## Contact information

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## Project Name: Roan Plateau II

### 1. ALTM Specifications

This survey used an Optech Gemini Airborne Laser Terrain Mapper (ALTM) serial number 06SEN195 mounted in a twin-engine Cessna Skymaster (N337P). This ALTM was delivered to the UF in 2007 as the first operational system of its kind in the United States. System specifications appear below in Table 1.

| | |
|---|---|
| Operating Altitude | 80 - 4000 m |
| Horizontal Accuracy | 1/11,000 x altitude; ±1-sigma |
| Elevation Accuracy | 5 - 10 cm typical; ±1-sigma |
| Range Capture | Up to 4 range measurements per pulse, including last |
| Intensity Capture | 4 Intensity readings with 12-bit dynamic range for each measurement |
| Scan Angle | Variable from 0 to 25 degrees in increments of ±1degree |
| Scan Frequency | Variable to 100 Hz |
| Scanner Product | Up to Scan angle x Scan frequency = 1000 |
| Pulse Rate Frequency | 33 - 167 KHz |
| Position Orientation System | Applanix POS/AV including internal 12-channel 10Hz GPS receiver |
| Laser Wavelength/Class | 1047 nanometers / Class IV (FDA 21 CFR) |
| Beam Divergence nominal (1\e full angle) | Dual Divergence 0.25 mrad or 0.80 mrad |

**Table 1 – Gemini ALTM specifications.**

## 2. Survey area

The survey area is a rectangular polygon north of Parachute, Colorado enclosing approximately 40 square kilometers. The survey polygon is shown below in Figure 1.

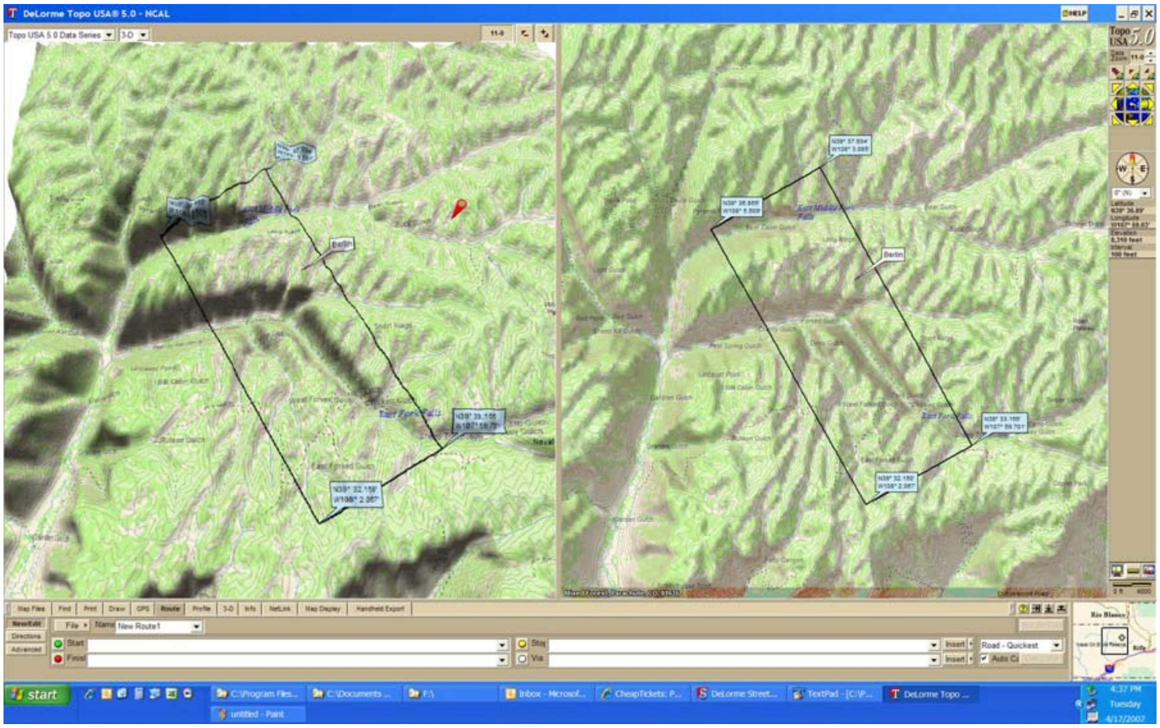


**Figure 1 – Size, shape and location of survey polygon.**

### 3. Survey Times
This area was flown on Friday April 20, 2007 in two flights originating out of Walker Field, Grand Junction's local airport

### 4. Survey Parameters

The survey required 19 flight lines, shown below in Figure 2.

