

## Integrated GIS Work Environment for Development of 'Cartographically Styled Geo-databases'

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### **Abstract**

Increasing dependency on GIS for business decision-making coupled with its integration into mainstream IT, has brought GIS to the center stage, of the 'Management Information Systems', for analytical modeling and real-world representation. This has created a need for digital presentation, of the GIS datasets, in the most aesthetic form.

Recent enhancements in ESRI products enable efficient development of 'cartographically styled geo-databases' that enhance visual presentation, increase usage, and allow easier management of data updates, editing, text placement, cartographic styling and product development for publishing of digital and paper maps.

This paper describes the extensive utilization of ESRI products, for establishing an integrated GIS work environment, through the effective use of ArcGIS empowered with flexible customizations using VB, ArcObjects and VC++ etc. for development of 'cartographically styled geo-databases', using variety of inputs including paper resources, CAD datasets, and GIS datasets from various sources and formats.

### **Introduction**

Currently, Geographical Information Systems (GIS) seem to be evolving into 'Geospatial Information Systems' and with their increased use in today's business environment they are sometimes also referred to as Spatial Decision Support Systems (SDSS). Technology has been the key driver for this rapid development, with increased processor speeds, cheaper large size computer memories and newer 'information collation and dissemination' methodologies, including increased reliability of Global Positioning Systems (GPS), laser range finders, and cost effective mobile computing in the form of laptops, and Personal Digital Assistants (PDA). All these technologies are converging to allow GIS components to be used as a kind of specialized business toolkit.

It is necessary to have an efficient production environment to enable geospatial solution providers to keep pace with the demand for specialized services, such as development of cartographically styled geo-databases, which significantly enhance the visual presentation of a GIS dataset. Integration is the key for interfacing multiple processes, and the complete GIS data cycle, into a common platform.

After a detailed study of the various competing platforms, ESRI was identified as having the range of products able to meet most of the requirements as the central process enabler.

### **GIS Data Cycle**

The GIS Data cycle is as its name suggests, a cyclical flow of data, which is temporal in nature and is both iterative and interdependent. The GIS data cycle incorporates stages from the creation of the geographic data from different paper/digital raster and vector formats, such as maps, aerial or satellite imagery, CAD formats and tabular data, to the utilization of GIS data for analysis, including digital vector formats, and presentation, such as maps that can be on-the-fly-

representations. The GIS data cycles are not mutually exclusive and can largely be defined in the following broad categories:

- a) GIS Data Development
- b) GIS Data Collation (field data collection / verification)
- c) GIS Data Update (improvements and temporal change implementations)
- d) GIS Data Usage (visualization / analysis / componentization / presentation)

**GIS Data Development** starts with conceptualizing the business needs and defining the modeling specifications. GIS data development includes creation and modeling of data in a digital format, which can be related to a space on the globe and can represent the spatial features of that space, derived from a collection of input datasets.

**GIS Data Collation** is a continuous process, which aims to maintain the primary data of an organization in the most up to date manner possible, using on-site surveys and data sanity checks, as well as tracking for temporal changes.

**GIS Data Update** can be a complete data update or a change only update, depending on how the data is structured at the supplier's end.

**GIS Data Usage** includes customized displays, shown online or on-screen or on specialized paper maps designed for providing adequate information to the user.

### **Integrated Work Environment Using ESRI products**

Integrating the work environment, largely centered on a given family of products, enables:

- Seamless workflows across the various GIS data cycles
- Data inter-operability across various stages / cycles
- Development of re-usable custom software application components
- Focused expertise: generating effective processes and innovative solutions

The continuous use of ESRI products across various GIS data cycles is illustrated through the following case study of a live project carried out by RMSI.

### **Cartographically Styled Geo-databases**

The following sections detail the processing of cartography styled geo-databases through the entire GIS data cycle of creation, field verifications, updating and presentation.

#### **Background**

Cartographically styled road maps and atlases are an essential reference for travel, tourism, web mapping, GIS, Internet applications, routing applications, vehicle tracking, location based services, customized maps and bespoke mapping.

