Sensor to Internet: A Complete Workflow from Pixels to the Web with On-Demand Geoprocessing

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ABSTRACT

As raw data is captured from an airborne sensor or a satellite, geospatial authoring solutions are used to produce geospatial data such as stereo-images, ortho-images, terrain, 2D and 3D feature datasets, land cover classification, vegetation health and other geospatial data products. Using theses geospatial data products as input, spatial models can then be created that allow for the extraction of application specific information such as change detection, feature extraction, GIS analysis, site selection, and inter-visibility. The spatial models along with the input data products are subsequently cataloged in an enterprise data management system and are published as interoperable Open Geospatial Consortium (OGC) web services such as WMS (for maps), WCS (for images and terrain), WFS (for features), WPS (for spatial models). GIS, CAD and web client applications can then directly access the web services and begin exploiting the data and information over the internet. ERDAS provides software solutions that span the entire geospatial information lifecycle, allowing users to extend pixels captured from sensors and intelligently and rapidly deliver them and all derived information over the internet.

1. INTRODUCTION

Increasingly, geospatial information is being used to drive decisions in large organizations. In the past, geospatial technology companies focused on developing and providing solutions to data providers, geospatial service providers, airborne sensing organizations, national mapping agencies, state mapping agencies, DoD/National Programs and the natural resources sector. However, as awareness in geospatial technology has increased, more organizations outside this traditional geospatial customer base are discovering the offerings, with increasing interest in integrating this technology into their organization's existing enterprise business system.

Rather than understanding the vast array of remote sensing, GIS, photogrammetry, or other related geospatial offerings, these new customers speak only in terms of their business need, requiring a solution that operates and integrates with their existing software applications. For these new customers, it is vital that geospatial technology providers adequately understand their requirements, matching these needs appropriately. The geospatial tools must also meet the organization's existing security and sharing specifications.

Incorporating geospatial information into the large quantities of existing data an organization maintains adds immense value. Maturing standards and improvements in web services, data compression, metadata standards, delivery and processing power are bringing geospatial data exploitation to the enterprise, making this technology readily available to non-traditional geospatial businesses. Organizations integrating geospatial technology are more equipped to manage their data and storage, with new tools to automate, extract, collaborate and share information.

Previously, geospatial technologies operated in the desktop environment, or via web applications detached from other vital software packages. Without interoperability, geospatial technology remained separate from other integral applications, including those associated with an organization's manufacturing, supply chain, financial, human resources and customer resource management systems. Separated from geospatial applications, data spread throughout an organization could not be adequately analyzed and fully transformed into the most comprehensive and understandable information. However, recent innovations and Service Oriented Architecture (SOA) developments have introduced a growing number of interoperable, platform agnostic geospatial solutions. These technological advancements allow an organization to maximize the effectiveness of their existing business system.

