Garmin GPS for Accurate Topography

Innovation Spinoff from

Appalachian Region AOC Studies

January-April, 2010

2010 AOC Studies

- Random sample of permits with planned AOC reclamation:
  - Reflect latest SRA AOC policy
  - Phase 1 bond released portion available
- State-specific policy variations factored in (e.g., drainage, slope requirements)
- Compare topography (cross-sections the minimum):
  - Pre-mine
  - Approved reclamation plan
  - On-the-ground
- Post-mine topo from LiDAR ideal; otherwise site visits with measurement by clinometer, GPS, survey, etc.
- GPS preferred, but sub-meter requirement a problem

The GPS Problem

- Limited number of 3 sub-meter units (~$3,000) available – 10 site visits necessary
  - Only 2 confident operators – neither available
  - Some offices “gun-shy” after bad post-processing experiences
- Alternatives?
  - Contract work – no $, no time
  - Are less capable, user-friendly GPS units good enough for AOC studies?

Why Garmin?

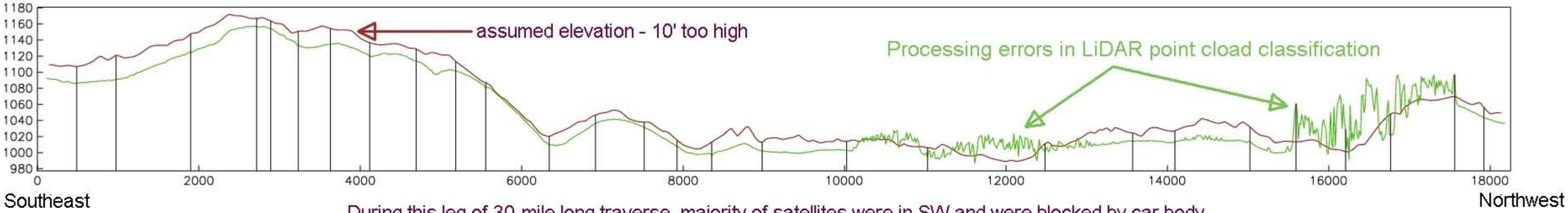
- eTrex Vista (~$250) features:
  - WAAS -Rugged
  - 24MB memory -Aneroid altimeter record correction
  - Lightweight -2 AA batteries
  - One-hand operation -Easy to learn; easy to use
- Proven utility by OSM, PA, others since 2000
- 34 Vistas available due to TIPS’ popular class; 17 in Pittsburgh
- Familiar and trusted by majority of OSM field/technical folk
- Over 350 people have received the training; 311 under TIPS

Concept

- 1/26/10, Mike Dunn, playing with old Garmin Vista, recorded every 1/100th mile on his dash driving to work.
- Plotted on cross-section with LiDAR topography, the 2,200 points rather faithfully followed the contour.
- Min Kim: "Wow! How well does it work in hilly terrain like the coalfields?"

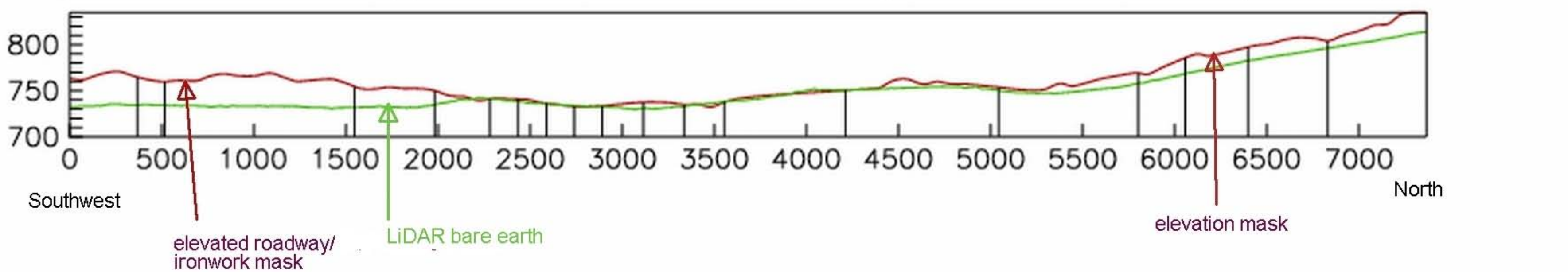
Cranberry Traverse

Garmin Altimeter (RED) vs. 2006 LiDAR (GREEN). 10X V.E.

