SHELLY & SANDS
JOHN DOWALTER, PE, PS

3-D MODELING FOR MACHINE CONTROL

Trimble
TOPCON
Dale Carnegie
Public Speaking Training
Ben Stein’s Public Speaking Training
JOHN DOWALTER, PE, PS

S&S Survey Manager

- Ohio University, BSCE ’92
- Columbus State CC ’04, completed survey hours

- Kokosing Construction Co. ’90 – ’99, Survey Dept
- Buckeye Positioning Systems ‘03, Survey Sales & Support
- Miller Pavement Construction ‘04 – ‘05, Surveyor
- Shelly & Sands, Inc. ’06 – ’18, Survey & 3D Manager
SHELLY & SANDS
SURVEY SQUAD

• S&S work is primarily ODOT, but also Counties and Municipalities
• 10 Crew Chiefs (2 office / 8 field) & 3 I-Men
• Survey Group handles 120+ projects per year ($100k to $100-million in size).
• Survey Group manages the Machine Control Fleet: purchasing, training, scheduling, job setup
• Survey Crews equipped with Trimble Robotic total stations and GPS
M/C EQUIPMENT

ATS / GPS M/C EQUIPMENT

- 6 EA – UTS Robotic 3D Graders (Trimble)
- 22 EA – GPS 3D Dozers
  (13 EA Trimble // 9 EA Topcon)
- 10 EA – GPS Base Stations (Trimble)
- 56 EA – GPS Rover Units (Trimble & Topcon)
- 2 EA – Topcon RDMC Paver / Mill Sys.
- 1 EA – Topcon RDM-1 Scanner Sys.
SOME KEY CONCEPTS IN 3D MODELING

- 3D M/C Equipment (AMG)
- Project Control
- Construction Tolerances
- Data Translation
- DTM/TIN Densification
Trimble Base Station Setup
Trimble GCS900 GPS Dozer Sys.
Topcon 3DMC GPS Dozer Sys.
Topcon 3D-MAXX GPS Dozer Sys.
Trimble GCS900 UTS Grader Sys.
Topcon Millimeter GPS Grader Sys.
Trimble GPS Excavator System
Topcon GPS Excavator System
Trimble GCS900 UTS Milling Sys.
Topcon RDMC Paver Sys.
Topcon RDMC Paver Sys.
Topcon RDMC Mill Sys.
Topcon RDM-1 Scanner Sys.
Stringless Concrete Paving Sys.
Conceptual vs. Constructible

Two General Types of Models to consider:

Conceptual vs. Constructible

Two General Types of Models to consider:

2. **Constructible** – Mathematically / geometrically relevant to the contract specifications and field construction methods.
**PROJECT CONTROL**

- What is good enough?

- If you do NOT have good, tight project control, your 3D efforts may be all for not!

- Good Control will lead to Good Redundancy.

- You must know your construction grade tolerances for your project and your work.

- GPS vs. Conventional Methods
ODOT 2016 Construction Tolerances

• Side Slopes = +/− 1.0’
  • ODOT Spec 203.08.B Earthwork Construction Tolerances

• Shoulders & Ditches = +/− 0.17’
  • ODOT Spec 203.08.C Earthwork Construction Tolerances

• Subgrade Fine Grade = +/− 0.04’
  • ODOT Spec 203.08.D Earthwork Construction Tolerances
ODOT 2016 Construction Tolerances

• **Stone / Agg Base Fine Grade =** \(+0.04’\)
  - ODOT Spec 304.06 Finished Surface

• **Asphalt Pavement Finish Grade =** \(+/- 0.04’\)
  - ODOT Spec 401.19 Spreading & Surface Tolerances

• **Concrete Pavement Finish Grade =** \(+/- 0.04’\)
  - ODOT Spec 451.04 Spreading & Surface Tolerances
PROJECT CONTROL Accuracies

• What is good enough? 🤔

• GPS Accuracy (VRS vs. Base Station)
  • Horizontal = +/- 0.05’
  • Vertical = +/- 0.10’

• Conventional Robotic Accuracy
  • Horizontal / Vertical = +/- 0.02’

• Differential Leveling
  • Optical Engineers Level = +/- 0.02’
  • Digital Level = < +/- 0.01’
1. Set an RTK base point and observe using the ODOT VRS, then setup our RTK Base.

