Data Integration in Building Virtual Models

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Introduction

As an interdepartmental student research project we explored combining Aerial LiDAR data with terrestrial LiDAR data in order to form a realistic 3D model of a building.

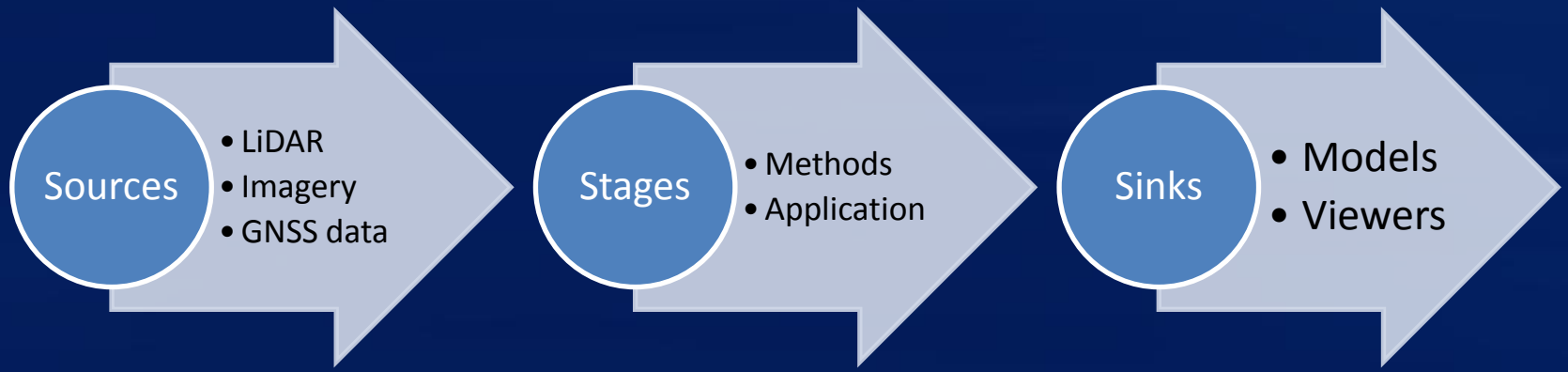
The long-term goal was to develop a campus-wide approach for use in mapping other buildings. The short-term goal was to develop proficiency in the software and methods.

The project's design and implementation were left in the hands of the students.

Overview

The project is described using three categories

- Sources – Input
- Sinks – Output
- Stages – Methods



Sources

- Data

  State Governmental Organizations

  – NCTCOG – Aerial Imagery

  – TNRIS – Aerial LiDAR

- Hardware

  Terrestrial LiDAR scanner and GNSS equipment

- Software

  Applications used to acquire source data

Sources - Data

- NCTCOG provided aerial imagery
  - 2009 6-inch georeferenced .tif files
  - State Plane Coordinate System
    - Texas North Central Zone / US Survey Feet
  - NAD-83 (1986) Horizontal Datum
- TNRIS provided aerial LiDAR
  - 2009 LAS v1.2 format / 1.0m accuracy hz (0.07m vt)
  - UTM Coordinate System Zone 14 / Meters
  - NAD-83 (1986) Horizontal / NAVD-88 Vertical Datum

Sources - Hardware

1. Riegl z620i Scanner
2. Nikon D300 Digital Camera with 20 mm Lens
3. Trimble Geo6000XH GNSS Data Collector
4. Topcon HiPer Lite+ GNSS Receivers
5. TruPulse 360B Laser Rangefinder


1

2

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4


5

Sources - Software

- *Riegl RiScan Pro*
  - In the field:
    - Identify and finescan Tie Points
  - In the office
    - Merge multiple scan occupations using Tie Points
    - Apply coordinates to Tie Points for georeferencing
- *Trimble Pathfinder Office*
  - Verify positional accuracy of 3D models
  - Transform coordinates across NAD-83 realizations
- *Topcon Tools*
  - Verify positional accuracy of 3D models
  - Collect coordinates of reflector positions
- *NGS Online Positioning User Service (OPUS)*
  - Post-process Topcon Base and Validation Point GNSS data

Sinks

- Deliverables
  - Formats for the models
    - Waveform objects (.obj) and material (.mtl) files
    - VRML (geo-VRML ?) files (.wrl)
  - Methods to view the models
    - *OpenSceneGraph* (Waveform)
    - *ArcGIS ArcScene* (VRML)

Steps

- Planning – Tools, Data, Formats, Methods
- Acquisition – LiDAR points, Imagery, GPS Data
- Assembly – Combine Georeferenced Data
- Conversion – From Point Cloud into Mesh
- Visualization – Review results
- Verification – Ground truth test sites

Planning

- Have a feedback system that updates the plan
- Development of the plan (workflow) a goal
- Issues to consider:
  - Coordinate Systems and Linear Units
  - Horizontal and Vertical Datums
  - When to Mesh LiDAR and when to CAD
  - Remaining Faithful to the Point Cloud

