Title:

Survey and GIS Integration for a Large Construction Project Using ArcGIS Server

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Biography:

Dr. Yongmin Yan is a GIS automation specialist for Bechtel, responsible for creating GIS application development standards and procedures and for leading GIS automation tasks.

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Joe Betit is survey manager for Dulles Transit Partners, a team led by Bechtel, responsible for technology implementation and system integration and for leading 40+ survey staff for the Dulles project.

Abstract:

The boundary between GIS and survey blurred significantly in the past decade. More GIS professionals are now doing the survey work thanks to the prevalence of portable GPS units, and more surveyors are using GIS to manage their work.

Located in Northern Virginia, the Dulles Corridor Metrorail Project is one of the largest civil infrastructure construction projects in the United States. After its completion, Washington Dulles International Airport, Virginia's top two largest employment centers (Tysons Corner and Reston-Herndon), and downtown Washington, D.C., will be connected through a 23-mile extension of Washington's rail transit system--Metrorail. Construction is underway for Phase 1 of the project, currently valued at 2.6 billion dollars.

The complexity of the project and the large volumes of survey work requests (SWR) make traditional ways of managing SWR via papers and spreadsheets no longer feasible. A Service-Oriented Architecture

(SOA) and a web-based ArcGIS Server application were developed to better manage SWR and to provide additional GIS support to streamline survey works.

The data access web services make it easy to interact with backend enterprise Oracle Spatial geodatabases. The coordinate conversion web services enable coordinate conversions between Geographic (latitude and longitude), UTM, State Plane, and project-specific coordinates. The alignment calculation web services translate stations (linear reference system used in railway) into Cartesian coordinates. Map services serve out interactive maps.

With a web browser, field engineers can now submit SWR through a user-friendly form; survey teams can get automated email notifications when a SWR comes in and modify SWR during its lifecycle; survey managers can manage thousands of SWR through advanced search and report functions; and field engineers, surveyors, and managers can use interactive maps to discuss survey work. This enterprise GIS system has significantly improved the efficiency of survey work and is ensuring construction activities go smoothly and on schedule for this multi-year endeavor.

Keywords:

GIS, Survey, Survey Work Requests, Service-Oriented Architecture, Web Services, ArcGIS Server, Dulles Corridor Metrorail Extension, Dulles International Airport

Introduction

The boundary between GIS and survey blurred significantly in the past decade. More GIS professionals are now doing the survey work thanks to the prevalence of portable GPS units and more surveyors are using GIS to manage their work.

Located in Northern Virginia, the Dulles Corridor Metrorail Project is one of the largest civil infrastructure construction projects in the United States. After its completion, Washington Dulles International Airport, Virginia's top two largest employment centers (Tysons Corner and Reston-Herndon), and downtown Washington, D.C. will be connected through a 23-mile extension of Washington's rail transit system--Metrorail. Construction is underway for the first phase of the project, currently valued at 2.6 billion dollars [1]. See Fig. 1 for project location map.

