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USA's National Digital Orthophoto Program

A Cooperative Effort Between Government Agencies and the Private Sector

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1. INTRODUCTION

This paper is presented from two different viewpoints; firstly from a top official of the USGS which contracts for the work to be done and issues contracts; secondly from one of the leading commercial contractors who perform the work.
The U.S. Geological Survey's (USGS) National Mapping Division has traditionally been responsible for providing base-map data for the United States. In the past, the USGS accomplished this mission largely through in-house production capabilities with appropriated funds for Federal mapping requirements. Due to declining funding resources, the organization has become more reliant upon cooperative funding to share in the cost for data production. Furthermore, in order to avoid any increase in government staff needed for this program, the use of private sector capabilities to perform the actual production work was an obvious alternative. This model requires partnerships with both the users of the data and the private firms which will produce the data. The introduction of a new digital orthophoto program provided an opportunity to implement the new model through the Architect and Engineering (A&E) contracting process. Clearly, an infrastructure is required for coordinating the overall program as well as a common data standard.

2. FEDERAL GOVERNMENT VIEWPOINT

2.1 Background

The USGS has been involved with the production of orthophotos since the mid-1960's through several generations of production hardware. Of course, as computers became commonplace in nearly every sector, Digital Orthophoto Quadrangles (DOQs) became popular and in high demand. By the early 1990's, prototype and development products were produced and evaluated. The technical specifications for developing DOQs were finalized in 1993 and endorsed by the Federal Geographic Data Committee (FGDC).

2.2 National Digital Orthophoto Program (NDOP)

The goal to complete DOQ coverage of the United States was first proposed in 1990 by the U.S. Department of Agriculture-Natural Resources Conservation Service, Farm Service Agency, and the U.S. Department of the Interior-U.S. Geological Survey. The National Digital Orthophoto Program (NDOP) emerged from this vision for a cost-effective product for the mapping and GIS community. The current expectation is to achieve this goal by 2004 through cooperative funding agreements with Federal, State and local agencies. DOQs are planned to be updated on a 10-year cycle for most areas and a 5-year cycle in areas where land use change is more rapid. Thus far, 50 percent of the conterminous United States i.e. excluding Alaska has been completed or is in progress. Already, there is interest in second time coverage.
The NDOP Steering Committee was chartered to provide program oversight and technical direction for the National Digital Orthophoto Program. The committee includes Federal agencies providing the

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major share of funding resources as well as state representation. The committee plans and coordinates program requirements with the National Aerial Photography Program, determines production strategies, reviews costs, monitors schedules, develops and maintains technical criteria, develops cooperative agreements and partnerships with Federal-State-local agencies, and makes data available to the public.

2.3 Funding Sources

With the exception of USGS requirements for digital orthophotos, the National Digital Orthophoto Program is entirely cooperatively funded. There are several mechanisms for agencies to share costs or to provide resources in building a National digital orthophoto database. The cost is generally shared by all parties through joint funding agreements. More partners means reduced cost for all. Some of the production is also accomplished through work-share agreements and data exchange agreements. These agreements generally do not involve an exchange of funds between agencies. Finally, others participate in the program through Innovative Partnership (IP) agreements and Cooperative Research and Development Agreements (CRADA). IPs and CRADAs provide the formal mechanisms for the Federal government to partner with private industry in new business opportunities. This is consistent with the administration's goal "reinvent" the Federal government in the United States.

2.4 Production Strategy

In the past several years, the focus has been to reduce the National debt and the overall size of government. The result is declining resources for all agencies; hence, the production strategy is to accomplish the majority of the work by contracting to the private sector. It should be noted that the sudden popularity and demand for digital orthophotos made contracting production work to the private sector as the only viable alternative.
It is useful to comment on the underlying principle with respect to what and how much to contract. There are certain functions and activities that are inherently governmental and can not be contracted to private industry. For some activities, such as the development of standards, the government has the responsibility to take a leadership role. For other activities, the use of the private sector is the preferred option whenever services and products can be cost effectively provided by the private sector. Finally, a modest amount of production work needs to be accomplished in-house in order to maintain a minimum staff with technical expertise, to test new technologies, to define technical specifications, and to provide quality assurance.