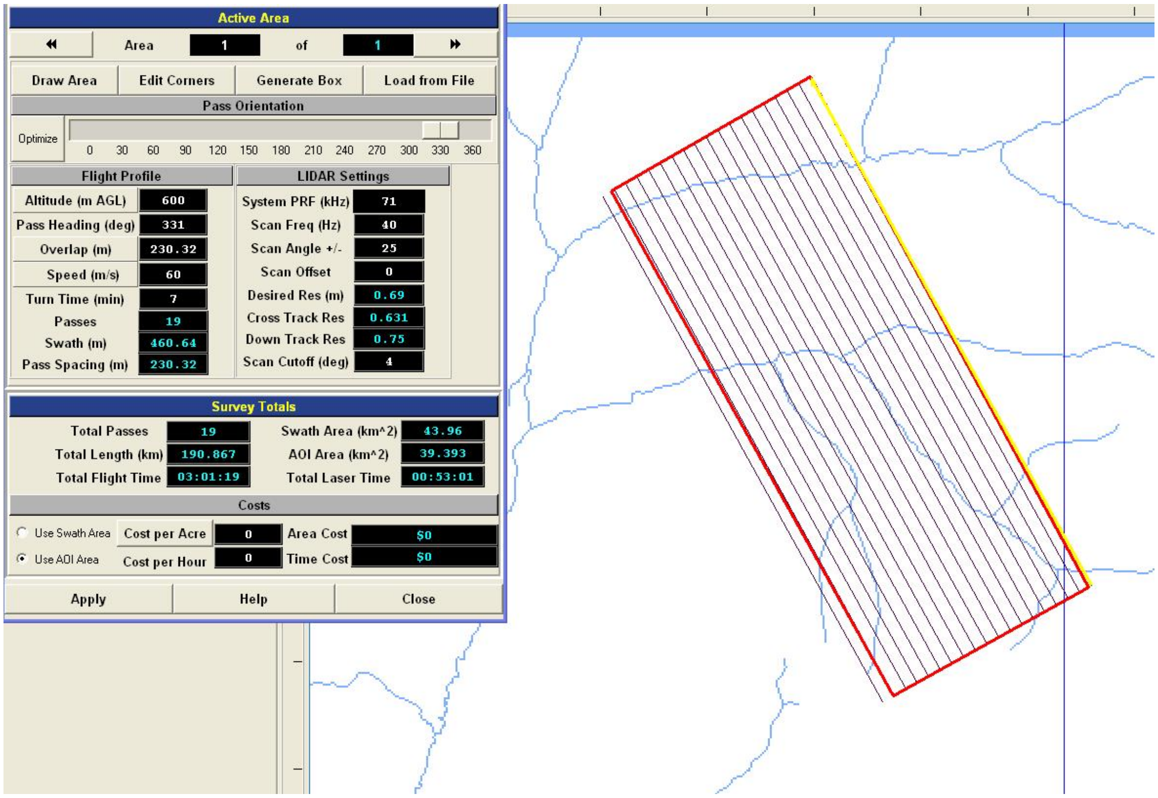



**Figure 2 - Flight lines with planning parameters.**

Survey totals appear below in Table 3.

| Survey Totals | |
|---|---|
| Total Passes | 19 |
| Total Length | 190 km |
| Total Flight Time | 03:02:00 |
| Total Laser Time | 00:53:01 |
| Total Swath Area | 44 km^2 |
| Total AOI Area | 39 km^2 |

**Table 3 – Survey totals.  Area of Interest is abbreviated AOI.**

LiDAR settings are shown in Table 4.

| LiDAR Settings | |
|---|---|
| Desired Resolution | 0.69 m |
| Cross Track Resolution | 0.63 m |
| Down Track Resolution | 0.75 m |
| Scan Frequency | 40 Hz |
| Scan Angle | +/- 25 deg |
| Scan Cutoff | +/- 4.0 deg |
| Scan Offset | 0 deg |
| System PRF | 70 kHz |
| Swath Width | 460 m |

**Table 4 – LiDAR settings.**

Actual point spacing and aircraft altitude varied from planned settings due to mountainous terrain.