Planning Issue
Coordinate Systems

Choosing a Coordinate System and Linear Units

- Aerial imagery is State Plane / US Feet
- Aerial LiDAR is UTM / Meter
  - *Meter is both the Horizontal and the Vertical UOM*
- Terrestrial LiDAR can be chosen freely

UTM and meters will be used

Planning Issue
Datums

Horizontal and Vertical Datums need to match

- NAD-27 vs. NAD-83 was bad enough …
- For precision NAD-83 *Realization* is critical
  NAD-83 (1986, HARN, CORS96, 2011, … etc.)
- NAVD-88 used for vertical orthometric heights
- OPUS uses Geoid 2012A for this

NAD-83 (1986) and NAVD-88 will be used

Planning Issue
Datums (Cont.)

Converting from NAD-83 (2011) using (CORS96)

- Actually converting NAD-83 (CORS96) into (1986)

B. NAD83(2011,MA11,PA11) epoch 2010.00 Coordinates

On September 6, 2011, NGS updated the National Spatial Reference System NAD 83 (CORS96, MARP00, PACP00) positions and velocities for all CORS sites, to NAD 83 (2011, MA11, PA11). The NAD 83 (2011) frame, which is relative to the fixed North American plate, is used to define the coordinates for sites located in the CONterminous U

The new realization of NAD 83 involves no datum change, which means that, the origin, scale, and orientation of NAD 83 (2011) are identical to those of NAD 83(CORS96), and the same for the two other frames.

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The new realization of NAD 83 involves no datum change, which means that, the origin, scale and orientation of NAD 83(2011) are identical to those of NAD 83(CORS96), and the same for the two other frames. The coordinates are not the same in the old and new realizations for multiple factors including the switch to absolute antenna calibrations, new/revised processing algorithms, improved discontinuity identification, several years of additional GPS data, change in reference epoch, and an improved definition of the global reference frame, IGS08. For a description of how NAD 83 is related to the global reference frame see Craymer *et al.*, 1999, Snay and Soler, 1999. Users working in Canada should consult Craymer, 2006 for a review of how NAD 83 is implemented in Canada. Concisely, the two biggest changes are caused by the change in reference epoch and the move from relative to absolute antenna calibrations.

http://www.ngs.noaa.gov/CORS/coords.shtml

Planning Issue
Mesh vs. CAD

When to Mesh from LiDAR and when from CAD?

- LiDAR meshing is best used on:
  - Irregular geometries / Terrain features
- CAD modeling is best used on:
  - Regular geometries / Man-made features

Models will be created from LiDAR meshes

Planning Issue
Remaining Faithful to Data

In processing, determine your approach

- Mesh and Deliver – Minimal edits
- Interpret – Choose a few points and sculpt
- Middle Approach

A middle approach will be used for processing

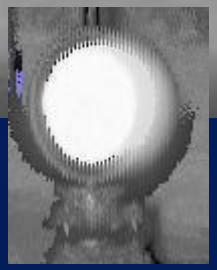
Acquisition

- Terrestrial LiDAR acquisition entails:
  - Scan with attached coaxial camera

Acquisition (Cont.)

- Terrestrial LiDAR acquisition entails:
  - Align scans

Panoramic Scan (360°)