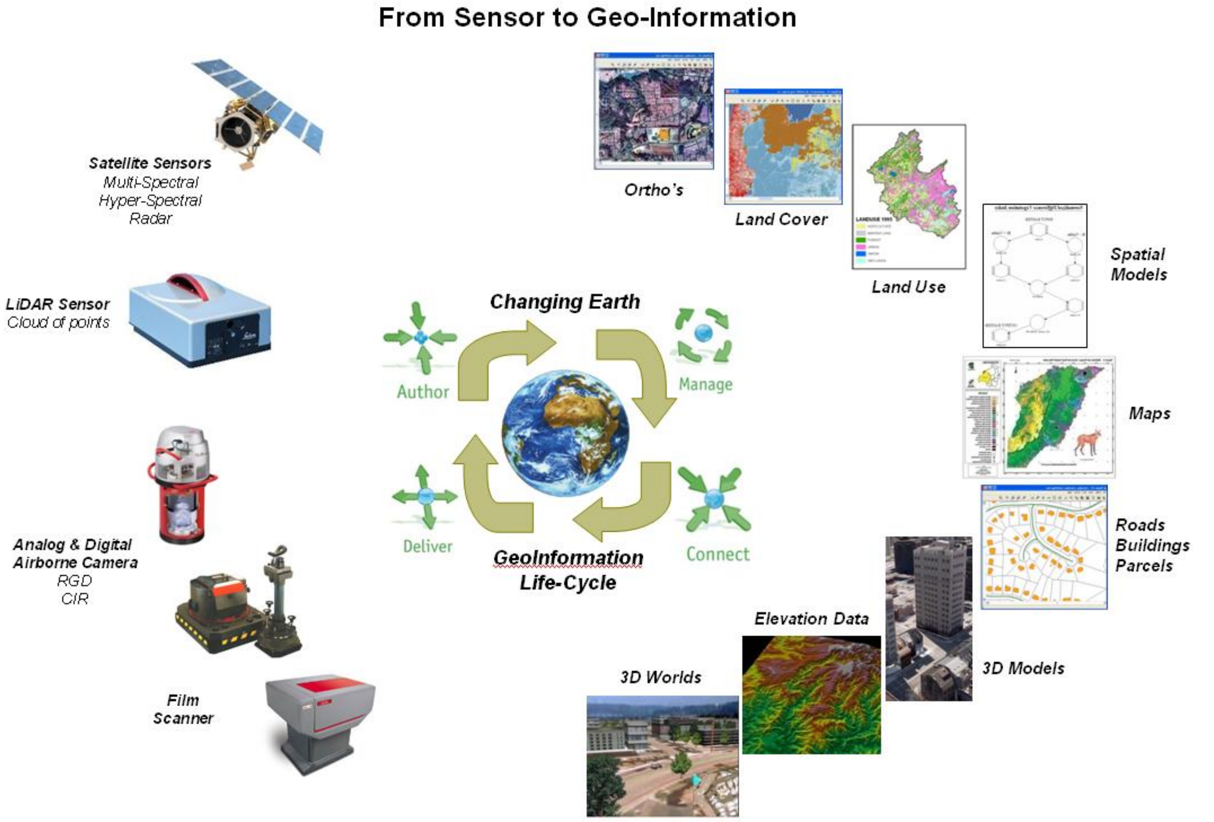

Fig. 1: Geo-Information can be derived from content captured from a variety of sensors.

By incorporating the geospatial component into a business system, organizations have the ability to transform data into geospatial information. On-Demand geo-processing allows existing users of desktop applications to author spatial models that perform a specific task for deriving information from data. Once a spatial model is authored, it is then cataloged by an enterprise data management system and can then be delivered as an interoperable web processing service (WPS). Non-traditional users can now go to a website and instead of simply looking at a static image of an area; they can request an information product for that area and then be delivered that product on-demand. In this scenario a geospatial server application operating within an IT application server performs the spatial model by referencing the content needed to create the product and then produces the product on the server. As the data progresses from authoring to delivery, the value of the information also increases, from captured source content to information providing valuable decision support.

1.1. Driven by Change

The earth's geography is continuing to change at a rapid pace. As a result, there is an increasing need for geographic information to understand the earth. This 'spark' fuels the lifecycle of geographic information. The lifecycle is broken down into four primary components: Author, Manage, Connect and Deliver. As the earth changes, we have an increasing need to 'sense' the earth. Data can be captured from a variety of sensors, including airborne, satellite and terrestrial. As the raw data is captured, it needs to be 'authored' in a form that is useable to derive information. As the volume of data increases, organizations experience a data management problem. Enterprise solutions are needed to manage the large volumes of data that have been 'sensed.' Once the data has been centrally managed, there is often a need to share that information with others distributed across an organization. Delivering all this information to end users is the final step. With an increasing need to understand our dynamic world, this is an ongoing, recurring lifecycle. Our thirst for understanding the earth ultimately provides us with more knowledge. This knowledge enables us to take necessary precautions to protect our planet and ensure a viable future.

Geospatial Business Systems allow an organization to build, implement and maintain a comprehensive Spatial Data Infrastructure (SDI). This assumes that data is being dynamically produced and subsequently cataloged and web service enabled, disseminating data made available through discovery services. This allows users within and outside an organization to securely find and retrieve necessary information they need from the SDI. All of this is possible by making contents of an SDI available through an open extensive geospatial environment.