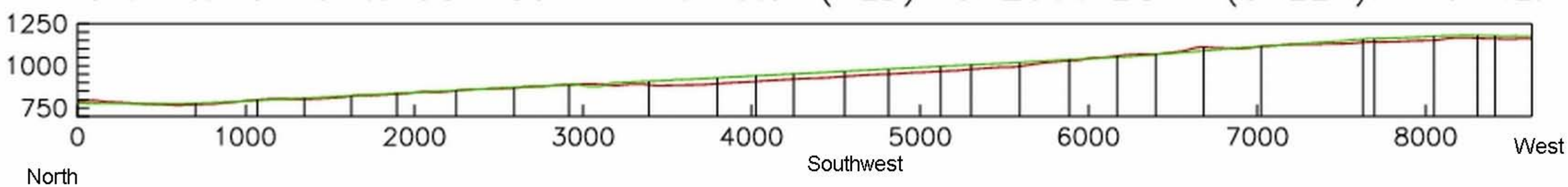


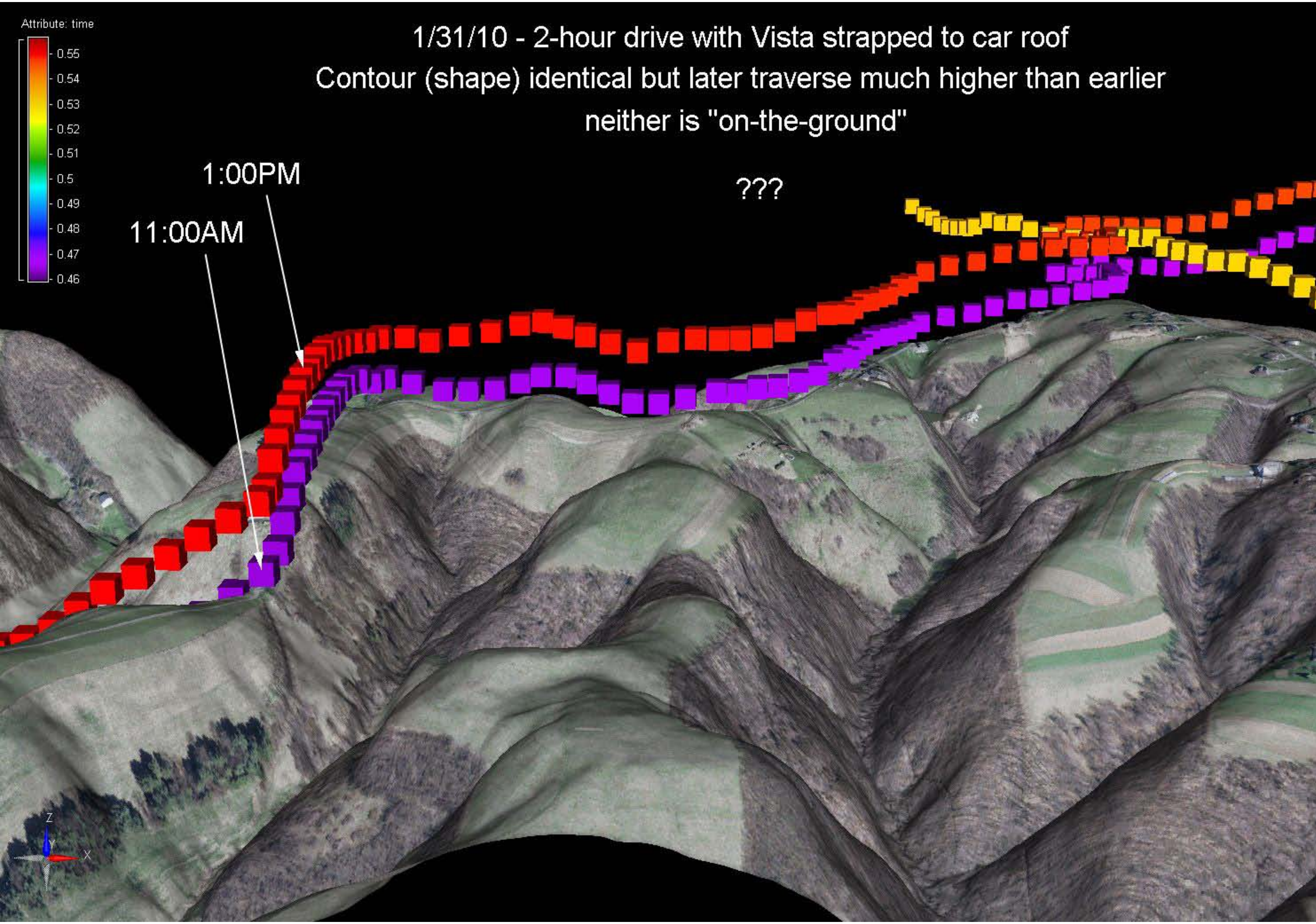
During this leg of 30-mile long traverse, majority of satellites were in SW and were blocked by car body.
Caused northwestward shift of peaks and valleys.

I–279 (East Street Valley) Garmin Altimeter (RED) vs. 2006 LiDAR (GREEN). 5X V.E.



Fort Pitt Tunnel to OSM Garmin Altimeter (RED) vs. 2006 LiDAR (GREEN). No V.E.




Attribute: time
0.55
0.54
0.53
0.52
0.51
0.5
0.49
0.48
0.47
0.46
1/31/10 - 2-hour drive with Vista strapped to car roof
Contour (shape) identical but later traverse much higher than earlier
neither is "on-the-ground"
1:00PM
11:00AM
???
Z
Y
X

Concept/Gamble

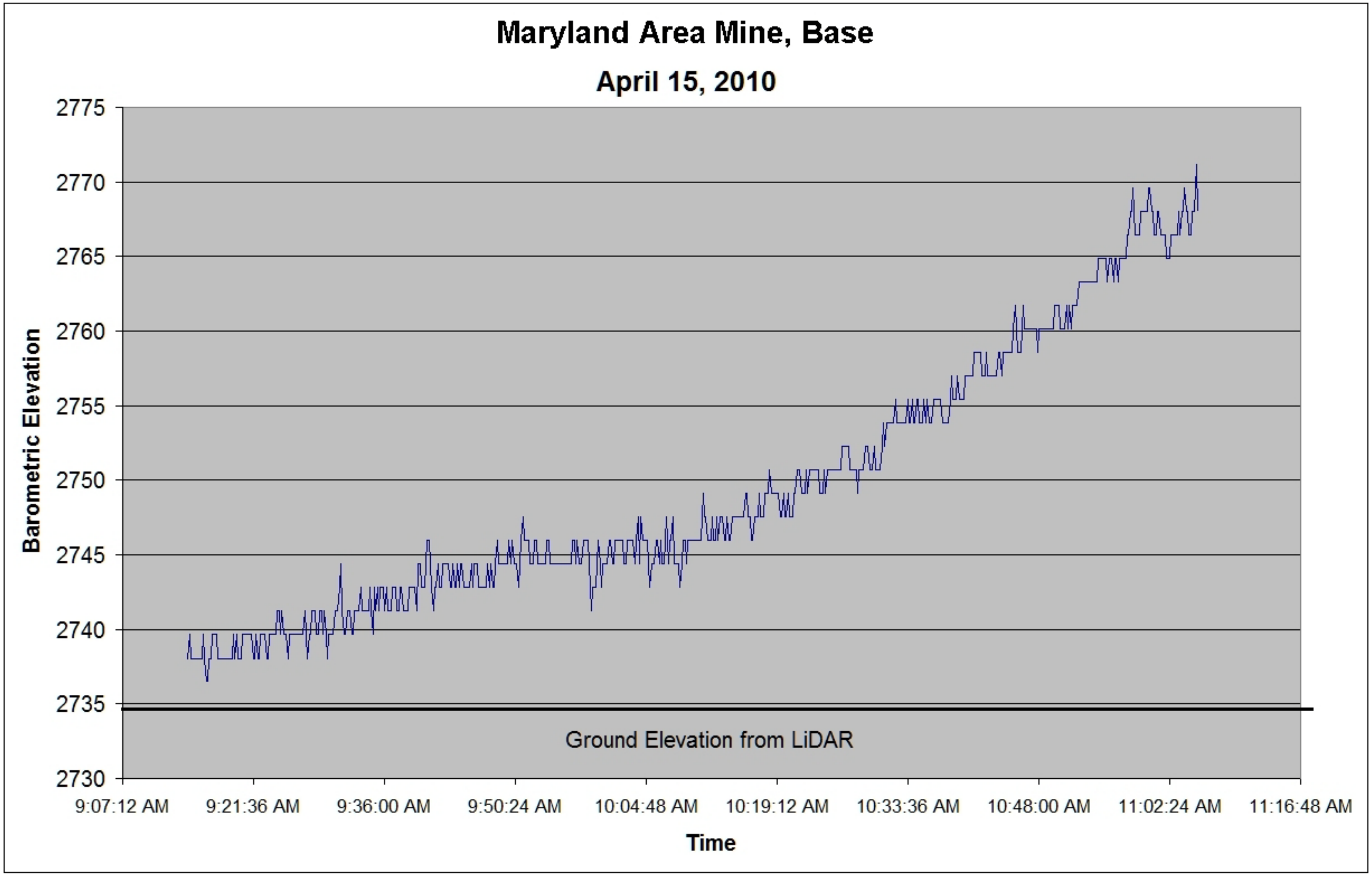
- Figured out changes:
  - daily heating = less dense warmer air
  - air pressure drops = higher elevation
  - How to compensate for pressure change?
  - Repeatedly traverse known elevations, figure the correction, and distribute.
- Worst case, total failure.
- No study site more than 3 hours’ drive if revisit needed to use different technology *(or figure out what went wrong and revisit with a fix)*

