INTRODUCTION TO GPS

OSU GPS WORKSHOP
February 10, 2011

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PART VIII – RTK/RTN GNSS Overview

- RTK Survey Styles
- RTK/RTN vs. PP
- Conditions for Real-Time Work
- Initialization
- Calibration (localization)
- Sources of Error
- RTK Project Control
- Good Practices

RTK SURVEY STYLES

- **Control** – Typically not as accurate as a static network adjusted survey
- **Stakeout** – Requires a map projection or project calibration (localization)
- **Topographic** – Fill in terrain data
- **Continuous RTK** – stop and go 1 second positions. Requires a radio or cell modem
- Must have initialization between base station and rovers

REAL-TIME VS. POST-PROCESSED

- Results are available in the field, so checks can be verified immediately
- Staking out is now possible
- One base receiver supports multiple rovers (unlimited)
- No post-processing time required in office
- Transformation parameters needed prior to survey, for proper relationship between GPS WGS84 and local system

CONDITIONS FOR REAL-TIME SURVEYING

- At least 2 receivers required
- At least 5 common SV's must be tracked from each station (base and rovers)
- Visibility to the sky at all stations should be sufficient to track 5 SV's with good geometry (4 SV's required for baseline solution, but 5 are required for initialization)
- Initialization must take place at beginning of survey
- Radio/cell link must be available between base and rover
- "Lock" to SV's must be maintained, or re-initialization must occur
- Transformation parameters must be available to get from GPS WGS84 LLH to local NEE

WHAT HAPPENS IN REAL-TIME

- Data is logged simultaneously at base and rover
- Base data is transmitted via radio/cell link to radio antenna at rover
- Survey is "initialized" using data from both base and rover (data is processed inside roving receiver)
- Survey is conducted, with processing within roving receiver continuing throughout
- Results of processing are sent to the data collector for logging and viewing (results normally ~2 seconds behind actual reception)
- Results viewed may be either lat/long/ellipsoidal height or northing, easting, elevation, depending on whether sufficient information exists in the data collector for transformation

WHAT IS INITIALIZATION?

- Determination of integer wavelength counts up to the satellites
- Required at beginning of all real-time surveys before you can work
- Required in the middle of surveys, if continuous tracking of at least 4 SV’s (*in common with the base*) has been interrupted

TYPES OF INITIALIZATION

- **Fixed Baseline**
  - Antenna swap
  - Known point -- should be previously surveyed with GPS
- **Automatic Initialization**
  - While moving -- (often referred to as "OTF", or on-the-fly)

FIXED BASELINE VS. AUTOMATIC

- Fixed baseline initialization may be performed with single frequency receivers
- Automatic initialization requires dual frequency receivers

GRID COORDINATES (CALIBRATION)

- Initial result of GPS survey is precise network based on (possibly) inaccurate coordinates
- WGS-84 coordinates must be transformed to meaningful local system
- 3 horizontal and 4 vertical control points with values in desired coordinate system and vertical datum are *minimum* required for transformation. Note that they can be the same points (h+v).
- In RTS, 5-6 control points are minimum number recommended for calibration, and up to 10-18 may be desirable for large project areas

