

1. Reference Documents

GeoTIFF Specification, version 1.8.2, found on the web at <http://www.remotesensing.org/geotiff/spec/geotiffhome.html>

2. Requirements

2.1 Characteristics

2.1.1 Image Format

Images shall be delivered in GeoTIFF format. Individual GeoTIFF images shall form a mosaic that covers the areas of interest. The file format shall conform to the GeoTIFF Specification, version 1.8.2 at <http://www.remotesensing.org/geotiff/spec/geotiffhome.html> . Proprietary tags shall not be used. Image size shall be 5000 x 5000. Projection information in .XML format should accompany each ortho-image.

The No Data value shall be specified in the metadata and shall not occur within the image data. A No Data value of (0,0,0) shall be used. No Data areas shall only occur outside the boundary of the specified Area of Interest (AOI).

All ortho-imagery shall be delivered on individual external hard drives by Area of Interest to the State of Michigan, CSSTP.

Image files from each AOI shall be labeled with names that end in five digit numbers. The number fields at the end of the filenames within an AOI shall all be consecutive without omission or duplication and shall begin with "00001". The text preceding the image number within the image filename shall be of the form

(area of interest code)_(contractor code)_YYYYMMDD

where YYYY is the year, MM is the two digit month, and DD is the two digit day of acquisition.

2.1.2 Image Type

Image tiles shall be 4-band image files comprised of the three visible bands and the near-infrared band. Band order to be as follows:

- Band 1: Red
- Band 2: Green
- Band3: Blue
- Band4: Near-Infrared

Image radiometric resolution should be set to 8 bits per channel to create 32-bit image files. All bands should be balanced such that natural-color (Red, Green, Blue) and standard false-color composites (Infrared, Red, Green) are spectrally correct. Natural color composites should appear natural to a human observer.

2.1.3 Image Coordinates

All ortho-imagery and derivative data, such as tile footprints and flight line files, shall be referenced to the following coordinate space:

Coordinate System: Michigan State Plane, appropriate zone

Datum: North American Datum 1983(1986)

Units: International Feet

Care must be taken such that the datum is actually NAD1983(1986) rather than another realization of NAD1983, such as NAD1983(CORS96) or NAD1983(HARN). As of September 2012, GPS data collected in Michigan using real-time correction data from the Continuously Operating Reference Network (CORS) will be referenced to NAD1983(CORS96). It is important that the vendor transform any data to the correct datum before image processing begins.

2.1.4 Image Scale

Data collection shall occur at 12 inch (0.30 meter) ground sample distance (GSD) $\pm 10\%$. This will be considered the standard product GSD. Optional data collection at 6 inch (0.15 meter) GSD and 3 inch (0.075 meter) GSD will also be available as an optional product per details in Section 6 of this document.

2.1.5 Metadata

Metadata shall be supplied for all images and shall include

- Image location and outline
- Accuracy statement giving the measured RMS 2D error and the corresponding error at the 95% confidence level, assuming a circular Gaussian error distribution
- 2D accuracy statement referencing the National Map Accuracy Standard for geospatial data at the 95% confidence level
- Camera used
- Date and time of acquisition
- Ground sample distance as collected
- Focal ratio and exposure time
- Remarks on image quality and artifacts, if any
- FGDC compliant metadata for the Area of Interest
- The name of the supervising Certified Photogrammetrist

2.2 Image Quality

Certified Photogrammetrist: All production shall be under the supervision of an American Society of Photogrammetry and Remote Sensing (ASPRS) Certified Photogrammetrist. All products shall be reviewed and approved by an ASPRS Certified Photogrammetrist. The name of the supervising Certified Photogrammetrist shall be included in the metadata.

2.2.1 General Image Quality

Images shall appear sharp when viewed at 1 pixel per GSD and displayed or printed on high quality equipment at 80 to 100 pixels per inch. Mosaicking artifacts and other image artifacts shall be minimal or completely unnoticeable. Color mosaics shall be free from clouds, cloud shadows, haze, prominent seams, gridding due to uncorrected camera vignetting, and other obvious, uncorrected artifacts. Hot spots and water glint shall be corrected.

2.2.2 Instrument Corrections

Instrument corrections for distortion and radiometric level shall be applied to raw data values based on most recent and up-to-date camera calibrations. Camera calibration records shall be maintained on file by the aerial photography company and copies of these records shall be provided.

2.2.3 Radiometric Correction

Images shall be color balanced to minimize perceptible differences in color tones within and between adjacent images. Color balancing shall result in colors which appear natural to a human observer.

Image contrast and brightness shall be adjusted to minimize perceptible differences within and between adjacent images.

Adjustment(s) as necessary shall be undertaken based on State of Michigan (SOM) review of each AOI.

