ACCURACY ASSESSMENT OF AUTOMATED AERIAL TRIANGULATION FOR THE ORTHORECTIFICATION OF AERIAL IMAGERY

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ABSTRACT

To make aerial imagery products more useful and timely the USDA Forest Service's Forest Health Technology Enterprise Team (FHTET) has recently integrated an Applanix Airborne POS system into its image acquisition procedures. This automated aerial triangulation system (without ground control) eliminates the time and expense of collecting ground control points for every image and results in rapid project turnaround. To assess the performance of the Applanix system 15 random images were selected from images taken during recent missions over Mississippi and Texas in response to hurricane forest damage. From each of the images 10 random points are compared to the equivalent location on USDA Forest Service orthophotoquads and National Agriculture Imagery Program (NAIP) orthoimagery. A statistical comparison was made to test how closely images processed through automated aerial triangulation match traditional USDA Forest Service digital orthophotoquads and NAIP imagery.

INTRODUCTION

Forest Health Technology Enterprise Team

The Forest Health Technology Enterprise Team (FHTET) develops technology for forest health related concerns across the United States. In support of small projects with a rapid turn-around FHTET operates a Beechcraft King Air A100 equipped with a 20 inch optical window. Mounted above the optical window FHTET employs either a Zeiss RMK mapping film camera or a Kodak DCS-420 digital camera.

Automated Aerial Triangulation

In an effort to improve image orthorectification procedures FHTET has recently integrated an Applanix Position and Orientation System (POS) with the onboard camera equipment. This system provides the data needed to perform automated aerial triangulation (AAT), in which high-speed positioning, inertial motion, and 3-axis orientation are combined to determine a very precise location of each image at the moment of exposure. This information is used to generate the exterior orientation (EO) parameters of the image. The EO parameters are used in conjunction with a Digital Elevation Model (DEM) and the camera's calibration parameters to evaluate the image's interior orientation and automatically generate image tie-points used for the triangulation of blocks of images.

Prior to the use of this system, "geo-located" imagery was created using resource-grade Global Positioning System (GPS) connected to the camera. As data from the GPS was outputted at 1Hz, the camera data buffer would output the location data with each image header. Due to latency in the camera buffer and motion of the aircraft this system resulted in poor geo-positioning (Figure 1a), with positioning errors ranging up to 200 meters. Subsequent "geo-corrections" (Figure 1b) were of limited utility.

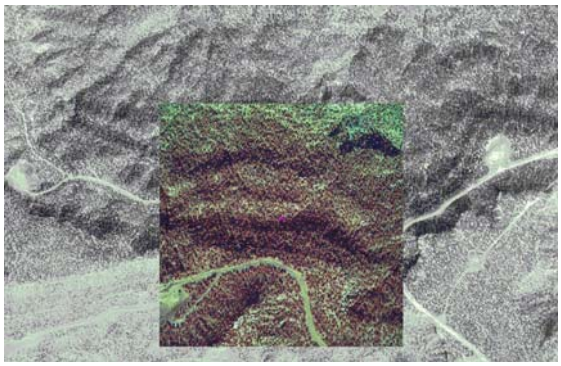


Figure 1a. "Geo-located" image

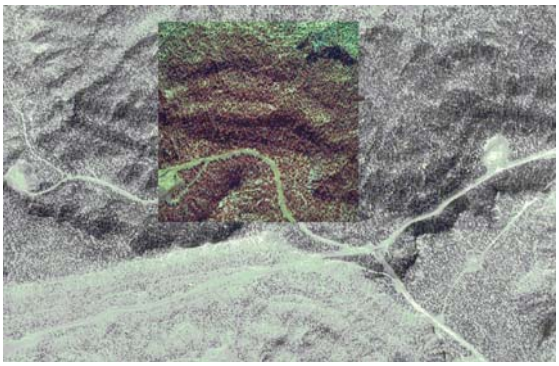


Figure 1b. "Geo-corrected" image

With the high speed GPS (50Hz) and Inertial Measurement Unit (IMU), the Applanix POS system has the potential to produce mapping grade imagery. Automated aerial triangulation also greatly increases project turn-around by eliminating the need to manually collect ground control points in the orthorectification process. As a result, project turn-around has been reduced from several weeks to just a few days allowing the tasking agency to tend more rapidly to pressing forest health issues.