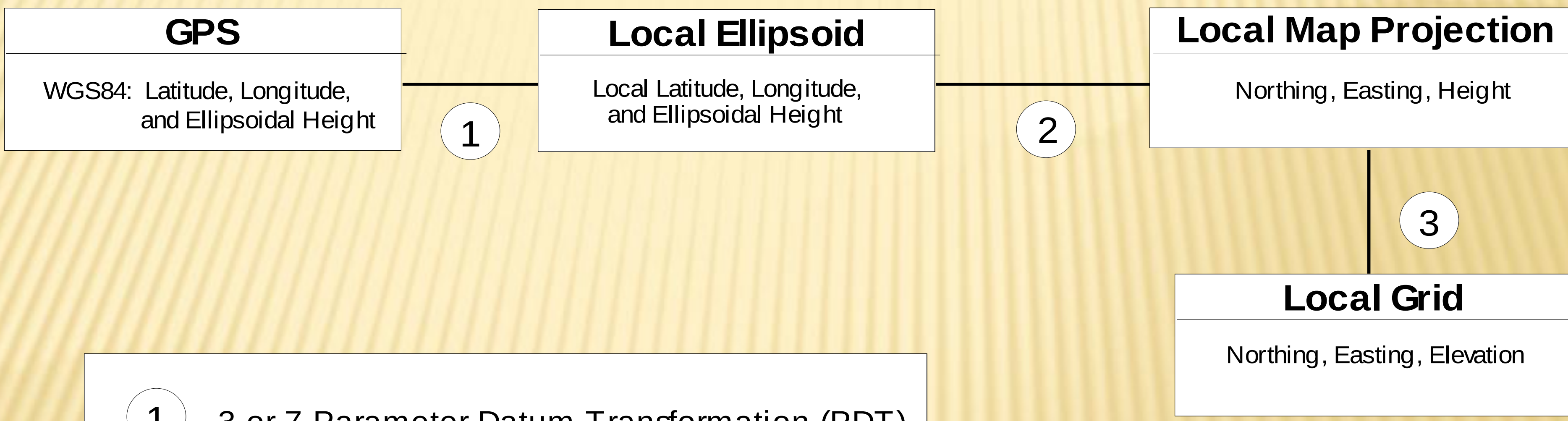
GRID COORDINATES (CALIBRATION)- CONT.

- Control points are first located with GPS to determine WGS-84 values
- WGS-84 values and known NEE on control points are matched up and used to generate proper transformation parameters from GPS system to local grid
- After transformation parameters have been determined in the office or field, they are uploaded to the data collector and used for all subsequent field work, which can now be performed in local grid system

STEPS IN CALIBRATION

- Locate control points in the field
- Occupy control points using GPS
- Enter control (NEE) and GPS-derived coordinates (WGS-84 LLH) into data collector or computer
- Perform GPS calibration
- Continue field survey, which can now be performed in local grid system

GPS CALIBRATION



1. 3 or 7 Parameter Datum Transformation (PDT)
2. Projection
3. 2D Transformation and Height Adjustment

ANOTHER VIEW OF GPS CALIBRATION

- **CALIBRATION IS 2-STEP PROCESS:**
  - 1. Deriving GPS coordinates for local control points (in the field)
  - 2. Computing calibration parameters for the project in the office or the field (data collector)

- **THREE POSSIBILITIES:**
  - GPS to LLH on Local Datum: Datum Transformation
  - Local LLH to Local NEH: Mapping Projection
  - Local NEH to Local NEE: 2-D Transformation and Height Adjustment

COMPONENTS OF RTK SYSTEM

- **BASE**
  - Receiver with RTK firmware -- may be single or dual frequency; internal memory (GPS data logging capability) not required

  - GPS antenna
  - Radio modem
  - Radio antenna (7db recommended)
  - Battery
  - Cables
  - 2 Tripods (one for GPS antenna, one for radio antenna) and 1 tribrach (radio antenna has mounting bracket with 5/8 thread)

COMPONENTS OF SYSTEM -- CONT.

- **ROVER**
  - Receiver -- may be single or dual frequency; internal memory not required
  - RTK firmware
  - GPS antenna
  - Radio antenna
  - Battery
  - Cables
  - Recommended: backpack and range pole with bipod

THE RADIO LINK

- Typical range, with ideal conditions is up to 10 km
- Repeaters can be used to extend range
- All radios, including repeaters, must be on same frequency
- One base radio can be received by unlimited rovers
- Rover can receive real-time data from normally one base, but some systems can support up to 3 bases, each data set using 1/3 of a second.

SOURCES OF ERROR IN RTS

- Multipath (deflected GPS signal which can give erroneous results -- watch for reflective surfaces in survey area)----- Base + Rover (glass of water)