Historically map publishing data preparation was considered a manual process, which initially used hand drawn methods and later CAD systems. However, the conventional methods and formats had certain limitations, such as:

- Updating an existing map required that a complete recreation process is followed, which could be a tedious, expensive and time-consuming task
- The difficulty of using paper maps in a moving vehicle
- Maintaining paper maps over a long period of time is a cumbersome process

Recently, the development of 'cartographically styled geo-databases', which are created by using GIS dataset and / or various digital CAD sources, has been gaining acceptance. The key drivers behind this are:

- Availability of newer technology toolsets enabling the production of cartography quality styling in the GIS environment
- GIS datasets, otherwise a parallel industry with their own periodic update cycles, are becoming cost effective, due to their wider use across various industry sectors
- Bringing the GIS dataset developers and the mapping industry together affords a new opportunity to both, by utilizing the survey / research based enhancements and the data update cycles of the two. This brings greater value for a similar or lower level of effort
- The GIS based digital format enables easier access while on the move, through potential linking of visual frames to GPS tracking

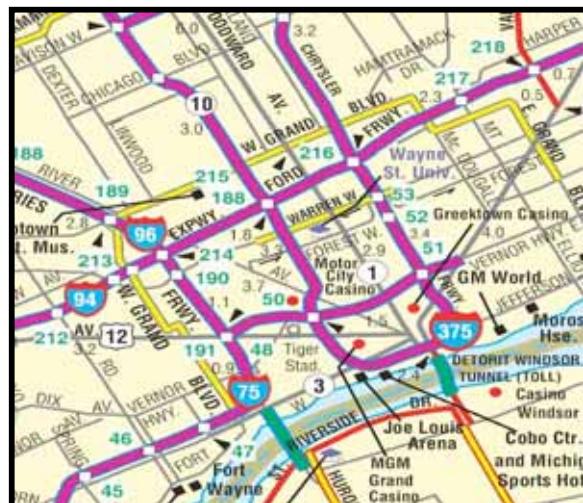
The client, a leading provider of geographic information and mapping solutions in the USA, has a wide range of paper products that include both large scale map products such as entire USA road atlases, educational maps and small-scale map products such as fold maps, flip maps, as well as customized wall maps and private label publications. The client also has the potential to develop customized mapping content by using its comprehensive cartographic databases.

The client, perceiving the increased impetus for GIS data analysis in its business, and the increased focus on the presentation of GIS data, decided to bring all of its products into the GIS environment.

Working with a team of GIS Specialists, RMSI offered several mapping solutions, including custom GIS mapping, a comprehensive process to create a publishable-quality GIS file based on client specifications. The intelligent cartographically styled geo-database is routable, searchable and geo-referenced, allowing for ease of integration with technologies such as GPS.

The key project objectives were:

- To collate the multiple products into a consolidated source base that provides a common platform for the future enhancement and updating of all products
- To benefit from the updated datasets available from the GIS data developers, to set a mutual data update cycle in conjunction with GIS data providers
- To potentially increase the scope of its mapping products, from the currently distributed printed paper maps, to intelligent desktop based maps using GIS datasets and / or various digital CAD sources as the base input. The intelligent desktop based maps are the digital vector formats, which incorporate all the visualization appeal of cartography styling, earlier possible only in paper or digital raster formats. They also have the benefits of the GIS enabled datasets and offer a significant step forward for those involved in community based retailing, helping them understand the potential of their trading locations. Consequently, it is possible to offer a complete package of customized mapping solutions to the client.



**Cartographically styled geodatabase using multiple input files like Corel and EPS**

The project deliverables included the 'cartographically styled geo-database' with print ready adobe illustrator format files as an additional output in some cases. The plan was to eventually collate all the work into an SDE server, to gain nationwide coverage. Initially, the individual production titles were worked on in the personal geo-database.

GIS Data Development (Stage-1) involved the creation of a structured geo-database using multiple input sources such as a vector database, including the street, railroad, hydrographic features and Places of Interest (POI) layers, provided by another leading GIS data developer in the USA, the current paper and digital products of the client and in a few instances, third party and public domain datasets.

