North Carolina
Technical Specifications for
Digital Orthophoto Base Mapping

Land Records Management Division
North Carolina Department of
The Secretary of State
Edited by Thomas W. Morgan

December 11, 2014

State of North Carolina
Department of the Secretary of State

ELAINE F. MARSHALL
SECRETARY OF STATE

Order Adopting North Carolina Orthophotography Standards
For Base Mapping

WHEREAS, the Department of the Secretary of State (Department) is required by G.S. §102-17 and §147-54.3 to adopt technical standards and detailed specifications for base mapping to be used to achieve a greater degree of statewide standardization for use in land records, and

WHEREAS, over the past year the Department has worked extensively and cooperatively with stakeholders to produce a set of revised standards for Orthophotography, and

WHEREAS, the North Carolina Geographic Information Coordinating Council has recommended the adoption of the revised standards, and

WHEREAS, I have considered the recommendations of the staff of the Department of the Secretary of State, as well as the recommendation of the North Carolina Geographic Information Coordinating Council,

NOW, THEREFORE, IT IS HEREBY ORDERED AND DECREED that pursuant to the authority granted me by G.S. §102-17 and §147-54.3(c), effective on this date, I hereby adopt the revised Orthophotography Standards for use to achieve a greater degree of statewide standardization of land mapping for use in land records in the State of North Carolina.

A copy of the adopted Orthophotography Standards is posted on the Land Records Management page of the Department's website at http://www.secretary.state.nc.us/land/ThePage.aspx or may be obtained by contacting the Department at:

Land Records Manager
N.C. Department of the Secretary of State:
P.O. Box 29626
Raleigh, NC 27626-0626
By Facsimile: (919) 807-2285
By Email: tmorgan@sosnc.com

This the 11th day of December, 2014.

Elaine F. Marshall
North Carolina Secretary of State

PO Box 29622 • Raleigh, NC 27626-0622

State of North Carolina
Department of the Secretary of State

ELAINE F. MARSHALL
SECRETARY OF STATE

December 11, 2014

N.C. Land Records Advisory Committee
Chair Patrick K. Hetrick
Campbell University Norman Adrian Wiggins School of Law
225 Hillsborough St., Suite 401
Raleigh, NC 27603

Dear Chair Hetrick:

Please find enclosed the Order adopting North Carolina's revised Orthophotography Standards for Base Mapping. I would like to thank and congratulate all of the stakeholders for their hard work on this important set of standards, which will help North Carolina achieve a greater degree of statewide standardization of land mapping for use in land records.

If you have any questions on this topic or other land records related matters, please contact:

Thomas W. Morgan
Land Records Manager
N.C. Department of the Secretary of State:
P.O. Box 29626
Raleigh, NC 27626-0626
By Phone: (919) 807-2268
By Facsimile: (919) 807-2285
By Email: tmorgan@sosnc.com

Sincerely,

Elaine F. Marshall

Elaine F. Marshall

Enclosure

PO Box 29622
Raleigh NC 27626-0622

website: www.sosnc.com

Telephone (919) 807-2005
Facsimile (919) 807-2010

State of North Carolina
Department of the Secretary of State

ELAINE F. MARSHALL
SECRETARY OF STATE

December 11, 2014

N.C. Board of Examiners for Engineers and Surveyors
Chair Willy E. Stewart, PE
4601 Six Forks Rd., Suite 310
Raleigh, North Carolina 27609

Dear Chair Stewart:

Please find enclosed the Order adopting North Carolina's revised Orthophotography Standards for Base Mapping. I would like to thank and congratulate all of the stakeholders for their hard work on this important set of standards, which will help North Carolina achieve a greater degree of statewide standardization of land mapping for use in land records.

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ELAINE F. MARSHALL
SECRETARY OF STATE

December 11, 2014

N.C. Bar Association Real Property Section
Chair Elizabeth Harrison
721 W. Morgan St.
Raleigh, NC 27603

Dear Chair Harrison:

Please find enclosed the Order adopting North Carolina's revised Orthophotography Standards for Base Mapping. I would like to thank and congratulate all of the stakeholders for their hard work on this important set of standards, which will help North Carolina achieve a greater degree of statewide standardization of land mapping for use in land records.

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State of North Carolina
Department of the Secretary of State

ELAINE F. MARSHALL
SECRETARY OF STATE

December 11, 2014

N.C. Property Mappers Association
Chair Kevin Locklear
c/o GIS Department
337 S. Salisbury St., 5th Floor
Raleigh, NC 27601

Dear Chair Locklear:

Please find enclosed the Order adopting North Carolina's revised Orthophotography Standards for Base Mapping. I would like to thank and congratulate all of the stakeholders for their hard work on this important set of standards, which will help North Carolina achieve a greater degree of statewide standardization of land mapping for use in land records.

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Sincerely,

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State of North Carolina
Department of the Secretary of State

ELAINE F. MARSHALL
SECRETARY OF STATE

January 30, 2013

N.C. Real Estate Commission
Chair Thomas R. Lawing, Jr.
P.O. Box 17100
Raleigh, NC 27619-7100

Dear Chair Lawing, Jr.:

Please find enclosed the Order adopting North Carolina's revised Orthophotography Standards for Base Mapping. I would like to thank and congratulate all of the stakeholders for their hard work on this important set of standards, which will help North Carolina achieve a greater degree of statewide standardization of land mapping for use in land records.

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Sincerely,

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Enclosure

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State of North Carolina
Department of the Secretary of State

ELAINE F. MARSHALL
SECRETARY OF STATE

December 11, 2014

N.C. Geographic Information Coordinating Council
Center for Geographic Information & Analysis
Chair Stan Duncan
20322 Mail Service Center
Raleigh, NC 27699-0322

Dear Chair Duncan:

Please find enclosed the Order adopting North Carolina's revised Orthophotography Standards for Base Mapping. I would like to thank and congratulate all of the stakeholders for their hard work on this important set of standards, which will help North Carolina achieve a greater degree of statewide standardization of land mapping for use in land records.

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Sincerely,

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Facsimile (919) 807-2010

CERTIFICATE OF SERVICE

I certify that a copy of the foregoing Order was served upon the following by depositing a copy of the Order in the United States Mail, addressed as follows:

N.C. Geographic Information Coordinating Council
Center for Geographic Information & Analysis
Chair Stan Duncan
20322 Mail Service Center
Raleigh, NC 27699-0322

N.C. Land Records Advisory Committee
Chair Patrick K. Hetrick
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337 S. Salisbury St., 5th Floor
Raleigh, NC 27601

N.C. Real Estate Commission
Chair Thomas R. Lawing, Jr.
P.O. Box 17100
Raleigh, NC 27619-7100

This the 11th day of December, 2014.

Jennell Baughman

Jennell Baughman, Executive Assistant
N.C. Department of the Secretary of State
P.O. Box 29622, Raleigh, NC 27626-0622

PREFACE

The "Land Records Management Program" (LRMP) was established in 1977 by the North Carolina Legislature in order to provide technical and financial assistance to local governments for the modernization of their land records systems. The Technical Specification(s) for Base, Cadastral, and Digital Mapping (Orthophotos)" are thus prepared as an essential element of the LRMP and is applicable to all county or municipal mapping projects. To the maximum extent practicable, these specifications should also be utilized by state agencies involved in mapping operations. Section 6, "Digital Orthophotos", was adopted on August 18, 2004, by the North Carolina Geographic Information Coordinating Council (GICC).

Invaluable guidance and assistance have been provided by the Standards Committee of the North Carolina Property Mappers Association and by representatives of local governments. Assistance was also provided by the North Carolina Geodetic Survey (NCGS), the Center for Geographic Information and Analysis (CGIA), the North Carolina Department of Transportation, and the North Carolina Department of Revenue. I also want to thank Atlas Geodata, Spatial Data, Surdex and Photo Science for providing industry prospective.

Edits and Additions:

As you use this standard if there are edits or suggestions that you wish were included, please forward them to Landrecords@sosnc.com , Subject: Orthophoto technical Standards (Proposed Revisions). Depending on the nature of the update and the update cycle of the standard there may be a delay in evaluating the suggestion and including it in the standard. Be assured that we are appreciative of your help in making the standard better.

TECHNICAL SPECIFICATIONS FOR ORTHOPHOTO DIGITAL MAPPING

Table of Contents

SECTION 1

GENERAL

GENERAL

Definitions:

Aerial Frame Camera:

Aerial Frame Camera is an aerial digital imaging sensor, which may be comprised of multiple digital cameras, whose shutters open and close while collecting imagery one frame at a time as the aircraft moves along a flight line.

Aerial Pushbroom Camera:

Aerial Pushbroom Camera is an aerial digital imaging sensor, which collects a strip of imagery with digital arrays as the aircraft moves along a flight line. Pushbroom cameras have nadir, forward, and aft sets of arrays that simultaneously and continuously record. The forward array is pitched forward along the flight line and the aft arrays are pitched backward along the flight lines. Stereoscopic imagery is obtained by viewing forward and aft array imagery over common areas.

Band:

A band is image data gathered within a range of wavelengths of electromagnetic radiation. Typically the bands are Red, Blue, Green, and Near Infrared.

Brightness Value:

Brightness value is a number (normally 0-255 for 8-bit imagery) representing a discrete intensity color level of a pixel in an image. Also referred to as a "digital number" (DN).

Burning:

Burning is the manipulating of the intensity of part of a photograph to make something darker.

Chip:

A Chip is each separate piece of an image mosaic that contributes to the final image.

Client:

Client shall be construed to include not only county governments, but also municipal governments, state governmental agencies or any other agency or party wishing to enter into a mapping contract with a Contractor under the provisions of these specifications.

Clipping:

Clipping is a result of capturing or processing an image where the intensity in a certain area falls outside the minimum and/or maximum intensity which can be represented by that image. This is evidenced by the presence of pixels exhibiting the minimum or maximum digital count in an image's dynamic range.

Contracting Officer:

Contracting Officer is the officially designated representative of the state or local government obtaining the mapping products or services. This individual's authority and responsibilities shall be prescribed by the appropriate state, county, or municipal governing board or authority.

Contractor:

Contractor is that firm, company, or organization to which the mapping or service contract has been let. References to the Contractor in these specifications shall also apply in full to any subcontractor working for the named Contractor.

Digital Number (DN):

Digital Number (DN) is the color value assigned to a pixel within a band (R,G,B,NIR) or luminosity. This number shall be 0-255 for 8-bit images.

Dodging:

Dodging is the manipulation of the intensity of part of a photograph to make something lighter.

Exploitation Images:

Exploitation images are the result from post-processing the "raw" images by sensor-specific software. The sensor-specific software applies geometric and radiometric processing to the images which enables common professional and consumer software to view and manage the resulting "post-processed" images. "Exploitation" images exhibit a natural color balance, contrast, and intensity and are ready for introduction into the production process.

Field:

Field refers only to the entire field, including the value, of the geokey (as defined in the TIFF Specification).

Global Navigation Satellite System (GNSS):

GNSS includes all satellite navigation systems. Formerly the Global Positioning System (GPS) term was used and only referenced the US Satellite navigation system.

