Land Surveying Capabilities
Washington Water Science Center
How close is close enough for government work?
ITAC presentation 10/7/09

1981

2009

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Surface-Water Specialist

Outline

- GPS Equipment
- GPS fundamentals
- GPS applications
- How close is “Close enough for Govt. work”?
- A new digital level and total station

GPS Equipment

- **Last Year—Purchase a pair of Trimble R8 dual frequency receivers with a pair of TSC2 controllers– about $50K**

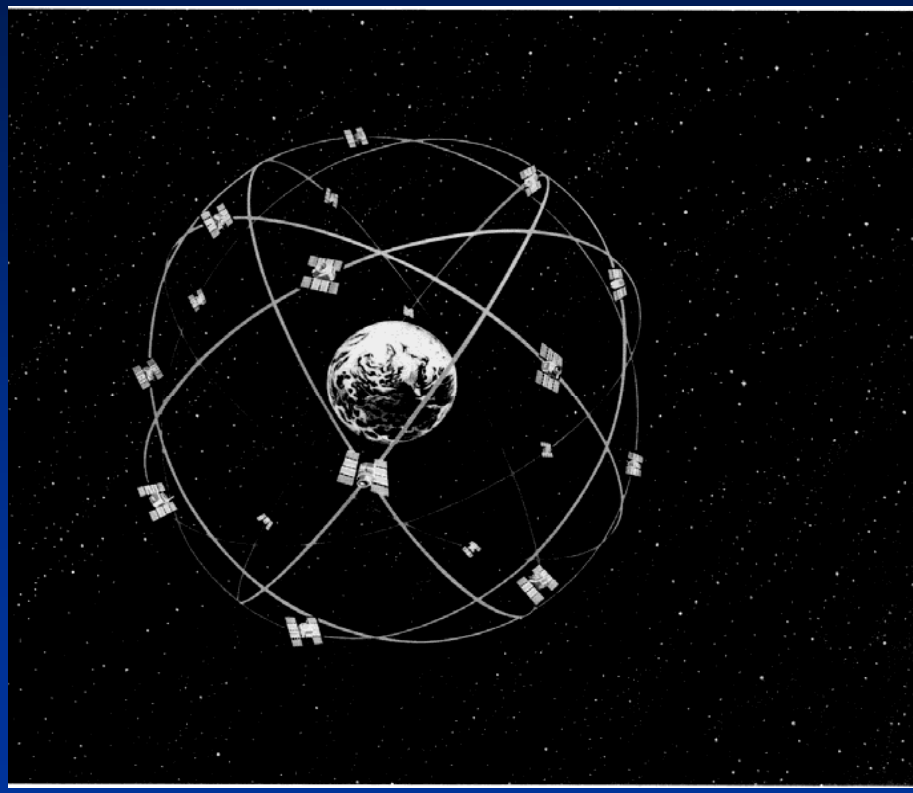
- **This Year—Purchased a radio, blackberry and laser range finder/ angle inclinometer**

Trimble R8 receivers

- Dual frequency L1/L2 also L2c and L5
- GNSS (Global Navigation Satellite System, US) and GLONASS (Russian) satellites—capable of monitoring 44 satellites
- Integrated 5W radio
- RTK capabilities

GNSS Satellites

- 25 satellites in final constellation
  - 6 planes with 55° rotation
  - each plane has 4/5 satellites
- Very high orbit
  - 20,183 KM, 12,545 miles
  - approximately 1 revolution in 12 hours
  - for accuracy
  - survivability
  - coverage



