Survey Handbook - Aerial Photogrammetry Section

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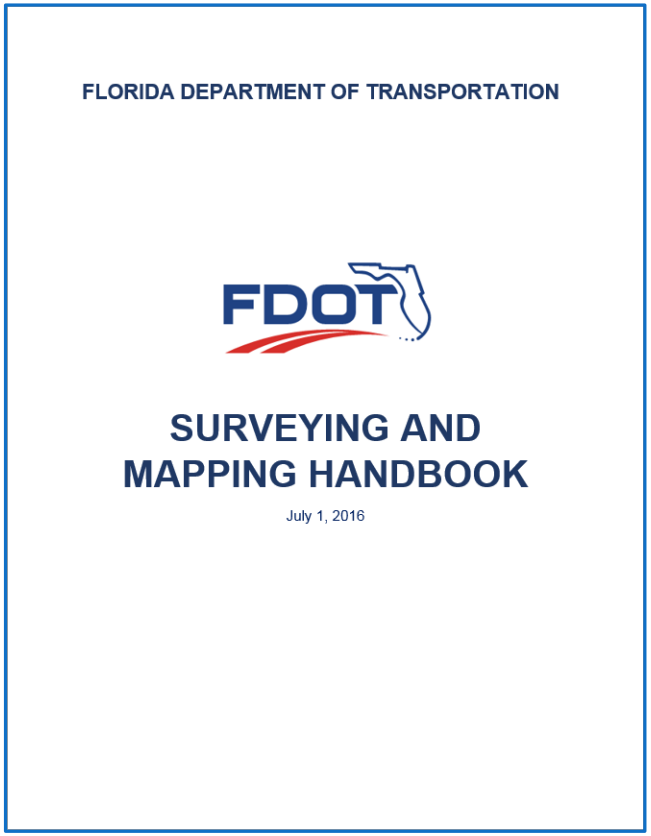
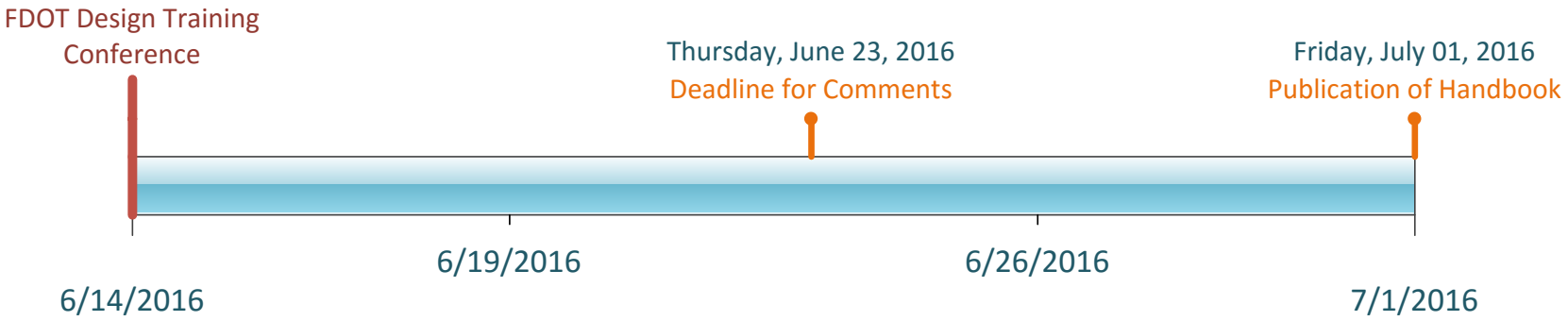
Agenda

