Guidelines for Surveying with the California Real Time Network (CRTN)

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About Dave Olander

- Was the kid that took things apart
- Suffers as a Critical Thinker
- Thrives in an environment of change
- Working at Caltrans for 21 years
- Started using RTK in the late 90’s
- Professional License in 2003
- Special Projects, control and support for Caltrans Dist. 11 (San Diego/Imperial Counties)

RTK Experience

- Started in the late 90's
- Extensively since around '02
- Mostly with Trimble hardware and software
- Used Topcon and Leica
- Have used various Internet relayed corrections since around '05
- Worked with Caltrans and others to expand CGPS network availability in San Diego

Why am I here?

Because I want to:

- To Support CRTN
- To help people
- To learn

And in spite of:

- My not being a polished speaker
- My being a “power user” not an “expert”

Topics I will not cover

- How to configure the Connections
- How to *establish* project control
- History and future of CRTN
- Details of RTK utilization
  - Most of you know this stuff
  - Would take most of the day
  - Refer to references
  - Refer to equipment documentation

Choose your Phrase

- “I don’t like change”
- “If it ain’t broke, don’t fix it”
- “I’ll wait until ‘they’ get the bugs out”
- “As soon as I do that then ‘they’ will tell me to do something else”
- I’m going to retire soon
- I have to leave something for the youngsters to look forward to

Learn to Change

- My aim today is to help you incorporate the incremental change from going from RTK to CRTN
- People don't resist change, they resist *being changed* – Peter Senge
- People should only "Hate" the change they aren't prepared for
- It isn't the change itself that people dread, it is all the stuff that it entails
- Adopt change that is a real benefit, not a fad
- Make incremental changes regularly (little bites)

Key Topics

- Main differences between using CRTN and regular RTK
- You have to use good RTK procedures
- Nothing is accurate without good Project control
- Evaluate your observation methods
- Configure your equipment with intent
- How to test your precision with CRTN

Main Differences between CRTN and Regular Old RTK

- Reference frame/Base coordinate issues
  - Can be changed
- Distant Dependent Error
  - Wasn't a big issue when 'tethered' by radio
- Reference stations are different
  - Some are better than others
  - Variety of features – GLONASS, L2C, L5
  - Antenna may not be loaded in your equipment
- Arguably more complex…….

Which one looks more Complex?

CRTN is just RTK with some else's base

- RTK was Revolutionary
  - CRTN is Evolutionary
- RTK transformed the way we work
  - RTN's modify the way we use RTK
- CRTN is a tool like a total station or a level
  - It has its own applications and limitations
  - Learn when and how to apply it
  - Test your capabilities with it

A glimpse at good RTK practices

- Take care of the basics
- Look around at each observation
- Know your equipment
- Have good project control
- Take the right type of observations
- Plan ahead

‘Cheating’ on the basics will come back to bite you

- Calibrate your antenna poles
- Use the right configurations
- Don’t “Push It”
- Understand the equipment and yourself
- Learn to say “within expectations” not “good enough”
- Pay attention to quality indicators

Pushing It

- Using a reference station too far away
- Working in areas where you know you will get inconsistent results
- Using RTK when other methods should be employed
- Working with high PDOP
- Experimenting is fine, but prove it out before accepting it.

Know your equipment (and yourself)

- Learn what is normal and ask why something doesn't seem right
- Initialization performance is indicative of how things are working (at the moment).
  - When everything is going good, initializations should be fast
  - If you lose fix, ask yourself why and check previous work
- Test yourself and your equipment
  - More on this later

Pay attention to quality indicators

- PDOP is real and can be predicted
  - Get on the NANU e-mail list
  - For GPS only, make PDOP chart weekly.
- High RMS
  - Can be a sign of Multipath
  - Good RMS doesn’t mean good results
- Error Display
  - Usually 1 Sigma
  - Not totally reliable

Passive Control

- This sessions assumes that project control is already established which surrounds the site in all 4 quadrants.
- Don’t rely on the network to provide your reference frame
- Do a Site Calibration/Localization
- Have reliable checks on the site that you always check to

Passive Control Plan

- 1 page document describing everything
  - Reference station(s) with coordinates and network
  - Calibration/projection information
  - Calibration Stations with coordinates
  - Check points with coordinates
  - Other passive marks with coordinates
  - Geoid model used
  - Expected precision using CRTN
  - Recommended settings if out of the ‘usual’

Terrestrial work

- CRTN can’t be used everywhere
- Plan to set the temporary passive control when PDOP is low
- Plan to do the terrestrial work when the PDOP is high
- Use the “Control” methods
- Occupy, Check and backsite existing passive control where possible

Data Management

- I have used Trimble Software and Hardware almost exclusively
- I have found that it is possible to get going with the wrong configuration(s)
  - If you do “good enough” checks, this can be a problem
- If you can’t create survey and project templates, write them down
- If you can create templates, write protect them
  - As soon as something doesn’t work, people have a tendency to start messing with things they don’t understand

Survey Style

- This might be a ‘Trimble Thing’
- Create a Survey Style for each project
  - References the connection to use, including the base
  - Never use “nearest base”
  - Set up the observation styles to give you the precision you need for that site
- Write protect it so that if someone wants to play around, they have to copy it

Project Template

- Create a Project Template for each site
- Include
  - Site calibration
  - Control points
  - Base Points
  - Units
  - Other settings for the site
- Use this project template to create “request” jobs.

