that identifies the geographic location and characteristics of natural or constructed features and boundaries on the earth” as noted by Masser (1998, 5) citing the Executive Order of the President in 1994 Section 1b. Another statement identifies a GIS as “a complex system of interrelated parts, and at the center of this system is a smart person or team of people who understands the whole” (Tomlinson 2013, 1). More specifically, Tomlinson states that “geographic information systems integrate seemingly disparate information quickly and visually, which facilitates communication, collaboration, and decision making” and that “through GIS, geography is actually becoming an organizing tool” (Tomlinson 2013, xix). This discussion shows that some consider a GIS as software, others consider it to be software and hardware, and others consider it to be application of user resident knowledge. Through review of the definitions, the revelation that each stakeholder has a different understanding of GISs becomes evident. Developers of GISs appear to view GISs in the frame of elements required to support functionality of a GIS and users tend to view a GIS in the frame of the information it can provide. Both views are important and are considered during context generation.

2. Context Generation

With disparity in the definition, detailing the context of a GIS is helpful. Detailing attribute location as inside or outside the GIS context boundary will ensure the GIS description developed is comprehensive, sufficiently descriptive, and not overly restrictive. Ensuring that the GIS context boundary does not confine its application to a specific use case or area is important. The GIS context boundary also needs to be specific enough to restrict the GIS definition to exclude other, more general, visualization software such as Computer Aided Design (CAD). Input and output description allows external functions and actions to be distinguished from internal ones.

Based on the definitions, candidates for GIS inputs are geographic data, geographic information, spatial data, geographically referenced information and disparate information.

Combining some of these terms into a more generic form for context description is possible. Location reference appears to be a common theme within the input candidates, which is logical due to the geographic nature of a GIS. Multiple GIS definitions make the distinction between raw geographic data and geographic information (as manipulated data), so this research will also maintain the distinction. To maintain this distinction, location-based data will be one GIS input. One GIS input that is not detailed explicitly in any of the definitions is that a GIS requires a question. Gathering and manipulating location-based data is not beneficial unless there is a defined question or goal for which an answer is desired. As such, the second and final inputs for the GIS context boundary used in this research is questions.

Candidates for GIS outputs are geographic data, geographic information, maps, query source, graphical display, and visual information display. As mentioned, the distinction between geographic data and geographic information will be maintained. The main question when evaluating the concept of geographic information with respect to the GIS context boundary is whether geographic information is an output or whether geographic information is simply used to develop GIS outputs. The presence of geographic information on maps or other graphical displays as outputs is understood, but this research assumes that the GIS output is more than geographic information. Likewise, the GIS output is more than a simple map. As such, information products will be an output for the GIS context boundary generated in this research. The generalized term “information products” could include a map combined with geographic information for a visual display but could also include other outputs such as reports. With respect to the output of a query source, information products can be the source of a query. To maintain consistency with the input of questions, the second output of the GIS context boundary in this research is answers. Figure 1 describes the high-level inputs and outputs for a GIS.



Figure 1. GIS Inputs/Outputs

The next step for generating a comprehensive GIS definition is to use the definitions to determine the functions and actions that occur within the GIS context boundary. Within the GIS context boundary, location-based data turns into information products and questions turn into answers. Re-visiting one key input generalization is necessary at this point. The input data can be from any source and does not need to be previously associated. This idea is important since information products are manipulated location-based data, with the main manipulation being the development of associations among the location-based data. Inside the GIS context boundary disparate location-based data is associated to answer questions, the output being information products.

Several of the definitions provided discuss more of what a GIS is used for than what its functions are. For a GIS to change data into information, the data must be manipulated in some way. As shown in Figure 1, location-based data is inputted into a GIS. It follows that from this input the data needs to be stored so it is available for retrieval and manipulation. In addition, to provide information products as an output, the GIS must have an export capability. For manipulation to take place, there must be mechanisms for users or operators to conceptualize, interface with, and change the data. Visual conceptualization, although possibly the most readily accessible conceptualization method, is not the only means of conceptualization. Therefore, conceptualization of data is not limited to visualization for the purposes of defining a GIS in this research. User interaction with data is necessary, and therefore the user is internal to the GIS context boundary. There are several other factors, such as scale and data format, which contribute to the ability to turn location-based data into information products. These other factors, while important, are

challenges that must be overcome while using a GIS and therefore are not included in the high-level context. Figure 2 provides the GIS context boundary depicting internal functions and internal users.

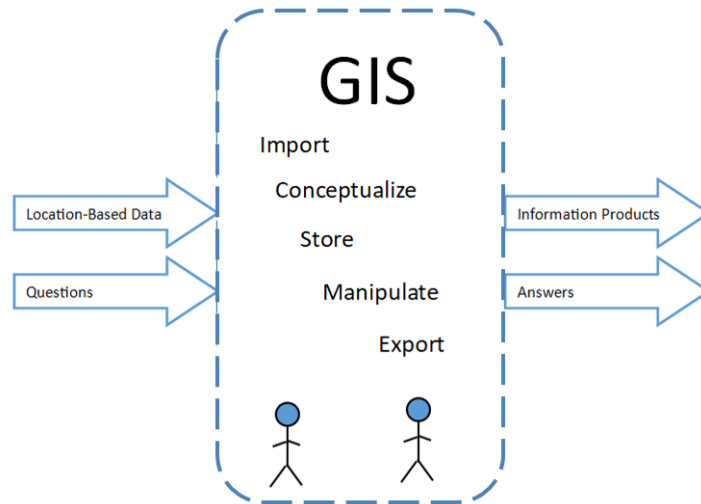


Figure 2. GIS Context Boundary

3. GIS Definition

With the GIS context boundary, inputs, and outputs defined development of a comprehensive definition of a GIS is possible. Users are included in the GIS context boundary because user interaction is required for inputs to be transitioned into outputs. Including users within the context boundary introduces the need for human-machine interface analysis. Candidate GISs which are included in this research are existing commercial products. A review of interface tradeoffs and shortfalls is helpful for a real-world scenario where GIS products can be changed to better support manpower and personnel needs, but this analysis is outside the scope of this research. Scoping of the GIS definition to exclude human-machine interface factors produces a definition of a GIS which identifies user interaction as a mechanism for GIS function.

For the purposes of this research, a GIS is defined as a capability that allows users to import, conceptualize and manipulate location-based data to transform it into exportable information products to answer specific questions. This definition is exclusive of CAD and

other visualization products in that it is specific to location-based data. The definition is also general enough not to limit the capability solution to a hardware or software tool. With the general definition provided, the GIS capability could be achieved through a verbal or physical protocol, although visual representation of GISs are most common. This definition includes the top-level functions within the GIS.

4. Functional Decomposition

The GIS definition and context boundary developed previously are used to generate the IDEF0 and functional decomposition for the generic GIS. The IDEF0 and functional decomposition in Figure 3 and Figure 4, respectively, include the main functions detailed in the GIS context boundary and facilitating functions, respectively.

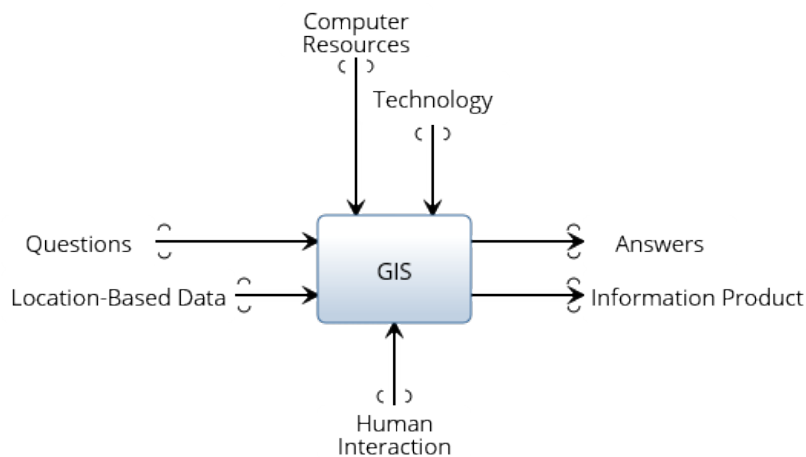


Figure 3. GIS IDEF0 Diagram

The GIS IDEF0 Diagram purposely looks like the context. The main difference is the addition of constraints to the GIS. As mentioned in the commercial definitions, a GIS can include hardware and software. Increased compiling power requires increased hardware processing capability. This is an example of a resource constraint. Technology is also a constraint. For a visually impaired person, a physical GIS interface may be most appropriate, however technology may not be available to support physical interaction. This is a technology constraint.

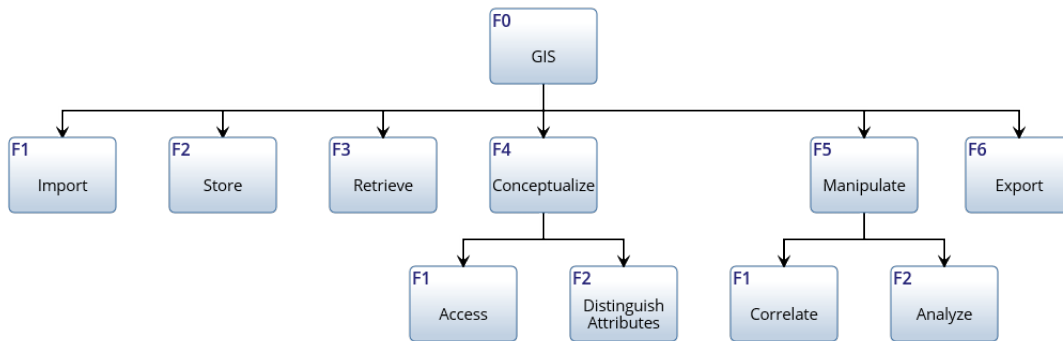


Figure 4. Generic GIS Functional Decomposition

The conceptualize function is decomposed further to denote the ability to access information. The access function can be accomplished through any form of perception, including visual, physical, or auditory. To conceptualize the data, different data sets must also be distinguishable. With respect to a GIS, manipulation of the data requires association to be made between the data. The major association made is through location, but for meaningful information to be generated additional associations are necessary. The correlate functional component encompasses the ability to make associations. The analyze functional component encompasses the ability to generate information products from location-based data.

B. ARCHITECTURE REVIEW

Several applications claim to be GISs, but some may not align to the definition obtained in the previous section. The generic GIS functional decomposition will be used to evaluate applications for inclusion in analysis of common architecture and processes. If applications are determined not to be GISs, they will be excluded from the process analysis to follow. First, the physical architecture of the candidate GIS applications will be documented. The documented physical architecture will then be used to generate a functional decomposition of the candidate GISs. The candidate GIS functional architectures will be compared to the derived generic functional decomposition and use cases to determine if the candidate is, in fact, a GIS.

1. GIS Candidate Physical Decomposition

Four candidate GISs were reviewed. As with a word processor or other complex system having the ability for customization through extension programs, the GISs evaluated are highly customizable. Unlike word processors, the location of internal windows or screens within the GISs are also highly customizable. The ability to add or remove functions and create a custom visual environment is a beneficial capability for the user, but quickly becomes unnecessarily complicated to document. New users typically do not explore customization (Nielsen 1993), and as a result documentation of customization option similarities are not explored in this research.

For this research, the physical layout of the candidate GISs are described using three distinct classifications. The first type of classification is a Container. The Container classification is used to describe a panel, frame, window, group, area, or general section of the GISs. Containers can be visible and accessible to the user, or can be supporting, background structures of the candidate GISs required for operation. Containers are used to generalize the location of Physical Components. Physical Components, the second classification type, are buttons, selections and interface points (where a user makes a request and the candidate GIS provides a response). Physical Components are distinguished by the function. Data Display is the third classification type. Data Display is a visual representation to the user of metadata and/or data. The method of Data Display to the user can be either textual or graphical.

As with a word processor, there are instances where multiple buttons or selection options perform the same function. As an example, the “floppy disk” icon can be clicked to save, or a user can go to the “File” menu and select “Save,” or the user can select the “ctrl” and “S” keys simultaneously on the keyboard (if the keyboard shortcut function is supported by the word processor). If multiple options exist to perform the same function in one Container of the candidate GISs, the function is only documented once in the physical architecture to simplify the presentation. Review of the candidate GISs also revealed that Physical Components performing the same function were labeled differently in different applications. To reduce complexity, physical architecture presentation is simplified

through a library of generic terms. Table 1 provides the list of terms, their attributes, and their classification.

Table 1. Physical Decomposition Terms and Meanings

Term	Attribute	Classification
AI (Application Interface)	The portion of the GIS with which the user directly interfaces. Other portions of the GIS may be available to the user for review or modification, but these actions would primarily occur through the AI.	Container
Database	The physical location and construct where all data associated with the GIS resides. When a user makes a request in the AI, the data is retrieved from the Database.	Container
Panel	Denotes a partition or section within the AI viewing area. Panels can contain buttons or display textual information to the user.	Container
Display	The partition or section within the AI in which primarily non-textual data (such as images) is displayed.	Container
Map	Denotes the base image which serves as the location reference for all additional data.	Data Display
Overlay	Any data which is displayed in a specific reference location on the Map.	Data Display
Navigate	A Panel which primarily contains physical components for functions associated with general file setup, AI arrangement, and troubleshooting.	Container
Content	A Panel which primarily contains textual information concerning maps and overlays.	Container
Manipulate	A Panel which primarily contains physical components for functions associated with direct interaction with data in the display. Data added through Manipulate Physical Components is geographically referenced but is not used for computational efforts; it is only used to enhance understanding of information viewed in the Display.	Container
Retrieve	Accesses the Database and makes the requested data available in the AI. Retrieve includes typical functions such as open and recent documents.	Physical Component

Table 1 (Continued). Physical Decomposition Terms and Meanings

Term	Attribute	Classification
Store	Sends manipulated data to the Database. Store includes typical functions such as save and save as.	Physical Component
Import	Vehicle for data to be added to the Database. Import is different than Store in that the Store Physical Component does not add any data to the Database.	Physical Component
Print	Formats the display for printing. Print includes printing selection windows.	Physical Component
Export	Denotes the capability to tailor the presentation of information for storage, printing, or transfer to other applications.	Physical Component
Scale	Permits changes in the size of objects in the Display. Scale includes zoom in, zoom out, and zoom to a specific location.	Physical Component
Catalog	Allows direct user interface with the Database. Catalog can provide access to only metadata, or metadata and data.	Physical Component
Query	Requests for information based on data. In the physical decomposition, query includes all pre-programmed request functions (such as slope analysis).	Physical Component
Move	Permits movement of objects in the Display. Move includes pan.	Physical Component
Isolate	Selection of a specific subset of data. In the physical decomposition, Isolate includes all Physical Components associated with filtering data, either through the Catalog or the Display.	Physical Component
Attributes	Items unique to a set of data. Attributes includes metadata and data.	Physical Component
Locate	Denotes the Physical Components which allow for computation of data based on location parameters, or the ability for the Display to navigate to a specific point.	Physical Component
Help	A feature for additional general AI and troubleshooting information.	Physical Component
Layers	Separation of data within the AI. One layer is present for each unique data set.	Container
Delete	Removes data from view and computation.	Physical Component
Copy	Adds a duplicate of selected data to the Database.	Physical Component

Table 1 (Continued). Physical Decomposition Terms and Meanings

Term	Attribute	Classification
Visibility	Controls whether data can be viewed in the Display.	Physical Component
View Order	Identifies the order in which the Overlays are shown in the Display.	Data Display
Draw	A group of Physical Components which are used to highlight information on the Display. This function includes the functions of drawing different shapes.	Physical Component
Identify	An index or term provided for data or to denote something in the Display.	Data Display
Splash Screen	An initial viewing window which requires user response prior to proceeding to the AI.	Container
Metadata	Descriptive information about data, but not the data itself.	Data Display
File Type	The format in which the data is stored.	Data Display
Color	Denotes the Physical Components which display and allow modification to the color attribute for groups of data. Data color differentiation is beneficial for distinguishing Overlays in the Display.	Data Display
Data	Geographically referenced information sets.	Data Display

Identification that the candidate GISs have Physical Components or Data Display not captured in the terms is important. A three-dimensional view is an example of a Data Display classification that is not detailed in Table 1. These additional features are associated to functions or information that are not core to the GIS definition provided in the previous chapter and are therefore excluded from the physical decomposition.