## 5. GPS Reference Stations

Four GPS reference station locations were available during the survey two of the four belonging to the Mesa County Cooperative CORS network. Station identifiers of these stations are MC01 and MC03. More information on these sites can be found at http://www.ngs.noaa.gov/CORS/. The third available station (P031) belongs to the UNAVCO PBO network (see http://pboweb.unavco.org/) and one additional station operated by NCALM personnel was located at the in Battlement Mesa.  Coordinates for the Battlement Mesa station were established from the NOAA/NGS online OPUS – see http://www.ngs.noaa.gov/OPUS/ for more information.

All CORS GPS observations were interpolated to a 1 Hz rate either by the User Friendly CORS or by a NOAA/NGS software utility called INTERPO.  For further information on this utility see http://www.ngs.noaa.gov/UFCORS/ . The airborne receiver is an internal TRIMBLE GPS receiver logging at 10 Hz.

## 6. Navigation Processing and Calibration

Airplane trajectories for this survey were processed using APPLANIX POGPS kinematic processing software with yields an ionosphere-free fixed integer solution. Figure 3 (below) illustrates the positional difference between two aircraft trajectory solutions as processed from station P031 and NCALM station BAT_.

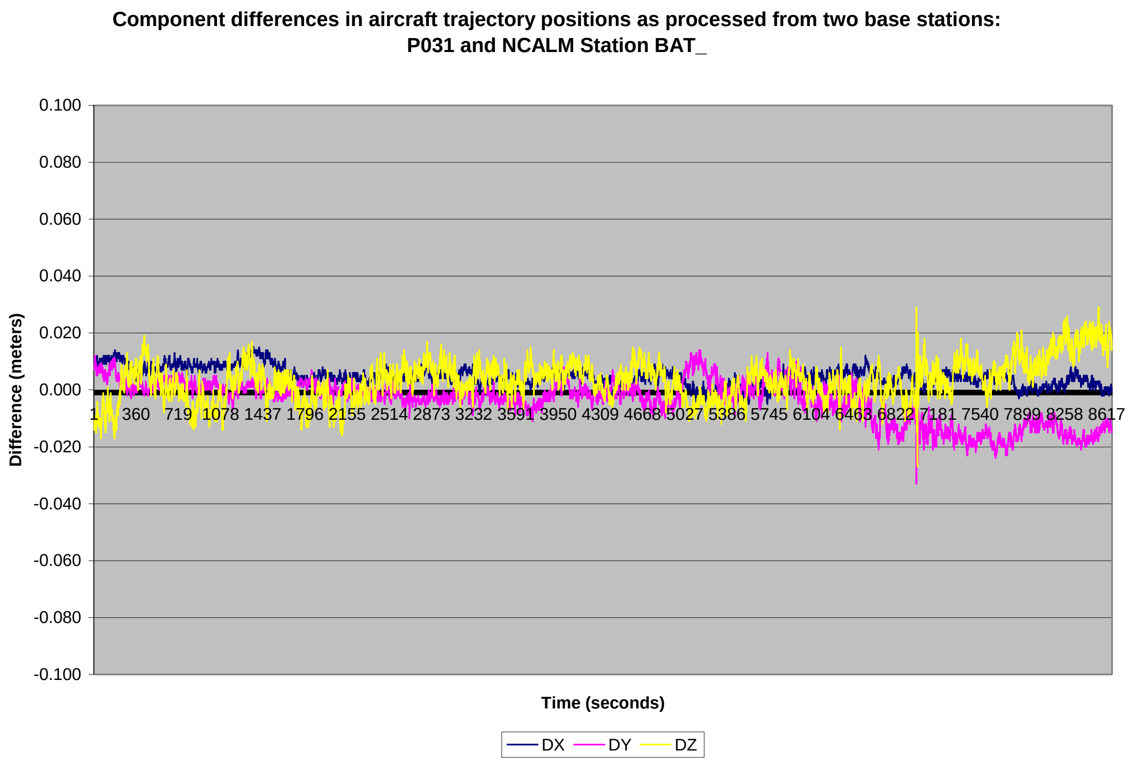



**Figure 3 - Positional differences in the aircraft trajectory. Yellow line is the height difference.**

The RMS of the height differences is 7 mm.

After GPS processing, the trajectory and the inertial measurement unit (IMU) data collected during the flights were input into APPLANIX software POSPROC which implements a Kalman Filter algorithm to produce a final, smoothed, and complete navigation solution including both aircraft position and orientation at 200 Hz. This final solution is known as the SBET (Smoothed Best Estimated Trajectory).