Ground Sampling Distance (GSD):

GSD is the physical measure of the level of detail expressed in linear units of data collection for remote digital imaging of the surfaces of the Earth.

Nadir Ground Sample Distance (NGSD):

NGSD is the physical measure of the level of detail expressed in linear units of data collection of the surfaces of the Earth vertically under the center of the remote digital imaging sensor.

Transportation Feature Ground Sample Distance (TGSD):

TGSD is the physical measure of the level of detail expressed in linear units of data collection of the surfaces of the Earth at any given transportation feature.

Image File Directory (IFD):

IFD contains information about the image. There must be at least 1 IFD in a TIFF file and each IFD must have at least one entry.

Inertial Measuring Unit (IMU):

IMU is an electronic device hard mounted to or integrated with a sensor that measures and reports the sensor's velocity and orientation using a combination of accelerometers and gyroscopes. With post processing of the recorded orientation data, the exterior orientation angular values (Omega, Phi, Kappa) of a frame camera exposure can be determined. IMU data is required to produce a virtual frame with a line scanner sensor system.

Metadata:

Metadata is a description of the content, quality, condition, and other characteristics of the geospatial data that is compliant with the North Carolina Geographic Information Coordinating Council's endorsed metadata standard. The Council adopted the Federal Geographic Data Committee (FGDC) Content Standard for Digital Geospatial Metadata (CSDGM) in 1994 and is in the process of adopting a North Carolina State and Government Profile based on the ISO-19115-1 metadata standard (2014). A valid metadata record may be compliant with either FGDC or ISO standards as adopted by the Council.

Orthophotography/Orthoimagery:

Orthophotography/Orthoimagery is an aerial photograph geometrically corrected ("ortho-rectified") such that the scale is uniform and can be used to measure true distances, because it is an accurate representation of the Earth's surface, having been adjusted for topographic relief, lens distortion, and camera tilt.

Photography:

Photography and/or aerial photography shall be used inclusive of a film image or a digital sensor image.

Raw Images:

Raw images are defined as the original captured image and metadata, devoid of the application of geometric and radiometric processing and generally unfit for introduction into a production process. This data is typically in a proprietary format and its form and format readable only by sensor-specific processing software. This data must be post-processed by sensor-specific software.

Re-sampling:

Re-sampling is a software method that is used to increase or decrease the size and/or resolution of a digital image by interpolation of pixel values based upon neighboring pixel values.

Tag:

Tag refers only to the identifying number portion of the geokey (as defined in the TIFF Specification).

Work Statement:

The Contractor shall furnish all materials, superintendence, labor, equipment, and transportation and shall execute and complete all of the work required by the contract in conformance with these specifications and any contractual modifications to these specifications. Any deviation from these specifications, unless specifically authorized in writing by the Contracting Officer or his representative, shall be sufficient cause for rejection of any part or all of the work performed.

General Mapping Specifications:

a) Orthophotography/orthoimagery is to be collected with an aerial digital sensor unless specifically authorized by the Client in writing.
b) Unless otherwise specified the deliverable will be a seamless mosaic product with no boarders or overlay masks.
c) All orthoimagery shall be adjusted to the North Carolina Official Survey Base as defined in NC GS Chapter 102 - http://www.ncleg.net/gascripts/Statutes/StatutesTOC.pl?Chapter=0102 and adjusted to the latest realization released by National Geodetic Survey. All deliverable hardcopy maps/overlays and/or softcopy maps/overlays shall contain a statement identifying the above information: i.e. **"This map/overlay is correlated to the North Carolina State Plane Coordinate System, NAD83(2011) epoch 2010.0."** The contracting officer may require additional deliverables that are converted to another datum. If so, the above statement will be modified to reflect that the product was so converted.

d) All lettering on all deliverable hardcopy maps or overlays and softcopy maps or overlays shall be produced solely by mechanical or electronic means. Hand lettering will not be permitted.

Visits to Contractor's Site:

The Contract Officer or officially designated representatives or agents may visit the Vendor's site to inspect work in progress and verify that the procedures and equipment being used are in compliance with these Specifications and contract requirements. The Contractor agrees to allow access to its production facilities for periodic visits by the Client representatives or agents. These visits may be unannounced and/or may be upon short notice.

Surveying Activities:

All surveying activities, as defined in North Carolina General Statute § 89C, http://www.ncleg.net/gascripts/Statutes/StatutesTOC.pl?Chapter=0089C undertaken by the Contractor shall be conducted by surveyors licensed by the North Carolina Board Examiners for Engineers and Surveyors. Photogrammetry services shall only be provided by North Carolina licensed surveyors who are competent by virtue of education and experience in the discipline of photogrammetry. At the beginning of a project involving photogrammetric services, the Contractor shall identify the licensed surveyor who will sign and seal the completed project, and who will have direct supervisory control of the project. If in the course of the project the surveyor designated as being "In Responsible Charge" is replaced, the Contractor shall notify the contracting officer immediately in writing. The Surveyor that is in responsible charge is required to abide by Board Rules North Carolina Administrative code (NCAC title 21, Chapter 56)
http://reports.oah.state.nc.us/ncac.asp?folderName=\Title%2021%20-%20Occupational%20Licensing%20Boards%20and%20Commissions\Chapter%2056%20-%20Engineers%20and%20Surveyors

21 NCAC 56 .0701 RULES OF PROFESSIONAL CONDUCT

(3) Shall not affix the signature or seal to any engineering or land surveying plan or document dealing with subject matter for which the licensee lacks competence by virtue of education or experience, nor to any such plan or document not prepared under the licensee's direct supervisory control. Direct supervisory control (responsible charge) requires a licensee or

employee to carry out all client contacts, provide internal and external financial control, oversee employee training, and exercise control and supervision over all job requirements to include research, planning, design, field supervision and work product review. Direct supervisory control may be accomplished face to face or by other means of communication. A licensee shall not contract with a non-licensed individual to provide these professional services. Research, such as title searches and soil testing, may be contracted to a non-licensed individual, provided that individual is qualified or licensed to provide such service and provided the licensee reviews the work. The licensee may affix the seal and signature to drawings and documents depicting the work of two or more professionals provided it is designated by a note under the seal the specific subject matter for which each is responsible; and

(4) In circumstances where a licensee in responsible charge of the work is unavailable to complete the work, or the work is a design plan signed and sealed by an out-of-jurisdiction licensee (not a site adaptation of a standard design plan under Rule 21 NCAC 56 .1106) a successor licensee may take responsible charge by performing and documenting all professional services to include developing a design file including work or design criteria, calculations, code research, and any necessary and appropriate changes to the work. The non-professional services, such as drafting, need not be redone by the successor licensee but must distinguish in a clean and obvious manner and accurately reflect the successor licensee's work. The burden is on the successor licensee to show such compliance. The successor licensee shall have control of and responsibility for the work product and the signed and sealed originals of all documents.

21 NCAC 56 .1101 GENERAL

It is misconduct for a Professional Engineer or Professional Land Surveyor to seal work done by another individual unless the work is performed under the "responsible charge" of the Professional Engineer or Professional Land Surveyor.

SECTION 2

AERIAL PHOTOGRAPHY

AERIAL PHOTOGRAPHY

Project Area and Client Contract Map:

The location, size, and boundaries of the areas to be mapped will be outlined on a Client Map and further subdivided and designated in a way to show the number and scales of the final base maps to be prepared; the map shall be at a scale adequate for its purpose and shall be in an electronic format. When the mapping project includes the entire county or portions along county boundary lines, the area to be mapped shall extend 2,000 feet beyond the county boundary or to the extent defined by the Contracting Officer. This marked Client Map shall be entitled "Client Contract Map" and shall be attached to and become a part of any contractual agreement. The flight plan proposed by the Contractor shall be generated and referenced to a copy of this map and submitted to the Contracting Officer for approval prior to flying aerial photography (see **Flight Plan**). The Client Contract Map may be prepared by the Client or by the Contractor at the request of the Client.

Conditions During Photography:

Photography shall be undertaken only when conditions meet capture specifications as described below.

Vertical photography shall be flown during the period when deciduous trees are barren and when the sun angle or elevation is not less than 33 degrees above the horizon (Mountain area: e.g. west of the Blue Ridge Escarpment shall be limited to a sun angle or sun elevation of not less than 38 degrees above the Horizon). The precise line of demarcation between 33 degrees and 38 degrees shall be defined by the contracting officer. It shall be the contractor's responsibility to monitor atmospheric conditions such as haze, dust, fog, water vapor, etc., and adjust the

flight time window to maintain visual image quality. If possible the flight window should be centered on solar noon. The United States Naval Observatory has an online Sun Angle Calculator and the present web address is: http://aa.usno.navy.mil/data/docs/AltAz.php .

The Contracting Officer may require a higher sun angle to reduce the risk of long or objectionable shadows caused by relief, vegetation or manmade objects. Images will not be undertaken when atmospheric conditions such as moisture, haze, fog, or dust will hinder the capture of clear imagery of the ground. Images will not be used in orthophotography production that show streams not within their normal banks. When an area is obscured by snow, clouds, cloud shadows and/or smoke, the obscured area will be evaluated for the nature of ground cover and improvements. The Contracting Officer has the authority to accept or reject the inclusion of obscured areas. If rejected a refight may be required. Images shall only be used in the production of Orthophotography project when capture specifications are met. Manufactured snow areas (Ski Slopes), snow piles from roads and parking lots, or other clearing activity and remnant snow areas (small patches of snow remaining in shadows) are exempt from the requirement. If the contractor has a question about flooding or snow extent the contracting officer is to be consulted. Re-flights of areas obscured by smoke from forest fires or control burns shall be required once smoke conditions have ceased. Single point sources fires where the smoke is minimal and does not appear to obscure manmade structures may be acceptable with contracting officer approval. Obscured ground features due to permanent smoke sources such as cooling towers or industrial smoke stacks cannot be avoided but the contractor should make efforts to minimize the obscurity. The contracting officer may set additional project restrictions if it is felt that these restrictions would insure additional usefulness of the product. Lunar tide levels or wave conditions on large open bodies of water are examples that could have additional requirements

Ground Sampling Distance (GSD) for Final Orthoimagery Deliverable:

Map Class or Map Scale shall have the pixel size of the final deliverable product:

Description	Map Scale	Ground Sampling Distance	Recommended Land Cover
Class D	1’= 400’	1.00 ft pixel	Rural
Class C	1”= 200’	0.50 ft pixel	Suburban / General overall
Class B	1”= 100’	0.25 ft pixel	Urban

Class A	1"= 50'	0.125 ft pixel	Ultra-Urban

Actual Image Acquisition Geometry

The flight plan shall be designed such that the actual image acquisition geometry meets the following GSD and overlap specifications.

