

# **The National Agriculture Imagery Program (NAIP): Options and Challenges**

**Prepared for the 2007 ESRI International Users' Conference  
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*Title Page: Rio, Washington Parish, Louisiana; NAIP 2005 2-meter image*

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## **Abstract**

The USDA National Agriculture Imagery Program (NAIP) provides ortho-rectified imagery to meet Farm Service Agency business requirements, and is used by numerous other federal, state, and local governments, private business, and individuals. NAIP is one of the largest orthoimagery programs in the country, and is also one of the fastest from image acquisition to field usability. The challenges of providing a quality and quick product are ever present. Many factors of the program are reevaluated yearly, and improvements are made when justifiable and possible. Discussion will include: image compression issues, data formats, number of image bands, elevation data, control data, film and digital sensors, radiometric issues, inspection, data distribution, and web services. The key factor in acquiring this imagery is the timely delivery and ease of use by USDA county office personnel in more than 2,000 county service centers using ArcGIS.

# **The National Agriculture Imagery Program (NAIP): Options and Challenges**

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## **I. The Background of NAIP**

### **A. Introduction**

The National Agriculture Imagery Program (NAIP) is an aerial imagery acquisition program of the United States Department of Agriculture's Farm Service Agency. The agency is constantly striving to improve every aspect of NAIP. The program is administered by the Aerial Photography Field Office (USDA-FSA-APFO) in Salt Lake City, Utah. APFO's website describes the NAIP program:

*NAIP acquires imagery during the agricultural growing seasons in the continental U.S. A primary goal of the NAIP program is to enable availability of digital ortho photography within a year of acquisition.*

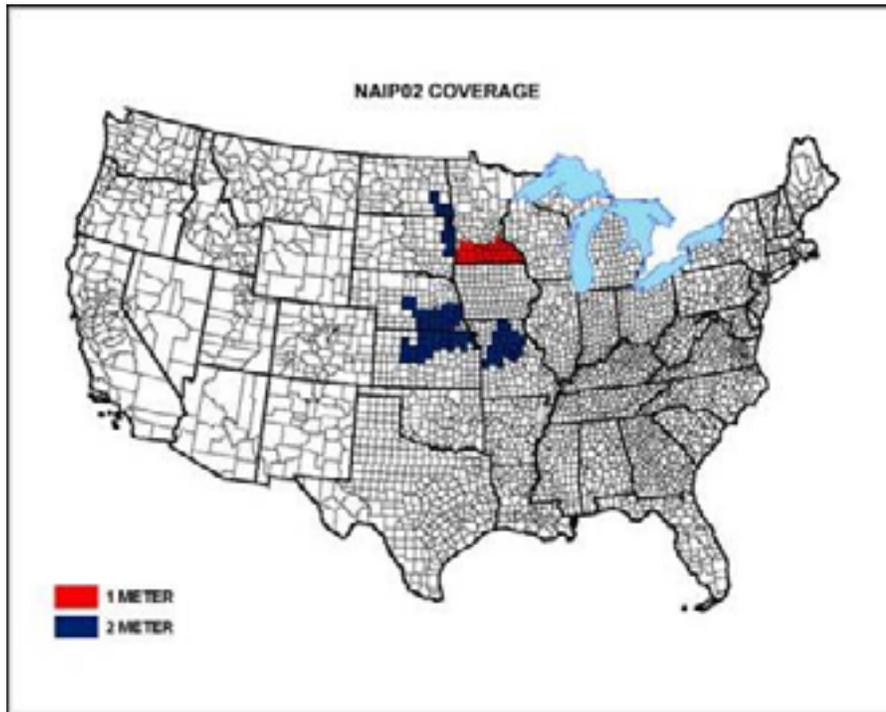
*NAIP imagery can be acquired under two sets of specifications: A one meter ground sample distance (GSD) with a horizontal accuracy that matches within five meters of a reference ortho image, and a two meter GSD image that matches within 10 meters of reference ortho imagery. The reference ortho imagery is mosaicked digital ortho quarter quads (DOQQs) that were used to digitize USDA FSA common land unit boundaries*

*NAIP imagery products are available either as quarter quad tiles or as compressed county mosaics (CCM). The mosaics are generated by compressing digital quarter quadrangle image tiles scanned from natural color positive or color infrared positive aerial film into a single mosaic. The mosaic may cover all or portions of an individual final product. Each individual image tile within the mosaic covers a 3.75 x 3.75 minute quarter quadrangle plus a 300 meter buffer on all four sides. All individual tile images and the resulting mosaic were rectified to the UTM coordinate system, NAD 83 and cast into a single predetermined UTM zone. Contractually, every attempt will be made to comply with the 10% cloud cover per quarter quad tile, weather conditions permitting.*

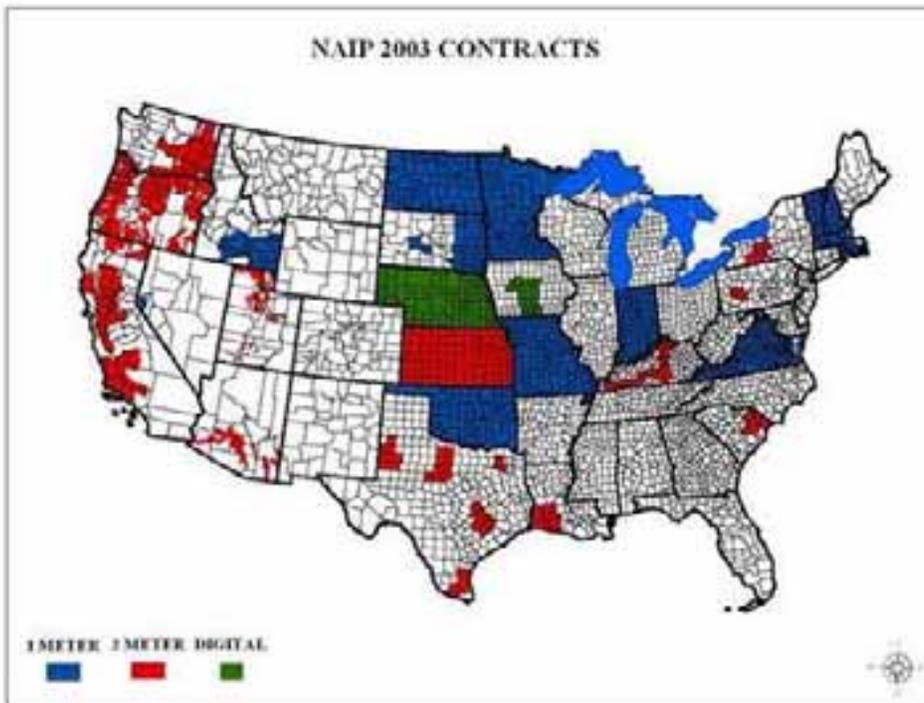
*The one meter GSD NAIP imagery is intended to provide updated digital ortho photography. The two meter GSD NAIP imagery is intended to support USDA programs that require current imagery acquired during the agricultural growing season but do not require high horizontal accuracy.*

NAIP began as a pilot program in 2002, and in 2003 expanded into a five year cycle of flying the entire country at a 1 or 2-meter resolution. The 1-meter acquisition is on a five year cycle of roughly 7-9 states per year. Its primary purpose is to replace the original base imagery. The 2-meter acquisition is

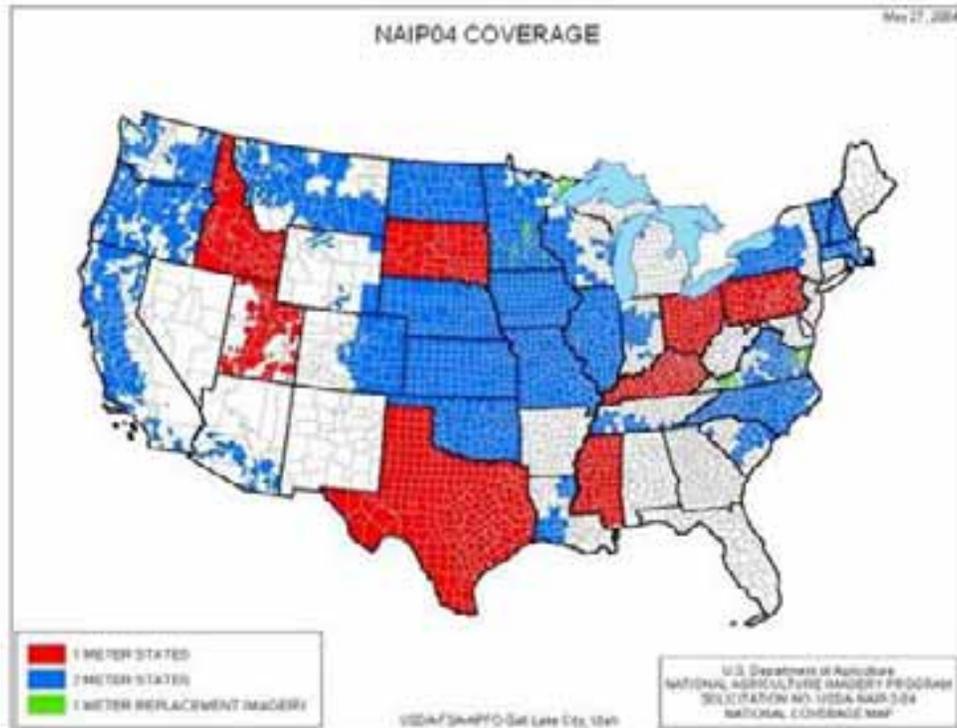
annual, is often restricted to areas with croplands, and is planned to meet the needs of FSA programs.



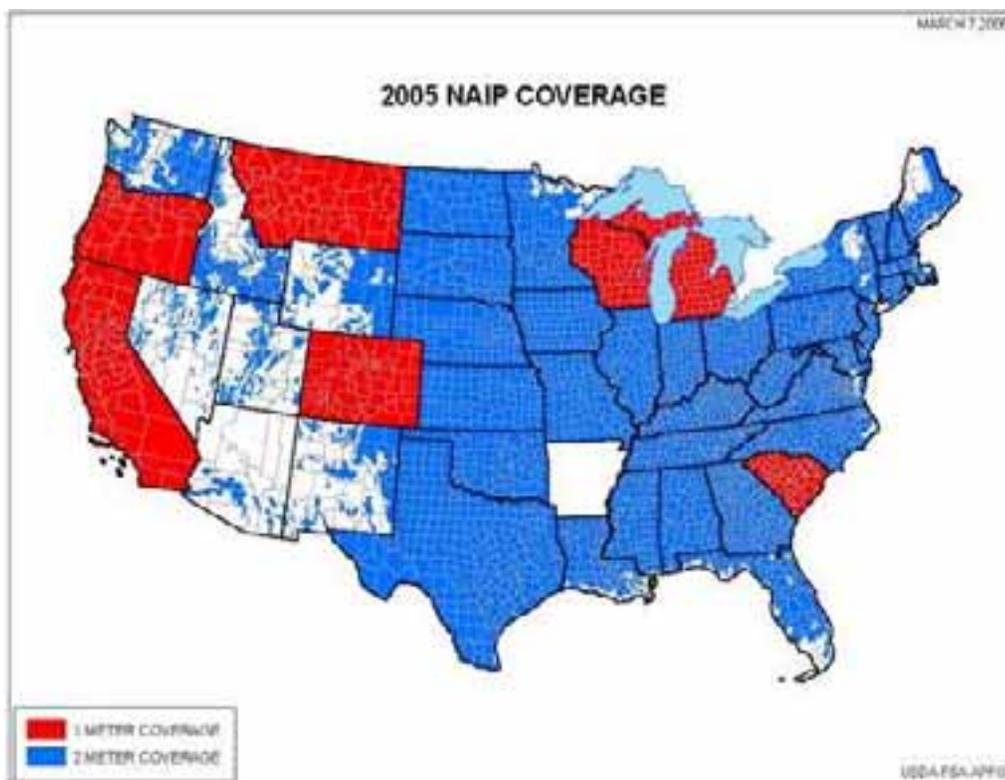
Map 1: NAIP 2002 was a pilot project in some of the important agricultural areas of the Midwest.



Map 2: NAIP 2003 included the first digitally acquired imagery.



Map 3: NAIP 2004 expanded the program, including more 2-meter imagery for compliance purposes.



Map 4: NAIP 2005 included farmland in nearly all of the states.



Map 5: NAIP 2006 included farmland in all of the states, and provided 1-meter base replacement for 11 states.