The diagrams in Figures 5–18 depict the physical decomposition of the candidate GISs reviewed. Each candidate GIS requires multiple figures to capture the Physical Components and Data Display items identified in Table 1 due to complexity of the physical decomposition.

The top-level physical decomposition diagrams for the four candidate GISs are shown in Figures 5–8. Colors are used to distinguish between Containers within the candidate GISs. The assigned colors are maintained throughout this research to assist with rapid visual queuing of similarities and difference within diagrams.

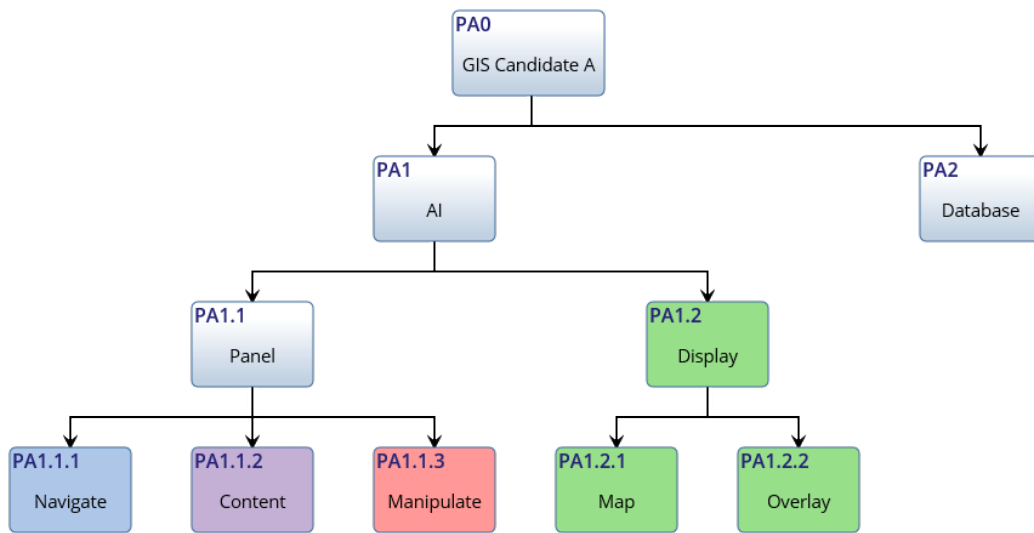


Figure 5. Top-Level Physical Decomposition of GIS Candidate A

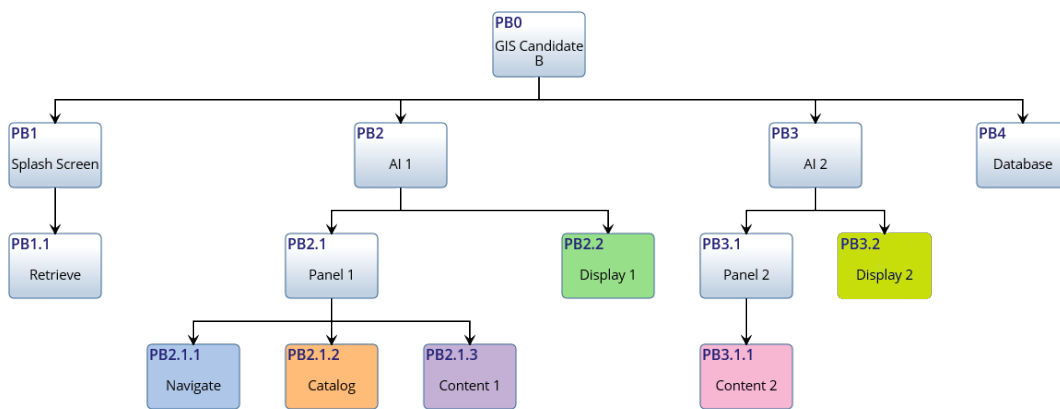


Figure 6. Top-Level Physical Decomposition of GIS Candidate B

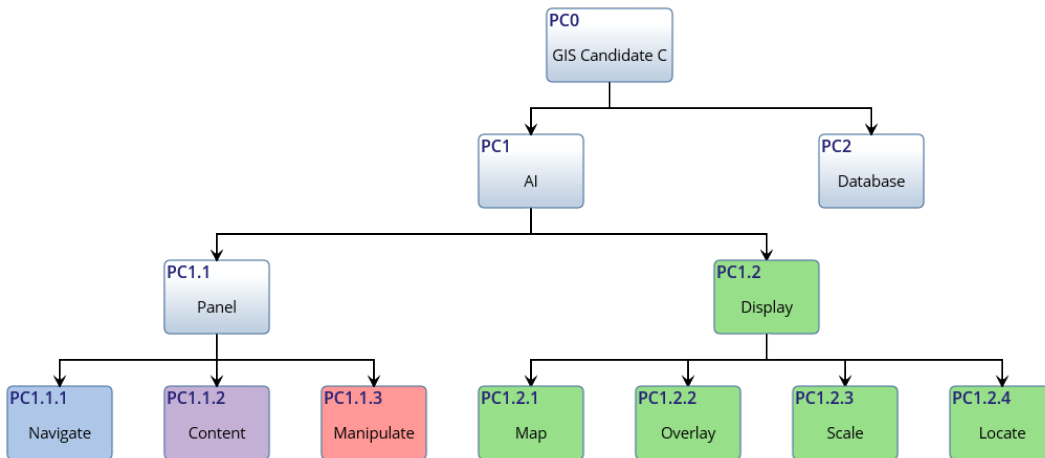


Figure 7. Top-Level Physical Decomposition of GIS Candidate C

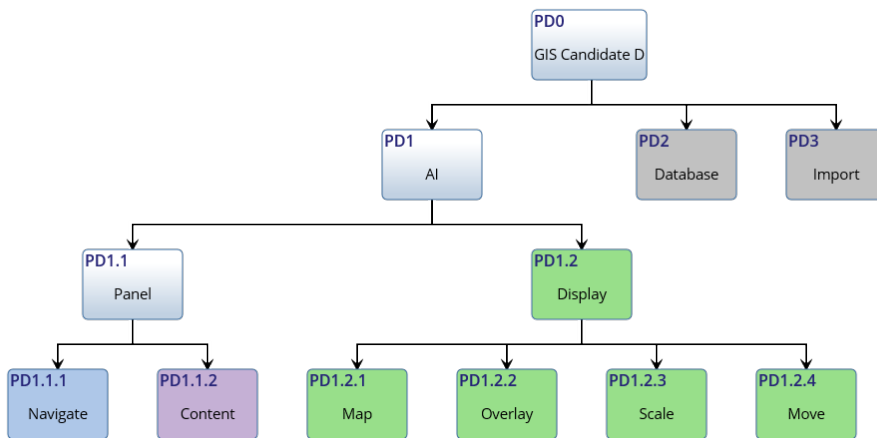


Figure 8. Top-Level Physical Decomposition of GIS Candidate D

A review of Figures 5–8 show that each of the candidate GISs have, at a minimum, an AI and a Database. The AI on all candidate GISs are decomposed into two primary Containers, Panel and Display. These similarities show promise for common architecture development.

The interface for GIS Candidate B is shown to be more complex than the other GIS candidates, consisting of multiple AIs. The AI 2 Container is accessed through the Catalog Container of AI 1, but because it is an entirely separate interface once initiated, it is shown at the same level as AI 1 in the physical hierarchy. The Database Container and Import Physical Component shown in GIS Candidate D are grey in color. Within GIS Candidate D, queries for locational data that produce Overlays in the Display Container can be completed. To support this function, the Database Container must exist. Although query and overlay functionality supports the existence of the Database Container, it is not accessible to the user. The grey color denotes the presence of the Container, but the inability of the user to interact with or alter it in any way. The Import Physical Component is grey in color for similar reasons. While the Import function must exist for data to exist in the database, it is not accessible to the user. Since the user is unable to introduce locational data into the GIS or manipulate data within the Database, it is possible, without completing the comprehensive functional decomposition, to determine that GIS Candidate D does not align to the GIS definition identified earlier in this research. As such, GIS Candidate D will be excluded from further evaluation.

The diagrams in Figures 9–18 show the lower level physical decomposition of the Containers in each of the candidate GISs. Diagrams are grouped by Container to facilitate comparison. The physical decomposition diagrams for the Navigate Container are shown in Figures 9–11.

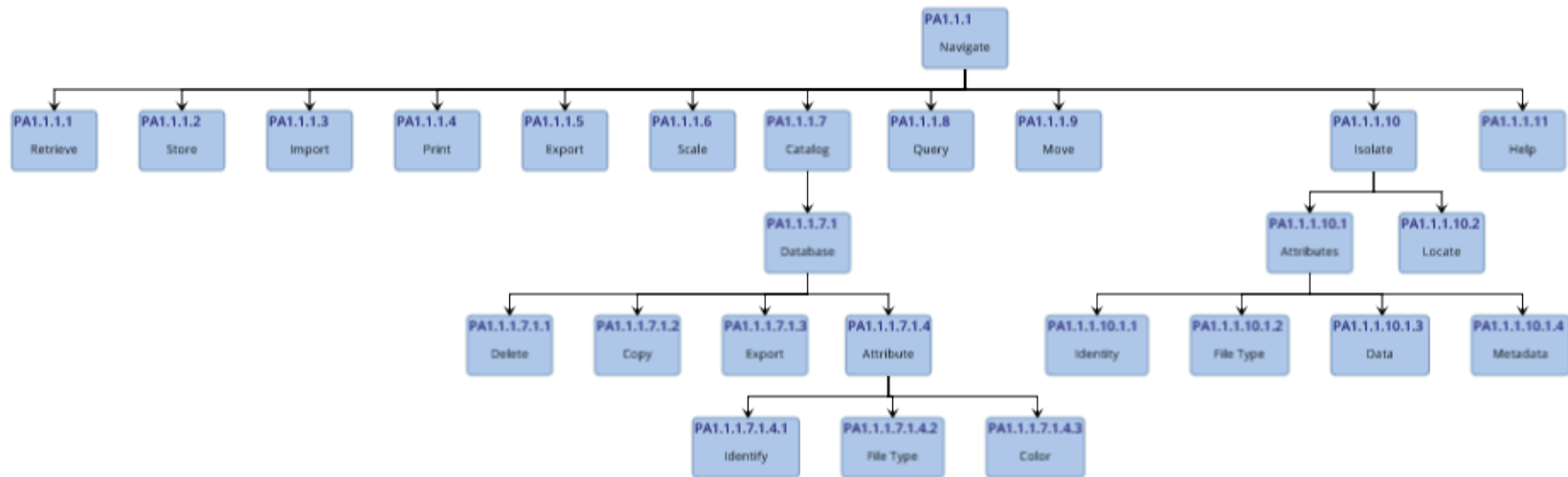


Figure 9. Physical Decomposition of Navigate Panel for GIS Candidate A

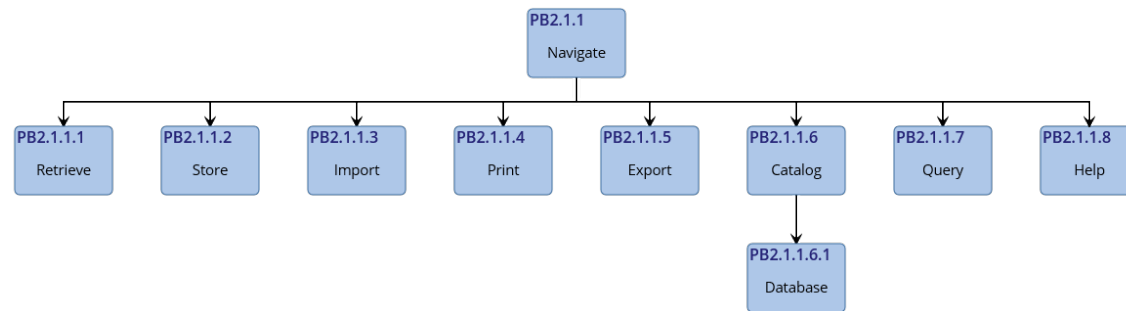


Figure 10. Physical Decomposition of Navigate Panel for GIS Candidate B

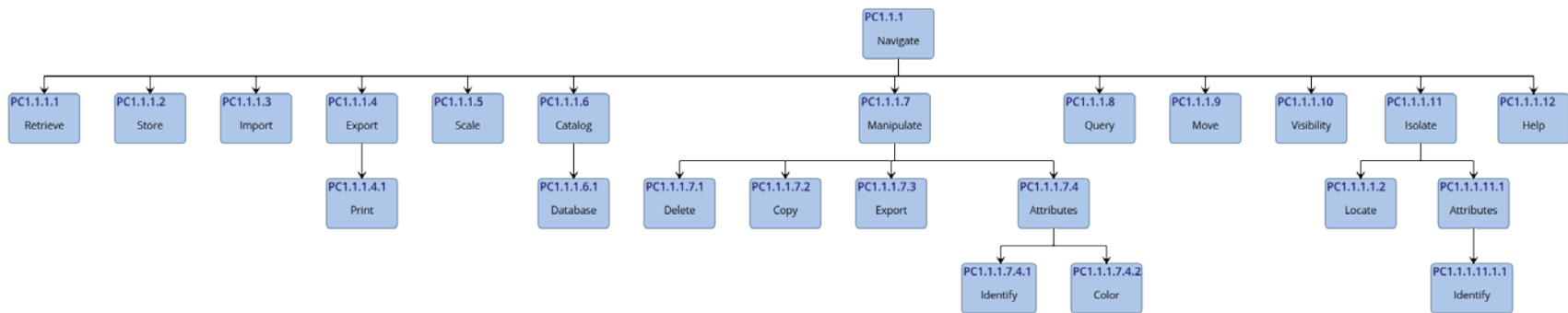


Figure 11. Physical Decomposition of Navigate Panel for GIS Candidate C

The diagrams in Figures 9–11 show increased complexity of the Navigate Panel of GIS Candidates A and C to that of GIS Candidate B. One potential source of this difference in complexity is the addition of a secondary AI Panel in GIS Candidate B. The secondary AI Panel in GIS Candidate B is primarily a Content Panel but also contains Physical Components that are found in the Navigate Panels of GIS Candidates A and C. GIS Candidates A and C also contain the Isolate Physical Component in the Navigate Panel whereas GIS Candidate B does not. The function performed by the Isolate Physical Component is important to management of data sets for analysis, and the difference in location may affect the ability to generate a consistent generalized process for data analysis. GIS Candidate B includes a Catalog Container, shown in Figure 12, that is not found in GIS Candidates A and C. This Catalog Container requires textual commands to be provided to directly access the Database. Although the functionality is present, it will not be discussed further in this research because this feature is for advanced use, which is outside of the scope of this research, and because data interface can be conducted through other means in the AI.

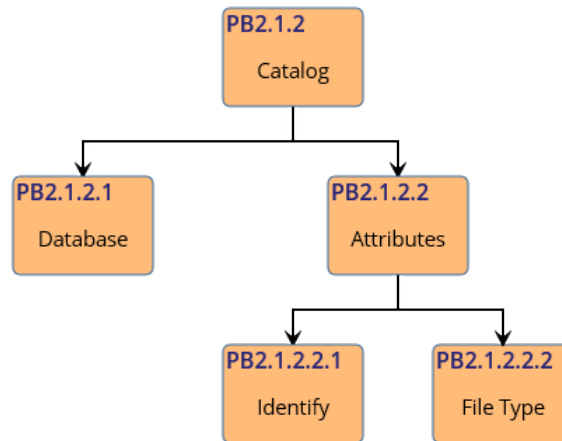


Figure 12. Physical Decomposition of Catalog Panel for GIS Candidate B

Review of Figures 9–12 also shows that there is a high degree of similarity in location of Physical Components which are associated to administrative functions (such as saving and retrieving). High localization of administrative Physical Components may support consistent generalized processes. Generalized processes will be evaluated further in a following section in this research. The diagrams in Figures 13–15 display the physical decomposition of the Content Panel.