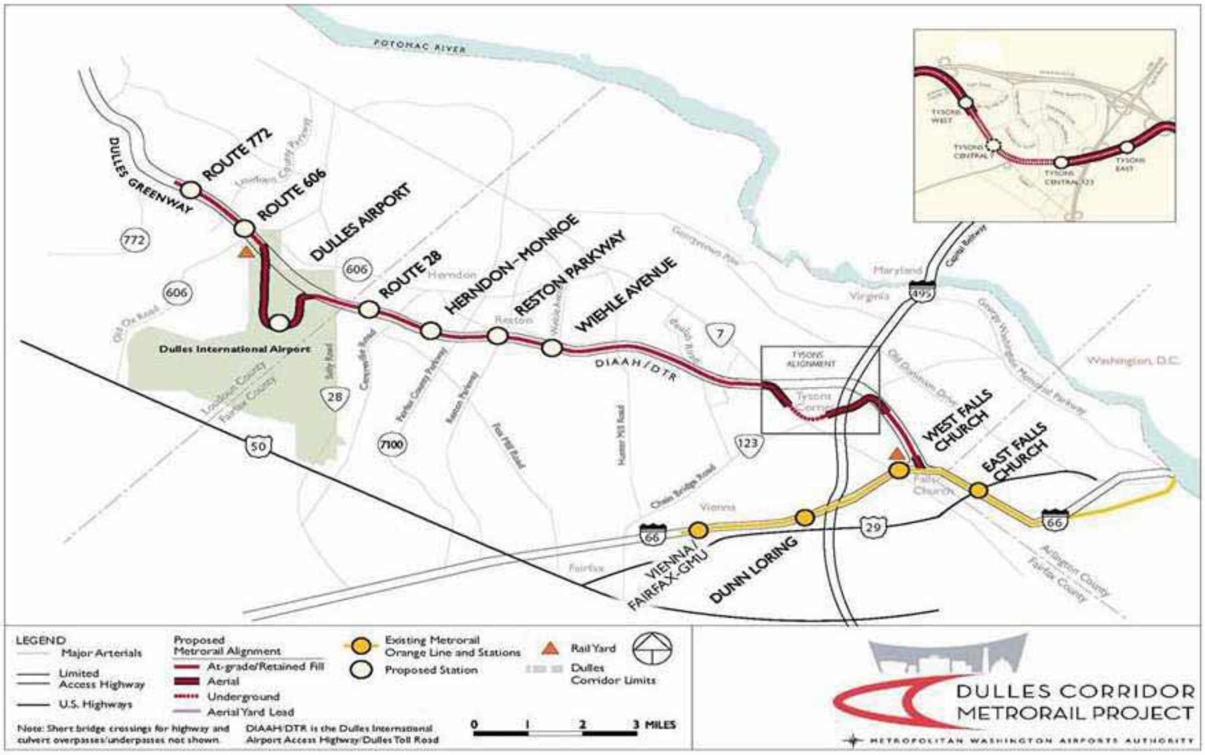

Figure 1. Dulles Metrorail Project Map (courtesy of Metropolitan Washington Airports Authority)

The complexity of the project and large volumes of survey work requests (SWR) make traditional ways of managing SWR via papers and spreadsheets no longer feasible. A web-based SWR system based on Service-Oriented Architecture (SOA), Microsoft .Net, Oracle Spatial database, and ArcGIS Server were developed to better manage SWR and to provide additional GIS support to streamline survey works.

Service-Oriented Architecture and Web Services as Backbone

Bechtel has developed GIS application development standards, from simple naming conventions to advanced reusable software components and resources. The core of this standardization is Bechtel's Enterprise GIS Application Development Framework (ADF), which is developed based on the principle of Service-Oriented Architecture using Microsoft .Net technology. As part of ADF, web services are the primary resources that Bechtel uses to share common business functionalities, *e.g.,* data access web services that are built upon Microsoft Enterprise Library make it easy to interact with the backend enterprise Oracle Spatial database [2].

In addition, the coordinate conversion web services enable coordinate conversions between Geographic (latitude and longitude), UTM, State Plane, and project-specific local coordinates. For example, engineers usually use the local project coordinates while emergency response teams need to know the actual geographic coordinates. The coordinate conversion web services make it much easier to bring together coordinates from different coordinate systems.

The alignment calculation web services translate stations and offsets into Cartesian coordinates. Offsets are the perpendicular distances away from the rail alignment with negative values indicating left side and positive values indicating right side (inbound and outbound rail segments are defined separately with their own specific directions). Stations, used primarily in railroad design, are similar to the linear reference system in GIS, specifying the distances along the rail alignment (see Fig. 2 for illustration of stations and offsets). However, rail segments are mathematically defined by lines, curves, and spirals, which are very precise (see Fig. 3 for an example of rail alignment comprised of various lines, curves, and transitional spirals between lines and curves). Spirals are not directly available in GIS (they are approximated by a series of small straight lines). Also, station equations are often used to adjust station values at certain locations, making it extremely hard if not impossible to develop an equivalent and precise linear reference system in GIS. Therefore, alignment calculation web services were developed, which use specific mathematical formulas for lines, curves, and spirals to accurately calculate Cartesian coordinates from stations and offsets. With alignment calculation web services, users no longer have to rely on third party CAD software to translate stations and offsets, as the alignment calculation web services are directly incorporated in the web application.