## B. The History of Aerial Imagery in Farm Service Agency Programs

The use of aerial photos in farm programs traces its lineage to a difficult period in our nation's history. The 1930s – years of the Depression and the Dust Bowl – prompted the Federal Government to enact legislation aiding farmers. As the APFO website explains:

*In 1933, the Agricultural Adjustment Act established farm programs designed to balance production and stabilize farm produce prices. Farmers, or producers, who participated in the farm programs needed to have accurate measurements made of their fields.*

*"Precise" survey measurements were made by carrying chains around the farmer's field, and then maps of the field were drawn by hand. A more accurate, inexpensive and efficient method was needed to measure the millions of acres of farmland across the United States. The use of aerial photographs to calculate acreage would replace this cumbersome method, and in the 1940's the United States Department of Agriculture (USDA) under the then named Agricultural Stabilization and Conservation Service (ASCS) established two aerial photography labs; one in Asheville, North Carolina and another in Salt Lake City, Utah. By 1976 photo production was consolidated to the Salt Lake location of the Aerial Photography Field Office (APFO).*

*At that time, the mission of APFO was to provide rectified aerial photographs for accurate field measurement. Field measurements were made from aerial enlargements with a planimeter. These annotated enlargements served as the basic record of producer land use information for each county office to administer programs.*

The mission statement of the Farm Service Agency (FSA) states “The Farm Service Agency is a customer-driven agency dedicated to supporting the agricultural producers of America. Through methods new and old, FSA will help US agriculture feed and clothe America and the world and conserve America's natural resources at less cost to consumers and greater profitability to its producers.” Over the years, APFO has provided imagery for “methods old and new;” initially, the County Offices were provided with 24” x 24” enlargements at a scale of 1:40,000. The County Offices drew farm tract and field boundaries onto the enlargements, calculated acreages, and made other notations. The photography served as a base map for county personnel, and since “a picture is worth a thousand words,” could serve as an eloquent means of communication.



*Figure 1: Farm programs were administered with APFO's photo enlargements and a planimeter for calculating acreage.*

In the mid 1990s, the Farm Service Agency began to consider the use of Geographic Information Systems software and digital aerial imagery to replace the paper enlargements and record keeping. Computers had come into use in the County Service Centers for tabular records, but more efficient and accurate administration could be done with GIS.

APFO began work in 1997 to create seamless mosaics from Digital Ortho Quarter Quads from USGS into a product called a Mosaicked Digital Ortho Quad (MDOQ). These mosaics, made in Leica Geosystems' SocetSet, were tonally balanced, and the seamlines were placed manually to minimize offset between images. The MDOQs were used to create Compressed County Mosaics (CCMs) with Lizard Tech's MrSID Compressed Publisher. The tract and field boundaries were digitized from the CCMs, and the data was ready for use in everyday operations.



*Figure 2: CLU boundaries were digitized on the MDOQ imagery in this example from the San Joaquin Valley in California, 1998..*

The change to a GIS mode of operation facilitated activities such as updating field boundaries (called Common Land Units (CLUs) in areas of landuse change (Figures 2 and 3), GIS based crop reporting and compliance applications, identification and tracking of disaster events, conservation planning and tracking, and gave the producers (farmers) and partners direct access to information.



*Figure 3: The same area in California with 2004 NAIP imagery. The use of GIS can very effectively display the dramatic land use change due to development.*

NAIP began with a pilot in 2002, flying small areas in five Midwestern states. In 2005 and 2006, most of the agricultural lands in the continental U.S. were flown as either 1 or 2-meter imagery. 1-meter imagery is used to replace the older MDOQs, which are usually Black and White, and may be from as early as the late 1980s. 2-meter NAIP is used only for administering farm programs. NAIP imagery is usually Natural Color, unless a state specifically requests Color Infrared. By the end of the 2007 flying season, 46 states will have NAIP imagery as a base layer; several states have received more than one year of NAIP imagery, in at least some counties.

### C. NAIP Funding and Partnerships

NAIP is a Farm Service Agency program, and the funding is primarily from the agency's budget. However, the program is always willing to accept partners for NAIP acquisition. For 2007, Maryland and Tennessee are receiving new 1 meter imagery out of the planned acquisition cycle because of partnership agreements. Georgia and Arizona, already scheduled for base replacement, also had partnerships.

Partnerships are usually made by a cooperation of different groups. APFO prefers to have partners work together, pool their money, and make a proposal to partner as a group.

From 2003 – 2006, NAIP has received partnership dollars from the following Federal agencies: Natural Resource Conservation Service, U.S. Forest Service, U.S. Geological Survey (USGS), Bureau of Land Management (BLM), and the U.S. Air Force Space Command.

A U.S. Forest Service assessment demonstrated the value for their agency in partnering for NAIP acquisition.

Source	Cost per Sq Mile	Total Cost	Savings
NAIP Partnership	\$ 6.25	\$2,931,000	
NAIP Full Cost	\$12.50	\$5,862,000	\$2,931,000
FS Sole Contract	\$18.75	\$8,793,000	\$5,862,000

The BLM values NAIP for a wide range of monitoring projects because it is a consistent standardized source, which is flexible and has a reasonable cost per square mile.

USGS noted cost savings in three states during the 2006 season because of partnerships.

	USGS	FSA	Partners	Savings
Washington	\$ 98,010	\$366,036	\$601,267	56.4%
Nevada	\$1,381,818	\$131,772	\$243,306	13.4%
Wyoming	\$529,960	\$183,576	\$840,144	54.1%

NAIP has also received partnership money from state agencies in California, Colorado, Idaho, Illinois, Kentucky, Maryland, Michigan, Minnesota, Missouri, Montana, Nevada, North Carolina, Ohio, Oklahoma, Oregon, Pennsylvania, Tennessee, Texas, Utah, and Washington.



Figure 4: Funding for the NAIP program, with partner contributions, including a wishful projection for 2007.

Some of the advantages of partnerships are upgrading the resolution from 2-meter to 1-meter, requesting a change in the band (or perhaps changing to a four band product), adding coverage to the areas already selected for the state, and being able to contract additional products or services directly from the vendor.

2007 is potentially seeing a reduced budget for NAIP flying. As of May 1, eleven states will receive 1-meter NAIP, and three states will receive 2-meter NAIP.

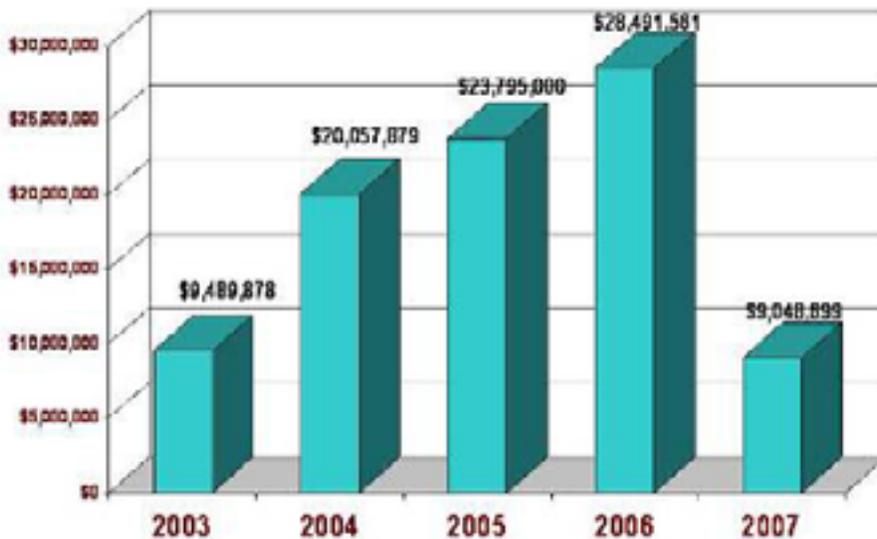
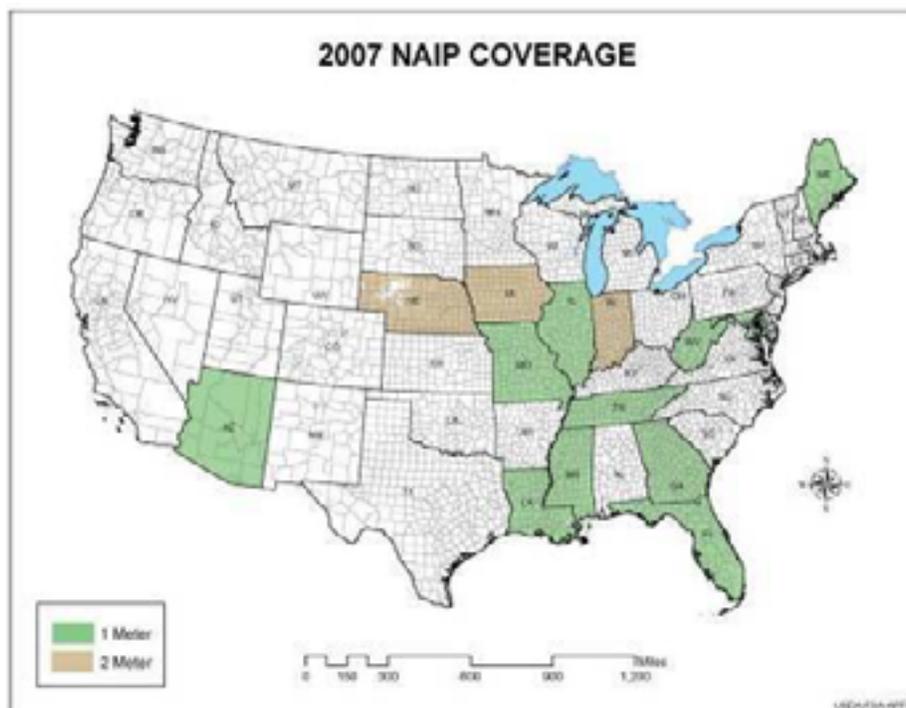


Figure 5: Funding for the NAIP program as of May 1, 2007

## D. NAIP in 2007

There are a number of exciting changes to the NAIP program for 2007. These are:

- Arizona will be flown in four bands (Red, Green, Blue and Near Infrared (NIR)) with the possibility of creating either Natural Color or Color Infrared imagery.
- Arizona imagery will be terrain corrected with control points tied to true ground coordinates rather than to older imagery.
- Vendors will be required to match specific metrics for image quality.
- Vendors will be required to use the most current Digital Elevation Model from the National Elevation Dataset (NED).
- Yazoo County, Mississippi will be flown in a pilot project using IFSAR
- A seamline shapefile will be created for Arizona. This will show the locations for each exposure used in creating a CCM.
- Nine states will be flown using digital cameras; five will be with film.
- The APFO website will feature a web service showing changes to NAIP acquisition as it occurs. In the past .jpg files had been posted to the web on a weekly basis.
- The 2007 contract is for one year with four optional years. Awards are based upon budget and need, with “indefinite delivery and indefinite quantity.” Although fewer states were awarded for the 2007 growing season, we are hopeful that we can return to a larger budget and greater coverage in 2008. Funding for the program is a continual challenge.



*Map 6: The 2007 NAIP contract as of May 1, with a reduced budget, is almost entirely for 1-meter base replacement.*

## II: Changes in Imagery Acquisition

### A. Moving from Film to Digital Imagery

In the years since the NAIP program has been operational, vendors have increasingly been using digital cameras in imagery acquisition. The first digital project, Nebraska, was flown in 2003. This expanded to five states with digital acquisition in 2004, 11 in 2005, and 26 in 2006. In five years' time, acquisition has moved from 11% digital and 89% film in 2003 to 62% digital and 38% film in 2007. The estimate is for a move to 70% digital and 30% film over the next two years.