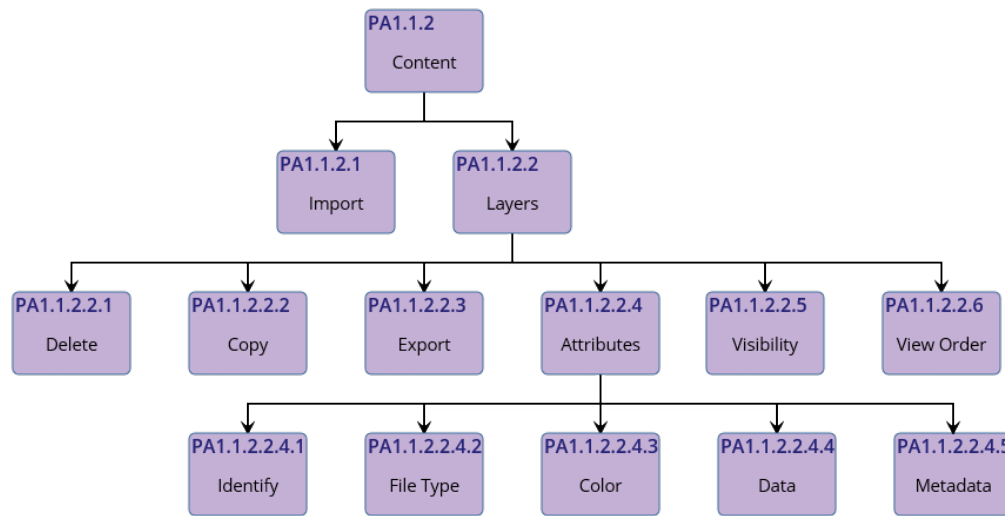


Figure 13. Physical Decomposition of Content Panel for GIS Candidate A

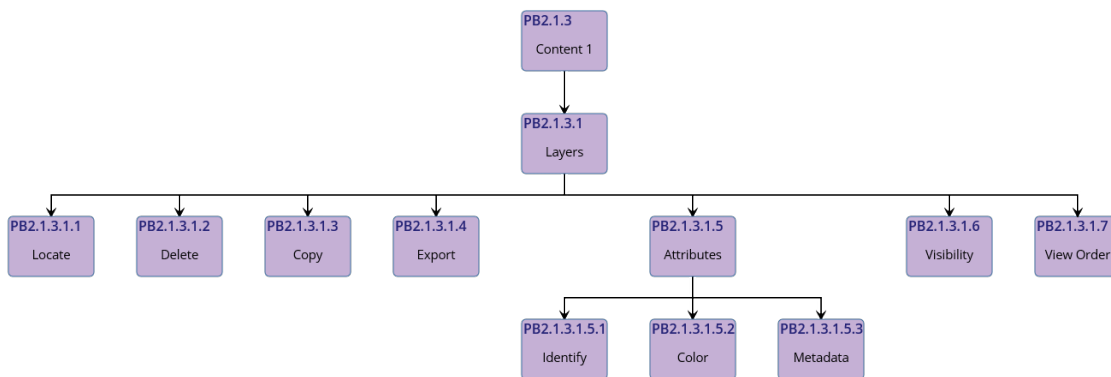


Figure 14. Physical Decomposition of Content Panel for GIS Candidate B

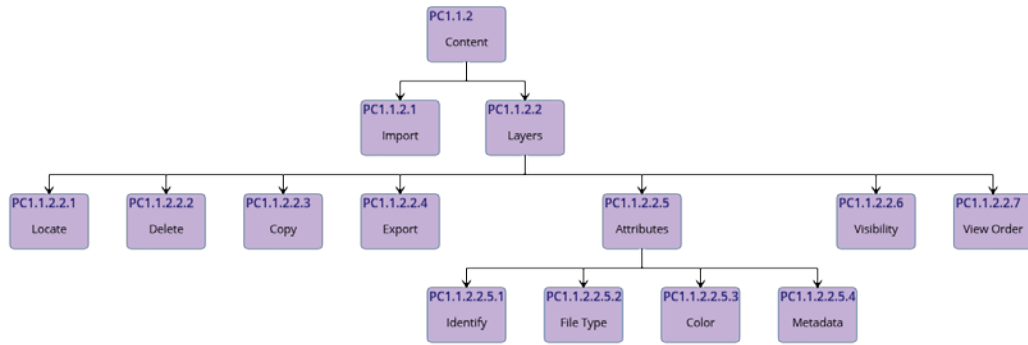


Figure 15. Physical Decomposition of Content Panel for GIS Candidate C

Again, GIS Candidates A and C have an increased level of similarity to each other than with GIS Candidate B when evaluating the initial instantiation of the AI (AI 1). Review of Figure 16 shows that GIS Candidate B Content Panel similarity to GIS Candidates A and C increases when using AI 2. With the Layers Container and Import Physical Components contained within the Content 2 Panel in AI 2, the Content Panel display is more similar to GIS Candidates A and C. The Layers Container is found to be identical across all candidate GISs with the exceptions of the presence of the Locate Physical Component in GIS Candidate A and minor differences in the attribute Data Display. Within the Content Panel, the Locate Physical Component is used for viewability not for analysis. For this reason, the lack of Locate Physical Component within the Layers Container of GIS Candidates B and C is not a significant detriment to physical decomposition commonality.

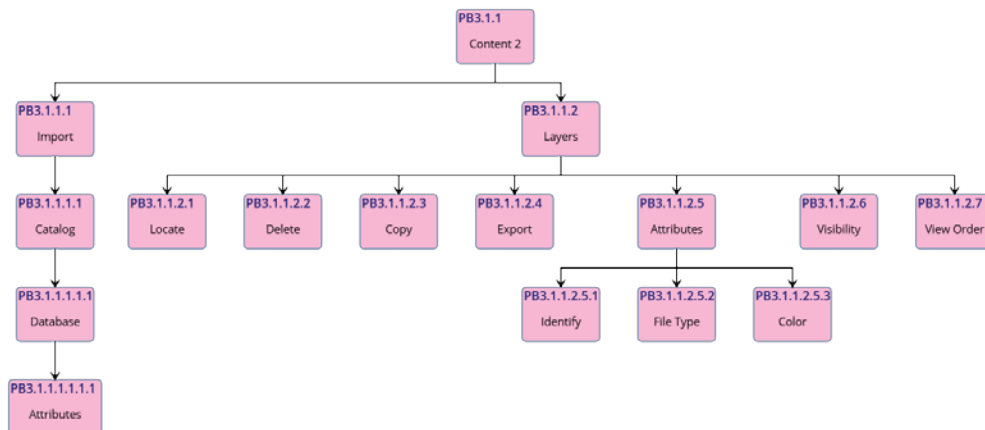


Figure 16. Physical Decomposition of Content Panel 2 for GIS Candidate C

The diagrams in Figure 17 show the physical decomposition of the Manipulate Panels for GIS Candidates A and C. GIS Candidate B does not have a Manipulate Panel. The functions performed by the Physical Components in the Manipulate Panel are used to identify areas for analysis in the Display Container in GIS Candidates A and C. This identification functionality is wholly contained in the Isolate Physical Component in GIS Candidate B.

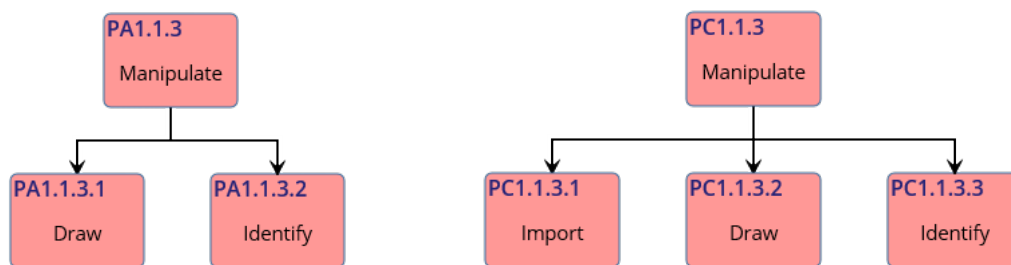


Figure 17. Physical Decomposition of Manipulate Panels for GIS Candidates A and C

As shown in Figure 17, the physical decomposition of the Manipulate Panel is highly similar. Aside from the ability to import in the Manipulate Panel of GIS Candidate C, the two Manipulate Panels are identical.

Due to the complexity of the top-level physical architecture of GIS Candidate B, the Display Containers are not broken down into their physical components in Figure 6. The physical decompositions of the two Display Containers of GIS Candidate B are shown in Figure 18.

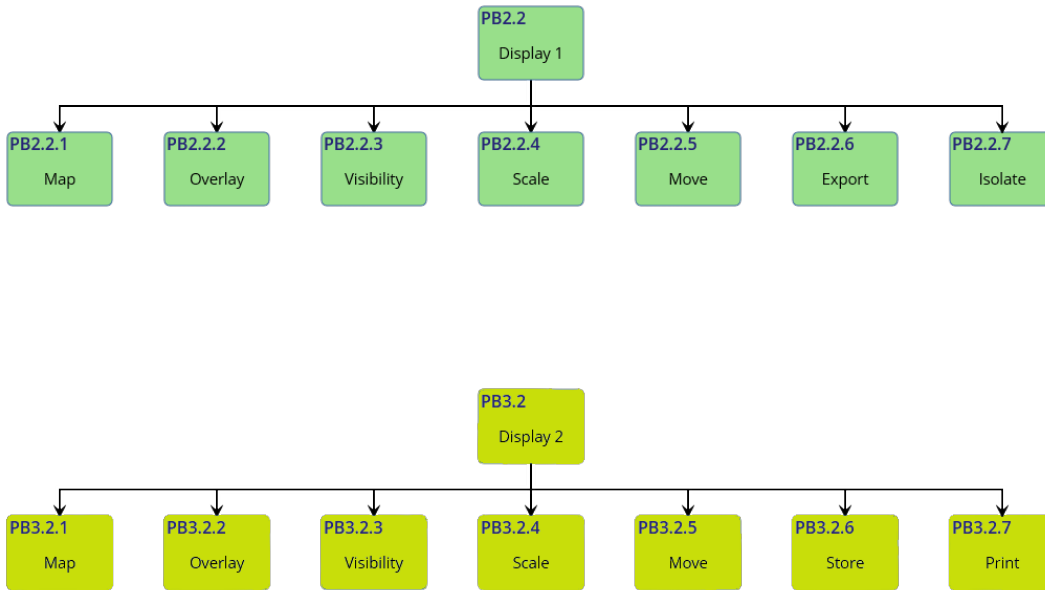


Figure 18. Physical Decomposition of Display Containers for GIS Candidate B

Review of the Display Container decompositions in Figure 18 shows that the Display Containers within GIS Candidate B are significantly more complex than that of GIS Candidates A and C, which only have the Map and Overlay Physical Components.

A cursory evaluation of the candidate GISs physical decomposition concludes that there are many similarities in physical architecture. The high degree of similarity is promising for development of a common architecture. Although the physical decomposition is promising, the functional decomposition review for GIS Candidates A, B and C still needs to be completed to ensure that the GIS candidates qualify as GISs based on the definition developed.

2. GIS Candidate Functional Decomposition Review

The first step in extracting the functional decompositions of the candidate GISs is to extract generic functions from the functions existing in the Physical Components of the physical decomposition. This task is relatively straightforward. Complexity is introduced into the task with the revelation that the Physical Component descriptions do not detail the

breadth of inputs for each function performed. In addition, the grouping of Physical Components is not by function. As such, the effort of stepping backwards from the physical decomposition to the functional decomposition required functional use information to be provided in addition to the physical decomposition. The GIS context developed is used to provide the use case basis. This additional information is visible in the functional decomposition of the candidate GISs in Figures 19–21.

