CONSTRUCTION ENGINEERING SOLUTIONS, LLC

Specializing in GPS Consultation, Management, and 3-D Data Prep

Getting to Know Machine Control

"Providing Clarity to the World of Machine Control and the Data"

There are numerous types of hardware and software options available for GPS and/or Robotic infrastructure and machine control systems. This class will focus on the most common infrastructure software, hardware/sensors, and machines encountered in the field and office regarding site prep and road construction projects utilizing construction technology. We will also discuss the data prep file configurations needed for effective use of each system and best practices/troubleshooting for the provided data in efforts to ensure efficient ongoing productivity while minimizing costly delays and errors for you and your client throughout the life of the project.

Contractors most commonly use GPS for dozers, graders, and excavators and occasionally Robotics for graders and asphalt/concrete pavers on the site along with takeoff, data prep, data management, and file transfer software in the office. Intimate knowledge of the following topics will make great strides in effective and productive communication and work performance when providing surveying and engineering services to a contractor utilizing construction technology. Although important, we will not focus a great deal on the first topic of machine hardware/sensors but it is vital to understand that, although similar in nature, each system will require different file formats and information in order to efficiently and correctly utilize provided data for each construction task.

Upon completion of this class you should have: General knowledge of the various manufactures systems, hardware/sensors, and software; A solid understanding of the planning, establishment, and maintaining of a GPS base station in order to maintain consistent coordinates and elevations throughout all phases of construction; Detailed knowledge of the various file types encountered for machine control and the use/benefit of each type; And a basic understanding of optimal data prep concepts, efficient file transferring between field and office, effective communication with contractors, and troubleshooting the multiple file types.

It is important to understand that the following data, information, ideas, and recommendations are a combination of numerous successes and failures based on multiple experiences with users, manufacturers, processes, machines, hardware/sensors, and software that all combine to shape opinions and "Best Practice" recommendations that cover a wide range of construction technology applications. However, every situation warrants consideration of the specific circumstances in order to effectively choose the best course of action for the task at hand. Technology changes at an extremely rapid pace therefore making it nearly impossible to provide a presentation of current error proof methods, equipment models, and software capabilities. This class is designed to give insight to the world of Machine Control and inspire each attendee to go forth and create their own diverse and extraordinary vocabulary and service that best serves their clients.

Construction Engineering Solutions, LLC (CES) is not affiliated with any manufacturer of any GPS equipment or software. CES is an independent consulting firm that utilizes and through thorough examination and training, maximizes the efficient planning, implementation, and use of all construction technology to its clients.

I. Common Systems, components, and software

ALL Systems have the same basic components regarding Infrastructure, Sensors, and Benefits

Infrastructure = Base Station or Robotic Total Station with Radio for sending location information to the machines and rovers.

Machines = In-Cab Control/Display box, GPS Antenna(s) w/receiver or Prism target, Radio unit, slope sensors, hydraulic valve sensors (for automatics), and usually cables connecting the various components.

Base/ Rovers = Data collector, GPS Antennas w/receivers or Prism target, and Radio unit (usually built in with the GPS receiver or data collector) and Bluetooth used for communication (occasionally cables are involved).

Benefits = The benefits of MC for contractors is undeniable. Having cut/fill and site feature location across the entire project at all times for operators, grade checkers, and supervisors increases machine production which means less machine/man hours on a site, faster job completion, better/smoother finish surfaces, and less re-work or costly delays from grade checking mistakes. Instead of looking out of the cab for up/down information from a stake, hub, or grade checker, the operator has this guidance at his fingertips anywhere on the site. Grade checkers and Supervisors benefit by having the ability to track/calculate volumes and plan ahead by utilizing the data without costly staking fees or inaccurate guestimates.

A. Carlson Grade

1. Carlson Machines
   - **a.** Carlson Machine Control w/Carlson Grade for dozers, graders, excavators, & Pan Scrapers
     - ***i.*** Carlson Commander MC Control Box
     - ***ii.*** Carlson MC Pro Lite Dual Axis sensor
     - ***iii.*** Carlson MC Pro 500 or MC Pro Lite Dual GNSS Receiver
2. Carlson Base/Rovers
   - **a.** Carlson Surveyor or Carlson Supervisor Field Table Tablet data collector w/Carlson SurvCE for surveyors & grade checkers, Carlson Field for supervisors & grade checkers, or Carlson Grade Supervisor for supervisors & grade checkers
     - ***i.*** Carlson MC Pro GS Smart GNSS Receivers w/Radio & Antennae