ERDAS technologies offer an interoperable solution for the entire lifecycle of building and maintaining an SDI. As data is produced by ERDAS IMAGINE and LPS, it can be cataloged and the metadata harvested and centrally stored so users can securely discover the information they need. Using ERDAS APOLLO, customers have the ability to build an SDI and the geo-portal that would enable discovery and delivery of the information.

2. AUTHORING GEOSPATIAL DATA AND SPATIAL MODELS

Geospatial authoring solutions enable users to utilize raw data captured from a variety of sources to produce data sets. Users may prepare this data to be used in numerous applications, increasing its versatility and the ability to derive additional information. With authoring solutions, users may perform a number of processes and analytics. For example, users may reference raw data to location, classify land cover, or develop a spatial model to compute change in an area. Authoring solutions transform source data into products, including orthos, terrain, features, maps, 3D data, land cover data and processing models.

ERDAS ER Mapper provides functionality directly applicable to analyzing and exploiting the types of data used in a variety of industries, including oil and gas and mining. ERDAS IMAGINE provides geospatial tools with an even higher degree of capability, including the ability to orthorectify satellite and aerial imagery. In addition, ERDAS IMAGINE offers a great number of file formats that can be interchanged, extensive vector editing and analysis capabilities, the ability to design custom geospatial analysis tools, hyperspectral and other advanced classification techniques, as well as the ability to interpolate continuous gridded surfaces from large point data sources. Together, both ERDAS ER Mapper and ERDAS IMAGINE provide advanced geo-processing support. Spatial models are built using a variety of spatial operators. Each model is constructed as a workflow to produce an output information product. Once spatial models are created, they are then published to ERDAS APOLLO. ERDAS APOLLO catalogs the spatial model and service enables the spatial model as an OGC WPS.

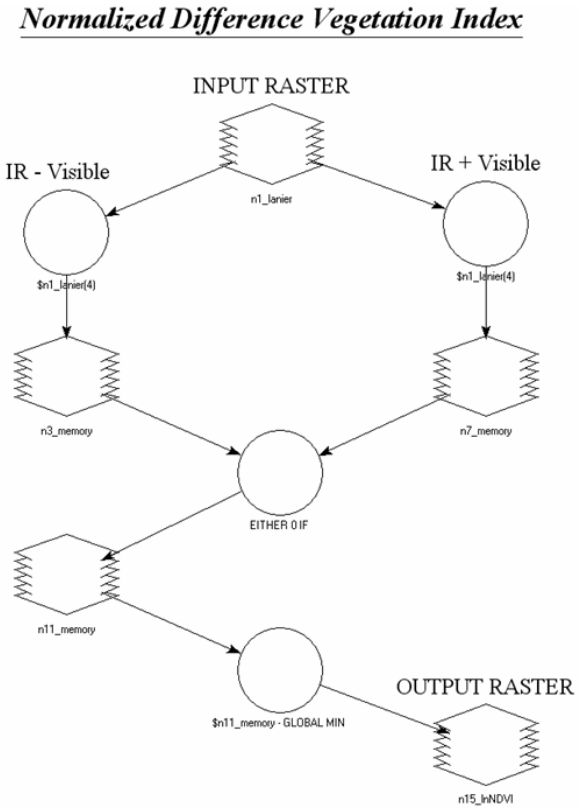

Fig. 2: A spatial model authored in ERDAS IMAGINE for assessing Vegetation Health.

Photogrammetric production workflows have increased in productivity since the development of digital photogrammetric workstations. Imagery is ingested as image files, projects are setup to manage the collections of data, interior orientation is established, exterior orientation is established through point matching and bundle adjustment, stereo models are created and used for interactive extraction or automated extraction. The final products (stereo-images, digital terrain models, orthos, mosaics, vectors, 3D models etc) are then delivered to the customer. A great deal of work has gone into accelerating the various production steps because of their highly computer intensive nature (faster CPUs, multiple processors, distributed computing) but each of these has been a specialized or proprietary system. The overall workflow at the project level and at the business level has been disconnected from the photogrammetric workflow. Photogrammetric systems remain contained within enterprise departments as standalone silos. Enterprise and information technologies have now matured to such a level that they can now be brought to bear on the photogrammetric workflow, or perhaps it is better to say that the photogrammetric workflow can now be part of the larger enterprise business system.