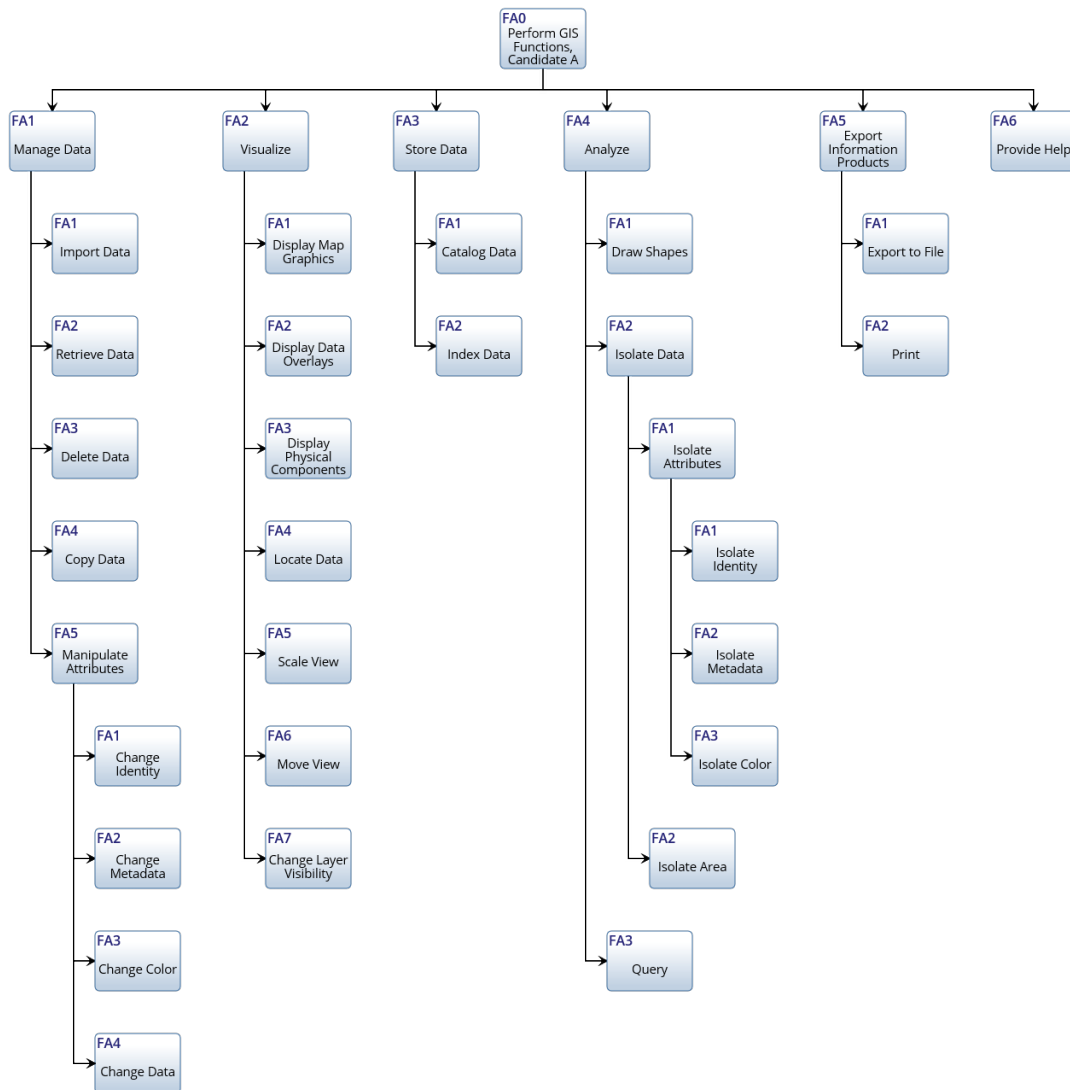


Figure 19. Functional Decomposition of GIS Candidate A

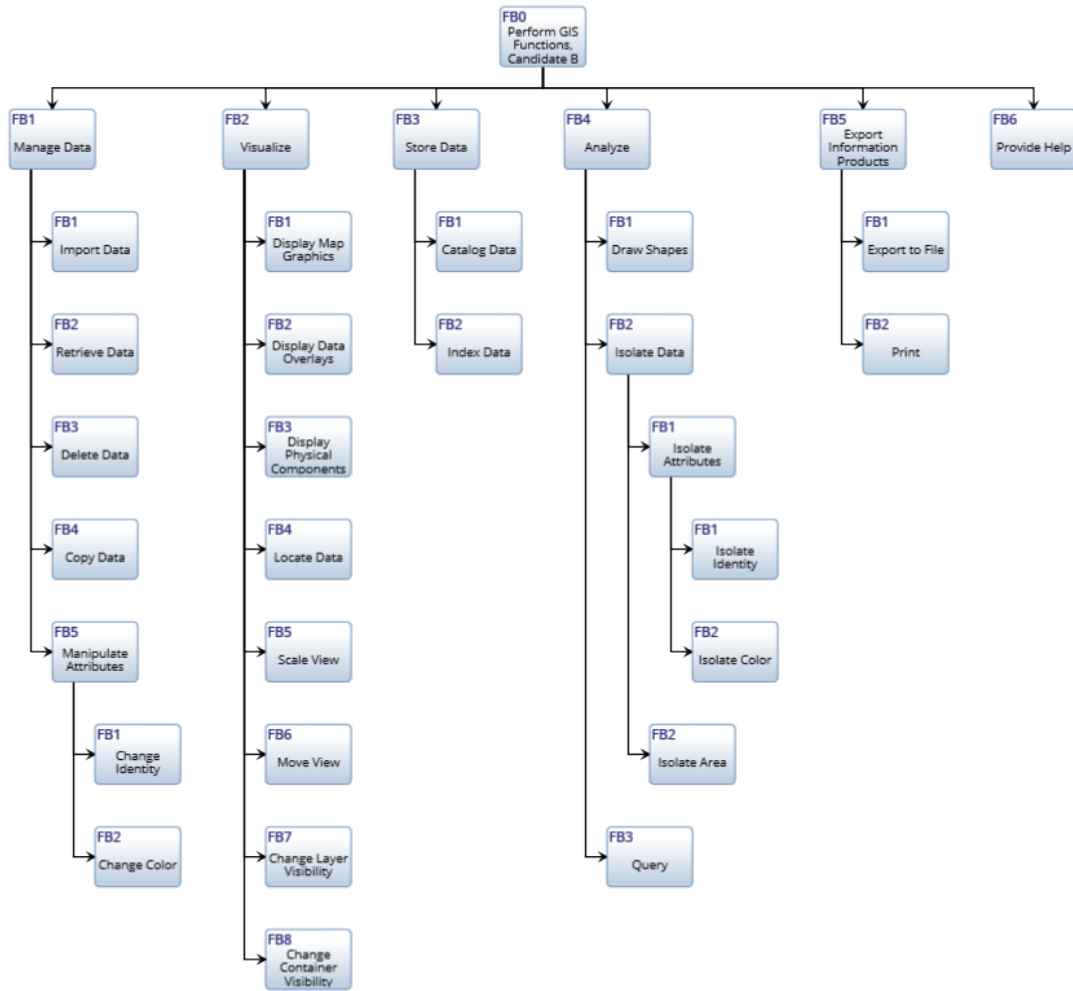


Figure 20. Functional Decomposition of GIS Candidate B

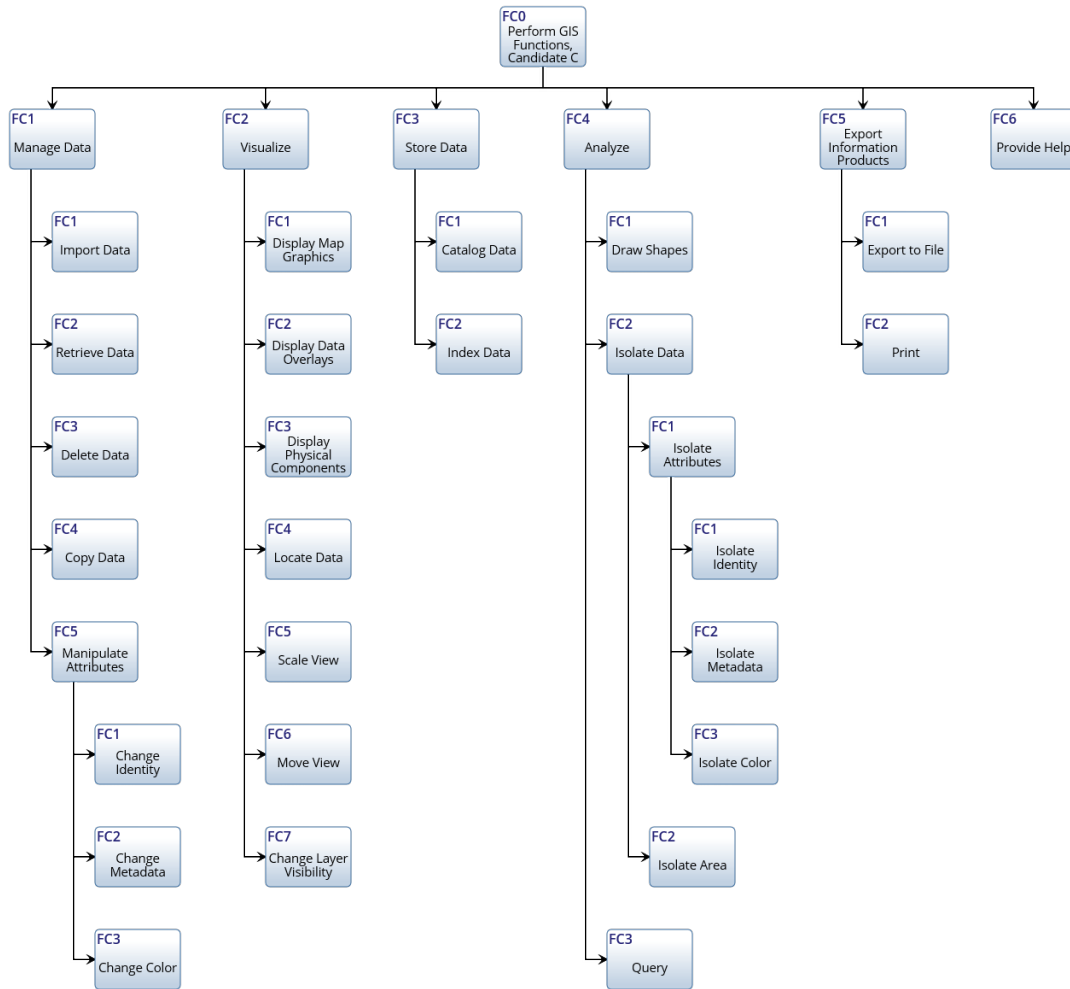


Figure 21. Functional Decomposition of GIS Candidate C

The next step for validation that the candidate GISs meet the definition of a GIS derived in Section A of this chapter is to compare the candidate GISs to the generic GIS functional decomposition. The import, export, retrieve and store functions are directly linked to the common GIS functional components of the same name. The conceptualize and manipulate functions in the common GIS functional decomposition do not map as directly.

The conceptualize function, as noted earlier, allows users to access data. In the case of all candidate GISs, the visualize function provides data access. The visualize function displays the map that is used as a reference for associations and data. The display of overlays meets the functional requirements for data access. The second portion of the conceptualize function is the ability to distinguish between the attributes of different data sets. The attributes provide access to metadata, at a minimum, and provide the ability to modify display parameters such as color. In addition, the visibility physical component provides a logic gate response for the displayed data. If the data is “on” it is visible in the display, if the data is “off” it is not visible in the display.

The manipulation function of the common GIS functional decomposition can also be associated with functions from the candidate GIS functional decompositions. The correlate function from the common GIS functional decomposition can be associated to the isolate data function of the candidate GIS functional decompositions. The isolate data function provides location association and the option to filter for subset of related attributes. Filtering may include all data of a bounded area of the display, or data could be minimized through a specific attribute field such as zip code. View order manipulation allows users to arrange data within the Display Container through Overlays. When perceived in a different manner additional associations, trends, or points of interest may be discovered. The query function of the candidate GISs is related to the analyze function of the generic GIS. Query results provided by the GISs are a direct result of defined input parameters. The scoping of input parameters and receipt of feedback from this scoping constitutes analysis. Since the functions in the candidate GISs link to functions in the generic GIS, GIS Candidates A, B, and C are considered GISs.

C. ARCHITECTURE COMPARISON

Initial comparison of the physical and functional architectures of GIS Candidates A, B, and C has been completed during the architecture review for GIS conformity. Through this cursory review, commonalities have been identified. This section provides an in-depth discussion of the functional and physical architectures to determine if development of a common GIS architecture framework is possible.

1. Candidate GIS Functional Decomposition Comparison

The top-level function for each of the candidate GIS is “Perform GIS Functions.” This function denotes that each of the candidate GISs perform the functions their designers associated with a GIS. Additional similarities are visible in the functional decomposition. All candidate GISs manage and store data, allow for visualization, analysis, and export of information products, and provide help. Similarities continue through lower levels of the functional decomposition. In fact, the functional decompositions of the candidate GISs are highly similar, with a departure of only one or two functions from the other candidate GISs. Due to the high degree of functional similarity, this detailed evaluation contains only those functions that differ between the candidate GISs.

There are no differences at the first level of functional decomposition, so the next level is evaluated. The only difference found amongst the functional architectures at the second level of functional decomposition is the ability of GIS Candidate B to allow for changing the visibility status of Containers. Although GIS Candidates A and C can show and hide Panels or “toolbars,” to use a common computer application term, their ability is differentiated from that of GIS Candidate B in that GIS Candidate B supports a separate, fully functional AI. The secondary AI in GIS Candidate B can operate independent of the first AI, allowing for independently manipulated views. This difference in capability led to documentation of a function not present in GIS Candidates A and C.

There are minimal differences at the third level of functional decomposition, all of which are centered around the types of data and metadata available for isolation and manipulation. To this point, an in-depth discussion of the file types and structure of imported data has not been completed. This lack of clarity has been intentional in that the information presented here is meant to be agnostic of data file and structure type with the only requirement being that data contain location identifiers. The assumption for this approach is that the GIS in question can accept data if it is properly formatted according to the requirements of that GIS. This approach is acceptable for generalized physical and functional evaluation, but additional information is required to verbalize the significance of the difference in attribute manipulation.

Data imported into a GIS is in a format that associates information with locations. The association of information with location can be portrayed through rows of information, such as in a table. In the table construct, each row would have columns for information and a separate column or columns for location information. These rows of information constitute the data. In addition to data, imported files may have a header that contains information about the entirety of data within the file. Header content may include data source, title, and date and location collected. File header content constitutes metadata. Once data is imported into the GIS and stored in the GIS Database, additional metadata fields are available. The additional metadata fields are information that is associated with the data through manipulations within the GIS.

With the understanding of data and metadata attributes, the differentiation of functions within the candidate GISs can be qualified. All candidate GISs allow for manipulation of the identity and color of data, but GIS Candidates A and C have additional manipulation capabilities. GIS Candidate C supports manipulation of metadata, and GIS candidate A supports manipulation of both metadata and data. Identity is a metadata field but is separated due to its lack of direct association to the data. For instance, a location-based data containing information about snowfall in the United States could be identified as “Precipitation.” While not incorrect, this identification is not completely descriptive of what is inclusive and exclusive to the data set. GIS Candidates A and C support manipulation of identity and any other metadata associated with the data such as source and time of collection. As with any structured analysis, understanding the validity of the input data is important. If the metadata contains source information, the source is displayed in the GIS and the validity of the source can be evaluated external to the GIS. If adjustments to the metadata are required, they must be performed external to the GIS for GIS Candidate B. Modifications to metadata can be made within the GIS for GIS Candidates A and C. In addition to the function discussed, GIS candidate A supports manipulation of the data itself. The difference between manipulation of metadata, or information about data, and data is significant. GIS Candidate A allows users to filter and update data directly within the GIS. This ability is significant because the user can view the data within the GIS to determine if there are any inconsistencies or outliers and deal with them within the same view without

the need for external manipulation, re-import and possible duplication of data within the database.

The other location where there is a difference with attribute capability is within the isolate function. GIS Candidates A and C allow for isolation of the identity, metadata, and color attributes. GIS Candidate B only supports isolation of identity and color. The lack of support for isolation of metadata in GIS Candidate B has the potential to affect the overall performance of the GIS. Isolation of metadata can assist with faster processing of queries resulting from reduced data set size. In GIS applications where extensive amounts of data are processed, reduction of data to process is critical for a relevant and timely information product to be provided to the user. In this way, the inability of GIS Candidate B to isolate metadata is significant.

Although there are some significant differences in the capabilities of the candidate GISs, the functional architectures are highly similar. Differences in functionality are, for the most part, localized to access to and manipulation of attributes and data. These changes impact to the ability of the user to complete GIS applications in an efficient manner but are not core functions of the GISs. The functions that are not present in all candidate GISs can be performed external to the GISs. To manage scope this research assumes that users have a basic understanding of geospatial principles and data validity prior to using a GIS, and therefore the functional gaps are determined not to be critical in understanding or using the GISs.

2. Candidate GIS Physical Decomposition Comparison

There are more differences in the physical decompositions of the candidate GISs than there are differences in the functional decompositions; however, the physical architectures developed earlier revealed that there are similarities. This section will review the differences in physical components, to include the overall structure of the GISs as well as the steps required to perform typical GIS functions. This review will be used to determine if a common physical architecture can be developed in addition to a common functional architecture.

a. Physical Architecture Comparison

Through review of the physical decompositions presented earlier, clearly the high-level structures of the candidate GISs are consistent. All candidate GISs have containers for Database and AI. In addition, GIS Candidate B varies the most from the other candidate GISs in that it has multiple AIs. To remove complexity from physical architecture comparison, the secondary AI, since it is accessed through the primary AI, will not be included in the comparison. The other major departure from commonality for GIS candidate B is that it includes a Splash Screen. To access the AI of GIS Candidate B, an entry or selection must be made within this Container. For this reason, the difference in physical architecture of GIS Candidate B must remain. This difference in physical architecture affects creation of a common GIS physical architecture. Although a common physical architecture is not possible at the highest level of decomposition, it may be possible to develop a common physical architecture for lower level Containers.

When examining the AI, all candidate GISs contain a Panel Container and a Display Container. There are, however, differences at the next level of physical decomposition. GIS Candidates A and B contain the Navigate, Content, and Manipulate Containers, and GIS Candidate B contains the Navigate, Content and Catalog Containers. Noting this difference, the secondary physical decomposition level does not support a common physical architecture. The review of steps taken to perform common GIS functions within each candidate GISs will determine if there is suitable commonality in location of Physical Components to warrant creation of a common physical architecture at the third level of decomposition. There are differences in the Display Container, with the Map and Overlay Data Display being the only consistency amongst the candidate GISs. Although differences exist, the commonality of these two Data Display provide the minimum functions necessary for GISs.

The comparison of the AI Container can be expanded to include the placement of Panels and the Display within the AI. Figures 22–24 provide a visual description of the non-customized AI layout of each candidate GIS.