2. Recon and observe primary Plan Control points to perform a GPS calibration / localization.

3. Set secondary construction control points at a maximum of 500-ft stations outside of construction work area.
4. Perform digital level loops through ALL primary and secondary control points.

5. Generate “Control Comparison” XLSX sheet to compare **Plan** vs. **GPS** vs. **Leveled** values.

6. Generate our **Project Control CSV file** using **GPS North & East** values and **Leveled Elevations**.
• A solid project Elevation Datum must be established for the use of 3D M/C!

| PLAN PT# | PLAN ELEV | MOR | VERT | GPS PT# | GPS ELEV | VERT | MOR | MOR VERT | VERT MO | GPS - PLAN | GPS - PLAN | GPS - PLAN | GPS - LEVEL | LEVEL # | LEVEL ELEV | IDN Linea | (LEVEL - PLAN) |
|---------|-----------|-----|------|---------|----------|------|-----|------|-------|--------|----------|----------|----------|-------------|--------|-----------|-----------|----------------|
| CP1     | 507771.918 | 2236873.247 | 1021.660 | RTX_CP1 | 507771.918 | 2236873.247 | 1021.660 | IP IND IN CONCRE | 0.000 | 0.000 | 0.000 | 0.000 | LVL_CP1 | 1021.660 | SCLPCE BM | 0.000 |
| CP2     | 509647.056 | 2237260.351 | 998.610 | RTX_CP2 | 509647.056 | 2237260.351 | 998.610 | IP IND IN CONCRE | 0.000 | 0.000 | 0.000 | 0.000 | LVL_CP2 | 998.610 | SCLPCE BM | 0.000 |
| CP3     | 511322.823 | 2237823.143 | 1015.780 | RTX_CP3 | 511322.823 | 2237823.143 | 1015.780 | IP IND IN CONCRE | 0.000 | 0.000 | 0.000 | 0.000 | LVL_CP3 | 1015.780 | SCLPCE BM | 0.000 |
| CP4     | 512475.872 | 2237314.157 | 1010.000 | RTX_CP4 | 512475.872 | 2237314.157 | 1010.000 | IP IND IN CONCRE | 0.000 | 0.000 | 0.000 | 0.000 | LVL_CP4 | 1010.000 | SCLPCE BM | 0.000 |
| CP5     | 510272.312 | 2239252.802 | 1013.829 | RTX_CP5 | 510272.312 | 2239252.802 | 1013.829 | IP IND IN CONCRE | 0.000 | 0.000 | 0.000 | 0.000 | LVL_CP5 | 1013.829 | SCLPCE BM | 0.000 |
| CP6     | 510229.270 | 2237065.465 | 1016.100 | RTX_CP6 | 510229.270 | 2237065.465 | 1016.100 | IP IND IN CONCRE | 0.000 | 0.000 | 0.000 | 0.000 | LVL_CP6 | 1016.100 | SCLPCE BM | 0.000 |
| CP7     | 510306.621 | 2237925.104 | 995.189 | RTX_CP7 | 510306.621 | 2237925.104 | 995.189 | IP IND IN CONCRE | 0.000 | 0.000 | 0.000 | 0.000 | LVL_CP7 | 995.189 | SCLPCE BM | 0.000 |
| CP8     | 509647.100 | 2237611.396 | 997.280 | RTX_CP8 | 509647.100 | 2237611.396 | 997.280 | IP IND IN CONCRE | 0.000 | 0.000 | 0.000 | 0.000 | LVL_CP8 | 997.280 | SCLPCE BM | 0.000 |
Well-Established Project Datum

• Will carry consistent elevations from setup to setup.

Setup ‘A’
1500-ft

Setup ‘B’
1500-ft

Setup ‘C’
1500-ft
Poorly-Established Project Datum

- Will NOT carry consistent elevations from setup to setup.
Major 3D Modeling Software

- Trimble BC-HCE
- Trimble Terramodel
- Carlson Survey
- Topcon Magnet Office
- AutoDesk Civil-3D
- Bentley OpenRoads (not Geopak)
- And yes, Microsoft Excel

- NO single program will do everything!
Data Translation

• Perhaps one of the most important concepts, but least understood concepts in 3D data prep.
• Involves moving data (2D or 3D) from one platform to another.
Data Translation – File Types