Nadir Ground Sample Distance (GSD) for acquisition

1. Nadir GSD shall be between 70% less than ortho specification (0.15 feet for .50 feet GSD) to GSD ortho specification (0.50 feet GSD) for 75.0% of planned exposures or pseudo exposures for the pushbroom cameras
2. Nadir GSD shall not be less than 76% less than ortho specification (0.12 feet for .50 feet GSD) or greater than 6% greater than ortho specifications (0.53 feet for .50 feet GSD) of planned exposures or pseudo exposures for the pushbroom cameras
3. For pushbroom cameras, GSD nadir values will be computed at pseudo exposure station spacing along the flight line at 400 times GSD (200 feet for .50 feet GSD) intervals
4. If either Nadir GSD actual image acquisition specification is not met, then re-flights may be directed at the sole discretion of the Contracting Officer after consultation with the vendor

Transportation Feature Ground Sample Distance (GSD)

1. Transportation feature GSD shall b**e** between 70% less than ortho specifications (0.15 feet for .50 feet GSD) to 10% greater than ortho specifications (0.55 feet for .50 feet GSD) feet for 98.0% of tested points
2. Transportation feature GSD shall not be less than 80% less than ortho specifications (0.10 feet for .50 feet GSD) or greater than 20% greater than ortho specifications (0.60 feet for .50 feet GSD)
3. For pushbroom cameras, transportation feature GSD values will be computed at a distance not to exceed 200 times GSD (100 feet for a .50 GSD) foot spacing along the flight line
4. If either Transportation feature GSD actual image acquisition specification is not met, then re-flights may be directed at the sole discretion of the Contracting Officer after consultation with the vendor

Flight Plan:

The Contractor's flight plan shall be overlaid on the Client Contract Map. The map may be digital or hard copy at the Client's discretion. Every effort shall be made to avoid breaks within individual flight lines. When breaks within a flight line are necessary, the entire flight line composed of the resulting segments shall meet all of the requirements set forth in these specifications. Where breaks occur, there shall be forward overlap between flight lines to ensure at least 10,000 times the final orthoimagery Ground Sample Distance (GSD) of stereo coverage. (See Ground Sampling Distance (GSD) For Final Orthoimagery Deliverable.) For pushbroom sensors, the replacement imagery shall include full forward and aft stereoscopic coverage. All photos within a single flight line shall be acquired with the same aerial sensor and with the sensor oriented in the same direction. The principal points of the first two and the last two exposures of each flight strip shall fall outside the boundaries of the area to be mapped. For pushbroom sensors, the flight design shall ensure that the forward and aft imaging arrays coverage fall outside the ends of each strip to accommodate stereo viewing of the entire project area. All side boundaries shall include an overlap at least equal to the sidelap specifications for the project. The flight plan will be designed using the primary side and forward overlap percentages specified in **Forward Overlap** and **Side Overlap.** The flight plan submitted to the Contracting Officer is to be executed by the contractor. The rejection limits incorporated within **Forward Overlap** and **Side Overlap** are to help with unforeseen flying conditions and will not be used as the minimum criteria for the basic flight plan. In addition the Contracting Officer may include special flight lines for areas of interest; tall bridges, tall buildings, deep gorges, etc. These areas will be flown as close to nadir as possible (by increased forward and/or side overlap or direct feature overhead exposure) and be included in the orthoimagery.

Re-flights:

Within one week of the flight mission, the Contractor shall submit a detailed quality control report to the Contracting Officer confirming compliance to the aerial photography specifications. If the Contractor cannot meet the one week reporting time frame the Contractor shall inform the Contracting Officer in advance of the delay. Unacceptable aerial photography shall be corrected by the Contractor at no additional cost to the Client, with re-flight coverage overlapping the accepted photography by at least 10,000 times the final orthoimagery Ground Sample

Distance (GSD) of stereo coverage. For pushbroom sensors, the replacement imagery shall include full forward and aft stereoscopic coverage. Replacement exposures shall be acquired with the same sensor make and model used to acquire the original exposures and shall be exposed as nearly as possible to the same time and lighting conditions as the original exposures. Re-flights shall be flown immediately (ideally within one week of the original flight), provided ground conditions have not yet terminated the photographic "season." A Digital Sensor System or its components may be substituted if approved in writing by the Client.

The contractor will apply a file naming convention for all exploitation images that shall adhere to the following guidelines:

1. StudyAreaNumber_FlightLine_FrameNumber (Use all underbars, not dashes). EXAMPLE: SA3_100_01
2. Initial planned flight line numbers will be represented as three digits (e.g. 100/101/102 or 001, 002, 003). The flight line number for re-flights will be represented as four digits by adding increments of 1000 up to 9000 to the initial flight line designation (e.g. 1100/1101/1102 or 2001, 2002, 2003).
3. For the frame, there will be leading zeros only on frames 1-9 (01, 02, 03).

Spacing of Photographs:

Overlapping photographs in each flight line shall provide full stereoscopic coverage of the area to be mapped. Flight line planning shall use the 60% forward overlap and 30 % side overlap as constraints over a digital terrain model. Varying flight line spacing and varying photo center spacing along the flight line are recommended in achieving the overlap requirements to comply to minimum/maximum GSDs from terrain variations within raw imagery At all times pixel size (GSD) requirements shall be maintained. The Client may specify a digital elevation model to be used for the flight planning.

Forward Overlap (not applicable to pushbroom cameras):

Planned forward overlap between successive exposures shall average no less than sixty percent (60%) plus or minus two percent (±2 percent). Greater forward overlap may help reduce building lean. Clients shall have the option when dealing with large changes in elevation due to natural ground elevation or man-made

differences such as a tall building to increase forward overlap requirements. Dependent upon the local terrain variation and direction of the Contracting Officer, the contractor should either use 2-D flight planning with the flying height set to average mean elevation over the planned flight lines or use full 3-D flight planning software in conjunction with a terrain model of the project area. As a rule of thumb any project area with elevation variations of 2,000 times or more the final orthoimagery Ground Sample Distance (GSD) requirements or greater is a good candidate for 3-D flight planning with a terrain model. With 3-D flight planning, flight line spacing and exposure spacing may vary. Adhering to project GSD specifications shall be required regardless of 2-D or 3-D flight planning used to prepare the project flight plan. Deviation from the planned image acquisition to the **actual image acquisition** resulting in a forward overlap of less than fifty-five percent (55%) may be cause for rejection of a flight line or any portion thereof, and shall be subject to re-flights as determined by the Contracting Officer.

Side Overlap:

Planned side overlap between adjacent parallel flight lines shall average no less than thirty percent (30%) plus or minus two percent (±2 percent). Greater side overlap may help reduce building lean. Clients shall have the option when dealing with large changes in elevation due to natural ground elevation or man-made differences such as a tall building of increased side overlap requirements. Dependent upon the local terrain variation and direction of the Contracting Officer, the contractor should either use 2-D flight planning with the flying height set to average mean elevation over the planned flight lines or use full 3-D flight planning in conjunction with a terrain model of the project area. As a rule of thumb any project area with elevation variations of 2,000 times or more times the final orthoimagery Ground Sample Distance (GSD) or greater is a good candidate for 3-D flight

planning with a terrain model. With 3-D flight planning, flight line spacing and exposure spacing may vary. Adhering to project GSD specifications shall be required regardless of 2-D or 3-D flight planning used to prepare the project flight plan. Deviation from the planned image acquisition to the **actual image acquisition** resulting in a side overlap of less than twenty-five percent (25%) may be cause for rejection of a flight line or any portion thereof, and shall be subject to re-flights as determined by the Contracting Officer .

Angular Exterior Orientation Parameters for Actual Image Acquisition

1. Omega (Roll):
   Omega of the sensor from verticality at the instant of exposure shall not exceed three (3) degrees, nor shall it exceed five (5) degrees between successive exposure stations. Absolute average omega over the entire project shall not exceed one (1) degree.

2. Phi (Pitch):
   Phi of the sensor from verticality at the instant of exposure shall not exceed three (3) degrees, nor shall it exceed five (5) degrees between successive exposure stations. Absolute average phi over the entire project shall not exceed one (1) degree.

3. Kappa (Yaw)
   Kappa shall not exceed three degrees (3º) from the planned flight line orientation nor deviate more than three degrees (3°) measured with respect to any two successive exposures.

   Deviation from the angular exterior orientation parameter specifications stated above may be cause for rejection of a flight line or any portion thereof, and shall be subject to re-flights as determined by the Contracting Officer**.**

Aircraft:

The aircraft to be used shall be equipped with all essential geodetic GNSS-IMU navigational and photographic instruments and accessories including, sensor position and sensor orientation necessary to satisfactorily produce the required imagery. The aircraft and sensor system shall be operated by a well-trained and experienced crew. The GNSS-IMU system shall be integrated into an aerial survey Flight Management System to provide navigation along the proposed flight lines and real time precise sensor positioning and sensor orientation. The geodetic GNSS-IMU navigation system must also have the capability to capture and store spatial positioning information for determining exterior orientation of the sensor and geographic location of the photo center at the instant of exposure.

The design of the aircraft shall be such that, when the sensor is mounted with all of its parts above the outer structure, an unobstructed view is obtained, shielded from exhaust gases, oil, effluence, and air turbulence. There is neither a requirement nor a prohibition to place the camera lenses behind a port glass in the aircraft. The sensor shall be mounted vertically in the aircraft in a gyro stabilized mount designed to isolate the sensor from angular motion and vibration of the aircraft. Angular vibration of the sensor shall be reduced to such a level so as to have no significant detrimental effect on resolution.

The aircraft shall have a proven service ceiling with an operating ceiling of not less than five percent (5%) above the highest altitude requirements to secure the specified imagery. It shall be the responsibility of the Contractor to secure all licenses and authorizations for overflight of contract areas and to secure necessary permits or clearances for controlled or restricted airspace areas. If the flight area includes a military installation, the Contractor must comply with security regulations. The Contractor shall notify the Contracting Officer as soon as possible if difficulties in obtaining the appropriate authorizations are encountered. The Contractor shall be responsible for operating and maintaining the aircraft in accordance with all applicable regulations of the Federal Aviation Administration.

Digital Sensor System:

The digital sensor system shall have the following general, large-format digital camera characteristics:

1. The cross track width shall be approximately 12,000 pixels or greater.
2. Simultaneous capture of red, green, blue, and infrared for each exposure. A captured radiometric resolution of at least 12 bits/pixel (bpp) for each band/channel.
3. If utilized, a pan-sharpening ratio of 5:1 or better.
4. Include a gyro stabilized mount, survey grade GNSS components, and an Inertial Measurement Unit (IMU).
5. The Contractor shall present the most recent manufacturer's calibration certificate or the manufacturer's most recent Geometric Calibration Verification Report for each digital sensor system. The Contractor shall also present proof that the digital sensor system has been approved by the State of North Carolina for orthoimagery projects within the past 4 years.

