

## Aerial Imagery & Lidar: Categories of Service

1. **Aerial Imagery Deliverables, Standards and Requirements.** This section is for imagery acquisition planning, data standards, data processing and product deliverables.
  - a. **Aerial Imagery Deliverables.** Potential products delivered under this contract include, but are not limited to, the following:
    - i. Digital Aerial Photos (all four-band imagery)
    - ii. Planimetric Data
  - b. **Hardcopy color prints of image mosaics in a variety of scales, format sizes and cartographic layouts Aerial Imagery Standards.** All work performed and imagery provided under the program must meet the following standards. Environmental and Seasonal Conditions will be defined in each individual Work Order Contract.
    - i. Radiometric Resolution: Delivered imagery shall consist of 8 bits per band
    - ii. Spectral Resolution: All imagery provided in four spectral bands: blue, green, red, near infrared
    - iii. Projection/Grid Coordinate System: Geographic projection of the deliverables will be determined on a work order basis, but may include the following:
      1. UTM Zone 15, NAD83, Meters as described in the Minnesota State Standard Coordinate Specifications for Spatial Data Exchange Between Minnesota State Agencies, which can be found here: <https://mn.gov/mnit/government/policies/geo/spatial-data-exchange.jsp>
      2. Minnesota County Coordinate System, NAD83, defined as using Lambert Conformal Conic, Transverse Mercator, or Oblique Mercator mapping projections as described by the Minnesota Department of Transportation Land Management Division <http://www.dot.state.mn.us/surveying/toolstech/mapproj.htm>
      3. Minnesota SPCS2022, NATRF2022 as described by the National Geodetic Survey<sup>3</sup>
      4. Minnesota Regional Coordinate System, NATRF2022 as described by the Minnesota Department of Transportation Land Management Division<sup>4</sup>
    - iv. Tiling schemes
      1. USGS Quarter Quads
      2. Counties
      3. Custom - e.g., townships, engineering-level sites, management regions
    - v. Image formats
      1. JPEG2000
      2. GeoTIFF
      3. Subscription. Access to aerial imagery via a subscription model.
    - vi. Horizontal Accuracy: Horizontal accuracy shall meet or exceed the ASPRS horizontal accuracy standard for specified ground sampling distance. Accuracy testing methodology should follow the guidelines and specifications of NSSDA.

Ground Sample Distance	High Accuracy RMSE(x and y)	NMAS Standard Mapping Accuracy RMSE(x and y)	Visualization Accuracy RMSE(x and y)
5.0 cm (~2 in)	5.0 cm	10 cm	15 cm
7.5cm (~3 in)	7.5 cm	15 cm	22.5 cm
15 cm (~6 in)	15 cm	30 cm	45 cm
30 cm (~12 in)	30 cm	60 cm	90 cm
50 cm (~20 in)	50 cm	100 cm	150cm