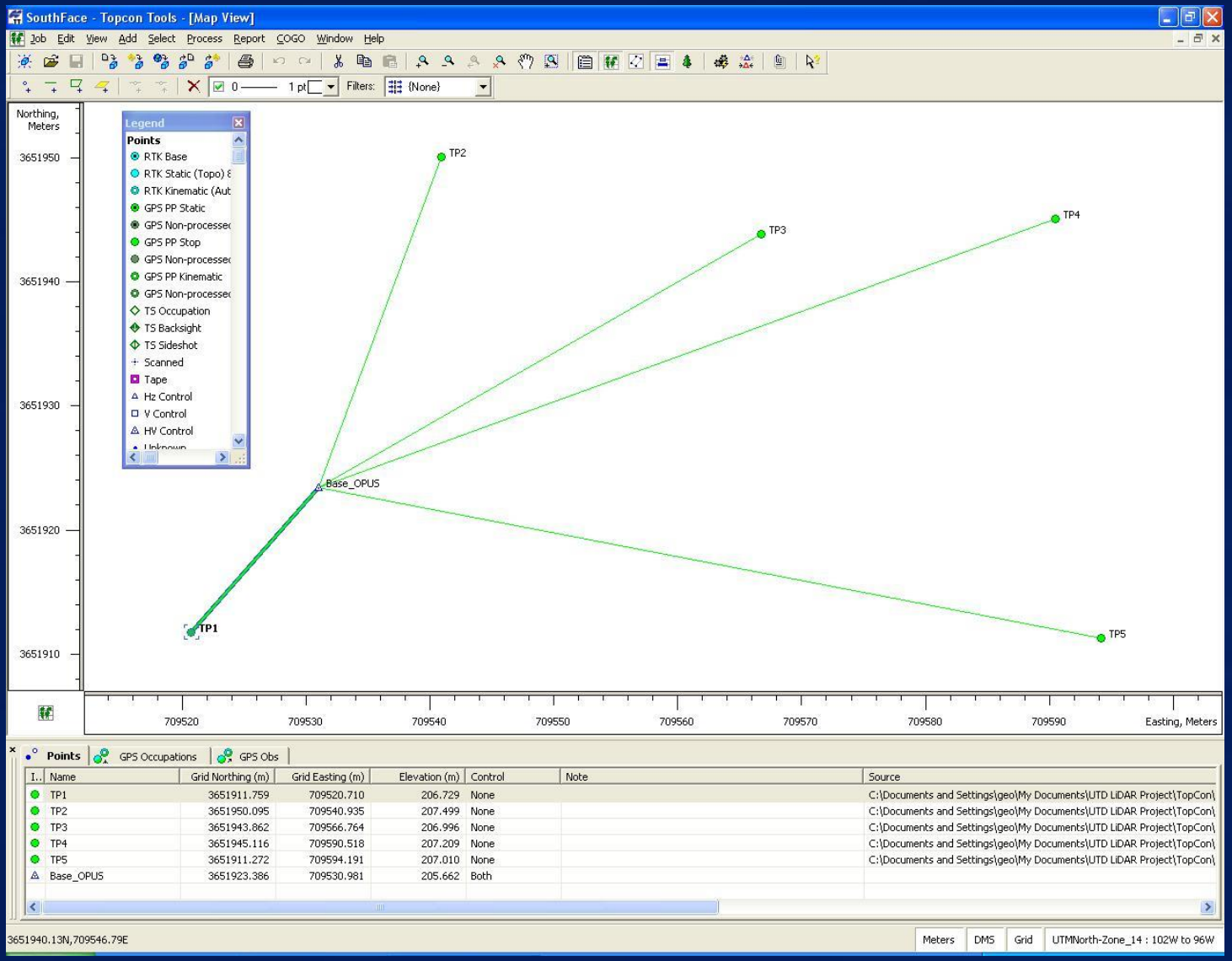


Reflector

Acquisition (Cont.)

- Georeferencing requires:
  - GNSS coordinates for the reflectors
  - Topcon GNSS receivers for “on-the-fly” survey
  - Submit the survey data to OPUS (continued …)

Acquisition (Cont.)



Acquisition (Cont.)

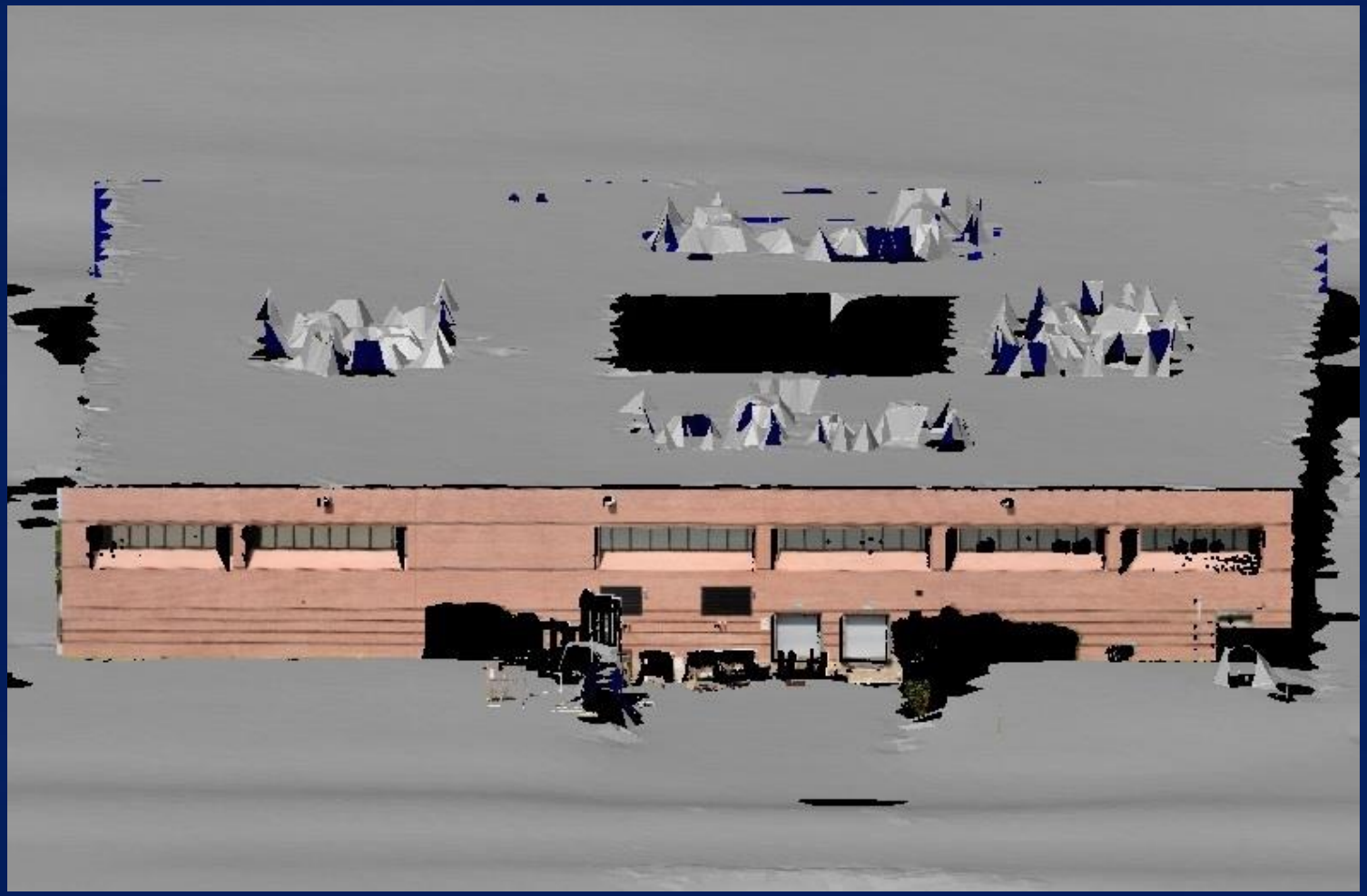
- Georeferencing requires (Cont.):
  - Conversion into UTM NAD-83 (1986) NAVD-88.

