

## 5. ANALYTICAL TRIANGULATION

Aerotriangulation is essentially an interpolation tool, capable of extending control points to areas between ground survey control points using several contiguous uncontrolled stereo models. 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 stereo model is to be scaled and leveled using the adjusted coordinate values of the pass points located in the stereo model. Ground control should be located along the perimeter of the project area; within the project area, ground control should be added as necessary to limit error propagation in the adjusted pass point coordinates. The use of airborne GPS (ABGPS) in combination with ground survey is required; the amount of ground control may be reduced but not eliminated by the use of ABGPS technology. An aerotriangulation solution should never be extended 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 accuracy requirements.

### 5.01 Nominal Scales for Triangulation:

Aerial triangulation may be used for horizontal scaling to produce maps of 1" = 400', 1" = 200', and 1" = 100'. The nominal scale of the mapping photographs will be 1" = 2,400' for 1" = 400' maps, 1" = 1,200' for 1" = 200' maps, and 1" = 600' for 1" = 100' maps.

### 5.02 Ground Coordinate Systems:

All ground positions determined by aerial triangulation will be in the North Carolina State Plane Coordinate System, NAD 1983 and NGVD 1988.

### 5.03 Standards:

- a. Positional Accuracy. The root-mean-square error (vector of both northing and easting coordinate errors) of passpoints established by aerial triangulation shall not exceed 1/8,000 of the flight altitude.
- b. Elevation Accuracy. The elevation accuracy of passpoints shall not exceed 1/6,000 of the flight altitude.

#### **5.04 Softcopy Aerotriangulation:**

Aerotriangulation shall be accomplished by softcopy procedures that involve softcopy workstations, fully analytical aerotriangulation software, and high-resolution scanners. All interior, exterior, and control point mensuration shall be read from the scanned images. The Contractor must follow accepted softcopy 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 stereo and monoscopic modes, capable of interior, relative, and absolute orientation, as well as single photo resection. Once acceptable scanned images are created, the softcopy aerotriangulation process used by the Contractor shall conceptually follow the process used with a traditional analytical stereo plotter. Latitude will be used in allowing the Contractor to use specific expertise in softcopy aerotriangulation as it relates to the number and type of pass points selected. Individual scanned photo frames will carry a minimum of nine (9) pass points, with the exception of end frames of flight lines which will carry a minimum of six (6) pass points; however, it is assumed that more pass points per frame will be selected to improve the triangulation solution. The Contractor is ultimately responsible for designing the aerotriangulation scheme that will meet the accuracy requirements of the project.

#### **5.05 Drop Points:**

Drop points may be used to control lower altitude flights for direct compilation from photography of smaller scale. These points shall be marked, measured, and carried as extra passpoints in the aerial triangulation of the higher altitude photography.

#### **5.06 Checkpoints:**

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.

#### **5.07 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:

a. Control and Flight Line Indexes.

- Flight lines

- Exposure stations or model layout
- All control points appropriately labeled with station designations, computer designations (if any), agency responsible for establishing the stations, and orders of accuracy

All indexes will be generated 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.

b. Aerial Triangulation Results.

1. Sigma naught.
2. GPS accuracy of camera station.
3. 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.
4. Standard error of adjusted tie-point terrain coordinates (RMS errors of z vertical coordinates) referenced to photo scale in micron and ground units.
5. RMS errors (absolute accuracy) of x, y and z at independent checkpoints in microns at photoscale and in ground units.
6. Space resection parameters for each frame of aerial photography included in the aerial triangulation adjustment.
7. Photogrammetric measurements for each camera fiducial mark and photo center measured for each frame included in the aerial triangulation adjustment.
8. All misclosures at ground control points with and without use of checkpoints.
9. 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.
10. Identification of all points which were included in the initial solution and were subsequently discarded, with an explanation of the reasons for being discarded.
11. Identification of the weighting factors applied to all points used in the final solution.
12. An ASCII file on CD containing the coordinate data and the results of the FAAT adjustments.

- c. Narrative. The report shall include a brief narrative tying together items 5.10 a. and b. 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 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 land 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.