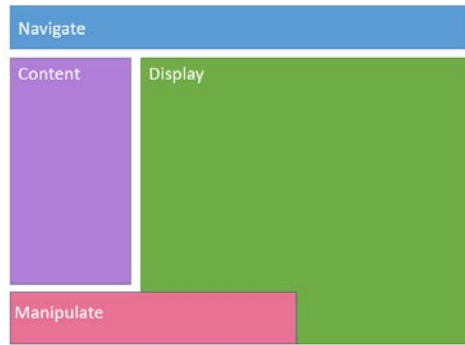


Figure 22. AI Layout of GIS Candidate A

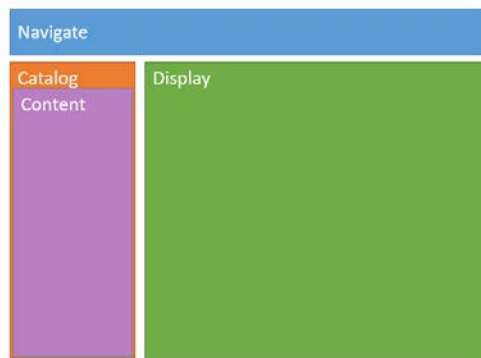


Figure 23. AI Layout of GIS Candidate B

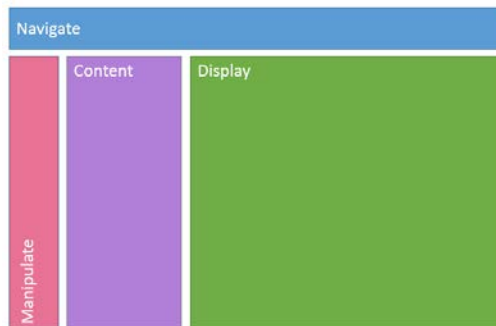


Figure 24. AI Layout of GIS Candidate C

A review of the AI layout shows that there are similarities in the visual presentation of Containers. The Navigate Panel is at the top of the view, the Display Container is at the right side of the view, and the Content Panel is to the left of the Display Container in all candidate GISs. The Manipulate Panel, when present, is in a different place. The Catalog

Panel of GIS Candidate B is in the same location as the Content Panel; there are tabs at the bottom of each Panel to transition between the two. This brief overview shows that there is consistency in the layout of GIS AIs with respect to the Navigate, Content and Display Containers. As such, a common GIS physical instantiation should not proceed beyond these Containers. To note again, GIS applications are highly tailorable, and the layouts depict the new installation configuration.

b. Action Comparison

In addition to functional and physical architectures, the processes for completion of primary GIS actions are included in this research. The generic GIS functional decomposition as well as inputs and outputs from the IDEF0 were used as a basis for primary action determination. The primary GIS actions evaluated were import data, export information product, change visibility order, and query. These actions have direct linkage to the primary functions of the generic GIS. To map the process for each primary GIS action, an action flow diagram is generated. The action flow diagrams show the Physical Components that are used to complete the identified action.

The action flow diagrams for import data are shown in Figures 25–30.

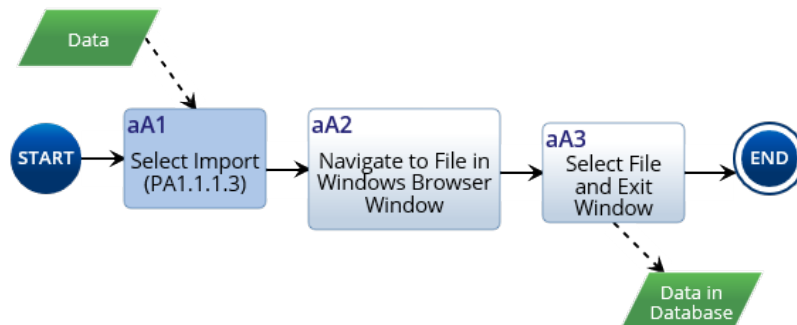


Figure 25. Import Process GIS Candidate A, Option 1

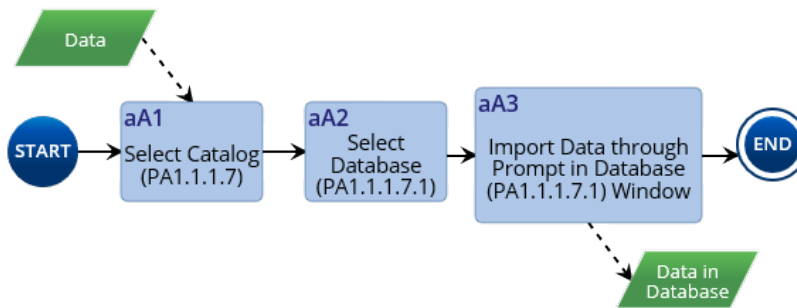


Figure 26. Import Process GIS Candidate A, Option 2

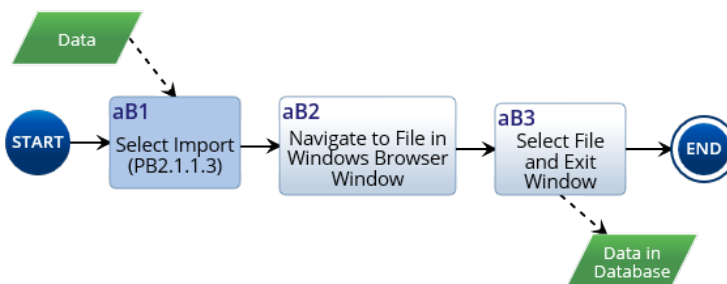


Figure 27. Import Process GIS Candidate B, Option 1

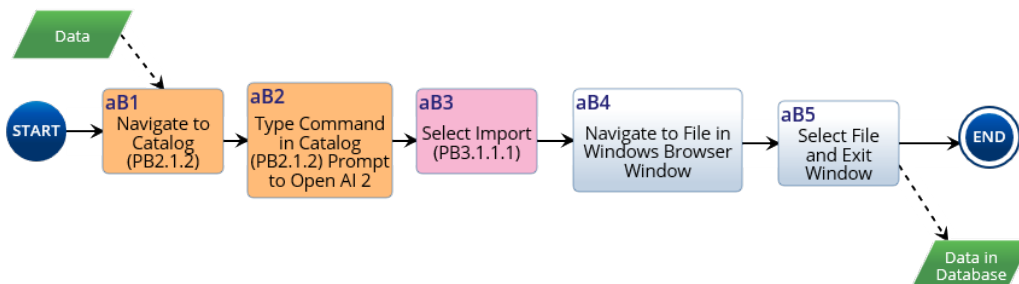


Figure 28. Import Process GIS Candidate B, Option 2

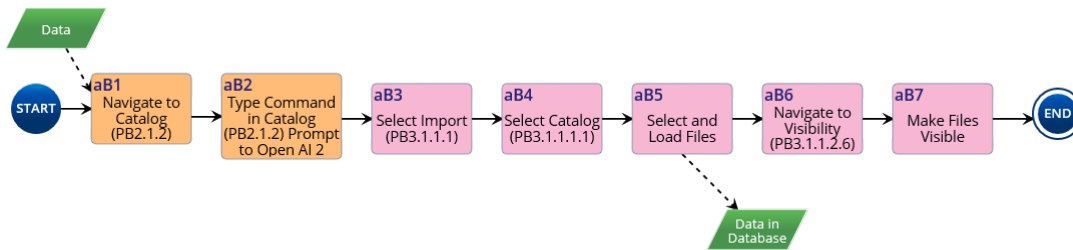


Figure 29. Import Process GIS Candidate B, Option 3

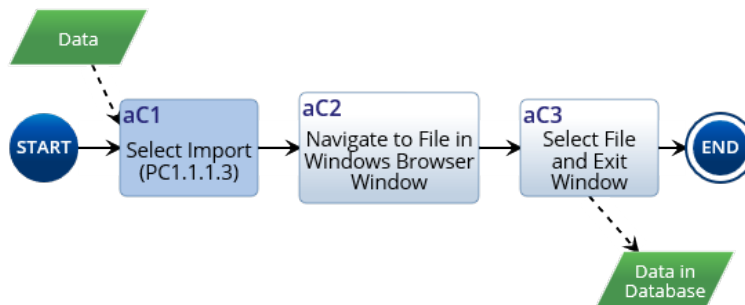


Figure 30. Import Process GIS Candidate C

As with many actions within GISs, there are multiple options for importing data. However, GIS Candidate C only offers one method for importing data. Each of the import data processes relies on the location of data to be imported to be known and accessible. There is complexity behind the location and availability of data in that the GIS may require a specific directory or file location to be selected as the source for imported data. This administrative task is critical to the function of the GIS but is an advanced feature and administrative task. This task is separate from general use and is therefore not included in this research.

Additional complexity for importing data is attributed to the type of data imported. Data imported into a GIS comes in two primary forms, vector and raster (Galati 2006). The two primary forms of data are processed differently within a GIS, and therefore some of

the candidate GISs separate import functions for importing vector and raster type data into separate windows. This qualification is noted in Table 2.

Table 2. Candidate GIS Import Method

GIS Candidate	Import Method
A	One Import Window
B	Separate Raster and Vector Import Windows
C	Separate Raster and Vector Import Windows

In this case, proper input of data requires the user to be cognizant of the form of data to be inputted. As stated, this research assumes that users will be aware of basic GIS concepts including forms of data prior to receiving training on specific applications or a common framework. The disparity in paths for importing different forms of data is not captured in the action flow diagrams.

Export of data is another critical GIS function. Figures 31–38 detail the processes for data export of the candidate GISs.

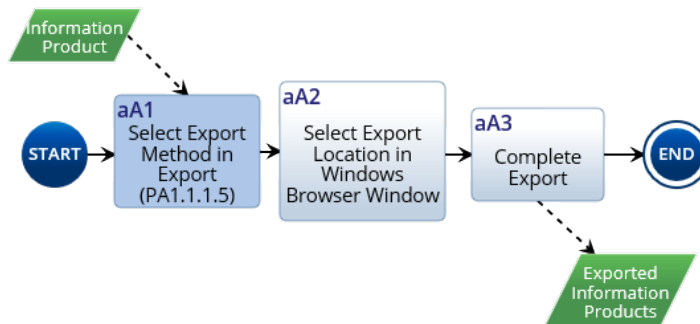


Figure 31. Export Process GIS Candidate A, Option 1

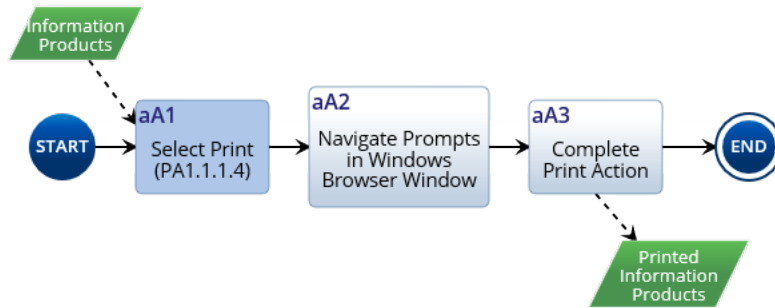


Figure 32. Export Process GIS Candidate A, Option 2

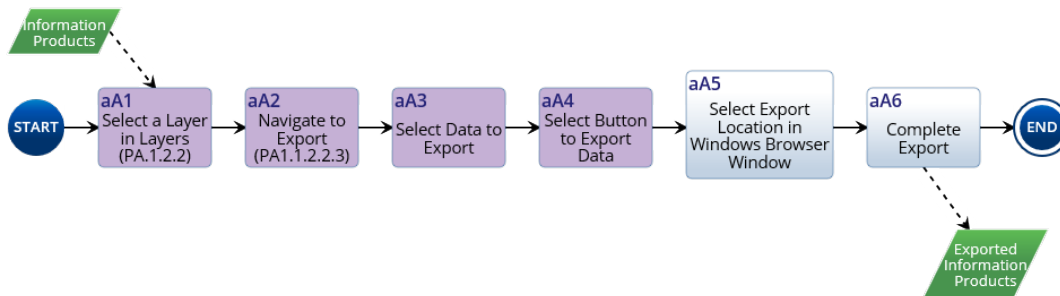


Figure 33. Export Process GIS Candidate A, Option 3

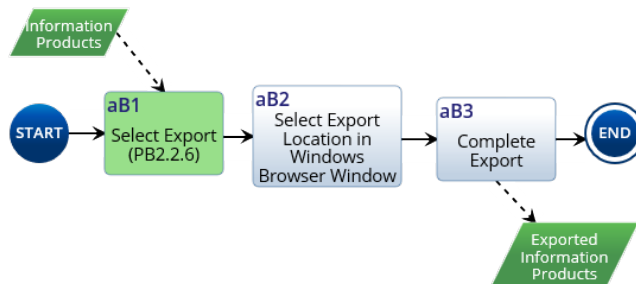


Figure 34. Export Process GIS Candidate B, Option 1

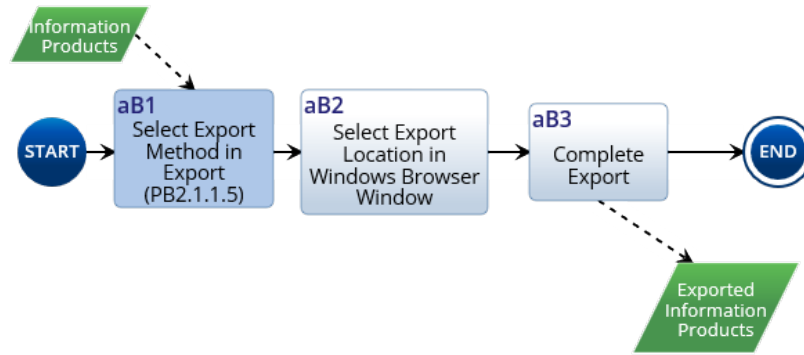


Figure 35. Export Process GIS Candidate B, Option 2

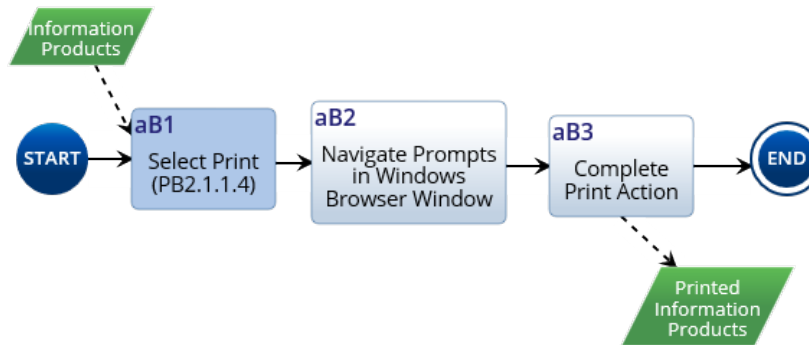


Figure 36. Export Process GIS Candidate B, Option 3

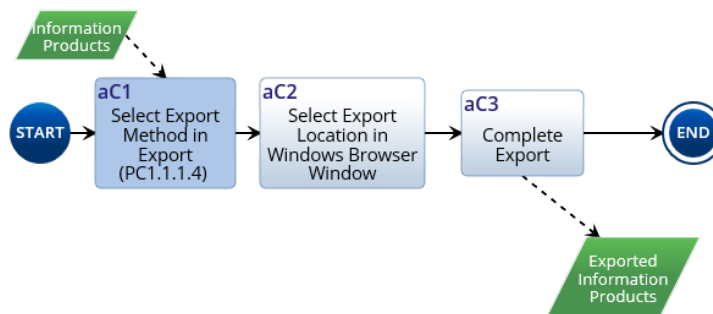


Figure 37. Export Process GIS Candidate C, Option 1

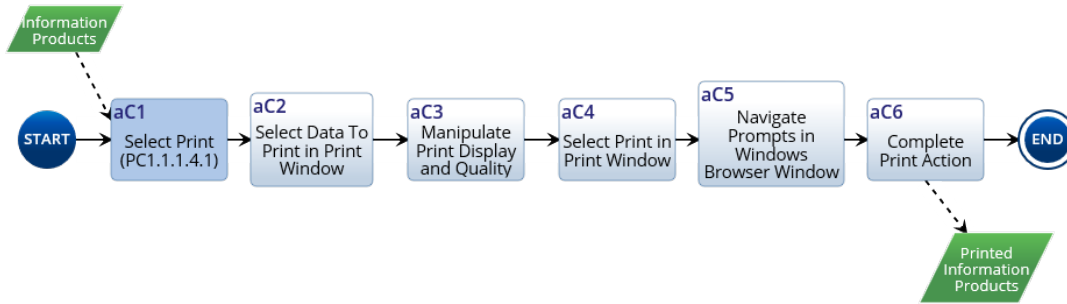


Figure 38. Export Process GIS Candidate C, Option 2

As can be seen in Figures 31–38, there is some variability in the export capability. Some of the export options require users to manage tasks in several Panels, and GIS Candidate C has an entirely separate window for printing functions.

Import and export are actions that cross the context boundary. In addition to these actions, the user needs to perform actions within the context boundary to interpret information. The process for completion of the actions of changing layer visibility and querying are shown in Figures 39–49.