- vii. Image Quality: Images shall be tonally balanced and image mosaics shall be uniform in contrast without abrupt variations between image tiles. Imagery shall be free of blemishes, scratches, and artifacts that obscure ground feature detail. Pixel resolution shall not be degraded by excessive image smear. Imagery shall have a tonal range that prevents the clipping of highlights or shadow detail from the image. No more than 2% of the pixels may have a luminosity value in the first five or last five histogram bin values (0 to 4 or 251 to 255). If needed, contrast of the tiles should be stretched. All tiles shall have a pixel histogram peak for all bands between 108 and 148 except for tiles that are mostly comprised of water bodies.
- viii. Sun Angle: The Contractor shall acquire imagery only during that portion of the day when the sun angle exceeds the minimum twenty-five degrees (25°) above the horizon unless otherwise specified by a work order.
- ix. Environmental Conditions: Imagery shall be acquired when skies are clear, free from clouds, smoke or excessive haze, and well-defined images can be resolved. The ground shall be free from snow, standing water (other than natural or man-made ponds and lakes), flood waters from streams which have overflowed their banks, and wet ground which obscures field, soil or crop lines. The Contractor shall minimize specular reflections, by patching the area using imagery from other frames, if they exist.
1. Snow-free means less than 5% of the ground surface is covered by snow for any image tile. Minimal snow cover from residual snow stockpiles and along fence and windrows is acceptable. Open water bodies smaller than 20 acres should be ice-free.
  2. Cloud-free means less than 5% of any image tile is affected by clouds or cloud shadows and free from distinct dark shadows. It includes areas under overcast, or showing clouds, cloud shadows and ground fog, or heavy haze.
  3. Smoke-free means less than 5% of any image tile is affected by smoke or haze.
  4. Flood-free means less than 5% of any image tile is affected by floodwater.
- x. Seasonal Conditions: Imagery may be collected under various seasonal conditions as specified by the work order. Since there is variability in timing of the desired conditions, the State will issue a flight Authorization and a Stop Work Order by electronic mail (e-mail) on or about these dates. No acquisition work is to take place outside the authorized period. The work order will specify one of the following seasonal conditions:
1. Spring leaf-off is defined as the period in spring before leaves of any tree species have developed to the point where leaf shape can be observed. This typically occurs in April for southern Minnesota and later April to mid-May for northern Minnesota.

2. Summer leaf-on is defined as the period after most trees have developed leaves and before the leaves of any tree species have changed color in the fall. Typically from later May through early September.
  3. Fall peak color is defined as a phase of autumn deciduous leaf color change, in which approximately the following visual conditions prevail: lowland black ash (*Fraxinus nigra*) has dropped most or all its leaves; a majority of northern hardwoods, e.g. maples (*Acer* spp.) and basswood (*Tilia Americana*), have turned bright yellow or red; tamarack (*Larix laricina*) needles should be changing to a yellow color, but most oaks (*Quercus* spp.) and aspens (*Populus* spp.) remain green. This typically occurs in late September for northern Minnesota and early October for southern Minnesota.
- xi. Control: Airborne GPS (Global Positioning Systems) and IMU (Inertial Measurement Unit) systems or equivalent methodology, along with any ground control points required to meet horizontal accuracy specifications. The State and its partners will utilize quality control points established by MNDOT and other governmental partners.
  - xii. Project Flight Planning: The contractor is responsible for all necessary flight planning, including, but not limited to determination of photographic scale, exposure stations, altitudes, and flight directions, required to acquire the imagery. Additionally, the contractor is required to provide the necessary project management, coordination, and supervision to conduct project planning, flight planning and acquisition, image processing, product delivery, and related technical and progress reports.
  - xiii. FAA Certification: All aircraft used in the performance of this contract shall be maintained and operated in accordance with all regulations required by the U.S. Department of Transportation, Federal Aviation Administration (FAA). Aircraft operated in the acquisition of digital imagery under this contract shall be FAA certified to a service ceiling with operating load (crew, camera, film, oxygen, and other required equipment) of not less than the highest altitude required.
  - xiv. Positive Control Airspace: The project areas may contain areas of controlled or restricted airspace. It is the responsibility of the Contractor to obtain all approvals necessary to assure that required clearances are achieved. When the flight plan and location of any project area coverage fall within positive-control airspace, the aircraft must contain the appropriate equipment to operate in such positive-control areas within the purview of the Federal Aviation Regulations. In addition to all FAA requirements, all flights requesting clearance in the vicinity of "VIP" type airspace with Temporary Flight Restrictions (TFR) shall notify the Contracting Officer prior to receiving FAA clearance for instructions.
  - xv. Aircraft Configuration: The design of the aircraft shall be such that when the camera is mounted with all its parts within the outer structure, an unobstructed field of view is obtained. The field of view shall be shielded from the exhaust gases, oil, effluence, and air turbulence. The camera port glass shall be free of scratches and of such quality that it will not degrade the resolution or the accuracy of the camera.
  - xvi. Progress Reporting: Between issuance of the Flight Authorization and the Stop Work Order, weekly progress reports showing progress of aerial imagery shall be e-mailed to the Project Manager as listed in the Work Order Contract, starting with the week in which Flight Authorization is issued and continuing until photography is completed, whether photo crews are active or not. Each reporting week shall end on Saturday, and the report shall be e-mailed by the end of the following Monday. The report must list flight hours and line segments flown by aircraft and date for the entire week. When crews are not actively employed on the project, the report should so state, and give the reason.