First Try

- 2/11/10:
  - MD area mine; 4’ snow.
    - N-S traverse worked; Ken Eltschlager fell on E-W traverse and correction distribution became problematic.
  - MD contour site: short traverse (10 minutes)
    - global correction worked and Garmin traverse ~ LiDAR!

New Approach

- Minimum-
  - one base Garmin
  - one roving Garmin (2 is better!)
- Calibrated to same elevation and time; recording same interval (3 to 30 seconds)
- Pressure “drift” is distributed to all rovers using base unit time-of-day corrections
- Maryland area mine revisited 4/15/10 – astounding!



Maryland Area Mine, Base
April 15, 2010
Barometric Elevation
2775
2770
2765
2760
2755
2750
2745
2740
2735
2730
Ground Elevation from LiDAR
9:07:12 AM
9:21:36 AM
9:36:00 AM
9:50:24 AM
10:04:48 AM
10:19:12 AM
10:33:36 AM
10:48:00 AM
11:02:24 AM
11:16:48 AM
Time

Garmin Base Data

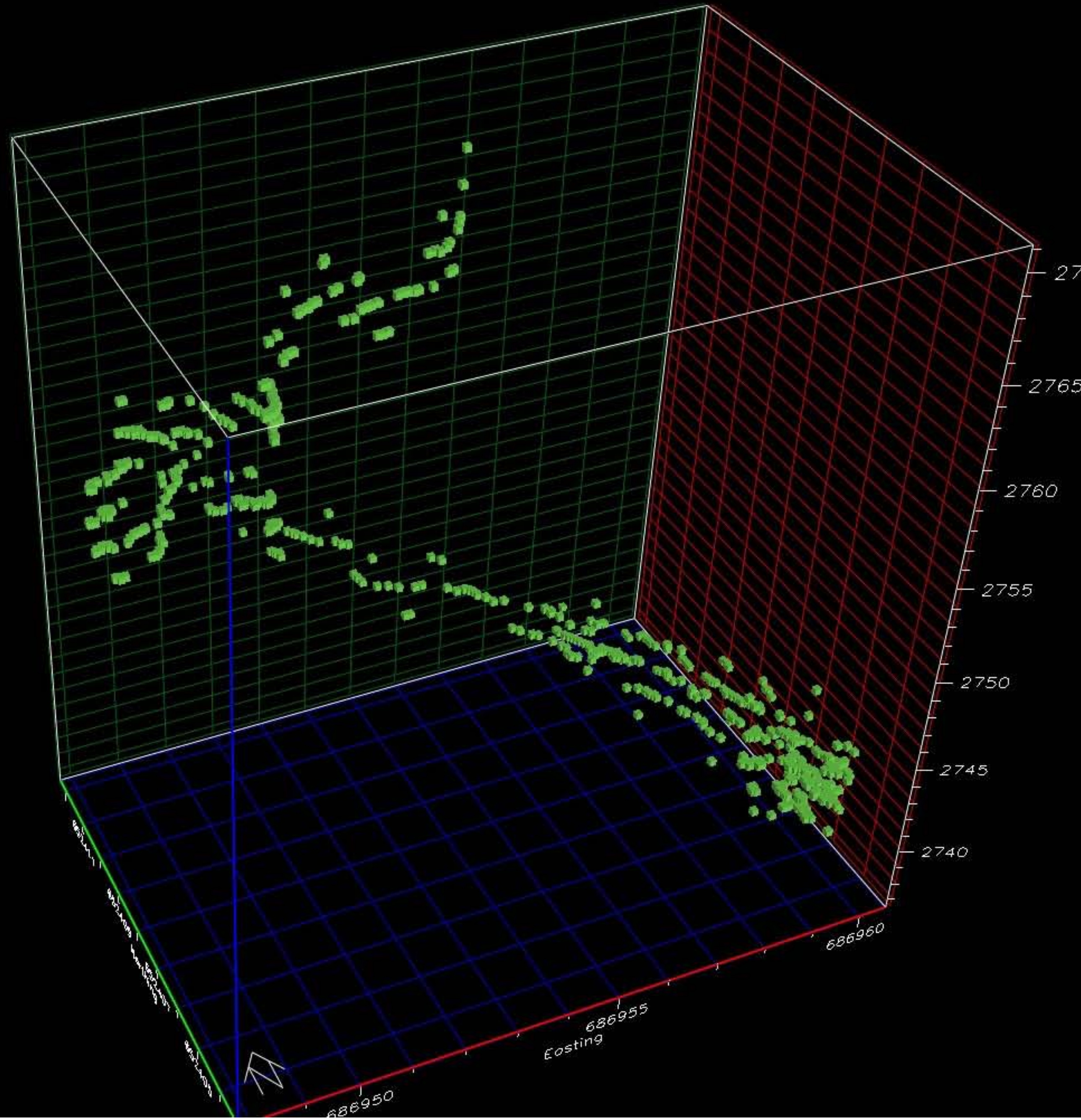
~ 90 minutes:

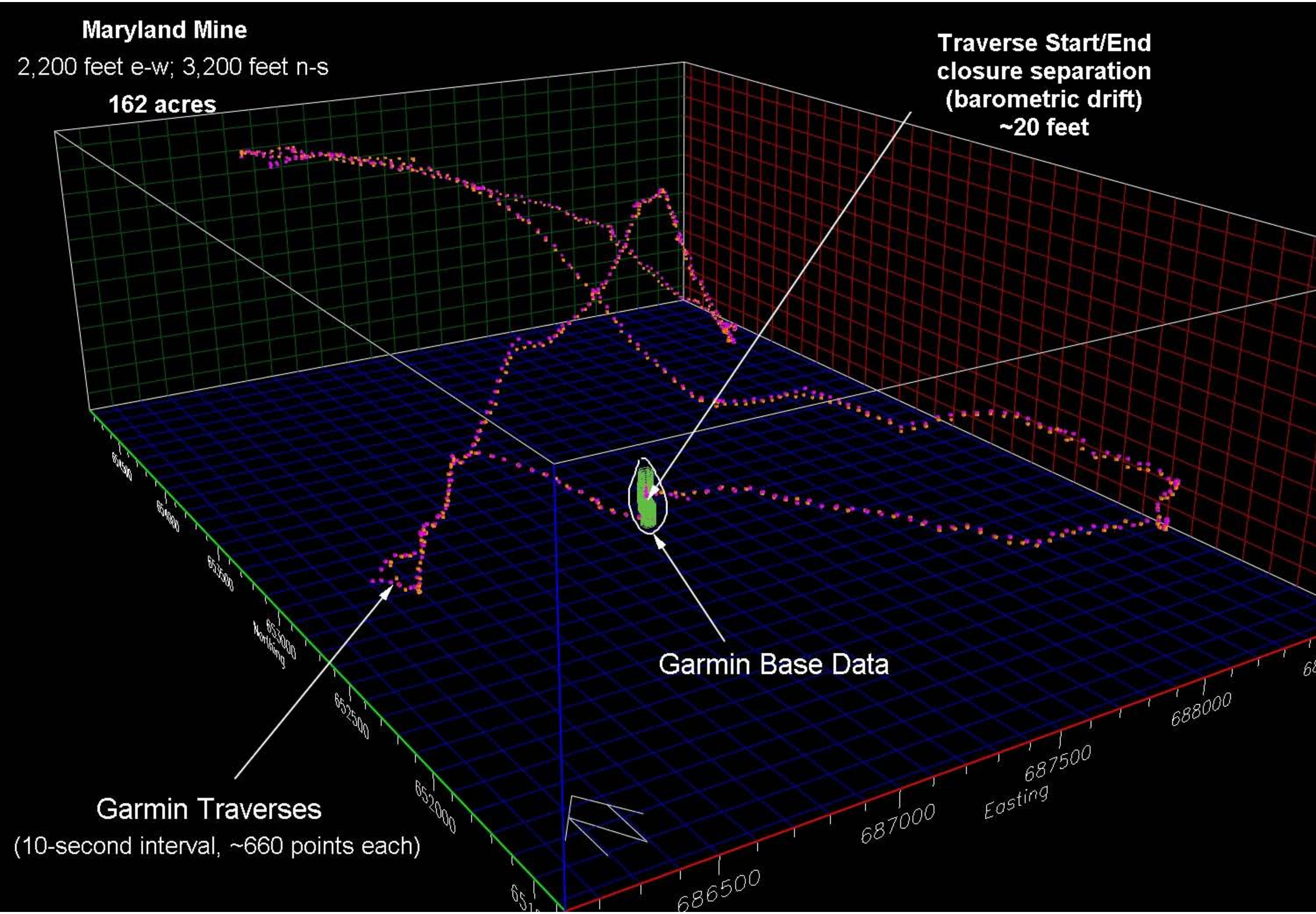
GPS Range =

13 feet X; 8 feet Y

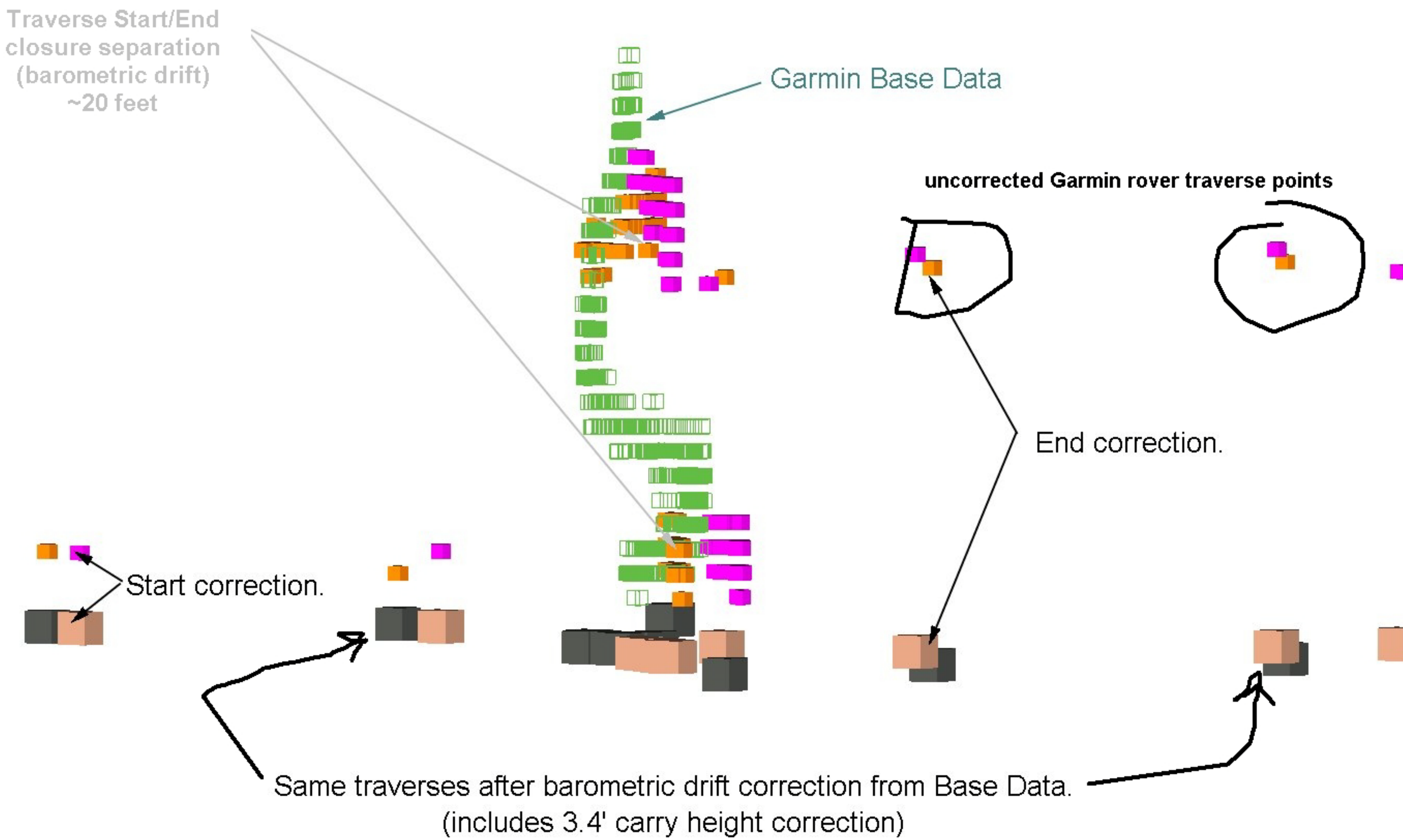
Barometric Range =

34 feet Z




Maryland Mine
2,200 feet e-w; 3,200 feet n-s
162 acres
Traverse Start/End
closure separation
