# REAL TIME POSITIONING- BEST METHODS FOR HIGH ACCURACY RTN DATA COLLECTION

**CGSIC 49th Meeting-Civil GPS Service Interface Committee**
**CORS User Forum**
**Hilton Garden Inn**
**Savannah, Georgia**
**21-22 September 2009**


**Bill Henning**
**Senior Geodesist, PLS.**
**301-713-3196 x 111,**
**william.henning@noaa.gov**

# ACCOMPLISHING ACCURATE DATA COLLECTION 95% CONFIDENCE

- SBAS- 3 M H, 6 M V
- COMMERCIAL DGPS – FEW DM, $$
- USCG BEACON – METER+
- CLASSICAL SURVEYING – 2-4 CM, LABOR/TIME INTENSIVE, $$$
- USER BASE RTK – 2-4 CM H, 3-5 CM V
- RTN – 3-4 CM H, 5-7 CM V
- AERIAL MAPPING - .15 M H, .25 M V, $$$
- SATELLITE IMAGERY – 0.5 METER H RESOLUTION, 3 M LOCATION, $$$
- LOW ALTITUDE AERIAL IMAGERY – 2-4 CM h, 3-5 CM V, $$
- TERRESTRIAL LASER SCANNING – PROJECT SITES ONLY, 0.015 H, 0.02 V

# A CONFLUENCE OF TECHNOLOGY- USE OF RTK

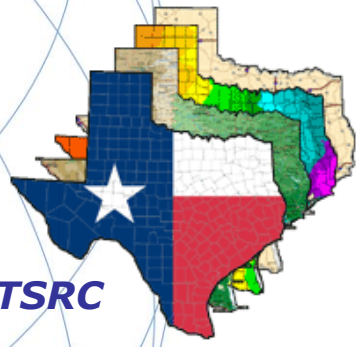

- INTERNET DATA VIA CELL TECHNOLOGY
- SOFTWARE/FIRMWARE ALGORITHMS
- GNSS HARDWARE
- SATELLITE CONSTELLATIONS
- SATELLITE CODES/FREQUENCIES

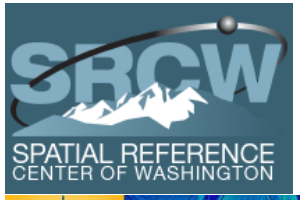
# III. OUTREACH, COOPERATIVE EFFORTS AND LEADERSHIP





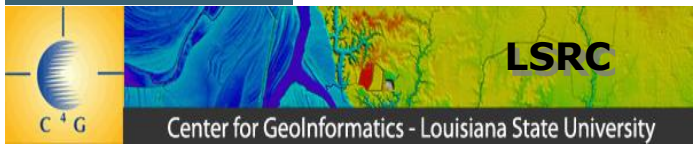






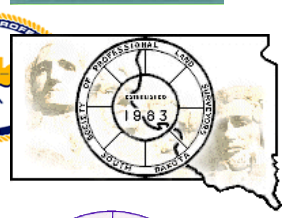



TSRC

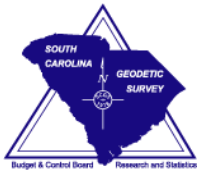




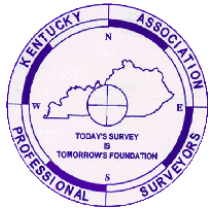











**+ PUBLIC & PRIVATE *RTN ADMINISTRATORS* SPANNING MORE THAN 35 STATES**

# GOAL OF RTN USER GUIDELINES: TO HELP PRODUCE PRECISE, REPEATABLE POSITION COORDINATES AT THE ROVER

SOME ISSUES:

- ACCURACY / PRECISION
- ORTHO HEIGHTS: CALIBRATION – 2 MONUMENTS, 4+ MONUMENTS / HYBRID GEOID MODEL
- COORDINATE DELTAS: PASSIVE MONUMENTS / ACTIVE STATIONS
- DATUMS / ADJUSTMENTS / EPOCHS FROM THE RTN
- METADATA
- PLANNING – SATELLITE AVAILABILITY, SPACE WEATHER, STORM FRONTS, MULTIPATH, ETC.

