ASPRS Report to the U.S. Geological Survey on Digital Orthoimagery

November 23, 2005

Introduction

The USGS digital orthophoto program must be considered one of the most successful government mapping programs ever. In addition to fulfilling its original goal, the production of national coverage of digital orthoimagery to serve as the base layer of the National Spatial Data Infrastructure (NSDI), it has been outstanding in its technical innovation and the amount of commercial development that it has helped spawn. The program was nothing less than a major step toward today's widespread adoption of digital technology in photogrammetry and image-based geography.

What made the program successful was a confluence of technology and programmatics. Technology, in the sense that it was conceived at the time when computing power adequate for image processing and display was becoming widely available; and programmatics, through interagency coordination of requirements and standards and the critical sharing and leveraging of funds at multiple levels of government. This coordination was accomplished mainly through the National Digital Orthophoto Program (NDOP) steering committee, a committee consisting primarily of Federal agencies which coordinates data acquisition and specifications.

Rapid technological development has greatly influenced and expanded the uses of orthoimagery since NDOP was begun. New acquisition, processing, and distribution technologies have made digital orthoimagery as instantly accessible as a mouse click. Geographic Information System (GIS) technology, enabled in large part by the wide availability of digital orthoimagery, has spread to all levels of government and commercial use, and has in turn encouraged online-mapping and location-based services.

However, the maturity of orthoimagery technology brings new challenges. USGS shares its formerly leading role in the acquisition of digital orthoimagery with many players at the federal, state, and local levels in both the public and private sectors. With this natural – although perhaps unanticipated – growth, the program has dissipated its ability to coordinate and manage orthoimagery acquisition, resulting in duplication of effort, uneven coverage, and varying quality.

The panel was given the charter to examine the status and forecast the future of orthoimage technology, to describe how such technology will affect current and future orthoimage programs, and to make recommendations based on these predictions. To prepare this report, the Panel has examined current and future technology trends and interviewed a wide range of government and non-governmental users and producers. Based upon these inputs this panel submits several recommendations for the future of the USGS digital orthoimagery program and NDOP, within the context of national geospatial requirements.

Technology Overview and Predictions

Recent technological advances have transformed the acquisition, processing, distribution, and utilization of digital orthoimagery. The traditional production method used digitized film imagery from airborne cameras with digital elevation models produced by stereo methods. The state-of-the-art now includes airborne and satellite digital sensors, with elevation models produced by standard and new stereo methods or directly from lidar (Light Detection And Ranging) or ifsar (InterFerometric Synthetic Aperture Radar) sensors. Source and processing have significant implications for the orthoimage properties, accuracy, and downstream usage.

Imaging Sensors

Standard film frame cameras have been the workhorse of the mapping industry for generations, but digital mapping cameras from Intergraph, Leica, Vexcel, and others are becoming more widely used. Acquisition costs of digital mapping cameras are currently higher than for film cameras, but prices should fall rapidly as development costs are amortized across increasing numbers of users and as new competitors enter the field. The Panel believes that the increasing economic advantages of digital sensors in all-digital production workflows, eliminating the costs and problems of film scanning, will lead to their widespread adoption within the next few years.

Currently-available digital mapping cameras are based on two main geometric paradigms: individual frame sensors having multiple

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The Blue Ribbon Panel study of the U.S. Geological Survey (USGS) digital orthoimagery program was initiated in September 2004. The report was finalized on November 23, 2005 and delivered to Dr. P. Patrick Leahy, acting director, USGS, on December 1, 2005.

Executive Summary

This report presents the findings of a panel formed by the American Society for Photogrammetry and Remote Sensing (ASPRS), under contract from the U.S. Geological Survey (USGS), to examine the future of USGS digital orthoimagery activities, and, where applicable, the National Digital Orthophoto Program (NDOP). This panel was given the charter to examine the status and forecast the future of orthoimage technology, to describe how such technology will affect current and future orthoimage programs, and to make recommendations based on these predictions.

To prepare this report, the Panel examined current and future technology trends and interviewed an extensive cross-section of federal, state, county, city, and commercial users to understand current orthoimagery programs and applications as well as the current state-of-the-art of orthoimage technology.

A brief overview of current orthoimage technology is included in the report. New sensors and production techniques are currently revolutionizing the production of orthoimagery, providing increased spectral and spatial information content while reducing acquisition costs. While, to some extent, "pixels are pixels" in that all production methods provide a digital orthoimage, the accuracy and content characteristics of each method must be understood, characterized and recorded in accompanying metadata.

The other impact of technology is in the ease of distribution of digital imagery, made possible by the explosive growth of the Internet and commercial sites providing orthoimagery, often with no direct cost, as part of their business plan. Archiving of the enormous volumes of digital imagery generated by the user community poses a challenge which should be addressed to ensure ongoing availability for historical, legal, and scientific purposes.

Based on interviews and written input from users, the Panel has formulated a comprehensive set of recommendations for the future of the USGS digital orthoimagery program and NDOP, within the context of national geospatial requirements. These recommendations are intended to move the USGS, and as applicable, related programs such as the NDOP, toward a new role in the Nation's geospatial infrastructure, taking into account current marketplace, government, and technical realities while addressing important functions which are currently unsupported. The recommendations of the Panel are:

1. The USGS should formulate, maintain, and execute a business plan which leads to the acquisition and ongoing maintenance and distribution of orthoimagery and surface models for the entire country, including establishment of an external advisory board.
2. The USGS should re-embrace and execute its historical and organizational leadership responsibilities in geospatial data.
3. The USGS should coordinate orthoimagery activities and program plans across all levels of government to reduce duplication of effort and to ensure data compatibility.
4. The National Digital Orthoimagery and National Digital Elevation programs should be merged.
5. The USGS should take the lead, in conjunction with data producers, data users, professional societies, and existing entities such as the Federal Geographic Data Committee, in formulating an integrated, flexible, and extensible set of standards for digital orthoimagery and surface model collection, production, and distribution for all levels of government.
6. The USGS should actively work toward a comprehensive central clearinghouse and distribution strategy for digital orthoimagery and associated digital surface models, including those from state, local, and other government producers.
7. The USGS should function as the "archive of last resort," expanding its archives to include orthoimagery and digital surface models produced by other governmental agencies (federal, state, county, municipal, etc.).
8. The USGS should provide "honest broker" support to digital orthoimagery providers, consumers and the general public in research, development, engineering, and operations to promote the goal of a sustainable, interoperable and integrated digital orthoimage foundation layer that meets national requirements.

In conclusion, the Panel believes that USGS should:

- Continue and expand its critical leadership role in coordinating a National orthoimagery program that satisfies state and local needs as well as federal requirements. Accordingly, USGS should also continue its leadership role in defining standards that meet the requirements of state and local governments.
- Seek funding or allocate resources to ensure/incentivize National orthoimage coverage on a cyclic basis.
- Establish a National mechanism to ensure a collective National archive for orthoimagery generated by all levels of government. The associated standards, policies and funding resources need to be developed.

