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Project Name: Sediment Storage at the Transition Between Debris-Flow and Fluvial Processes

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 areas are two rectangular polygons 50-70 km southwest of Eugene, Oregon enclosing a total area of approximately 35 square kilometers. The survey polygons are shown below in Figure 1.

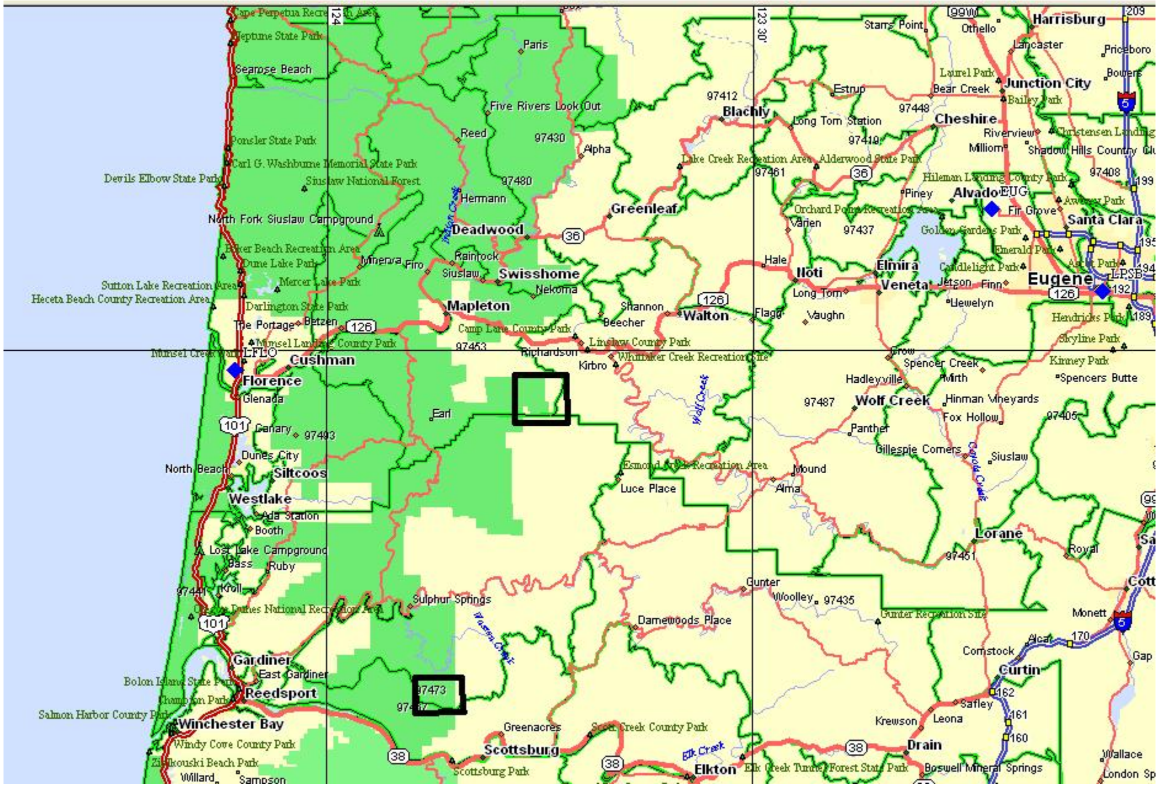

Figure 1 – Size, shape and location of survey polygons – GPS CORS stations are shown as blue diamonds.

3. Survey Times

This area was flown on Thursday April 26, 2007 in a single flight approximately 5 hours in duration.

4. Survey Parameters

The survey required 34 flight lines, 20 in the northeasterly rectangle and 14 in the smaller southwesterly rectangle. Planning parameters are shown below in Figure 2 along side the smaller southwesterly rectangle..

