Lesson Plan: **Navigation - GPS**

Brett Wuth

Objectives:

At the conclusion of this lesson the participants will be able to:

1. explain how a GPS works
2. identify purposes for which a GPS is sufficient, a help, not useful
3. identify circumstances under which a GPS may fail
4. identify the significant configuration options of most GPS models
5. identify when to use UTM vs. Lat/Long
6. identify when to use NAD27 vs. NAD83/WGS84
7. configure a particular model for local SAR usage
8. read a UTM off a particular model and translate that to and from the UTM notation used with topographic maps.
9. determine the UTM of the location where they are at and the accuracy of their reading
10. given a destination UTM know what direction and distance to go to get to it
11. be able to record their current location as a Waypoint in a particular model
12. select a Waypoint on a particular model and have GPS determine distance and direction to it
13. create a distant Waypoint with a given UTM in a particular model
14. use GPS to convert between UTM and Lat/Long, and between NAD27 and NAD83/WGS84

Time Plan:

Total Time: 2 hours 30 minutes

Start	Material

00:00
5 min
	• Introduce topic title
	• Introduce Instructor
	• Determine experience level of students.
	  • Who uses GPS regularly?
	  • Who is comfortable reading UTM's off a map?
	  • Recruit more advanced students to assist in illustrating material.
	• Present Objectives
	  • explain how GPS works/fails
	  • identify purposes for which GPS is sufficient/help/not useful
	  • configure particular GPS; convert between UTM & Lat/Long, NAD27 & NAD83-WGS84
	  • read UTM
	  • know where you are
	  • determine direction and distance to remote UTM
	  • record local/remote waypoints, select as destination

Start	Material

00:05
5 min
	How a GPS works
	• 3 major components
	  • 1. radio receiver
	  • compares time for radio signal to arrive from satellites
	  • receives information on satellite locations
	  • 2. computer
	  • computes where GPS currently is (needs 4 separated satellites)
	  • 10-15m accuracy
	  • records where GPS has been
	  • allows entry of remote locations
	  • calculates distance and direction between points
	  • calculate speed/time
	  • draw a route on a map
	  • place points on map
	  • 3. magnetic sensor (only some models)
	  • determines direction GPS is facing
	  • GPS without magnetic sensor tells what direction GPS has moved, but not direction GPS is facing
	  • test GPS by turning it. Does the direction arrow change?

00:10
6 min
	How a GPS fails
	• radio signal not received from 4 satellites
	  • heavy tree cover
	  • blocked view of sky (hills, mountains, building)
	  • satellites not in right positions (below/at horizon, clustered)
	  • satellites not working/disabled (military selective availability)
	  • radio interference
	  • multipath (reflected) signals[3]
	  • weather does not affect signal
	• computer fails
	  • batteries (-15C)
	  • temperature (too hot)
	  • water/condensation (if not sealed)
	  • electromagnetic interference
	• magnetic sensor fails (same as compass)
	  • metal (belt buckles, cars)
	  • magnetic fields (power lines)
	  • magnetic anomalies (far north)

00:16 3 min	Alternatives/Aids to GPS • location: dead recogning / distance-bearing / triangulation • recording: paper • distance/direction: subtraction & estimation; plot on map • map (better choice) • bearing: compass (better choice)

Start	Material

00:19
7 min
	When is a GPS sufficient/help/not helpful
	discuss examples, compare with other alternatives
	• determine location when at
	  • hill top
	  • valley bottom
	  • heavy trees
	  • canyon
	  • downtown city
	  • under power lines
	  • heavy fog
	  • blizzard
	• determine direction/distance to
	  • known UTM
	  • some place you can see
	  • some place you've been
	  • a LatLong
	  • a street address
	• route selection
	• remembering a UTM

00:26
5 min
	Significant configuration settings
	• Most GPS's allow you to configure:
	  • True North vs. Magnetic North
	  • use True North
	  • GPS's don't generally allow you to set declination to exact same value used on compasses.
	  • UTM vs. Lat / Long
	  • UTM generally used by SAR
	  • Map Datum: NAD27 vs NAD83/WGS84
	  • measurement of the shape of the Earth
	  • NAD “North American Datum”
	  • WGS “World Geodetic Survey”
	  • should use same as the topo map being used
	  • Pincher SAR maps generally NAD27

00:31 9 min	configure a particular model for local SAR usage *Handout PCSAR GPS Configuration sheet* *Exercise:* Students configure their GPS *Help students to configure if their particular model not same as PCSAR GPS*

Start	Material

00:40
23 min
	Reading a UTM
	Assume students have basic background in UTM
	Distribute: topo maps
	• ZEN (Zone Easting Northing)
	• long form of numbers
	  • read off corner of topo maps
	  • northing: number of meters north of the equator
	  • easting: number of meters east of imaginary zone line (500km center line)
	  • converting to short form
	• Read the current/last known UTM
	  • last location where GPS was turned on and could see satellites
	  • instructions on front of Pincher SAR GPS's
	  • determining accuracy
	  • Garmin eTrex: on Satellite Page
	• *Exercise*:
	  • Record last known UTM in long form
	  • Give last known UTM in short form
	  • Go outside, record current UTM in long and short form, note accuracy.
	  • *assist students that don't have Pincher SAR GPS*