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CCD imaging heads that are post processed into an equivalent frame image; and pushbroom sensors which scan the terrain with one or more linear sensors.

Some manufacturers and producers offer orthoimages over small areas using medium format (< 4K x 4K) digital cameras. Careful validation and quality control of these production processes will be required, since the construction of such cameras was not designed for geometric stability. Commercial satellite imagery now provides another imaging option, with available panchromatic resolutions as fine as 0.6 meters.

Most digital sensors support color (R,G,B) and near-infrared bands, allowing the simultaneous generation of true color and false color infrared (IR) orthoimages. Hyperspectral imagers divide the visible and IR portions of the spectrum into 20 to 200 separate narrow bands and are increasingly used. Displaying this large number of bands in a visually-meaningful way is difficult and misguided efforts to do so may actually mask the aspects most valuable to certain needs. Consequently, visualization attempts are likely to be restricted to specific applications and users.

Digital Surface/Elevation Model Production

The elevation model used to produce the orthoimage is as important to the final product as the raw imagery. Until recently the only option for producing the elevation model was stereo compilation, with varying degrees of reliable automation. Automated stereo correlation has improved so that it is dependable over most areas. Furthermore, improved computing power has enabled the rapid generation of stereo elevation data, either onboard the collecting aircraft or in near real-time at a ground station [Lathrop, 2005].

Lidar and ifsar sensors directly collect elevation data using active sensing technologies. Lidar is being rapidly incorporated into production, with some producers integrating small format (4K x 4K) digital imagers onto the same platform. A current limitation is that lidar sensors need to be flown at a lower altitude than the imaging sensor to obtain good elevation data. Ifsar requires a greater investment in mobilization and data collection equipment and also requires more elaborate processing to obtain elevation data, so it has mostly been employed for surveys over large areas or areas which are frequently cloud-covered. The recent Shuttle Radar Topography Mission (SRTM), a near-global ifsar collection sponsored by NASA and the Department of Defense, has made publicly available 100-meter post-spacing data over 80% of the Earth's land surface. The density of elevation information, however, is not sufficient to produce high quality, high resolution orthoimages.

Orthoimage producers also distinguish between a terrain elevation model and a surface model. Imaging sensors record the first reflective surface, which includes building exteriors, vegetation, etc, while in engineering and mapping applications the elevation of the terrain itself is of interest. Traditional orthoimagery has been based on terrain (bare-earth) elevation which renders areas with natural and man-made features above the surface not completely orthorectified. An orthoimage variant, with emerging user demand, is the completely rectified orthoimage – popularly called a "true" orthoimage. Buildings and other features with heights are added to the elevation model, so that relief displacement of such elevated features can be corrected. Areas formerly hidden by the leaning features or their shadows are filled by judicious collection of multiple images.

This panel expects, based upon listening to the interviewed users, that completely rectified orthoimages will become much more important in the orthoimage marketplace. Traditional orthoimage processes have not adequately dealt with urban scenes but the new techniques greatly improve the orthoimage's utility as the base layer of an urban GIS. First responders, city planners, taxing entities, event sponsors, and tourists will all benefit from this latest development in orthoimagery.

Rochester, New York: Produced in 1992 through a partnership with the USGS and the State of Minnesota, the B&W image is among the earliest DOQQs developed through the orthophoto program. The color image of the same area is a 2-meter resolution 2002 National Agriculture Imagery Program (NAIP) image produced through a partnership with USDA and Minnesota.

Orthoimage Resolution and Accuracy

Recent national geospatial datasets, often derived from USGS topographic quadrangle maps, had claimed RMS accuracies of 5 to 15 meters. Purchasers and consumers now expect orthoimagery to register with data overlays having a relative precision to within one to three screen pixels or ground resolution elements. Orthoimagery is often expected to register with surface data to allow for 3D visualization and to facilitate co-registration of vector data having comparable or better accuracy than the imagery.

Typical absolute spatial accuracy specified for orthoimagery in populated regions is 0.25- to 1.0-meter CE (circular error) horizontally and 0.5- to 2-meters LE (linear error) vertically, with accuracy in rural areas up to twice these levels. These accuracy levels have been specified over the past three years in West Virginia, Virginia, New Jersey, New York and Tennessee and are expected to be applied elsewhere.

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Higher resolutions will become more prevalent as acquisition costs decrease. Orthoimages with resolutions as high as 10 to 20 centimeters have been produced in high-value urban areas.

While nominal accuracy statements or specifications are usually included in orthoimage metadata, there are seldom precision statements specific to a given image and based on its input sources and processing chain. As the requirements for merging independent data sources increase, better understanding of the precision of each input will allow for more informed and rigorous adjustment of the individual data sets. Increasing data processing and storage capabilities now enable the computation and storage of meaningful covariance information for individual products; covariance information should become part of the metadata for standard products.

Orthoimage resolution requirements depend on the scene content and the intended application. Orthoimage accuracies should be consistent with the collection capabilities of sensors that use direct georeferencing (GPS/IMU with dynamic updating to position the sensor in real time). For example, lidar elevation datasets using direct geopositioning can obtain 3D surface accuracies of 0.15 to 0.50 meters. There is an increasing expectation that the ground resolution of the orthoimagery, the overlay of planimetric feature vectors, and the ability to georeference elevation data and real-time surveillance video have accuracies consistent with the base orthoimagery layers.

Consistency among independent datasets remains a difficult issue. For years, geospatial information conflation efforts have been stymied by an inability to consistently determine the most accurate data element amid conflicting sources. Unless the accuracy of each dataset element or attribute is understood, effective and reliable merger, use and reuse is not possible. Existing older national vector datasets, having 5 to 15 meter accuracies, are sometimes adjusted to fit more current orthoimagery. However, new feature extraction or collection is often preferable to salvaging older data.

Orthoimage and DEM Distribution

The Internet is the future of distribution for both basic orthoimagery and digital elevation models as well as for products derived from these data sources. Technology prognosticators predict that half of the population of the U.S. will have high speed access to the Web within the next few years. Image repositories will be distributed among data servers across the country and linked virtually using Web services. These Web-service applications will be interoperable and users will expect metadata and standardized tools to facilitate data interoperability as well. Virtual communities of users will continue to develop Web portals that exploit combinations of geospatial framework data with other private datasets. Those private datasets may be geospatial, such as business locations, or enterprise specific, such as sales revenue.

Example of imagery acquired through an agreement with a State. High resolution CIR imagery of a portion of Princeton University acquired through agreement with the State of New Jersey. Pixel resolution is 1 foot.

A broadened user community will have much different expectations about the utility or practicality of the data than today's traditional GIS user. They may or may not want to view a map or map-emulation. They will know little about photogrammetry and cartography. They will clamor for timeliness, currency, and exquisite detail. They will be intolerant of anything other than ease of discovery and access to the data. They will assume interoperability of the various information sources. Abstract or obtuse concepts like absolute or relative accuracy and arguments about metadata specifications will not worry them.