  Topcon Tools exports point list in NAD-83 (2011).

  Trimble Pathfinder Office transforms to NAD-83 (1986). Another point list is exported in this datum.

  RiScan Pro will use these values for the Tie Points and export georeferenced point clouds.

Acquisition (Cont.)



Terrestrial Colored Mesh integrated with Aerial LiDAR Mesh

Acquisition (Cont.)

- Aerial LiDAR data needs to be cropped
  - LAStools *las2las.exe* can extract a subset of points
    - Based on classification
    - Based on a bounding box
  - LAStools *lasview.exe* allows one to review changes
  - LAStools *las2txt.exe* can export to a text file
- Created LiDAR text files for roof and ground
- ESRI *LAS to Multipoint* and *Create Tin* tools

Assembly

- Terrestrial point clouds are exported twice

  RiScan Pro exports two files for each scan:

  – Georeferenced text files with RGB data

  – Proprietary Riegl (.3dd) data files
- Import text files into *Polyworks*
- Import 3dd files into *Polyworks* and align

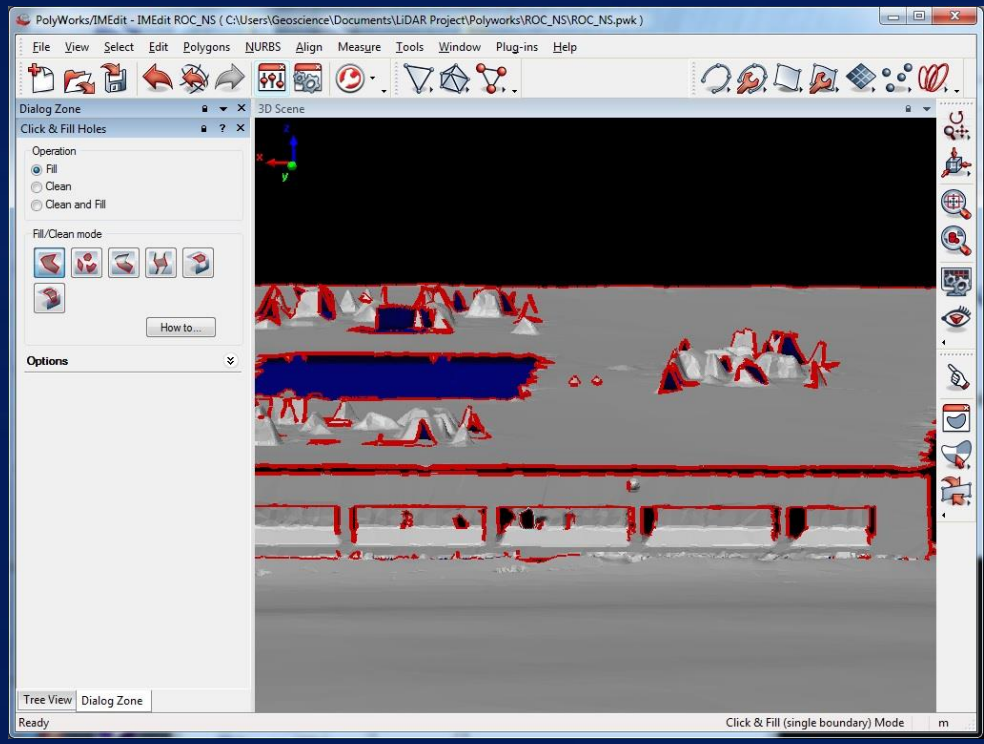
  – Use the corresponding text file for a basis

  – 3dd files contain more detail on each point

  – 3dd files create better quality meshes

Assembly (Cont.)