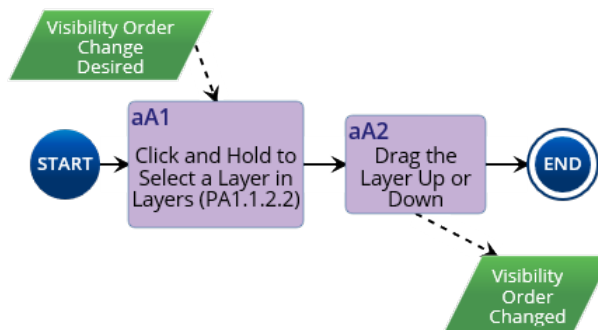


Figure 39. Visibility Change Process GIS Candidate A

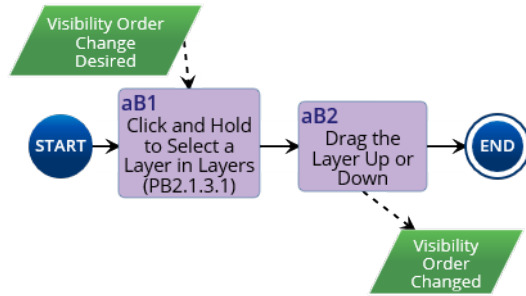


Figure 40. Visibility Change Process GIS Candidate B

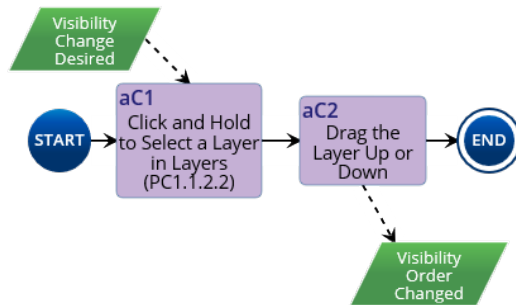


Figure 41. Visibility Change Process GIS Candidate C

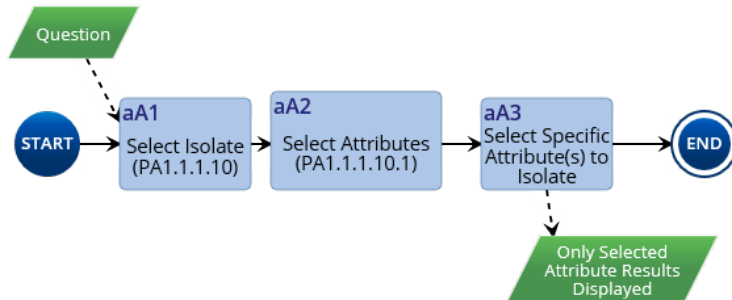


Figure 42. Query Process GIS Candidate A, Option 1

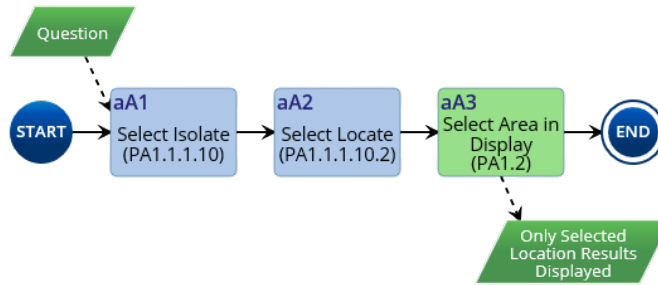


Figure 43. Query Process GIS Candidate A, Option 2

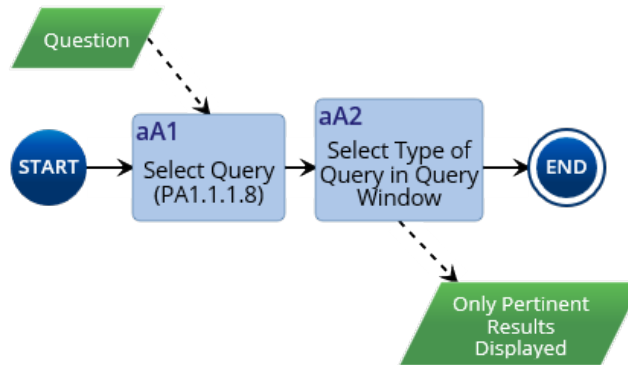


Figure 44. Query Process GIS Candidate A, Option 3

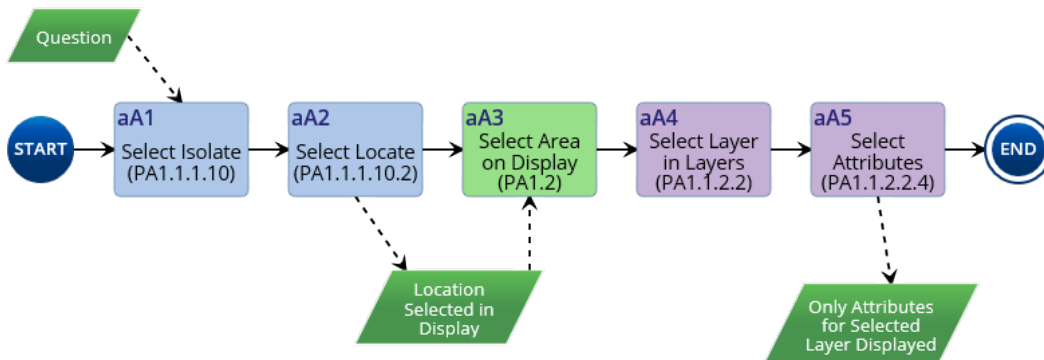


Figure 45. Query Process GIS Candidate A, Option 4

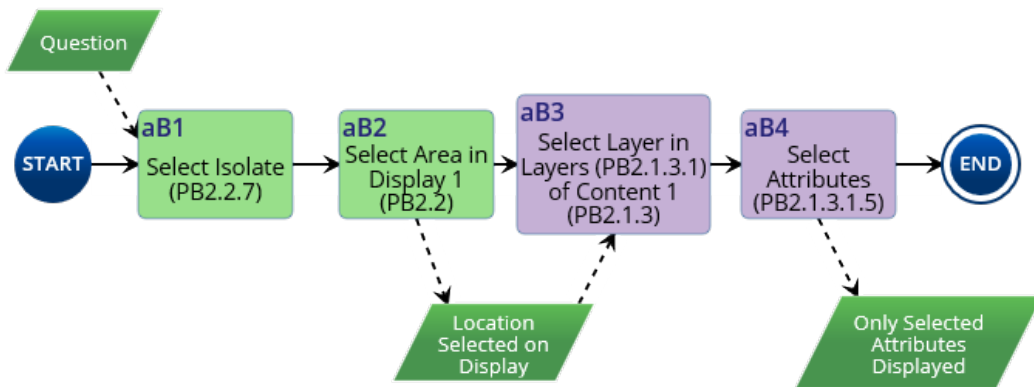


Figure 46. Query Process GIS Candidate B, Option 1

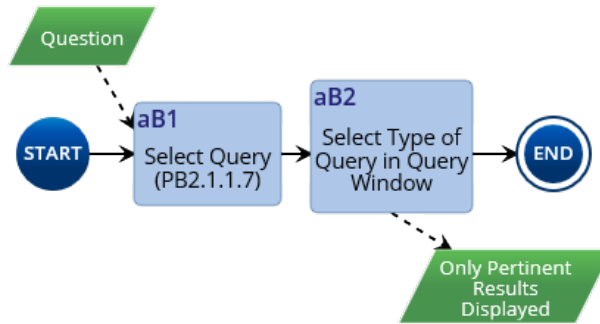


Figure 47. Query Process GIS Candidate B, Option 2

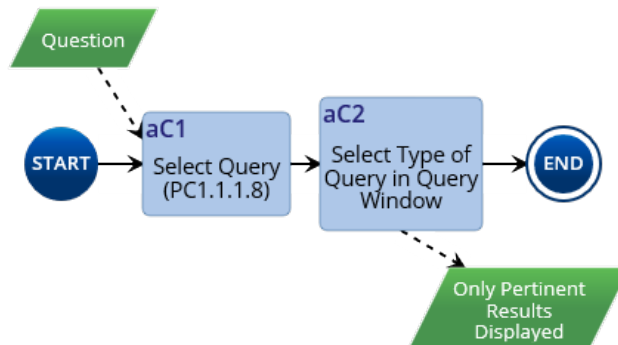


Figure 48. Query Process GIS Candidate C, Option 1

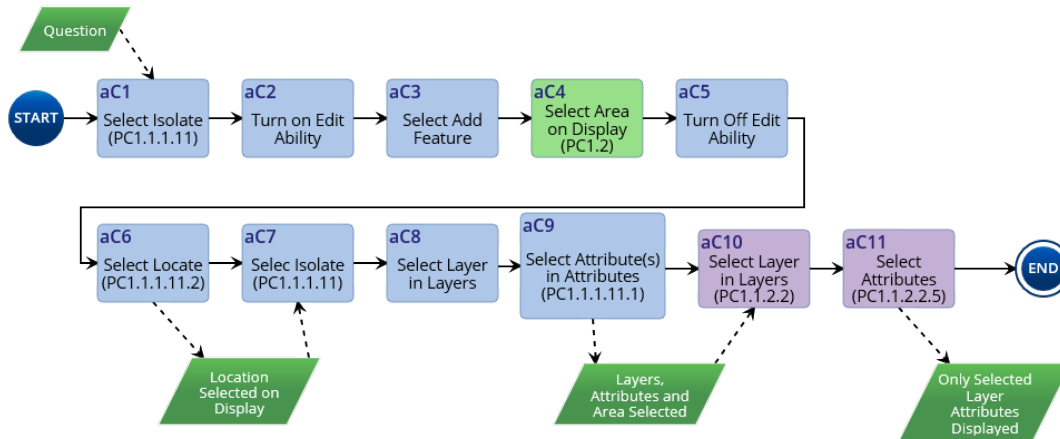


Figure 49. Query Process GIS Candidate C, Option 2

Figures 39–41 show that the process to change the visibility of data within all candidate GISs is the same. Figures 42–49 show that there are several methods within each candidate GIS for querying data. While complex queries have little commonality, the process for basic query is consistent throughout all candidate GISs.

D. COMMON ARCHITECTURE

Commonalities were discovered between the candidate GISs during the architecture review. Due to these commonalities, creation of a common functional architecture for a GIS is possible. The common functional architecture for a GIS is shown in Figure 50.

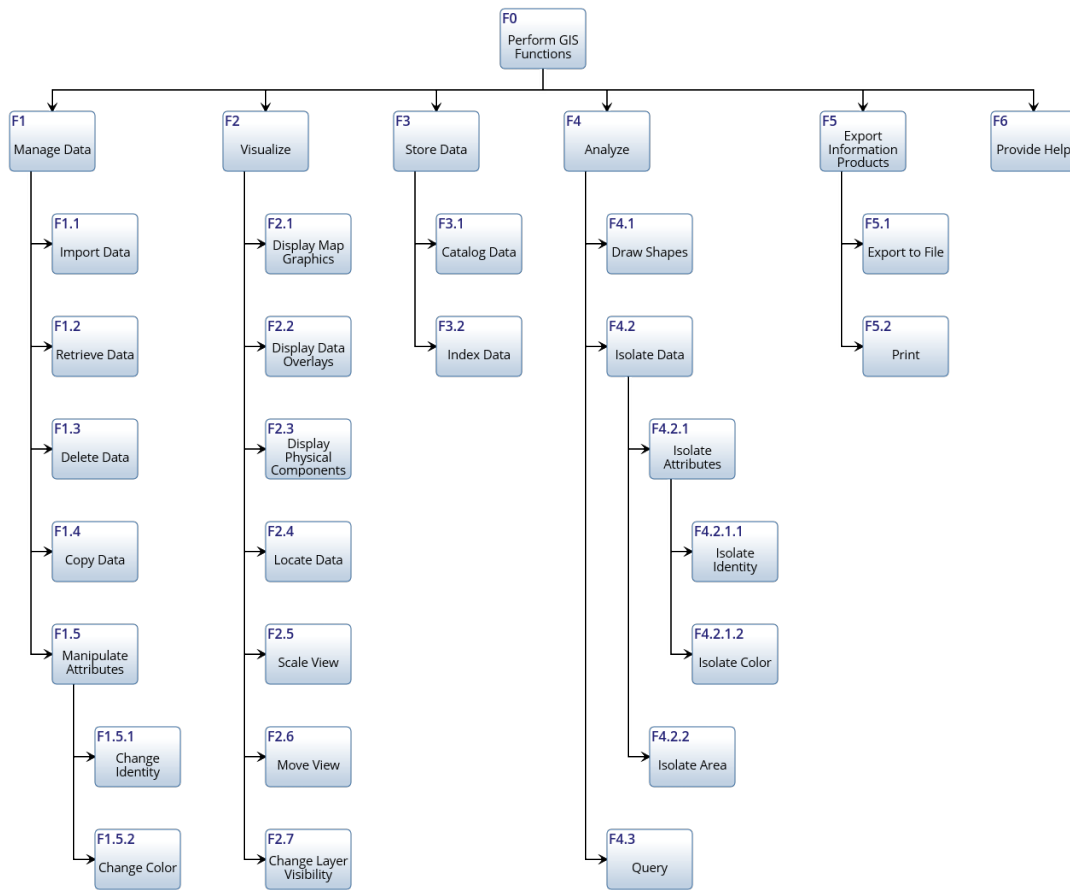


Figure 50. Common GIS Functional Architecture

As described, there are sufficient differences in physical decomposition at the top levels of physical architecture to prevent generation of a common physical architecture at the GIS level. Although differences exist in high levels of the physical architecture, commonalities exist within lower-level Containers. These similarities allow for development of common physical architectures for some Containers. The common architectures for physical Containers are found in Figures 51–53.

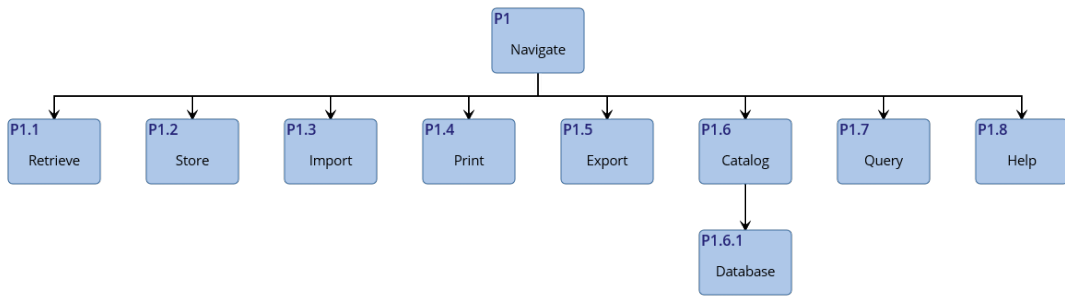


Figure 51. Common Navigate Panel

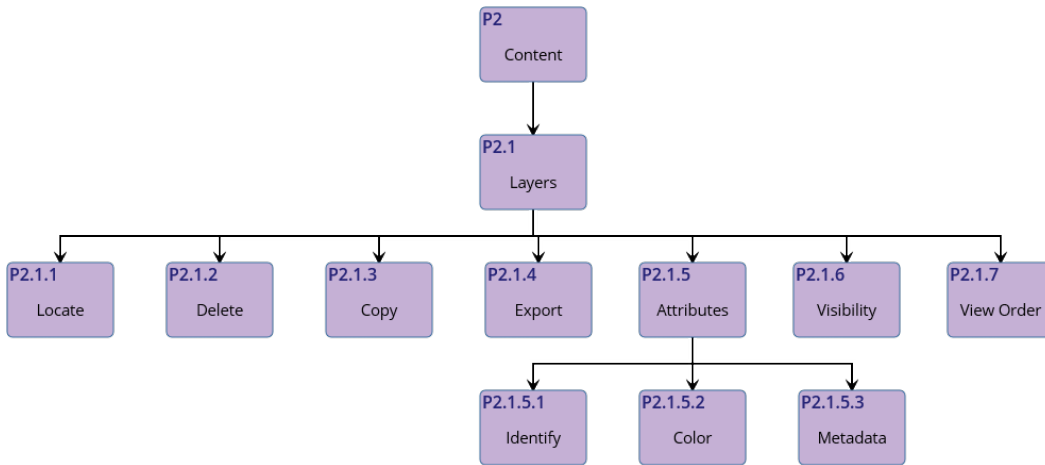


Figure 52. Common Content Panel

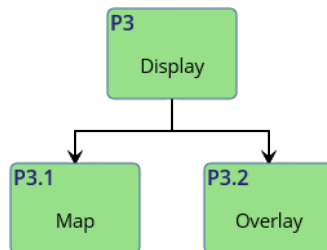


Figure 53. Common Display Container

Generation of common physical architectures at the level described in Figures 51–53 is significant since functions in these Containers are used to perform general GIS activities. The location within the GIS of these common Containers is again similar, which facilitates use of a common physical architecture framework. Figure 54 details the common AI layout.