3. Carlson Office Software
   a. Carlson Civil and/or Survey for design, data prep, & calculations
   b. Carlson Takeoff for estimates/bidding, data prep, & calculations

B. Leica Geosystems

1. Leica Machines
   a. Leica PowerGrade 3D for dozers & graders
      i. Leica MPC1350 PowerGrade 3D Panel
      ii. Leica GPS/GNSS PowerBox Receiver w/TCPS 27S Radio Modem
      iii. Leica GPS/GNSS Antenna or PowerTracker Target and optional blade slope sensor
   b. Leica PowerDigger 3D for Excavators
      i. Leica MPC1350 PowerGrade 3D Panel
      ii. Leica GPS/GNSS PowerBox Receiver w/TCPS 27S Radio Modem
      iii. Leica GPS/GNSS Antennas and boom/stick/bucket slope sensors
   c. Leica PaveSmart 3D for Concrete Pavers
      i. Leica MPC1310 Control/Display Box
      ii. Leica PowerTracker Target
      iii. Multiple Leica Slope Sensors and multiple Radio Modems
2. Leica Base/Rovers
   a. Leica Redline PowerController or CS25 Tablet w/Leica GeoPad or Leica Site Foreman (by Carlson) for grade checkers & supervisors
      i. Leica PowerAntenna GPS antennas or Leica PowerTracker Robot(s)
      ii. Leica GPS/GNSS PowerBox Receiver w/internal radio
3. Leica Office Software
   a. Leica Construction Office for data prep, management, and calculations

C. Topcon Positioning

1. Topcon Machines
   - **a.** Topcon 3D GPS+ and 3D MC^2 for dozers, graders, & scrapers
     - ***i.*** Topcon GX-60 Control Box
     - ***ii.*** Topcon MC-A1 GPS Antenna
     - ***iii.*** Topcon MC-R3 GPS Receiver w/internal radio
     - ***iv.*** Hydraulic Valve and optional Topcon MC^2 Slope Sensor
   - **b.** Topcon X63-GPS System for Excavators
     - ***i.*** Topcon GX-60 Control Box
     - ***ii.*** Topcon MC-A1 GPS Antennas
     - ***iii.*** Topcon MC-R3 GPS Receiver w/internal radio
     - ***iv.*** Topcon 360 degree Tilt Sensors
   - **c.** Topcon 3D-millimeter GPS+ for dozers, graders, and concrete/asphalt pavers
     - ***i.*** Topcon GX-60 Control Box
     - ***ii.*** Topcon MC-A1 GPS Antenna
     - ***iii.*** Topcon MC-R3 GPS Receiver w/internal radio
     - ***iv.*** Hydraulic Valve and optional Topcon MC^2 Slope Sensor
     - ***v.*** Topcon PZL-1 Positioning Zone Laser Transmitter w/PZS-MC Positioning Zone Sensor
2. Topcon Base/Rovers
   - **a.** Topcon FC-25, FC-250, FC-2500 data collector w/TopSURV for surveyors & grade checkers or Pocket 3D for supervisors & grade checkers
     - ***i.*** Topcon HiperLite, Hiper II, or GR-5 GPS Antennas w/internal radio
3. Topcon Office Software
   - **a.** Topcon 3D-Office for data prep and data management
   - **b.** SiteMaster for surveying, data prep, and data management
   - **c.** SiteMaster Lite for data management

D. *Trimble Navigation and Caterpillar*

1. Trimble/CAT Machines
   - **a.** Trimble GCS900 or CAT Accugrade for dozers, graders, and excavators
     - ***i.*** Trimble CB430 or CB460 Control Box (CAT CD700)
     - ***ii.*** Trimble/CAT MS99x GPS/GNSS Antenna(s) or MT900 Robotic Prism Target
     - ***iii.*** Trimble/CAT SNR9x0 Machine Radios
     - ***iv.*** TrimbleVM4x0 Hydraulic Valve driver (CAT ECM)
     - ***v.*** Trimble/CAT AS or RS400 Slope Sensors, and PM400 Power Regulator
     - ***vi.*** Trimble/CAT AS450 Angle Sensors for excavators
   - **b.** Trimble PCS900 for asphalt pavers
     - ***i.*** Trimble CB430 or CB460 Control Box (CAT CD700)
     - ***ii.*** Trimble/CAT SNR9x0 Machine Radios
     - ***iii.*** Trimble/CAT AS450 Angle Sensor
     - ***iv.*** Trimble AS200 Crossfall Sensor
     - ***v.*** Trimble MT900 Robotic Prism Target
     - ***vi.*** Trimble VM200 Hydraulic Valve driver
     - ***vii.*** Trimble SPS930 Robotic Total Station(s)
2. Trimble Base/Rovers
   - **a.** Trimble Tablet, TSC2, or TSC3 w/SCS900 for surveyors, grade checkers, & supervisors or Survey Controller for surveyors and grade checkers
     - ***i.*** Trimble SPS8xx GPS/GNSS Antennas w/internal radio
3. Trimble Office Software
   - **a.** Terramodel for data prep and calculations (No longer being developed or supported)
   - **b.** Paydirt for estimating/bidding (No longer being developed or supported)
   - **c.** SiteVision Office or AccuOffice (CAT) for machine file exports and file management
   - **d.** Business Center – Heavy Construction Edition for estimating, data prep, file management, calculations, machine file exports (free base version for file management and machine file exports).