- Meshes need to be exported simultaneously
  - Moved from *Polyworks IMAlign* into *IMEdit*
  - *IMAlign* uses Huge Translation coordinate system
  - *IMEdit* uses a local coordinate system
- Now the model is finessed in *IMEdit*
  - Holes are filled
  - Model verified as watertight, topologically sound
  - Errant vertices deleted, model re-meshed



Conversion

- Export completed model into desired format
  - VRML for use in *ArcScene*
  - Waveform for use in *OpenSceneGraph*
- Keep Huge Translation offsets handy
  - VRML models can be converted to geo-VRML

Visualization

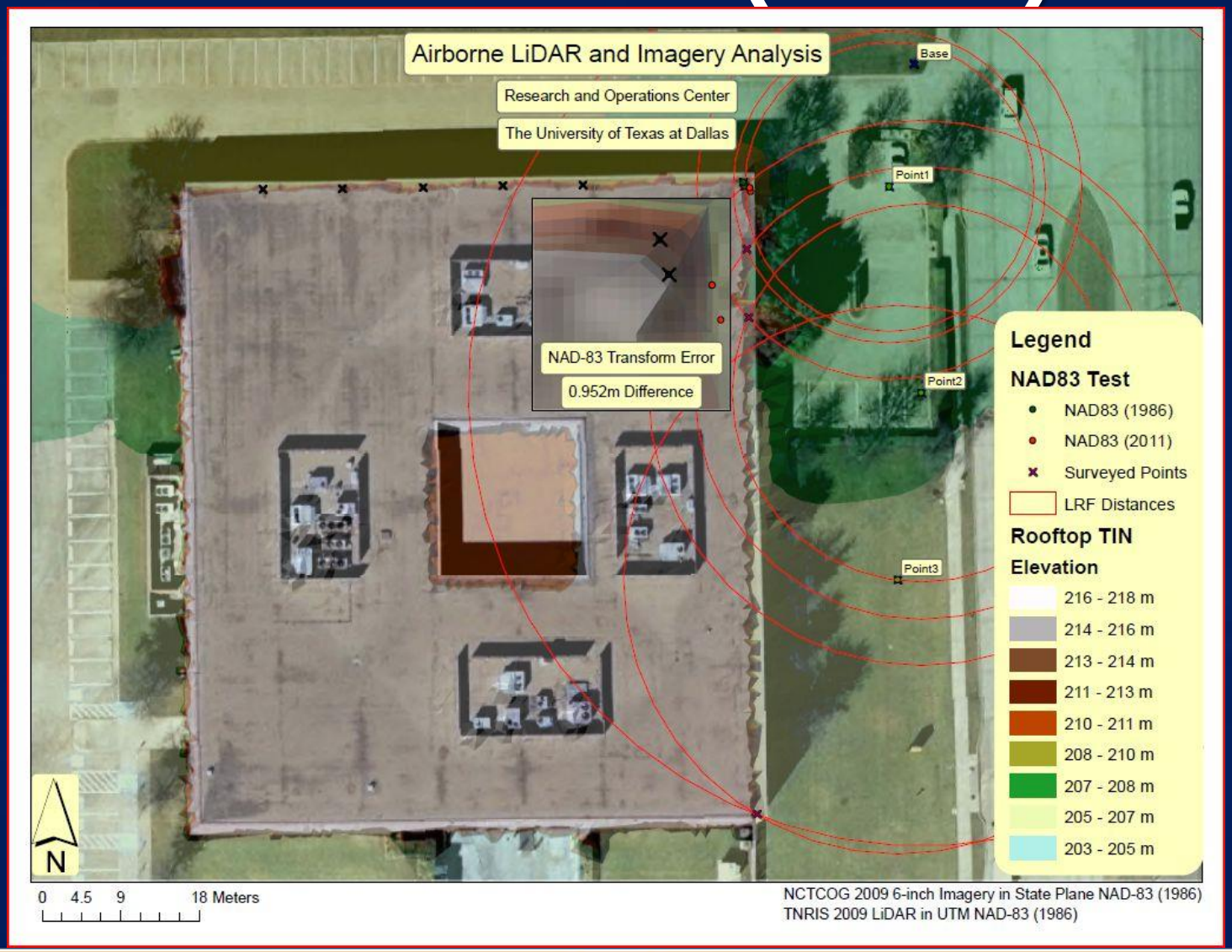
VRML non Georeferenced Model

ArcScene Georeferenced TIN with Draped Imagery

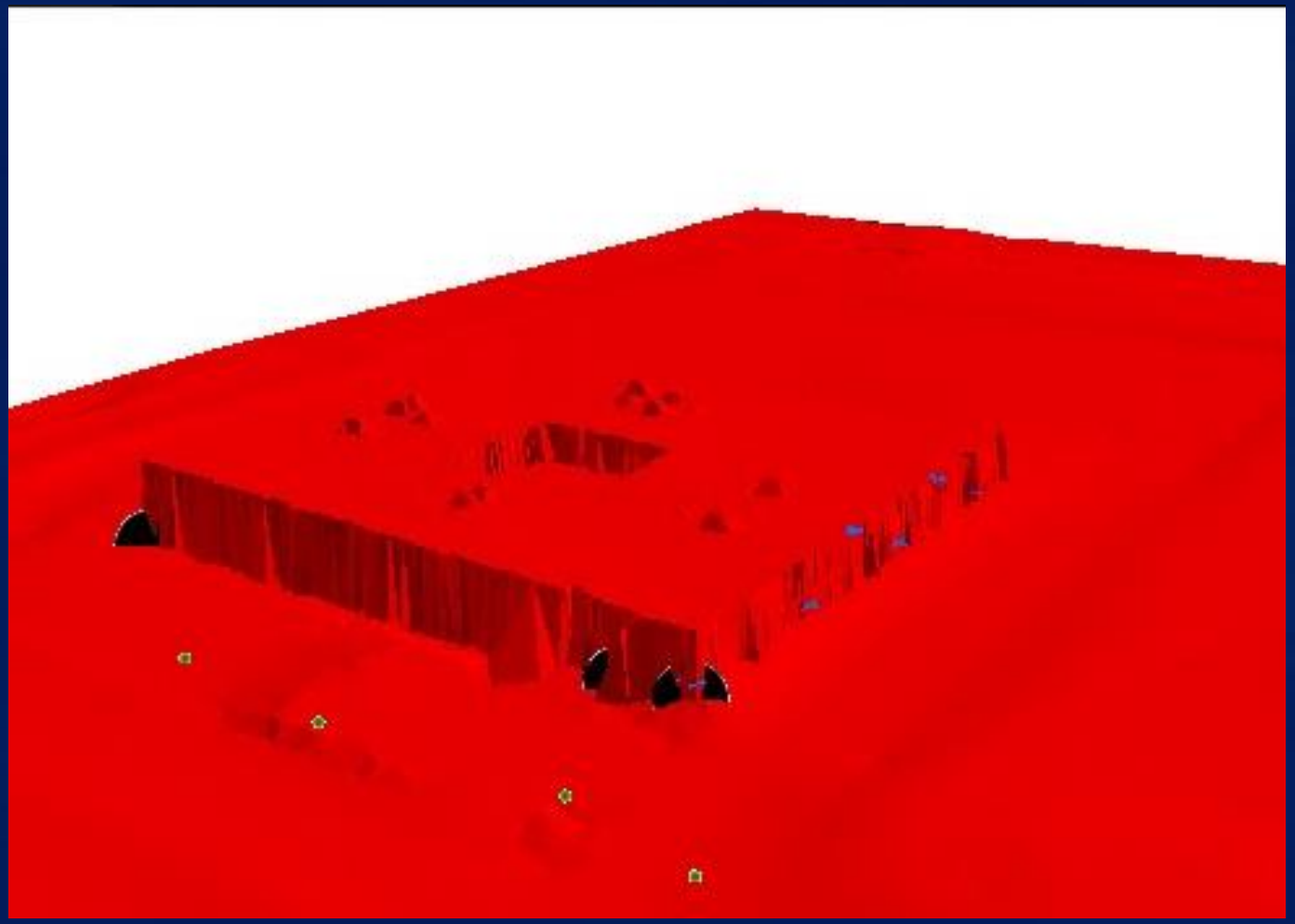
Verification

- Gathered GPS points for North and East walls
  - Tru Pulse laser rangefinder for distances
  - GeoXH to get north face points
    - Using offsets with the data collector was easy
  - Topcon receivers for the east face
    - *ArcMap* to buffer offset distances from points
    - Intersected these buffer radii to place east wall points
- North face points showed up well in 3d
- East face points obscured by wall slope in 3d

Verification (Cont.)



Verification (Cont.)



Future Study

- Georeferenced VRML models (.wrl)
- Waveform models used in Game Engines
- The CAD approach to creating these models
- Use of UTD's image transformation software
- Google Earth's 3D Building applications
- Determine exact cause of roof misalignment

Conclusion

- Aerial and Terrestrial LiDAR data were combined.
- VRS RTK values fit within a centimeter of the post processing survey GNSS
- Horizontal accuracy is within the specifications of the source data
- Vertical accuracy was slightly outside of specifications. This is likely due to datums.
- Find the balance…
- Pick a method appropriate with your allotted time, detail needed, project size…