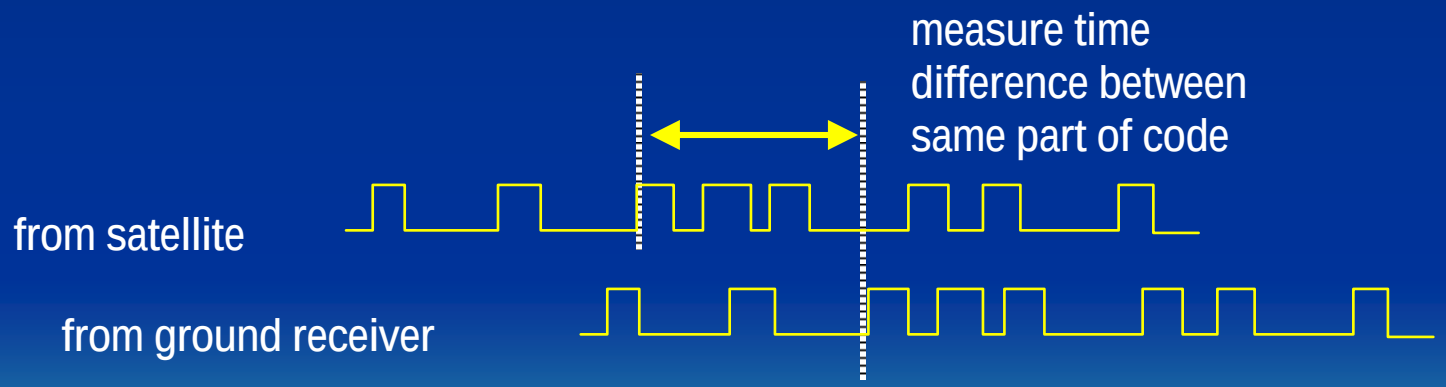
Copied from “GPS Navstar User’s Overview” prepare by GPS Joint Program Office, 1984

GPS Positioning

- Establish positions through the trilateration of distances from at least 4 satellites
- **Survey-grade** receivers observe the "**carrier phase**"—count the number of wavelengths (1 wavelength = 19 cm); sub-centimeter accuracy
- **Mapping-grade** receivers time the signal to compute distance-- "**code phase**"; 0.5 to 5 meter accuracy with differential correction

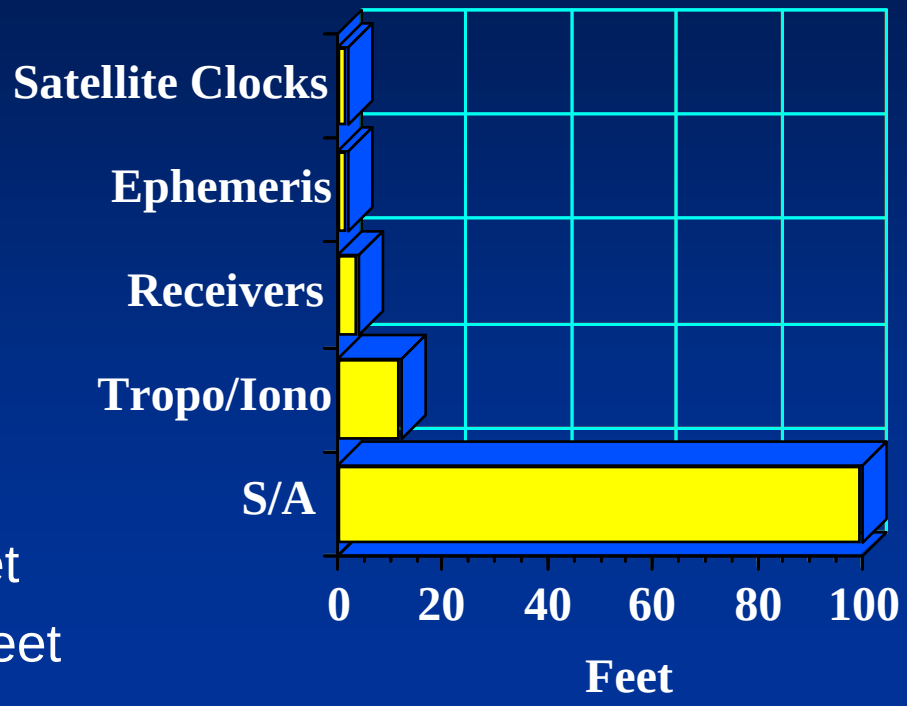
How do we know when the signal left the satellite?