We expect a continuing trend of Web-service providers offering orthoimagery to consumers and businesses. Examples include:

- MicroSoft's Terraserver [http://terraserver-usa.com/] which serves USGS DOQQs,; MapPoint [http://mappoint.msn.com/] which offers business mapping service; and Virtual Earth [http://virtualearth.msn.com/],
- GlobeXplorer [www.globexplorer.com/] which serves commercial satellite and high resolution aerial imagery,
- A9 [http://maps.a9.com/] which

provides sidewalk views of storefronts along roadways, and
- Google Earth [http://earth.google.com/] which serves Digital Globe and other orthoimagery, along with 3D city models.

This does not mean that imagery or its value-added derivatives will be a free commodity available to everyone with Web access. Many of these "free" consumer Web services depicting imagery are paid for by the Web-service provider (in the form of Web advertising) instead of by the consumer. The imagery often carries restrictions on the extent of consumer use. Enterprise use of these same images usually requires additional licenses and fees.

Image/DEM formats

Systems should be developed to transform and merge multi-resolution datasets, having different spectral sensitivities and stored in a multitude of coordinate systems, on-the-fly and at the time of viewing or downloading. As a general policy, the USGS should not re-process data from orthoimagery from partner repositories into one uniform format and resolution.

Imagery to be archived will be more than orthoimagery. The USGS can expect users to view and store images from vertical, oblique and horizontal perspectives and allow users to access these images (or stereo sets of images) and associated metadata within applications providing both 2D and 3D visualization. Full 3D city models are emerging. Those models drape orthoimagery over the surface elevation that has been augmented by heights of features in the scene. The building models are also enhanced with ground or oblique images that can show all surfaces of the buildings. For example, Pictometry [http://www.pictometry.com/] has introduced aerial oblique image datasets that can be used to build more realistic 3D city models. Some sensors (e.g., ifsar and satellite-borne imagers) use side-looking views of the terrain. In other instances, there is user interest in viewing the landscape in stereo.

Emerging interest supports incorporating data constructs within the image file to create a kind of "smart image." For instance, the National Imagery Transmission Format (NITF) standard could be considered a smart image. NITF allows the transmission of a file including an image accompanied by sub-images, symbols, labels, text, and image metadata. NITF incorporates additional standards for the creation of an output product, including the Computer Graphics Metafile (CGM) standard for graphics, user-selectable Joint Photographic Experts Group (JPEG)-compliant compression for images and tactical communications support capability which allows it to be transferred using any of a set of user-selectable protocols and media. In another version of the concept, a "smart image" could incorporate route data, nadir (near-vertical in orientation) imagery, Computer Automated Drafting (CAD) data, oblique imagery, and building sensor location information along with communications protocols.

Given the larger volumes of imagery and derivative products to be archived and distributed, image compression will become increasingly important. Current lossy techniques (e.g., wavelet-based or Discrete Cosine Transform (DCT)) can maintain adequate quality for most applications, but lossless techniques, such as those implemented in JPEG 2000, should be employed for archival copies.

Interoperability standards apply to data, applications and Web services. The abilities to access orthoimagery (network standardization) and to use that dataset (application interoperability) have more importance than storage in a standard data format. The Open Geospatial Consortium (OGC) [http://www.opengeospatial.org/] continues to define interoperability standards for data and applications via the Web. These standards should be demanded of all users and suppliers. The ongoing Geospatial One Stop II initiative is one example of applying OGC interoperability standards to data and applications and directly influences the utility of orthoimagery and digital elevation data.

Orthoimagery User Community Requirements and Inputs

Overview of the user-input process

The Panel requested inputs from users representing a wide range of interests, including federal, state, local, commercial, and non-governmental entities. Most of these users made presentations to the Panel so that an interactive dialog could occur. A small number of users were interviewed by a subset of the Panel and another small group submitted written comments to the Panel. Users were asked to address their current use of orthoimagery, their future requirements for orthoimagery, their plans to obtain orthoimage coverage, and their concept of the role of the USGS in future orthoimage programs. A complete list of the users who were consulted is included in the appendix.

The following discussion summarizes the statements made to the Panel by users in various categories. To encourage open dialogue among participants, the specific comments remain non-attributed and the presentations themselves are not included in this document. However, the discussions addressed many of the technology advances and standards issues described in the first section of this report.

Federal Users

Federal users who presented to the Panel represented agencies which are involved in the major acquisition and use of orthoimagery. Although these individuals gave significant insight into the requirements that their acquisition, production and exploitation programs were meeting, they were not representing agencies which are less well-recognized users of orthoimage products. The Panel did not feel that this fact created any significant shortfall, however, since the orthoimage needs of federal government agencies are reasonably well known. Furthermore, agencies, whether major or minor consumers of orthoimagery, have a ready means of making their current and future requirements known through the Federal Geographic Data Committee (FGDC).

USDA

The U.S. Department of Agriculture (USDA) sponsors the National Agriculture Imagery Program (NAIP), which acquires imagery during the agricultural growing seasons in the continental U.S. The USDA specifies the completed orthoimage products as the only contract deliverable. Contractors retain the original film/image collection and any other use rights. Prior to destruction of the film/image, it must be offered to the National Satellite Land Remote Sensing Data Archive (NSLRSDA). Data archiving poses information management challenges with rapidly increasing complexity, as NAIP now covers large portions of the country every year.

Discussion about the future of the orthoimagery program included recognition of changing roles and responsibilities within the federal sector. As an example, NAIP, through state cost-sharing, allows states to upgrade the USDA-specification-compliant two-meter NAIP

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requirement to one–meter product if they pay the cost differential. That imagery program flexibility within USDA may be mitigating the need to have USGS update aging NDOP data. The reduction in delivery time for both an interim as well as finished NAIP product relative to NDOP has been enabled by enhanced technology and has been streamlined by having single contractors both acquire the imagery and complete the orthoimage production. This improvement is also very attractive to state users who are quite willing to cost-share when their specific needs can be accommodated. The interim product satisfies several states that can use the imagery even before quality control is complete to meet needs requiring very timely imagery.

USGS

As a closely related function to acquisition and use of orthoimagery, the Panel and presenters shared significant discussion about archiving and access issues. The USGS stated that they will no longer provide hard copy imagery services from their film archive, and their representatives described the film digitizing initiatives well underway. Softcopy imagery holdings, including orthoimagery, will be readily available with additional improvements anticipated at the National Center for Earth Observation and Science (EROS). Film which is delivered as a byproduct of orthoimage production will be archived, but reproduced images on film will not be available to consumers.

One question which was not answered specifically by any of the federal presenters is how any orthoimagery collected by various agencies for specific projects is incorporated into the archives, and how the existence of that data can be discovered by potential users. Although these datasets are small in comparison to national-coverage programs, they nevertheless exist and have potential value in reuse.

State Users

The Panel interviewed several users from states with active orthoimage programs. All of their programs provide systematic periodic update of the data. States with less active or less well-funded programs set different resolution and update criteria reflective of their budgets. The perspectives presented by these active states on the role of the federal orthoimage program contributed to the Panel's analysis and influenced the final recommendations, although some variance in opinions about cost-sharing and ability to use federal programs would be expected among the numerous less-aggressive state programs.