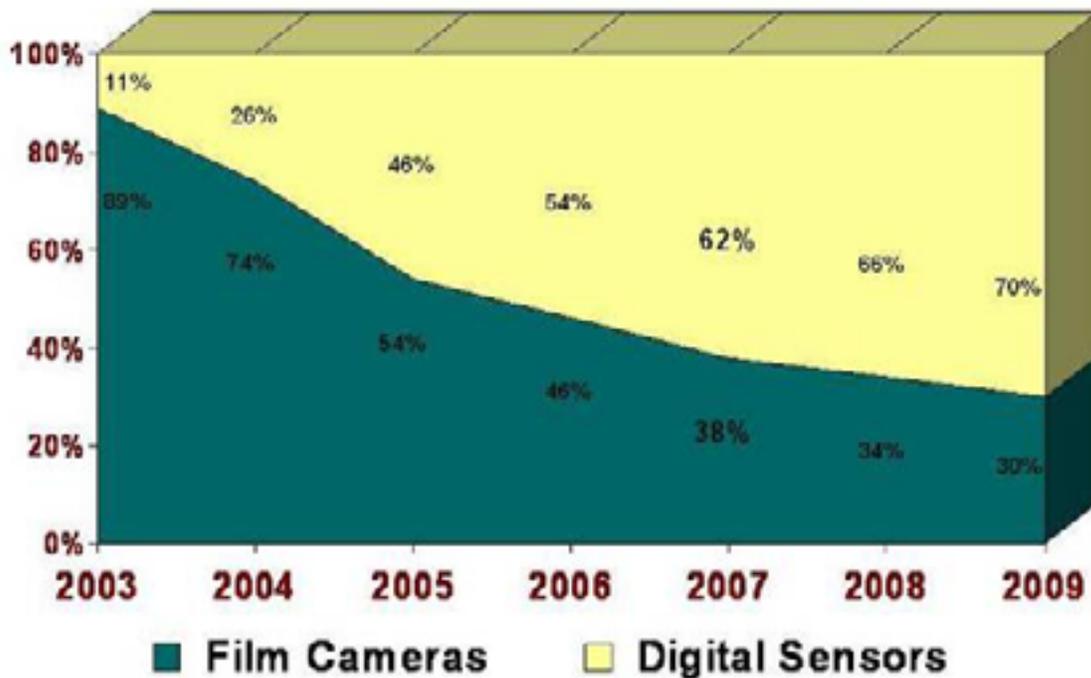
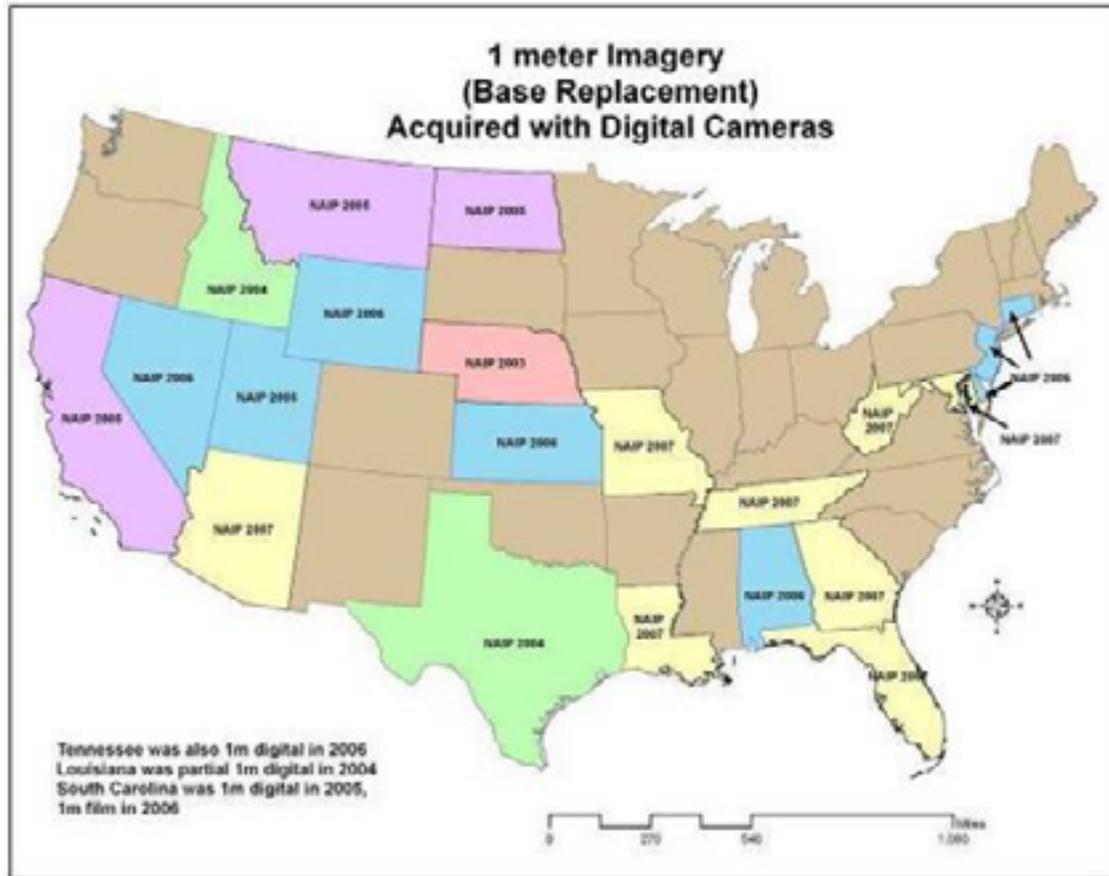


Figure 6: Contractors are acquiring more imagery in a digital format than they did when NAIP began.

In 2007, Arizona, Florida, Georgia, Indiana, Louisiana, Maryland, Missouri, Tennessee and West Virginia will receive digitally acquired imagery. They will all have a 1-meter GSD except Indiana, which is 2-meter GSD. Illinois, Iowa, Maine, Mississippi, and Nebraska will receive imagery acquired with film cameras. Iowa and Nebraska will receive 2-meter GSD imagery, and the rest will be 1-meter.

One meter imagery is available to the public through our distribution portals. The states which now have one meter base imagery acquired with digital sensors are shown below.



Map 7: States with digitally acquired base replacement imagery.

## B. Pilot Project to Acquire Four Band Imagery

2007 will include as a pilot project a contract for delivering four bands of imagery, instead of three. This will be done in Arizona, which will be the site of two other pilot projects, absolute control and the seamline shapefile. Four band imagery allows the user to select either Natural Color or Color Infrared in the application by changing the band assignments. This product would be more attractive to potential partners. The decision to acquire four bands was made because different customers prefer a different format. The cost of adding the fourth band to the deliverable product is not significantly more, since digital cameras will acquire the infrared band at the same time as the customary three bands for Natural Color. The DOQQs from this project will be delivered as 4 band Geotiffs, and the CCMs will be 3 band Natural Color.

A problem with four band imagery is that color balancing is often restricted to only three bands at a time; either Natural Color or CIR would be balanced, but not both. This is a problem that some vendors are working to address by developing their own code for processing the imagery.

### **C. Pilot Project with IFSAR**

Another pilot project is using a dual-sided, dual-frequency, interferometric synthetic aperture radar mapping system, flown in Yazoo County, MS by EarthData (recently acquired by Fugro N.V.) This will be flown with their GeoSAR, technology which includes the X and P bands. The X band collects “scatter[ing] off the first surfaces of vegetation, buildings, and bare earth, and the P band penetrates the foliage and records substructures. This imagery will be used to develop and test the Automated Crop Cultivation Assessment Tool This type of data could also be very useful in providing more accurate DEMs, especially in sparsely vegetated areas or in supplying control as we move away from doing the terrain correction based from older imagery. It could also potentially be used for crop/acreage compliance, disaster relief, or conservation practices. The GeoSAR X and P band image data will be examined to determine whether the common crop types present in datasets (corn, soybeans, wheat etc.) are separable within the feature space. This acquisition can support automated statistical classification algorithms for crop type verification.

FSA will assess the ability of IFSAR to alleviate aerial photography acquisition issues:

- Difficulties posed by high humidity and cloud cover characteristic of the southeastern US during the summer months;
- Identifying and digitizing field boundaries through tree/forest canopy or shadows cast due to low sun angle;
- Difficulties discerning boundaries between agricultural crops and non-crop vegetative cover that may have similar appearance in natural color or black & white ortho imagery.

The IFSAR project is technically not a part of NAIP 2007, but the findings of this pilot could be useful in providing more options when planning future NAIP projects.

### III. Changes to Image Processing in 2007

With each new growing season, APFO strives to improve the NAIP product. In 2007 there will be changes to the processes affecting positional accuracy, and tonal quality.

#### A. Radiometric Quality Changes

In the earlier NAIP seasons, APFO has provided the contractors with image samples to match. Discussions of image quality were somewhat subjective, with no clear way to fairly evaluate the imagery as it is inspected. Farm Service Agency (FSA) worked with ITT Space Systems of Rochester, NY on a study to determine parameters for image quality. In early February, they delivered an assessment of Best Practices to be used in Image creation. ITT studied the color perceptions and preferences of FSA employees who would be using the imagery, and made recommendations for image processing which would meet the users' needs. In 2007, the vendors will be required to comply with metric guidelines given to them by APFO.

ITT's report states:

*The initial phase of the contract (the FSA User Sensitivity Study), documented that USDA end users of NAIP imagery are sensitive to image quality, and that degraded image quality impacts their ability to discern CLU [Common Land Unit] boundaries. For example, imagery that was low contrast caused fatigue and was prone to inaccuracy as the definition of fields was less clear. Also, the study documented that users desired consistent and sufficiently saturated color reproduction to aid in the determination of crop type for compliance issues.*

ITT recommended ideal quantitative measurements for the image parameters, and, in their report, defined the equations to be used in measurement. The four metrics to be implemented in 2007 are for Overall Clipping, Contrast, Histogram Peak, and Color Balance.

The histogram is a starting point for discussions of digital image quality. Digital imagery information is stored as a numeric value for each picture element (pixel). In aerial imagery the pixel size, or Ground Sample Distance (GSD), refers the geographic area on the ground to which it corresponds. NAIP imagery has either 1 or 2-meter GSD, and each pixel is coded with one unique tonal value for the entire 1 m<sup>2</sup> or 4 m<sup>2</sup> area. A histogram is a chart showing how many pixels contain each of the possible values within the image's range. These discrete values are known as "bins."

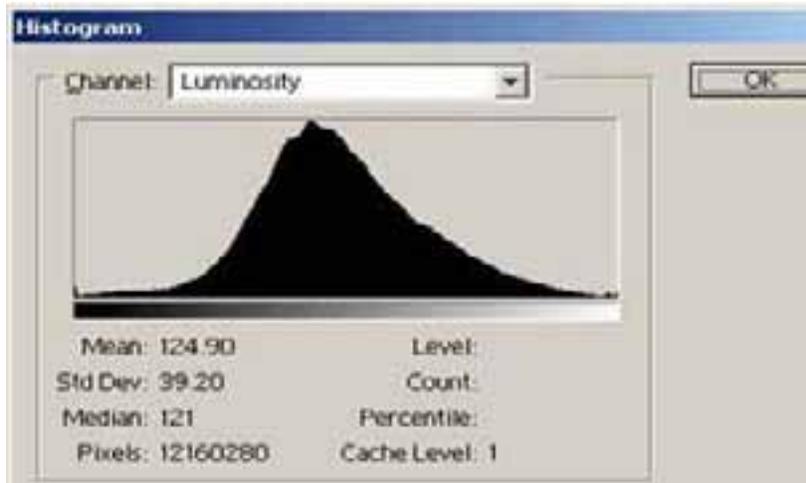


Figure 7: Statistics for the Luminosity Histogram (displayed in Photoshop)

Because NAIP is 8 bit imagery, there are 256 potential values for each pixel in an image. The three histograms for a given color image display the distribution of pixel values for each band of the image (red, green, and blue). The luminosity histogram, (shown in this example) is a composite for the three bands combined. The target for the Histogram Peak (not shown in these statistics) is  $\pm 15\%$  of the center value (127.5), or between 108 and 148. This would assure that the image is neither too light nor too dark; since the bin with the most pixels would be near the center. This specification makes it more likely that the histogram would have the classic “bell shaped curve.”

Color Balance is defined by ITT as a “natural look of colors within an image without the dominance of any individual color.” In a color balanced image, the same metric value for each of the three bands would produce a neutral gray tone. The pixel values which actually do produce a neutral gray in a given image should be close to each other, if not equal. The histograms of the different bands should have no more than  $\pm 10$  pixel values between the “gray value”, with a target of  $\pm 5$  values difference between them.

The Contrast metric relates to the range of the maximum and minimum values of an ideal color range; contrast would define the width, but not the shape, of the histogram curve. ITT determined that FSA users would prefer a contrast of at least 120; the target is 150. In the context of farm programs, contrast can assist with crop identification. Contrast is largely a function of the image enhancement process, but flying on a sunny day will also increase the contrast of the images.

Overall clipping refers to the number of pixels with values in the outer bins of the histogram. No more than 2% of pixels should be in the first or last five bins of the luminosity histogram, with the target being no more than 1%. Clipping can result from an overly aggressive contrast enhancement, and creates a histogram curve wider than the 256 values allowed, with values above 255 or below 0. These values are assigned to the outer bins, resulting in a high number of pixels on the

edge of the ranges of tonal possibility. Clipping on the left of the histogram heightens shadows; while clipping on the right intensifies highlights.