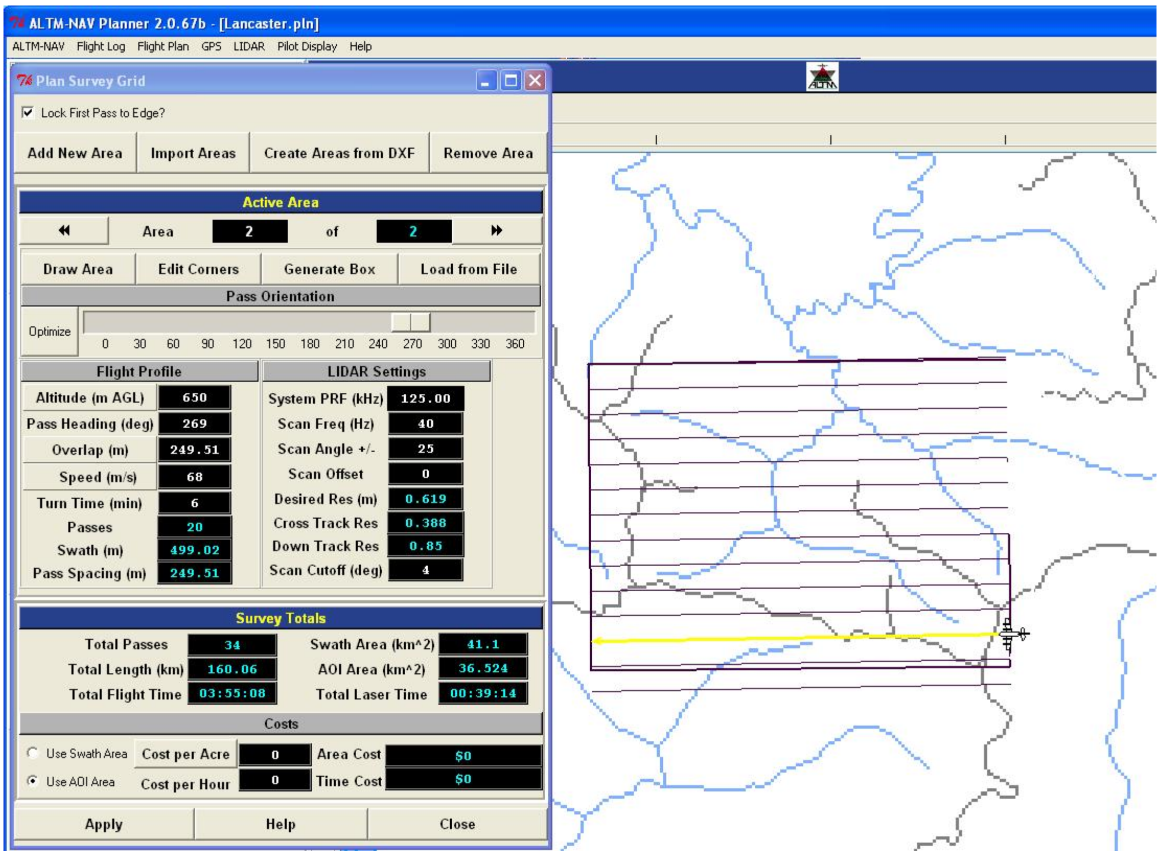

Figure 2 - Flight lines with planning parameters.

Survey totals appear below in Table 3.

Survey Totals	
Total Passes	34
Total Length	160 km
Total Flight Time	03:55:08
Total Laser Time	00:40:00
Total Swath Area	41 km^2
Total AOI Area	37 km^2

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

LiDAR settings are shown in Table 4.

LiDAR Settings	
Desired Resolution	0.62 m
Cross Track Resolution	0.39 m
Down Track Resolution	0.85 m
Scan Frequency	45 Hz
Scan Angle	+/- 25 deg
Scan Cutoff	+/- 4.0 deg
Scan Offset	0 deg
System PRF	125 kHz
Swath Width	500 m

Table 4 – LiDAR settings.

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

5. GPS Reference Stations

Two GPS reference station locations were available during the survey both belonging to the Lane County Cooperative CORS network. Station identifiers of these stations are LFLO and LPSB. More information on these sites can be found at http://www.ngs.noaa.gov/CORS/. See Figure 1 for locations of these CORS.

All CORS GPS observations were logged at a 5-second rate and 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 from both GPS reference stations using both APPLANIX POGPS kinematic processing software and KARS (Kinematic and Rapid Static) written by Dr. Gerry Mader of the NGS Research Laboratory. Both processing engines yield an ionosphere-free fixed integer solution. Figure 3 (below) illustrates the positional difference between the aircraft trajectory as processed from station LFLO and LPSB using POSGPS.