GIS Data Collation (Stage-2) comprised multi-tiered data verifications including secondary research carried out by RMSI and primary research and geography based interactive research carried out by the client.

GIS Data Update (Stage-3) involved incorporation of all the research input into a 'structured geo-database'. Change detection mechanisms were also implemented to check for any parallel changes in the vector database of the GIS data developer, and potential incorporation in the 'structured geo-database' for the mapping client.

GIS Data Usage (Stage-4) involved presenting the finalized digital dataset in the form a 'cartographically styled geo-database', keeping to the scale determined and in the pre-defined projections. For some products the scope also included print ready outputs such as eps / pdf / adobe illustrator (ai) formats.

### **The Project Phase**

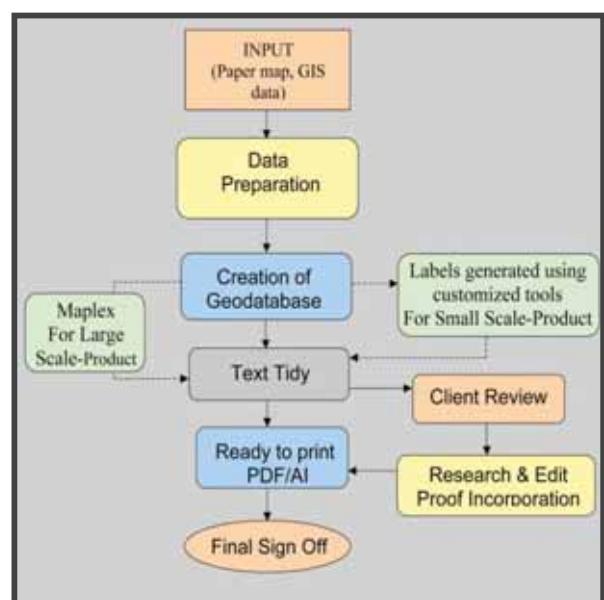
The first step in the GIS data development stage involved putting together a team of GIS professionals with experience in USA street data capture and knowledge of modeling rules, as well as expertise in cartography, conceptualization and process and system developments on various platforms, including Arc-GIS.

The project conceptualization, implementation, execution, and sign-off processes for the various GIS data cycles are shown below.

#### **GIS Data Development - The development of a cartographically styled geo-database:**

The client had a range of map products varying in scale, from a large scale of 1: 5000, for downtown and city center areas, to a small scale of 1:10 million for a map of the entire USA. The client had different products at various interim levels, such as city maps, metro area maps, regional maps county maps, state maps, and inter-state maps.

After studying the various map products, it was agreed to have two main streams for the GIS datasets, one to cater to the larger scale map products, using GIS datasets from a regular GIS dataset developer, as the primary base, and the other to cater for the smaller scale map products using varied paper products and/or digital CAD sources, as the primary base. In both cases researching of alternative information sources was carried out for additional enhancements.



**Sequential flowchart**

A typical data flow for the USA Road Atlas product, a small-scale map product, included:

- Geo-referencing the CAD files, which were primarily in the Corel Draw / AutoCAD format
- Migration of CAD files to ESRI shape file format and GIS modeling
- Restructuring the shape files in terms of attributes and geometry editing
- Conversion of shape files to a personal geo-database
- Creation of a cartographically styled geo-database, by using the customized applications in ArcGIS to generate annotations, and then doing manually cleaning the text placement.
- The geo-database was then exported to Adobe Illustrator format to provide a print ready format

A typical data flow, for the large-scale map products basket, involved:

- Use of GIS datasets in the ESRI shape file format, as the input source
- Restructuring the shape files in terms of attributes and geometry editing, as required
- Converting shape files to the personal geo-database.
- Generating feature-linked annotations, by using the Maplex application, as the data for the city areas is normally quite dense
- ArcGIS's customized editing applications were used to do text tidy for cleaning up text placement and for finalizing the cartographically styled geo-database.
- The geo-database was then exported to Adobe Illustrator formats (ai / pdf) to provide a print ready format

The data flow stages are illustrated below:

### **Base GIS Data Preparation**

Inputs from the client mainly consisted of existing paper maps, CAD files and GIS data in the ESRI shape file format.