   The State of North Carolina, through the North Carolina Geodetic Survey, maintains a digital camera validation range in Surry County for the purpose of testing, evaluating and certifying digital imagery sensor systems for use on orthoimagery projects in North Carolina. In order to receive approval from the State of North Carolina, potential contractors are required to acquire GNSS-IMU controlled digital imagery at least every 4 years at the validation range and submit aerotriangulation data and orthophotos for evaluation by the state. Upon satisfactory evaluation of the Contractor submittals, the NCDOT Photogrammetry Unit will issue an Advisory Report indicating the digital sensor system is approved for orthoimagery projects in North Carolina

Digital Image Data Files:

Digital image data files and any interim or final products are the property of the Client. The Contractor will be responsible for storage of digital image data files under proper file maintenance and backup procedures for a period of at least 5 years at the contractor's cost. Digital data should be stored on negotiated media; internal servers and/ or redundant external hard drives. All digital media should be readable by both Windows and UNIX systems. All digital media should contain finalized closed sessions, no multi-session discs. All digital media should be properly labeled. The Contractor shall not make, sell, or loan copies of the digital

image files or any other products without the expressed written approval of the Contracting Officer. The data file shall be handled carefully before, during, and after authorized use to ensure that the quality is not degraded and is safeguarded from defects. It is the Contractors' obligation to inform the Client if he is no longer able to meet the 5 year storage requirement due to going out of business and provide an opportunity to transfer the records to the Client or their designee.

Digital Sensor Exposure History:

The contractor shall be responsible for the following deliverables as a minimum requirement: GNSS-IMU Post Processed or Aerotriangulated Exterior Orientation Parameters (NC State plane coordinates). For the pushbroom camera, exterior orientation parameters and GNSS time shall be provided at spacing equal to nominally times the final orthoimagery Ground Sample Distance (GSD).

1. Date and time of exposure (GNSS time)
2. Aircraft tail number
3. Sensor manufacture, model, serial number
4. Planned and actual altitude (MSL)
5. Sensor-specific settings.
6. Exposure ID
7. Flight line ID

(The file format shall be specified by the contracting officer)

Flight Log:

For each flight day, the pilot or sensor technician shall prepare a signed flight log containing the date, project name, aircraft used, and names of crew members. In addition, the following shall be prepared for each flight line: altitude, digital sensor make and serial number, beginning and ending exposure numbers and times, and any other comments relative to the flight conditions. Pertinent data about the sensor settings shall be included. These flight logs, or copies, shall be delivered to the Contracting Officer at the end of the project flights.

Exploitation Images:

Exploitation images result from post-processing by sensor-specific software and are ready for introduction into the production process. All radiometric and geometric

calibrations have been applied, but the images shall be in full (original) bit depth (e.g.: 12 or more bits per pixel) and include all contracted bands. This imagery shall be supplied in GeoTIFF format with overviews and accompanying TFW (TIFF World) files establishing approximate position and orientation in the project reference frame. These images, combined with aerotriangulation (or geopositioning) data shall be directly viewable in a stereoscopic imagery workstation. A shape file shall also be delivered that represents the image exposure stations in the project reference frame. The shape file attributes shall include, at a minimum, the textual name of the sensor system, the serial number of the sensor system, the name of the image file, exposure date, exposure time, position (x,y,z), orientation (omega, phi, kappa), and focal length. The contracting officer may approve the substitution of an excel file for the shape file for all or part of the information.

SECTION 3

HORIZONTAL AND VERTICAL CONTROL

HORIZONTAL AND VERTICAL CONTROL

General:

Sufficient horizontal and, if applicable, vertical control surveys shall be established by the Contractor for all photogrammetric mapping purposes. Prior to the establishment of the necessary basic horizontal and vertical control, the Contractor shall make a thorough search of the project area for existing control that has published (by the National Geodetic Survey or NC Geodetic Survey) NAD 83 horizontal positional information of the latest realization of NAD 83(at the time of the adoption of the standards the realization was NAD83 (2011) epoch 2010.0,as established by the National Geodetic Survey (NGS, formerly the United States Coast and Geodetic Survey [CGS]), North Carolina Geodetic Survey (NCGS), or the North Carolina Department of Transportation (NC DOT). North Carolina Geodetic Survey (NCGS) Station Recovery Forms are to be filled out using online forms and electronically submitted to NCGS on monuments that a recovery effort was made. This includes both monuments found and monuments not recovered or destroyed. Additional control points established by the Contractor may require permanent monuments as described in subsection **Horizontal and Vertical Control – Permanent Monuments**. All such control recovered or established shall be utilized to the fullest extent. All control used in the project will be paneled prior to flying the aerial imagery acquisition unless such control is clearly a photo-identifiable point. The Contractor will indicate on a copy of the Client Contract Map the horizontal control stations (existing and to be established). Control previously established in an adjacent county will be utilized by the Contractor to the fullest extent possible to assure compatibility of maps from county to county. The Contractor will provide the Contracting Officer a brief description of the equipment

and methods to be used for new ground surveys prior to conducting any control surveys. All horizontal and vertical control surveys shall be performed using procedures and/or accuracy standards consistent with professional surveying and photogrammetric practices. The use of Airborne Global Navigation Satellite System (ABGNSS) in combination with ground survey is required; the amount of ground control may be reduced but not eliminated by the use of ABGNSS technology. All ground control surveying activities will be directed, approved, and certified by a North Carolina Professional Land Surveyor whose area of expertise is surveying.

Horizontal Control Surveys:

All basic horizontal control shall be established by Global Navigation Satellite System (GNSS). At a minimum, all horizontal ground control placed as a result of this project shall be established at an accuracy level of Class AA (Local Control Network Surveys, 21 NCAC 56.1603) or better. OPUS-S. RS and the using of the NC Real Time Network are acceptable as long as the results meet or exceed Class AA (Local Control Network Survey) standards. NCGS and FGDC standards as applicable to the order and class of survey shall be followed. All horizontal control shall be correlated to the North Carolina Official Survey Base as defined in NC GS Chapter 102 and adjusted to the latest realization released by the National Geodetic Survey. At the time of the adoption of this standard that was **NAD83(2011) epoch 2010.0**. Said survey shall be certified in accordance with the North Carolina Board of Examiners for Engineers and Surveyors (21 NCAC 56.1607).

Vertical Control Surveys:

All basic vertical control shall be established by Global Navigation Satellite System (GNSS) using NGS-58 guidelines and/or traditional leveling techniques (21 NCAC 56.1605). At a minimum, all vertical ground control placed as a result of this project shall be established at an accuracy level of Third Order Class I or better. NCGS, NGS, and FGDC standards as applicable to the order and class of survey shall be followed. All vertical control shall be correlated to the North Carolina State Plane Coordinate System, National Geodetic Vertical Datum (NAVD), 1988.

Photo Control Points:

The Contractor is required to establish a sufficient number of control points to meet the accuracy requirements of the project. Control points may be photo-identifiable points or targeted control points. Control points may be marked and targeted for aerial imagery and then surveyed after the imagery has been flown. Control points that are not painted or paneled targets may also be used. Permanent features such as parking lot corners, sidewalk or driveway intersections, street corners, cattle guard corners, fence intersections, and other such clearly defined features selected by the project surveyor can also be used. These points may then later be used for subsequent acquisition of city, state, or national programs such as NAIP since they do not need to be repainted or paneled. Control points shall be situated on well defined, distinct, and photo-identifiable features or points that have been targeted by the Contractor (see Horizontal and Vertical Control - Targeting).

Control points shall be:

1. Situated at or very near ground level, *not* on an elevated surface.
2. Have a clear view of the sky
3. Located in relatively level terrain, away from steep embankments.
4. Located in areas where the target has a high probability of remaining undisturbed during the project.
5. Located outside of areas that may be covered by shadows at time of minimum sun angle.
6. Semi permanent markers, such as nails, should be set when possible to define the exact location of survey point observed. Example: PK nail set at the corner intersection of a private driveway and public roadway or PK nail set at the end of a paint stripe.

Note: if photo-identifiable points are use, the accompanying location description shall be sufficient to positively identify the designated point.

Permanent Monuments:

If requested in writing by the Contracting Officer, some or all control points established by the Contractor will be monumented with permanent monuments which meet the requirements for permanent monuments established by the NCGS. Said monument information is to be submitted by the Contractor to NGS Opus

database for publication if Opus is used, if a static observation is used the monument report shall be submitted as is required in Control Data section of this standard.

Survey Records:

The following information shall be delivered to the Contracting Officer as hard copy and a digital (ASCII) file:

Field Notes and Observation Logs.

Field Notes and Observation Logs shall be carefully and neatly prepared, identified, indexed and preserved. All data regarding the establishment and extension of horizontal and vertical control, including descriptions of all established and recovered monuments, shall be recorded. Where existing control points are recovered by the Contractor in extending the basic control, the field notes shall contain:

(1) Information as to the general condition of the recovered mark,
(2) The original description,
(3) Exact letter and numbers stamped on (not cast in) the mark,
(4) Amended description, if applicable,
(5) Additional tie data, if any,
(6) A sketch of the location as appropriate to facilitate future recovery.

Observation Logs shall contain:

(1) Monument name and location
(2) Name and title of the observer
(3) Time of arrival at monument
(4) Height of instrument at beginning of observation (in feet and meters)
(5) Type and serial number of the GNSS receiver(s)
(6) Type and serial number of the Tribrach(s) or type of fixed height pole
(7) Observation period (indicate if programmed)
(8) Epoch rate
(9) Satellites observed
(10) Height of instrument at end of observation (in feet and meters)
(11) Additional notes describing problems encountered during the observation period

An additional sheet containing an obstruction diagram shall be provided for each existing and/or new monument observed. North Carolina Geodetic Survey (NCGS) Station Recovery Forms are to be filled out and submitted to NCGS on searched for monuments. Each baseline shall be identified by a number and brief description in the field notes. If the field notes are electronically recorded, printouts of the electronically recorded field notes shall be provided.

Computations.

The Contractor shall do all computations necessary to comply with 21 NCAC 56 .1607 GLOBAL POSITIONING SYSTEMS SURVEYS at a minimum. Said Computations will be provided to the contract Officer upon request.

Control Diagram.

The Contractor shall furnish a control diagram report indicating all horizontal and vertical control pertinent to this project on a copy of the Client Contract Map. This report shall document all existing and established control points utilized in the project with sufficient metadata to identify the location of the control points. . The report shall be delivered to the client in the format requested by the client.

Control Data.

The Contractor shall provide the Contracting Officer with the complete information as listed below for all monumented control points established and/or recovered by the Contractor:

1. Information on control points established by the Contractor shall include the following information.
   (a) Designation of station (County name and sequential number).
   (b) Establishing agency (name of Contractor or subcontractor who established the control point).
   (c) Date of establishment.
   (d) Horizontal and/or vertical control data.
   (e) A complete description of the nature and location of the point to include the coordinate of the point and identified by field survey

ties (bearing and distance) to three or more definable photo image points in the immediate vicinity.

(f) The location of all horizontal control points, shall be provided in a Shape file oriented in the project coordinate system, and shall include each station designation. (See section (a) of this section)

2. Information on existing points recovered by the Contractor. The information will be submitted on a completed NCGS Station Recovery Form (see the web based form at NCGS's web site).

GNSS Observation Summary.

The observation summary shall contain a discussion of the results of the ground GNSS survey, including accuracies achieved, problems encountered, and a statement of the overall quality of the survey. The summary must contain the signature and seal of the Professional Land Surveyor certifying that the survey meets accuracy requirements and is tied to the proper datums.

Feet/Meter Conversions:

The U. S. Survey Foot (l meter = 3.2808333333 feet) shall be used in all conversions of North Carolina State Plane Coordinates from meters to feet or feet to meters. All final control data shall be in feet, and the datum used (e.g. **NAD83(2011) epoch 2010.0**) , and Geoid will be noted on any sheets bearing coordinates.