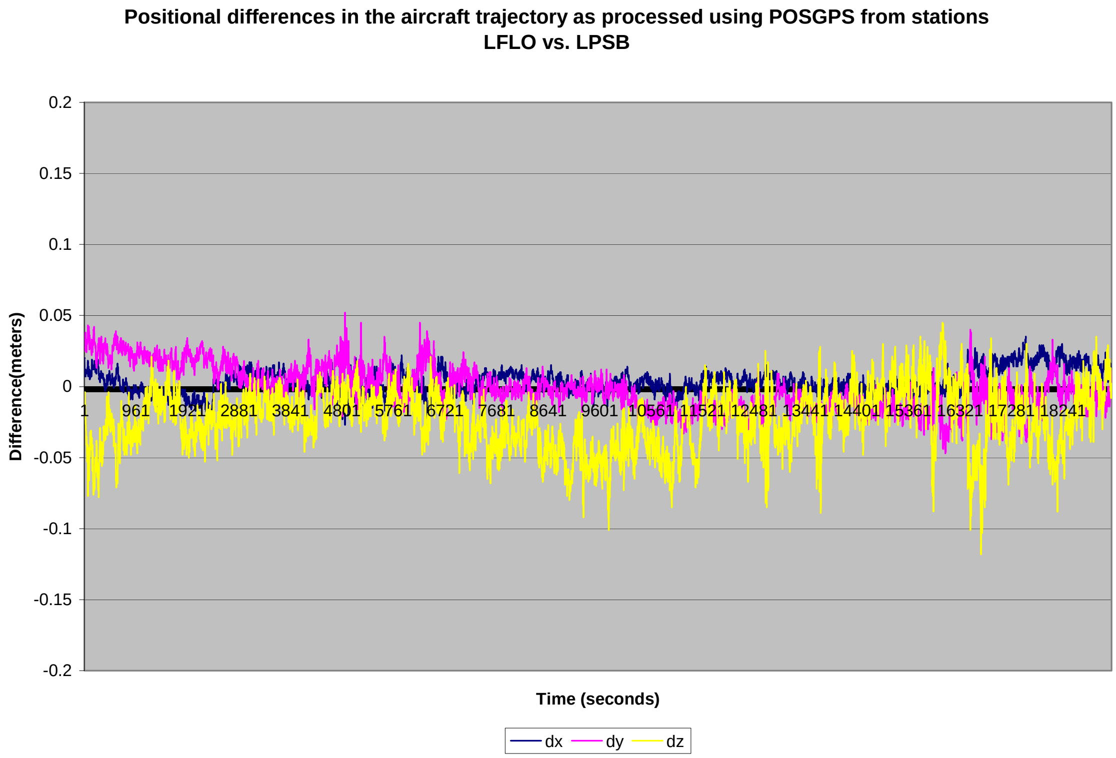

Figure 3 - Positional differences in the aircraft trajectory positions as processed from LFLO and LPSB using POSGPS. Yellow line is the height difference.

The RMS of the differences between these two solutions is 21 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.

Absolute ground calibration was performed on these data by collecting test points by vehicle mounted GPS on some sections of roads in Eugene. Analysis of the test point elevation versus the laser point elevation differences yielded an RMS of less than 8 cm. Figure 4 (below) is an image showing the calibration cross lines and the ground truth used for the calibrations