c. **Planimetric Data Elements**

- i. Features captured may include, but are not limited to the following:
          1. Water bodies-lakes, rivers, streams, ditches, ponds, islands
          2. Buildings/Structures-buildings, parking lots, tanks, water towers, swimming pools, decks, docks
          3. Transportation-roads (edges, medians, and centerlines), bridges, railroads, sidewalks, trails
        - ii. Data Structure: The structure of the data including the data format (e.g.: DWG, SHP, DGN, FGDB), number of layers, attribute field names, geographic project, and geographic representation (point, line, polygon) will be defined on a work order basis.
        - iii. Content: May be new planimetric and/or updates to existing planimetric data.
      - d. **General Requirements.** All work performed under the Program must meet the following requirements:
        - i. Metadata Information: Metadata for this project shall meet the requirements of the Minnesota Geographic Metadata Guidelines (see <http://www.mngeo.state.mn.us/chouse/meta.html>) or the Federal metadata standard (see <http://www.fgdc.gov/metadata/geospatial-metadata-standards>).
          - i. Metadata for ortho and stereo imagery: Supplemental metadata information includes the following: (1) tested horizontal accuracy statement, (2) lineage, including, but not limited to: flight height, photo acquisition dates (and reflights if any), overlap, sidelap, number of flight lines, number of exposures, direction of flight lines, control, resolution, tiling scheme, file sizes, description of the process used to create digital orthophotos, source of DEM, etc., and (3) spatial reference information: projection, ellipsoid, horizontal and vertical datum, horizontal and vertical units, grid coordinate system name and/or UTM zone number.
          - ii. Ownership: All data received from the vendor shall become the property of the State of Minnesota without restriction. A copy of all work performed, whether for the State or another master contract user, will be sent to the Minnesota Geospatial Information Office (MnGeo). Ownership of data provided via a subscription will be negotiated on a per work order basis.
          - iii. Timeline: The timeline for work will be specified by the work order but will not extend beyond the termination date of the Master Contract.
2. **Lidar Deliverables, Standards and Requirements.** Except where explicitly stipulated in a Work Order Contract solicitation issued under the program, all products delivered under this program must conform to the most current USGS Lidar Base Specification. The Contractor must be able to meet the highest lidar quality level requirements for data submission to the USGS 3D Elevation Program, currently defined as quality level - 0 (QL0). The most current USGS Lidar Base Specification can be found here: <https://www.usgs.gov/core-science-systems/ngp/ss/lidar-base-specification-online>
  - a. **Lidar Deliverables.** Potential products delivered under this contract include, but are not limited to, the following:
    - i. Metadata
    - ii. Bare-Earth Digital Elevation Model (DEM)
    - iii. Breaklines (PolylineZ and PolygonZ)
    - iv. Survey reports (control points and check points)
    - v. Collection/Mission, Processing, and QA/QC Reports
    - vi. Lidar swath polygon
    - vii. Product metadata and metadata tags