Global Navigation Satellite System (GNSS):

All basic horizontal and vertical control shall be established by GNSS. All GNSS network design, observation techniques, and data adjustments must be according to the specifications in the most current FGCC "Geometric Geodetic Accuracy Standards and Specifications for using GNSS Relative Positioning Techniques and the most resent specifications and standards adopted by North Carolina Geodetic Survey, including NAD and Geoid.

Global Navigation Satellite System & Inertial Measurement Units (GNSS-IMU):

The use of post processed airborne GNSS-IMU exterior orientation in combination with ground survey is required; the amount of ground control may be reduced but not eliminated by the use of GNSS-IMU technology. The following specifications shall be met for airborne GNSS-IMU exterior orientation:

General.

Airborne GNSS-IMU solutions shall be required to utilize dual-frequency GPS systems during the aerial imagery missions. The Contractor shall post-process the airborne GNSS-IMU data relative to simultaneous observations collected at fixed land-based reference stations. Geodetic positions corresponding to the photo centers at the instant of exposure shall be calculated and (later) combined with ground control point values in an analytical aerotriangulation solution.

Accuracy.

Sensor perspective centers must have accurately located position offsets with respect to the GNSS antenna phase center positions.

Ground Stations.

Simultaneous with the aerial imagery acquisition and use of airborne GNSS-IMU data, a minimum of two static GPS reference receivers must be used to record satellite data over known geodetic control points on the ground. CORS maintained by North Carolina Geodetic Survey may be used to meet this requirement. These additional receivers must be active during the entire flight mission. The base stations must be in the most appropriate locations within the project area.

Satellite Geometry.

It is the duty of the contractor to verify that space weather and satellite geometry is suitable of accurately positioning the aircraft to meet the requirements of this project.

Post-processing Software.

The GNSS-IMU post-processing software must be capable of backward and forward processing.

Reporting.

At the conclusion of Airborne GNSS collection, the Contractor shall be required to submit a report of GNSS observations and results data, observation logs, and data analysis and adjustments as part of a combined GNSS-IMU Post Processing and Aerotriangulation Report. This report shall be kept for reference. The Client reserves the right to obtain any and all data, readings, records, or any other information relating to the conduct of the survey for this project from the Contractor. This information is part of the official report and will be required to meet the requirements of the North Carolina Board of Examiners for Engineers and Surveyors rules.

Targeting:

It is the responsibility of the Contractor to place the ground control targets (panels), to monitor and repair the targets to ensure that targets have not been damaged or removed before the aerial imagery acquisition has been completed, and to remove the targets in a timely fashion once the aerial imagery acquisition has been completed. A notice shall be attached to each target identifying the contractor responsible for the targets with contact information and anticipated time of target removal. Targets shall be of an appropriate size, color, and shape to adequately appear on the selected scale of aerial imagery.

Property Entry:

Targets and ground control points should be placed on public property whenever possible; however, it is recognized that it may be desirable or necessary to locate some targets and control points on private property. It is the Contractor's responsibility to obtain owner's permission when it is necessary to pass through or locate targets or control points on private property. At the written request of the Contractor, the Contracting Officer will assist in any reasonable effort to attain permission for entry to private property.

Target Removal:

Paneling material shall be removed by the Contractor, at the Contractor's expense within 30 days after final flight approval. If the targets are painted, the paint should be such a type that is biodegradable and will wash away over a relatively short time.

SECTION 4

ANALYTICAL TRIANGULATION

ANALYTICAL TRIANGULATION:

Aerotriangulation (general):

Aerotriangulation is essentially an interpolation tool, capable of extending control points to areas between ground survey control points using several contiguous uncontrolled stereomodels. The Contractor shall use fully analytical aerotriangulation to extend the horizontal control from relatively few ground survey control points to additional supplemental control points – pass points. Each stereomodel is to be scaled and leveled using the adjusted coordinate values of the pass points located in the stereomodel. Ground control should be located along the perimeter of the project area and within the project area; should be added as necessary to limit error propagation in the adjusted pass point coordinates. The use of post preprocessed airborne GNSS-IMU data in combination with ground control surveyed points is required. The amount of ground control may be reduced but not eliminated by the use of airborne GNSS-IMU technology. An aerotriangulation solution should be limited to the areal extent of ground control wherever feasible, but may be extended beyond ground control boundaries by airborne GPS-IMU data where ground control is not feasible such as across large water bodies, into restricted military ground space, into large rural forested inaccessible areas, etc. (beyond the ground control of the project area). In conducting the aerotriangulation, the Contractor shall perform a fully analytical simultaneous bundle adjustment using a weighted least squares adjustment to meet project accuracy requirements.

Nominal Scales for Triangulation:

Aerial triangulation may be used for horizontal scaling to produce maps of 1" = 400', 1" = 200', and 1" = 100'.

Ground Coordinate Systems:

All ground positions determined by aerial triangulation will be in the North Carolina State Plane Coordinate System (see 3.02 and 3.03), Based on the NAD + Realization and NAVD + Geoid as adopted by NC Geodetic Survey. The contracting officer may require additional deliverables that are converted to another datum.

Aerotriangulation:

Aerotriangulation shall be accomplished by procedures that involve fully analytical aerotriangulation software. The Contractor must follow accepted aerotriangulation procedures and utilize equipment that will achieve the aerotriangulation accuracy required to meet or exceed required orthophoto accuracy standards. Software and hardware used by the Contractor must be capable of model orientation in both the stereo and monoscopic modes, capable of interior, relative, and absolute orientation, as well as single image resection. Manual or auto correlated pass and tie point image measurement is acceptable. The contractor will have image measurements for frame sensors at the 9 traditional Von Gruber locations per image. Those measurements will be made available to the contracting officer upon request. In regions of frame imagery where auto-correlated image measurements are not produced at the 9 traditional Von Gruber locations per image as a minimum, the Contractor shall make every effort to manually measure pass or tie points. For pushbroom sensors, pass points shall be located along each strip at intervals corresponding to, at a minimum, half of the nadir imaging array format width. Additionally, tie points in overlapping strips shall be measured at the same interval. If the Contractor elects to use photogrammetrically derived coordinates as “tie control points” between adjacent aerotriangulation blocks, then these points shall be manually measured on the ground surface, preferably at a photo-identifiable feature. The Contractor is

ultimately responsible for designing the aerotriangulation scheme that will meet the accuracy requirements of the project.

GNSS-IMU Post Processing & Aerial Triangulation Report:

Immediately upon completion of all aerial triangulation, the Contractor will prepare a formal aerial triangulation report for submission to the Contracting Officer. Two copies of the report are required and shall include, but not be limited to, the following:

Control and Flight Line Indexes.

1. Flight lines
   - Exposure stations or model layout identifying digital camera and date of acquisition
   - All control points and check points appropriately labeled with identification designation.
   - All indexes will be generated strictly from digital data sources and are printable on suitable materials at a scale suitable for presentation. The indexes will contain grid lines labeled with their corresponding northing and easting coordinate grid values. The indexes will also be labeled with the County name, map scale, title, and date. Digital index files such as shapefiles and/or pdf drawings are a required deliverable.

2. Aerial Triangulation Results.
   - Sigma naught.
   - GNSS accuracy of sensor. For pushbroom systems, the accuracy of the trajectory solution shall be presented.
   - Standard errors of adjusted tie-point terrain coordinates (RMS errors in x, y for horizontal coordinates) referenced to photo scale in micron and ground units.
   - Standard error of adjusted tie-point terrain coordinates (RMS errors of z vertical coordinates) referenced to photo scale in micron and ground units.
   - RMS errors (absolute accuracy) of x, y and z at independent checkpoints in microns at photoscale and in ground units.

- Space resection parameters for each frame of aerial imagery included in the aerial triangulation adjustment. This requirement does not apply to pushbroom systems.
- All misclosures at ground control points with and without use of checkpoints.
- Computer printout of the final adjusted aerial triangulation solution to horizontal and vertical ground control. The printout should contain the final State Plane Coordinates for all ground control points, pass points, and checkpoints.
- Identification of all points which were included in the initial solution and were subsequently discarded, with an explanation of the reasons for being discarded.
- Identification of the weighting factors applied to all points used in the final solution.
- An ASCII file on approved electronic media containing the coordinate data and the results of the FAAT adjustments.
- An RMSE report of ground control held back and used as checkpoints (not to include photogrammetric determined pass or tie points) independent of a subsequent final RMSE report that incorporates all included ground control.

3. Narrative.

   The report shall include a brief narrative tying together items from **GNSS-IMU Post Processing & Aerial Triangulation Report** and **Aerial Triangulation Results** as well as descriptions of equipment, procedures, and computer programs used. Root-mean square (RMS) error summaries shall be provided for bundle adjustment photographic measurement residuals or strip tie point residuals and misclosures at control/check points. In addition, significant misfits encountered at control points, and steps taken to analyze such misfits and to rectify the discrepancies, will be described. All control shall be listed in the report with an explanation of how the control was used in the FAAT. Also, the report shall contain a statement signed and sealed by the North Carolina Professional Surveyor (photogrammetrist) in charge of the project that the aerial triangulation

solution will provide sufficient control to produce orthophotos that meet the accuracy requirements of the project.

Drop Points:

Drop points may be used to control lower altitude flights for direct compilation from imagery of larger scale. These points shall be marked, measured, and carried as extra pass points in the aerial triangulation of the higher altitude imagery. Any drop point procedures must be specifically described within the Triangulation report narrative.

Blind Checkpoints:

Blind Checkpoints are horizontal control points that have been established through ground control procedures by the Contracting Officer for accuracy checking purposes and will not be used in the analytical adjustment. These points are for quality control and not to be shared with the Contractor.

SECTION 5

DIGITAL ORTHOPHOTOS

DIGITAL ORTHOPHOTOS:

General:

A digital orthophoto is a digital image that has the properties of an orthographic projection. It is a digital representation from a perspective aerial image by differential rectification so that image displacements caused by sensor orientation and terrain relief are removed. A simplified work flow is that a digital orthophoto is created by using a raw aerial image that is processed into an exploitation image which in turn is then rectified to an orthographic projection by processing each image pixel through photogrammetric space resection equations. This process requires, as input, aero triangulated exterior orientation parameters and a digital terrain/elevation model.

Traditional Digital Orthophotography In Built Up Areas:

Any aerial imagery will exhibit a characteristic known as relief displacement. Relief displacement is the geometric distortion that occurs due to elevation differences in the terrain being imaged. Objects of higher elevation, like buildings, hills, and trees, will be displaced radially outward from the center of the image. The greater the elevation of the object, and the further it is from the center-of-view, the greater the radial distortion. The process of ortho-rectification corrects these distortions by performing, on the image, a mathematical transformation that takes into account the shape of the terrain depicted in the form of a digital terrain model (DTM). In traditional digital orthophotography, objects like buildings and bridges are not modeled in the DTM. Therefore, the elevated portions of these features are displaced from their true location in the final orthophotography. This displacement shows up in the form of leaning buildings, towers and warped bridges. In severe cases, this displacement can be aesthetically displeasing and may impact the usefulness of the orthophotography. For example, a tall building may “lean” over a street, hiding

information like manholes, fire hydrants, and utility poles. Complex, multi-level freeway interchanges appear badly deformed. When a vector GIS layer is overlaid with the imagery, building outlines do not match up with the imagery representing the tops of the buildings, and vector road edges may appear as passing through buildings.