Katrina and Rita Missions

The hurricane season of 2005 took a heavy toll on the Gulf Coast region of the United States. In response to forest damage resulting from hurricanes Katrina and Rita, the FHTET aerial photo program collected 3735 images over National Forest areas in Mississippi (Bienville N.F., Chickasaway N.F., and South DeSoto N.F.) and Texas (Angelina N.F., Sabine N.F., Davy Crockett N.F. and Sam Houston N.F.).

Figure 2. Hurricane Katrina forest damage

These projects were the first major test of FHTET's newly implemented automated aerial triangulation system. To assess image accuracy in this rapid response scenario the FHTET generated orthophotos were compared to traditional U.S. Forest Service (USFS) orthophoto quads and National Agricultural Imagery Program (NAIP) imagery. Since most forest health issues deal with individual tree damage or mortality, an assessment of high resolution imagery needs to be concerned with comparing locational information of individual trees. By comparing the standard high resolution imagery products, this assessment determines the potential of matching individual trees through temporal changes–testing FHTET's ability to achieve reasonable accuracies of comparable tree locations.

METHODS

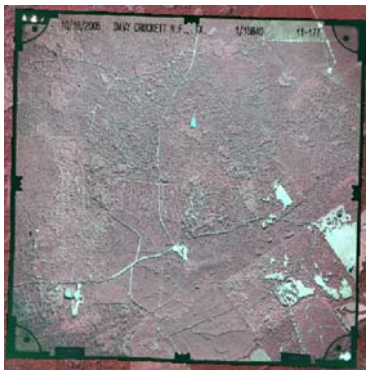
Processing of Applanix Data

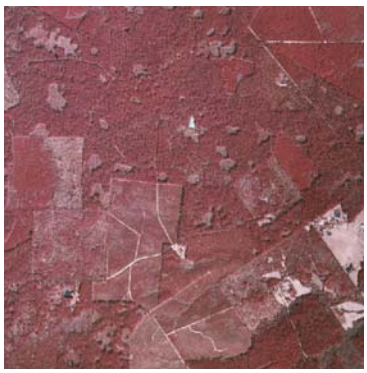
The Applanix data from each mission was processed using Applanix's Position and Orientation System (POS) software which performs differential GPS correction to the airborne GPS data and integrates the IMU data to create the Exterior Orientation (EO) parameters for the imagery. The resulting EO files are used in the Leica Geosystems Leica Photogrammetery Suite software in conjunction with 1/3 Arc Second National Elevation Dataset (NED) DEMs to orthorectify the images.

Acquisition of imagery

The orthoimagery created by FHTET was compared to two existing image datasets: 1-meter ground resolution USFS orthophoto quads; and 1-meter ground resolution USDA NAIP orthoimagery. The Forest Service imagery

was supplied by the USFS Geospatial Service & Technology Center in Salt Lake City. The NAIP imagery was acquired via the USDA GeoSpatial Data Gateway.





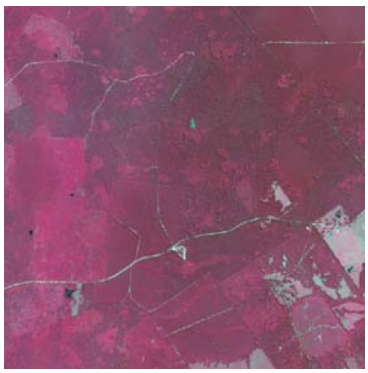


Figure 3a. FHTET orthophoto **Figure 3b.** USFS orthophoto **Figure 3c.** NAIP orthoimagery

Random Selection of FHTET Images

The FHTET orthoimages used in this study were selected randomly using a random point sampling routine developed by the FHTET office (Thomas 2006). Two random images were selected for each National Forest areas—three forest areas located in Mississippi, and four located in Texas. Thus a total of 14 images were randomly selected for the study. A fifteenth image (for the Bienville N.F. in Mississippi) was selected later in the study to compare the effects of GPS baseline distances.

Generation of Random Points

Ten random points were selected from each image using the same random point generating application used to select the images. These points were used to compare the proximity of the three different image types in this study.