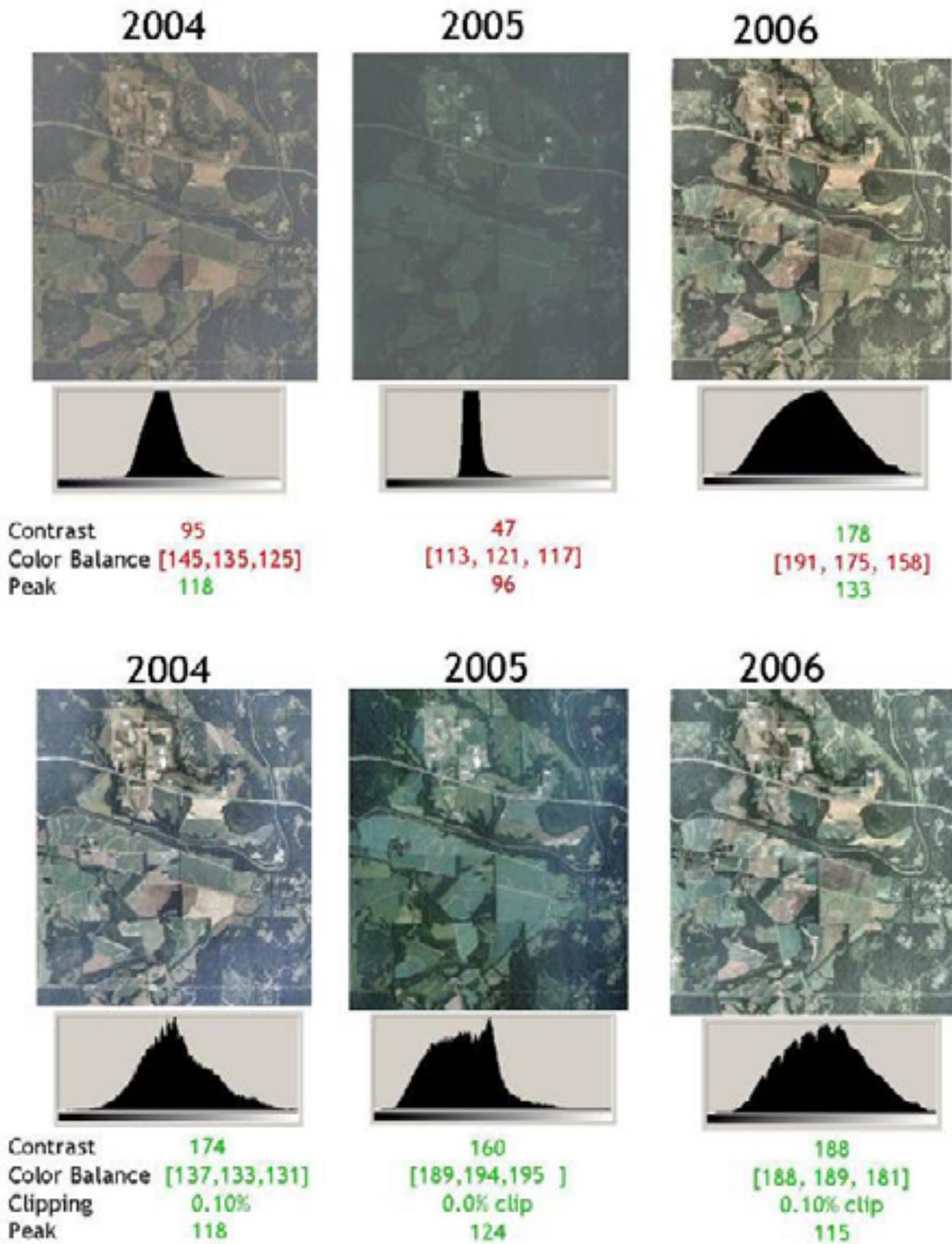


Figure 8: NAIP imagery adjusted to meet the metric standard, before and after reprocessing (displayed in Photoshop).

ITT provided samples of images before and after processing. In this example, imagery was chosen from the same area in Mississippi from 2004, 2005, and 2006. The histograms from 2004 and 2005 had very narrow shapes, indicating low contrast. In addition, the peak for 2005 was too far to the left, making the image darker. After the imagery was reprocessed, the images meet all of the specifications, and are more pleasant visually.

Compliance with three other metrics, Saturation, Noise, and Sharpness, will not be required for this flying season, although recommendations were established.

The saturation metric is the standard deviation of a measurement called the saturation channel; it should ideally be between 0.08 – 0.10, with a minimum allowed range of between 0.06 - 0.12. The following examples show high and low saturation on the same image.



*Figure 9: Examples of Low Saturation*

### High Saturation



Figure 10: Examples of High Saturation

Sharpness is calculated with a measurement called the Relative Edge Response. This parameter is especially important in FSA because farm field boundaries are digitized from the base imagery.

ITT writes that sharpness can be influenced by:

- Atmospheric degradations for different ranges
- Variations between along-track and cross-track measurements due to forward motion of the aircraft
- Variations along the focal plane.

### Sharpness

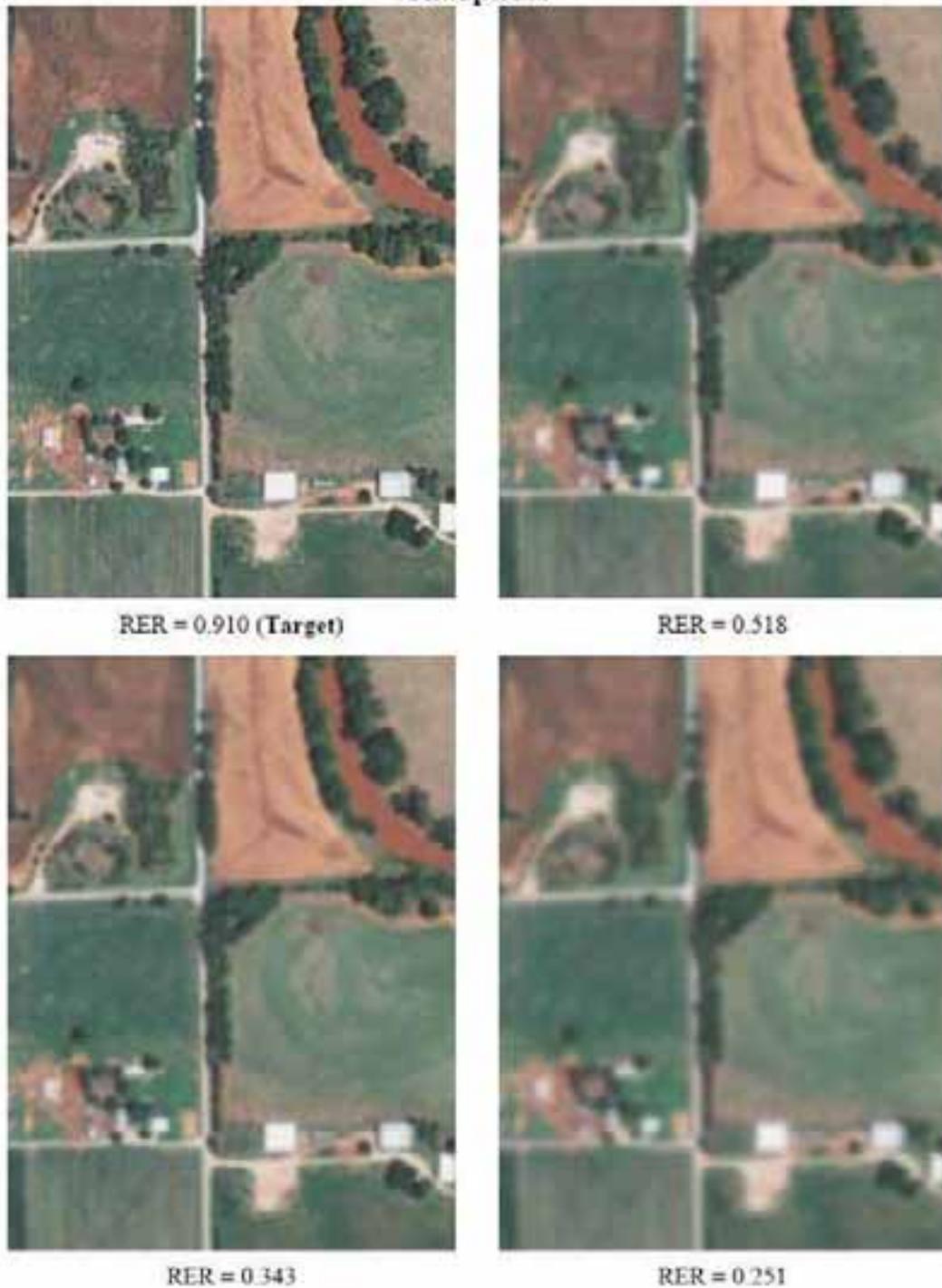


Figure 11: Examples of Sharpness

Noise is measured by the Signal to Noise ratio, a ratio of mean pixel values to the standard deviation of pixel values. In using this measurement, a reading of less than 12 was judged unusable for FSA business. Noise is defined as non-

image wise variations in intensity, and has a “grainy” appearance. ITT made some recommendations for flying to reduce noise

- Take imagery close to peak times and with maximum light and optimum exposure settings.
- Keep camera lenses clean from any debris and have optics equipment cleaned regularly. Monitor vibrations to any equipment used during pre or post image capture.
- If using film as a medium, keep stored in a cold location if possible, and have exposed film processed quickly to avoid UV radiation effects on the imagery. Old film can also introduce grain, which causes noise.

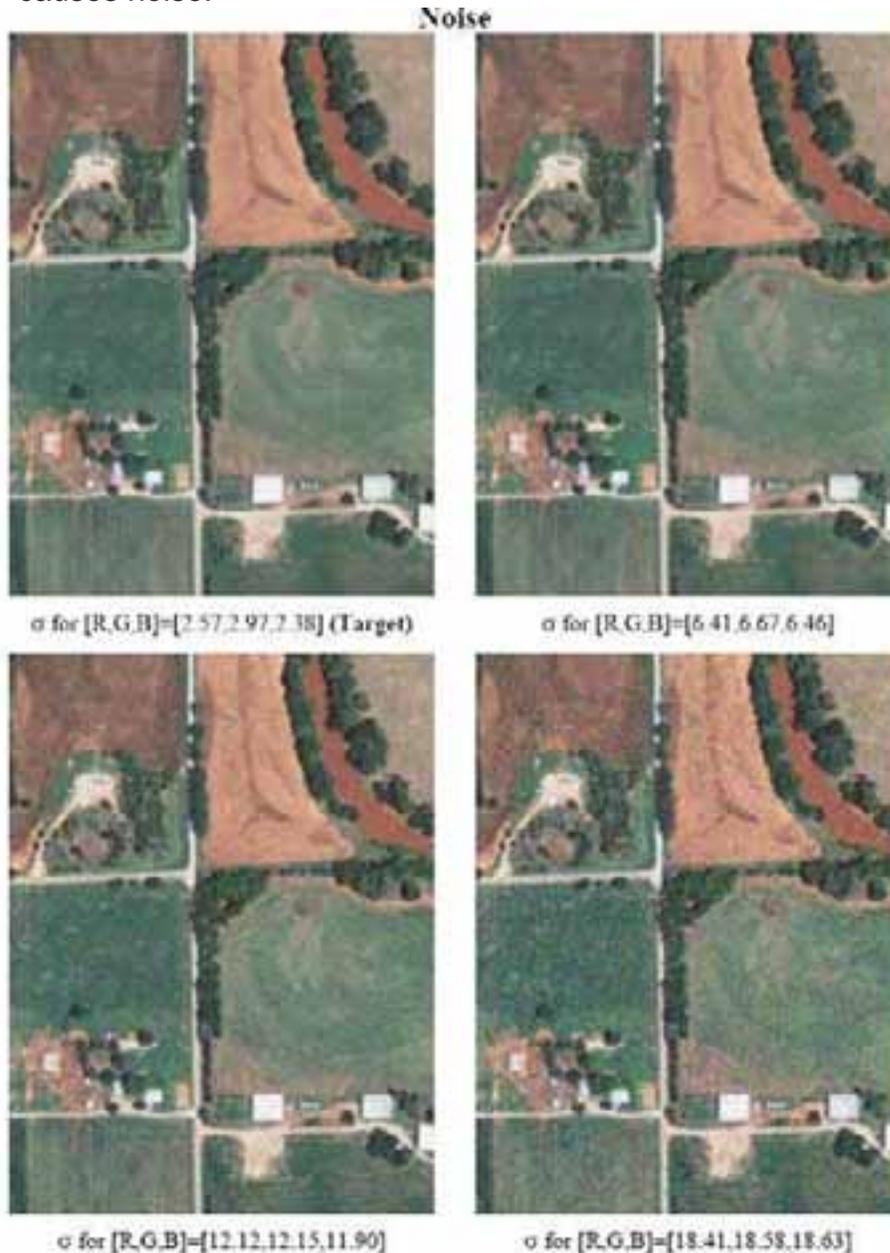


Figure 12: Examples of Noise

In the example on the preceding page, the image becomes progressively more “grainy” as noise is increased.