- Publication Timeline
- Review
- Common Questions
- Questions and Discussion

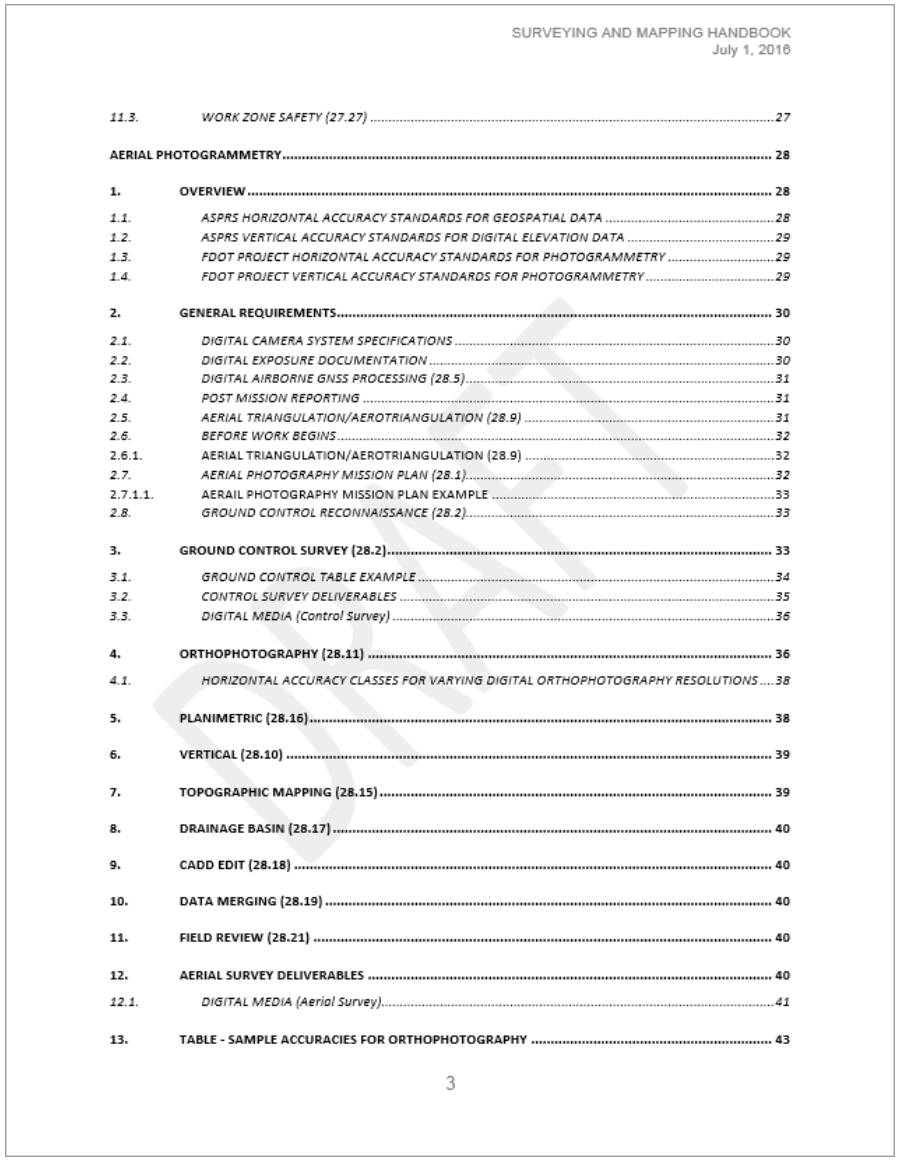


Publication Timeline



Review

- Equipment
- Accuracies
- Photo Resolution
- Orthophotography
- Before Survey Begins
- Mission Planning
- Deliverables



Equipment

- Accepting imagery from digital sensors only
- No longer requiring USGS certifications for digital and film based cameras

USGS Optical Science Lab

The USGS Optical Science Laboratory (OSL) is closing April 1, 2017. The Lab will accept camera calibration requests through 3:00 pm, December 30, 2016. Any request after that shall not be considered. Please see closure announcement here.

- Accepting factory specifications and calibrations
- Boresight Calibrations annually
- Camera calibrations

Accuracies

- * ASPRS Positional Accuracy for Digital Geospatial Data
  - Based on the Ground Sample Distance (GSD) of the final digital orthophotography as a basis for imagery specifications.
  - Three main categories


ASPRS Positional Accuracy Standards for Digital Geospatial Data
(EDITION 1, VERSION 1.0. – NOVEMBER, 2014)

- FDOT Project Horizontal Accuracy Standards for Photogrammetry

Horizontal Accuracy Class	Project Horizontal Accuracy			Orthoimagery Mosaic Seamline Mismatch (ft)
	RMSEx and RMSEy (ft)	RMSEr (ft)	Horizontal Accuracy at 95% Confidence Level (ft)	
X-feet	≤ *X*	≤ 1.414**X*	≤ 2.448**X*	≤ 2**X*

- FDOT Project Vertical Accuracy Standards for Photogrammetry

Vertical Accuracy Class	Project Vertical Accuracy	
	RMSEz Non-Vegetated (ft)	Vertical Accuracy at 95% Confidence Level (ft)
Z-feet	≤ ***Z***	≤ 1.96**Z*

* American Society for Photogrammetry and Remote Sensing. (2014, November). ASPRS Positional Accuracy Standards for Digital Geospatial Data. Photogrammetric Engineering & Remote Sensing, Vol. 81, No. 3, pp. A1–A26. Retrieved from http://www.asprs.org: http://www.asprs.org/PAD-Division/ASPRS-POSITIONAL-ACCURACY-STANDARDS-FOR-DIGITAL-GEOSPATIAL-DATA.html

Accuracies - NSSDA

- Minimum 25 Check Points
- Cross Sections

TABLE D.l NSSDA ACCURACY STATISTICS FOR EXAMPLE DATA SET WITH 3D COORDINATES (American Society for Photogrammetry and Remote Sensing, 2014)