2.2.4 Spatial Correction

The best available Digital Elevation Model (DEM) or Digital Terrain Model (DTM) representing the ground surface (e.g., Bare-earth) should be used to ortho-rectify the imagery. The elevation data may be obtained from the United States Geological Survey (USGS), or from another source, such as the State of Michigan or a partner. Elevation data may be derived from LiDAR, photogrammetry or aerial triangulation autocorrelation as long as it provides sufficient accuracy and precision to support ortho-imagery horizontal accuracy requirements.

Cultural features such as roads, bridges, overpasses, buildings and other important features that are impacted by DEM artifacts shall be repaired.

During ortho-rectification, images shall be re-sampled at the specified GSD.

2.2.5 Mosaicking

Prior to tiling, image seams shall be placed to minimize disruption of important features of cultural or geographic significance—for example, large buildings, bridges, and major rivers. Image seams shall not run through elevated structures, such as bridges, overpasses, and large buildings. When feasible, seams shall be placed at naturally occurring lines in the image to render them less noticeable. Skews greater than one pixel shall be corrected.

2.2.6 Accuracy

All ortho-imagery shall meet the horizontal accuracy requirement for 1:1,200 scale data, National Standard for Spatial Data Accuracy (NSSDA) at the 95% confidence level. The horizontal accuracy value

is equal to or less than 3.80 feet, or 1.159 meters. In other words, 95% of the positions in the dataset must have an error with respect to true ground position that is equal to or smaller than 3.80 feet.

To ensure the data meets the horizontal accuracy requirement, the vendor will calculate the horizontal root mean squared error (RMSE) by comparing transformed ortho-imagery coordinates with field-based ground control point and check point coordinate locations. The vendor will then calculate the horizontal accuracy at the 95% confidence level using the following equation.

$$\text{Accuracy}_r = \text{RMSE}_r * 1.7308$$

Where:

Accuracy_r = Horizontal Accuracy at the 95% confidence level

RMSE_r = Horizontal Root Mean Squared Error

To obtain this level of horizontal accuracy the vendor shall employ Airborne Global Positioning System (AGPS) and Inertial Measurement Unit (IMU) technologies to record the precise location (X,Y,Z) and attitude (roll, pitch, yaw) of the sensor during image capture.

The vendor must also collect additional field-based ground control points (GCPs) to supplement the airborne data such that minimum accuracy requirements are met. **At least 2** check points must also be located in each county or AOI, whichever is smallest in extent. In other words, if an AOI is composed of 5 counties, there must be 10 check points collected; 2 for each county. Check points may be located anywhere in the AOI but should not be in the same vicinity as the GCPs. Check points are not to be used in the Aerial Triangulation solution.

GCPs and check points must be accurate to equal to or less than 0.10 meters in the horizontal (x,y) and equal to or less than 0.20 meters in the vertical (z).

Existing ground control supplied by the State of Michigan, a partner or a commercial entity may be used if available, assuming it meets the minimum accuracy requirements. Some data supplied by the State of Michigan may need to be marked by the vendor. For example, existing monuments may need to be marked prior to aerial acquisition but coordinates will be supplied.

All field-based ground control points and check points shall be taken at locations which are clearly identifiable on the aerial imagery.

2.3 Image Collection Constraints

2.3.1 Equipment

All Imagery from a single Area of Interest (AOI) shall be collected using a single digital aerial survey camera in good working order with up-to-date calibrations, an image stabilization system using an inertial measurement unit (IMU) and equipped with airborne GPS (AGPS).

Imagery shall be acquired using a large-format digital, metrically calibrated imaging sensor capable of simultaneous multi-spectral capture of red, green, blue and near IR bands.

The digital camera shall employ methods for preventing image smear related to forward motion if necessary. Frame-based cameras must utilize Time Delayed Integration (TDI), or an equivalent technology, to address image smear.

The camera lens and detector array shall be clean and free of excess dust or lint.

2.3.2 Flight Path

Imagery in all AOIs shall be collected on either north-south (which is preferred) or east-west lines whenever feasible, and all imagery in a single AOI shall be collected on parallel lines, unless flight path restrictions in the area make this impractical.

2.3.3 Camera Orientation

Imagery shall be collected at a crab angle of less than 5 degrees, which is measured between the camera's along-track image axis and the aircraft line of flight. The camera shall be nadir pointed within 2 degrees on average and shall not exceed 4 degrees off nadir at any time during image collection.

2.3.4 Image Overlap and Sidelap

Imagery of the AOIs shall be collected with $\geq 60\%$ in-track overlap and $\geq 30\%$ sidelap.

2.3.5 Camera Settings

Camera aperture and exposure time shall be adjusted for light conditions to achieve optimal image quality, consistent with the camera manufacturer's recommendations or automated settings, unless the camera operator has data which demonstrate that a different setting produces superior results under conditions at the time of collection.

2.4 Environmental Conditions

Imagery shall be collected under clear skies. The air shall be free of smoke, dust, and excessive haze.

Imagery shall be collected at sun elevation angles greater than 30 degrees. Adjacent flight lines shall be flown at sun elevation angles which differ by less than 15 degrees.

Roadways shall not be wet from recent precipitation.