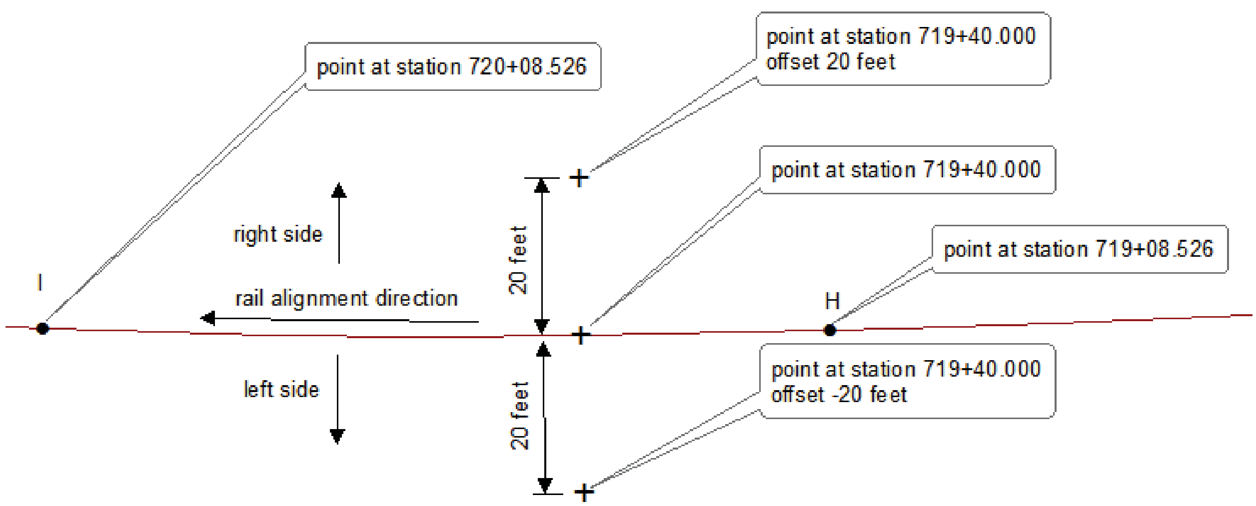

Figure 2. Stations and Offsets

AB: straight line

BC: transitional spiral from line to curve

CD: curve

DE: transitional spiral from curve to line

EF: straight line

FG transitional spiral from line to curve

GH: curve

HI: transitional spiral from curve to curve

IJ: curve

JK: transitional spiral from curve to line

KL: straight line

Note: in addition to start locations, lines are defined by length and direction; curves are defined by center, radius, length, and start and end directions; and spirals are defined by start and end radii and directions, and length, etc.

Figure 3. Rail Alignment Comprised of Lines, Curves, and Spirals

Map services serve out interactive maps. ArcGIS server provides a quick and easy way to deploy map services and web applications. Its rich API is also highly customizable, making it suitable to either rapidly set up a prototype or to develop a more sophisticated solution over time.

Fig. 4 shows the relationship between different software components.