Point ID	Map-derived values			Survey Check Point Values			Residuals (Errors)		
	Easting (E)	Northing (N)	Elevation (H)	Easting (E)	Northing (N)	Elevation (H)	6x Easting (E)	6y Northing (N)	6z Elevation (H)
	meters	meters	meters	meters	meters	meters	meters	meters	meters
GCP1	359584.394	5142449.934	477.127	359584.534	5142450.004	477.198	–0.140	–0.070	–0.071
GCP2	359872.190	5147939.180	412.406	359872.290	5147939.280	412.396	–0.100	–0.100	0.010
GCP3	395893.089	5136979.824	487.292	359893.072	5136979.894	487.190	0.017	–0.070	0.102
GCP4	359927.194	5151084.129	393.591	359927.264	5151083.979	393.691	–0.070	0.150	–0.100
GCP5	372737.074	5151675.999	451.305	372736.944	5151675.879	451.218	0.130	0.120	0.087
Number of check points							**5**	**5**	**5**
Mean Error (m)							**–0.033**	**0.006**	**0.006**
Standard Deviation (m)							**0.108**	**0.119**	**0.006**
RMSE (m)							**0.102**	**0.106**	**0.081**
RMSEr (m)							**0.147**	**=SQRT($RMSE_x^2$ + $RMSE_y^2$)**	
NSSDA Horizontal Accuracy$_r$ (ACCr) at 95% Confidence Level							**0.255**	**=RMSEr × 1.7308**	
NSSDA Vertical Accuracy$_z$ (ACCz) at 95% Confidence Level							**0.160**	**=RMSEz × 1.9600**	

Accuracies - Orthophoto/Planimetric

- Aerotriangulation (AT)
  - Section 7.7 of the "Accuracy Requirements for Aerial Triangulation and INS-based Sensor Orientation of Digital Imagery" (American Society for Photogrammetry and Remote Sensing, 2014).
  - "Accuracy of aerial triangulation designed for digital planimetric data (**orthoimagery and/or digital planimetric map**) **only:**

    RMSEx (AT) or RMSEy (AT) = ½ * RMSEx (Map) or RMSEy (Map)
    RMSEz (AT) = RMSEx (Map) or RMSEy (Map) of orthoimagery

    Note: The exact contribution of aerial triangulation errors in z to the overall horizontal error budget for the products depends on ground point location in the image and other factors. The relationship stated here for an RMSEz (AT) of twice the allowable RMSE in x or y is a conservative estimate that accommodates the typical range of common camera geometries and provides allowance for many other factors that impact the horizontal error budget.
- Ground Control
  - Accuracy of ground control designed for planimetric data (orthoimagery and/or digital planimetric map) production **only:**

    RMSEx or RMSEy = 1/4 * RMSEx (Map) or RMSEy (Map),
    RMSEz = 1/2 * RMSEx (Map) or RMSEy (Map)

Accuracies -Vertical

- Aerotriangulation
  - Section 7.7 of the "Accuracy Requirements for Aerial Triangulation and INS-based Sensor Orientation of Digital Imagery" (American Society for Photogrammetry and Remote Sensing, 2014).
  - "Accuracy of aerial triangulation designed for digital planimetric data (orthoimagery and/or digital planimetric map) and **elevation data** production**:**
  - For elevation data derived using stereo photogrammetry, the horizontal accuracy equates to the horizontal accuracy class that would apply to planimetric data or digital orthoimagery produced from the same source imagery, using the same aerial triangulation/INS solution.

RMSEx (AT), RMSEy (AT) or RMSEz (AT) = ½ * RMSEx (Map), RMSEy (Map) or RMSEz (DEM)

- Ground Control
  - Accuracy of ground control designed for elevation data, or planimetric data and elevation data production:

RMSEx, RMSEy or RMSEz= 1/4 * RMSEx (Map), RMSEy (Map) or RMSEz (DEM)

Accuracies – Note on Vertical

- Vertical Accuracy Standards for Elevation Data
  - Vertical accuracy is computed using RMSE statistics in non-vegetated terrain and 95th percentile statistics in vegetated terrain.
  - The Non-vegetated Vertical Accuracy at the 95% confidence level in non-vegetated terrain (NVA) is approximated by multiplying the accuracy value of the Vertical Accuracy Class (or RMSEz) by 1.9600.
  - The NVA, based on an RMSEz multiplier, should be used only in non-vegetated terrain where elevation errors typically follow a normal error distribution.