The consensus among the state representatives who met with the Panel was that orthoimage coverage needs to be renewed at least on a five year cycle, with areas of rapid change renewed more frequently. All endorsed the position that orthoimagery is the most cost-effective of all GIS layers in terms of information content, and is the basis of a geospatial program. Tax mapping and disaster relief were mentioned as the primary drivers for the programs.

The problems identified echoed common themes:

- Maintenance of a reliable underlying digital elevation (or surface) model (DEM) was identified as a significant, yet unsatisfied, requirement for the orthoimagery. The lack of a sufficiently accurate DEM was cited by many of the states as a significant inhibitor to their orthoimage program.
- The states mentioned that a delivery cycle of less than 12 months from the acquisition of imagery was preferred, and some said such a schedule was absolutely required.
- Many commented that the data should be kept in the public domain.
- Several states suggested that it would be desirable for the federal government to provide consistent quality control processes and specifications. They also advised that the specifications should be sufficiently flexible and adaptive to address state needs with characteristics as needed by the states for their purposes. For instance, widely-varying population densities, land values, and levels of Federal land ownership would indicate that differing levels of orthoimagery resolution could be appropriate. However, the states preferred not to necessarily be restricted to complying with one federal-level specification, although compatibility to allow interoperability and data reuse was desirable. Specifications should also avoid dictating the process by which orthoimage products are produced.
- Several commented that provision and maintenance of detailed metadata are essential so that the multiple users could determine if the specifications relevant to a particular dataset address their need.
- Noting that one-shot programs were not effective to meet long-term needs, sustained funding was also cited as a necessity for maintenance of orthoimagery and elevation data, and other essential program elements.

Downtown Reno, Nevada (left) and the Reno Hilton Hotel (right), site of the ASPRS 2006 Annual Conference.

- The recurring concern about the lack of a long-term archive was also raised by the state representatives, who would prefer someone else take over that responsibility from them. The states, in general, lack the funding and the expertise to maintain a long-term archive.

The Panel acknowledges that the states interviewed are among the more proactive in their use of orthoimagery. Had the Panel talked to states with less active programs, more need for federal assistance to support a consistent national approach might have surfaced, just as the frustration or confusion in dealing with the several federal agencies involved in the acquisition and production of orthoimagery might have been reinforced. The states interviewed typically had the ability to sustain their own programs with minimal federal support.

City/County Users

To complete the examination of orthoimagery use across all levels of government, the Panel also interviewed several representatives of municipal governments. Their offices often had requirements which differ from those of the state and federal agencies. Better resolution and more frequent coverage are needed, because detailed features must be visible and change at the local level can be rapid. 15 to 30-centimeter resolution true-color orthoimagery is the typical requirement. True orthoimagery, described earlier as having all effects of terrain and structure elevations eliminated, is also often required for urban areas with tall buildings. One city, as an example, required updates to the true-color imagery every two years, with another requiring five year updates.

Governmental Accounting Standards Board (GASB) 34, a new accounting requirement for tracking inventory and infrastructure, helps drive the geospatial information needs of cities. The GASB 34 standard directly affects the rating of bonds issued by the community, and therefore is critical to the ability of the communities to finance investment and improvements. One approach to strengthening a community's bond ratings is to put in place a geospatial data program for tracking their infrastructure. Orthoimagery is a logical base layer of such a program. At present, only 57% of communities under 50,000 population have an active GIS program, and 42% of the local jurisdictions lack the technical expertise to implement such a program. 64% of local communities lack the funding to institute a viable geospatial program [PTI, 2003].

Another consideration is that high resolution orthoimagery, with detailed attribution, is increasingly used to support emergency preparedness, law enforcement, and first responders. In addition to the orthographic view, first responders also request oblique imagery so that the sides of buildings and terrain perspectives can be viewed. A detailed DEM or CAD data would permit imagery to be draped over the wire frame, with all building faces visible in a display for accurate 3D modeling in preparedness exercises as well as actual emergencies. City representatives, as had their state and federal counterparts, cited the need for digital elevation models, in this case emphasizing the desirability of the reflective surface (including buildings in populated areas) which also would help correlation of subsequent sets of orthoimagery.

Standards development will also be critical to the development and adoption of these new types of interfaces and integration of new sets of users, as will be seamless access to data across jurisdictional boundaries.

Commercial Users

The commercial presenters identified the real estate industry as an important user of orthoimagery. Insurance companies frequently use orthoimagery as verification of damage claims, by determining the structure's status prior to the incident.

Orthoimagery is also used to support precision agriculture. Such images are used to determine field dimensions and area, but precise guidance to distribute fertilizer or to plant crops and studies to predict productivity of fields are facilitated by direct GPS measurements. Remote sensing in general does not have the frequency of coverage or rapidity of delivery to be useful as a monitoring tool in precision farming applications.

Other Users

Another, and growing, commercial application involves the distribution of imagery over the Web supporting various interests and provided a range of services. Example businesses for this emerging activity include advertising and market assessment (often relevant to location displayed), sales of prints or maps of displayed imagery, or subscriptions to allow access to extra features. TerraServer began as a technical demonstration of Microsoft's database management capability. Some initial proof of concept of an earlier version was tested through a cooperative research and development agreement between Microsoft and the USGS. TerraFly, funded by NASA, has been focusing on real estate marketing applications. Other sources, like Google Earth, offer free imagery anticipating the growth of a commercial market for other imagery or imagery-based products.

These exemplars represent a potentially large market. It is unclear at this time how economically feasible each endeavor will become.

Panel Recommendations

Recommendation 1: The USGS should formulate, maintain, and execute a business plan which leads to the acquisition and ongoing maintenance and distribution of orthoimagery and surface models for the entire country, including establishment of an external advisory board.

In late 2004, the National Geospatial Programs Office of the USGS drafted a plan for the USGS National Orthoimagery Program [USGS, 2004]. Its stated objective describes the program strategy between the federal and state efforts and identifies the time and funding requirements essential for cooperatively-maintained digital orthoimagery for the nation. The draft plan proposes to have the USGS lead – in cooperation with public agencies and private industry – the effort to ensure that all public domain orthoimagery is maintained and available to the Nation through The National Map. In addition, because orthoimagery relies upon appropriately dense and accurate surface models, the Panel recommends that surface models for the entire country need to be included in the business plan. The Panel also recommends that the vision as articulated in that draft plan be extended.

Funding for the first generation orthoimagery acquisition and production program relied upon extensive partnerships, with the USGS providing just over 47 percent of the budget required. The referenced draft plan identifies the "Ortho Acquisition Approach" with a proposed 5-year cyclic image acquisition strategy that should be readily extensible to include the surface models [USGS, 2004, pp.