(barometric drift)
~20 feet
Garmin Base Data
Garmin Traverses
(10-second interval, ~660 points each)
Northing
652500
652000
Easting
686500
687000
687500
688000

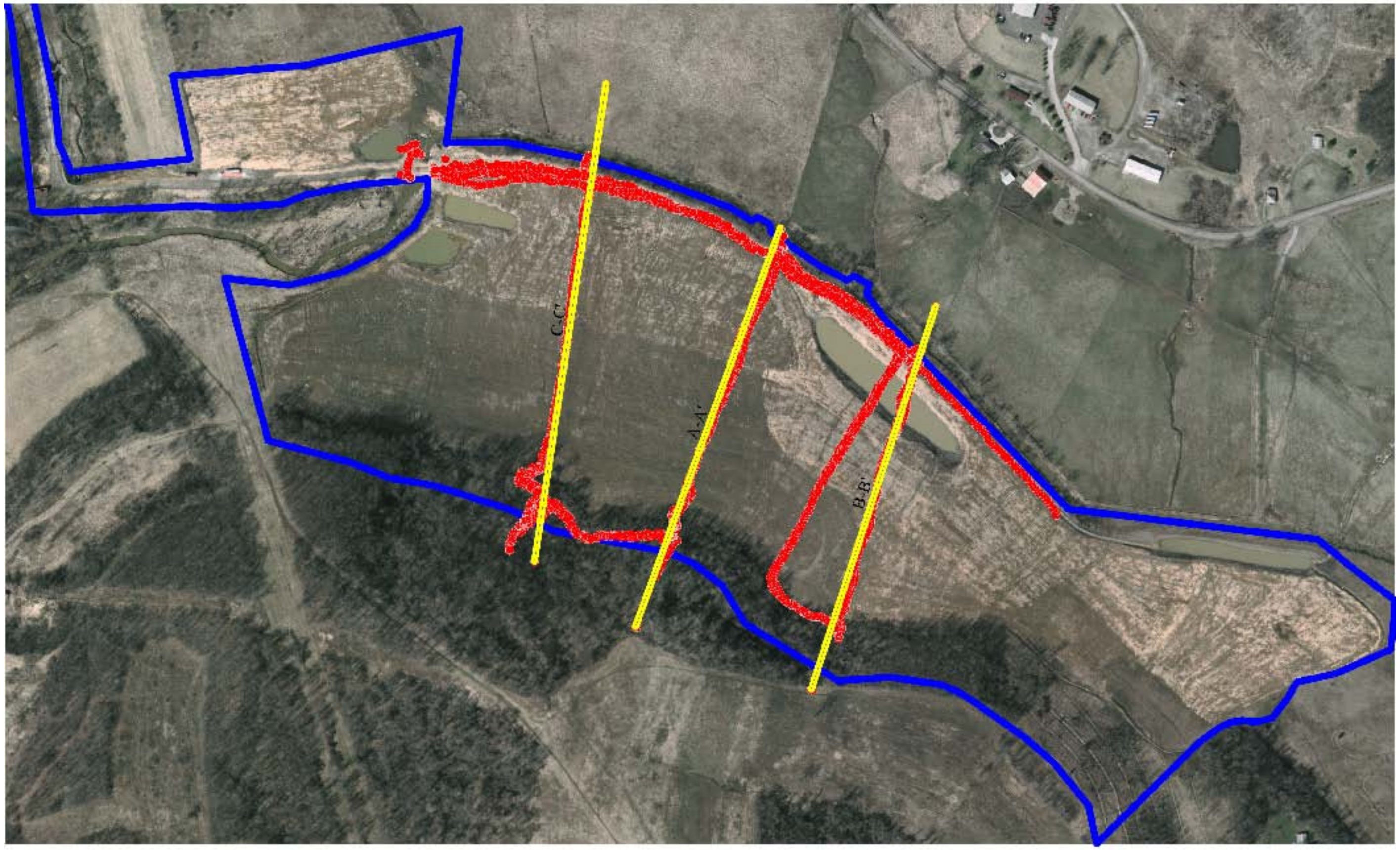
Maryland Mine: 3 Garmins-one person "Survey" Results