- Both the RMSEz and 95th percentile methodologies are currently widely accepted in standard practice and have been proven to work well for typical elevation data sets derived from current technologies.
  - The Vegetated Vertical Accuracy at the 95% confidence level in vegetated terrain (VVA) is computed as the 95th percentile of the absolute value of vertical errors in all vegetated land cover categories combined, including tall weeds and crops, brush lands, and fully forested areas.
  - For all vertical accuracy classes, the VVA standard is 3.0 times the accuracy value of the Vertical Accuracy Class.

Photo Resolution

- Ground sample distance (GSD) is the ground distance represented by a single pixel on the image.
  - The raw camera GSD or "source" GSD is governed by the camera focal length, the flying height, and the size of a pixel in the camera.

$$\frac{f}{H} = \frac{Ps}{GSD}$$

f = Focal Length
H = Height above ground,
Ps = Camera Pixel Size
GSD = Ground Sample Distance

In **digital imaging**, sensor native pixel size (P_S) is fixed. Specified GSD is achieved only by varying the imaging altitude. Image scale is simply:

Image Scale = P_S/GSD

Since Image Scale = f/H also, therefore f/H = P_S/GSD. Imaging altitude (H) can be derived from:

H = GSD x f/P_S

In the Z(I DMC f = 120mm and P_S = 12µ, to achieve a 20cm GSD:

H = 20cm x 120mm/12µ = 2000m

Imagery Source	f	P_S	f/P_S
Film			
Scanned @ 10µ	152mm	10.0µ	15,200
Scanned @ 10µ	305mm	10.0µ	30,500
Digital			
JenOptik JAS-150	150mm	6.5µ	23,077
Leica ADS-40/52	63mm	6.5µ	9,692
Vexcel UC_D	100mm	9.0µ	11,111
Vexcel UC_X	100mm	7.2µ	13,889
Z(I DMC	120mm	12.0µ	10,000

N.B. A short-hand method in determining imaging altitude is to multiply the required GSD by the fixed f/P_S factor in each imaging system.

http://www.mypurview.com/index.html

Photo Resolution

- Not directly related to accuracy
- Can affect accuracy
- Must always be ≥ Accuracy requirements
- Must be sufficient to identify features in scope

"Given current sensor and processing technologies for large and medium format metric cameras, an orthoimagery accuracy of 1-pixel RMSEx and RMSEy is considered achievable, assuming proper project design and best practices implementation." (American Society for Photogrammetry and Remote Sensing, 2014)

Horizontal accuracy classes for varying digital orthophotography resolutions

Orthoimage RMSEx and RMSEy in terms of Pixels	Maximum Orthoimage Mosaic Seamline Mismatch (2 x Pixel*)	Allowable Aerotriangulation (AT) or INS-based (Pixels)		Allowable Ground Control RMSE (pixels)		NSSDA Horizontal Accuracy at the 95% Confidence Level (2.4477 x Pixel*)
		RMSEx and RMSEy (0.5 x Pixel*)	RMSEz (1 x Pixel*)	Horizontal x and y (0.25 x Pixel*)	Vertical z (0.5 x Pixel*)	
1	2	0.5	1	0.25	0.5	2.448
2	4	1.0	2	0.50	1.0	4.895
3	6	1.5	3	0.75	1.5	7.343
4	8	2.0	4	1.00	2.0	9.791