II. Best Practices for Site Set-Up of GPS/Robotic Infrastructure

A. Establishing Control Points

1. Horizontal coordinates should be established by a traditional traverse or other survey standards.
   - **a.** 5 to 8 points surrounding the site is ideal (one or two in center is good).
     - ***i.*** All points with unobstructed view of the sky above 10 degrees to the horizon in all directions if possible.
   - **b.** Can be set with GPS if site tolerances can be met and intimate knowledge/confidence with this method is possessed by the GPS user.
     - ***i.*** A state plane coordinate system and GEOID can be used if desired.
2. Elevations should be established or verified via a traditional level loop at the required project accuracies.
3. Control for Robotic use should be at max 1000' intervals adjacent to the area being graded.

B. Establishing a Base Station

1. Choose a spot that will be unaffected by the site construction if possible.
   - ***a.*** Away from daily construction traffic, trees, tall fences, buildings, or hills.
   - ***b.*** Highest point in the area with a full view of the sky in every direction and no objects above a 10 degree angle on the horizon if possible.
   - ***c.*** If a building or tall pole is used, make sure the base is solid enough to withstand wind gusts and deep enough to survive winter freeze/thaw cycles.
2. Record all pertinent data of the base set-up location.
   - ***a.*** Keep a detailed record of GPS Latitude, Longitude, Height, antenna Height, Radio Channel, etc. for future reference.
3. Avoid multiple base mounts within a 100' radius or on the same pole.
   - ***a.*** This can be confusing for contractors.
   - **b.** Radio interference can occur between multiple base stations at close range even if on different frequencies.

C. Performing a Site Calibration (Most critical part of the site set-up)

1. Ensure that the GPS pole and level vial have been properly serviced before beginning this process.
2. A 3 to 10 minute Static observation is recommended for each control point observed.
   - **a.** Using a State Plane coordinate system in conjunction with a GEOID can be used to avoid this process but most contractors do not understand these complex surveying methods and some of their machines may not accept calibrations with embedded GEOIDS.
3. Avoid multiple site calibrations in order to remain consistent with all on-site GPS users.
   - **a.** Share a single Site Calibration - GPS and control point data can be extracted from any data collector software and used to re-construct a nearly identical calibration in the other systems' office or data collector software in order to maintain a consistent GPS correction.
   - **b.** If disaster strikes the base station avoid the urge to re-perform the site calibration.
     - ***i.*** Identify the cause or source of error and correct the problem ASAP.
     - ***ii.*** Re-establish a temporary base location by setting the base on a fixed height tri-pod over a control point used in the calibration. Be aware of antenna height and check another control point used in the original site calibration to verify accuracy of the temporary set-up.
     - ***iii.*** Locate a new base pole position with the rover (Be aware of antenna height).
     - ***iv.*** Move the base station to the new location and once again re-check a control point used in the original site calibration to verify accuracy.

*****It is a good idea for the surveyor to have off-site points that can be used to quickly and accurately re-establish a damaged base station position as often this happens late in the construction cycle when on-site control has been nearly obliterated!!*****

III. Common File Types Encountered

A. Office File Formats

1. Dwg = a standard CAD file for 2D or 3D data.

- ***a.*** Often houses hidden or embedded formats of blocks, hatches, linetypes, and references that can cause problems when sharing data and balloon file sizes.
- ***b.*** Can be used or imported by nearly all software.
  - ***i.*** Land Desktop, AutoCadd, Civil 3D, Eagle Point, Carlson, Business Center, Leica Construction Office, Terramodel (before 2009), Topcon 3D-Office, Topcon SiteMaster, etc.