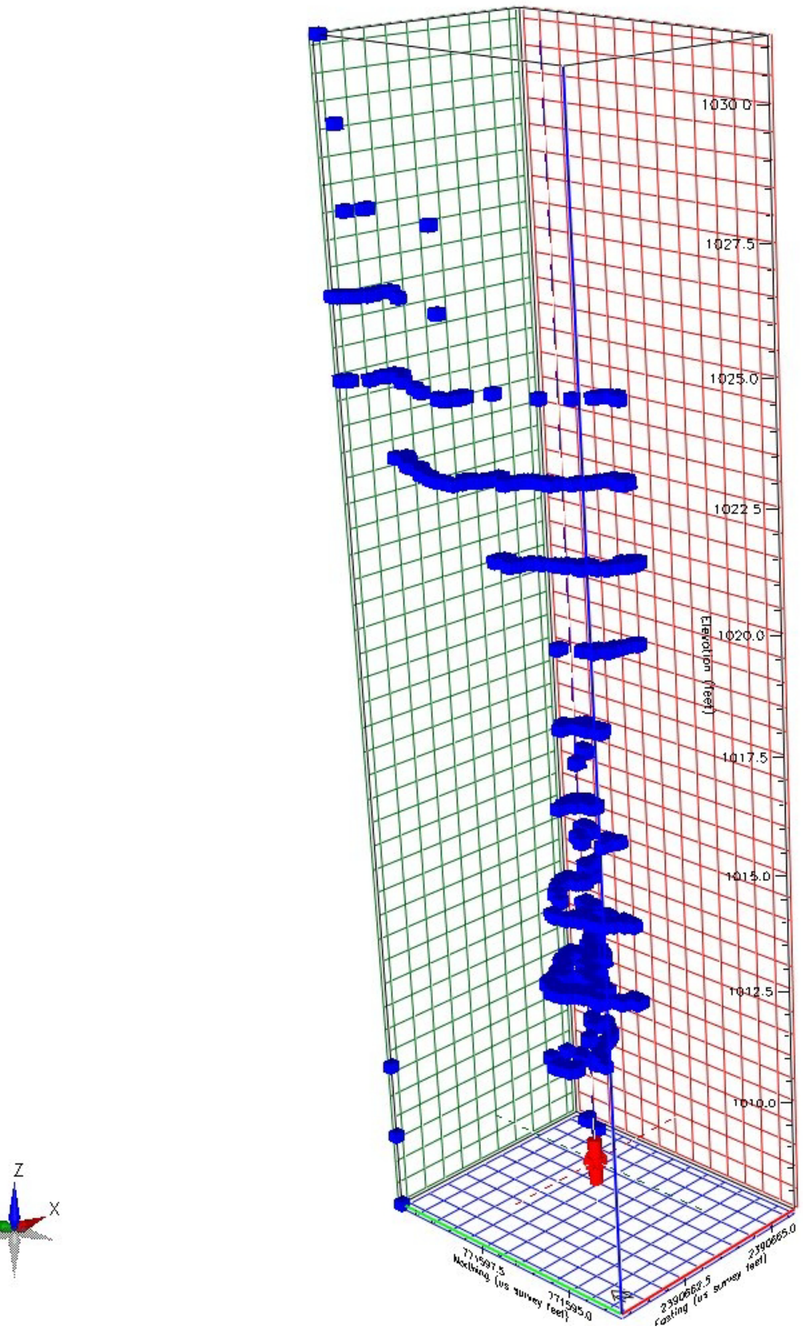
How Does this Approach Compare?

- Another crew (Stefanie Self and Dave Agnor) used the base/rover Garmin approach on 3 Ohio mines:
- Full proof-of-concept resulted