2.5 Standards Development

As already discussed, production of DOQs for the National Digital Orthophoto Program can be funded and accomplished by many methods. Beyond the requirement by executive order that all spatial data produced by Federal agencies meet national standards, it is obvious that data and technical standards are essential to building a National digital orthophoto database. With respect a data standard for Federal agencies, the U.S. Geological Survey is a member of the Federal Geographic Data Committee (FGDC) and is taking the lead role among Federal agencies in develop the National Digital Orthoimagery Standards. Currently, the proposed standard has been reviewed by members of the FGDC and is now in the public review process.
Meanwhile, the U.S. Geological Survey defined its digital orthophoto standards and technical specification, which have been in use since 1993. These standards have been recently revised and adopted by the NDOP Steering Committee as the Federal profile until the FGDC completes its work on the National Digital Orthoimagery Standards. Currently, all DOQs produced by the NDOP must

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meet the USGS Digital Orthophoto Standards. The new USGS Digital Orthophoto Standard was intentionally developed to allow flexibility for other agencies and organizations to develop digital orthophotos with the necessary metadata information to meet current digital orthophoto data standards. The standard was also designed to accommodate individual organization requirements for specific metadata elements.

2.6 Relationship to Development of a National Spatial Data Infrastructure (NSDI)

A critical component of the National Spatial Data Infrastructure (NSDI) is *Framework*. *Framework* provides a base on which to collect, register, and integrate geospatial information accurately and consistently. The FGDC proposed that *Framework* include geodetic control, orthoimagery, elevation, transportation, hydrography, governmental units, and cadastral data. The National Digital Orthophoto Program is a working model on how Federal, State, and local government, as well as private industry, can cooperate to develop the orthoimagery *Framework* for the Nation.

2.7 Technical Characteristics

The primary characteristics of DOQs produced through the NDOP are listed below:

Source imagery	black-and-white or color infrared
Photo scale	1 : 40000
Full resolution file size	approximately 55 megabytes (MB) per band
Compression format	JPEG, 5 MB per band
Resolution	1-meter ground sample distance
Scale	1 : 12000
Image overedge	50 to 300 meters
Reference coordinate system	UTM coordinate system-NAD 83 datum
Coverage format	3.75' x 3.75' geographic cell
File-specific data	Contained in keyword header

2.8 A&E Contracting Experience

The contracting mechanism used for the NDOP was an architect and engineering (A&E) contract. The A&E contract is a qualifications-based contract in contrast to least-cost type of contracts. All participants of the NDOP, both government and the private sector, have been very satisfied with this type of contracting mechanism which emphasizes quality over low bid. The A&E contracting process also separates the roles of government and private sector. That is, the government has defined the final product and the standards while it is the responsibility of the private sector to propose how it will produce the product and what it will cost.

2.9 Current Production Data Flows

The NDOP relies very heavily on two other programs which provide the basic elements for the digital orthophoto, photography and elevation data. The photography is acquired from the National Aerial Photography Program and elevation data is from the Digital Elevation Model Program. These are separate and distinct programs; however, these programs are coordinated with the National Digital Orthophoto Program. Photography and elevation data are retrieved from archives when available and

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provided to contractors for DOQ production. Existing photogrammetric control is also provided to reduce the requirement for new field control and to reduce the overall cost of the DOQ. The contractor produces the DOQ and delivers any new data generated. These data are archived in various operational databases for future use. Finally, the DOQ is also archived in the USGS Sales Database (SDB) which sells the data to government agencies and the general public. Figure 1 shows the current data flows for the entire DOQ production process.