As the NAIP program continues, there will be continuing efforts to improve image quality.

## **B. Geometric Quality Changes**

In the past, NAIP contractors were required to use the “best available” digital elevation model. In 2007, the contract is more specific, and states “the Contractor shall use the most current/recent version of USGS National Elevation Dataset (NED) for terrain-correcting the imagery.”

A more important change, however, is the move from “relative” to “absolute” control. Since its inception, the horizontal accuracy of NAIP imagery has been tied to the Mosaicked Digital Ortho Quads (MDOQs), most of which were created at APFO from USGS DOQQs, between 1997 through 2004. The actual flying dates of the imagery were usually much earlier (late 1980s – early 1990s). The MDOQs were used as an initial base layer when the FSA Service Centers began using GIS to administer their programs. They were used as a reference layer for digitizing the Common Land Units (CLUs). CLUs are field boundaries, and are the basic land unit used by the Farm Service Agency in working with farmers.

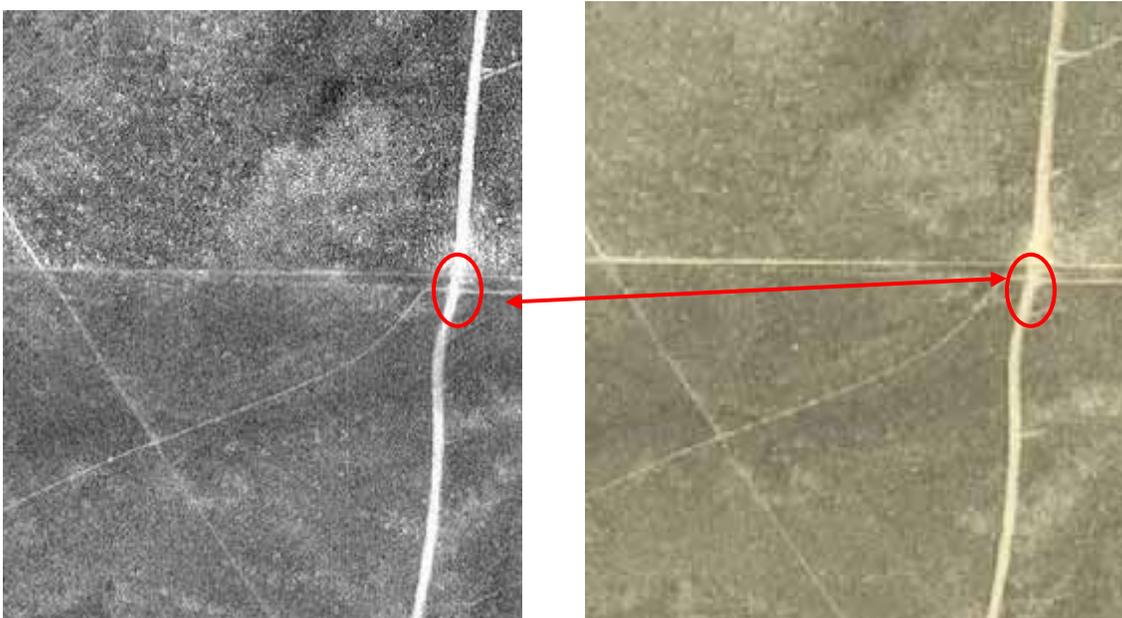
The problem with using the MDOQs as a reference for horizontal accuracy is obvious: any errors that might exist in the older base imagery would be passed on to the newer products. The CLU boundaries which had been digitized from the MDOQs might still match the NAIP, but the data would not be as accurate as it could be. In addition, even though the CLUs would match the NAIP imagery, other vector datasets might not. This would make the NAIP products less valuable and less appealing to potential partners.

The contract for 1-meter NAIP imagery required that 90% of inspected points fall within 5 meters of the base; for the 2-meter NAIP, 90% of inspected points had to fall within 10 meters or less of the base. Because the NAIP imagery was tied to another imagery dataset rather than true ground measurements, this has been called “relative accuracy.” The MDOQ base was itself created with specifications allowing a certain degree of inaccuracy. If the base was, for example, 5 meters off from true ground, and NAIP was 5 meters off from the base, the error in NAIP could potentially be as much as 10 meters from true ground rather than five.

As NAIP becomes an established program, it will be necessary to make the imagery as accurate as possible. One of the crucial elements in improving accuracy will be the program’s change of the reference used in terrain correcting the imagery. In 2006, NAIP ran a pilot using absolute control points in Utah. For 2007, the same methodology will be used when processing Arizona’s imagery.

APFO has always provided the contractors with the MDOQ base imagery to reference. When moving to absolute control in the Arizona pilot we will instead furnish a set of ground control points to use in the creation of orthos.

The major problem in making this change is finding accurate control points to be used not only by the contractors creating the imagery, but by inspectors at APFO validating the accuracy of the product. There is no freely available, nationwide, standardized, photo-identifiable control point database available for use in production and inspection. Obtaining control data requires additional time and money, and possibly requires more time in processing the imagery. This method also will require changes to APFO's inspection, database, and contracting procedures.



*Figure 13: Working with relative control involves measuring the same location on old and new imagery, and calculating the offset between them. Contractors used the older MDOQ imagery as a control source when creating the NAIP ortho images. APFO inspectors selected spots to measure on both sets of imagery.*

The Service Center Support Section at APFO worked to locate enough control points for the state of Utah. Previously collected control points were eagerly sought for this project. Points were found from several different sources: US Geological Survey (USGS) and Forest Service (USFS), National Geodetic Survey (NGS), and the Utah Automated Geographic Reference Center (AGRC). A usability test was conducted on the points collected. In addition to having accurate locations, the points needed to have suitable documentation to help the user in identifying them. The data came with a variety of supplemental data – sometimes very clear, and sometimes just a brief phrase.

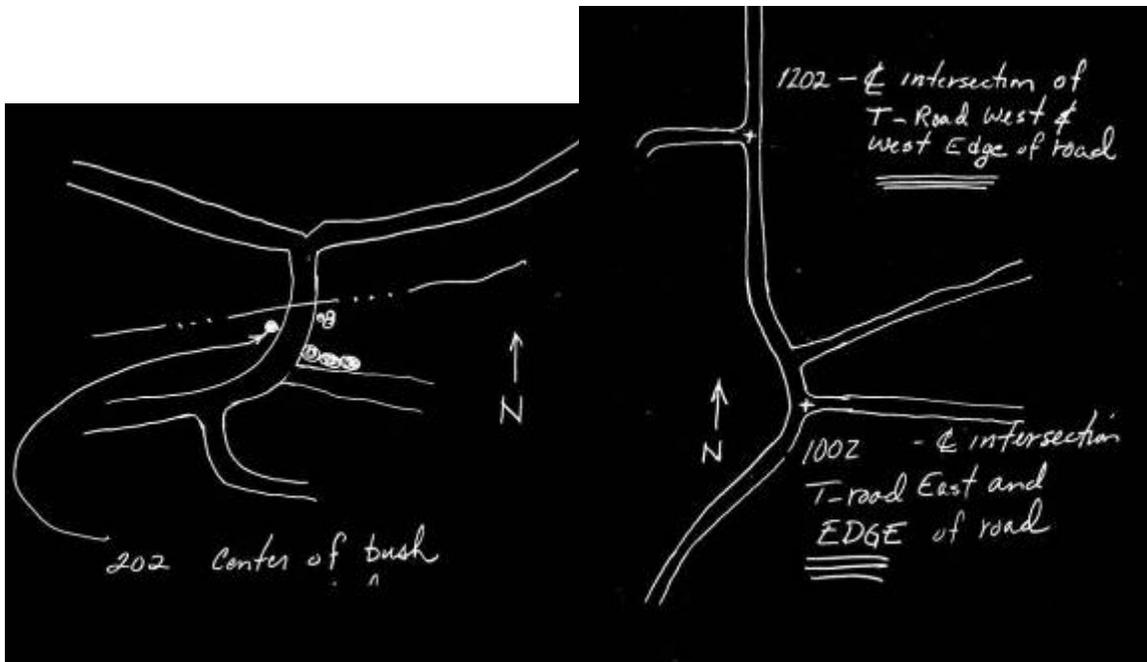


Figure 14: Previously collected control points were very valuable if their locations could be clearly determined from the supplemental data.

Three new control points in each county were acquired by Utah Automated Geographic Reference Center (AGRC). AGRC is run by the Utah state government, and they entered into a partnership with APFO for the 2006 flying season. APFO selected the points to be surveyed, and AGRC then acquired the survey grade control points for the selected locations.

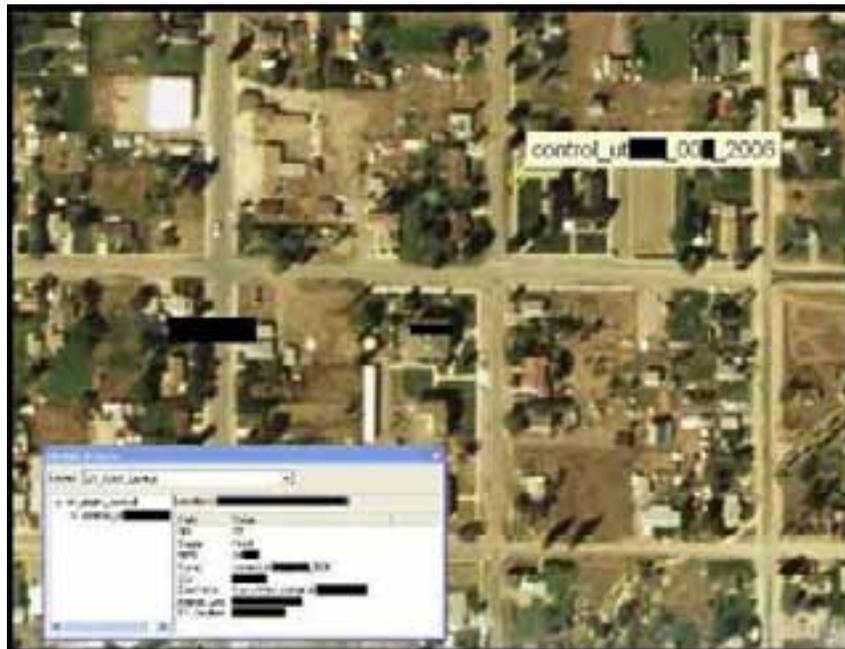


Figure 15: APFO selected potential sites for absolute control point collection by Utah AGRC.

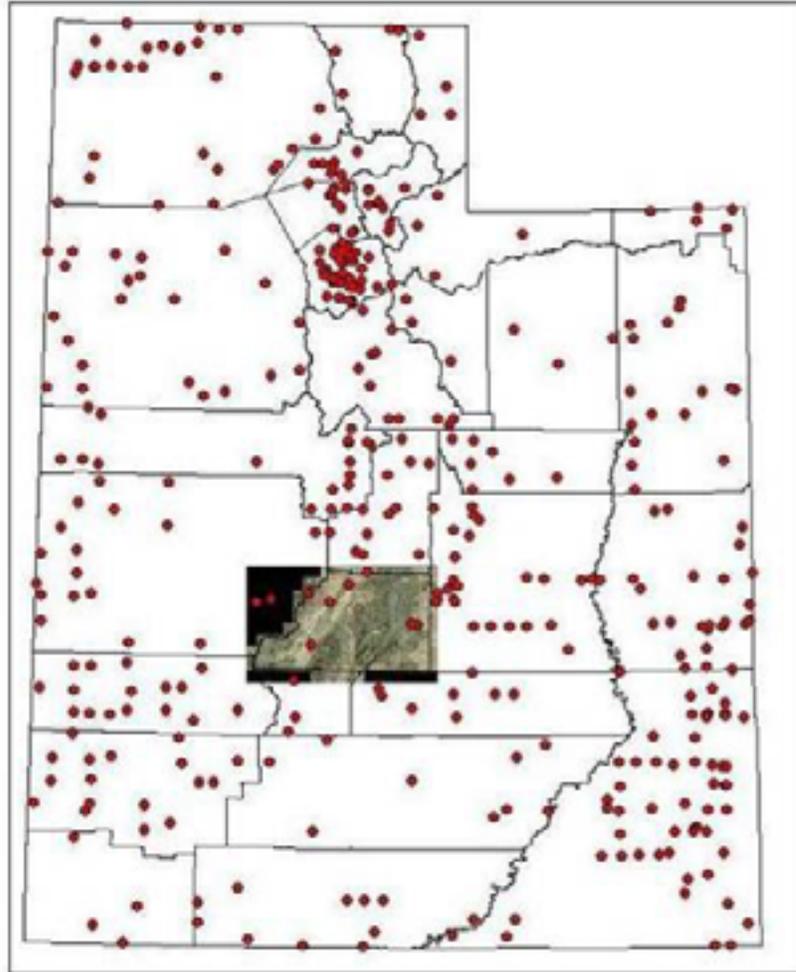
### NAIP 2006 GPS Observation Sheet

Control Station			
Station Name	State	Dist	County
Contact Name	Contact Phone		
Source Agency	IGTC	Date	01
Rover Receiver			
Type	Trimble	Model	5800
Serial Number	Antenna Type	5800	Antenna Height 3.19 ft
Monument Description and Comments			
North west corner of ditch line.			