The key challenges in this phase included:

- The wide variety of input formats, including multiple paper maps, CAD format digital datasets, PDF format files, and GIS datasets
- Wide variations in the map scales of the paper maps and the CAD format digital datasets
- Undefined overlaps between various input / reference products
- Disparity between the attribute tables and the projection coordinate systems, of the various source GIS datasets
- Disparity between the layer classification names / feature names and data structures, of the various CAD source datasets
- Topological issues associated with migration of the CAD dataset to GIS modeled datasets

As with the first step, all the required paper maps were scanned and geo-referenced and extent files for the respective products were created. The CAD format digital datasets were also geo-referenced and then extent files were created. Various overlapping / adjoining geographic extents were combined into 'Program Base Extents' (PBE), where each PBE represented the consolidated extents of multiple products that could be created from a singular geo-database, avoiding the need for duplications of efforts for overlapping areas.

RMSI developed methods to convert, or reformat, the varied inputs to a common GIS



**Program based output**

format, such as ESRI Shape files, along with the data attributes such as feature names and feature classifications.

### Development of Structured Geo-Database

The consolidated shape files were imported as a personal geo-database, with the cartographic styling fully configured as specified. The importing of shape files and the cartographic styling of the various graphical features was semi-automated using ArcObjects and VBA based applications. The user applications and tool sets enabled cartography styling by reading the specifications and rule-base stored in MS Access data tables.

The updating of the attributes and editing of the graphics was possible by using customized toolsets, with a mix of native functions and custom functions developed using ArcObjects. Feature editing involved specific fine-tuning of the GIS datasets to make them aesthetically pleasing, and removing feature overlaps after the line weights and symbol sizes were applied, so that the respective adjoining features are easily distinguishable at the map print scales.

### Development of Feature Annotation Layers

Names of streets, features and POIs are the prime component of a road map. As the feature names in the geo-database were part of the primary attribution, specific processes were developed to convert labels to annotations and to manually edit duplicate and over-lapping annotations.

As previously mentioned, the project goals include the development of two distinct streams: one for the smaller scale mapping products and other for the larger scale mapping products.

In the case of the smaller scale mapping products, custom applications were developed using Arc Objects on ArcMap version 8.3 base, for auto-annotation-generation with a rule-base predefining font size in page units, for respective scale, and font types pre-defined by the feature class code. This ensured that text alignment was in line with the feature chain to which it is linked. Some algorithms were developed to avoid text baseline overlaps and to mark areas of potential overlaps for manual editing.

In the case of the larger scale mapping products, Maplex was used as the primary application to generate text annotation layers, using a given rule-base to define the font types for the respective layers. This was based on the feature class codes defining the category of road attributes, font sizes and other selections to determine the quality of such things as the annotation placements. In this case feature linked annotations were used. As there were a great deal of labels, it was necessary to manually appropriate the 'unplaced labels', which also involved re-tidying the 'placed labels'.

Custom applications were developed using ArcObjects with ArcView typically being used for editing of feature-linked annotations. The customized functions included clipping and appending tools for feature linked annotations in ArcView and text tidy tools for editing text annotation placement, alignment, stacking and indexing. Applications were also developed for automated verification of the specifications for styling and font size and types.



Process Automation Toolsets

## Creation of 'Cartographically Styled Geo-Database'

The cumulative output of the previous 3 steps i.e. data preparation, development of the structured geo-database and development of annotation layers and text tidy is termed as a cartographically styled geo-database. The following pictorials illustrate the difference between a conventional GIS dataset and cartographically styled geo-database. From these pictures it is clear that the cartographically styled geo-database enhances the visual representation significantly while retaining the benefits of associated attribute data for analysis and structured queries.