2. Dxf = a universal CAD file for 2D and 3D data.

- ***a.*** Eliminates issues with proprietary embedded formats.
- ***b.*** Works with nearly all office software and data collectors.

3. DGN = Microstation file format similar to DWG

- ***a.*** Can be imported by nearly all software.
  - ***i.*** Land Desktop, Civil 3D, Eagle Point, Carlson, Business Center, Leica Construction Office, Terramodel (before 2009), Topcon SiteMaster, etc.
- ***b.*** XML = an increasingly universal file sharing format.
  - ***i.*** Works best for sharing data when used correctly.
  - ***ii.*** Imported and exported by most office software.

4. Pro = Terramodel file format similar to dwg and dgn for 2D and 3D data.

- ***a.*** Usually only compatible with Trimble office and field software.
- ***b.*** A pro can also be a Road Alignment file exported from Business Center –HCE for Trimble data collectors running the SCS900 software.

5. Other = Each GPS manufacturer has their own proprietary software format for project files.

- ***a.*** Business Center – HCE = vce Carlson = dwg
  Leica Construction Office = cnf Topcon 3D-Office = tp3 or Topcon SiteMaster = ccx

B. *Field File Formats*

1. Carlson - Data Collectors

- ***a.*** dxf – 2d linework for visible map of site features
- ***b.*** tin – 3D surface for cut/fill information
- ***c.*** crd – point data information
- ***d.*** dat - GPS site calibration
- ***e.*** cl - for station/offset information

2. Leica - Data Collectors and Machines

- ***a.*** dxf – 2d linework for visible map of site features
- ***b.*** dxf – 3D surface for cut/fill information
- ***c.*** csv – point data information
- ***d.*** loc – GPS site calibration
- ***e.*** lin - for station/offset information
- ***f.*** Leica machines will import these file types and the on-board control box will convert the imported files to the proper file types for machine control use if necessary.

3. Topcon - Data Collectors and Machines

- ***a.*** ln3 – 2D linework for visible map of site features
- ***b.*** tn3 - 3D surface for cut/fill information
- ***c.*** pt3 – point data information
- ***d.*** gc3 - GPS site calibration
- ***e.*** rd3 - for station/offset information

4. Trimble

- ***a.*** Data Collectors
  - ***i.*** dxf – 2d linework for visible map of site features
  - ***ii.*** ttm – 3D surface for cut/fill information
  - ***iii.*** surface.dxf – 3D surface for cut/fill information
  - ***iv.*** pro – 3D Road surface file for cut/fill and station/offset information

v. csv – point data information

vi. cal - GPS site calibration

vii. dc – GPS correction data in SCS900 and GPS Site Calibration in Survey Controller

a. dc – can also be a road template file created in Survey Controller, Terramodel, or Business Center

b. Machines

i. svl – 2d linework for visible map of site features

ii. svd – 3D surface for cut/fill information

iii. cfg - GPS correction data

IV. Troubleshooting Field and Office Files

A. Data Transfer Problems

1. Use zip files and download links via file hosting sites.

a. Minimizes file corruption via emails.

2. Keep USB stick information to a minimum.

a. Extra data on the devices slows the transfer process to data collectors and machines.

3. Use cables or USB sticks to data collectors when possible.

a. Most effective and quickest way to transfer data while minimizing the possibility of file corruption.

B. File sizes

1. Keep surface file sizes to a minimum while still holding the design drainage patterns and site features as best possible.

a. Most Data Collectors and Machines do not have the graphics capabilities and memory that equal the level of the office computer being used to generate the field data.

b. A surface with very tight vertices will look excellent in the office software but may be slow or unresponsive when loaded to a data collector or a machine.

i. Each project is different so try to create as many uniform triangles as necessary at the longest interval possible without compromising the accuracy of the surface.

ii. General Rule of thumb is somewhere between 5' to 25' for node intervals.

a. Shorter interval for small, extremely undulating sites

b. Longer interval for larger, flatter sites and road projects.

2. Dxf maps for linework typically cause the most errors with regards to slow and unresponsive equipment.

a. Only include needed data for the dxf map files in data collectors and machines.

b. All dxf linework for maps should be 2D.

i. Unless you are creating a 3D dxf linework file for surfaces or trench work.

c. All dxf linework should be continuous polylines with nodes only present at curves, bends, and hi/low points of the site feature being mapped.

d. Use a consistent color/naming/layering scheme with solid linetypes only.

i. Other linetypes can work but often cause more issues than benefits.

e. Explode or delete all blocks, external references, special linetypes, and hatching.

i. Major source for slow or non-responsive data collectors.

ii. Blocks and Hatches are not readable by most machine software programs.