Locating Matching Points on Each Image

In many instances it was impossible to locate the matching point on all three images. This was largely due to temporal differences resulting in changes in landcover and illumination. The FHTET imagery was taken during September-October of 2005; most of the USFS orthophotos date to 1996; and the NAIP imagery are dated to 2004. The shading, due to differing viewing, angles also makes it difficult to match points. To resolve this issue it was necessary to search for matching points within a 250 meter radius of the original random point. In most cases this resolved the issue of matching image points. Typical matching point features included the corner of homes or structures, obvious trees or shrubs, and road intersections. In some cases, due to complete landcover change, it was necessary to rely on the relative position of the point, for example in the curve in a road or stream.

Distance Measurements

For each of the 150 random points measured, three distances were evaluated: the distance from FHTET to USFS; the distance from FHTET to NAIP; and the distance from USFS to NAIP. The distance measurements were calculated using an ArcView 3.x extension developed by Jeff Jenness (Jenness 2006).

RESULTS

Calculating the RMSE

For each of the fifteen images examined, the RMSE was calculated for the three different categories: distance from FHTET to USFS; distance from FHTET to NAIP; and distance from USFS to NAIP. Figures 4a and 4b display the RMSE for the hurricane Katrina imagery.

	FHTET to USFS			FHTET to NAIP			USFS to NAIP		
FHTET Image	Mean	Std. Dev.	RMSE	Mean	Std. Dev.	RMSE	Mean	Std. Dev.	RMSE
Bienville 05-059	4.42	3.41	**5.47**	4.24	3.46	**5.37**	3.66	1.86	**4.00**
Bienville 06-026	3.48	2.53	**4.22**	3.69	2.27	**4.27**	3.17	1.91	**3.64**
Bienville 07-271	3.13	1.61	**3.48**	1.83	0.79	**1.97**	2.99	1.33	**3.24**
N. Desoto 07-070	3.37	1.68	**3.73**	4.10	0.97	**4.20**	3.08	1.14	**3.25**
N. Desoto 11-132	4.98	1.13	**5.10**	6.85	1.76	**7.05**	3.72	1.93	**3.95**
S. Desoto 19-118	3.25	1.38	**3.50**	5.27	2.06	**5.62**	3.33	1.37	**3.57**
S. Desoto 9a-019	3.57	0.86	**3.66**	3.61	1.53	**3.89**	3.21	1.55	**3.51**
Average RMSE			**4.17**			**4.63**			**3.60**