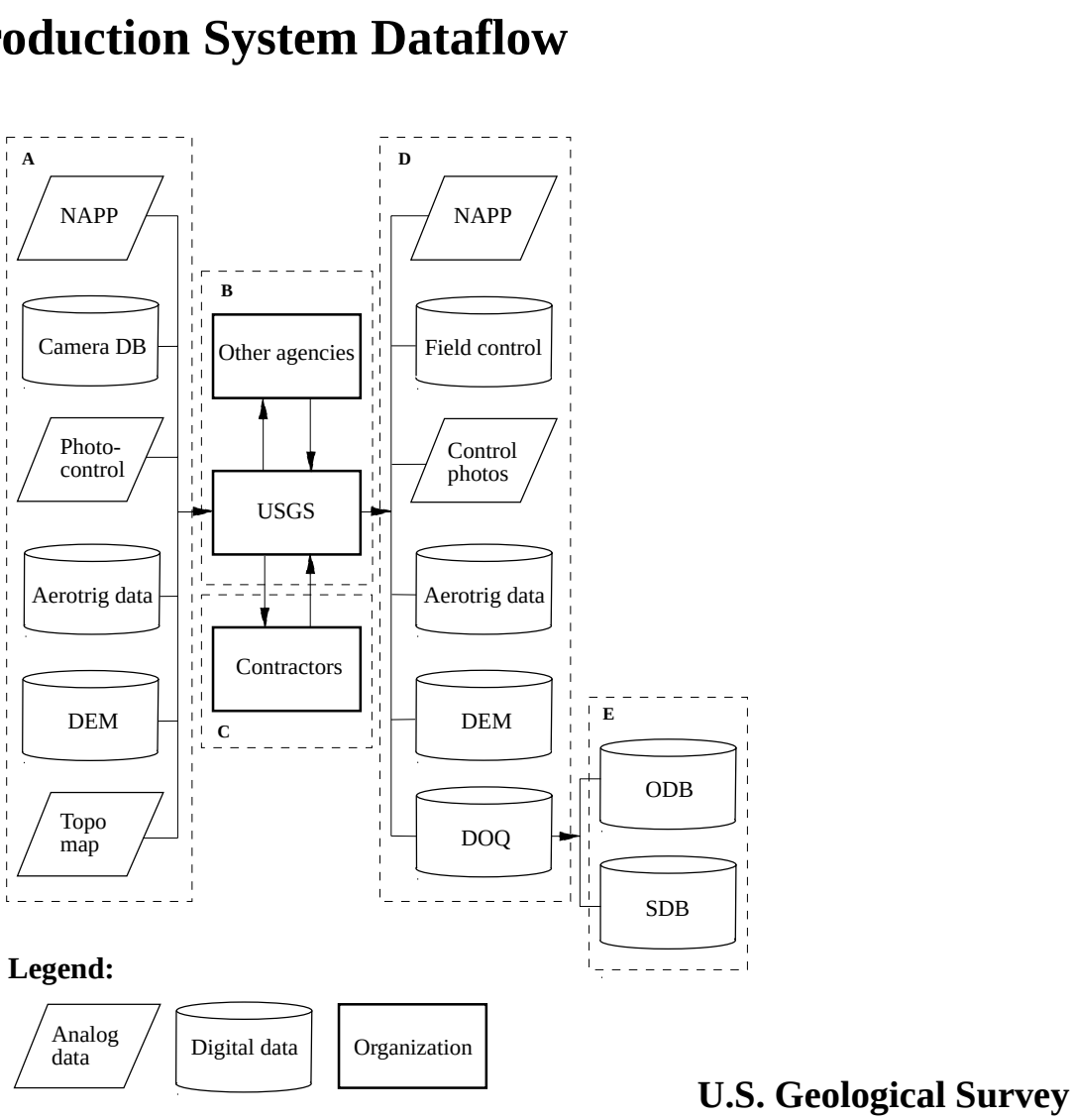

Figure 1

2.10 Quality Assurance Procedures

While it is the contractor's responsibility to produce DOQs which meet National Map Accuracy Standards, intermediate products are delivered to the government for review. These are products are usually photography, field control, aerotriangulation data, and DEM data. There are separate quality inspection paths for all data derived from the NDOP. All new photography is inspected on a frame by frame basis and must meet the National Aerial Photography Standards. Field control and aerotriangulation data are reviewed, but are not independently checked. Each DEM delivered is checked for accuracy and consistent elevation over larger water bodies. Image quality data of DOQs is checked by statistical sampling while the metadata information is checked for each DOQ.

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2.11 Federal Applications

The government agencies cooperating in the funding of the National Digital Orthophoto Program have specific organizational missions which require up-to-date base maps. The DOQ serves as a cost-effective tool way to fulfill this need. The Natural Resources Conservation Service uses to DOQ as a common base for all their soil mapping. The Farms Service Administration currently uses DOQs to support agricultural programs. The U.S. Forest Service is using DOQs for GIS applications in forest resource management. Finally, the U.S. Geological Survey uses the DOQs for map revision requirements and to fulfill its goal to ensure the availability of base maps. Other Federal agencies also use DOQs to accomplish their missions. In general, all resource management agencies require an accurate, up-to-date, and consistent image base. The DOQs fulfill these requirements.

2.12 Data Storage and Delivery Plans

Quality assurance is performed on all DOQs produced or acquired by the NDOP and archived in an Operational Database (ODB) and Sales Database (SDB). The ODB is for internal needs of the production centers while the SDB is for sales to the outside community. Both databases were implemented using modern database management systems. The Sales Database provides for near-line access to all DOQs. On-line access is currently not practical because of the large file sizes of the DOQs. The delivery of DOQs to cooperators are made directly from the Sales Database.

2.13 State-of-the-Art Production Systems

The production systems used by contractors are generally systems which are commercially available. Several contractors have developed their own software in-house and have the advantage to customize their production procedures and also to make additional enhancements as new requirements develop. The USGS has also developed its own production software which includes validation software for the DOQ headers.