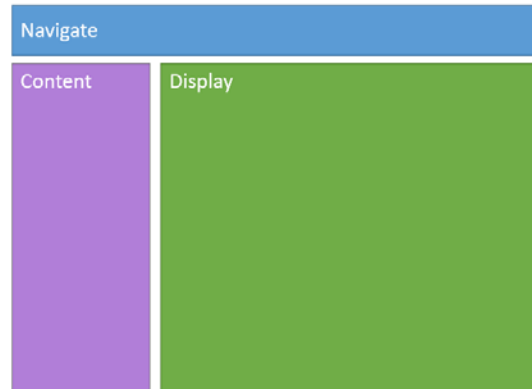


Figure 54. Common AI Layout

Through the action review, generation of common processes for typical GIS processes is possible. The common processes are shown in Figure 55–58.

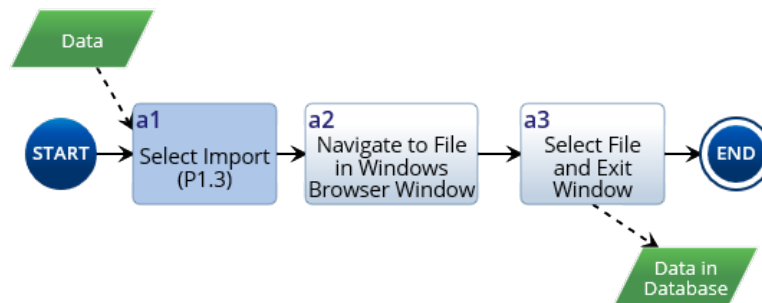


Figure 55. Common Process for Import

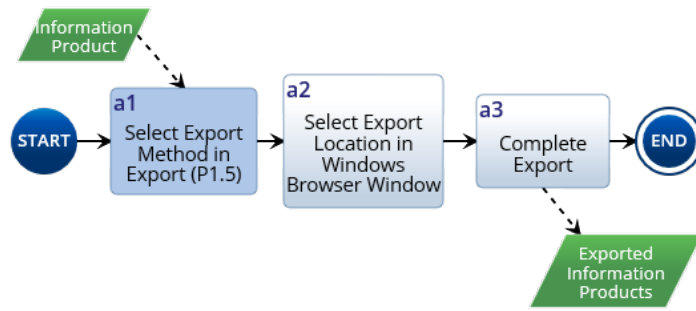


Figure 56. Common Process for Export

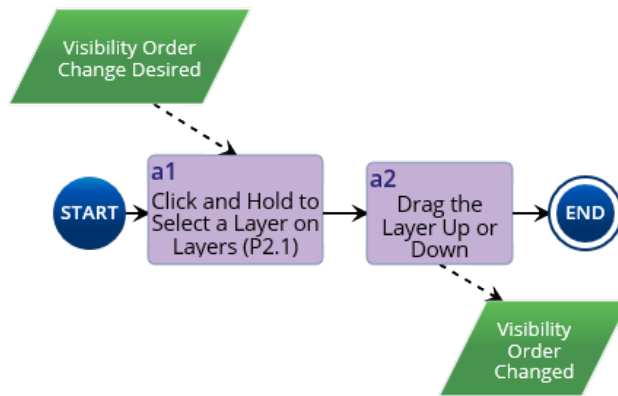


Figure 57. Common Process for Visibility Change

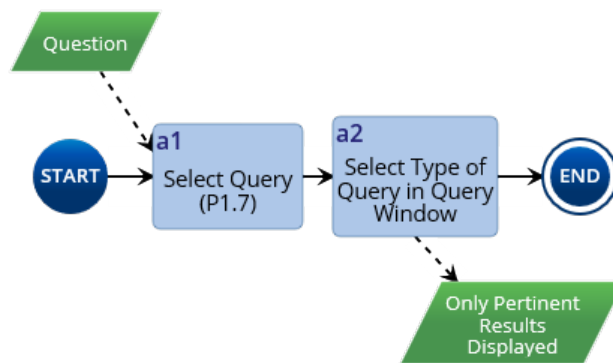


Figure 58. Common Process for Query

Generation of common processes for typical GIS functions is significant because it identifies that there are minimal differences between the candidate GISs with respect to core actions. With increased knowledge and familiarity with the GIS tools additional process options within the GIS can be used, but that is outside the scope of this research. This research focuses on the ability to convey the basic actions needed to perform GIS functions.

The development of a common functional architecture, physical architecture, and common processes supports the concept that training effort may be minimized through training to a common GIS framework. The next chapter will evaluate the common GIS framework against training techniques and transfer concepts to determine if a common framework training approach is expected to produce the same degree of knowledge retention as training specific applications.

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III. MILITARY TRAINING APPLICABILITY AND EFFECTIVENESS

A. TRAINING CONCEPT AND PARADIGM DEFINITION

Generalized constructs for delivery of information are present in formal education, however there is a distinction to be made between education and training. Education provides the generalized background for learners to answer questions that can be framed with “why?” and training addresses those questions that can be framed with “how?” (Human Systems Integration Program Naval Postgraduate School 2014). As an example, education would answer the mechanics of why seat belts exist and training would answer the question of how to buckle the seat belt. An educational curriculum may provide a process for completing actions, but again this at a generalized level. A prime example of this is the scientific process. At a basic level students in educational programs learn to ask a question, conduct research, and provide results. While this generalized process is useful and applicable as a framework, it does not provide the specifics of how to generate a question, the tools and processes for conducting research, and in what form the results should be presented. Identification of the optimal way to associate and transfer general knowledge to a specific application is a topic that continues to be explored (van Merriënboer, Jelsman, and Paas 1992). The relevant question for this thesis is whether the common GIS framework developed can provide information transfer and support training initiatives.

Research into the use of GIS applications for proven training methods such as serious gaming is in its infancy (Afyouni et al. 2016). There are, however, studies that detail training aspects which influence the transfer of information and which are applicable to all types of information transfer (Raja Kasim et al. 2013; Fitzgerald, Allen, and Reeves 1999; Cheng and Prabhu 2013). The concept of instructional design benefits information transfer and is applicable to technological and military systems (Chen 2011). The ability of the common GIS framework to be implemented within the instructional design concept will be evaluated. In addition, transfer of training is affected by motivation of the learner (Liu, Toprac, and Yuen 2011) and similarity of the training experience to actual application

(Osgood 1949). The applicability of core training motivation factors (Liu, Toprac, and Yuen 2011) will be evaluated. Osgood (1949) demonstrated that a high degree of information transfer occurs when functional input and responses of information provided in a training environment are highly similar to real-world application. Osgood's similarity paradox concept will be used to determine the anticipated transfer of information using the common GIS framework.

B. COMMON ARCHITECTURE TRAINING CONCEPT

1. Instructional Design Model

The first training concept discussed is Instructional Design (ID). ID is “the systematic process of planning events to facilitate learning” (Chen 2011, 80). There are several variations within ID models. The military is currently using the Analyze, Design, Develop, Implement, and Evaluate (ADDIE) ID model variant (Department of Defense 2001; Department of the Navy 2016). The current military guidance to use ADDIE is dictated in a Department of Defense guidebook and not a standard. Guidance may change, so this research approaches ID in a more generalized view. All variations have a basic structure (Chen 2011). Chen notes the basic structure of ID includes project planning, development and implementation. Project planning and development will be discussed further. Implementation is outside the scope of this research.

a. Project Planning

At a generalized level project planning encompasses the efforts of problem statement definition and scope determination (Chen 2011). There are multiple problem statements that can be generated to support common GIS framework training. Two pertinent questions are “if a common GIS framework is used, will it facilitate transfer of training?” and “is it possible or feasible to use a common GIS framework in training?” These questions sound similar but have different implications. The first question is related to the outcome of the training, the second is specific to generation of the training package. Combining these ideas, the question can be formulated as “how can one train a common GIS framework to support transfer of training?” This question, while comprehensive for the needs of the common GIS framework training, is not sufficient for ID because it does

not include the context of the problem. Research into the association of GIS in training is in its infancy (Afyouni et al. 2016), so it is difficult to generate a context for the learning environment. Without additional data available, the assumption used for this research is that in the current environment training is conducted for individual GIS applications for specific purposes. As such, the problem statement can be formulated as “is training to a common GIS framework followed by mission specific and application specific training feasible and does it support proficiency goals.” This problem statement meets the needs of the ID concept because it helps training designers to understand the discrepancies between the current atmosphere and the desired end state. Proficiency goals are discussed in the training motivation section of this paper, but in the ID problem statement the understanding is that the proficiency goals are defined as part of the product planning phase of the ID process. This question becomes the problem statement. Since the parameter for generation of a problem statement is met, scope determination is evaluated.

Scope for the common GIS is described in the introduction to this research. These scope parameters defined previously contribute to the scope definition for the ID model. Additional scope factors include training only to the common GIS framework and training only critical processes. Training only to the common GIS framework excludes training GIS concepts such as types of data, fidelity of data, and applications for which a GIS is applicable. This training concept assumes that learners come into the training session with this knowledge. Training only critical processes excludes advanced features and specific use cases. With these additional parameters, the scope of the common GIS framework training is defined. Since the requirements for the planning phase are met, the development phase can be evaluated.

b. Development

Development factors include the ability to structure a training package and include evaluation of training delivery methods, described in detail in Chen (2011). The common GIS framework supports generation of a training package because it has a logical organization and separation of components. The common functional architecture, physical architecture components, and processes are separate self-contained entities. Each of these

entities, as well as context definition, could translate into a training module within the training package. The ID model also identifies the importance of order of information presentation (Chen 2011). In this case, a logical order of module presentation would be context, functional decomposition, physical decomposition, and processes. This module order may help a learner to understand the application and shortfalls of the presented material since the first module would provide the frame of reference for which to internalize the successively presented information.

Training delivery methods will not be discussed in this research further than to say that regardless of the method of presentation, simulation may assist learners with knowledge retention. Including processes within the common GIS framework allows learners to conduct actions through simulated situations. Active engagement has been shown to assist with transfer of information (Liu, Toprac, and Yuen 2011; Collins 2009). Proposing simulation does not restrict application to a specific delivery method. Simulation of the process could be as simple as asking a user to fill in missing Physical Components on a process sheet, or an agnostic GIS AI where learners navigate through Panels and make selections as they would within a specific GIS application. The important factor when assessing the validity of the simulation is assessing whether there is an accurate representation of the necessary functions that need to be completed to achieve a certain outcome given the provided input.

2. Training Motivation

Training motivation has been demonstrated as critically important to the degree of training transfer (Liu, Toprac, and Yuen 2011; Wei-Tao 2006; Dweck 1986), with some research indicating that it is of greater significance than aptitude and course material (Wei-Tao 2006). Intrinsic motivation, which is defined as “task interest or the enjoyment of effort” (Dweck 1986, 1042) and training motivation, which is defined as “the direction, intensity, and persistence of learning-directed behavior in training contexts” (Colquitt, LePine, and Noe 2000, 678) are both important indications of training success. One research study identifies that the “four perspectives on the sources of intrinsic motivation are commonly expressed as challenge, curiosity, fantasy, and control” (Liu, Toprac, and

Yuen 2011, 54). Other research identifies autonomy and possessing the ability to learn through failure as motivational factors (Dweck 1986; Collins 2009). In addition to these factors, age, gender and personality can affect motivation (Colquitt, LePine, and Noe 2000). To narrow the scope, this research will only examine the attributes of goal format, interest, challenge and control, and introductory content.

There are two primary goal formats, performance and learning. Mastery goals are those in which “the result is defined as meeting an absolute or intrapersonal standard” (Collins 2009, 477) and performance goals are those in which “the result is defined as meeting a normative standard” (Collins 2009, 477). In other words, mastery goals are those goals in which the knowledge seeker understands the reason for needing to know the knowledge and performance goals are those goals which are externally enforced without the knowledge seeker understanding the purpose. The reward structure for performance goals is also competitive while learning goals are autonomously rewarded (Dweck 1986). Mastery goals for GIS training are discussed in this research as they are associated with higher motivation, involvement, and knowledge retention (Dweck 1986; Collins 2009). Common GIS framework training, for this research, is scoped to only include overarching architecture and general process steps at a tool or application level.

The assumption that users will enter the training with background knowledge of GIS introduces risk in that this format also assumes that users will understand why they are completing actions. This risk directly affects mastery in a negative manner since mastery goals are reliant upon understanding the core need for instruction. One approach to alleviate this concern and improve mastery goals is to include background GIS instruction as the first portion of the lesson, followed by common GIS framework instruction. Although this approach is recommended, discussion of the content and format of instruction for background GIS is outside the scope of this research and will not be discussed further. The other aspect of mastery goals, autonomous reward, is achievable with common GIS framework training. The reward structure for common GIS framework training can be constructed to focus on each user understating the function of each Physical Component in the framework, and not in a competitive manner. Reward association with extrapolation and application of content to evolving scenarios could be developed as

opposed to a binary approach such as association of higher performance with the ability to match Physical Component and functional definition. The extrapolation and application approach supports mastery goals. Both attributes of mastery goals are achievable with common GIS framework training, leading to the conclusion that common GIS framework training can support mastery goals. Timeframe for proposed goal attainment also affects motivation, with short-term goals being more highly associated motivation than long-term goals due to the ability of knowledge seekers to realize improvement (Collins 2009; Wei-Tao 2006). The common GIS framework supports short-term goal development because it deconstructs the complexity of a GIS into smaller, more understandable units. For a GIS, a long-term goal could be to learn how to apply a GIS to a specific use case, with several short-term goals, such as learn how to import data into a GIS, as increments of proficiency to reach the long-term goal. The deconstruction of GIS concepts within the common GIS framework supports short-term goal development and achievement.

Challenge, interest and control are each associated with motivation, with increased interest, and sufficient challenge and control being linked to higher motivation (Collins 2009; Dweck 1986; Colquitt, LePine, and Noe 2000). Previous research describes challenge as encompassing aspects of being able to solve problems and become proficient in a subject (Liu, Toprac, and Yuen 2011). Simulation is a suitable means for generation of situations in which learners must react to an input and produce an output. With repeated simulation, proficiency can be gained. The common GIS framework can support simulation generation, but simulations would be generalized and a departure from the application-specific and mission-specific simulations which are more highly correlated to real-world scenarios. Interest can be “generated by such things as novelty, mystery, and possibility” which is supported by “activities such as puzzles and group work” (Collins 2009, 478). Inconsistencies may be introduced into simulations to increase interest, but this application would need to be effectively managed to avoid frustration if resolution was not achieved. Puzzles or challenges could also be introduced into a simulation and the instruction could be structured so that users work in teams, but the structure of training discussed in the ID section of this research is one-directional with instructors imparting knowledge to users. Puzzles, if included in a simulation, are more closely linked to the concept of challenge

than of interest as they are not anticipated to cover material outside the scope of the common GIS framework training. The principle behind development of the common GIS framework is to uniformly and consistently present information, and it would therefore not possess the qualities that Collins (2009) identified as necessary for interest generation. Liu, Toprac, and Yuen (2011) describe control as encompassing the learner's ability to decide what actions to take within a learning environment, and Colquitt, LePine, and Noe (2000) suggests that control can also relate to the knowledge seeker's ability to attend the training. Although Colquitt, LePine, and Noe (2000) proposes that independent selection of training attendance increases motivation, other research suggests that direction to attend training is more motivational (Wei-Tao 2006). For this reason, the users' ability to attend or not attend, including specific sections or topics, is not included in the discussion of control in this research. For this research control is synonymous with autonomy. As with interest, the prescribed processes and structured approach provide little ability for the learner to make decisions within the training environment outside the potential simulation application. As such, the concept of training to a common GIS framework has a negative correlation with control.