Figure 4a. Katrina imagery RMSE table

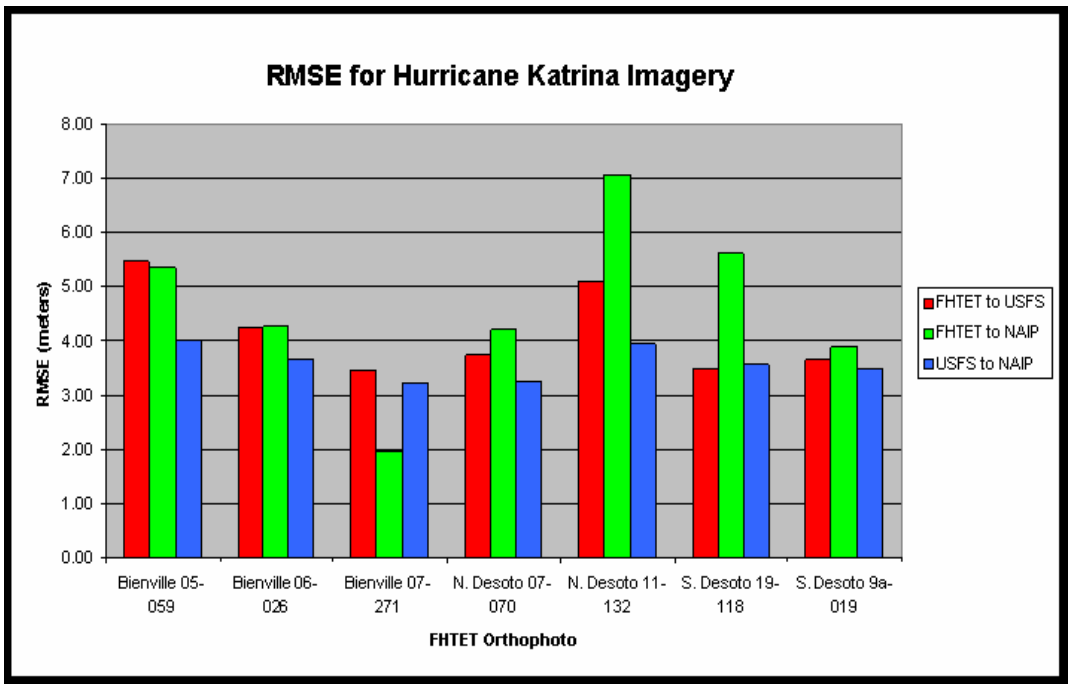


Figure 4b. Katrina imagery RMSE graph

Figures 5a and 5b below display the RMSE for the hurricane Rita images.

	FHTET to USFS			FHTET to NAIP			USFS to NAIP		
FHTET Image	Mean	Std. Dev.	RMSE	Mean	Std. Dev.	RMSE	Mean	Std. Dev.	RMSE
Angelina 04-067	4.06	3.16	**5.04**	4.49	2.82	**5.22**	3.98	2.79	**4.75**
Angelina 11-368	7.75	2.52	**8.11**	5.48	3.03	**6.19**	4.09	2.17	**4.36**
Sabine 09-158	6.41	2.50	**6.83**	3.82	1.81	**4.19**	3.61	1.32	**3.80**
Sabine 09-168	6.93	2.18	**7.23**	3.97	2.47	**4.61**	4.85	2.37	**5.29**
Crockett 09-074	2.99	2.26	**3.68**	4.10	3.14	**5.07**	2.82	2.39	**3.39**
Crockett 11-177	4.06	1.72	**4.37**	4.08	1.79	**4.42**	3.53	2.28	**4.10**
Houston 19-181	3.61	2.62	**4.38**	3.98	1.51	**4.23**	5.22	2.31	**5.49**
Houston 24-364	3.37	1.41	**3.63**	4.13	2.18	**4.62**	3.82	2.95	**4.72**
Average RMSE			**5.41**			**4.82**			**4.49**