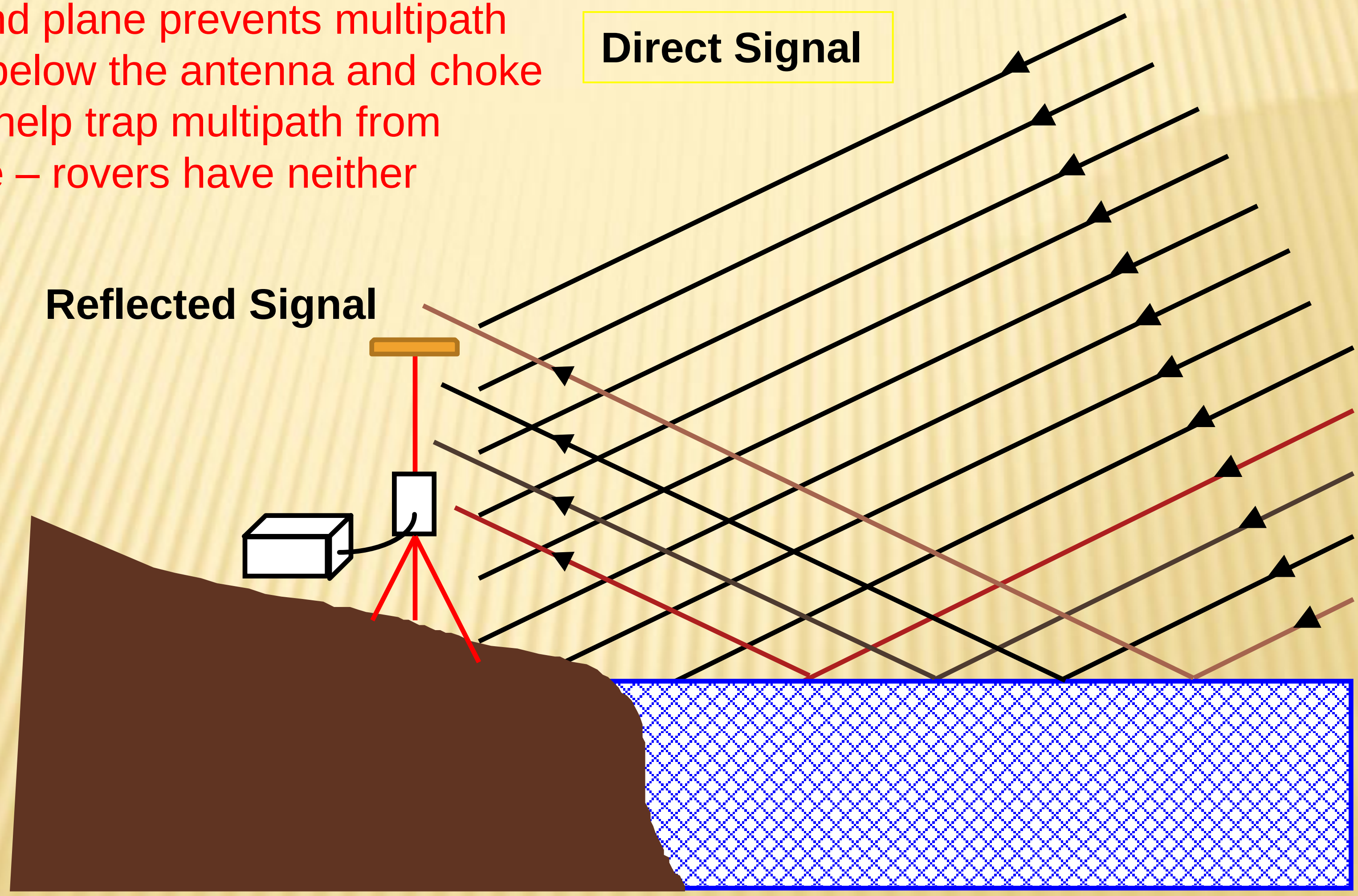
- Poor PDOP -- weak satellite geometry (PDOP should be less than 6 and ideally between 2 & 3)

- Erroneous antenna heights

- Interference with radio link -- select a different frequency or use cell phone

MULTIPATH AT STATION

Ground plane prevents multipath from below the antenna and choke rings help trap multipath from above – rovers have neither