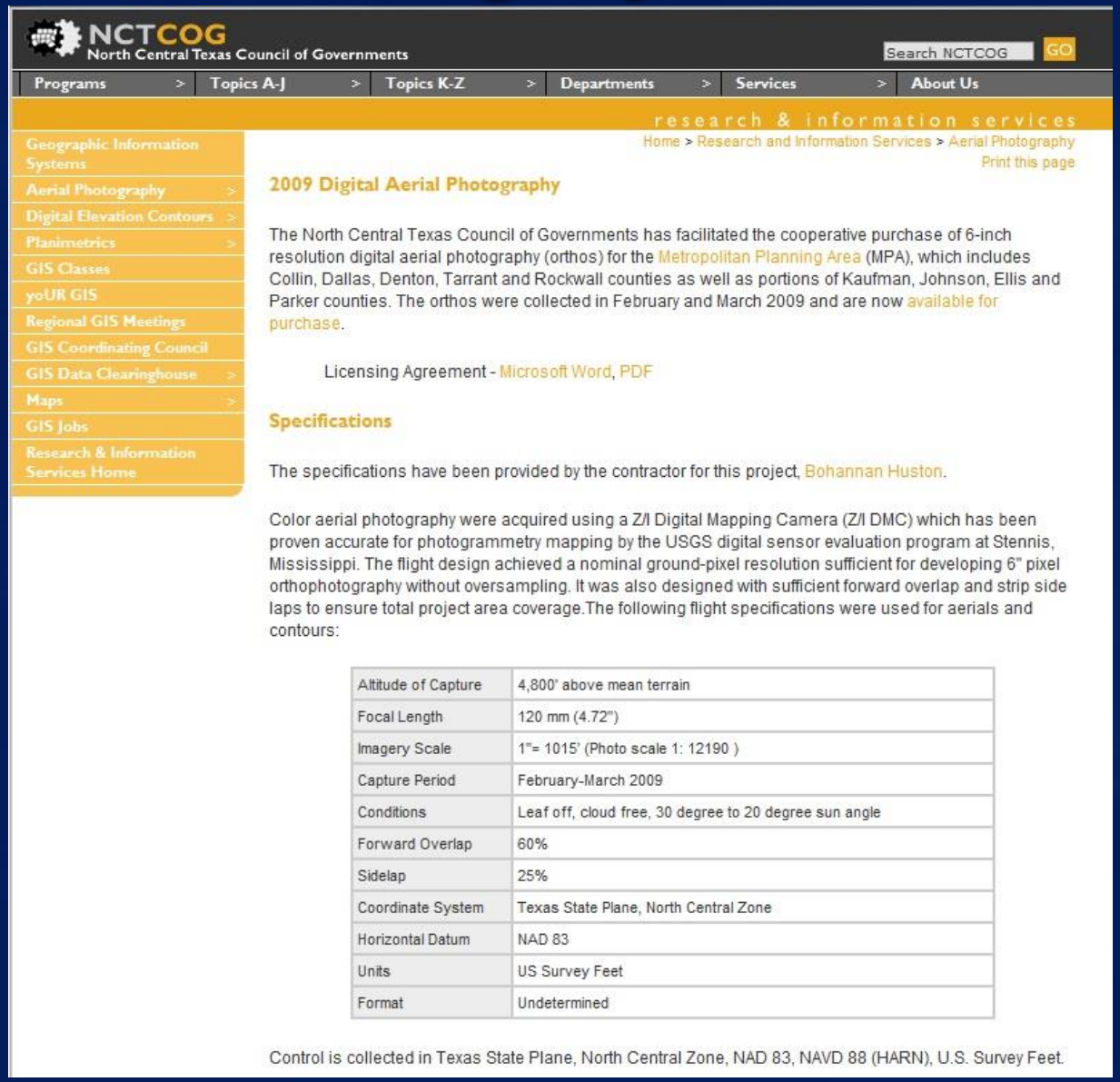
Acknowledgements

- Cody Cantrell, Western Data Systems (GeoXH)
- NCTCOGs, high resolution aerial imagery
- TNRIS, aerial LiDAR data

Useful Links

- http://www.ngs.noaa.gov/
- http://www.cs.unc.edu/~isenburg/lastools/
- http://www.google.com/earth/explore/showcase/3dbuildings.html
- http://www.ai.sri.com/geovrml/
- http://geospatial-solutions.com/nightmare-on-gis-street-accuracy-datums-and-geospatial-data/
- http://forums.esri.com/Thread.asp?c=93&f=984&t=266837 The NAD-83 Datum – Which flavor?

Aerial Imagery Metadata



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2009 Digital Aerial Photography

The North Central Texas Council of Governments has facilitated the cooperative purchase of 6-inch resolution digital aerial photography (orthos) for the Metropolitan Planning Area (MPA), which includes Collin, Dallas, Denton, Tarrant and Rockwall counties as well as portions of Kaufman, Johnson, Ellis and Parker counties. The orthos were collected in February and March 2009 and are now available for purchase.