In the production of orthophotography the Contractor shall use Best Management Practices to minimize relief displacement. For tall buildings, the image nearest to nadir should be used, building lean should be held to a maximum coverage of 50% of the adjacent road where possible. Horizontal displacement along seam lines in images shall be held to no more than ±3 pixels along transportation features, unless project specifications specifically state otherwise. Clipping of features (e.g. radio towers, water tanks, buildings) at seam line boundaries shall be held to a minimum. Smearing shall be held to a minimum. Structure warping (bridges) shall be adjusted for viewing. While elevated structures normally are not corrected, elevated transportation features shall be corrected using Best Management Practices for viewing. It is not required that transportation features be adjusted for accurate 3D modeling.

Orthophoto Horizontal Accuracy Standards:

Orthophotos shall meet or exceed the horizontal accuracy standards as follows:

1.0' GSD - 1"=400' scale - limiting RMSE X or RMSE Y of 3.0 feet

0.5' GSD - 1"=200' scale - limiting RMSE X or RMSE Y of 1.5 feet

0.25' GSD - 1"=100' scale - limiting RMSE X or RMSE Y of 1.0 feet

0.125' GSD - 1"=50' scale - limiting RMSE X or RMSE Y of 0.5 feet

All orthophotos may be subject to quality control testing by the Contracting Officer, by independent third parties, and/or by the Contractor working under the direct review of the Contracting Officer to ensure that orthophotos comply with the accuracy requirements. See **Addendum 2, NC Orthoimagery Quality Assurance**

(QA) Procedures. If during the quality control testing position anomalies are detected, the contractor may be required to investigate said anomalies and explain or fix said anomalies even if the total project would pass the Quality Assurance Procedures with the anomalies included.

Reporting of Horizontal Accuracy:

Reporting of Horizontal Accuracy shall be as follows:

1. "This county orthophoto project was checked and found to have a RMSE X value of _____Feet and a RMSE Y value of _____feet which conforms to the horizontal accuracy standard as defined in the Orthophoto Horizontal Accuracy Standards section of North Carolina Technical Specifications for Digital Orthophoto Base Mapping by The Land Records Management Division of The North Carolina Department of the Secretary of State and

2. "This North Carolina orthophoto project was tested using the Case 1 formula and procedures set forth in FGDC-STD-007-1998. The result of that test was _____feet horizontal accuracy."

Horizontal accuracy quality control shall be implemented under the following guide lines located at:

http://www.fgdc.gov/standards/projects/FGDC-standards-projects/accuracy/part1/chapter1

http://www.fgdc.gov/standards/projects/FGDC-standards-projects/accuracy/part3/chapter3

Processed Digital Imagery:

The finished digital orthophoto shall have an image visually consistent within reason relative to the source exploitation image. The following provides a holistic approach model whereas a single contractor or multiple contractors are considered to ultimately deliver a consistent radiometric product. This product should be one defined by minimal adjustment and considers scene dependent factors such as acquisition date, time of day, environmental conditions, and landcover:

Contractors shall perform exploitation image post processing such that exploitation images are visually consistent (within reason) across the following:

1. across AT blocks within the boundaries of a study area and internally across the jurisdictions of sub-contractors
2. between study areas and specifically in overlap areas
3. internal to study areas and between multiple sub-contractors
4. with existing imagery if applicable and/or practical
5. with existing land cover representative of differing regions

Exploitation image post processing shall be such that resulting exploitation images have the following characteristics when viewing at full (1:1) resolution.

1. Pavement markings and concrete with pavement interfaces shall have clear, well-defined edges with minimum noise, minimum visual artifacts, and the absence of "black outlines".
2. Imagery should not demonstrate a "haze" effect or kept to the absolute minimum.
3. Achieve good contrast without losing detail in shadow and highlight areas

Digital Terrain Model/Digital Elevation Model:

1. A Digital Terrain Model (DTM)/Digital Elevation Model (DEM) shall be developed at a density level necessary to support the orthophoto production. Terrain/elevation data used in the development of the DTM/DEM may be captured by photogrammetric editing/updating techniques from using the most recent LIDAR dataset that is approved by the Contracting Officer. The Statewide DTM generated by North Carolina Floodplain Mapping Program is one example of an acceptable LIDAR product. If an existing LIDAR data set is used, the project area must be reviewed to determine if significant terrain altering activity has occurred since the LIDAR data was acquired. If such an area is identified the contractor shall update the DTM. The DTM/DEM will consist of points spaced at regular intervals along a grid, points of significant high or low elevations, and ortho specific breaklines at all significant terrain breaks. It is not necessary to capture breaklines at all curbs, ditches, stream banks, or other similar minor terrain breaks. Elevation/terrain data shall be captured at a density level sufficient to accurately represent the shape of the ground and to meet the required orthophoto accuracy standards defined in the contract.
2. The DTM/DEM data is <u>not</u> to be stored as a record (Z component) for each pixel of the orthophoto image.

3. The Contractor shall provide to the Client the DTM/DEM in a format that can be used on the Client's GIS system or in an acceptable standard data exchange format. Note: The DTM/DEM data will be used for the orthorectification of images and data sets, and it is acknowledged that the DTM/DEM is not suitable for detailed engineering activities.
4. DTM/DEM data generated from aerial photography of a prior project shall not be used for a new project without a quality control review and then only if approved by the Contracting Officer.

Image Completeness:

There shall be no areas of an orthophoto tile where ortho production process was incomplete due to incomplete data (i.e., lack of DTM/DEM data, image gaps, etc.).

Ground Resolution:

The horizontal ground resolution (pixel - x and y components) of the finished digital orthophoto image (both hardcopy and softcopy) shall be at a contracted Ground Sampling Distance (GSD).

Image Rectification Algorithm:

Image rectification shall be carried out using either cubic convolution or better algorithm.

Tile Coverage Area:

The geographic extent of each softcopy digital orthophoto shall be based on the North Carolina Land Records Management Program's "Basic Modular Unit" and shall cover the same geographic area. The softcopy digital orthophoto shall only contain the neat image of the corresponding map unit, and there shall be no image overlap between adjacent softcopy digital orthophotos.

Image Mosaicking:

Mosaicking shall be accomplished using both automated and interactive (manual) methods; the sole use of fully automated methods is not acceptable. Mosaic join

lines (seam lines) shall not cross through building, bridges, or other structures or items which could be considered as a visual entity and shall try to follow features such as roads, tree lines, water bodies, etc when possible. Acceptable mosaicking must produce quality orthophoto imagery of consistent tone and contrast and must do so without obvious join lines.

1. Interior mosaicking.

   Interior mosaicking occurs when an orthophoto cannot or is not made from a single digital aerial photograph, and the orthophoto is made from two or more digital aerial photographs. The join line between photograph images shall be chosen so as to minimize the obtrusiveness of the join itself and to reduce the difference in brightness, tone and contrast between the different photograph images. Interior mosaicking shall not affect the positional accuracy of the orthophoto.

2. Edge mosaicking and feathering.

   Mosaicking and feathering at/near the edge lines of adjacent orthophotos is permitted in order to create a nearly seamless image of the entire project area and to minimize any visual edge lines of adjacent orthophotos due to tonal variations. The mosaicked edge line between adjacent orthophotos shall be chosen so as to minimize the obtrusiveness of the edge line itself. If feathering (a process used on the join between two adjacent orthophotos to help reduce the difference in tone and contrast between the adjacent orthophotos) is used along the edge line, it shall not result in any noticeable image degradation such as image blurring or double imagery. Edge mosaicking and feathering shall not affect the positional accuracy of the orthophoto. The Contractor shall provide the Contracting Officer with samples of edge mosaicking and feathering to evaluate. The Contracting Officer will select one image set (four adjacent orthophotos) which will become the reference to which all sequent softcopy orthophotos will be compared for edge mosaicking and feathering acceptance/rejection.

3. Radiometry Balance.

   When a mosaic of two or more chips is made, the brightness and color values of the other chips will be adjusted to match that of the principal chip. The join lines between the overlapping chips will be chosen to minimize tonal variations. Localized adjustment of the brightness and

color values will be done to reduce radiometric differences between join areas.

4. Edge-Matching.
All chips shall not have more than ±3 pixels offset between the principal chip.

5. Seam Lines.
The contractor will provide the final seam line data set that was used to construct the Othophotos presented for quality control at the same time as image delivery. The seam line file shall be in a polygon feature class shape file format. The seamline polygon shall contain attribute fields at minimum:
    a. Flight line ID
    b. Exposure ID
    c. Image acquisition date

A North Carolina Panel Naming Convention:

OC6I_37_000_ 20765400_20100601 (name format)

- **OC** -2 digit product code: O= orthoimagery, C = color. Other product codes OB (B&W) OI (Infrared) DE (DEM)
- **6I** – 2 digit pixel size: 6 = measurement, I= unit of measure 6I = 6 inches. 1F= 1foot, 1M= 1 meter, etc
- **37** – 2 digit NC ANSI (FIPS) Code
- **000** – 3 digit alphanumeric custodian code. For county maintained data this would be county ANSI (FIPS) code, 000 for statewide, or city code (RAL) agency code (DOT)
- **20765400** – 8 digit SOS LRM Numbering of the Basic Modular Unit with Millionth place digit. (See section 6.17)
- **20100601** – 8 digit tile processed date (YYYYMMDD)
- Additional user generated info can be appended at the **END** of the file name

Mapping Basic Modular Unit: (8 digit SOS LRM BMU):

a. The 1" = 400' map is the smallest scale map included in these specifications and is designated the "Basic Modular Unit" in a series of maps which provide for four map scales, as follows:
b. 1" = 400'. The boundaries of each Basic Modular Unit shall be the grid ticks of the North Carolina State Plane Coordinate System evenly divisible by 10,000 ft. in north-south and east-west directions.
c. 1" = 200'. Each map will be one-quarter (1/4) of a Basic Modular Unit (see Attachment 1). The neat image area shall be bounded by the North Carolina grid ticks whose eastings and northings are evenly divisible by 5,000 feet.
d. 1" = 100'. Each map shall be one-sixteenth (1/16) of a Basic Modular Unit (see subsection Attachment 1). The neat image area of this unit shall be bounded by the North Carolina grid ticks with eastings and northings evenly divisible by 2,500 feet.
e. 1" = 50'. Each map shall be one sixty-fourth (1/64) of a Basic Modular Unit (see subsection 6.16 a. and Attachment 1). The neat image area of this unit shall be bounded by the North Carolina grid ticks with eastings and northings evenly divisible by 1,250 feet.

Final map tiles will conform to the Basic Modular Units as defined in this section.