Orthophotography

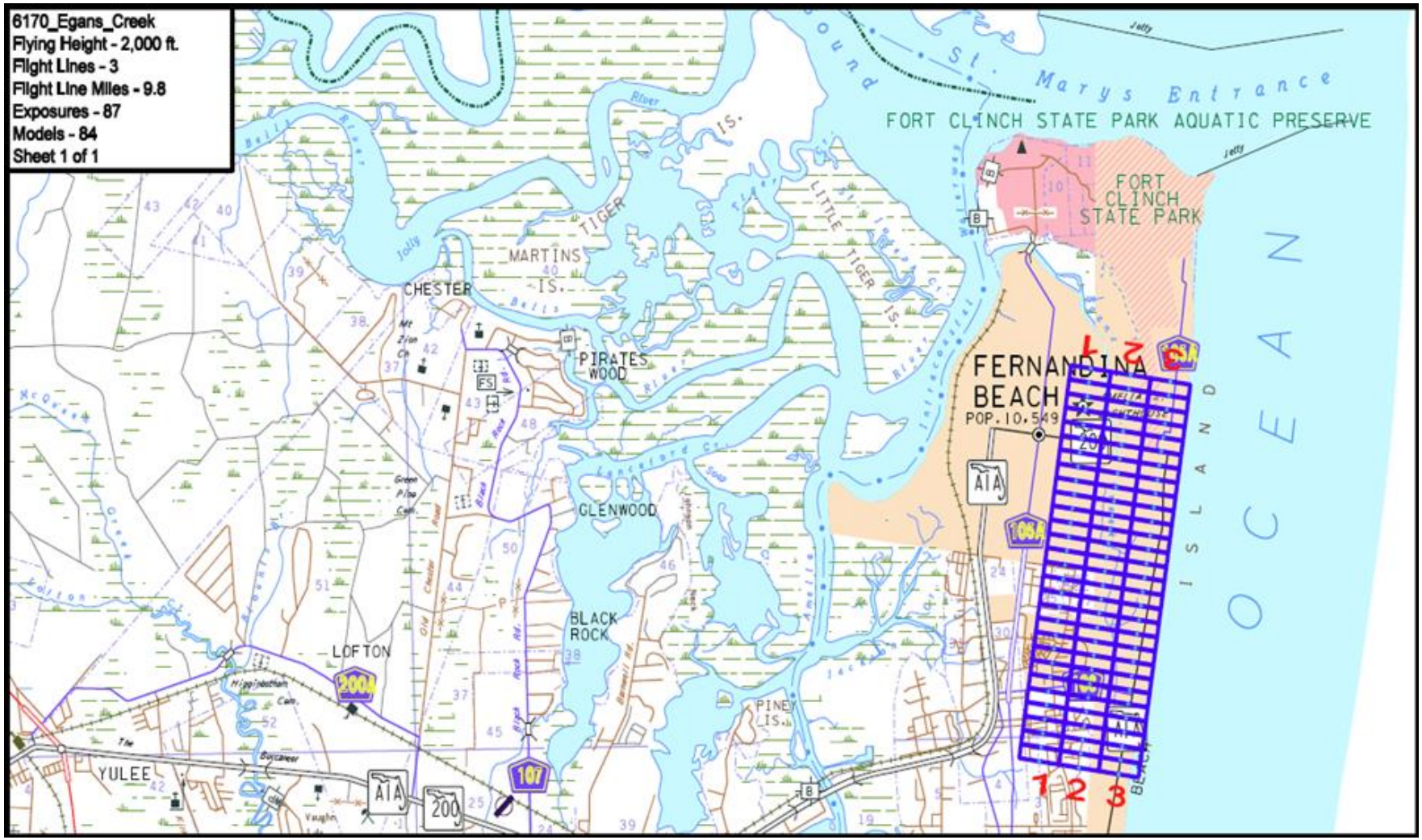
SAMPLE ACCURACIES FOR ORTHOPHOTOGRAPHY

Final Ortho Image Pixel Size (ft)	Horizontal Accuracy Class RMSEx and RMSEy (ft)	Ortho Image RMSEx and RMSEy in terms of pixels	Horizontal Accuracy RMSEr (ft)	Maximum Ortho Image Mosaic Seamline Mismatch (Pixels)	Maximum Ortho Image Mosaic Seamline Mismatch (ft)	Allowable AT or INS-based (ft)		Allowable Ground Control RMSE (ft)		NSSDA Horizontal Accuracy at the 95% Confidence Level (ft)
						RMSEx and RMSEy	RMSEz	Horizontal x and y	Vertical z	
0.05	0.05	≤1-pixel	0.071	2	0.10	0.025	0.05	0.013	0.025	0.12
	0.10	2-pixels	0.141	4	0.20	0.050	0.10	0.025	0.050	0.24
	0.15	3-pixels	0.212	6	0.30	0.075	0.15	0.038	0.075	0.37
	0.20	4-pixels	0.283	8	0.40	0.100	0.20	0.050	0.100	0.49
0.10	0.10	≤1-pixel	0.141	2	0.20	0.050	0.10	0.025	0.050	0.24
	0.20	2-pixels	0.283	4	0.40	0.100	0.20	0.050	0.100	0.49
	0.30	3-pixels	0.424	6	0.60	0.150	0.30	0.075	0.150	0.73
	0.40	4-pixels	0.566	8	0.80	0.200	0.40	0.100	0.200	0.98
0.50	0.5	≤1-pixel	0.707	2	1.0	0.250	0.50	0.125	0.250	1.22
	1.0	2-pixels	1.414	4	2.0	0.500	1.00	0.250	0.500	2.45
	1.5	3-pixels	2.121	6	3.0	0.750	1.50	0.375	0.750	3.67
	2.0	4-pixels	2.828	8	4.0	1.000	2.00	0.500	1.000	4.90
1.00	1.0	≤1-pixel	1.414	2	2.0	0.5	1.00	0.250	0.500	2.45
	2.0	2-pixels	2.828	4	4.0	1.0	2.00	0.500	1.000	4.90
	3.0	3-pixels	4.243	6	6.0	1.5	3.00	0.750	1.500	7.34
	4.0	4-pixels	5.657	8	8.0	2.0	4.00	1.000	2.000	9.79