The current procedure for producing imagery for the DOQs is to generate dodged scan diapositives from the original rolls of photography. Hence, the scanning diapositive is always second generation. Most of the contractors are using scanners which do not have roll scan capability. The current production process is a hybrid system of analog and digital components and there is no immediate justification to routinely scan all photography acquired. As production systems become entirely digital the roll scanning feature will become more useful. Furthermore, recall that the photography used for DOQ generation comes from the National Aerial Photography Program. The photography acquired in this program is not solely for the DOQ Program, so the flight lines do not match the later-defined DOQ project boundaries. Therefore, there is no need to scan an entire roll of photography for the DOQ program.

There has not been extensive use of correlation methods for DEM generation in the current production systems. This is because digitizing existing contour plates is more cost-effective. Whenever new elevation data must be acquired because of significant terrain changes, most contractors are using stereo-profiling methodology because softcopy systems are not fully implemented into production operations, neither in the government nor the private sector.

Finally, it is useful to comment about airborne-GPS technology. There have been several projects in which airborne-GPS technology has been used, specifically in areas where existing photography was not adequate for the DOQ users. The National Aerial Photography Program does not require airborne-GPS data to be collected because of the additional expense.

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3. COMMERCIAL VIEWPOINT

3.1 Overview

The DOQ program is one of the finest mapping programs in the world, comparable with the European country-wide mapping programs and the USGS 1 : 24000 quad-sheet program. It is the first medium-scale raster mapping program ever attempted. Of great significance is the fact that almost the entire work is being performed by the private sector.

3.2 Production Process

The USGS supplies the contractor with all available source materials including a DEM, and a set of contact prints on which existing USGS control points have been identified from their mapping archives and transferred to the new photographs. The USGS specification is that one horizontal control point is required at the corner of each 1" = 2000' quad sheet, i.e. every 7.5 minutes of latitude and longitude. As each quad covers four DOQ's, this means that control is required every second strip and every four stereo-models along the strips. Vertical points are identified from quad sheet spot elevations, and the USGS requirement is about three points per model, which is possibly an excessive number. See Figure 2.

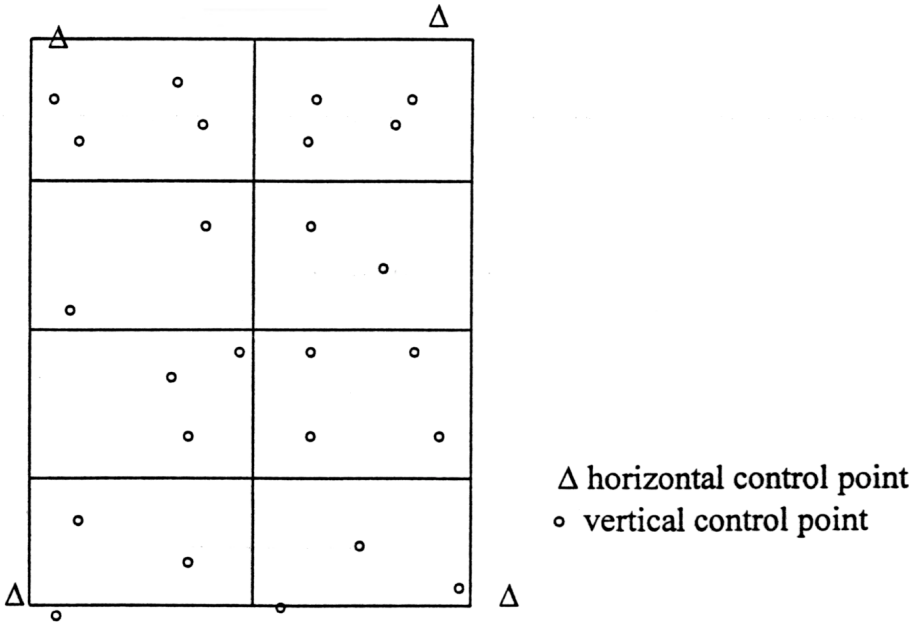

Figure 2

The contractor enters negotiations for any additional control which may be needed, and any required DEM development. New control is acquired using GPS techniques. The contractor then proceeds with the aerial triangulation, which must meet strict accuracy requirements and must be approved by the USGS. The DEM is normally supplied by the USGS in a quad sheet (four DOQ's) format, with a spacing of 30 meters and an accuracy of 7.5 m rms. If the DEM is unavailable, it is derived from 1" = 2000' quad sheet contours which are vectorized by the contractor and used as a basis for interpolation of a new 30 m DEM. A separate clean set of supplied alternate diapositives is scanned at 25 micron resolution (one meter ground resolution), and the orthophotos are created. Quality control is assured by the checking of at least four additional pugs inside each image.