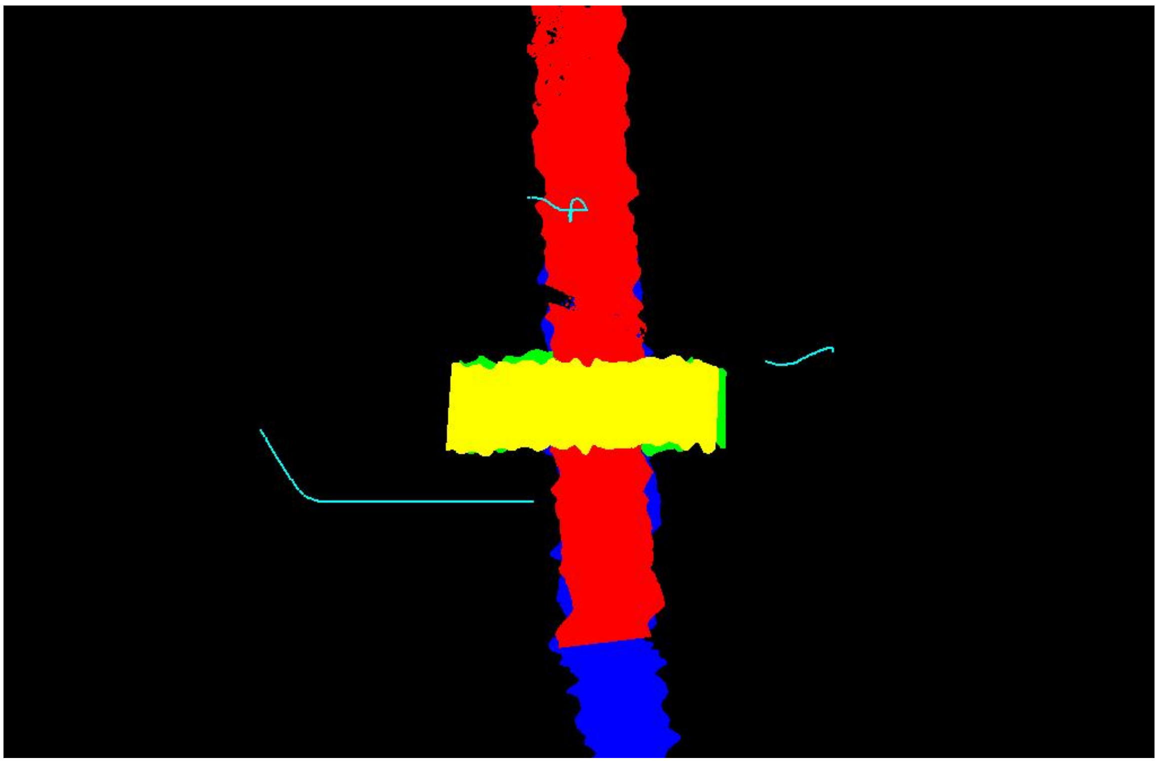

Figure 4 – Cross lines and ground truth points (in light blue) in the Eugene area.

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. Many of the tiles were deemed to have little or vegetation and were NOT filtered.

The classification routine consists of three algorithms:

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:

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Search for: Groups of Points
Max Count (maximum size of a group of low points): 6
More than (minimum height difference): 1.0 m
Within (xy search range): 10.0 m
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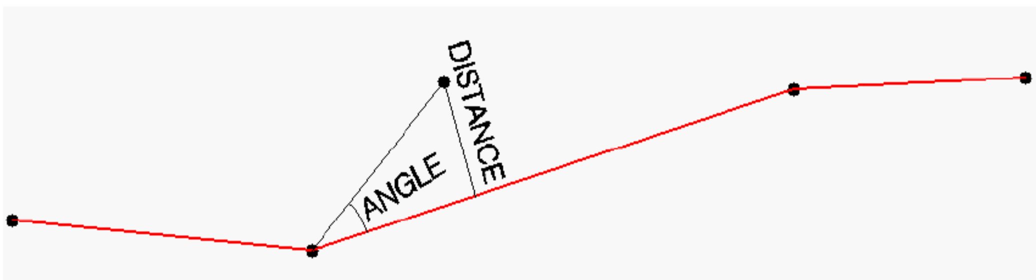
2) Ground Classification. This routine classifies ground points by iteratively building a triangulated surface model. The algorithm starts by selecting some local low points assumed as sure hits on the ground, within a specified windows size. This makes the algorithm particularly sensitive to low outliers 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 avoid adding unnecessary points to 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
Max Terrain Angle: 89.0
Iteration Angle: 12.0
Iteration Distance: 10 m
Reduce iteration angle when edge length <: 5.0 m

3) Below Surface removal. This routine classifies points which are lower than other neighboring points and it is run after ground classification to locate points which are below the true ground surface. For each point in the source class, the algorithm finds up to 25 closest neighboring source points and fits a plane equation through them. If the initially selected point is above the plane or less than “Z tolerance”, it will not be classified. Then it computes the standard deviation of the elevation differences from the neighboring points to the fitted plane and if the central point is more than “Limit” times standard deviation below the plane, the algorithm it will classify it into the target class.

Below Surface classification parameters used:

Source Class: Ground
Target Class: Low Point
Limit: 3.00 * standard deviation
Z tolerance: 0.15 m

After classification the points were outputted in 1km x 1km ASCII XYZ tiles with 40m overlap, for both filtered (bare-earth) and unfiltered data sets. The tile names includes the coordinates of the lower left corner (without considering the overlap) and are prefixed by the letters “f” for filtered tiles or “u” for the unfiltered points.

Digital Elevation Models were produced at 1.0 meter spacing for the tiles using SURFER (Golden Software) Version 8.04. Interpolation parameters were as follows in Table 5.

Algorithm	Kriging
Variogram	Linear
Nugget Variance	0.15 meters
MicroVariance	0.00 meters
Quadrant Search	4
Search Radius	variable
Minimum points per quadrant	5
Maximum points per quadrant	7

Table 5 - Gridding parameters.

The Surfer grids were converted to ArcInfo grid format, the overlap was trimmed and the tiles merged to create seamless raster datasets for the two survey boxes.