- Use same code at receiver and satellite
- Synchronize satellites and receivers so they're generating same code at same time
- Then we look at the incoming code from the satellite and see how long ago our receiver generated the same code



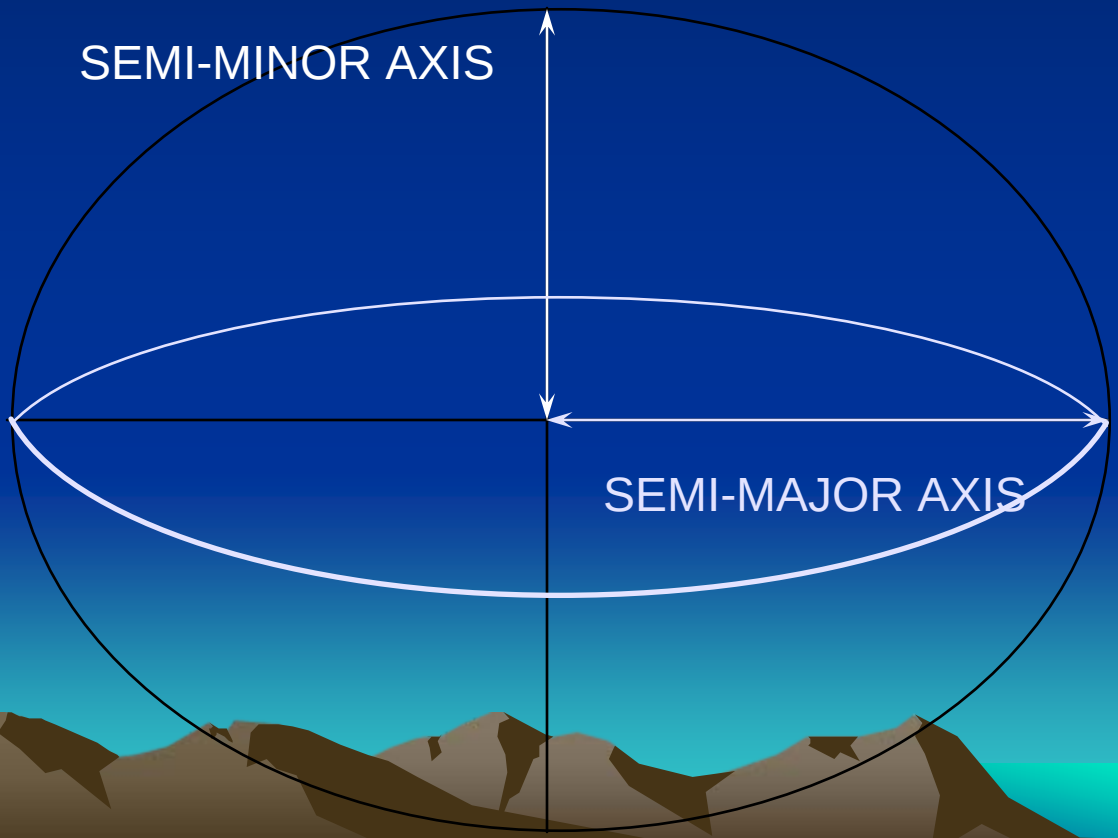
Error Budget

- Typical observed errors
  - satellite clocks 2 feet
  - ephemeris error 2 feet
  - receiver errors 4 feet
  - tropospheric/iono 12 feet
  - S/A Range error 100 feet
- No S/A Total (rt sq sum) 13 feet
- with S/A Total (rt sq sum) 100 feet



Ellipse in 3-D: an Ellipsoid

- Rotate ellipse about semi-minor (polar) axis to obtain 3-d ellipsoid
- Semi-major axis is equatorial axis