Figure 5a. Rita imagery RMSE table

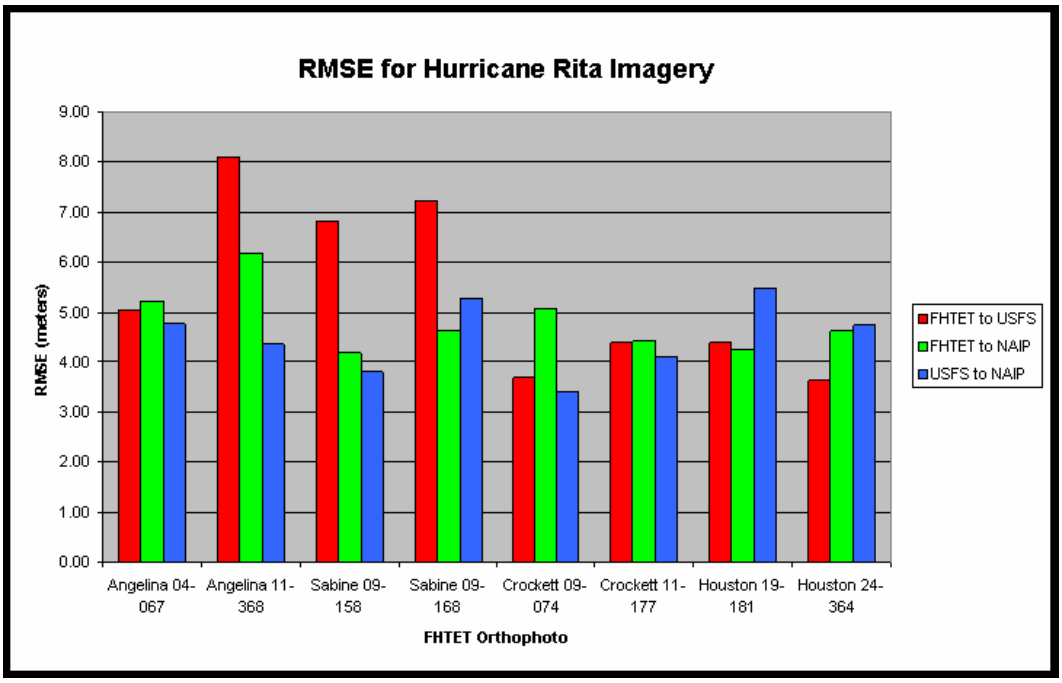


Figure 5b. Rita imagery RMSE graph

Differential GPS Baseline Distances

The CORS (Continuously Operating Reference Stations) GPS base stations do not have extensive coverage within the state of Mississippi. There are only five stations within the state's boundary, primarily on the periphery. The location of the Katrina forest damage flights occurred within the center of a DGPS black hole, with the closest available CORS station to the Bienville NF located 200 kms away in Alabama (CORS station MLF1 pictured in Figure 6 below). For this reason a remote GPS base station was set up at the mission airport in Meridian, MS, narrowing the baseline distance for the Bienville N.F. to 80-95 kilometers.

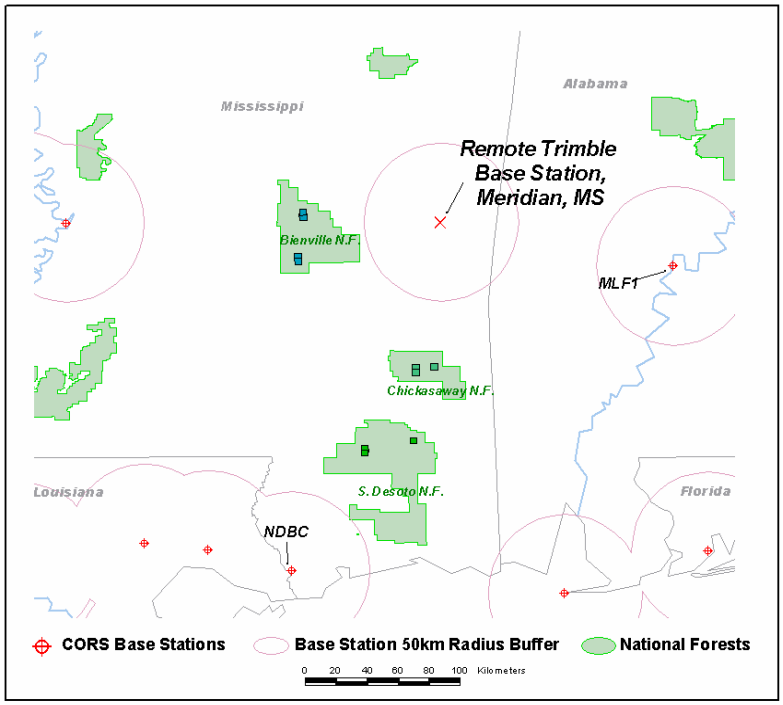


Figure 6. CORS base stations and FHTET remote base station used for hurricane Katrina DGPS

To test the impact of the GPS baseline distance on the orthorectification of the FHTET imagery an additional image was tested for the Bienville NF (Bienville 07-271). With the remote GPS base station, the baseline distance for this additional image is approximately 80 kilometers (50 miles).