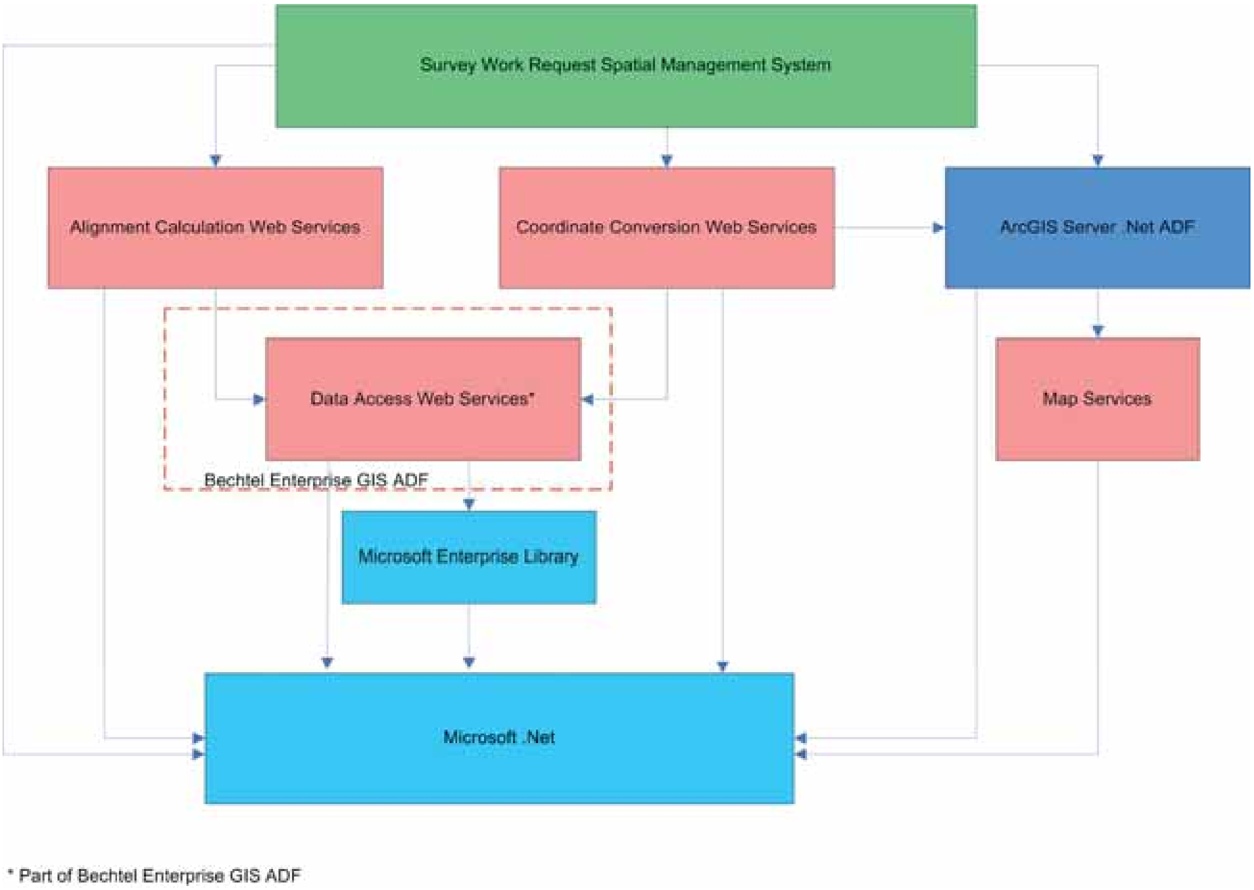

Figure 4. Software Components of Dulles SWR

Standard Data Model and Integration of Survey Grade Project Data and Public Data

Bechtel adopted a standard enterprise data model called the Spatial Data Standards for Facilities, Infrastructure and Environment (SDSFIE) which was first developed for the military but the usage of which has spread throughout many other federal, state, and local GIS organizations. Even though this data model is quite comprehensive, it is actually very flexible and expandable. The standard data model allows Bechtel to maintain uniformity across all projects. All survey grade project data, such as boreholes, survey controls, rail extension centerlines, rail stationing lines, wastewater lines, pipe lines, culverts, storm sewer lines, power lines, pier structures, etc., were loaded to the enterprise geodatabase, conforming to this data model. These project data are in project specific local coordinate system. The public data, obtained from ESRI Data & Maps, such as roads, railroads, rivers, water bodies, landmarks, airports, etc., are in geographic coordinate system WGS 84. For performance reasons, these public data sets were clipped, reprojected to the local project coordinate system, and loaded to the enterprise geodatabase.

The SWR system also makes use of publicly available ESRI ArcGIS online base map and imagery services for quick overlay of some small data sets.

Lidar data were used to create videos for 360 degree 3D viewing of any rail segments, accessible directly from the SWR system.

With all these spatial data at their finger tips, field engineers and surveyors have a better knowledge of their survey locations (see Fig. 5 for an example of spatial data that are available: high resolution orthophoto, survey controls, borehole locations, pier structures under construction, utilities, etc.).

Figure 5. Detailed Survey Location Information at Finger Tips

User friendly Web Application

An application's success in large part depends on whether or not it is easy to use. User-friendly interfaces were developed that keep the system as simple as possible.

Field engineers can use a simple web form to enter basic information of a SWR, with extensive use of dropdown lists and AJAX to improve ease of use, system response time, and performance; while surveyors have an expanded web form to record additional information on survey work execution. Both forms make use of alignment calculate web services and coordinate conversion web services so that a user can simply enter station and offset values for a survey location and the system will automatically calculate Cartesian coordinates in various coordinate systems and store the geometry directly in the enterprise geodatabase for immediate mapping and database query. Files such as design drawings can be attached for quick reference.

The system can automatically generate email notification once a SWR is submitted, making it more streamlined and manageable.

Survey managers can manage thousands of SWRs through advanced search and report functions. *e.g.*, SWRs can be searched by a combination of ID range, group, key word, reference document, operating area, segment, section, station, requestor, request department, surveyor, date, status, etc. and/or spatial bounding box or distance from a certain location. Reports can be exported to a PDF file or an Excel spreadsheet.

Field engineers, surveyors, and managers can conveniently use the mapping interface to browse survey locations and to discuss survey work before, during, and after a survey.

All of these functionalities have significantly improved the efficiency of survey work, and are ensuring that construction activities go smoothly and on schedule.

Conclusion

To meet the challenges of coordinating and managing thousands of survey work requests for the Dulles Corridor Metrorail Project, a web-based ArcGIS Server application was developed based on Service-Oriented Architecture, Microsoft .Net, web services, and Oracle Spatial. This user-friendly system brings a wealth of spatial data to the finger tips of field engineers, surveyors, and managers. With enterprise spatial management of SWR and reusable web services for coordinate conversion and alignment calculation, this system has demonstrated to have significantly improved the efficiency of survey work and help to ensure that construction activities go smoothly and stay on schedule during this multi-year endeavor.

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