Figure 16: Points were measured and very clearly documented with photos from north, south, east, west, and straight down, in addition to written descriptions.

Point collection involved traveling to the sites, measuring the points, and clearly documenting their locations. The points were added to the previously collected points from other agencies in a database, with the necessary attributes. Some of the points were given to the contractors for their photogrammetric solutions, and some were used for accuracy measurements in APFO's inspection process. Since this was a pilot, the accuracy inspection was "offline" (not a part of the automated inspection process)



*Map 8: All control points used for accuracy inspection*



*Figure 17: The points were databased and used for an accuracy inspection  
(The point is oversized for demonstration purposes)*

In 2007, Arizona will supply control points to APFO for use in a process similar to that which was used for the 2006 UT NAIP imagery.

The success of this effort in the future will depend upon our ability to successfully locate usable control points in all the states and territories where FSA needs to acquire imagery, and hopefully to create partnerships within the states so that we can obtain a growing database of control with increasing degrees of reliability and ease of use for contractors and inspectors. We are exploring all possibilities and sources, including LIDAR and the proposed Elevation for the Nation program.

Another possibility would be to use commercially available control points. These are very expensive, and APFO would prefer to spend the NAIP budget on acquiring imagery rather than control points.

The creation and maintenance of a control point database will be a major project for APFO. More details about the pilot study can be found on our website, [www.apfo.usda.gov](http://www.apfo.usda.gov). Select *Support Documents*, then *White Papers*, and then *2006 NAIP UT Pilot Project: Absolute Accuracy Summary Report*.

### **C. Seamline Shapefile**

Arizona will have an additional deliverable this year, a shapefile of seamlines designating the different exposures which will make up the CCM. This is information which customers have been wanting for years, because it allows them to know the exact date on which a portion of the image was flown. APFO will supply the vendor with a metadata template defining the fields to be used. The shapefile will record the image date, starting and ending date/time, the camera type (film or digital), the camera manufacturer (such as Leica Geosystems), the camera model (such as ADS40), sensor serial number, and the polygon area. Polygons will need to be at least 10 acres in size and be topologically correct, with no slivers or overlaps. It must cover the entire area of the image.

### **D. Image Compression**

Many different image compression formats exist. Several formats are specifically designed and suited for geospatial data. FSA and NRCS have used image compression for many years in an effort to save disk space as well as to distribute and/or package data in a more convenient form. APFO has created compressed county mosaics (CCMs) from USGS DOQQs for most of the continental U.S. (CONUS) using the MrSID format. These CCMs as well as the non-compressed MDOQ tiles have been used as an image base layer for Service Center Agency (SCA) GIS.

The MrSID format from LizardTech was used by APFO in large part because a number of other government agencies were already using this format or were evaluating the software. The earlier versions of the MrSID software not only could compress the imagery, but could also mosaic multiple images into a single seamless, compressed county mosaic. This made for a base layer for GIS or hardcopy uses which was easy to use and pleasing to the eye.

In the geospatial arena two main players existed, and for the most part continue to dominate the market for image compression. These two companies are LizardTech, the developer of the MrSID format and ER Mapper, the developer of the ECW format. MrSID (Multiresolution Seamless Image Database) & ECW (Enhanced Compressed Wavelet). Both formats have their pros and cons, and have made several changes involving the software, pricing, and company structure. Both companies now offer JPEG2000 compression in addition to their own formats.

Until 2004 all of the compressed digital imagery products produced by APFO were in the original MrSID or MrSID Generation 2 (MG2) formats. The National cartography and Geospatial Center (NCGC) has produced compressed imagery products in both the MrSID and ECW formats for various locations. For the NAIP 2004 contract the option of changing to the MrSID MG3 format or the JPEG2000 format was investigated. Because of the desire to ensure that the imagery could work with any of the ESRI software products being used by SCA it was decided to stay with the MrSID MG2 format. The ArcPad software was not compatible with the MrSID MG3 format. For the NAIP 2005 contract it was decided that the superior capabilities and features of the MrSID MG3 format outweighed the possible use of ArcPad by SCA. Assurances were also made by LizardTech that ArcPad MG3 compatibility would be resolved by early 2005. ArcPad now supports the MG3 format. Mobile applications are also possible using ArcGIS or ArcView, with a Pentablet or Tablet PC type of computer.

When CLU digitizing first began, FSA was required to use the non-compressed tiles because of concerns of offset or other possible changes to the imagery caused by the compression. When APFO first began using the MrSID software it was found that a ½ pixel offset was occurring in the compressed imagery. This problem was documented and then submitted to LizardTech. The problem was later corrected by LizardTech. An evaluation was done by APFO to determine whether offset was occurring in the MrSID compressed imagery as well as if digitizing done on compressed imagery or non-compressed imagery showed different results. The final analysis showed no statistical difference using the compressed or non-compressed imagery. In February of 2001 the approval for using compressed county mosaics for digitizing CLU was given.

Imagery in the MG3 format can be manipulated using GeoExpress in ways not previously available. With MG2 imagery it was necessary to convert the imagery back to TIFF or completely start over on a project to perform many functions.

The GeoExpress software, using imagery in the MG3 format, can reproject and save a mosaic in a new projection. Areas in a mosaic of missing, defective, or older imagery can be updated without remaking the compressed image. Imagery of different resolutions can be mosaicked into a single image, and different portions of the mosaic can be compressed at different ratios.

The GeoExpress software allows for compression to the MG2, MG3, or JPEG2000 formats. The imagery does not need to be converted first to TIFF; it can be converted back and forth between the various formats.

The five year NAIP contracts awarded in 2007 state that the compression format will be specified in the individual task orders. For 2007 that format is Lizard Tech's MrSID Generation 3 (MG3). By not mandating a specific format in the contract itself, APFO has the option of changing this in the future.

There have been many requests for a move to other formats: JPEG2000, ECW, and back to MG2. A return to MG2 was suggested because MG3 was not compatible with some (older) types of software, and would require a plug-in, if available. Many of the compatibility issues, such as MG3's use in ArcPad, have been resolved.

ER Mapper's ECW is, like the Lizard Tech products, a proprietary format. If APFO makes a change in the compression format, it would probably be to a non-proprietary product like JPEG 2000. The primary concern with JPEG 2000 is that the different programs do not all use the same process in creating the output. The results may differ tonally, and produce an inconsistency to the user. APFO has been testing file formats, but was not prepared to make a change for this flying season.

## Section IV: Data Distribution

NAIP imagery is contracted, acquired, and delivered over an 18 month period. Flight planning activities begin in the fall, the request for proposals is issued in February, and the contracts are awarded by April. By the time the imagery is delivered, APFO is already making plans for the next flying year. The basic timeline for imagery acquisition and delivery is shown below.

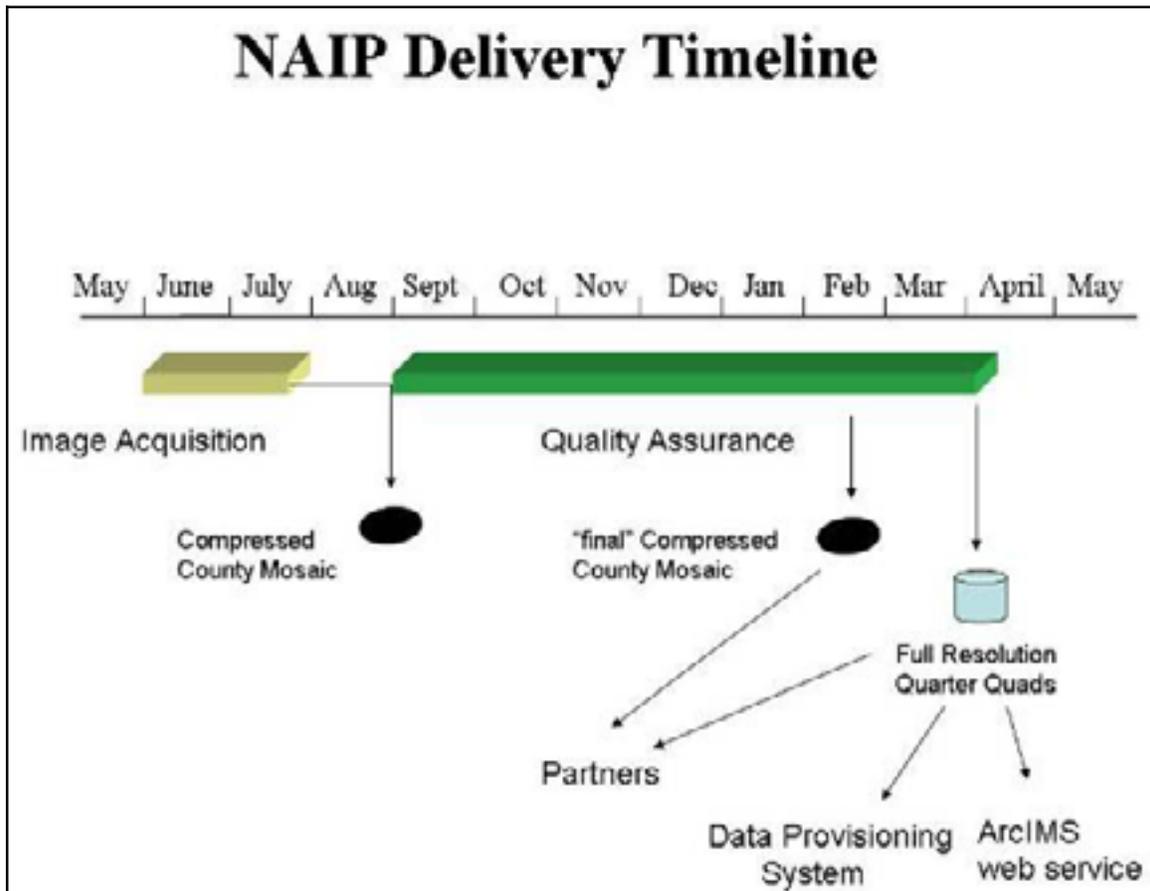


Figure 18: NAIP imagery is available in an interim version shortly after flying; the final inspected version will be approved several months later.

Progress reports on NAIP acquisition are posted daily on the website during the flying season. Status maps are updated and posted on the APFO website on a weekly basis. Beginning in 2007, APFO will host an FSA intranet web service that will be constantly updated as the office receives new imagery.

After the data has arrived at APFO from the contractors, the DOQQs are run through an initial python script to find any basic elements which do not adhere to the contract specifications, such as the Geotiff headers, buffers, ground sample distance, UTM Zone, etc. Any imagery failing this initial test is returned to the contractor for rework. The CCMs are visually inspected and then loaded into the

APFO archiving system. A day later they are available for download on the Geospatial Data Gateway web page.

Beginning with 2006 imagery, the DOQQs are being loaded into the Geospatial Data Warehouse very shortly after arrival, and are made available through web services as an interim version. They are available to the public after going through the APFO inspection process. All imagery is inspected for geometric and radiometric quality by the Quality Assurance Branch, and sold through the Customer Service Branch.

The new elements in 2007, such as the absolute control pilot and the use of metrics in image quality, will require new inspection procedures at APFO. These are currently under development.