Before Survey Begins

- Mobile Survey Tracking System (MSTS)
  - All correspondence and project deliverables
- QA/QC Plan
  - All survey projects must have a detailed QA/QC plan developed by the consultant and provided to the DSMO for approval before work begins. *See Section 10.3*
  - Basis for Review and Survey Report

Mission Planning



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Deliverables – Survey Report

- Project title, Financial Management Number, and MSTS number
- Name and address of corporation including certificate of authorization number
- Name and address of the surveyor in responsible charge
- Abbreviations; data sources; etc.
- Description and scope of work
- Describe equipment, software; specifications, calibration, etc.
- Statement cross referencing digital media as part of the report by referencing media drive label items. See Section 12.1 of the Aerial Photogrammetry portion of this handbook for information on digital media.
- A reference citing ground control survey accuracies. If ground control survey performed by others a reference to the control survey report as well as a certified copy of the report is needed.
- An index of files on digital media listed by filename, file location (path), and brief description. The imagery and metadata files need only be referenced by directory, and not individually.
- Describe the planning, collection, processing, adjustment, and quality control methodology used to produce aerial surveying and mapping product(s)
- Appropriate horizontal and/or vertical NSSDA accuracy reporting.
- List the field and office personnel who worked on project, and their responsibilities.
- Field date of aerial survey (Last imagery acquisition flight date).
- Map displaying the project location

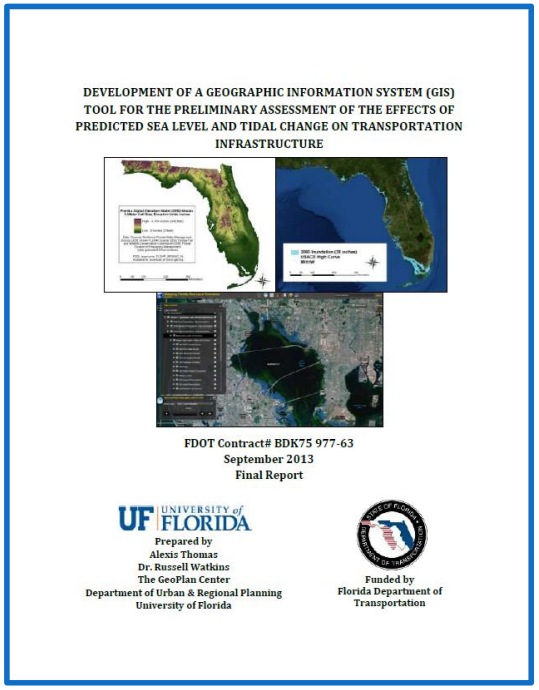
Deliverables – Digital Media

- Labeling
  - Statement cross referencing digital media as part of the survey report by including survey report title, Financial Management Number, MSTS number, and date of survey information from the survey report.
  - Digital media make, model, and serial number
  - Consultant name and contact information.

- Content
  - Final photogrammetric product(s); survey scope items, i.e., orthophotography, planimetric map, topographic map, surface, etc.
  - Digitally signed copy of the control survey report
  - All raw imagery
  - Sketches and digital pictures of base station sites identifying measured point location and identification of mark.
  - Copies of field notes or GNSS data logs/static occupations.
  - All airborne system (GNSS/INS) data observed including the raw observation data and processed sensor trajectory information including reports.

Common Questions

- Why the recent focus on photogrammetry standards?
  - Remote sensing
  - Department re-evaluating the handling of information including geospatial data.
  - Consistency and confidence


DEVELOPMENT OF A GEOGRAPHIC INFORMATION SYSTEM (GIS) TOOL FOR THE PRELIMINARY ASSESSMENT OF THE EFFECTS OF PREDICTED SEA LEVEL AND TIDAL CHANGE ON TRANSPORTATION INFRASTRUCTURE