Numbering of the Basic Modular Units:

Each Basic Modular Unit map shall be identified by a map number derived from selected paired digits of the east and north coordinates of the southwest corner of the module. For example, a map with the lower left corner coordinates of E = 640,000 and N = 530,000 will be named as Map Number 6543. The digit "6" in the 100,000th place of the east coordinate is paired with the digit "5" in the 100,000th place of the north coordinate; the digit "4" in the 10,000th place of the east coordinate is paired with the digit "3" in the corresponding position in the north coordinate. These four digits uniquely define the modular map unit in any one county. This map numbering system also forms an integral part of the parcel identifier number (PIN) system. In counties where the coordinate values equal or

exceed 1,000,000 feet, the digit in the millionth place is redundant and will be dropped. However, the map must be clearly identified with its proper county name. Thus, the map in Gates County having coordinates for its southwest corner of E = 2,660,000 and N = 1,010,000 can be identified as Gates County Map Number 6061. The map numbers at the 1" = 400' scale will contain only four digits. The map numbers at the 1" = 200' scale and the 1" = 100' scale will contain only six digits. For these larger scales, the first four digits of the map numbers shall be those of the Basic Modular Unit with the addition of a two-digit suffix determined according to the chart in Attachment 1. There will be a decimal point between the four digits of the Basic Modular Unit and the suffix, for example Gates County Map Number 6061.15. (See Attachment 1)

Border Data:

Traditional hardcopy map border data such as map number, north arrow, grid ticks, grid coordinate values, etc shall not be a part of the digital orthophoto image. A digital border may be included as a user applied overlay if requested by the Contracting Officer. If said overlay is included pertinent data will be inserted in the boarder overlay from the panel header. If said overlay is available for use at different zoom levels the scale ratio should be included in the information within the digital border.

Reference Product:

There shall be sample digital images chosen to represent the overall image quality here after known as the reference product. It shall be specified in the contract as to who is responsible for the production of the Reference Product. These images shall consist of defined different land cover areas: swamp/marsh, woods, rural, urban, and industrial/commercial. Contracting Officer will select sample digital image sets to evaluate and accept as examples of overall image quality. This Reference Product will be the project visual quality control reference standard. If quality control issues arise during final review, this Reference Product will be used as the project standard. The Contracting Officer will select one or more image sets that will become the reference to which all subsequent digital orthophotos will be compared for image quality acceptance/rejection. The sets will consist of four or more adjacent, like

scale orthophotos and also three or more adjacent, unlike scale (e.g. 100' against 200') orthophotos. Care should be taken to include a variety of visual conditions (large white areas – concrete, large dark areas – conifer woods, and large shadows) when choosing the reference product. The Contractor and Contractor Officer shall agree on the Reference Product area. This procedure may vary from contract to contract.

Orthophoto Image Quality:

The digital orthophoto image shall be compared to representative samples of exploitation images, the approved Reference Product and the guide lines listed below to determine if image degradation has occurred during the orthophoto process. Spot Blurring or haze that does not appear in the original imagery will be considered processing error. Depending on the severity, the contractor may be required to correct any problems. It is recognized that processing of imagery will inevitably cause some image change. North Carolina is interested in the final orthophoto products being visually consistent within reason, rather than specifying processes and procedures which vary from vendor to vendor based on their available tool sets and practices.

1. Clipping. The images shall exhibit minimal clipping by exhibiting information and detail within both shadow and highlight areas. Contrast adjustments that produce artifacts or excessive clipping shall be considered detrimental to the product and may be rejected

2. The Reference Product will be consulted.

3. Color Balance. All images should have a neutral color balance without the dominance of any individual color. Pixel color should closely represent the natural color of the ground represented by that pixel at the time of image capture if possible. In particular, pavement areas must correctly represent the gray scale of the actual pavement in development of overall color balance. There should be no attempt to mask the existing color of the ground. The contractor will make every attempt to minimize the temporal displacement between flight lines. **The Reference Product will be consulted**.

4. Band to Band Registration Accuracy:
   Registration between any color bands shall not exceed 1 pixel.

5. Image blemishes and artifacts. Imagery shall be free of blemishes, and artifacts that obscure ground feature detail. Artifact and blemishes that are introduced during the processing of the orthophotography will be reviewed on an individual basis with a bias toward rejection. Blemishes and artifacts that are a result of the capture process, such as light flashes, ghosting of moving objects, etc will be reviewed by category for acceptability.

Radiometric Resolution:

The native 12-16 bit format will be maintained though the production cycle and it may be reduced only at the production of the deliverable product. The deliverable product shall include the near infrared spectral band and can be delivered as either separate color infrared orthoimagery tiles or as 4 band orthoimagery tiles as directed by the Contracting Officer. The Contracting Officer may also elect to not include the near infrared spectral band as a deliverable in which case only 3 band color orthoimagery would be delivered.

Color Imagery.

All color imagery shall be an 8-bit RGB image in accordance with Section 6, RGB Full Color Images, of **TIFF Revision 6.0 - Adobe Partners** (https://partners.adobe.com/public/developer/en/tiff/TIFF6.pdf).

Color Infrared Imagery.

All color infrared imagery shall be an 8-bit image with bands ordered near infrared (NIR), R, G image in accordance with Section 6, RGB Full Color Images, of the **TIFF Revision 6.0 - Adobe Partners** (https://partners.adobe.com/public/developer/en/tiff/TIFF6.pdf). Modification of the near infrared band in the radiometric adjustment process shall be performed at the direction of the Contracting Officer.

4-Band Imagery.

All imagery that contains both natural color and the additional near infrared band shall meet the same requirements as color imagery specified in the paragraph above and shall have the bands ordered as Red, Green, Blue, and Near Infrared (RGBN, bands 1,2,3,4). Modification and/or inclusion of the near infrared band in the radiometric adjustment process shall be performed at the direction of the Contracting Officer.

File Compression:

The Contractor shall deliver to the Client a complete set of uncompressed digital orthophoto images in a format (GeoTIFF or TIFF with world file) on portable hard drives supplied by the contractor. In addition to the uncompressed images, the Contractor shall also deliver to the Client one sets of compressed orthophoto images using an industry accepted compression too , compression ratio, and format agreed upon by the Contracting Officer.

Deliverable Product Format:

The Contractor will only provide digital data to the Client in a format that can be used on the Client's GIS system or in an acceptable standard data exchange format. If the Contractor's GIS system either uses or can produce digital files in the same format that is used by the Client, the information shall be transferred in that format. If there is a specific intermediate format that will facilitate the transfer of the data between the two computer mapping systems, then the intermediate format may be used with the written approval of the Contracting Officer. Care will be taken by the Contractor in the construction of the data files to assure that data is compatible with and will work on the Client's GIS system. Data will not be considered as delivered until the data has been successfully loaded and utilized on the Client's system. (This assumes that the Client has an operating GIS system at the time of delivery and that problems are wholly data related and not hardware or software related.) The Contractor shall transfer the digital data to the Client on a media agreed upon between the Contracting Officer and the Contractor. Each media item will be accompanied by a label on the box

and the media, a summary report including the name of the Contractor, study area, date, etc. a fact sheet or spreadsheet that specifies the name of each file, the size of each file, the map number of each map on the media, and an index shape file that confirms the geographic extent.

Deliverable Items by Contractor:

At the completion of the mapping project as specified in the project contract or at times which facilitate the flow of work (delivery dates may be specified in the project contract), the Contractor shall deliver to the Contracting Officer for acceptance the items in Addendum 1.

Project Report:

At the completion of the project, the Contractor shall deliver to the Contracting Officer two copies of a project report. One copy of the project report shall be hardcopy (paper); the second copy of the project report shall be softcopy (as a PDF file) and shall accompany and be a part of the digital orthophoto delivery. The project report shall contain the following information:

a) Date of photography by scale.
b) Altitude of digital sensor and lens focal length**.**
c) Date of data set compilation by scale.
   Coordinate system for horizontal and vertical control (including GEOID Model) denoting metric or English units (i.e., **NAD83(2011) epoch 2010.0 and GEOID 2012A)**, assumed, or other coordinate system).
d) A list of the ground control points used for the project. The minimum data shown for each point shall include: physical attributes (i.e. iron rod, railroad spike, etc), X and Y Grid coordinates, and elevation, as applicable.
e) A statement of accuracy of the orthophotos.
f) A county map of suitable scale and detail depicting the individual orthophotos prepared by scale and map number and a count of the total number of orthophotos prepared by scale.
g) Company name, address and phone number.
h) The name of the Client agency for whom the project was conducted.

i) A statement that the orthophotos meet the Land Record Management Program Mapping Specifications with Specifications date and, if applicable, a listing of exceptions to the Mapping Specifications.

1. A certificate, substantially in the following form or a form required by the North Carolina Board of Engineers and Land Surveyors, signed, sealed, and dated by the surveyor in control of the project:

"I, _____, certify that this project was completed under my direct and responsible charge from an actual photogrammetric survey made under my supervision; that this survey was performed to meet Land Records Management Program Standards as applicable; that the imagery and/or original data was obtained on _____; that the survey was completed on _____.".

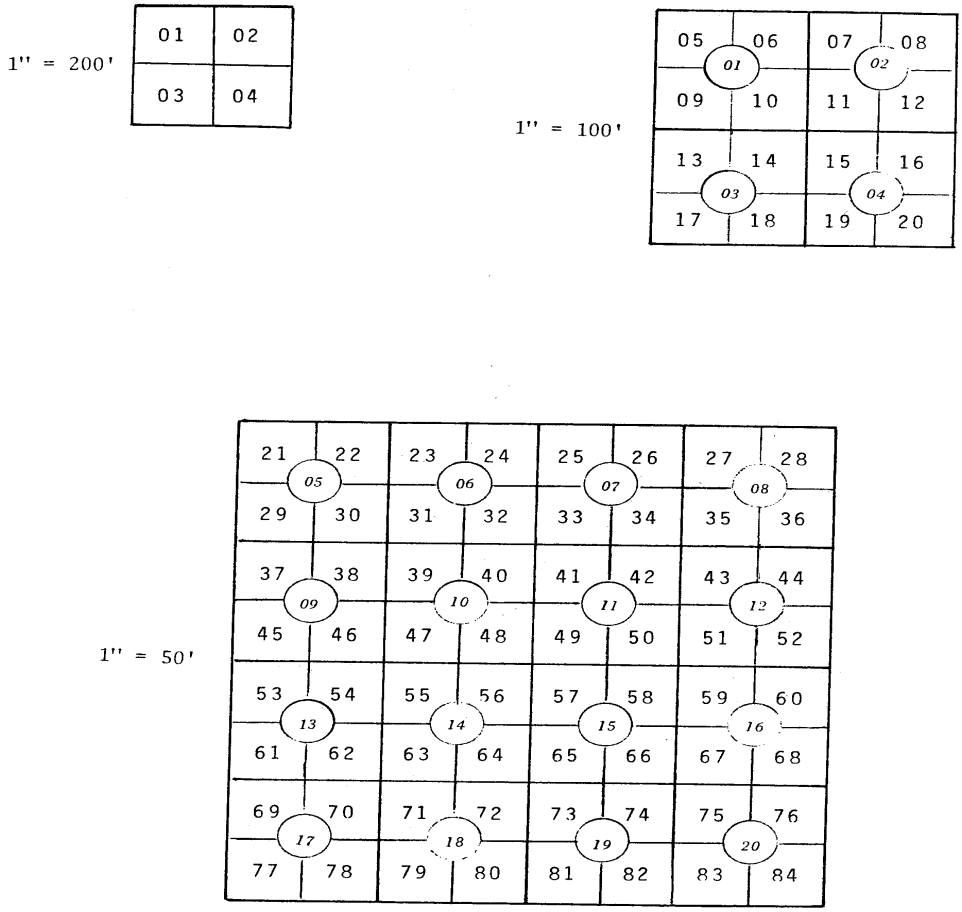
2. Identify sensor used and bands collected.