It is useful to begin with a definition of the term enterprise. A system that is comprised of the following can be thought of as an enterprise system:

- True multi-user, simultaneous access to the same production project from any workstation in the production network
- Transaction processing against a central database
- Real-time automatic status updates of client workstations in the network as the project progresses
- Project access and security on par with the system domain
- Rational schemes for managing high volume, highly transient data types
- Capabilities provided as interoperable services
- Scalable to meet the growing production and throughput demands of an organization
- Ability to persist all variables and parameters associated with the photogrammetric workflow
- Extensible platform for customizing the photogrammetric workflows and integrating them with other business workflows

These are common characteristics of traditional business systems like banking, but they are now key components of Geographic Information Systems (GIS). The success of these traditional systems has been based on the development of standards that allow the various components to interoperate, as it is rare that a single vendor can provide a single enterprise system and certainly, no single vendor dominates the industry to provide the interoperability that is needed for large distributed systems to interact. Standards like the hypertext transfer protocol (HTTP) allow for the transmission of information across disparate systems, while standards like the extensible markup language (XML) allow this information to be understood by these same disparate systems. These standards are now a part of the GIS world with specific applications of XML for feature data known as the Geographic Markup Language (GML). These same standards bodies are working to produce standards in the photogrammetric world such as SensorML and the Transducer Markup Language as a means of persisting sensor information and the Community Sensor Model (CSM) as a definition of a reusable sensor model API.

Any complex process such as the photogrammetric production workflow must be modeled and persisted or saved. The photogrammetric workflow has a very specific set of data entities that can be described within a photogrammetric data model. These data entities may include imagery (raw, oriented, and orthorectified), ground control points, automatically or manually measured tie points, terrain data, vector data, camera information and so forth. Photogrammetric projects also use metadata to describe these data assets. Important metadata include image identifiers, interior orientation parameters, exterior orientation parameters, coordinate system, descriptive data, and more. Together the photogrammetric data entities and the metadata describing them comprise the photogrammetric data model. In most systems, this model will take the form of some type of project. Storing and persisting all metadata associated with the photogrammetric workflow is critical to downstream geo-processing. Spatial models can leverage the metadata contained within a dataset and use that information to automate geo-processing workflows.

We can think of the various entities managed in the system as assets that are described by their various metadata. In this case, the model supports an asset from its inception through its processing and should continue to support the asset through its final dissemination. The more closely the data model agrees with the actual process the more automation can be brought to bear. In this example, the photogrammetric model begins with flight plans that are created at the time the project is planned. By including the flight plan in the model and carrying it through the system, it is possible to increase the automation at all points. In this case, the flight plan is loaded onto the control system and the camera can be controlled to define exposures. The exposure metadata are also carried in the model as flight data that can then be used to automatically establish the project on the desktop workstation.

3. MANAGING GEOSPATIAL DATA AND WEB SERVICES

Thorough and complete data management enables organizations to get the appropriate information to the right people. By centrally managing authored or purchased data, the data is organized for quick and efficient discovery. With ERDAS' solutions, users can easily manage their information, including finding, describing, cataloging and serving data and web services. Implementing the utmost security measures throughout the managing process, ERDAS adequately protects data, maintaining fidelity on the geospatial investments.

Geospatial disciplines and domains define the standards that allow sensor systems and software to operate. In our rapidly expanding industry, there is a growing need for standards-based geospatial data management and delivery solutions.

The majority of standards driving the geospatial industry are driven by one of two organizations. The International Organization for Standardization (ISO) located in Geneva, Switzerland and the

OGC located in Wayland, Massachusetts in the US. While the set of ISO standards work is very broad (ranging from agriculture, to mechanical engineering, to information technology) the OGC focuses specifically on standards that affect Geospatial Information Technology.