C. Surface Data Inspection

1. Use the multiple views of the data prep software to view the surface.

a. 3D view is most effective.

b. Cross section view is also helpful.

2. Contour the surface at 0.2' intervals.

a. Locate and correct jagged contours if possible without altering the design data.

i. Altering the design data shifts liability to the data prep provider. If it becomes necessary to alter the design data, seek instruction or verification from the owner and/or designer.

ii. Adding breaklines for ditches, berms, ridges, and site features such as edge of roads, parking lots, building pads, and curbs will create a smoother surface.

D. *Data/File Management*

1. Create a standard naming scheme for projects, folders, and files.
   - **a.** Include dates on all file names for faster recognition of current files.
2. Use a central location for storing files sent to the field that is quickly accessible by co-workers and clients from anywhere and any computer.
   - **a.** VPN's are too slow, cumbersome, and risky for sharing with clients.
   - **b.** Take advantage of "Cloud" file storage or free file sharing software.
3. Use automatic file syncing and transfers when possible.
   - **a.** Automatic syncing lowers the amount of file space needed for projects.
   - **b.** Automatic transfers minimizes the time spent waiting for files to transfer
   - **c.** Utilizing both minimizes errors due to out-of-date or incorrect data.

V. Communication Between Field and Office Personnel.

A. *Email, Texting, and Voicemail Communication*

1. Quickly transfer files and information to and from the field or others via email.
   - **a.** Only use email if a documentation of the conversation trail is absolutely necessary.
   - **b.** Use texting for all initial communication then write a summary email to all involved for the documentation in order to minimize documentation trails.
2. Use texting when possible to avoid short or non-urgent voicemails.
   - **a.** Much faster for receiving information, getting responses, and non-intrusive for the recipient.
   - **b.** A picture is worth a thousand words. Use multi-media texting to be more effective.
     - ***i.*** Send pictures of office software screen information, plans, or field software screens to more effectively communicate your concerns, issues, ideas, etc.

c. Efficiently establish a time best for both parties if a voice conversation is necessary.

d. Email and Voicemail can be a source of the biggest waste of time for you and your clients if not properly used.

B. *Remote Links, File Hosting, and Automatic File Transfers*

1. Remote links can quickly solve issues with a wide range of problems via an internet connection.

a. See what is being explained via such software as WebEx, Go To My PC, Teamviewer, etc.

b. Numerous providers with a variety of capabilities and price ranges to make this affordable.

2. Utilizing "Cloud" file hosting can minimize file transfer times without compromising the integrity of the data or the privacy of files in a system accessed via a VPN.

a. Quickly share files with anyone, anywhere, anytime with minimal effort and IT considerations.

b. Numerous options for file sharing via username and password.

i. Microsoft Share Point

ii. Topcon SiteLink

iii. Trimble Connected Community

iv. DropBox

3. Automatic File Transfers and email alerts.

a. Quickly transfer files between computers, data collectors, and machines via the internet with email alerts indicating file changes or additions.

b. Minimize the time required to update all computers, data collectors, and machines on a project via automatic file transfers.

c. Numerous options for automatic file sharing via username and password.

i. Microsoft Share Point

ii. Topcon SiteLink

iii. Trimble Connected Community

iv. DropBox

C. Questions

1. Anything you ever wanted to know about Machine Control but were afraid to ask… NOW is the time!!

D. Comments & Suggestions

1. Please don't hesitate to share your own experiences that may be similar or even counter to what has been discussed or suggested here. Construction Technology and its uses are best learned through healthy discussions of real experiences and results no matter the difference of processes or opinions.

Conclusion:

Construction Technology, specifically Machine Control, is not going away. It is only going to get bigger and more common. And although its presence has decreased the opportunities for surveyors and engineers to provide daily dirt checks and stakes/hubs to nearly every construction site, the opportunities for other services accompanied by the use of this technology far outweigh this loss. You are encouraged to be open-minded and assist your clients with the continued and deeper utilization of this technology. We have moved from the industrial age to the information age where sharing ideas, thoughts, and information are the keys to a successful project and business. The very core of technology is storing, accessing, utilizing, and transferring information, or "Sharing", at a high rate of speed. So "Share" and you will be amazed at the opportunities that begin flowing your way.

THANKS FOR ATTENDING!!!