# SINGLE-BASE USERS GUIDELINES

NATIONAL GEODETIC SURVEY
USER GUIDELINES
FOR CLASSICAL
REAL TIME GNSS POSITIONING

DRAFT

**http://www.ngs.noaa.gov/PUBS_LIB/NGSRealTimeUserGuidelines.v2.0.2.pdf**

v. 2.0.3 September 2008

William Henning, lead author

# NATIONAL GEODETIC SURVEY
# GUIDELINES FOR REAL TIME GNSS NETWORKS

**William Henning, team leader, editor**

**Dan Martin, Site Considerations group leader**

**Gavin Schrock, Matt Wellslager, Planning and Design group leaders**

**Gary Thompson, Administration group leader**

**Dr. Richard Snay, Aligning RTN to the NSRS**

**William Henning, Users group leader**

**September 2009**
**v. 1.0**

# BEST METHODS FROM THE GUIDELINES:

## THE 7 "C'S"

- CHECK EQUIPMENT
- COMMUNICATION
- CONDITIONS
- CALIBRATION (OR NOT)
- COORDINATES
- COLLECTION
- CONFIDENCE

***THE CONTROL IS AT THE POLE***

# ACHIEVING ACCURATE, RELIABLE POSITIONS USING GNSS REAL TIME TECHNIQUES

## (AUGMENTED FROM NGS SINGLE BASE DRAFT GUIDELINES CHAPTER 5: FIELD PROCEDURES)

**RT = single base, either active or passive**

**B = Both Single base and RTN**

# CHECK EQUIPMENT

- B BUBBLE- ADJUSTED?
- RT BATTERY- BASE FULLY CHARGED 12V?
- B BATTERY – ROVER SPARES?
- RT USE PROPER RADIO CABLE (REDUCE SIGNAL LOSS)
- RT RADIO MAST HIGH AS POSSIBLE? (5’ = 5 MILES, 20’ = 11 MILES, DOUBLE HEIGHT=40% RANGE INCREASE). LOW LOSS CABLE FOR >25’.
- RT DIPOLE (DIRECTIONAL) ANTENNA NEEDED?
- RT REPEATER?
- RT CABLE CONNECTIONS SEATED AND TIGHT?
- B“FIXED HEIGHT” CHECKED?
- RT BASE SECURE?

# COMMUNICATION

- RT UHF FREQUECY CLEAR?
- B CDMA/CELL - STATIC IP FOR COMMS?
- B CONSTANT COMMS WHILE LOCATING
- RT BATTERY STRENGTH OK?
- B CELL COVERAGE?

# CONDITIONS

- RT WEATHER CONSISTENT?
- B CHECK SPACE WEATHER?
- B CHECK PDOP/SATS FOR THE DAY?
- RT OPEN SKY AT BASE?
- RT MULTIPATH AT BASE?
- B MULTIPATH AT ROVER?
- B USE BIPOD?

# CALIBRATION (OR NOT)

- B ≥ 4 H & V, KNOWN & TRUSTED POINTS?
- B CALIBRATION RESIDUALS-OUTLIERS?
- B DO ANY PASSIVE MARKS NEED TO BE HELD?
- RT BASE WITHIN CALIBRATION?

$$x' = s \cos \alpha x + s \sin \alpha y + t_x$$
$$y' = s \sin \alpha x + s \cos \alpha y + t_y$$

**Where s is scale factor**
**x and y are coordinates from original system**
**x′ and y′ are coordinates of point in transformed system**
**$\alpha$ is rotation angle from original to transformed system**
**$t_x$ and $t_y$ are components of translation from original to transformed system**