The ground shall be free of snow cover and lakes free of ice. The ground shall not be obscured by fog.

Imagery shall be collected while deciduous trees are free of leaves, unless this requirement has been waived by the customer in writing for the specific AOI. The requirement for leaf-free collection may be waived by the customer, at the customer's option, in areas where this is not critical, such as open fields, pine forest, and urban areas, in order to allow collection of imagery after the leaf-off season is over with.

3. Areas of Interest

Areas of interest (AOIs) shall be identified by County boundary plus a designated buffer area. If an AOI includes an island within the Great Lakes, the island shall be flown and processed like any other land area. AOIs totaling the desired number of square miles shall be identified by the State and provided via an ESRI shapefile.

4. Quality Assurance Provisions

4.1 General

Independent quality checks shall be performed to certify the accuracy of the product and conformance to image quality specifications. Specific inspections shall be carried out at appropriate image scale and frequency to verify the Image Quality requirements.

4.2 Visual Inspection for Specific Artifacts

All Image Quality Requirements in Sections 2.2.1, 2.2.2, 2.2.3, 2.2.4, and 2.2.5 shall be inspected at a scale of 400 feet per inch or larger. Seam lines, glints, color balance, DEM artifacts, and bridges on roadways shall be addressed in this inspection, and artifacts noticeable at this scale shall be corrected. In urban areas, a scale of 200 feet per inch or larger shall be used for inspection.

4.3 Customer QA/QC

Successful vendor must have an existing, secure application website for use in project management, quality control and available for use in communicating project status. The website shall allow for viewing of incremental deliverable products for the purpose of performing QA/QC prior to final physical delivery. Imagery shall become available for viewing with the completion of the first AOI and a 2 week time period will be designated for each AOI to be available for review. Imagery made available for review must be fully processed and should already have passed the vendor quality control process. The application shall allow project stake-holders the ability to review ortho-imagery, identify and attribute items in-question for discussion with both the State's Project Manager and the PM of the successful Geospatial Contractor.

4.4 Warranty Against Image Defects

Defects in imagery collection that are reported by the customer within 90 days shall be corrected by re-acquisition and re-processing. Defects in image processing reported by the customer within 12 months shall be corrected by re-processing.

5. Deliverables

5.1 Hard Drives

All GeoTIFF image tiles organized into one sub-directory per County and items identified in Section 7, Deliverables, delivered to SOM via external hard drive.

Each partner to receive an external hard drive with the GeoTIFF image tiles and Section 7 items for their AOI.

5.2 Delivery schedule

Collected imagery in each season shall be delivered to the customer within 4 months of the end of the applicable flying season.

6. Buy-up Options

6.1 High Resolution Areas (HRA)

In addition to 12 inch (0.30 meter) GSD imagery, the vendor shall provide separate pricing for data collection at a GSD of 6 inch (0.15 meters) and a GSD of 3 inch (0.075 meters). The State of Michigan or its partners may elect to collect portions of an AOI at 12 inch (0.30 meter) GSD and other portions within that AOI at either 6 inch (0.15 meter) GSD and/or 3 inch (0.075 meter) GSD.

Spatial resolution shall match GSD $\pm 10\%$.

If this option is chosen for an AOI the area will be imaged at 6 inch or 3 inch resolution, rather than 12 inch resolution.

HRAs in high density urban areas shall be collected with $\geq 80\%$ in-track overlap and $\geq 60\%$ sidelap. This results in reduced building lean in these areas.

SOM shall provide an ESRI shapefile defining HRA areas.

HRAs shall meet the same image quality requirements as 12 inch (0.30 meter) GSD AOIs

6.2 Updated DEM (100% of AOI)

The vendor will provide pricing for the purchase of the updated DEM resulting from the image processing.

If this option is chosen for an AOI, the updated DEM resulting from image feature correlation processing and any DEM editing performed will be supplied to the customer for the AOI. The DEM supplied will be the DEM used to produce the orthoimagery for the AOI.

6.3 Compressed Image Mosaics

The vendor will provide pricing for the creation of a compressed image mosaic for each acquired County. In addition, pricing shall be provided for the creation of individual compressed mosaics for each City and Political Township within a County. This is to be accomplished by “clipping” the County mosaic using a boundary shapefile to be provided by SOM. All compressed mosaics to be delivered in JP2 or similar agreed upon file format and named using the common name for the County, City, and Township.

7. Additional Deliverables at no cost to the SOM

7.1 ESRI Shapefiles

To be delivered in the same coordinate system as the ortho-imagery.

7.1.1 Tile index

A polygon shapefile of the image tile boundaries shall be provided in the appropriate coordinate system. Each polygon will have a name attribute that corresponds with the image name and the flight date of the image.

7.1.2 Flight lines

A shapefile of the flight lines shall be provided in the appropriate coordinate system. Flight lines shall be attributed with the flight date.

7.1.3 Vector seam index

A shapefile representing the vectors used during the image seaming process shall be provided with a flight date attribute.