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11-14]. The Panel recognizes that the funding requirements for this effort may require additional study. In the referenced draft plan the estimated cost to the USGS for the annual orthoimagery program, including acquisition, archiving, distribution, continuing research, and standards advancement, was $28.6 M [USGS, 2004, p. 23], with the assumption that state and local governments would contribute an equal amount toward data acquisition. However, because the surface models are often a by-product of the orthoimagery process (in most cases sufficiently high resolution elevation models do not exist prior to the orthoimagery production) the additional cost for acquiring and maintaining these surface models for subsequent reuse should be marginal. Long-term cost avoidance for duplicative datasets renders this acquisition strategy more desirable.

The Panel recognizes that the cooperative partnership model will succeed only if incentives are incorporated into the business approach. As the Panel heard from many state and local speakers, there is often little motivation at those levels of government to consider the larger national interests, especially if the national specifications are inimical to the more local needs, add little benefit, or introduce additional costs. If the USGS were willing to underwrite the expense associated with compliance to the basic standards that facilitate interoperability and future reuse at all levels of government, cooperation could flourish.

The USGS has the authority to assume this leadership for national coverage of both orthoimagery and digital surface models. The USGS Survey Manual states that USGS is responsible for defining and maintaining the base map data categories of the National Mapping Program and for making these data available in forms that contribute to their timely and effective use [USGS, 1989]. OMB Circulars A-16, A-119, and the Federal Acquisition Regulation (FAR) further reinforce the role that the USGS has been authorized to lead in the acquisition of spatial data in compliance with underlying standards.

What is not clear to the Panel is the USGS commitment to obtaining the required funding for this vital national program which provides the foundation layers critical to the National Map. As noted previously, some states have very aggressive acquisition programs but many others lack the incentive and revenue necessary to collectively ensure national coverage. That challenging responsibility becomes one the federal government must heavily subsidize if a national program is to be achieved with even the most basic level of coverage. The USGS must energize the senior leadership in the Department of the Interior to support program budget requests. The Department of the Interior must further showcase the value of the National Map to OMB, to other departments like Homeland Security, and to the U.S. Congress, especially the committees who appropriate and authorize the tax dollars for the overall National Map program.

Example of 133 Urban Area imagery. This 2002 high resolution urban area imagery of a portion of downtown Seattle, Washington shows a portion of Qwest Field (upper right) and Safeco Field (below Qwest Field). Pixel resolution is 0.03m (approximately 1 foot).

To assist the USGS in rebuilding solid rapport with the public and private sectors who are unquestionably interested in orthoimagery and digital surface models for a variety of uses, the Panel strongly recommends that the USGS identify a group of experts to form an advisory board to its senior leadership. The composition of the board must be heterogeneous, permitting long-term mapping knowledge and experience to interact with the most current technologies and techniques. The advisory board should include both production/acquisition and

database/dissemination perspectives. Members should be drawn from academia, industry, and various levels of government. Selection criteria should preclude limiting this board to a traditional "grey beard" composition. Multiple functional models for this type of advisory board can be found (e.g., ACCRES in the Department of Commerce; NSLRSDA in the Department of the Interior; or the NGA Advisory Group (NAG) at the National Geospatial-Intelligence Agency).

Recommendation 2: The USGS should re-embrace and execute its historical and organizational leadership responsibilities in geospatial data.

The USGS has over 100 years of experience in leading national civilian topographic mapping efforts. Orthoimagery has become a key component of the national topographic and base mapping program, and has been identified as the most important framework layer of the NSDI. There is an increasing need for leadership of national civilian mapping programs, including orthoimagery. USGS is well suited to provide this leadership due to its historical role in this area. The USGS has also been delegated the responsibility for coordinating base image and elevation data (OMB Circular A-16 and others).

USGS should move from federal leadership to national leadership in the management of the National Orthoimagery Program. The NDOP has done a good job of coordinating the needs of several federal agencies with some state involvement, and has been successful in creating full conterminous coverage of the US. However, change is needed to gain greater state and local involvement, to improve data delivery times, and to meet higher resolution and accuracy needs. It is more than providing data for federal agency use; it is about leading the provision of data at all levels. There are three roles:

1. Manager of the federal program - The National Map
2. Coordinator of federal needs - efficient use of federal appropriations
3. Manager of the national program to provide image base for all needs.

In order to address these roles, particularly the third, a very inclusive program management structure is needed along the lines of that proposed by the FGDC Future Directions Governance Action Team (FGDC, 2005). The most important role for USGS to play is leading a program that integrates the needs of local to federal users. USGS has never been the exclusive producer of digital orthoimagery; it should not now attempt to become one.

Recommendation 3: The USGS should coordinate orthoimagery activities and program plans across all levels of government to reduce duplication of effort and to ensure data compatibility.

Government entities at every level have become more involved in geospatial data acquisition. While the widespread use of cartographic data has led to greater efficiencies in government, the large number of agencies currently contracting for image-based data has led to duplication in acquisition efforts and inefficiencies from flying multiple small jobs instead of consolidating efforts.

Many states have already set up coordinating mechanisms for their counties and cities but coordination with federal agencies, especially those other than the USGS, is poor [FGDC, 2005]. While there is no way to quantify the amount of duplication of coverage, anecdotal evidence led this panel to believe that it is significant. Indeed, one of the county users who spoke to the Panel became aware of a planned NGA data acquisition over his county at the Panel meeting. The USGS should establish and actively maintain an on-going registry of planned data acquisitions.

Recommendation 4: The National Digital Orthoimagery and National Digital Elevation programs should be merged.

The National Digital Orthophoto Program (NDOP) and the National Digital Elevation Program (NDEP) have been operated separately since their formation. The NDEP program has generally provided elevation data used in the production of orthophotography or orthoimagery, and to a lesser extent, digital elevation data has been derived as a by-product of orthoimagery projects. There has been some interaction in program planning, but to a large extent the two programs have been managed independently. The NDOP steering committee has been quite active with a significant interaction with state programs while the NDEP does not have the same level of direction from a steering committee nor as much cooperative funding. The NDEP steering committee has focused on developing national coverage, first at 30-meter and now 10-meter spacing. Most of the elevation data has been derived from the 1:24,000-scale topographic mapping program.

It is anticipated that future production of orthoimagery will include and demand the production both of higher quality Digital Elevation Models (DEM) and orthoimage-quality digital surface models. There are several reasons why the current elevation data is not suitable for future needs. First, user accuracy requirements for 3D display are increasing. Given the ability to produce 3D views of imagery for fly/drive/walk through display, users will expect and require this product. Second, "true orthographic" imagery of urban areas, where building lean is eliminated, is becoming more in demand and more affordable. Third, the need for orthoimagery with higher resolution and accuracy than current products requires more synchronized and accurate elevation data than currently exists for the nation or can be produced from the existing 1:24,000-scale maps. The need for higher accuracy elevation data will therefore require that elevation data be produced to support these needs. Fourth, many related application programs, such as FEMA's flood mapping program, demand higher accuracy elevation datasets for modeling and decision-making.