# COORDINATES

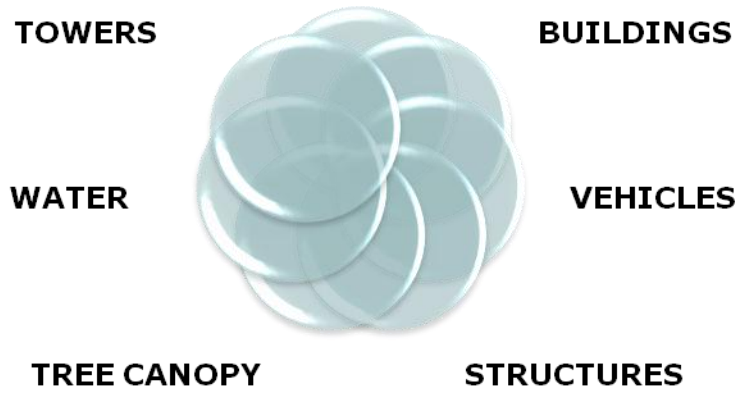
- B TRUSTED SOURCE?
- B WHAT DATUM/EPOCH ARE NEEDED?
- RT GIGO
- B ALWAYS CHECK KNOWN POINTS.
- B PRECISION VS. ACCURACY
- B GROUND/PROJECT VS. GRID/GEODETIC
- B GEOID MODEL QUALITY
- B LOG METADATA

# COLLECTION

- B CHECK ON KNOWN POINTS!
- B SET ELEVATION MASK
- B ANTENNA TYPES ENTERED OK?
- B SET COVARIANCE MATRICES ON (IF NECESSARY).
- B RMS SHOWN IS TYPICALLY 68% CONFIDENCE (BRAND DEPENDENT)
- B H & V PRECISION SHOWN IS TYPICALLY 68% CONFIDENCE
- B TIME ON POINT? QA/QC OF INTEGER FIX
- B MULTIPATH? DISCRETE/DIFFUSE
- B BUBBLE LEVELED?
- B PDOP?
- B FIXED SOLUTION?
- B USE BIPOD?
- B COMMS CONTINUOUS DURING LOCATION?
- B BLUNDER CHECK LOCATION ON IMPORTANT POINTS.

# MULTIPATH = NOISE
# SPECULAR(DISCRETE) & DIFFUSE

**SOURCES:**



# CONFIDENCE

- B CHECK KNOWN BEFORE, DURING, AFTER SESSION.
- B NECESSARY REDUNDANCY?
- B WHAT ACCURACY IS NEEDED?
- RT REMEMBER PPM
- RT BASE PRECISION TO NEAREST CALIBRATION POINT
- B AVERAGE REDUNDANT SHOTS – PRECISION DIFFERENCE WITHIN NEEDS OF SURVEY
- B BE AWARE OF POTENTIAL INTERFERENCE (E.G., HIGH TENSION TOWER LINES)

# DRAFT GUIDELINES- 95% CONFIDENCE

## ACCURACY CLASS SUMMARY TABLE

| | CLASS RT1 | CLASS RT2 | CLASS RT3 | CLASS RT4 |
|---|---|---|---|---|
| ACCURACY (TO BASE) | 0.015 HORIZONTAL., 0.025 VERTICAL | 0.025 HORIZONTAL., 0.04 VERTICAL | 0.05 HORIZONTAL., 0.06 VERTICAL | 0.15 HORIZONTAL., 0.25 VERTICAL |
| REDUNDANCY | ≥ 2 LOCATIONS, 4-HOUR DIFFERENTIAL | ≥ 2 LOCATIONS, 4-HOUR DIFFERENTIAL | NONE | NONE |
| BASE STATIONS | ≥ 2 , IN CALIBRATION PROJECT CONTROL | RECOMMEND 2 IN CALIBRATION | ≥ 1 , IN CALIBRATION | ≥ 1 , IN CALIBRATION RECOMMENDED |
| PDOP | ≤ 2.0 | ≤ 3.0 | ≤ 4.0 | ≤ 6.0 |
| RMS | ≤ 0.01 M | ≤ 0.015 M | ≤ 0.03 M | ≤ 0.05 M |
| COLLECTION INTERVAL | 1 SECOND FOR 3-MINUTES | 5 SECONDS FOR 1-MINUTE | 1 SECOND FOR 15 SECONDS | 1 SECOND FOR 10 SECONDS |
| SATELLITES | ≥ 7 | ≥ 6 | ≥5 | ≥ 5 |
| BASELINE DISTANCE | ≤ 10 KM | ≤ 15 KM | ≤ 20 KM | ANY WITH FIXED SOLUTION |
| TYPICAL APPLICATIONS | PROJECT CONTROL<br>CONSTRUCTION CONTROL POINTS<br>CHECK ON TRAVERSE, LEVELS<br>SCIENTIFIC STUDIES<br>PAVING STAKE OUT | DENSIFICATION CONTROL<br>TOPOGRAPHIC CONTROL<br>PHOTOPOINTS<br>UTILITY STAKE OUT | TOPOGRAPHY<br>CROSS SECTIONS<br>AGRICULTURE<br>ROAD GRADING<br>SITE GRADING | SITE GRADING<br>VETLANDS<br>GIS POPULATION<br>MAPPING<br>ENVIRONMENTAL |