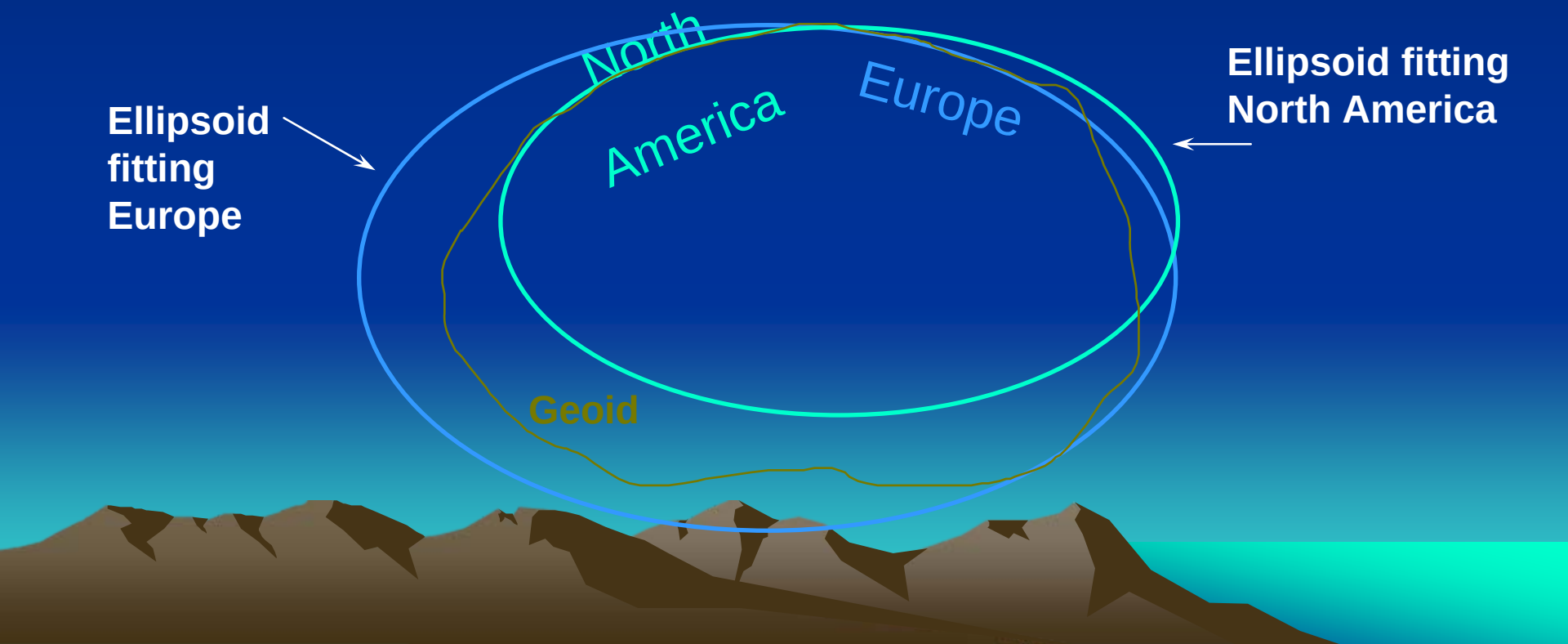


Working surfaces

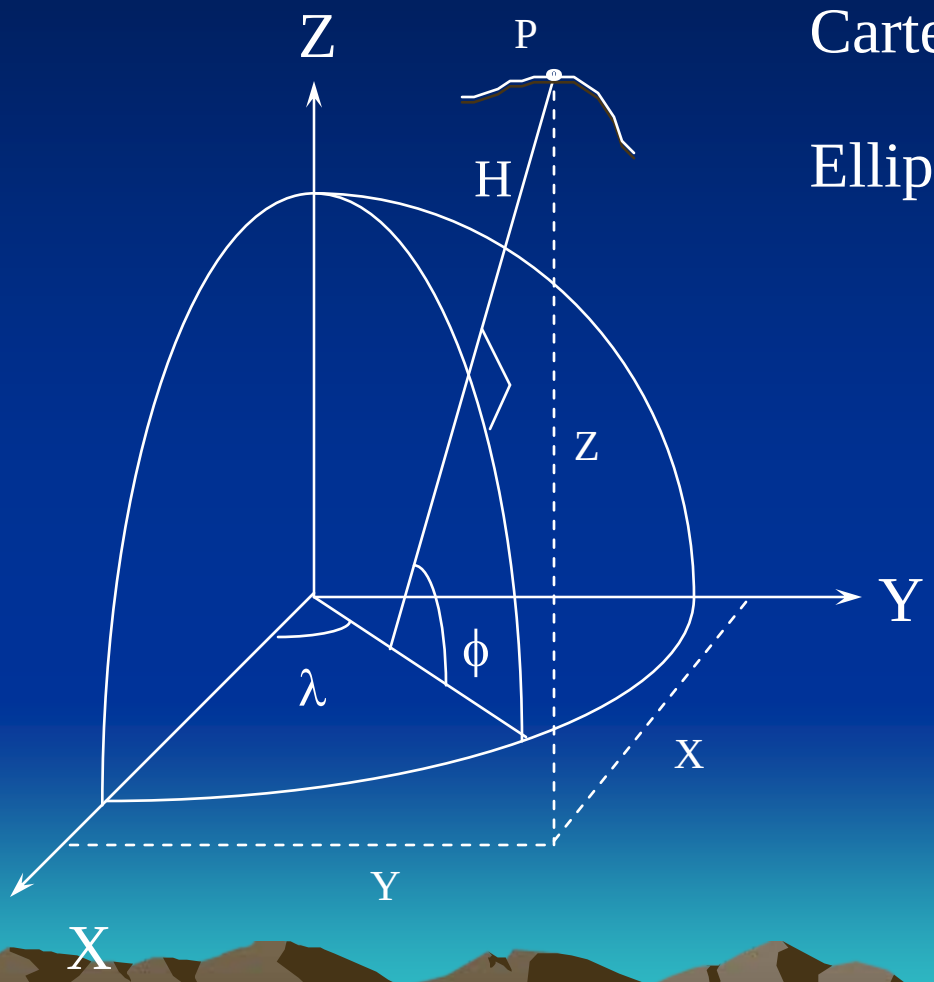
A Datum is described by a specifically oriented reference ellipsoid defined by 8 elements

- Position of the network (3 elements)
- Orientation of the network (3 elements)
- Parameters of the reference ellipsoid (2 elements)

Regional Datums are designed so that the ellipsoid conforms to the geoid over the desired region rather than the whole Earth



Coordinate Systems



Cartesian coordinates (X, Y, Z)

Ellipsoidal coordinates (ϕ, λ, H)