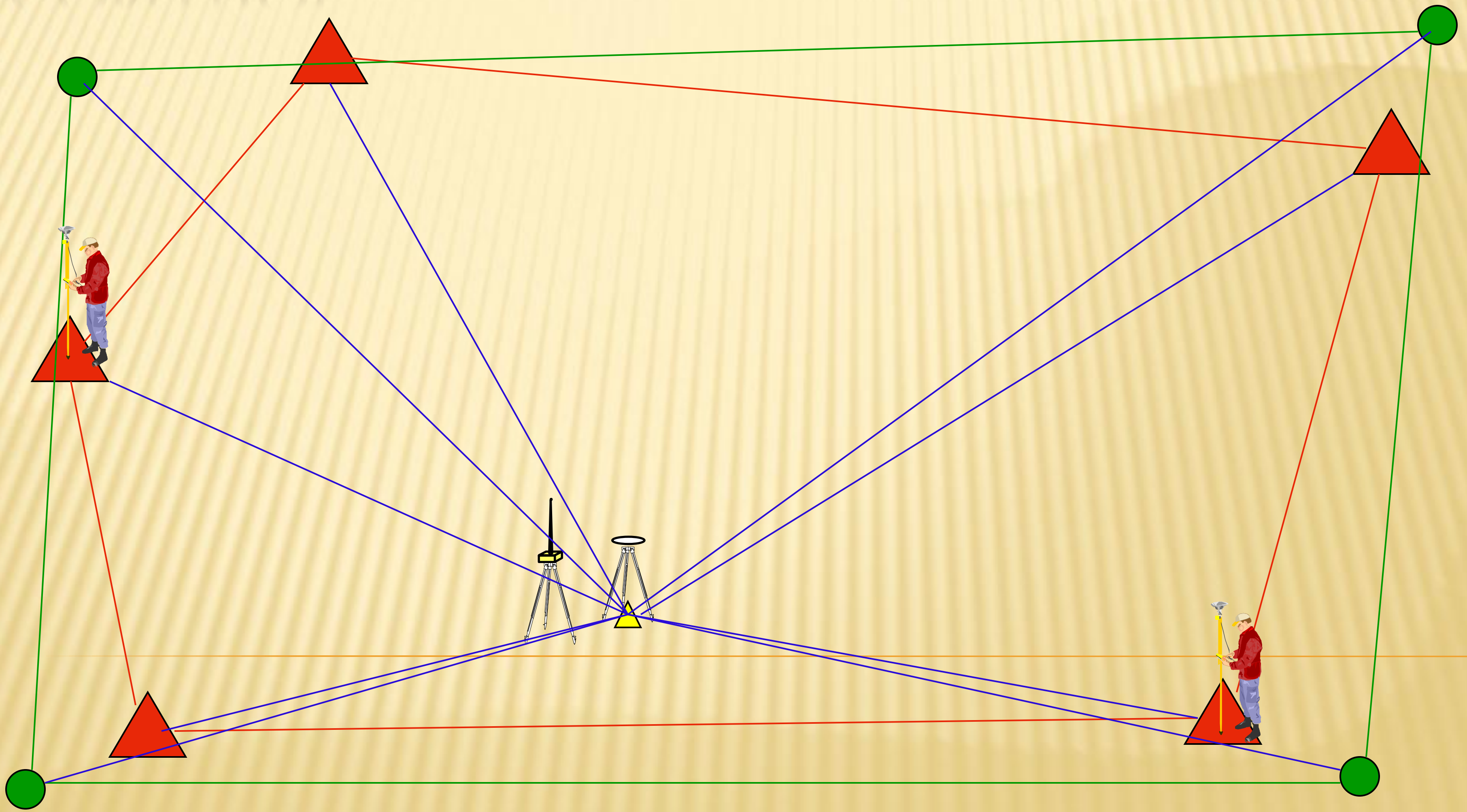


CYCLE SLIPS AND LOSS OF LOCK

- **Cycle slip** = interruption of GPS signal, due to:
  - Obstructions
  - Radio or other electromagnetic interference
- **Loss of lock** = Known integer biases on fewer than 4 SV's
  - i.e. Cycle slips on so many SV's that fewer than 4 integer biases are resolved

- **NOTE:** if satellite tracking is reduced to 4 SV's, then resulting PDOP may be too poor (i.e. high) to resolve integer biases on other SV's -- may require a re-initialization

RTK GPS PROJECT CONTROL



RTK GPS PROJECT CONTROL

- Get the right information before you start surveying!
  - Does the project have a defined horizontal and vertical datum? NAD27, NAD83, NGVD29, NAVD88

  - Does the project have a map projection? UTM, State Plane, Local Map Grid
  - What are the project units? USFT, INT.FT., Metric

WHAT DO I NEED??