The SBET and the raw laser range data were combined using Optech's DashMap processing software to generate the laser point dataset. A few small test sites containing crossing flight-lines were initially extracted and used for relative calibration with TerraSolid's TerraMatch software. This application measures the differences between laser surfaces from overlapping flight lines and translates them into correction values for the system orientation -- easting, northing, elevation, heading, roll and/or pitch. After obtaining adjustments to calibration values using TerraMatch, laser point processing was re-done and the calibration rechecked. Calibration values for this flight are archived at UC Berkeley along with all raw data.

Absolute ground calibration was performed on these data by collecting test points by vehicle mounted GPS some sections of roads near Walker Field airport. Analysis of 1131 test point elevation versus the nearest-neighbor laser point elevation differences yielded an RMS of 24 mm.  Figure 4 (below) is a shaded relief image showing the calibration cross lines and the ground truth near Walker Field.

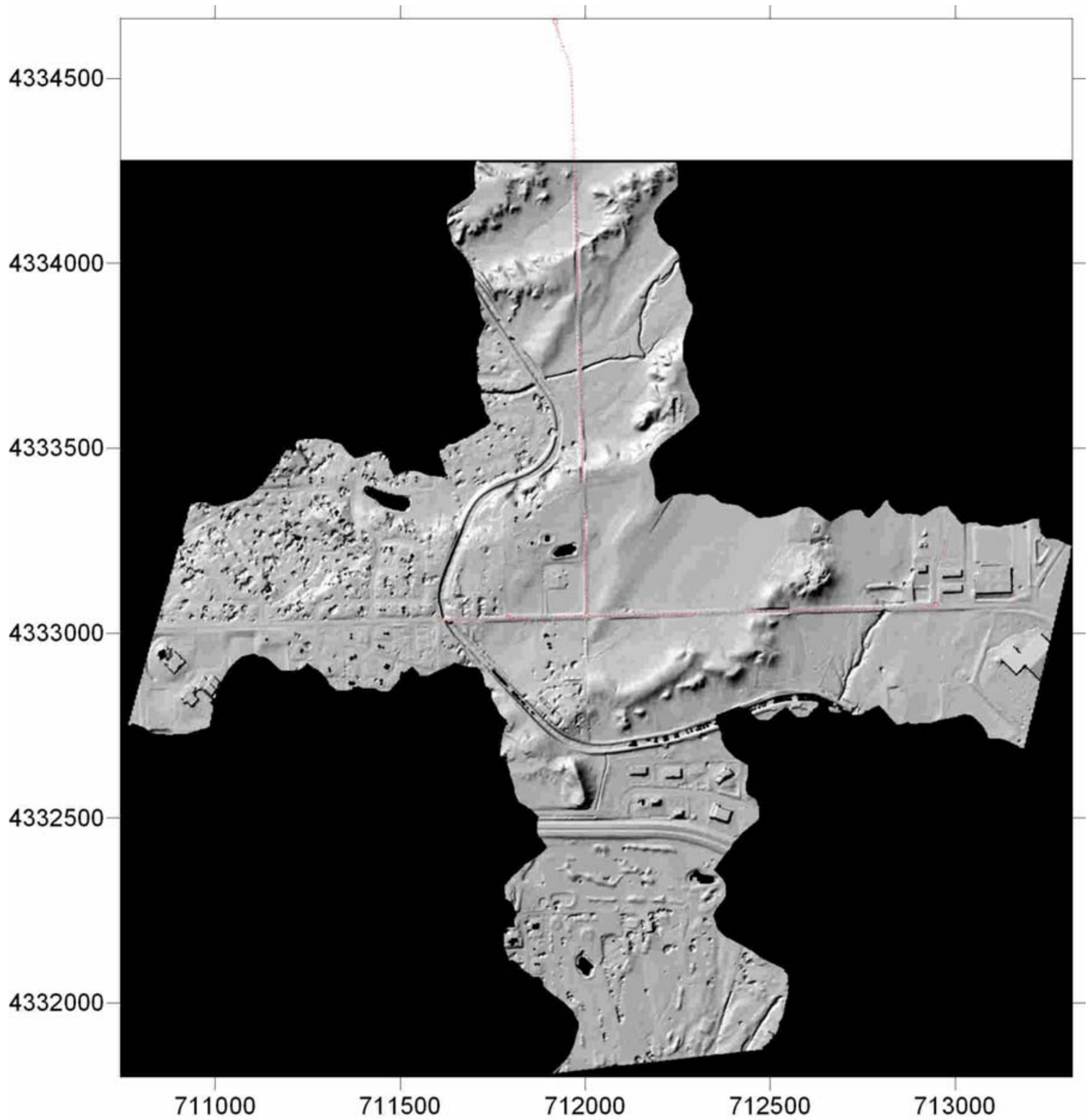



**Figure 4 – Cross lines and ground truth points (in red) near Walker Field.**

## 7. Filtering and DEM Production

Terrasolid's TerraScan (http://terrasolid.fi) software was used to classify the last return LIDAR points and generate the "bare-earth" dataset.