Because NAIP is funded by U.S. taxpayers, the data is in the public domain, and can be available to the public at no cost, or for a minimal charge. There are several different methods for viewing or downloading NAIP data:

- The Geospatial Data Warehouse (GDW). This site is for viewing via web services, and is hosted by APFO. DOQQs are available here, from NAIP and from the earlier MDOQ products.
- The Geospatial Data Gateway, hosted by NRCS and APFO, exists primarily to deliver data to the Service Center Agencies which use it for their daily activities. NAIP CCMs only are available from the Gateway.
- Any digital data can be ordered from the Customer Service Section at APFO for the cost of reproduction. Earlier years of NAIP and DOQQs must be ordered through APFO. Older historical imagery from APFO's extensive film library can be ordered as a photographic product or as a custom scan.
- An online ordering system at APFO should be available by August 2007.
- Bulk orders of NAIP imagery can be purchased on hard disk drives.
- NAIP imagery has been incorporated into products such as Google Earth and ESRI's new ARCGIS Online.
- NAIP 1 meter imagery is to be a part of the *Imagery for the Nation* initiative.

#### **A. The Geospatial Data Warehouse (GDW)**

The GDW is a warehouse for storing raster, vector, and tabular data, which was conceived as a part of the Service Center Modernization Initiative. It is accessed through an ArcIMS server. It is described on the APFO website:

*The GDW is a complex assortment of servers, networks, storage, data, software, and people that logically and physically have been overlaid on*

existing USDA IT infrastructure and business practices. It is composed of 2 main data warehouses located at the APFO in Salt Lake City, UT and at NCGC in Fort Worth, TX. The two data warehouses are populated by on-going production operations, which occur at each of the two data centers. Each warehouse provides fail-over capabilities reciprocally. Current data volumes are in excess of 15TB and growth is occurring by two terabytes per year.

An operational Geospatial Data Warehouse will provide more effective program delivery by providing an authoritative, trusted source of imagery and other geospatial data for Service Center Agencies (SCA). The GDW will reduce the delivery time of current imagery acquired for use in farm programs. It will facilitate the delivery of the data to cost share partners that are critical to minimizing costs for FSA, and ensuring the long term success of the of USDA image acquisition programs. The GDW will enable compliance to current mandates that include making data acquired or developed by SCA available to the general public.

The APFO and NCGC data centers are charged with managing several USDA imagery programs. APFO also contracts for, manages, and delivers imagery for USDA Forest Service as well as other federal agencies. Administration of these programs requires robust data management facilities and procedures, expertise in image collection and organization, effective quality assurance measures, and the capability of delivering the data in formats that meet customer requirements

The GDW also is connected to three Web Farms.

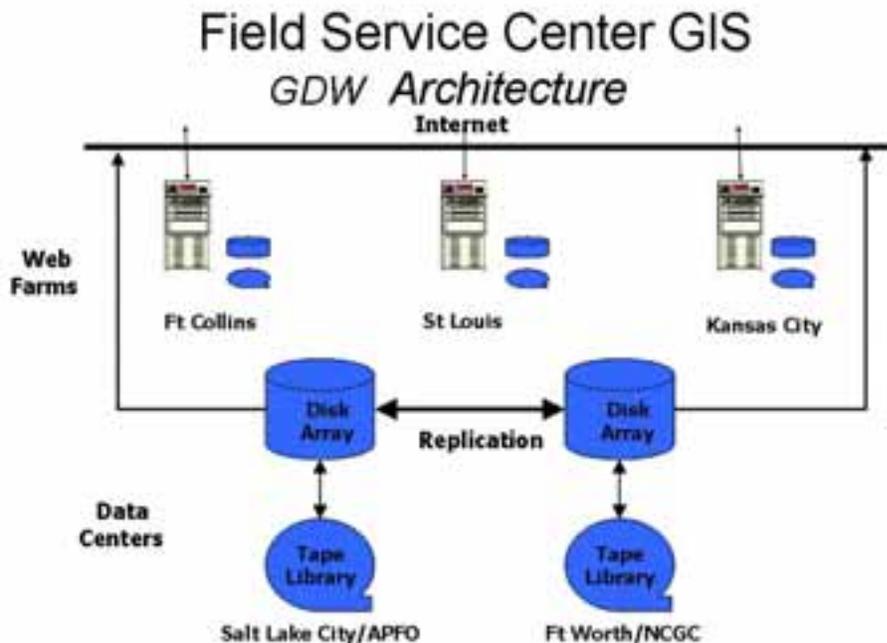


Figure 19: The GDW serves data from several different sources.

The basic purpose for APFO's data service is supplying the Service Centers with the imagery need to administer farm programs. However, this data is also available freely for viewing without GIS software. ArcIMS sites allow anyone to view the data through a web browser. These sites can be accessed through links on the APFO website, or with the URLs for the NAIP Viewer (<http://gdw.apfo.usda.gov/naip/viewer>) or the MDOQ Viewer (<http://gdw.apfo.usda.gov/mdoq/viewer>).



*Figure 20: The GDW data can be viewed in ArcGIS or through the NAIP data viewer, as shown above. This is a good option for the general user because it does not require GIS software. This example is the Lancaster County and the Susquehanna River Valley in Pennsylvania, seen with the NAIP Viewer. Pennsylvania received 1- meter Color Infrared imagery in 2004.*

GDW data can be accessed through the Add Data button in ArcMap, and provides secure public access. The URL is <http://gdw.apfo.usda.gov>

The data can be viewed, but not downloaded for further processing.

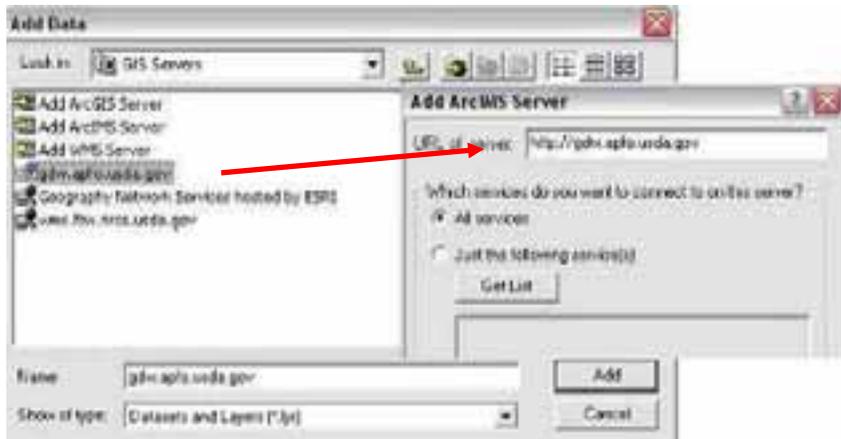


Figure 21: Adding data to the IMS server Geospatial Data Warehouse (GDW).

## B. The Geospatial Data Gateway

The USDA Geospatial Data Gateway is hosted by the National Resources Conservation Service in Fort Collins. The URL is <http://datagateway.nrcs.usda.gov/>. The Gateway allows free downloads of NAIP CCMs. At present, the volume of activity allows only 2006 NAIP to be accessed. Other requests will be sent to APFO via a link on the home page.

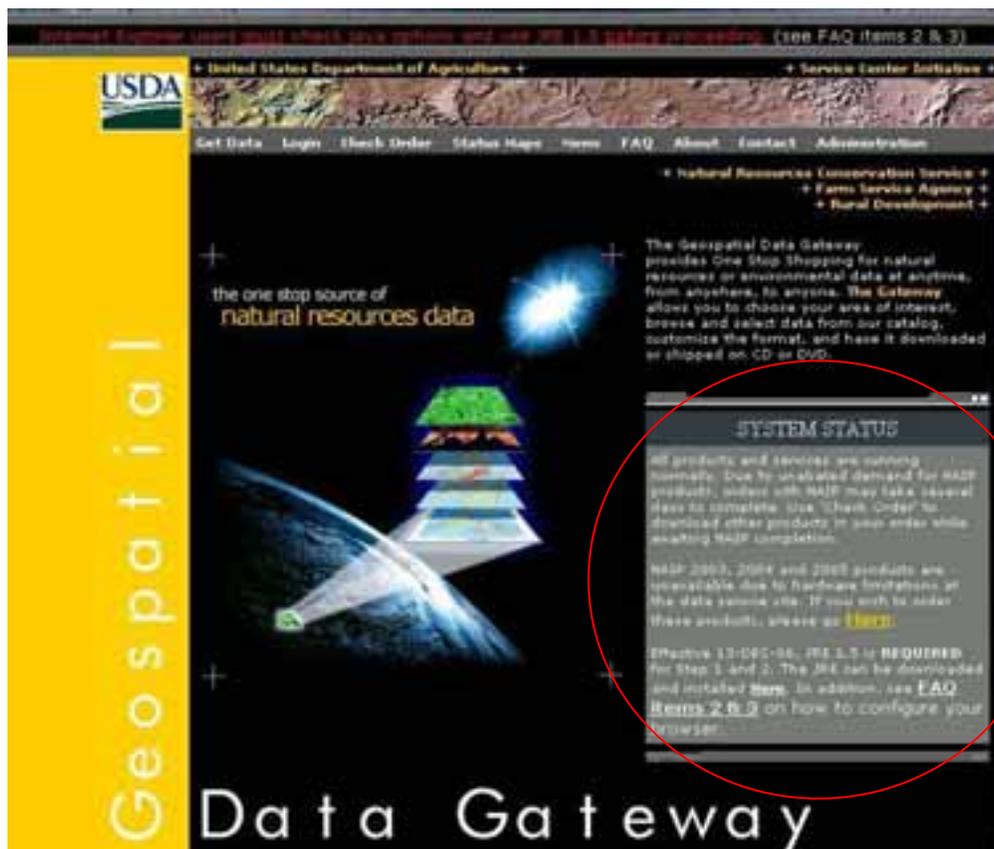


Figure 22: The most current Compressed County Mosaics (CCMs) are available for download from the Geospatial Data Gateway.

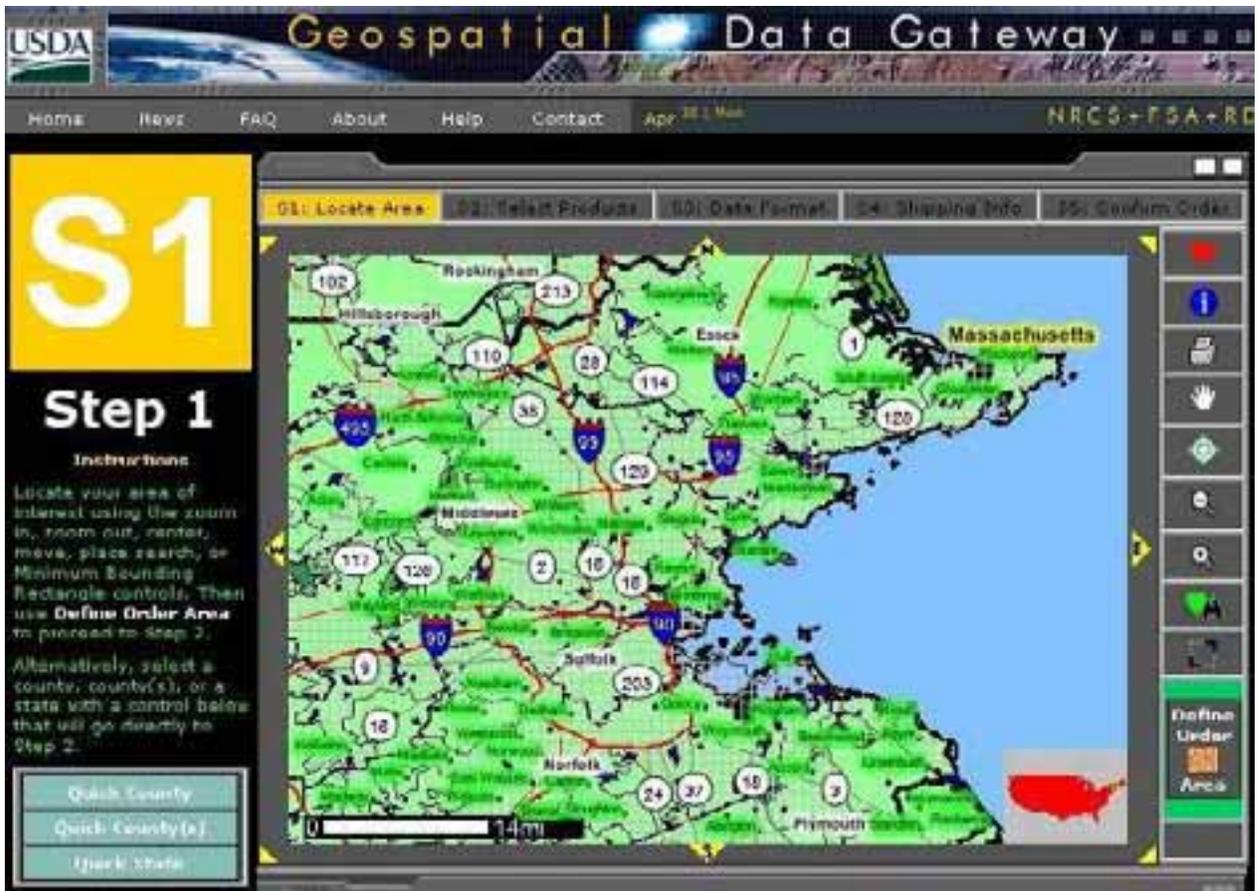


Figure 23: Selecting an area of interest narrows the search to all products in that geographic area.