- Datum Transformation
- Define Projection
- Horizontal Adjustment
- Geoid Model (necessary to get ortho hts.)
- Vertical Adjustment

DATUM TRANSFORMATION

- Needed if converting from the WGS-84 latitude, longitude, and ellipsoid height to a different latitude, longitude and ellipsoid height relative to the local ellipsoid model used for the project survey work.

- **Usually can pick from published parameters within software and data collector.**

DEFINE MAP PROJECTION AND COORDINATE SYSTEM

- A map projection to convert the local geographic coordinates onto the local map grid as northing and easting coordinates, thereby representing points on the curved surface of the earth as points on a plane.

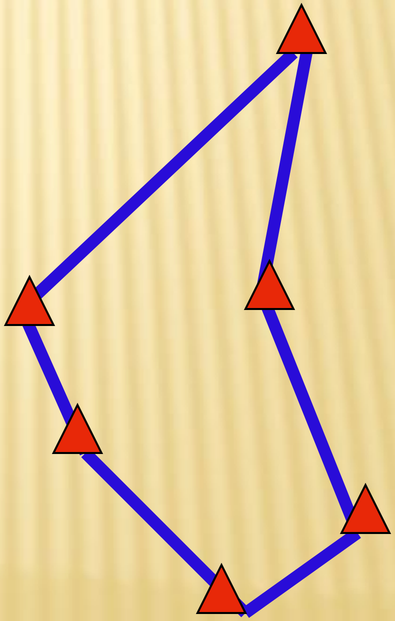
  - Typical map projections are:
    - Lambert Conformal Conic Projection
    - Transverse Mercator
    - UTM
    - Oblique Mercator

A CALIBRATION IS A TYPE OF HORIZONTAL ADJUSTMENT

- The horizontal adjustment is an unweighted least squares best fit of the coordinates for the points determined by GPS (WGS-84) to the coordinates of the project points accepted as true.
- The GPS measurements are thereby scaled and rotated to best fit the given project control.

HORIZONTAL CALIBRATION EVALUATION

- Ideal results show small equal residuals
- All primary control included
- Review rotation and scale factor
  - Rotation minimal < 1 second
  - Scale factor very close to 1
  - RECORD YOUR CALIBRATION FOR PROJECT RECORD AND SURVEY WORK LATER ON!



VERTICAL DATUM

- **NAVD 88**
  - North American Vertical Datum of 1988 (NAVD 88)
  - Fits well w/ all NAD 83 realizations
  - Fits well with geoid99 thru geoid09
  - Native units are metric
- **NGVD 29**
  - National Geodetic Vertical Datum of 1929 (NGVD 29)
  - Fits well with NAD 27
  - Various adjustments NGVD 29(47), (56) etc.
  - Native units are usft

GEOID MODEL INSERTION

- The geoid is an equipotential gravity surface model which, on average coincides with mean sea level in the open oceans. It is influenced by large masses on, or underneath the Earth’s surface.

  - H (orthometric height) = h (ellipsoid height) – n (geoid height)--- **H=h-(-n)**

VERTICAL ADJUSTMENT (CALIBRATION)

- Inclined Plane
  - Minimum of 4 vertical project control points.
  - Vertical control points need to surround the project work.

The inclined plane provides a simple planar (geoid) model using a least squares best fit of the separations (n) that are calculated using the known orthometric elevations (e) of project control points and the ellipsoid heights (h) obtained for those points with GPS.

VERTICAL CALIBRATION EVALUATION

- Vertical control must surround project so…
  - All stakeout points will be inside the inclined plane
- Ideal results show small equal residuals
- Single point high residuals reflect a non-fitting vertical control bench mark.
- Want best results: Run your own differential levels through vertical control before calibrating.