- b. **Additional Lidar Product Deliverables** include but are not limited to the following: (buy-ups)
- i. Full Waveform collection and delivery
  - ii. Additional Environmental Constraints (e.g., flood stages and tides)
  - iii. Digital Surface Model (DSM; non-hydro-flattened)
    0. Using all returns and first returns only
  - iv. Intensity Images (Normalized, 8-bit grayscale, tiled)
  - v. Additions to the Minimum Lidar Classification Scheme required by 3DEP (additional point cloud classifications)
    0. Class 3: Low vegetation; Class 4: Medium Vegetation (use for single vegetation class); Class 5: High Vegetation; Class 6: Buildings, other man-made structures
    1. Class n: Additional classes or features as agreed upon in advance
  - vi. Hydro-modified Digital Elevation Model (DEM) that establishes hydrologic connectivity across digital dams in the DEM surface.
  - vii. Hydro-breaklines (PolylineZ and PolygonZ) for additional hydrographic and topographic features beyond those features required to meet hydro-flattening requirements such as:
    0. For water bodies (inland lakes and ponds) smaller than 2 acres
    1. For water ways (inland rivers and streams) narrower than 30 meters and with double-lines (bank-to-bank)
    2. Culverts, man-made water control structures and other draining or blockage features
    3. Feature extraction and mapping for other hydrologic areas (i.e., swamp, marsh, and ephemeral watercourses)
  - viii. Extracted infrastructural elements (i.e., polygonZ; building footprints, bridges)
  - ix. Machine generated contours to a minimum of 1-foot intervals (PolylineZ)

c. **Lidar Specifications**

Collection Requirements. All deliverables produced under this contract must meet the most current USGS specifications for the following items:

- i. Seasonal Conditions: Lidar may be collected under various seasonal conditions as specified by the Work Order Contract. Since there is variability in timing of the desired conditions, the State will issue a flight Authorization and a Stop Work Order by electronic mail (e-mail).
- ii. Control: Airborne GPS (Global Positioning Systems) and IMU (Inertial Measurement Unit) systems or equivalent methodology, along with any ground control points required to meet accuracy specifications. The State and its partners will utilize quality control points established by MNDOT or other governmental partners.
- iii. Project Flight Planning: The contractor is responsible for all necessary flight planning, including, calibration, control, altitudes, and flight directions, required to acquire the lidar data. Additionally, the contractor is required to provide the necessary project management, coordination, and supervision to conduct project planning, flight planning and acquisition, data processing, product delivery, and related technical and progress reports.
- iv. FAA Certification: All aircraft used in the performance of this contract shall be maintained and operated in accordance with all regulations required by the U.S. Department of Transportation, Federal Aviation Administration (FAA). Aircraft operated in the acquisition of lidar data under this contract shall be FAA certified to a service ceiling with operating load of not less than the highest altitude required
- v. Positive Control Airspace: The project areas may contain areas of controlled or restricted airspace. It is the responsibility of the Contractor to obtain all approvals

necessary to assure that required clearances are achieved. When the flight plan and location of any project area coverage fall within positive-control airspace, the aircraft must contain the appropriate equipment to operate in such positive-control areas within the purview of the Federal Aviation Regulations. In addition to all FAA requirements, all flights requesting clearance in the vicinity of "VIP" type airspace with Temporary Flight Restrictions (TFR) shall notify the Contracting Officer prior to receiving FAA clearance for instructions.

- vi. Progress Reporting: Between issuance of the Flight Authorization and the Stop Work Order, weekly progress reports showing progress of lidar data acquisition shall be e-mailed to the Project Manager as listed in the Work Order Contract, starting with the week in which Flight Authorization is issued and continuing until lidar data acquisition is completed, whether data acquisition crews are active or not. Each reporting week shall end on Saturday, and the report shall be e-mailed by the end of the following Monday. The report must list flight hours and line segments flown by aircraft and date for the entire week. When crews are not actively employed on the project, the report should so state, and give the reason
- vii. Data Processing and Handling Requirements. All data processing and handling must adhere to the most current American Society for Photogrammetry and Remote Sensing (ASPRS) data processing specifications [https://www.asprs.org/wp-content/uploads/2010/12/LAS\\_1\\_4\\_r13.pdf](https://www.asprs.org/wp-content/uploads/2010/12/LAS_1_4_r13.pdf)