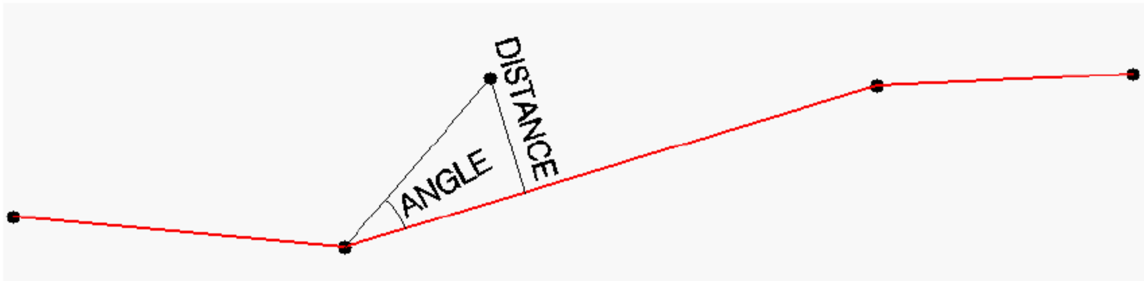
Two algorithms were run on the entire last return dataset:

1) Removal of "Low Points". This routine was used to search for possible error points which are clearly below the ground surface. The elevation of each point (=center) is compared with every other point within a given neighborhood and if the center point is clearly lower then any other point it will be classified as a "low point". This routine can also search for groups of low points where the whole group is lower than other points in the vicinity. The parameters used on this dataset were:

   Search for: Groups of Points
   Max Count (maximum size of a group of low points): 6
   More than (minimum height difference): 0.5 m
   Within (xy search range): 5.0 m

2) Ground Classification. This routine classifies ground points by iteratively building a triangulated surface model. The algorithm starts by selecting some local low points assumed as sure hits on the ground, within a specified windows size. This makes the algorithm particularly sensitive to low outliers in the initial dataset, hence the requirement of removing as many erroneous low points as possible in the first step.

   The routine builds an initial model from selected low points. Triangles in this initial model are mostly below the ground with only the vertices touching ground. The routine then starts molding the model upwards by iteratively adding new laser points to it. Each added point makes the model follow ground surface more closely. Iteration parameters determine how close a point must be to a triangle plane so that the point can be accepted to the model. **Iteration angle** is the maximum angle between point, its projection on triangle plane and closest triangle vertex. The smaller the Iteration angle, the less eager the routine is to follow changes in the point cloud. **Iteration distance** parameter makes sure that the iteration does not make big jumps upwards when triangles are large. This helps to keep low buildings out of the model. The routine can also help avoiding adding unnecessary point density into the ground model by reducing the eagerness to add new points to ground inside a triangle with all edges shorter than a specified length.




Ground classification parameters used:

Max Building Size (window size): 40.0 m
Terrain Angle: 89.0
Iteration Angle: 6.2
Iteration Distance: 1.8 m

After classification, the ground points were outputted in 2km x 2km overlapping tiles (60m overlap), ASCII format (XYZ).

Using the overlapping tiles, Digital Elevation Models were produced at 1.0 meter spacing using SURFER (Golden Software) ver. 9.01. Interpolation parameters were as follows:

Gridding Algorithm: Kriging
Variogram: Linear
Nugget Variance: 0.07 m
MicroVariance: 0.00 m
SearchDataPerSector: 10
SearchMinData: 5
SearchMaxEmpty: 1
SearchRadius: 40m for the filtered point cloud and 5m for the unfiltered.

We used overlapping tiles for making sure that the surface obtained from krigging is consistent when transitioning from one tile to the adjacent tiles. The surveyed area is too big to be gridded in one piece with the currently available software.

These 1m grids were afterwards imported in ESRI's ArcINFO (ver. 8.3) GIS package, the overlap trimmed and then all grids were merged into one seamless raster dataset.

A similar tiling and krigging process was used to create the unfiltered seamless raster dataset, based on the unfiltered last return point data.