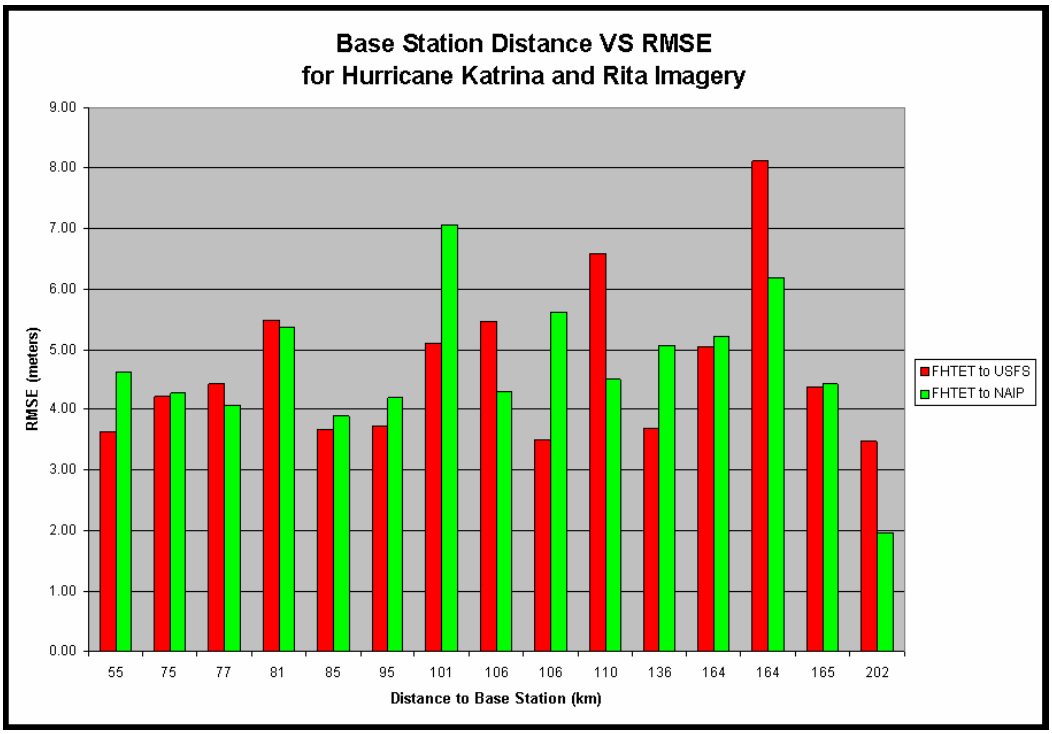


Figure 7. Relationship of base station distance to RMSE for the hurricane Katrina and Rita imagery.

DISCUSSION

There is not any evidence that distance to base station had a significant impact on the accuracy of the imagery. A linear regression analysis revealed an R-Square value of 0.00415 (Significance F = 0.735, 95% confidence interval) for the relationship of base station distance to FHTET-USFS RMS; and a value of 0.00339 (Significance F = 0.759, 95% confidence interval) for the relationship of base station distance to FHTET-NAIP RMS. It is possible that the remote base station did not achieve optimal positioning due to time constraints. It was set up approximately 45 minutes prior to the flight and ran for an additional 2-3 hours. Also to gain the most benefit from this remote base station it would be necessary to set it up at the site of the image acquisition. However this is not practical given the distance from the servicing airport to the project area, and time constraints.

The quality of the DEM has proved to be vital to accurate orthorectification. After initial point generation it was apparent that there was a significant RMS error (>45 meter) between the FHTET orthophotos and USFS/NAIP imagery for two of the Mississippi National Forest areas. This was perplexing since all of the other areas under investigation were showing initial RMS errors in the range of 4-5 meters. After investigating possible processing errors it was determined that the DEM was the source of error. For these two images a 1 Arc Second DEM had been used, downloaded from the USGS's Seamless Data website. After changing the DEM to a 1/3 Arc Second DEM and performing a new orthorectification, the RMSE for these two areas came in line with all of the other points tested in this study.

CONCLUSION

Through the use of automated aerial triangulation FHTET is capable of achieving orthorectification accuracies that meet the USGS National Map Accuracy Standards (NMAS) which state that "90 percent of well-defined points tested must fall within 40 feet [12.2 meters, or 1/50 inch] at 1:24000 scale." (USGS 1996) All of the points tested in this study fall within this range, with an average RMSE of 4.76 meters. To adhere to the more stringent NMAS standards for publishable maps, with an approximate mapping scale of 1:15840, 90 percent of the tested points must fall within 8.05 meters. Considering all points tested (FHTET to USFS and FHTET to NAIP), 93 percent of the 150 points tested were below the 8.05 meter benchmark. As the NMAS standards apply primarily toward mapping applications, it is essential to note the importance of "well-defined" test points. Unlike urban areas, heavily forested areas will yield few well-defined test points, thus making it more difficult to test map accuracy. In this accuracy assessment the test points were frequently very difficult to locate. Yet despite this problem, accuracy levels still fall well within an acceptable NMAS range both for digital and publishable standards.

Of the three image types tested, which one is correct? A much more thorough investigation that involves measuring identifiable ground control plots would have to be done to assess "absolute" accuracy (is there such a thing?). But from the perspective of tree location, the USFS, NAIP and FHTET imagery are all comparable.

REFERENCES

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