A short list of OGC standards includes:

- Coordinate Transformation Service − provides interfaces for general positioning, coordinate systems, and coordinate transformations
- Web Map Service (WMS) − provides three operations in support of the creation and display of registered and superimposed map-like views of information that come simultaneously from multiple remote and heterogeneous sources
- Geography Markup Language (GML) – provides an XML encoding for the modeling, transport and storage of geographic information including the spatial and non-spatial properties of geographic features
- Web Feature Service (WFS) – provides the means for a client to retrieve and update geospatial data encoded in Geography Markup Language (GML) from multiple Web Feature Services
- Catalog Service (CS) − defines common interfaces to discover, browse, and query metadata about data, services, and other potential resources
- Transducer Markup Langue (TML) – provides an efficient method for transporting sensor data and preparing it for fusion through spatial and temporal associations.
- The OpenGIS® Web Processing Service (WPS) Interface Standard provides rules for standardizing inputs and outputs (requests and responses) for geospatial processing services. The standard also defines how a client can request the execution of a process, and how the output from the process is handled. It defines an interface that facilitates the publishing of geospatial processes and clients’ discovery of and binding to those processes. The data required by the WPS can be delivered across a network or they can be available at the server

A short list of relevant ISO standards:

- ISO 19130 – defines sensor and data models for imagery and gridded data
- ISO 19115 − defines the schema required for describing geographic information and services.

In addition to the efforts ongoing at ISO and OGC to define various aspects of sensor models and their representations there has been work going on for the United States National Geospatial Administration (NGA) to create a common model for the implementation of sensor models called the Community Sensor Model (CSM). A key part of any photogrammetric system is the definition of the mathematics that governs the mapping of the 3D world coordinates onto the 2D image plane called the sensor model. While common sensors such as metric aerial cameras have well known models, more elaborate airborne and space borne sensor systems have sensor models which are either very complex, confidential or both. It is often very difficult (if not impossible) to get sufficient detail about a given sensor to write an effective sensor model for it. As NGA deals with a large number of vendors, it has found that it is very problematic for each of its different system providers to have to independently implement sensors models (often with varying degrees of accuracy). Therefore, NGA began a program to define a common API for sensor modeling that would enable a single implementation of a sensor model to be used with different vendors’ software, assuring common capability and accuracy across a broad range of applications. By writing to a common API, it is possible for a sensor model to be written by a single organization and then supplied in the form of a dynamically loaded library (DLL) to different organizations with the expectation that it will work with various software applications. Software from different vendors such as BAE, Sensor Systems and Leica Geosystems now use this standard and can be expected to work with the new models. This API, called CSM, is now gaining adoption among vendors of software to the US Defense, but more importantly, it is also being looked at by international organizations and organizations such as the OGC.

With a standard sensor model, API the end user wins because he can begin using new sources of data more rapidly. Instead of waiting for all of the vendors of his different software packages to incorporate a new model he only has to wait until one of them supports the model (ideally the sensor maker would actually provide the model as a working DLL). Once the model is on the system all of the different software packages can use it. This is not unlike having drivers for hardware that free all of the application programs from worrying about the specific details of each piece of hardware.

While CSM defines an interface for dealing with sensor models it does not address persistence of the metadata that is used by the sensor model. This is being addressed by the work of the ISO 19130 working group. As a result it is necessary to design a system which integrates these two mechanisms. The domain layer will use CSM as the computational engine and the data layer will look to ISO 19130 to provide system data interoperability.

As a Strategic Member of the OGC and actively involved in the ISO, ERDAS proves its commitment to interoperability. ERDAS is part of the OGC Technical Committee, Planning Committee, Europe Group and various ISO TC211 committees. Additionally, ERDAS is continually enhancing the company's technological developments to provide more extensive enterprise solutions to the larger marketplace. ERDAS is actively involved in helping define and establish standards and specifications for sensor modeling, geo-processing, web delivery and enterprise data management.

ERDAS APOLLO securely manages data and web services within an organization, including discovering, describing, cataloging and serving data into a variety of web and rich client applications throughout the enterprise. Many organizations need to aggregate and understand where data is located. ERDAS APOLLO is a business system that goes beyond a departmental deployment of photogrammetry, remote sensing and GIS. ERDAS APOLLO connects departmental deployments of geographic data and allows users across an organization to securely find, view and get geographic information. ERDAS APOLLO offers organizations the ability to successfully manage their data, thereby minimizing data redundancy, IT costs and offering a greater return on investment by extending the utilization of data throughout an organization. This means organizations do not have to produce or buy redundant data and they can now maximize the use of the data. ERDAS APOLLO increases an organization’s ROI, enabling both traditional and non-traditional users to find data, without necessarily understanding the specifics of the data that is needed to complete a workflow.