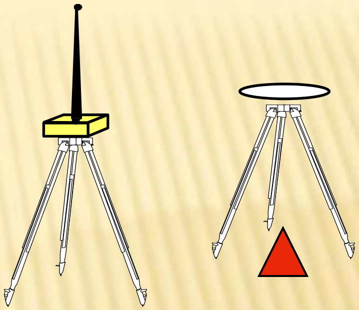
INCLINED PLANE + GEOID

- Adding a geoid model may reduce the size of the vertical residuals on larger projects.
- May not make difference on projects less than 10Km.
- Geoid09 (Conus) – Most recent published
- **When in doubt – add the geoid**

GPS SITE CALIBRATION FACTS

- Occupy a minimum of 3 horizontal and 4 vertical project control points. Can be same points!
- Up to 18 points allowed in a Trimble RTK calibration
- Order of control point occupation effects…
  - Rotation and Scale factor reported
  - Does not effect adjusted coordinate values
- **Record your calibration with project documents for future reference**

BASE STATION SETUP



- Setting up the base location
  - Maximum satellite visibility (all available)
  - 10 degree elevation mask
  - Minimizing multipath (use ground plane)
  - Picking a safe location for the base
  - Maximize radio coverage for the project
  - Use a fixed height rod, and sand bags

ROVER INITIALIZATION

- Rover Initialization
  - Requires 5 satellites in common with the base
  - Requires L1 & L2 frequencies
  - RMS under 130
  - Radio link to base receiver
  - Use latest receiver firmware for:
    - Improved multipath rejection
    - Quicker OTF initializations

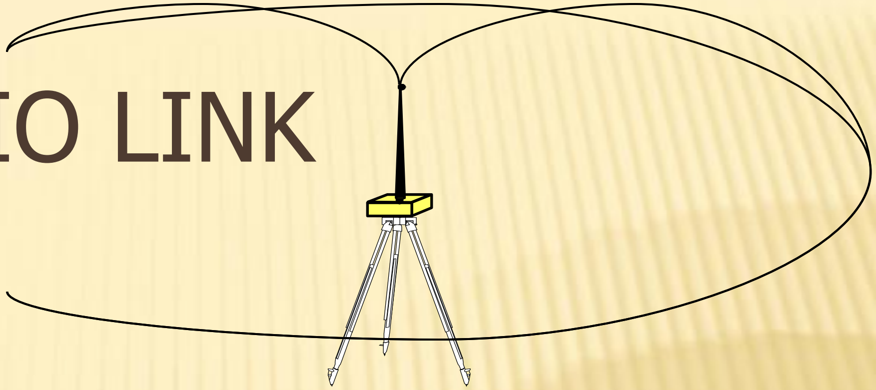
ADDING NEW CONTROL W/ RTK

- Kinematic control points
  - 180 to 480 occupation seconds per point
    - Min 180 epochs is NGS recommendation
      - Minimize chance of bad initialization
      - Reduce high RMS
  - Use tripod and fixed height rod
  - Rod plumb should be checked often
  - Older antenna types pointed north (same as base antenna)
  - Repeat observation under different SV geometry separated by >90 minutes

GATHERING TOPO AND STAKING POINTS

- Gathering and staking points with RTK
  - Typical 3 to 5 second occupation time (topo pts.)
  - Check and adjust fixed height rods (check rod points and replace when worn)
  - Use a feature code and attribute libraries
  - Use templates to gather typical lineal data

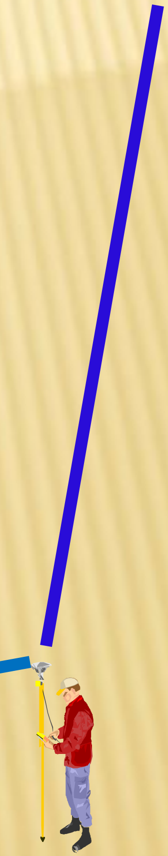
RADIO LINK



- Must have FCC license
  - Voice has priority
  - Call sign transmitted
- 25-35 watt transmitter at base receiver
  - 6 mile / 10 Km radius work area from base
  - Use quality antenna to maximize distance

CLOSING RADIAL BASELINES

- **RTK + Data Logging**
  - Using a CORS Station
  - Occupation times 8-20 minutes
  - Post process second baseline
- **Multiple base RTK**
  - Second RTK base and radio
  - Real-time result



QUESTIONS?