- **DGN** – Microstation ‘basemap’ files
- **DWG/DXF** – AutoCad ‘basemap’ files
- **XML** – LandXML surfaces or alignments
- **CSV** – comma delimited points files
  - **PNEZD format** (or) **SOZD format**
- **XLSX** – Microsoft Excel file
- **ICM.DGN** – Bentley iModel file
- **GEN** – Geopak ASCII cross-section file
- **Various GIS formats** – SHP, KML, KMZ
  - **GPK, CRD, TIN** – worthless Geopak files
Data Translation – Data Types

- Points
- Alignment Chains & Profiles
- Surface TIN / DTM’s
- 2D Polylines
- 3D Linetrings
- Text
- Stored Cross-sections
- Corridor Templates (possibly in the future)
Data Translation – Data Types
3D Model Process

- Different considerations for Roadway vs. Site
- Use as DTM only, or also use data for construction layout purposes.
- Ultimate goal is to generate one, big, “COMPOSITE MODEL”.

<table>
<thead>
<tr>
<th>Description</th>
<th>% of Project Area</th>
<th>% of Data Prep Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Roadway - Road + Bridge</td>
<td>70%</td>
<td>33%</td>
</tr>
<tr>
<td>Intersection / Pavement Details</td>
<td>15%</td>
<td>33%</td>
</tr>
<tr>
<td>Side slope / Ditches / Driveways / Curb Ramp Details</td>
<td>15%</td>
<td>33%</td>
</tr>
</tbody>
</table>
3D Model QA/QC

- Best done with 0.20’ or tighter contours, NOT 3D visualizers.
DTM / TIN Densification

- Consideration of the Final File Size is required – some 3D systems cannot handle large files.
- Typical Roadway @ 25-ft & Critical points
- Superelevations
  - Full Super @ 25-ft & Critical points
  - Super Transitions @ 5-ft
- Intersection / Pavement Details
  - Radius returns @ 10-ft or tighter
  - Ramps @ 25-ft & Critical points
- Side slopes / Ditches @ 50-ft & Critical pts
DTM / TIN Densification
Superelevation Example @ 25-ft
DTM / TIN Densification
Superelevation Example @ 5-ft
What can we do now?

odot jobname REQUEST FOR ELEC. FILES

I would like to request the electronic files for this project.
   ODOT #xxxxxxx / PID #xxxx - District x
   job name

The files I am requesting are:

- **PRIORITY FILES**
  - Microstation DGN basemap files *(Survey, Roadway, Drainage, ROW, Traffic, Utility, MOT)*
  - Alignment Chains (Hor / Vert) – ASCII report / XML File
  - Monument / Control Points – CSV / XLS Files *(Monument Report.csv)*
  - Survey Report for Project Control
  - Curb / Pavement Table – XLS File
  - Project Index XLS File
  - Existing DTM – XML File
  - Geopak Cross-Section Staking reports– ASCII report *(Existing & Proposed)*
  - Geopak Cross-Section GEN file at 25 foot stations and cardinal points – *(Subgrade & Finish)*

Please forward to ODOT.
Let me know if you have any questions. Thanks.

John Dowalter, PE, PS
Shelly & Sands
What can we do now and in the future?

- **Current CADD Manual & Specs**
  - See AppendixE_0413-Electronic Submissions Checklist

- **Future CADD Manual & Specs**
  - Electronic Submissions will be required before acceptance of plans. (Fall of 2018?)

- **Many Benefits to using 3D Modeling from Design to Bid to Construction.**
Garbage-In $\rightarrow$ Garbage-Out

- **3D Machine Control Systems** HAVE THE POTENTIAL TO BUILD IT WRONG VERY ACCURATELY!

<table>
<thead>
<tr>
<th>DESIGN INPUTS</th>
<th>CONSTRUCTION INPUTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>DESIGN SURVEY CONTROL</td>
<td>PROJECT SURVEY CONTROL</td>
</tr>
<tr>
<td>EXISTING SURVEY DATA</td>
<td>3D DATA / MODEL</td>
</tr>
<tr>
<td>DESIGN INTENT / PLANS</td>
<td>3D M/C EQPT</td>
</tr>
</tbody>
</table>

GI $\rightarrow$ GO
Use of Automated Machine Guidance within the Transportation Industry

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Contractor's Final Report for NCHRP Project 10-77
Submitted August 2017

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QUESTIONS – 3D Modeling

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