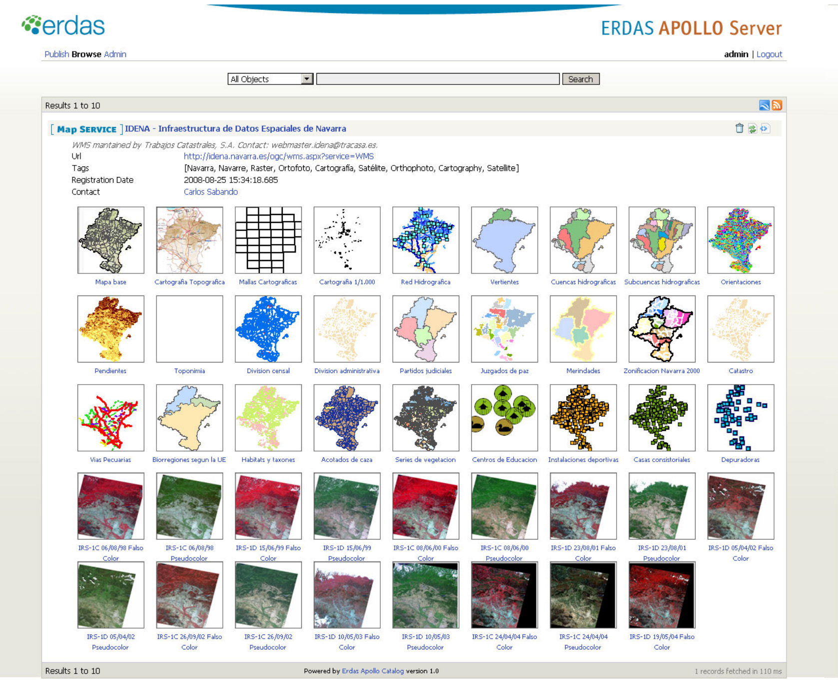

Fig. 3: ERDAS APOLLO manages geospatial data and web services distributed across an organization.

First, ERDAS APOLLO finds the data. We have crawler technology that securely crawls a network, finding GIS, remote sensing and photogrammetry data throughout departments and offices distributed across a business. Once that data is found, ERDAS APOLLO describes the data. We harvest metadata and map that metadata to an interoperable profile or standard. The end product is a centralized catalog. By cataloging the data, metadata is subsequently stored in an open database, thereby allowing users the ability to securely discover the data. Once you have that metadata within a relational database, people can search, find and subsequently access the data as a web service or a data streaming protocol. The fourth problem is rapidly serving the data directly to users: getting the data in a variety of different ways, whether it's through OGC web services, or ECW-P and JPIP, and getting it directly into the client application (CAD, GIS, remote sensing, photogrammetry, web or mobile client). Once the data is catalogued, ERDAS APOLLO also ‘service enables’ the data, which means we create a web service for data delivery. This happens automatically. Finally, ERDAS APOLLO exploits the geospatial data in its raw form. We look at things like geoprocessing, where a company or user can query an information product that has been created by an analyst using ERDAS IMAGINE, then published and subsequently cataloged in ERDAS APOLLO as a web processing service. Geoprocessing finds the data, processes the data on the server and subsequently delivers that information product in a usable form for the end user to utilize within their application of choice. You can see that we are now extending geographic information to the masses and moving away from the historical barriers that GIS, remote sensing and photogrammetry have artificially created. ERDAS APOLLO brings down those walls.

In the future, ERDAS APOLLO will support additional geoprocessing, location based service applications tracking Earth-based information and more. ERDAS APOLLO is also being extended to a variety of different vertical market applications for multi-user topological editing of feature data, particularly in the Defense and utility sectors. The plan is to integrate the ERDAS ADE technology into ERDAS APOLLO. ERDAS ADE currently operates within the Oracle stack, utilizing the Oracle application server and the Oracle Map Viewer technology for rendering geographic information.