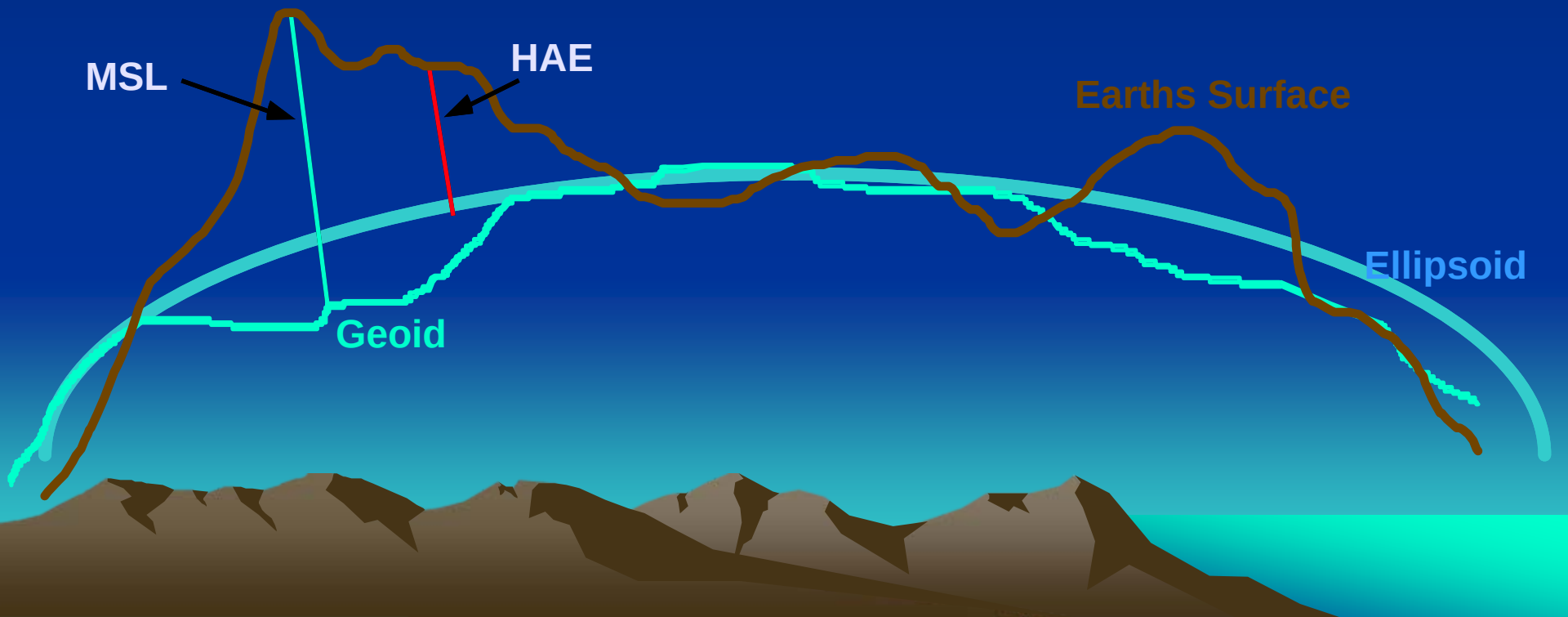
DATA FORMATS

WGS84--GPS positions in latitude, longitude, and **ellipsoid height** relative to the WGS84 ellipsoid

Grid—local Northing, Easting, and **elevation** in terms of specific datum and projection

Altitude Reference

- Ellipsoid
  - A smooth, mathematically defined model of the earths surface
- Geiod
  - A surface of equal gravitational pull (equipotential) best fitting the average sea surface over the whole globe



GPS Survey Styles

- Static
- RTK (Real-time Kinematic)
  - With local base station and radio
  - VRS (Virtual Reference Station) or RTN (Real-time Network)

Real Time GPS Surveying Applications

- Control
- Bathymetry
- High Water Marks
- Cross-section surveying

Static

- Collect data for 2 or more hours
- Convert data to RINEX format
- Send to OPUS (National Geodetic Survey)

NGS OPUS SOLUTION REPORT

All computed coordinate accuracies are listed as peak-to-peak values.

SOFTWARE:	page5 0810.20 master30.pl 081023	START:	2009/03/29 20:02:00
EPHEMERIS:	igr15250.eph [rapid]	STOP:	2009/03/29 23:59:00
NAV FILE:	brdc0880.09n	OBS USED:	4199 / 4998 : 84%
ANT NAME:	TRM_R8_GNSS NONE	# FIXED AMB:	32 / 35 : 91%
ARP HEIGHT:	1.317	OVERALL RMS:	0.013(m)