The customer is then given the opportunity to view all products within the Area of Interest, and order or download them. Download times may be quite long.

### C. NAIP Distribution through APFO

After the CCMs have arrived at APFO and been inspected, they are sent to the State FSA offices on CDs or DVDs. The county mosaics are then made available to the Service Centers.

Other customers can order NAIP imagery through the APFO Customer Service Section. Customers can call, write, or email with a map or shapefile of the area of interest. The price list is added as an appendix, and will be available as a handout at the ESRI Users' Conference.

Bulk orders for CCMs can be made on a statewide basis at a cost of \$10 per gigabyte. The data is sent "as is," meaning that some of the mosaics may be interim products, and/or incomplete. There is no version management of bulk orders; newer versions would need to be downloaded from the Gateway. The

CCMs are sent to customers on hard drive disks. Partners for a given state will receive new versions of the imagery at no additional cost.

APFO is working on developing an online ordering system. At present, the office is using EarthWhere for internal processing of work orders. The website describes this product:

*EarthWhere, an advanced software product from SANZ, automates the management of geospatial imagery —elevation data, scanned maps, and satellite and aerial photography — allowing companies and government agencies to quickly ingest, catalog, explore and provision raster data.*

*The imagery can be rapidly ingested, either on a case-by-case basis or automatically as it becomes available. Automated cataloging then supplies a fast, in-depth view of available assets so that users are able to quickly explore, access and leverage their mission-critical information.*

*Provisioning provides the ability to merge, mosaic, color correct, reproject, clip, and otherwise enhance or output the data. EarthWhere also provides access to raster data for use in ESRI ArcGIS by means of a streamlined and intuitive interface.*

*Predefined business rules ensure that the operations performed on any dataset are appropriate and adhere to the customer-defined standards for a particular set of users or applications.*

The NAIP Online ordering system should be operational by fall 2007.



Figure 24: The NAIP Online website will allow the user to select from several years of imagery.

The system will allow the user to look at an overall map to determine availability for a given state in each year, identify an area of interest, read a list of available imagery for that area, select an image, and preview it. As with any online website, it will be added to the cart, and purchased.

NAIP Online will offer DOQQs and CCMs, and initially the imagery will be sent out on CDs or DVDs. The options to enhance the data or change the output size or format will be implemented later, and may involve an additional charge.

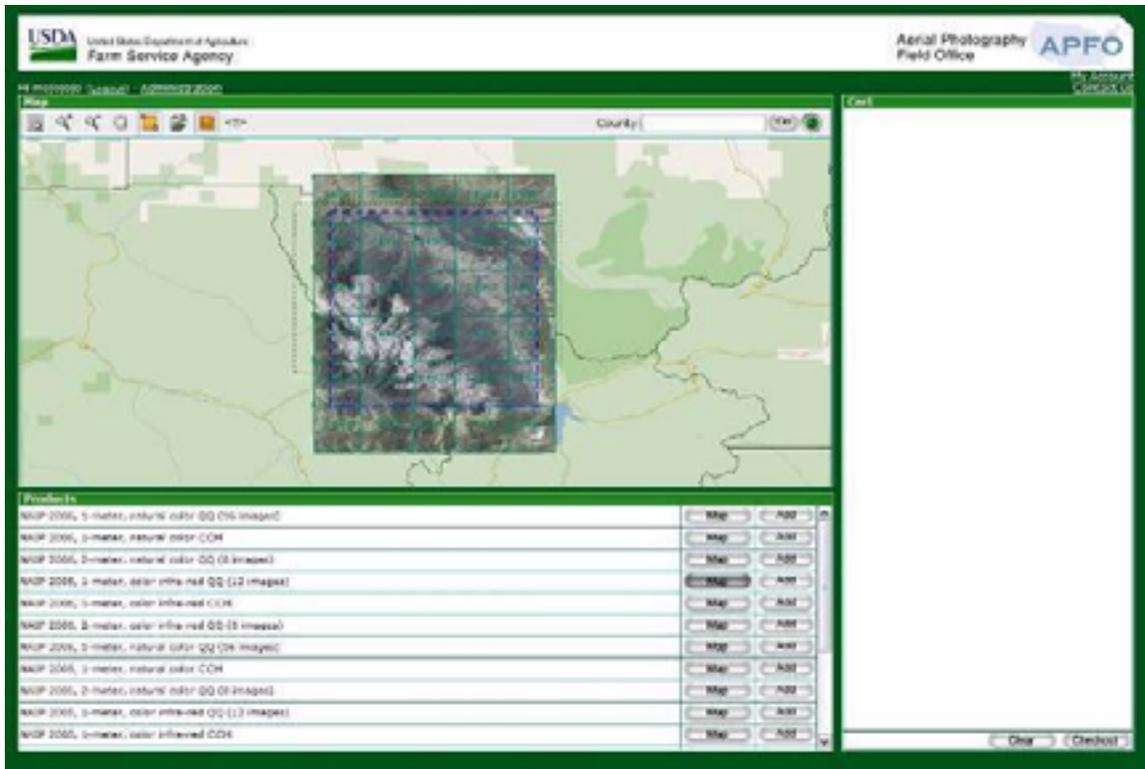


Figure 26: The user is shown all imagery falling within the area of interest, and can choose to preview the images before purchase.

#### D: Imagery for the Nation

The National States Geographic Information Council (NSGIC) hopes to incorporate NAIP into the proposed Imagery for the Nation. This would include digital orthoimagery from different sources and at different resolutions. NAIP would be unique because it is flown with leaf on.

More information on Imagery for the Nation is in the brochure: [http://www.nsgic.org/hottopics/iftn/briefing\\_document.pdf](http://www.nsgic.org/hottopics/iftn/briefing_document.pdf), or [www.nsgic.org](http://www.nsgic.org). If this proposal becomes a reality, NAIP will fill a vital role in providing a comprehensive imagery source.

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John Mootz  
Ronald Nicholls  
David Parry  
Dann Petersen  
Clifford Ruben  
Cindy Sessions  
Brenda Simpson  
Michael Sullivan  
Brian Vanderbilt  
Kent Williams

## Appendix 1: NAIP Contact Information

USDA - Farm Service Agency - Aerial Photography Field Office  
2222 West 2300 South  
Salt Lake City UT 84119-2020  
[www.apfo.usda.gov](http://www.apfo.usda.gov)  
Telephone: 801-975-3500

Viewing data online:

IMS Server for GIS - <http://gdw.apfo.usda.gov>

Web browser - <http://gdw.apfo.usda.gov/naip/viewer>  
<http://gdw.apfo.usda.gov/mdoq/viewer>

Download data from the Geospatial Data Gateway  
<http://datagateway.nrcs.usda.gov/>

Purchase data from the USDA Aerial Photography Field Office  
Email: [apfo.sales@slc.usda.gov](mailto:apfo.sales@slc.usda.gov)  
Telephone: 801-975-3503  
Fax: 801-975-3532

NAIP Program Coordinator: Kent Williams  
[kent.williams@slc.usda.gov](mailto:kent.williams@slc.usda.gov); Telephone: 801-975-3500 x261

NAIP Contract Questions: John Mootz  
[john.mootz@slc.usda.gov](mailto:john.mootz@slc.usda.gov); Telephone: 801-975-3500 x284

NAIP Partnership Information: Cindy Sessions  
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CCM Delivery Questions: Bridget Barlow  
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## Appendix 2: NAIP Pricing and Order Information

### Digital Products (Hardcopy)

A hard copy (or "hardcopy") is a printed copy of information from a computer. Sometimes referred to as a *printout*, a hard copy is so-called because it exists as a physical object. The same information, viewed on a computer display or sent as an e-mail attachment, is sometimes referred to as a [soft copy](#).

All digital aerial photographs are made from true digitally captured images or scanned from Color Positive (CP) or Color Infrared Positive (CIRP) film that include NAIP, NAPP, NHAP, and some Forest Service projects.

Full Frame = Entire Frame  
 Sectional = ¼ of Full Frame

### Enlargements produced from FILM SCANS:

SIZE	DIAMETER	SCALE	SCALE	PRICE
	Enlargement Factor	1:40,000	1:60,000	
20x20 Full Frame	2.0X	1667'/"	2500'/"	\$32.00
20x20 Sectional	4.0X	834'/"	1250'/"	\$32.00
24x24 Full Frame	2.5X	1320'/"	2000'/"	\$40.00
24x24 Sectional	5.0X	660'/"	1000'/"	\$40.00
30x30 Full Frame	3.0X	1100'/"	1667'/"	\$50.00
30x30 Sectional	6.0X	550'/"	834'/"	\$50.00

**Enlargements produced from NAIP QUARTER QUADS (QQ's):** Quarter Quad (odd size) color/color infrared digital paper enlargements are determined by the nearest established size as follows (i.e., actual size 16x20 is charged as 20x20).

ACTUAL SIZE (PRICE SIZE)	DIAMETER	SCALE	SCALE	PRICE
	Enlargement Factor	1m QQ	2m QQ	
16x20 Sectional (20x20)	4.0X	834'/"	834'/"	\$32.00
20x24 Full Frame (20x24)	3.0X	1100'/"	1100'/"	\$32.00
20x24 Sectional (20x24)	5.0X	660'/"	660'/"	\$32.00
26x30 Full Frame (30x30)	4.0X	834'/"	834'/"	\$50.00
25x30 Sectional (30x30)	6.6X	500'/"	N/A	\$50.00
30x36 Sectional (30x40)	8.0X	417'/"	N/A	\$60.00

Allow approximately 4-8 weeks for processing and up to 10 days for shipping.

## Digital Products (Softcopy)

A soft copy (sometimes spelled "softcopy") is an electronic copy of some type of data, such as a file viewed on a computer's display or transmitted as an e-mail attachment. Such material, when printed, is referred to as a [hard copy](#).

Please review the [National Agriculture Imagery Program \(NAIP\)](#) webpage and [NAIP Data Sheet](#) for a detailed description of the digital imagery program.

You may now obtain NAIP Compressed County Mosaics (CCM) as free downloads from the [USDA Geospatial Data Gateway](#). If you are unable to download from the USDA Geospatial Data Gateway, you may purchase the NAIP CCMs from the Aerial Photography Field Office.

There are no additional charges for media (CD/DVD). The current digital prices are as follows:

- NAIP Compressed County Mosaic (CCM) - \$50 per county image. Some counties may require more than one image.
  
- NAIP Quarter Quad (QQ) geotiff image
  - 1m Color/CIR (1-499) \$15 each or (500 and over) \$7.50 each
  - 2m Color/CIR (1-499) \$10 each or (500 and over) \$5.00 each.

Scanned images are made from original film whenever possible and provided in a standard tiff format (not georeferenced). Color or Color Infrared images are \$15 each. Black and White images are \$10 each. Quantity discounts are not available. Our standard scan is 1016dpi (25 microns) and the maximum is 2136dpi (12.5 microns). A 1m resolution can be provided from 1:40,000 scale film at 25 microns. Use our [Imagery Catalogs](#) with the [Ground Sample Distance \(GSD\)](#) and [Images per Media Type](#) documents for resolution desired.

Allow approximately 7-14 days for processing CCM's & QQ's, 6-8 weeks for scanned images, and 10 days for shipping.

**Please note:** The 'INTERIM' compressed county mosaic (CCM) product has been created to provide timely information for the Farm Service Agency's compliance program. FSA is distributing the interim product ONLY with the understanding the images have not yet undergone FSA's comprehensive quality assurance inspection process, which may require corrections and possible replacement of the imagery. Buyer should be aware, that the purchased interim CCM may be incomplete, may contain defects, and may have horizontal accuracy less than the specified tolerances. The 'FINAL' CCM product may be purchased upon completion of the inspection process.

To view additional information with sample imagery, [click here](#). It does require either the MSPowerPoint software or a viewer. [Click here](#) to open Microsoft's site to access their free viewer download.

## Sources

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