01:03
10 min
	Manual determination of Distance and Direction
	• use map
	• without map
	  • subtract Easting/Northing
	  • estimate distance or Pythagorean theorem
	  • estimate direction or calculate Tangent
	  • or draw scale map
	• *Example*:
	  • I'm at Zone:12U Easting: 0286623 Northing: 5484642
	  • I'm going to:12U Easting: 0287134 Northing: 5484419
	  • location is: 511 meters East and 223 meters South
	  • estimate: ESE 620m
	  • map/calculation: 129 degrees 661m

Start	Material

01:13
7 min
	Recording current location:
	• *Example*: Garmin eTrex
	  • Menu/Mark
	  • (enter to use current location)
	• *Exercise*: students record most recent location as a waypoint
	  • *Assist students using other models*
	Reviewing a Waypoint
	• Need to remember the name of the waypoint
	  • write down the name or give it a good name when creating waypoint
	• *Example*: Garmin eTrex
	  • Menu/Waypoints
	  • choose starting letter/number
	  • choose waypoint
	  • read UTM
	• *Exercise*: students review waypoint they just recorded
	  • *Assist students using other models*

01:20
6 min
	Manually entering a Waypoint
	• You can enter a UTM that you've never been to
	• *Example*: Garmin eTrex
	  • Menu/Mark
	  • down to UTM / enter
	  • up/down to select digits to change / enter
	  • up/down for new value of digit / enter
	  • repeat for other digits
	  • down to OK/enter
	  • up to OK/enter
	• *Exercise*: students enter an arbitrary waypoint
	  • use something close to current position
	  • *Assist students using other models*

01:26
4 min
	Direction and Distance to a Waypoint
	• selecting a Waypoint as a “Go To”
	  • *Example*: Garmin eTrex
	  • Menu/Waypoints
	  • select range waypoint is in (up/down then enter)
	  • select point (up/down then enter)
	  • up to goto then enter
	  • press down until “Bearing” appears
	  • *Exercise*: students determine distance and direction to waypoint they just entered.
	  • *Assist students using other models*

Start	Material
01:30 50 min	*Outside Exercise* *Distribute* radios, street map, exercise sheet. *In an outside area of a few blocks* In small groups of 2 or 3, the students will: • Be assigned a call sign: "Team A", receive radio, map • Be assigned a direction, subsequent teams being about 90 degrees apart • Create a waypoint for their start location, also record on paper. • Walk to a place of their choosing, 1 or 2 blocks in the direction. • Create a waypoint for this location, also record the location on paper. • Transmit the full UTM to the next team. Team A gives their UTM to Team B. Team B gives location to Team C, and so on. The last team gives their location to Team A. • Record the location transmitted to you. • Estimate the distance and direction to that UTM. • Create a waypoint for that location you received. • Set the GPS "Go To" to the new waypoint. • Walk to the GPS location. • Make note of the location. • Set the GPS "Go To" to the starting location. • Follow the GPS back to the start.

02:20
2 min
	Converting Waypoints between notations
	• UTM to/from LatLong
	• NAD27 to/from NAD83/WGS84
	• Procedure
	  • configure for source notation
	  • create waypoint (in field, or entered) in source notation
	  • configure for desired notation
	  • view waypoint

02:22 8 min	• Review Objectives • Questions

Aids:

- 5 Pincher SAR Garmin eTrex GPS's
- 1 Brett Wuth's Garmin eTrex GPS
- 5 copies topo map of locale (82 H/5)
- copy for each student of local street map
- copy for each student of PCSAR Doc-69 "GPS - Set-Up and Maintenance"
- copy for each student of outside exercise sheet, adapted to locale
- Radios

Frequently Asked Questions

- **Aren't 3 satellites enough?** No. 3 satellites would be enough if you knew precisely how long after the satellite sent its signal that it arrived. But the clock in the GPS is not accurate enough for that. Instead we can tell with 2 satellites the difference in time for the 2 satellite signals, and therefore the difference in our distance from them.

Knowing the difference gives our location on a paraboloid (3 dimensional parabola). Adding a 3rd satellite gives our location on an parabola or ellipse. A 4th satellite gives our location as one or two points. One of the points can be eliminated because it's no where near the surface of the earth or its moving at an impossible speed.[4] However, if we have only three satellites, and the arc happens to be close to vertical for likely elevations, then our horizontal location is the same regardless of where we are on the arc.

- **Can a GPS tell you the distance and direction between two points when you are not at either?** Most can't. It's not a commonly asked for feature, although it would be very useful at a SAR Command Post.

Feedback:

2004-06-01 Wuth presentation at PCSAR regular meeting

- Outdoor exercise needs more written instructions
- At 45 minutes, outdoor exercise felt a little rushed. 50 or 60 minutes might be better.
- Students naturally wanted to go in groups in outdoor exercise. Good learning resulted from working together.
- Easiest to let students just choose their points randomly from the outdoor exercise list.

License:

Reference Material:

- [1] "Does RAIN, SNOW, or CLOUDS affect reception of GPS signals?" http://gpsinformation.net/gpsclouds.htm Joe Mehaffey
- [2] GPS SPS Signal Specification, 2nd Edition (June 2, 1995) http://www.navcen.uscg.gov/pubs/gps/sigspec/default.htm
- [3] "Multipath Signals: How do they make my GPS have errors?" http://gpsinformation.net/multipath.htm Joe Mehaffey
- [4] http://www.trimble.com/gps/ Good tutorial on GPS theory. Justification for 4 satellites is a bit wonky, perhaps based on how calculation is done using spheres instead of parabaloids.

Notes:

- Weather (rain, snow, clouds) does not affect GPS [1]
- The GPS frequency was chosen to be unaffected by weather.[1]

To Do:

- Add section on WAAS