### GIS Data Collation

GIS data collation is a process involving numerous steps:

Preliminary research, carried out during the creation of the structured geo-database:

- Client research, to identify recent developments since the last update of their product
- Secondary research, by RMSI, comparing the geo-database with a product specified by the client, the goals being to further enhance the database, in terms of attributes and geometry, and to ensure that the output provides the current product information as a sub-set
- Client validation of queries raised by RMSI, based on anomalies observed during the secondary research

Edit proof research, following the creation of the structured geo-database:

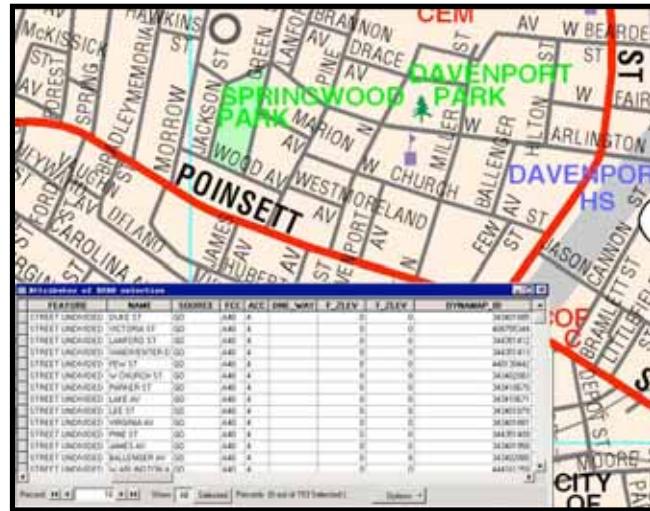
- Client verification of the additional features captured and delivered as part of the 'structured geo-database'

Final proof research, following creation of the cartographically styled geo-database:

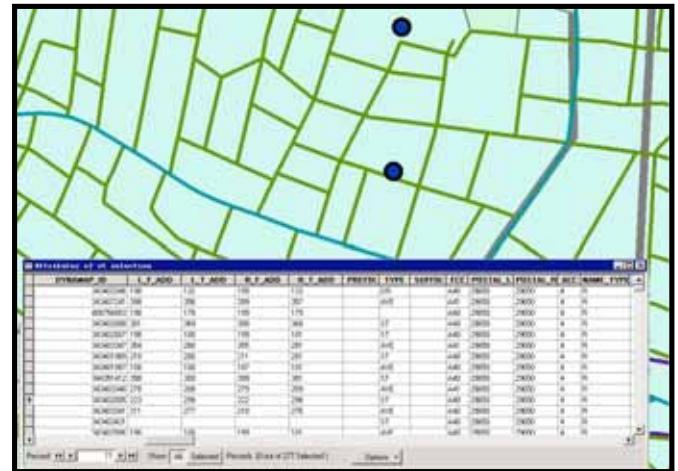
- Client research to confirm and verify additional features and attributes captured and delivered as part of the cartographically styled geo-database
- Continuous search for newer dataset and to determine if any elements have changed since the previous update

### The advent of the Digital Mark-Up (DMU)

Traditionally, paper plots and marked edits with colored pencils have been used to communicate the outcome of the research and data proofing observations. These paper plots would need to be

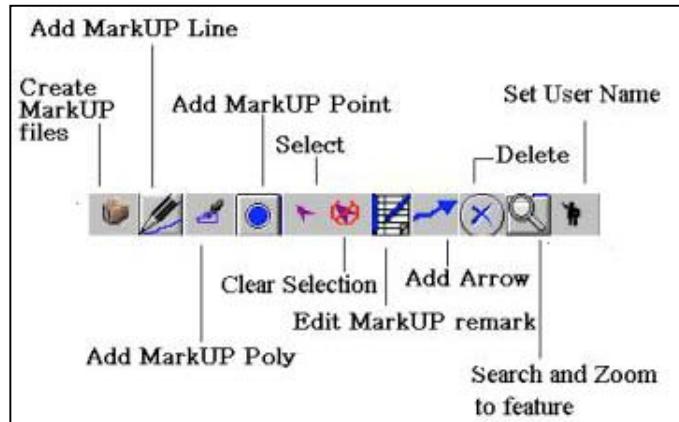


Cartographically styled geodatabase along with attribute information created using raw vector source



translated into a digital format to enable the mapping technician to make corrections directly in the geo-database. This approach to sharing information in paper form was considered a critical limitation for information flows and data collation at all stages of the project.