ERDAS APOLLO is open to all types of content; it does not just utilize photogrammetry data or remote sensing data, or GIS data, but all types of data. ERDAS APOLLO is open and agnostic to supporting data from airborne, satellite and terrestrial sources. ERDAS APOLLO transforms and extends the utilization of geocontent throughout an organization. If you look at other server applications in the GIS sector, they are focused on GIS or CAD or just OGC web services. ERDAS APOLLO focuses on the whole lifecycle of managing and delivering geographic information both statistically and dynamically through intelligent on demand geo-processing. ERDAS holds a unique position in the market place. Given our tradition and our vision within Hexagon, ERDAS understand our customers' lifecycle of information when derived from airborne, terrestrial and satellite acquisition sources.

4. SHARING GEOSPATIAL DATA AND WEB SERVICES ACROSS AN ORGANIZATION

Organizations need to connect their users to share data. Additionally, organizations often want to securely connect to other businesses (B2B) to exchange and share data efficiently. Increasingly, these organizations are utilizing geospatial data, web services and location-based content, which needs to be shared internally and externally, and to a variety of client applications. ERDAS provides geospatial solutions, securely connecting users and promoting the rapid sharing of content throughout an organization or business-to-business.

ERDAS TITAN is a powerful geospatial data-sharing infrastructure that enables users to publish their "top drawer" data to anyone across the network, without shipping gigabytes of data in a bandwidth intensive manner. The ability to quickly discover and visualize what collaborators within a community of interest are doing is critical for an organization to be nimble and address issues in a time dominant manner.

While large centralized data shares are a key part of geospatial enterprise systems, users also have the need to share local data stored on desktop systems.. ERDAS TITAN combines a 3D globe environment with ability to chat with any of the members of the service and to exchange geospatial data by dragging and dropping to the globe. This could be integrated with the previous workflow scenario to provide a means for remotely located people to work on the same large geospatial project. For example, operators in different locations working on adjacent areas could discuss how a particular feature might be captured and attributed via the collaborative capabilities, while sharing local data with each other.

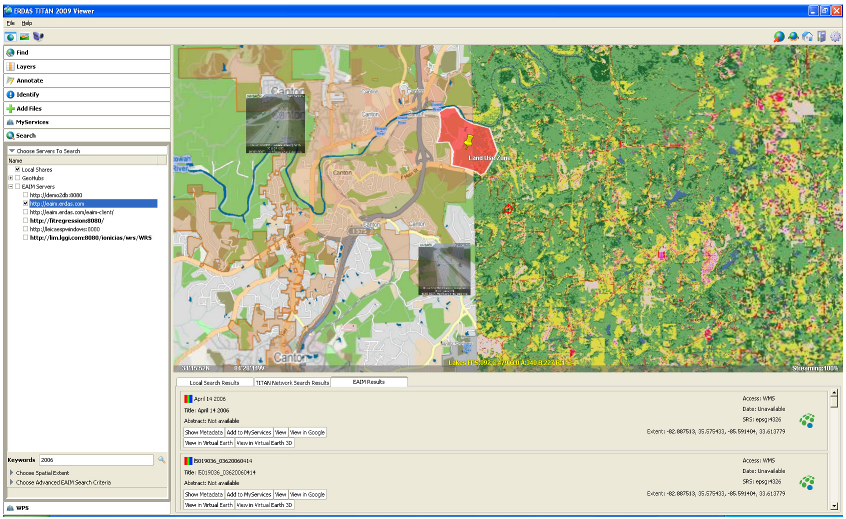

Fig. 4: ERDAS TITAN allows users to find, exploit and collaborate with geospatial data and web services distributed across an organization.