Some currently available digital imaging systems can produce the elevation data simultaneously as a part of the digital orthoimagery production process, significantly reducing the cost of digital elevation data. In other instances, related federal programs (e.g., FEMA's flood plain mapping) acquire lidar elevation data that is well suited for orthorectification of separately flown aerial imagery. As imagery is revised in the future, revised elevation data will be required. Because of this close linkage, the programs should be managed as a single entity. Granted there are needs for elevation data other than orthoimagery production, such as flood studies, and there are other methods of elevation data production, such as lidar. However, the Panel believes that the overall program efficiency will be improved if the management of the two programs is more tightly integrated.

Recommendation 5: The USGS should take the lead, in conjunction with data producers, data users, professional societies, and existing entities such as the Federal Geographic Data Committee, in formulating an integrated, flexible, and extensible set of standards for digital orthoimagery and surface model collection, production, and distribution for all levels of government.

Given the earlier recommendation that USGS serve as federal manager for the program plan that ensures the availability of appropriately current, complete and accurate digital orthoimagery and surface models for the United States, it is further recommended that USGS effectively

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lead the standards efforts required for interoperability of data from locality to locality and across federal, state and county agency needs and uses. The Panel recognizes that over the past two decades, USGS has participated in multiple forums for standards development but also notes that USGS has been largely unsuccessful in achieving the national standards goals at the state and local levels. In addition, new areas of standards development, extending into newer technologies, has also been lacking.

The standards under discussion should:

- provide common parlance for describing accuracy, resolution, and content, keeping abreast of technology advances in delivering the "true" orthoimage and incorporating a variety of sensor phenomenologies;
- immediately and without exception implement current metadata standards, specifically as endorsed by the Federal Geographic Data Committee (FGDC), extending them where necessary. The metadata information should also mandate inclusion of the source, resolution, rights of use, and accuracy of the elevation or surface model used to generate the orthoimagery; and
- identify best practices and standards for quality-conforming data but avoid specifying exclusive acquisition or production methods.

Technology offers multiple producers ample opportunity to build both digital orthoimages and digital surface models. However, no assurances exist that those datasets are of consistent quality, can be used collaboratively, or comply with any standards or guidelines. Digital orthoimages and digital surface models should offer a reliable foundation into which other relevant information can be incorporated. Common understanding about content, facile access to various databases, and accepted guidelines for data production and information management would reduce ambiguity of use and enable interoperable exchanges and beneficial augmentation of datasets. Orthoimagery produced in compliance with standards can be mosaicked or nested nearly seamlessly, thereby promoting interoperability. In February 2005, Bill Gates described very succinctly a meaning of interoperability which applies well here: "… letting different kinds of applications and systems do what they do best, while agreeing on a common 'contract' for how disparate systems can communicate to exchange data with one another."

Metadata is an essential step to enabling that interoperability. Metadata provides sufficient qualifying information about datasets so that applications and systems, in the hands of various users, understand the "pedigree" of the information that helps define utility, the production history of data, and the rights of use.

Repeatedly the Panel heard this request for strong USGS leadership from those interviewed. Little debate exists about the ability of various producers to deliver markedly distinct or subtly different orthoimagery products. Admittedly these products meet some specific needs but often cannot be reused for another purpose in the same geographic area or, more likely, cannot be seamlessly integrated with geographically-coincident or adjacent data.

Those interviewed believe that the USGS role should be to establish the minimum conformance standards that will allow both public and private entities to build orthoimagery and/or surface models – at a variety of resolutions – that will enable cost-saving reuse and unambiguous interoperability. No one requested that USGS dictate inflexible specifications or compliance penalties. Yet, with its historic expertise, USGS must more aggressively lead a community by identifying best practices for these two critical base datasets of the National Map. Among those best practices that encourage interoperability would also be establishing the protocols for Web portal access, both for adding to, and retrieving from, central or distributed data stores or archives. Aggressive leadership means the USGS would drive the pace of developing and implementing standard practices and would identify prudent management guidelines for data archive administration. The notoriety of standards groups taking years to reach consensus is out-of-sync with today's technology, industry innovativeness, and consumer demand.

Close-up of a portion of the Pittsburg, Pennsylvania 133 Urban Area showing Heinz Field (upper left) and PNC Park (upper right) and the surrounding area. Produced under contract for the USGS. The pixel resolution is 1-ft.

USGS should not control local or state funding prerogatives and decisions. However, through a more effective outreach program USGS could encourage the fiduciary and technical wisdom of building orthoimagery and surface models, with reuse and interoperability as essential characteristics of a plan that addresses the most specific local needs and the broadest homeland security considerations. In this outreach role across both the federal and non-federal producers and within the standards

community, USGS should provide funding incentives to compliant participants consistent with the first generation orthoimagery national model of conterminous U.S. coverage. USGS should also offer its services to maintain the historic archives of compliant data on some established time interval. That information management role itself would help instantiate the standards desired, especially with critical metadata.

As an example, mentioned earlier among the content of metadata is the "right of use." Restrictions may relate to data licensing but, increasingly, concern about safety and security has introduced additional considerations about "right of use." Security policy may require sensitive area obscuration techniques. Properly attributed datasets should contain the security restrictions within the metadata that define who is allowed access to the entire dataset. In some cases, however, some areas or aspects of either an orthoimage or a surface model may warrant protection from general public distribution. Accepted standard procedures to follow when reducing the accuracy or the resolution to obscure those features are required.

The Google Earth and Microsoft Virtual Earth service models of facile access to orthoimagery -- and additionally oblique views, attributed vectors about features in the view, and symbolized maps -- offers some insight into the "next generation orthoimagery" complexity. Government did not initiate this effort, although such innovations would not have been possible without the initial free availability of orthoimagery to serve as a base layer for the addition of other capabilities. The private sector continues to define and to redefine the dataset emerging either to meet or to set demand. On the other hand, consumer expectations about the reliable quality of that initial overhead perspective and the alignment of the detailed information and the versatility of application use will best be met if the orthoimagery and surface model conform to basic standards. Government can lead the standards effort and incentivize their use.

Recommendation 6: The USGS should actively work toward a comprehensive central clearinghouse and distribution strategy for digital orthoimagery and associated digital surface models, including those from state, local, and other government producers.

One of the fundamental roles of the USGS is the distribution of scientific information, including the cartographic data that provides the geospatial reference framework for much of that information. The availability of NDOP orthoimagery provided a major impetus to the GIS industry and to various governmental, commercial, and private users, and contributed greatly to the current boom in geospatial products and services.

Recent years have seen a rapid growth in the number and types of distribution channels available, mainly as a consequence of the Internet and the overall growth of the geospatial data industry. While the USGS need not serve as the only distribution source, it should continue current policies of supporting available distribution channels, to address the needs of specific user communities and to provide redundant data access.

Widely-used distribution channels outside of the USGS include:

- Regional mirror sites, such as state, county, or city servers providing imagery over a defined area
- Commercial servers, possibly providing data with value-added content (bundling, mosaicking, etc)
- Non-cartographic servers providing location-based information (e.g., Microsoft TerraServer and Google Maps)
- U.S. government agency servers, providing data for emergency or policy purposes.