Initially a digital mark-up system using map objects was designed but it had a limiting factor in terms of raster file sizes. This method involved creating raster files from the geo-database as a visualization layer for marking the further edit needs, and was therefore quite inefficient, as Map Objects did not support cartographic styling effectively. Based on the experience gained, RMSI designed a Digital Mark-UP (DMU) in ArcGIS, which enabled the editor to work directly with geo-database in the ArcGIS environment.



Digital mark-up tool set

The enhanced solution was developed with Arc Objects working on an ArcGIS platform, with sufficient functionality added for marking the potential edits in a cosmetic layer, including instructions for corrections to, and additions of, graphics and attributes.

This enhanced the digital transfer of edits and in turn reduced the need for reiterations. The DMU had the requisite functionality to enable marking up changes observed in the research and reporting this back to the mapping team. The editing functions provided are illustrated in the figure above

### GIS Data Update

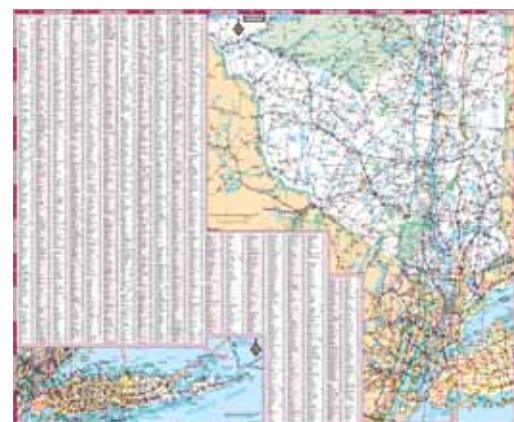
In the specific context of the dataflow applicable for this project, the GIS data update happens in multiple steps that are interactively re-sequenced with the data development and data collation stages.

In the first round, the input GIS dataset, as received from a GIS data developer, was enhanced using secondary research of data comparisons carried out by RMSI. Wherever more recent alternative public domain GIS datasets were available, these too were used, which typically involved a change detection methodology built on Arc-Info functions. During this phase RMSI also incorporated the preliminary research input from the client.

In the second round, the edit proof research inputs, received from the client, were incorporated. These edits were mostly from the cartographic perspective. In the third round, the final research inputs, as received from the client, were incorporated. This step involved making additions and changes to the cartographic data, based on current ground truth, research, and proof checks provided by the client. The editing for the above research input was done in the ArcGIS environment.

### GIS Data Usage: The Creation of Final Deliverables

In addition to the cartographically enabled geo-database, print-ready files in Adobe Illustrator EPS and PDF formats were prepared and delivered to the client. PDF and EPS files are prepared by porting the cartography styled geo-database into Adobe Illustrator and overlaying this with the map furniture such as the page layout, street index, town index, mileage chart, legend, scale bar and lat/long grid. The export functionality



Output in PDF

available in ESRI ArcGIS was not effective for certain sets of font types, so RMSI developed customized VBA and ArcObjects export tools to handle fonts and symbols. These tools were also used to generate indices for road names and other specific feature names that appeared within a respective grid.

Developing a cartography-enabled geo-database involves much more than simply showing political boundaries, or shipping routes on hand-drawn paper maps. Today, cartography uses cutting edge technology that makes good use of remotely sensed imagery and computer-software tools. It can be used to show anything from patterns of rainfall in a farming region to ocean trenches and mountain ranges. It is a field of study that is always changing and adapting to suit the needs of map-users.

The cartography-enabled geo-database was able to generate various products of the same scale basket, apart from the primary product, mostly by re-appropriating the product as per the respective cartography rule-base and the corresponding annotation re-sizing.



**City area maps**

**Further Directions**

RMSI plans to enhance the various applications developed for the project as an integrated tool kit, enabling efficient workflows in the ArcGIS environment. RMSI will review the applications and processes in the context of the recent release of ArcGIS 9.x, which is expected to have more functionality for such projects.

A further development is on-line routing mechanisms such as Smart Maps, which can be used to determine your coordinates and locate you in the world, enabling its use in location based service applications. Maintaining a contiguous database digitally for the whole of the USA would enable custom maps to be created on demand.

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