Cravat D-2228 on 2007 OSIP Aerial



Permit=Blue; Sections=Yellow; GPS=Red

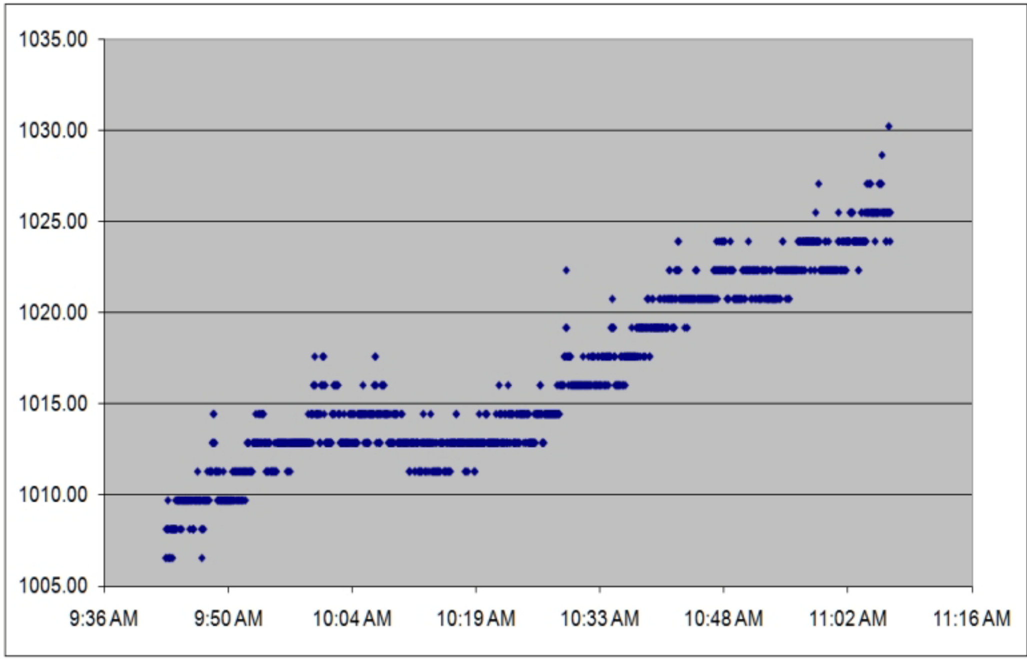


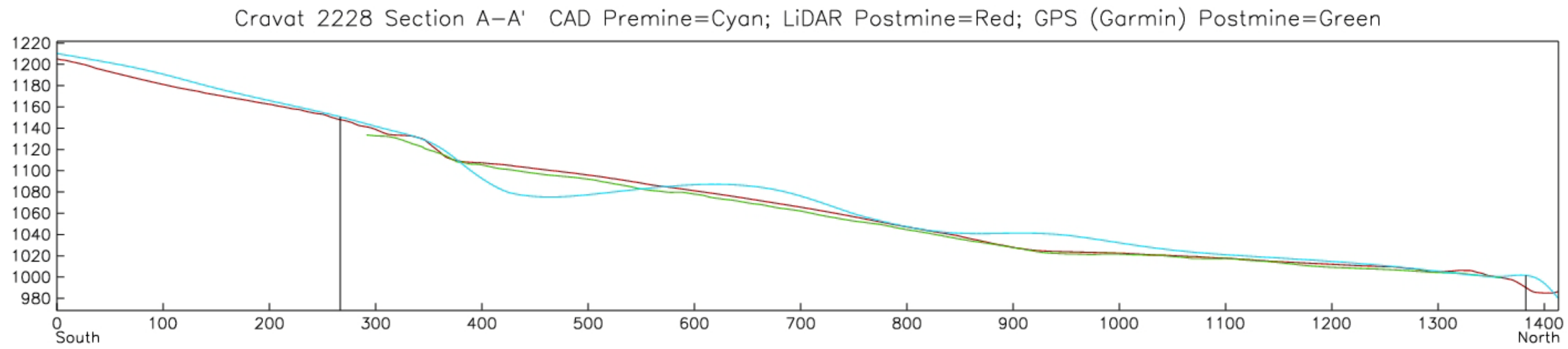
Cravat 2228 Garmin Base Data:

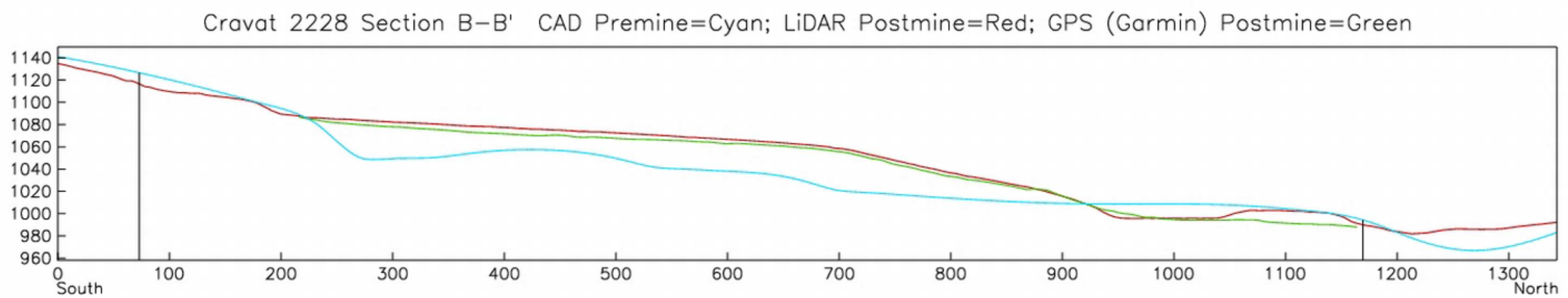
1,778 track points that fit into
a data range that is:

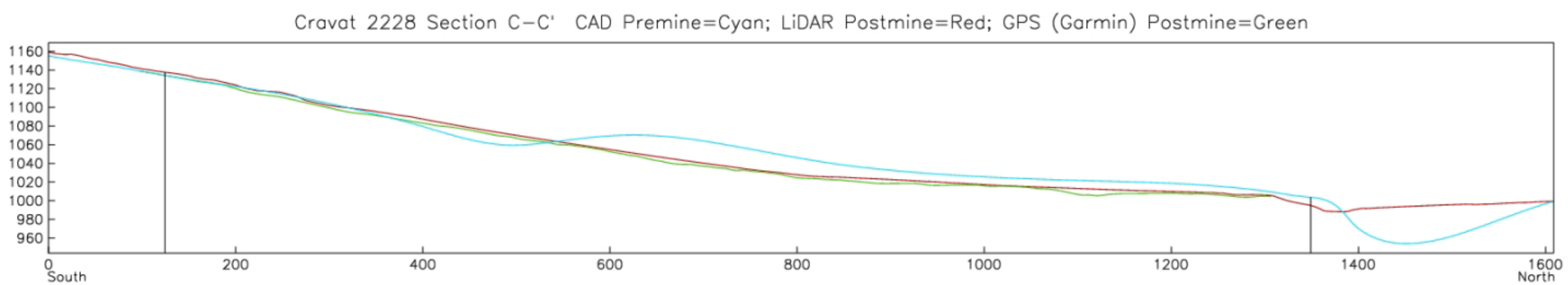
5 feet in X direction
6.5 feet in Y direction
and 24 feet in Z direction.

X,Y are from WAAS GPS
Z is from built-in aneroid altimeter:

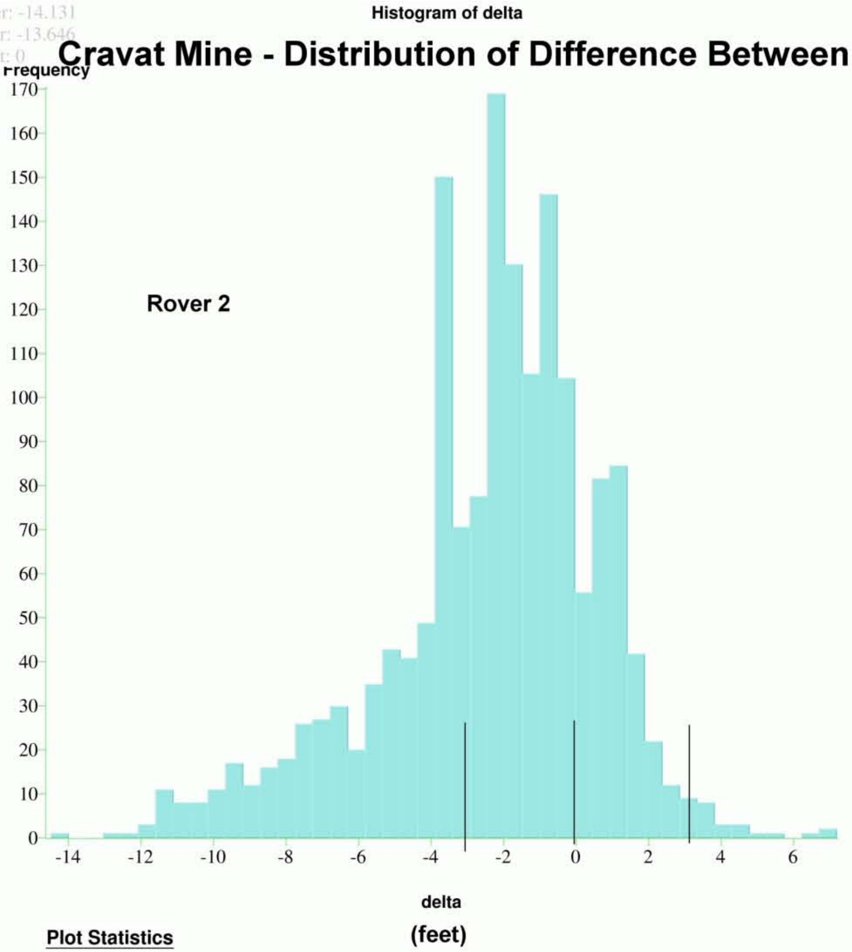



Cravat 2228 Section A–A' CAD Premine=Cyan; LiDAR Postmine=Red; GPS (Garmin) Postmine=Green
1220
1200
1180
1160
1140
1120
1100
1080
1060
1040
1020
1000
980
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
South
North


Cravat 2228 Section B–B' CAD Premine=Cyan; LiDAR Postmine=Red; GPS (Garmin) Postmine=Green
1140
1120
1100
1080
1060
1040
1020
1000
980
960
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
South
North


Cravat 2228 Section C–C' CAD Premine=Cyan; LiDAR Postmine=Red; GPS (Garmin) Postmine=Green
1160
1140
1120
1100
1080
1060
1040
1020
1000
980
960
0
200
400
600
800
1000
1200
1400
1600
South
North

Cravat Mine - Distribution of Difference Between Corrected Garmin Traverse Points and LiDAR Topography



Plot Statistics

Number of Data: 1664

Mean: -2.4305

Variance: 9.1078

Maximum: 7.1853

Median: -2.0456

Minimum: -14.615

Kurtosis: 0.83553

Number of Nulls: 0

Standard Deviation: 3.0179

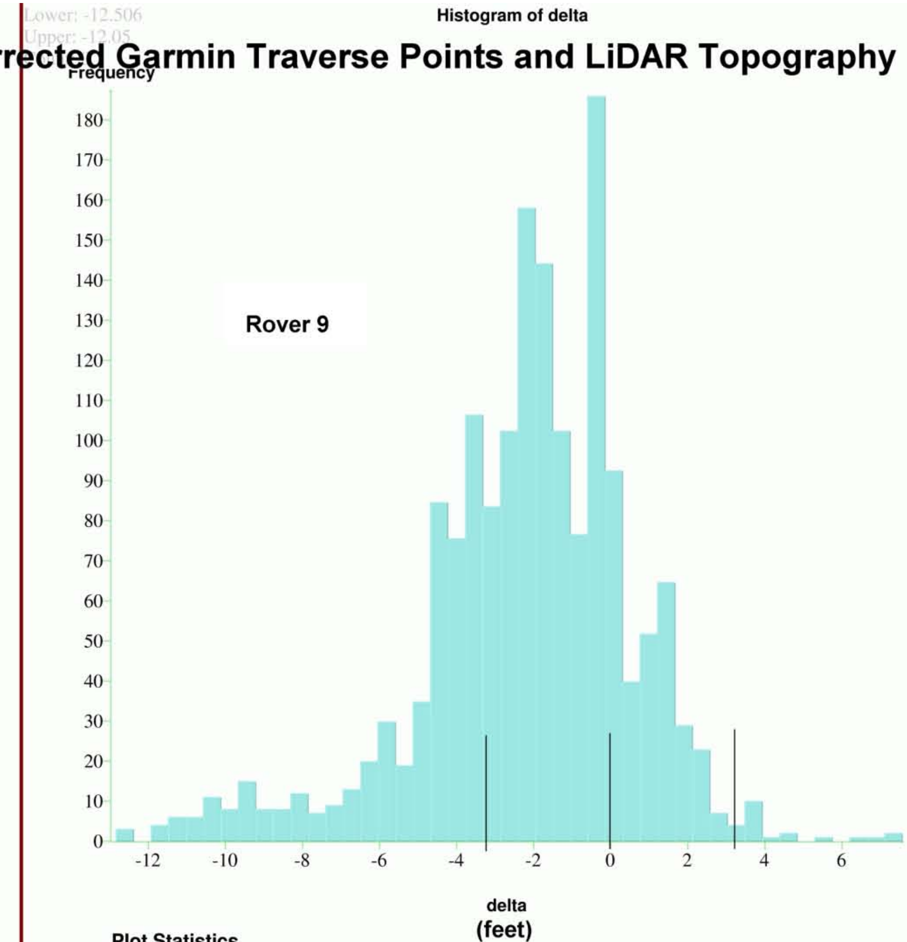
Coeffecient of Variation:-1.2417

Upper Quartile: -0.47966

Lower Quartile: -3.693

Skewness: -0.74728

Histogram plot of delta from gps\unit2_trim.pdat made on 05/06/10 12:50:12



Plot Statistics

Number of Data: 1671

Mean: -2.2362

Variance: 7.7

Maximum: 7.5602

Median: -1.9623

Minimum: -12.962

Kurtosis: 1.5825

Number of Nulls: 0

Standard Deviation: 2.7749

Coeffecient of Variation:-1.2409

Upper Quartile: -0.4454

Lower Quartile: -3.6902

Skewness: -0.79101

Histogram plot of delta from gps\unit9_trim.pdat made on 05/06/10 12:52:01

Conclusion

- While not survey-grade or sub-meter, this ***Innovation*** is easy, accurate, inexpensive, FAST, and was done with existing TIPS software and hardware.
- The AR AOC assignment could not have been completed without Garmin eTrex Vista GPS units.