Support of these distribution channels should be continued and expanded, both by adding new channels/servers and by adding additional data sources not currently available.

The presence of these non-USGS distribution channels does not relieve USGS of its distribution responsibilities. While an increasing number of commercial sites are distributing some types of data for "free," they have no requirement to maintain access other than their own marketing strategies. Other government sites, such as those sponsored by states or counties, serve data only over specific geographic areas and have a variety of data types, formats, and access policies and procedures. Reliable and consistent access to national data must be maintained.

The availability of "mirror" servers in widely-dispersed locations and with independent internet access, preferably maintained by separate organizations, is especially important for access during emergencies which may affect large geographic areas, for "load balancing" of data requests, and for protection against system faults or failures. Recent natural disasters have demonstrated the disruption of the information infrastructure across large areas, the necessity of having access to detailed data for specific regions from across the country, and the server capacity requirements necessitated by the large amount of imagery obtained during disasters.

A growing amount of geospatial data generated today comes with licensing restrictions on use or re-distribution. The USGS should explore ways to provide appropriate access to licensed data while maintaining data rights. Similarly, some datasets have security restrictions placed on them which must be respected during distribution.

Recommendation 7: The USGS should function as the "archive of last resort," expanding its archives to include orthoimagery and digital surface models produced by other governmental agencies (federal, state, county, municipal, etc.).

Congress found that it "is in the best interest of the United States to maintain a permanent, comprehensive Government archive of global Landsat and other land remote sensing data for long term monitoring and study of the changing global environment" [15 USC 5601] and authorized the establishment of the Archive [15 USC 5652]. The Secretary of the Interior was given the responsibility for providing for long term storage, maintenance, and upgrading of a basic, global, land remote sensing dataset and providing timely access to it [15 USC 5652(b)].

National Space Policy declares that the "United States requires a continuing capability for space based Earth observation to provide information useful for protecting public health, safety, and national security. Such a capability contributes to economic growth and stimulates educational, scientific and technological advancement" [National Space Policy, 1996, para.3(a)(iv)]. Therefore, it is mandated that "the U.S. Government will…produce and archive long term environmental data sets" [National Space Policy, 1996, para.3(a)(iv)]. To that end, the National Space Policy directs the "Department of the Interior, through the U.S. Geological Survey (USGS), [to] maintain a national archive of land remote sensing data and other surface data as appropriate, making such data available to U.S. Government and other users" [National Space Policy, 1996, para.6].

The Panel agrees with the motivation and direction provided by Congress to the Department of the Interior for the long term archival of spatial data assets. In fact, publicly acquired spatial data is not an "asset" unless it is:

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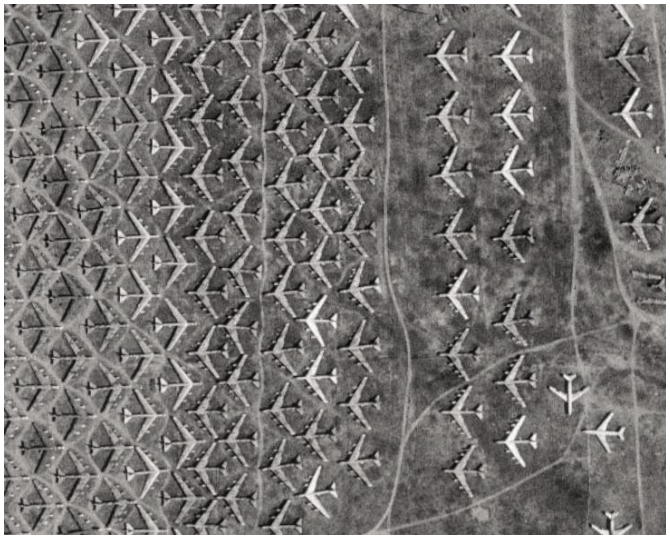
- preserved,
- catalogued, and
- accessible to a wide variety of users ranging from global change scientists to the general public.

The Panel recommends that the archiving mandate of USGS, described in the preceding paragraphs, be expanded from only space-based Earth observation to allow, as appropriate, inclusion of land remote sensing data from aerial platforms. This includes expanding the USGS national archive mission statement of "national archive of land remote sensing data and other surface data as appropriate" to specifically include:

- Orthoimagery produced by any public agency, including federal civilian agencies, state government agencies, and local agencies,
- surface model data produced as a by-product or as an input to the orthoimage creation process, and
- other surface data as appropriate.

The number of federal, state, and local government agencies spending public funds contracting for, producing, and distributing orthoimagery has exploded in the last decade. Most of these agencies are ill-prepared to handle the massive volumes of data being produced annually and worse, often do not have the budget to develop an archival and public distribution capability beyond their immediate application needs. Many of the new applications do not require imagery be retained over time. Thus, the nation can expect that many publicly-acquired orthoimagery and elevation datasets will be lost due to lack of funds and lack of expertise to properly archive and distribute the data over a long period of time.

The USGS EROS Center has developed the capability of cataloging, ingesting, and maintaining a very large – multi-petabyte – digital imagery archive. The EROS Center has demonstrated that they can adapt with evolving computer and storage management technology. In addition, they have already built the administrative and technical systems for archiving and re-distributing data from a wide variety of sensors such as satellites (MODIS, Landsat), aerial (DOQQ, NAPP), and scanned film products. The present EROS Center location is ideally suited for expansion at a low cost from both a physical plant perspective as well as having an able work force.



B-52 Aircraft, Davis-Monthan AFB, Tucson, Arizona. Image obtained from TerraServer USA.

The Panel recommends that the USGS, through its EROS Center, be chartered to expand the list of agencies it provides data archival services for – the Department of the Interior and NASA – to include any and all federal, state, and local government agencies which contract for or produce orthoimagery and elevation products with public monies. The EROS Center archival and distribution capabilities should be offered as a menu of service choices. Qualifying agencies can choose the retention policies, security, distribution services, and business model that suit their needs. For example, it is possible to imagine a state agency wanting the EROS Center to archive their data for a period of ten years, distribute the state's data to other government agencies for the cost of distribution, and distribute the state's data for a fee to the private sector and consumers for a cost plus fee where the "plus" is controlled and returned to the state.

The USGS is uniquely positioned to serve as the "archive of last resort" for all expertise-and budget-limited government agencies. By leveraging the experience existing at the USGS EROS Center and the economies of scale obtainable by distributing the capital investment in facilities, equipment, and personnel over a larger number of users will reduce the costs and increase the value of the national geospatial assets.

Recommendation 8: The USGS should provide "honest broker" support to digital orthoimagery providers, consumers and the general public in research, development, engineering, and operations to promote the goal of a sustainable, interoperable and integrated digital orthoimage foundation layer that meets national requirements.