FDOT Contract# BDK75 977-63
September 2013
Final Report

UF UNIVERSITY of FLORIDA

Prepared by
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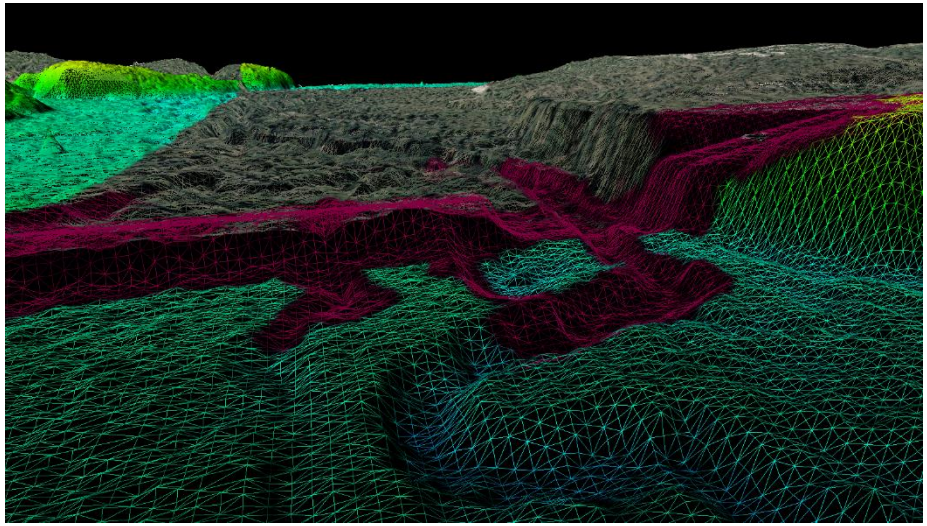
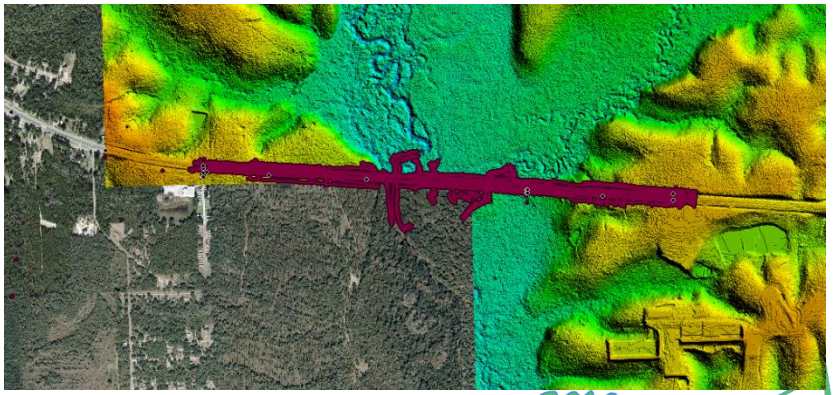
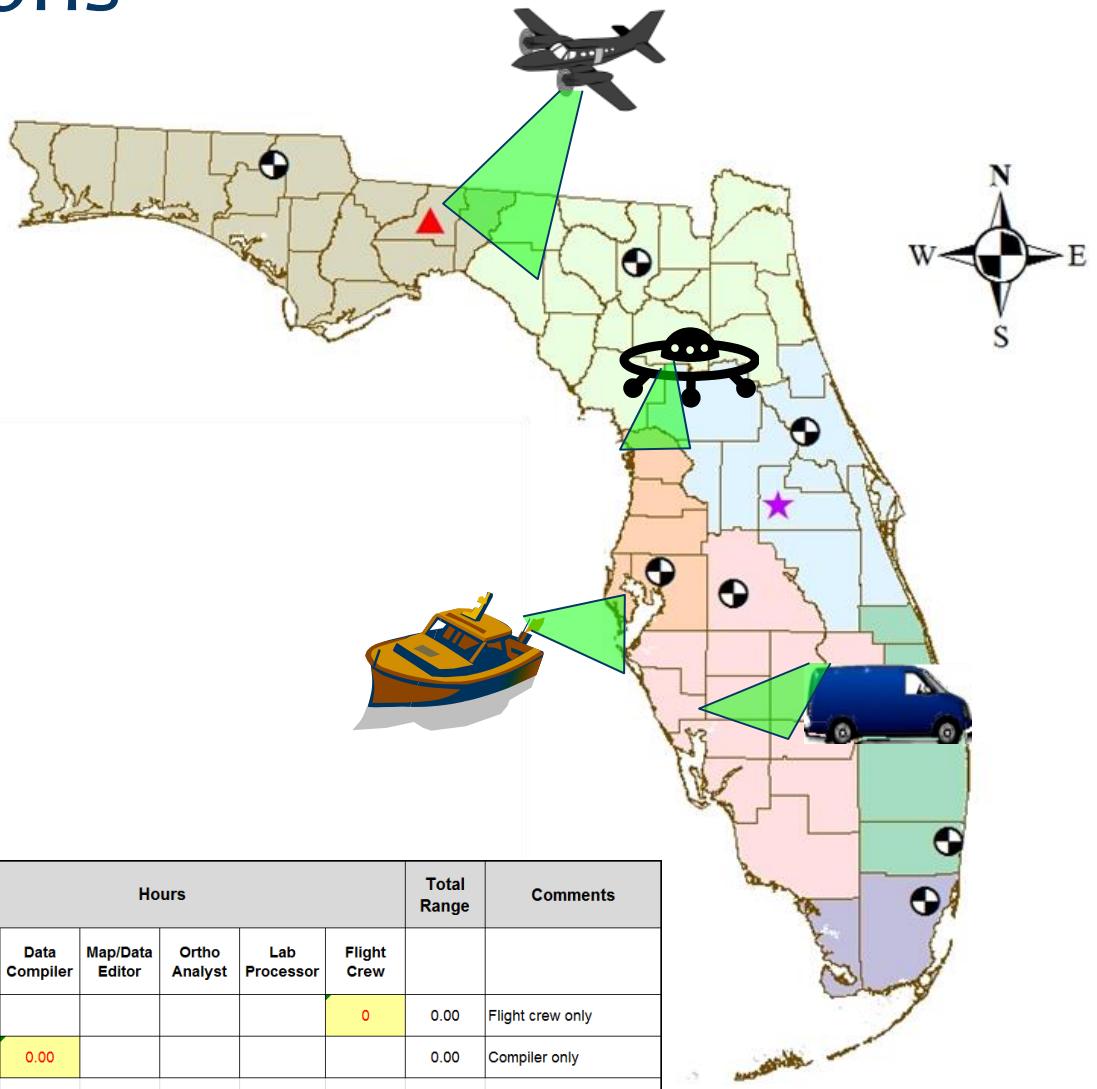
Funded by
Florida Department of Transportation