Introductory content is included in this research because previous research has shown that providing read-ahead type material for students increases their self-efficacy, interest, and retention of information covered within training (Wei-Tao 2006). The common GIS framework supports the introductory content concept in multiple ways. First, separating the common GIS framework training from GIS background training allows users to ingest and process the GIS background training, containing general concepts such as types of data and information sources, prior to being introduced to the common GIS framework, or "tool-type" training. Second, the ID structure of common GIS framework training, and if deemed appropriate the architecture and decomposition diagrams, could be provided to users prior to training initiation. Third, the common GIS framework can act as the introduction to application-specific and mission-specific training just as the GIS background training leads into the common GIS framework training. Leveraging these three supporting points, this research concludes that introductory content is supported by common GIS framework training.

3. Input and Response Similarity

The similarity paradox for transfer of training developed by Osgood (1949) relies on similarity of the training environment to that of the real-world environment to forecast the degree to which information will be transferred. Osgood determined that the appropriate level to compare training and real-world environments is at the functional level. As such, the comparison will begin with the functional architectures of the common GIS and the candidate GISs. The normalization of functions conducted earlier affects the similarity of inputs and responses. Figure 59 describes the way in which normalized inputs relate to responses.

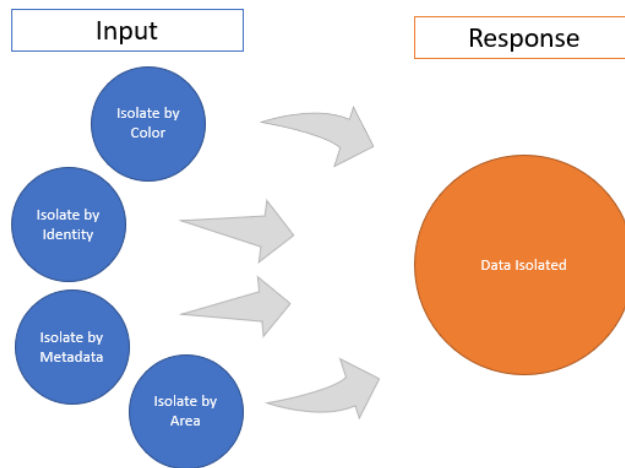


Figure 59. Input-Response Normalization.

As shown in Figure 59, multiple functional components in the architectures will produce the same response. Only the input stimulus is varied in this instance. Process comparison is also applicable. As with the functional decomposition, the responses are the same for each process. Comparison of the physical architectures is more complex. The location of Containers within the AI can be compared as well as the physical architecture. The similarity of location of the Physical Component location within the AI could also be evaluated if a physical simulation of the common GIS framework were developed. The concept of similarity can be applied to the physical simulation by determining the distances of Physical Components in the physical simulation to that of the candidate GISs. Although

this analysis would be interesting, physical simulation comparison will not be evaluated since Osgood (1949) recommends maintaining comparison at a functional level.

a. Functional Architecture Similarity

Similarity value will be used to quantify the degree of similarity of the common GIS functional architecture to that of the candidate GISs. Each function within the common GIS functional architecture is counted and the resulting number is used as a baseline for comparison of the candidate GISs. The number of functions in each candidate GISs are determined and used in the numerator for the comparison. Absolute value in the numerator is taken as the magnitude of the difference is the important metric for comparison. The similarity value equation used is shown.

$$\text{Similarity Value} = \frac{|N_{\text{Common GIS}} - N_{\text{Candidate GIS}}|}{N_{\text{Common GIS}}}$$

Using this equation, the similarity values of functions are found to be .09, .03, and .06 for GIS Candidates A, B, and C, respectively. In a construct where zero degrees signifies uniformity between functions evaluated and 180 degrees signifies significant differences between functions, a graphical representation of degrees of separation can developed using 90 degrees as the point at which negative correlation occurs. Figure 60 displays this concept.

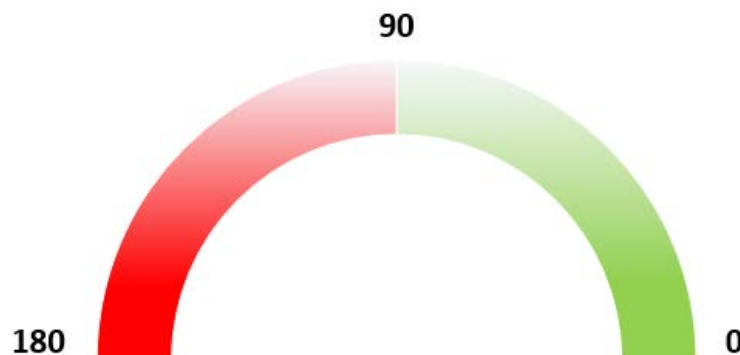


Figure 60. Degree of Similarity Visual Representation

Using 90 degrees as the transition between positive and negative correlation, the similarity values are multiplied by 90 to obtain the degree of separation.

$$\text{Degree of Separation} = \text{Similarity Value} \times 90$$

Using the degree of separation computation, the degree of separation values for functions are 8.4 degrees, 2.8 degrees, and 5.6 degrees for GIS Candidates A, B and C respectively.

The separation values are very low, but a limit is needed to bound acceptable degrees of separation. Developing and conducting common training in scenarios where the subject matter shows a negative degree of separation is not beneficial, nor is it effective to train in scenarios where the degree of separation is positive but near 90 degrees. These situations are inefficient because of the amount of material, or the differences, which would need to be covered separately in application specific training. This research will use 45 degrees as the cutoff for acceptable similarity. The selection of 45 degrees is made because it the median between complete similarity and inefficiency, and it provides sufficient separation from complete similarity to account for the generalizations and normalization that were made in the architecture. The 45 degrees bound is used in this research based on the generalized nature of the analysis; it is not applicable to future efforts or other common training constructs, the bounds of which should be adjusted based on empirical findings. All candidate GISs fall below the 45 degree threshold.

b. Process Similarity

Extending the similarity concept slightly past Osgood's (1949) recommended level of functional analysis may provide insight into the suitability of common process training. Using the same equations as the functional comparison, the degrees of separation are found to be zero degrees for all candidate GISs for all processes. The types of queries possible and the labels of buttons that users may be required to select to perform queries in each candidate GISs are different, so the correlation is not identical, but the inputs, outputs, Physical Component location, and actions are the same for all candidate GISs. Although there are differences in the buttons and query types, the identical finding for overall processes denotes a high degree similarity in input actions.

c. Physical Similarity

Again extending Osgood’s (1949) similarity concept, the similarity of physical architectures is evaluated. Maintaining the same equations, the degrees of separation for physical architecture are determined. These values are displayed in Table 3.

Table 3. Physical Architecture Similarity

	Navigate Panel Degree of Separation (°)	Content Panel Degree of Separation (°)	Display Container Degree of Separation (°)
GIS Candidate A	144	22.5	0
GIS Candidate B	0	0	270
GIS Candidate C	126	15	0

Table 3 shows that the common Container architecture is highly similar to candidate GISs in some areas, and highly dissimilar in other areas. Inclusion of the common Navigate Panel and Display Container in training is not recommended due to the high variability in physical architecture. The Content Panel degree of separation is within the threshold and is therefore recommended for inclusion in common GIS framework training. For the AI layout, there is a degree of separation for all candidate GISs of 30 degrees. Although this number does not lead one to believe a high degree of similarity exists, the common AI layout is very similar to the candidate GISs. The difference between the candidate GISs and the common GIS AI layouts is that each candidate GIS has one more Panel than the common GIS. Both GIS Candidates A and C have a Manipulate Panel, while GIS Candidate B has a Catalog Panel. The Panels that do exist are in the same configuration within the AI. The lower than expected degree of correlation is a result of the low number of components evaluated in the equation. Inclusion of the Navigate, Content and Display Containers in the common AI layout for training is recommended due to the consistency of location of containers.

C. TRAINING CONCEPT ASSESSMENT

As can be seen in the previous section, there are benefits and drawbacks to providing training for a common GIS framework. While the common GIS framework training approach does support the ID methodology already used in the military (Chen 2011), motivational attributes are not fully supported. Mastery goals can be developed, and the ID structure allows short-term, achievable goals to be set. In addition, the ID structure supports introductory content dissemination. The challenge motivational factor could be supported through simulation, but both the interest and the control motivational factors were negatively correlated with the concept of common GIS framework training.

Although some training motivation attributes were not supported, review of the similarity paradox shows that a high degree of information transfer can still be achieved due to the high degree of similarity of the material trained to the real-world environment. The high degree of similarity between the common GIS framework and the candidate GISs is partially facilitated by the scoping of the GIS definition and context. Normalization of functions also supports commonality.

A brief comparison between the current application-specific approach and the common GIS framework training approach assists the qualitative cost analysis. For this approach, the current approach is assumed to be each program or group using a GIS develops their own training, regardless of whether the GIS application they are using is used elsewhere. With respect to ID, the current application-specific GIS training is suitable for application of the ID methodology for the same reasons as the common GIS framework. For goal development and achievement, the development of mastery goals is consistent with that of the common GIS framework, but it may be more difficult to develop short-term goals for the current application-specific GIS training. Training packages in the current construct must contain information about tool use as well as mission specific applications. Increased content indicates increased training duration, and potentially having to learn the entire architecture to complete complex tasks. Comparing motivational factors, challenge, the interest and control attributes are consistent between the common GIS framework and the current application-specific GIS. The current application-specific GIS structure training is assumed to be provided in the same manner as the common GIS

framework training instead of using a less structured approach such as gaming where users can navigate the environment autonomously. Introductory content is less likely to be available in the current application-specific GIS training environment because the training packages would contain more information and it may be difficult to extract highlights that are mineable and understandable. Application-specific GIS training would have a degree of separation of zero because it exactly matches the real-world environment. Table 4 provides a visual reference of the performance of each solution against the desired training factors reviewed.

Table 4. Architecture Similarity

	Worse Performance	Same Performance	Better Performance
Instructional Design		X	
Mastery Goal		X	
Short-Term Goal	Current Application-Specific		Common GIS Framework
Challenge Attribute		X	
Interest Attribute		X	
Control Attribute		X	
Introductory Content	Current Application-Specific		Common GIS Framework
Similarity	Common GIS Framework		Current Application-Specific

The assumed current state is comprised of each project or user group with a GIS maintaining their own comprehensive training for that GIS that includes general training of the tool as well as mission specific applications. This current state view assumes that training material is not leveraged across multiple communities. The goal of this cost analysis is to determine if cost savings are feasible across multiple programs, user groups, and communities through consolidation of training.

With respect to anticipated cost of training, when comparing training the common GIS framework to that of localized training to specific applications, savings in training costs may be feasible based on a qualitative cost analysis. This research has demonstrated that abstract, common framework training is feasible. This approach will require additional mission-specific training to be conducted. Although additional training is required, the level of abstraction of common framework training can positively influence cost by requiring fewer updates to training design. Only minimal changes to major capabilities and functions of GIS applications are anticipated due to scope. The abstract application of common functional architecture, processes, and AI layout supports this concept of minimal change. An additional benefit that may be gained from training to a common GIS framework is that the training can be provided to a larger number of learners without significantly increasing the cost. This is beneficial as training can be provided to personnel who will be providing inputs to GIS applications but remain outside the context boundary. With knowledge of how the data provided will be used, collection personnel can ensure that the minimal parameters required for GIS use are captured. Since there are aspects of the candidate GISs that are not recommended for inclusion within the common GIS framework training, the common GIS framework training is anticipated to be abbreviated in comparison to current comprehensive and potential future application specific training. Allowing users to coordinate schedules with an abbreviated training window may allow more users to take the training.

This cost-benefit analysis is incomplete without discussion of user impact on training to the common GIS framework. Although not easily captured as a cost tradeoff, user satisfaction and training burden is an important factor for determining if training to a common framework and then training a mission-specific set of tasks is acceptable. With unlimited funding, each user could receive application-specific GIS training tailored to their specific mission set. Although unconventional, this research has demonstrated that important aspect that influence training are achievable through training to a common GIS framework. Table 4 demonstrates this concept. If these aspects are correlated with user satisfaction, concluding that user satisfaction will be high is reasonable. The training burden with respect to time and effort of involvement would be based on mission-specific

requirements. Fully understanding the training burden requires knowledge of specific uses and is therefore not included in this research. Although the user impact is not fully defined, there is enough justification for cost savings on a large-scale to warrant future evaluation.

As stated earlier, training delivery method is not covered in this research. Training delivery method can have an impact on information retention, but more importantly training delivery method can have a significant cost impact. The military is evaluating electronic technologies as a way forward for training deliveries (Department of the Navy 2017). Training delivery method will not be discussed any further than to note that the training design identified through the ID process can be applied electronically and non-electronically. Training delivery method should be explored in future research. This research finding, as well as the previous research findings discussed are summarized in the next chapter.

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IV. REVIEW OF RESULTS

This research selected the GIS construct as a representative of a complex system to determine if it was possible to decompose disparate complex systems into a series of common functions. The exercise of common function extraction was conducted to evaluate the degree to which a common framework for complex systems could be trained. The anticipated retention of training to a common framework is key to determining if this approach can be applied across military systems to reduce the burden of training individual systems and applications.

The research has shown that for the specific instance of GISs, a common functional architecture is obtainable. In addition, common processes for key actions are obtainable. The processes for importing data, exporting information products, changing the data visibility, and basic querying were similar enough for including them in the common GIS framework. Developing a common physical architecture that was comprehensive was not possible, but portions of the physical architecture could be structured into a common framework. Although portions of the physical architecture were abstracted to a common subset, a review of the similarity of these abstractions to the candidate GISs showed there were enough differences to not train most common physical components. A common AI layout is obtainable and is similar enough to the candidate GISs evaluated to include it in training design. With these results, the research supports extending commonality past a common functional architecture to a common GIS framework. This research also concluded that the common GIS framework better supports motivation attributes than the current application-specific GIS approach.

Overall, there is sufficient content to generate a training package for a common GIS framework. The brief qualitative cost analysis found in Chapter III Section C has shown that there may be cost and schedule benefits to structuring GIS training in two parts with the first being the common GIS framework and the second being application-specific and mission-specific training. This benefit is only realized across multiple programs using GIS applications. The cost for follow-on application-specific mission-specific GIS training

would still be present for each individual user group for their specific GIS application and mission set.

It should be noted that the results obtained in this research are specific to the context defined for a GIS. The context definition is the opinion of the author following a literature review. If different context, inputs and outputs are defined by other researchers, the results will be different. In closing, the ability to create efficiencies and reduce cost in training development is possible, but adequate scoping is critical for such efforts to be successful. Future research efforts are necessary to determine if the approach of adequate scoping for common architecture and transfer of training is applicable to information systems not evaluated in this research. The next chapter offers suggestions for future research.

V. FUTURE RESEARCH

Based on the findings reported in this research, future research should focus in three distinct areas where future research efforts could be applicable. The first area is to evaluate training delivery methods for information systems. The method for delivery of training can span from instructor-led training to user experimentation, with varying cost. The author was unable to locate research on the optimal methods for delivering training on information systems.

The second area for future research is applying training to common frameworks. This research was limited to theoretical evaluation of the potential information transfer and cost benefits. Further evaluation is required to determine if adequate information transfer does occur in real-world scenarios, and if cost benefits are attainable. This research does not need to be limited to GISs and can be evaluated across any information technology system. Common functions and processes may be present across multiple systems in multiple services that could consolidate training efforts. Extending this concept begins with the initial design of the system. If a system aligns to a high-level function, such as a GIS, and a common functional architecture already exists, the system could be designed to align with the existing functional architecture. An approach for following a common architecture from design through training may further reduce system life cycle costs.

The third area of future research includes evaluating the implications of including the user within the context boundary as shown in Figure 2. Cost and schedule impacts are highly dependent on human-machine interactions and including implications and shortcomings in future research efforts will provide a more comprehensive view of achievable efficiencies.

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