A project is not considered completed until a Project Report has been submitted to and accepted by the Contracting Officer.

Attachment 1

Numbering sequence for Tileing of areas smaller than 10,000 x 10,000

CHART SHOWING THE SUFFIXES TO BE ADDED TO THE MODULAR UNIT NUMBER FOR 1" = 200', 1" = 100' and 1" = 50' SCALES OF MAPPING



THE LARGER SQUARES CENTERED WITH CIRCLED NUMBERS REPRESENT THE LIMITS AND SUFFIX NUMBERS OF THE MAP AT THE NEXT LARGER SCALE.

Addendum 1

Deliverable Items by Contractor:

At the completion of the mapping project as specified in the project contract or at a time which facilitates the flow of work (delivery dates may be specified in the project contract), the Contractor shall deliver to the Contracting Officer for acceptance the following items:

Data:

1. One copy of each digital orthophoto image in GeoTiff format and its associated georeferencing world file.
2. One copy of each softcopy mask on the selected media (Optional)
3. One copy of the DTM/DEM used in the development of the digital orthophotos in uncompressed ASCII format on the selected media.
4. One optional compressed set of orthophoto files at the specified compression ratios for each orthophoto on the specified media
5. Original raw sensor data (at the Client's request)
6. Post Processed Exploitation Images for all contracted bands at pixel depth (bits/band) (at the Client's request)
7. Seamlines in shapefile format.
8. Map index in digital form showing the layout/location of the orthophotos.

Survey and Control:

1. Contractor will indicate on a copy of the County Contract Map the horizontal control stations (existing and to be established) that will be paneled.
2. The Contractor will provide the Contracting Officer hard copy and digital (ASCII) files of survey records:
    a. Field notes and observation
    b. North Carolina Geodetic Survey (NCGS) Station Recovery Forms are to be filled out using online forms and electronically submitted to NCGS
    c. Computations
    d. Control Diagram
    e. Control Data

f. GNSS Observation Summary

3. At the conclusion of Airborne GNSS collection, the Contractor shall be required to submit a report of GNSS observations and results data, observation logs, and data analysis and adjustments
4. The Contractor will provide the Contracting Officer a brief description of the equipment and methods to be used for new ground surveys prior to conducting any control surveys.

Acquisition and Data Reporting:

1. The sensor calibration report shall be submitted to the Contracting Officer for approval before proceeding with work.

2. The flight logs, or copies, shall be delivered to the Contracting Officer at the end of the project flights.
3. Within one week of each flight mission, the Contractor shall submit a detailed quality control report to the Contracting Officer confirming compliance to the aerial photography specifications. If the Contractor cannot meet the one-week reporting time frame the Contractor shall inform the Contracting Officer in advance of the delay.

4. The Contractor will provide the Contracting Officer the GNSS-IMU Posting Processing & Aerial Triangulation Report.

Reporting

1. A summary fact sheet shall contain the following items.
   a) Image Naming Convention Standard Definition
   b) Delivery date
   c) Nominal map scale
   d) Location map of tiled study area with base map
   e) Name of Contractor
   f) Name and license number of professional registered land surveyor/photogrammetrist in charge of project
   g) Number of tiles delivered
   h) Coordinate system of map - (NC State Plane)
   i) Horizontal datum
   j) Map unit - (feet)
   k) Feet /meter conversion – (US Survey Foot)

l) Image pixel resolution of final orthoimagery product (GSD)
m) Bounding coordinates
n) Digital sensor type
o) Sensor serial number
p) Acquisition scale of Imagery
q) Range of acquisition dates
r) Map horizontal accuracy
s) DEM development
t) Mapping standards used – (NC Land Records Management Mapping Specifications, 2014)

2. FGDC compliant metadata. See North Carolina endorsed standards and resources on NC OneMap http://www.nconemap.com/DiscoverGetData/Metadata.aspx .
3. Flight and Control Plan
4. Imagery Acquisition Compliance Report
5. Two copies of the Project Report
6. Aerotriangulation (AT) Report, including ASCII file
7. Ground Control survey report to include datasheets.
8. Airborne GNSS and IMU post processing data and report.
9. Horizontal Accuracy Assessment
10. Reference Product

Addendum 2

NC Orthoimagery Quality Assurance (QA) Procedures

A data delivery inventory is required at the beginning of the QA process. Deliverables are checked against the Statement of Work (SOW)/State Standard and task order to verify that all delivery specifications were met. Specific items inventoried include:

1. Formatting and Delivery

- Verify shipping manifest against materials received.
- Media drive is not corrupted and all orthoimagery files expected in delivery have been received.
- Media drive does not contain residual or stale data and manufacturer software has been removed.
- All media can be read by appropriate software, such as ESRI, Microstation, GeoExpress, and Intergraph products.
- All orthoimages have been correctly named as stated in the contract or partnership agreement.
- All data is organized by agreed upon folder structure to include orthoimagery files, metadata, seamline polygons, DEM adjustment areas, index grid or any other project related data.
- Verify any use or distribution restrictions with the data and document in the project file.
    - Notify Contractor of any discrepancies/problems immediately, before the rest of the QA process is begun.

2. Image Quality

Every image tile within a project is visually inspected for the following. The Reference Product will be the project visual quality control reference standard. If quality control issues arise during final review, this Reference Product will be used as the project standard. Examples of common visual and geometric discrepancies and guidelines for in and out of scope issues can be found at http://nconemap.com/Portals/7/documents/EP13_Voice_IssuesHelp.pdf.

2.1. Radiometric visual consistency demonstrated at a macro level.
2.2. Tonal quality demonstrating visual consistency within reason across the project area and between regions.
2.3. Tone, contrast, over/under exposure, and over/under saturation.
2.4. Leaf off conditions.
2.5. Cloud cover, shadows, smoke, haze, snow, and flooding that obstruct ground features.
2.6. Seamlines do not visibly impact structures or other manmade items (road, bridges, etc.) or are not noticeably visible in non-rural landcover.

2.7. Horizontal displacement is less than ±3 pixels along transportation features unless project specifications specifically state otherwise.
2.8. Artifacts, blurs, seamline displacement, pixel stretching.
2.9. Distortions, misrepresentations, smears, warped or wavy features or structures. Smearing that affects cultural features will be corrected by the Contractor.
2.10. Excessive tilt in bridges, buildings, and other raised features as to not obstruct more than 50% of any adjacent roads.
2.11. Clipped features and non-conforming edgematching at tile boundaries and edges.
2.12. Elevation issues that cause building or road distortion or warping.

Note: All edges are checked. During this inspection, individual images are checked for problems. The maximum allowable misalignment between transportation features is ±3 pixels.

3. Reference Data

- All orthoimagery files are GeoTIFF 6.0 compliant to not include custom tags.
- TIFF world file is delivered that aligns with the TIFF file name and is expressed to minimum of two decimal places.
- Imagery files are referenced to and use a defined projection for the North Carolina State Plane Coordinate System, NAD83 (2011) US Survey Feet, or other agreed upon coordinate system.

4. Horizontal Accuracy Assessment.

When test point control is available and "suitable", a horizontal accuracy check is performed to verify the veracity of the data producer's accuracy statement. In the interest of clarity, "suitable" test point control is defined to be:

4.1. Completely independent of data used in the production of the base dataset.
4.2. Independent accuracy of test point control should ideally be at least *three times* more accurate than the dataset being tested whenever possible. At an absolute minimum, test points must have a horizontal accuracy better than the ground sample distance (or pixel size), of the imagery being tested.
4.3. Situated on well defined, distinct, and photo-identifiable features.
4.4. Situated at or very near ground level, *not* on an elevated surface.
4.5. Preferably obtained by an entity other than the producer of the base data.
4.6. Located in relatively level terrain, away from steep embankments.
4.7. Not within shadows that might interfere with imagery measurement.

Test points should be dispersed throughout the project area as much as possible. If the dataset to be tested covers a rectangular area, at least 20% of the points should fall in each quadrant (NW, NE, SW, SE). The spacing between points should be at least 10% of the diagonal distance across the rectangular area. The minimum spacing guideline can be waived if more than the minimum number of independent test points are established. However, the logic behind the spacing requirement is to ensure that the points are not clustered in a few regions of the project dataset, and that requirement remains.

Reporting of Horizontal Accuracy shall be as follows:

1. "This _____ orthophoto project was checked and found to have a RMSE X value of _____Feet and a RMSE Y value of _____feet which conforms to the RMSE standard as defined in the North Carolina Technical Specifications for Digital Orthophoto Base Mapping

And

2. "This _____ orthophoto project was tested using the Case 1 formula and procedures set forth in FGDC-STD-007-1998. The result of that test was _____feet horizontal accuracy."

Horizontal accuracy quality control shall be implemented under the following guide lines.

http://www.fgdc.gov/standards/projects/FGDC-standards-projects/accuracy/part1/chapter1

http://www.fgdc.gov/standards/projects/FGDC-standards-projects/accuracy/part3/chapter3

5. Metadata Inspection

- Verify the existence and content of project-level metadata in an .XML and .TXT format metadata file that is FGDC compliant.
- Check for proper FGDC metadata structure and mandatory elements:
  - Check for correct project/urban area name usage.
  - Check for proper citations, abstract, and purpose.
  - Check for appropriate dates for time period, production and metadata.
  - Check for minimum bounding rectangle entry.
  - Check for Data Credits.
  - Check for pertinent placekey entries.
  - Check for production platform/software.

- Check for a production process description narrative.
- Check for an accuracy report narrative and RMS entry.
- Check for image, elevation, and control entries in the lineage.
- Check for data quality entries (logic and completeness).
- Check for accurate geospatial entries (coordinate system, units, horizontal datum).

References

"Positional Accuracy Handbook; Using the National Standard for Spatial Data Accuracy to measure and report geographic data quality;" Minnesota Planning Land Management Information Center; October 1999. http://www.mnplan.state.mn.us/pdf/1999/lmic/nssda_o.pdf

Checkpoint location cited in ASPRS Accuracy Standards for Large Scale Maps, July 1990

"Guidelines and Specifications for Flood Hazard Mapping Partners; Appendix A: Guidelines for Aerial Mapping and Surveying; FEMA; April 2003.
http://www.fema.gov/library/viewRecord.do?id=2206

"Geospatial Positioning Accuracy Standards; Part 3: National Standard for Spatial Data Accuracy"; Federal Geographic Data Committee; 1998
http://www.fgdc.gov/standards/projects/FGDC-standards-projects/accuracy/part3/chapter3