Science and technology (S&T) objectives should be developed by the agency and supported at an adequate level to meet this goal. Several recommended objectives are provided that maintain continuity with historical USGS activities, and build on the progress made toward meeting the recommendations of the ASPRS Camera Calibration Panel Report [ASPRS, 2000]. These objectives also extend the Calibration Panel Report to include essential, basic S&T capabilities that the USGS should maintain. These capabilities are required to support the roles that the orthoimagery community has asked the USGS to perform. Without these capabilities, it will be difficult for the USGS to maintain the technical expertise and critical mass necessary to play its necessary leadership role as requested by the community, and embodied in the extended recommendations of the Next Generation Orthoimagery Panel report.

- Testing, validation, and calibration: In accordance with the previous ASPRS Camera Calibration Panel recommendations, the USGS should continue to develop a robust, fully-funded calibration and validation science and technology effort that includes laboratory and in-situ calibration, and orthoimagery production process and product validation.
- Production process and product validation extends the Camera Calibration Panel findings to include the fact that orthoimaging technology is advancing rapidly and that camera calibration alone is insufficient to ensure that a quality product is delivered to end-users. A product-based quality assurance methodology would allow acquisition and production methods to change with technology as long as process control is maintained. Process control permits meaningful quality assurance sampling and testing to be performed on the end product.
- This effort should be fully harmonized with the coordination and facilitation role that the USGS plays in the acquisition of

digital orthoimagery and surface models with other national and international federal, state, county, city and non-governmental agencies. S&T in this area will not only promote the development of better orthoimagery products and acquisition processes, but it should also anticipate the development of commoditized lidar, ifsar, multi- and hyper-spectral imagery products as follow-on to the current generation of orthoimagery products, and complements to the next generation of orthoimagery.

- Research and development (R&D) should be supported in critical areas to sustain a world class USGS S&T effort. R&D may be conducted internally within the USGS, or sponsored by USGS and conducted by academic or commercial partners. Some possible R&D areas suggested include:
- Techniques for protecting sensitive features while allowing open distribution of orthoimagery should be researched to address local and national requirements. Leadership by the USGS will facilitate the uniform adoption of techniques rather than a piecemeal, jurisdiction-by-jurisdiction approach that may result in multiple incompatible image products.
- Automating the collection of change information from ancillary sources that could be used to determine areas for targeted collection and production of orthoimagery. By updating orthoimage coverage in areas of rapid change, it may be possible to extend the period between general, area-wide collection, and to maintain a better coverage at lower cost.
- New visualization techniques that integrate the 2D nature of orthoimagery and the 3D surface model.
- Investigate the impact of sensor development in the areas of imaging, georeferencing, and surface acquisition on orthoimage generation techniques.
- Operations research and systems engineering: USGS should provide systems engineering support to assist in the design and development of an integrated, interoperable approach for acquiring, accessing, and archiving nationwide digital orthoimage and digital surface model coverage that meets user requirements and anticipates technological advances. This function is necessary to collect and analyze user requirements, develop and maintain standards and best practices, and develop a nationwide orthoimagery system architecture. It should provide guidance to the national orthoimage coordination, standards, clearinghouse, and archiving elements on lifecycle management of the Nation's orthoimage and digital surface model resources. To be able to provide this support, the USGS should maintain a core technical expertise in orthoimagery and surface model acquisition and processing, in order to meaningfully contribute to and promulgate standards and to understand the impact of ongoing developments in technology.

Because maintaining a fully functioning production capability for this purpose is not practical, several different models are available for USGS to be able to maintain the expertise without needing to maintain an extensive production capability. These include:

- An academic model of labs and researchers,
- Developing technical panels or advisory committees of experts from outside the USGS,
- Assigning staff to cooperating vendors' facilities to observe and assist in modern production processes.

Key S&T objectives that are required for USGS to be an "honest broker" of technology have been identified from input received by the Panel. These objectives address and support the goals of national orthoimagery and digital surface model base layers, and they include:

- Lifecycle Management – cradle–to-grave management of a distributed system of orthoimagery products.
- Requirements Analysis – developing S&T guidelines from the needs gathered through the coordination program.
- Standards Development – maintaining the technical capabilities to support cooperative standards development activities.
- Configuration Management – an aspect of life cycle management that supports the development of cooperative feedback mechanisms/problem reporting through the combined use of integrated change detection research and best practices in information-push to consumers, acquiring authorities, and producers.

Other Reports Related to Digital Orthoimagery

While this report was in preparation, the Panel became aware of two other reports in process addressing aspects of USGS orthoimagery programs. Both were made available to the Panel in draft form. We do not mean to evaluate these reports or directly compare our conclusions to theirs, since each has differing goals and comes from different viewpoints. However, many conclusions are similar, as discussed below, and we comment on them to provide context for our own recommendations. We also acknowledge the existence of these other reports to highlight the widespread appreciation for the value of timely national orthoimage coverage and concern for the future directions of the orthoimagery program.

The first, written by the National Geospatial Program Office (NGPO) of the USGS and dated December 2004, outlines its program strategy for the National Orthoimagery Program. This strategy includes partnerships with other agencies, data acquisition strategy, and data archiving and distribution arrangements, along with standards, research and development, and applications activities supporting the program. A five-year update cycle is proposed, at an estimated annual cost to the USGS of $28.6 million. The programmatic aspects of the USGS report are addressed in Recommendation 1 of this report. The Panel is in general agreement with the goals and aims laid out in the NGPO report.

The second draft report, Imagery for the Nation, is written by the National States Geographic Information Council (NSGIC) and is dated September 12, 2005. This report recommends that the federal government fund 100 percent of the cost of acquiring orthoimagery with 1-meter resolution over sparsely-populated areas, 1-foot resolution over areas with greater than 25 people per square mile, and 6-inch resolution over defined urban areas. The cost of a 3-year acquisition cycle is estimated at $85 million per year. State or local governments who require higher resolutions or different types of imagery would pay the additional cost over the baseline imagery. This Panel agrees with the need for national coverage, although we suspect that a cooperative program which included more cost sharing would have a better chance of implementation. The panel agrees with NSGIC that developing, funding and governing a national program will require support from all stakeholder groups.

Conclusion

There is little debate over the value of a readily-available archive of comprehensive, timely orthoimage coverage of the United States. The

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main issues come in deciding how such a program would be implexxxmented and how it should be funded. The Panel strongly believes that the USGS is uniquely positioned to lead such a program and that it should vigorously advocate for the mandate and the resources to fulfill this urgent need.

While it is not an explicit part of our charter, the Panel notes with concern recent developments related to reorganization and restructuring of the mapping activities of USGS. As we have expressed in this report, we feel that there is a strong need for the USGS to exert leadership in the acquisition and dissemination of geospatial data. It is our hope that, whatever the outcome of current events, the USGS emerges with a well-defined vision to fulfill this role.

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Acknowledgements

This study was supported through contract number 04WRSA0612 issued by the U.S. Geological Survey. The Panel gratefully acknowledges the support provided by USGS, the willingness and enthusiasm of all the members of the user community who graciously shared their expertise and opinions during the preparation of this report, and those whose comments on the draft report helped greatly in refining the final product.

Appendix

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