Observation Methods

- May be different for different projects
  - Topo – Construction Layout, TOPO
  - Control – Work points, Control, Property corners
- These are the absolute minimum requirements
  - If you don’t stick to the basics, these will be inadequate
  - Don’t push it
  - See references for more information and learning
  - Test yourself and determine what meets your needs

TOPO/Construction

- Modify it based on the desired outcome
- Minimum 3 Epoch/5 Second observation
- Don’t rely on the Stakeout positioning
- Usually 1 observation only
- Lower precision/accuracy
- Used with other stakes or TOPO shots can identify outliers
- Should vary depending on the task
- When in doubt, observe it again later

Control

- Don’t RTK control that is close together
  - Supplement RTK with Terrestrial observations
- Cut the PDOP mask down to 4 or lower
- GPS has an observation that is WAY worse than the rest every once and a while
- Take multiple observations to identify outliers
  - Orient the rover pole differently
- Over short time periods, GNSS positioning is ‘clustered’ precisely, but inaccurately.
- Rule of 3’s, a MINIMUM of:
  - 3 observations
  - 30+ Epochs
  - 30+ Minutes apart
- NGS and other specification differ – See References

Positioning Examples

- High Rate
  - 5 Mile baseline
  - Single Epoch Observation
  - 1 Per Second
  - 10 Minutes
- Low Rate
  - VRS
  - 1 Per Minute
  - Single Epoch Observation
  - 2 ½ Hours

Positioning Examples

- TOPO
  - 3+ Epoch
  - 5 Second
  - 5 Mile baseline
  - 10 minute interval
- CONTROL
  - 30 Epoch
  - 5 Mile baseline
  - 10 minute interval

How to validate your work

- GPS precision can be evaluated using statistics
- Learn Statistics!!
  - It is the language our equipment speaks to us in.
- Once evaluated the results can be presumed to be indicative of precision for the same:
  - Location
  - Reference station
  - Observation Style
  - Equipment
  - People
  - AND Conditions

Steps to take to validate your work

- I don't know how many times I've heard surveyors say "what if I'm taken to court?"
- This is not a statistics or an Excel class
  - http://www.khanacademy.org/math/statistics
  - YouTube for Excel tutorials
- Take 15+ observations using the same method
  - You may have already done this
- Export a .csv file Northing, Easting, Elevation
- Open it in Excel
- Save it as a native Excel format file

How to estimate your precision

- Example File
- Average the North East and Elev. Columns
  - This is our estimate of the actual value (“Truth”)
  - Example: =Average(B1:B10)
- Create residual columns next to N E and El
  - This shows us how each observation differs from the ‘truth’
  - Example: =(B11-B1)*100 (for hundredths)
- Create an XY Scatter Plot
  - Ensures that the observations are normally distributed

How to estimate your precision

- Calculate the horizontal residual
  - Hypotenuse of the North and East Residual
  - "Square root of →the Northing Res. Squared plus the Easting Res. Squared"
  - Example: =POWER((POWER(C2,2)+POWER(E2,2)),0.5)
- Calculate the range of the northing and easting
  - First indication of precision but isn't very telling
  - Example: =Max(B1:10)-Min(B1-B10)

How to estimate your precision

- Calculate the Standard Deviation
  - This is how an individual measurement relates to the whole set of observations
  - Example: =StDev(B1:B10)
- Calculate 95% Confidence Interval
  - This number hints at how precise our work is
  - About 2x the Standard Deviation
  - Example: =B15*1.96
- Calculate the horizontal St. Dev. And 95%
  - Refer to the horizontal residual for hypotenuse calculation but use the N and E St. Dev and 95%

How many shots should I take?

- Calculate expected error (Standard Error)
  - How much will averaging multiple observations improve my results?
  - Use the error at the confidence desired (95%)
  - N is the number of observations
  - Since this is considered a sample you have to take an observation away
  - Expected Error=Error/$(N-1)^{1/2}$
  - Example: =F35/POWER((A39-1),0.5)

Points of Emphasis

- CRTN is just RTK with someone else's base
- Calibrate to passive control
- Check to "within expectations" to quality control points
- Have project specific configurations and Lock them down if possible
- Use proven observation methods
- Validate your precision at the project site

References

- NGS RTN Guidelines
  - http://www.ngs.noaa.gov/PUBS_LIB/NGS.RTN.Public.v2.0.pdf
  - The Seven C's
    - Check equipment
    - Conditions
    - Coordinates
    - Communication
    - Constraining to Passive Monuments
    - Collection
    - Confidence
- An Examination of Commercial Network RTK GPS services in Great Britain
  - Newcastle University study using OS (Ordinance Survey of the UK) network
  - http://eprint.ncl.ac.uk/file_store/production/138782/75BCF1EE-CD07-4ABE-96F3-17B9E0D16C00.pdf
  - Improving Solution Robustness: Single- and Double-window averaging
- The American Surveyor - RTN 101 – Gavin Shrock
  - http://www.amerisurv.com/content/view/3812/150/
- Caltrans Survey Manual Chapter 6B RTK GPS Survey Specifications (2006)
  - http://www.dot.ca.gov/hq/row/landsurveys/SurveysManual/06_Surveys.pdf