REF FRAME:	NAD_83(CORS96)(EPOCH:2002.0000)		ITRF00 (EPOCH:2009.2409)	
X:	-2366648.680(m)	0.060(m)	-2366649.409(m)	0.060(m)
Y:	-3565553.562(m)	0.130(m)	-3565552.395(m)	0.130(m)
Z:	4713724.504(m)	0.059(m)	4713724.595(m)	0.059(m)
LAT:	47 57 20.50040	0.137(m)	47 57 20.51606	0.137(m)
E LON:	236 25 32.31191	0.073(m)	236 25 32.25153	0.073(m)
W LON:	123 34 27.68809	0.073(m)	123 34 27.74847	0.073(m)
EL HGT:	196.517(m)	0.050(m)	196.203(m)	0.050(m)
ORTHO HGT:	216.482(m)	0.063(m)	[NAVD88 (Computed using GEOID03)]	

	UTM COORDINATES UTM (Zone 10)	STATE PLANE COORDINATES SPC (4601 WA N)
Northing (Y) [meters]	5311535.492	109901.272
Easting (X) [meters]	457118.892	295329.287
Convergence [degrees]	-0.42654018	-2.04074843
Point Scale	0.99962259	0.99994625
Combined Factor	0.99959181	0.99991545

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE(m)
AJ7208	TWHL TWHL_PNGA_WA2001 CORS ARP	N470057.243	W1225522.293	115448.0
AJ7202	CPXF CHARLES PACK EXPE CORS ARP	N465024.289	W1221523.409	159000.6
AF9670	SEDR SEDRO WOOLEY DNR CORS ARP	N483117.591	W1221325.791	118415.2

GPS with local base station

River Bathymetry

Bathymetry

- Hypak software needed to integrate GPS with echo soundings
- GPS reading every 1 second
- Echo sounding every 200 milliseconds
- 95,654 bathymetric points,
- 1,069 walking-survey points
- 4.7 kilometers of river