# FURTHER WORK IN THE OFFICE

CHECK:

- Antenna heights (height blunders are unacceptable and can even produce horizontal error - Meyer, et.al, 2005).
- Antenna types
- RMS values
- Redundant observations
- Horizontal & vertical precision
- PDOP
- Base station coordinates
- Number of satellites
- Calibration (if any) residuals

# METADATA !

**BESIDES ATTRIBUTE FIELDS, THE RT PRACTICIONER MUST KEEP RECORDS OF ITEMS NOT RECORDED IN THE FIELD,**
**FOR INSTANCE:**

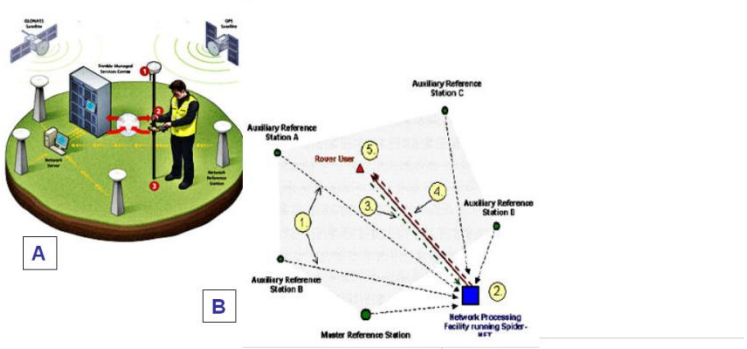
- ✓ **WHAT IS THE SOURCE OF THE DATA?**
- ✓ **WHAT IS THE DATUM/ADJUSTMENT/EPOCH?**
- ✓ **WHAT ARE THE FIELD CONDITIONS?**
- ✓ **WHAT EQUIPMENT WAS USED, ESPECIALLY- WHAT ANTENNA?**
- ✓ **WHAT FIRMWARE WAS IN THE RECEIVER & COLLECTOR?**
- ✓ **WHAT REDUNDANCY, IF ANY, WAS USED?**

# QUICK FIELD SUMMARY:

- Set the base at a wide open site
- Set rover elevation mask between 12° & 15°
- The more satellites the better
- The lower the PDOP the better
- The more redundancy the better
- Beware multipath
- Beware long initialization times
- Beware antenna height blunders
- Survey with "fixed" solutions only
- Always check known points before, during and after new location sessions
- Keep equipment adjusted for highest accuracy
- Communication should be continuous while locating a point
- Precision displayed in the data collector can be at the 68 percent level (or 1σ), which is only about half the error spread to get 95 percent confidence
- Have back up batteries & cables
- RT doesn't like tree canopy or tall buildings

# THE QUICK SUMMARY BOILED DOWN:

- **COMMUNICATIONS: THE KEY TO SUCCESS**
- **CHECK SHOT: FIRST BEFORE NEW WORK**
- **REDUNDANCY: FOR CONFIDENCE**



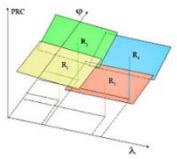

Three types of RTN:

A. VRS – Duplex Communication

B. MAC – Duplex or Broadcast

C. FKP – Broadcast Only

C



**≥200 RTN WORLDWIDE**
**≥80 RTN IN THE USA**
**≥35 DOT WITH STATEWIDE NETWORKS PLANNED OR OPERATING**