Common Questions

- What is next?
  - Staff Hour Form
  - Work type 8.5
  - UAS



Photogrammetry Tab 28

Task No.	Task	Units	No. of Units	Hour / Unit	Hours						Total Range	Comments
					PSM	Data Compiler	Map/Data Editor	Ortho Analyst	Lab Processor	Flight Crew		
28.1	Flight Preparation	Frame	0	0						0	0.00	Flight crew only
		Frame	0	0		0.00					0.00	Compiler only
28.2	Control Point Coordination											
	Post ID	Point	0	0	0.00						0.00	PSM only
		Point	0	0		0.00					0.00	Complier only

Questions and Discussion

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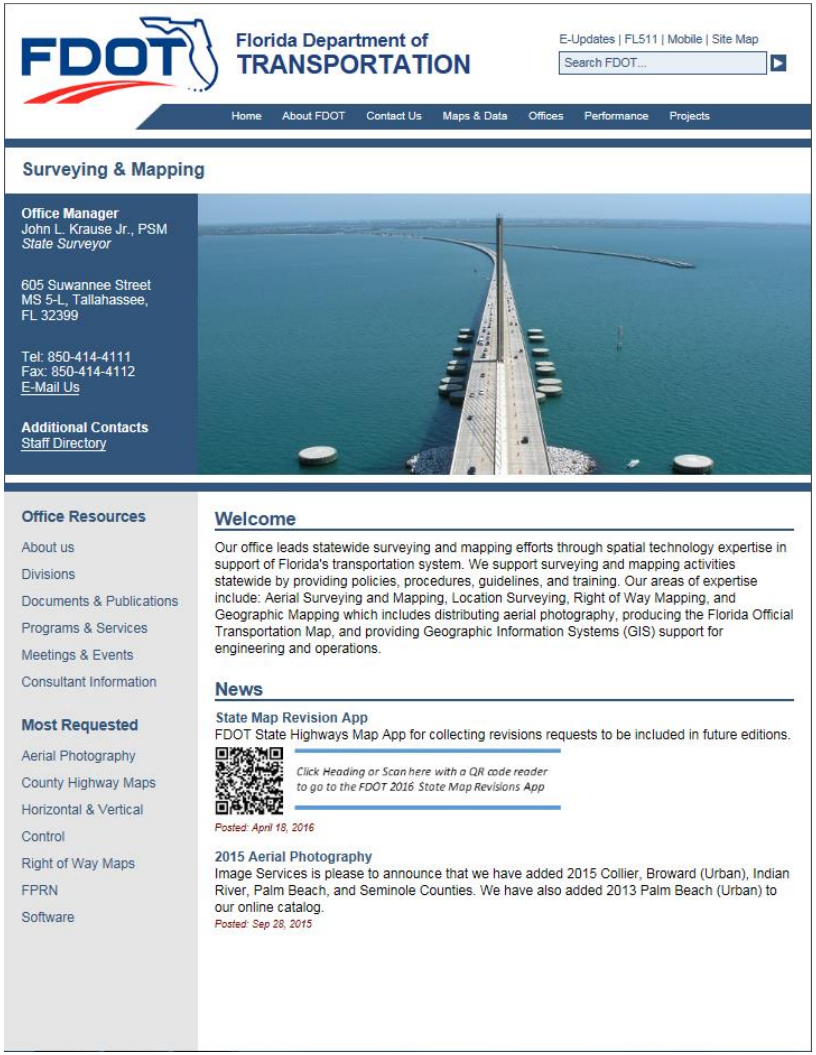

http://www.dot.state.fl.us/surveyingandmapping/

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