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Each ortho contains an overedge of 300 m outside the DOQ sheet edges, and no attempt is made to mosaic the orthos or to perform radiometric normalization between adjacent sheets. While this procedure could be open to some criticism, it has allowed the production of far more DOQ's at a much lower cost.
After delivery by the contractor, the USGS passes each DOQ through a computerized process which checks the data, and in particular the header information. The DOQ's are then made available to the public on CD-ROMs.

3.3 Use of New Technology

New technologies being employed include

- Airborne GPS
- Automatic aerial triangulation
- Automatic DEM extraction

It must be borne in mind that automatic aerial triangulation, which does not require a pugged diapositive, while eminently suitable for making orthophotos, is unsuited to further exploitation (such as stereo-digitizing of vectors) unless digital stereo workstations are used. When this technology becomes widely used in the future the USGS will consider making the interior and exterior orientations of each photograph available to allow immediate use by third parties.

3.4 Commercial Use of DOQ's

Although the DOQ's are sold on CD-ROMs at a very low price of $36.00 per county, they are not easily usable by most people because of the following limitations:

- They are not seamless, as they are stored in separate 55 MB files, with 300 meter (1000 feet) overlaps between them.
- They are in the UTM NAD 83 coordinate system which is used by Federal agencies but not by the general public which much prefers State Plane Coordinate Systems (SPCS).
- They are not radiometrically normalized to avoid light and dark mismatches between quads.
- They are compressed in JPEG, a user-hostile format.
- They are comprised of one meter pixels, not feet, and are single resolution only.
- The USGS does not provide viewing software with the raster files.

DOQ data are used extensively by other federal agencies to do map revision, land management, resource management, analysis and planning.
The US Soil Conservation Service is a major participant in cooperative development of DOQ's. They are using the raster imagery for soils mapping, farm-field boundary management applications as well as other planning applications. The US Forest Service uses DOQ's to manage timber reserves in the Pacific Northwest area of the US. The DOQ's are in both mono-chromatic and infra-red formats. The DOQ's allow them a cost-effective way to view the extent of logging activities as well as to calculate reserves. Newly reforested areas are also managed and the DOQ's permit them to assess dangers related to fires and insect infestations. The National Park Service has entered into cooperative agreements to have DOQ's prepared for various national parks throughout the country. In the western US the DOQ's have assisted the Park Service in battling wildfires. Yosemite National Park in California has extensively used DOQ's, supplied by USGS, in fire fighting planning activities. The Tennessee Valley Authority, a quasi-federal department which manages a number of hydro-electric

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plants in the south-eastern US, uses DOQ's as a management tool for several applications. The DOQ's are used for the purposes of permitting land around reservoirs, and also to manage the elevations of the water pools. The DOQ's provide them with a very effective tool for assessing impacts related to the environment when a reservoir has reached flood stage. In Texas, the Texas Geographic Information Systems Planning Council and the Texas Department of Transport will use DOQ's of the whole state as a base map for over 100 identified current uses. This cooperative agreement with the USGS involves over 50 counties and 2974 DOQ's, with additional DOQ's to be produced at a later date[5].

3.5 The Impact of Satellite Data

In 1998 one-meter resolution satellite data will become available, and this may become a major source of DOQ data. At the time of writing (June, 1997) it is unclear whether the satellite companies will be willing and able to produce DOQ's at competitive prices and still satisfy the USGS that accuracy specifications will be met, since the USGS will not be providing the basic imagery source. Only time will resolve these matters. It seems likely that Alaska will be mapped from this source, as conventional aerial photography is difficult and expensive in that state.

4. CONCLUSION

The National Digital Orthophoto Program is an ambitious program which will provide nationwide coverage of DOQs. The DOQs are in high demand because they provide a common, up-to-date image base for GIS and mapping applications. This program could not be accomplished without the partnerships among government, the private sector, and academia. While there is overlap of activities among the partners, there is a role for each in this important and valuable product to the Nation. The government sets the standards and provides a coordinating role for funding and resources; private industry provides the necessary state-of-the-art hardware and software tools; the private practitioner applies professional expertise to make a product which meets standards; and academia continues the strive for improvement through research. The success of the program is dependent upon all.

5. REFERENCES

U.S. Geological Survey (1996): Standards for Digital Orthophotos: National Mapping Program Technical Instruction.

Federal Geographic Data Committee (1997): Draft Standards for Digital Orthoimagery.

[5] Texas Orthophoto Imagery, by Karen Steede-Terry and Andy S. Bury; EOM Magazine, March, 1997.