Using the ERDAS TITAN Viewer 3D virtual globe, users can simultaneously broadcast a query across multiple data management systems, including ERDAS APOLLO Image Managers (EAIM) and ERDAS TITAN Network GeoHubs. There are also advanced search parameters available for searching multiple ERDAS APOLLOs, including time stamp, type and availability. User can discover data and metadata, and immediately visualize layers in the ERDAS TITAN 3D Viewer, or load layers directly into Google Earth or Microsoft Virtual Earth. Similarly, the ERDAS TITAN Viewer has the ability to consume an OGC WPS and view the results of a web processing service that was executed by ERDAS APOLLO.

5. DELIVERING GEOSPATIAL INFORMATION

After data has been provisioned, users need to be able to deliver the data customers need, the way they want it and when they need it. With ERDAS' solutions, value-added content may be delivered to domain-specific and business applications. ERDAS enables users to quickly and efficiently deliver information to a wide variety of clients, including desktop, web, mobile, OGC web clients and ECWP clients. In addition, ERDAS' solutions provide the ability to build geoportals as a vehicle for delivery and selling data and information products. With a geoportal, an individual can find the data they need, prepare it, and send it directly to the end-user.

ERDAS Image Web Server is a high-speed, specialized application that efficiently delivers massive amounts of geospatial imagery to thousands of users, all on a single server. Solving the infrastructure congestion problems traditionally associated with deploying large amounts of image data, users quickly access the information they need. With ERDAS Image Web Server, individuals may access imagery using CAD, GIS, mobile, web and desktop applications. Not only can users of geo-enabled websites see static data, but the results of dynamic on-demand geo-processing can also be reflected as a result of executing a geo-processing request from the server.

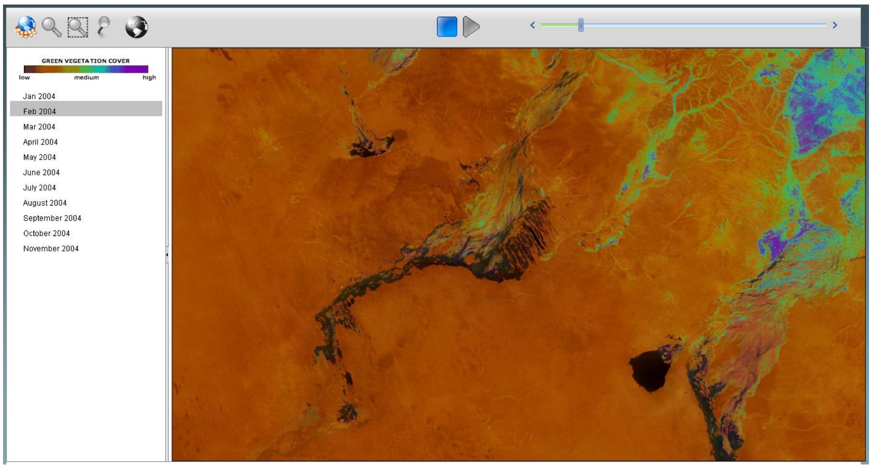

Fig. 5: Spatial Models can be executed on-demand with web processing services.

ECWP is a high-performance "streaming imagery" delivery protocol. It is the fastest, most efficient way to deliver large imagery datasets to desktop, mobile, server and web applications. ERDAS Image Web Server transmits ECWP. The ECWP protocol transfers compressed blocks (image data) from the server to the client. These compressed blocks are decompressed at the client-side, resulting in faster access to large image datasets, and an excellent user experience, including real-time roam and zoom. ECWP broadcasts ECW and JPEG 2000 file types. Datasets not in this format need to be migrated to these formats to enable ECWP. The ECWP protocol is recommended for heavy-use, enterprise systems since it provides the fastest response to client applications and reduces the network (over typical work patterns*) load dramatically compared to shipping image extraction files in the form of JPEG, GIF or PNG image files. ECWP also provides local image data caching.

6. CONCLUSION

The rapid pace of development in enterprise systems and the standardization of geospatial technologies are extending the application and utilization of desktop workstation applications to other parts of an organization. Geospatial processing will become a mainstream tool in the general enterprise toolbox, which can be integrated at many levels throughout an organization. This integration will allow wider collaboration, reduce production timelines, and make the sharing of geospatial data easier and intuitive to access. Ultimately, this serves to push previously niche-processing operations into the hands of a more mainstream audience.