Licensing Agreement - Microsoft Word, PDF

Specifications

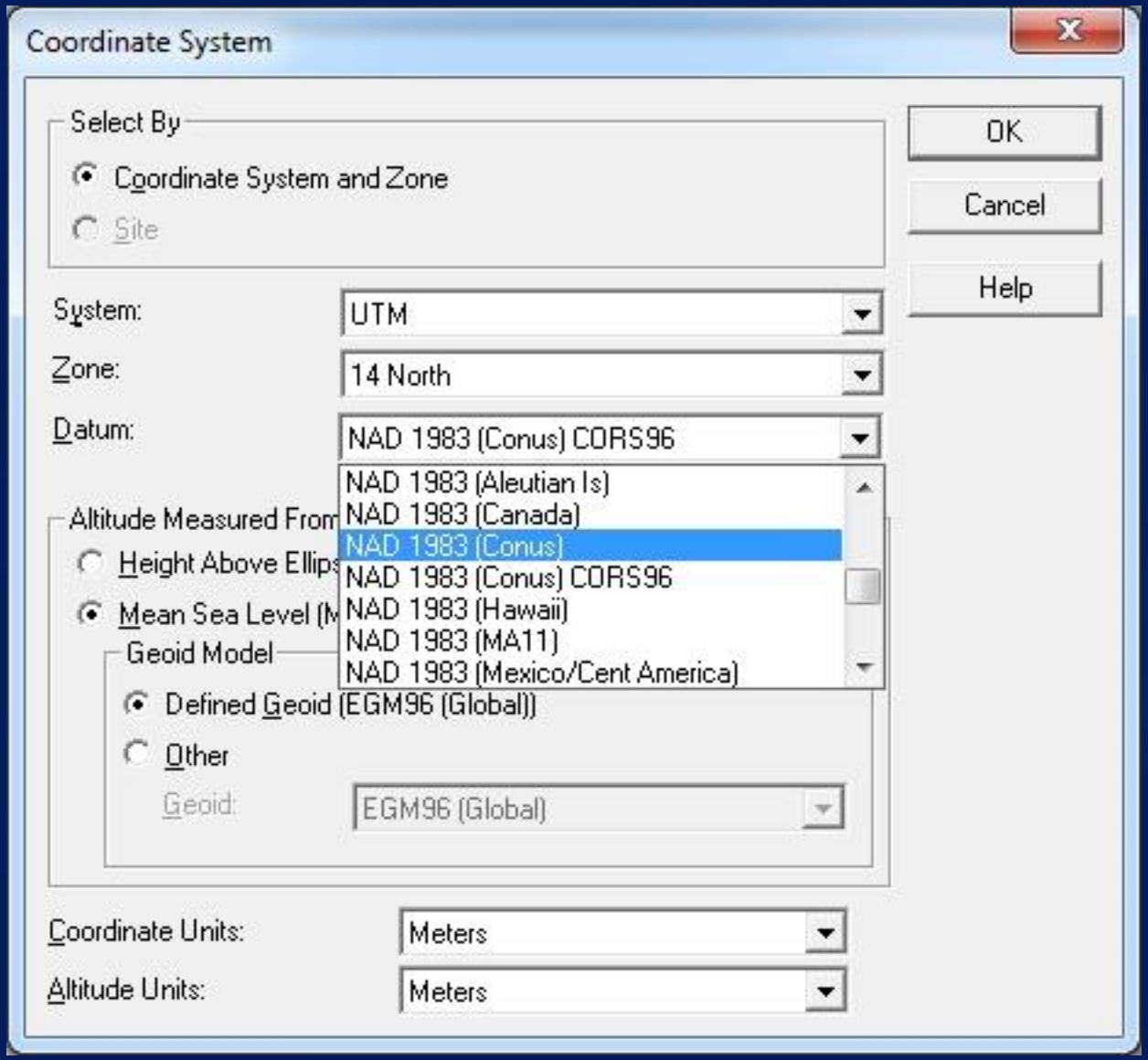
The specifications have been provided by the contractor for this project, Bohannan Huston.

Color aerial photography were acquired using a Z/I Digital Mapping Camera (Z/I DMC) which has been proven accurate for photogrammetry mapping by the USGS digital sensor evaluation program at Stennis, Mississippi. The flight design achieved a nominal ground-pixel resolution sufficient for developing 6" pixel orthophotography without oversampling. It was also designed with sufficient forward overlap and strip side laps to ensure total project area coverage.The following flight specifications were used for aerials and contours:

Altitude of Capture	4,800' above mean terrain
Focal Length	120 mm (4.72")
Imagery Scale	1"= 1015' (Photo scale 1: 12190)
Capture Period	February-March 2009
Conditions	Leaf off, cloud free, 30 degree to 20 degree sun angle
Forward Overlap	60%
Sidelap	25%
Coordinate System	Texas State Plane, North Central Zone
Horizontal Datum	NAD 83
Units	US Survey Feet
Format	Undetermined

Control is collected in Texas State Plane, North Central Zone, NAD 83, NAVD 88 (HARN), U.S. Survey Feet.

Datum Transformation



Overview (Cont.)

This will be a depth-first approach