EXPLANATION
Boat Survey Points
0
100
200
400
Meters

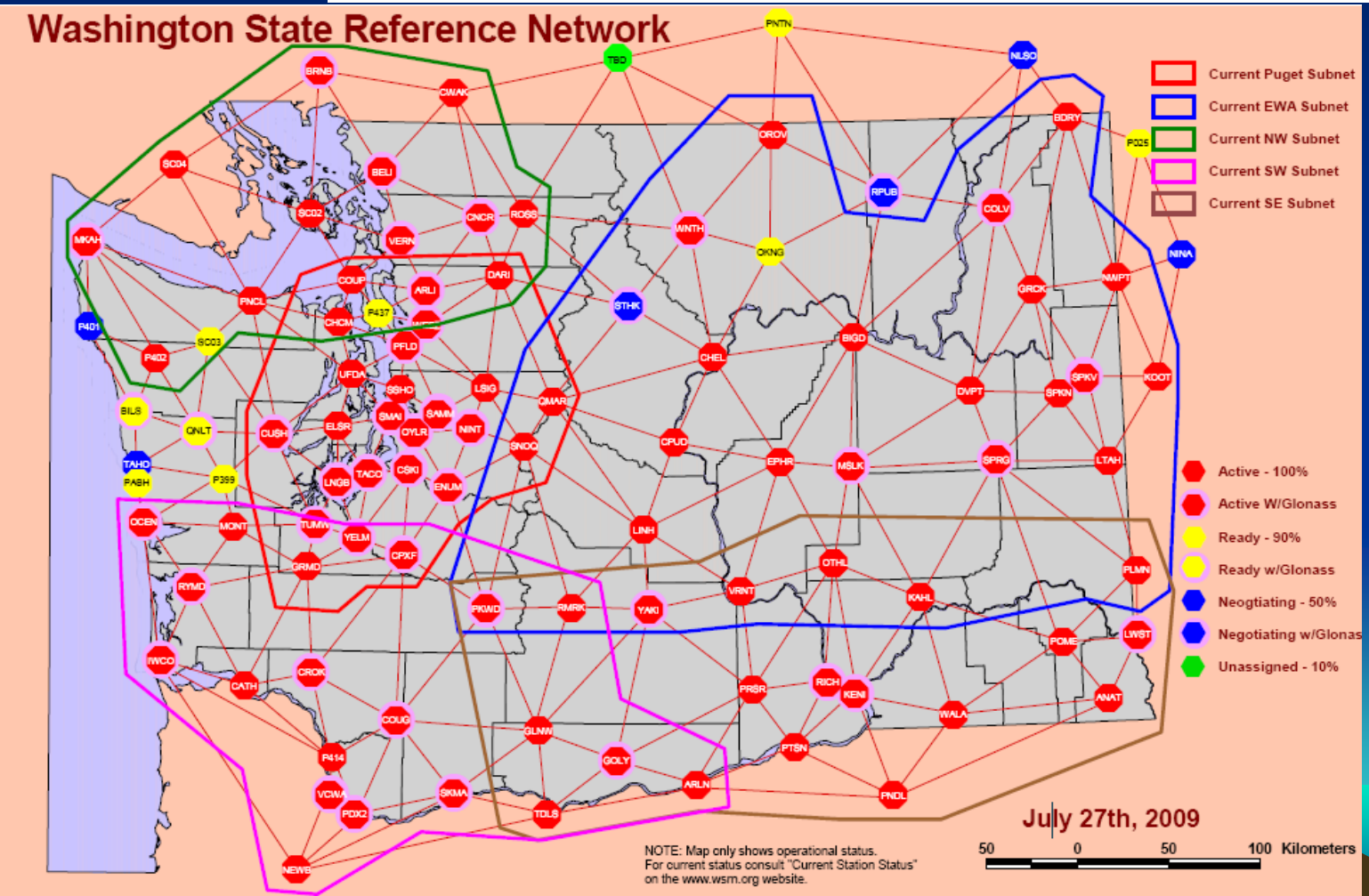
Bathymetry Accuracy

- Vertical GPS accuracy is +/- 2 cm plus 1ppm x baseline 5600 m x 2 = 11,200 m or 0.0312 m RMS or 2 sigma of **0.0624m**
- Horizontal GPS accuracy is +/- 1 cm plus 1ppm x baseline or 2-sigma error of **0.0212 m**
- GPS checks with control pts. from **0.014 to 0.047 m** in the horizontal and **-0.036 to 0.078 m** in the vertical.
- Add errors: echo sounder error, soft bed material, geoid error, pitch and roll, macrophytes, and unsurveyed areas.

RTK GPS using VRS (Virtual Reference Station)

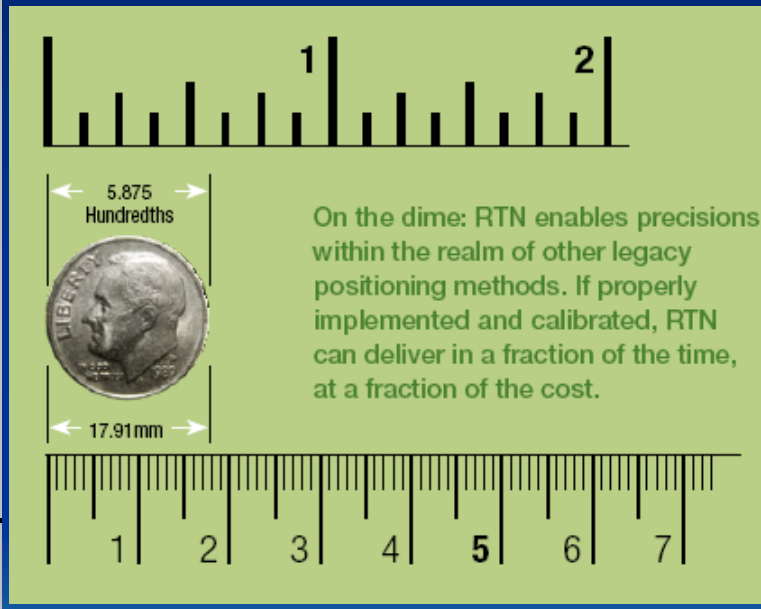
wsrn.org
Washington State Reference Network

A Regional Cooperative of Real-Time GPS Networks



GPS Errors (feet)

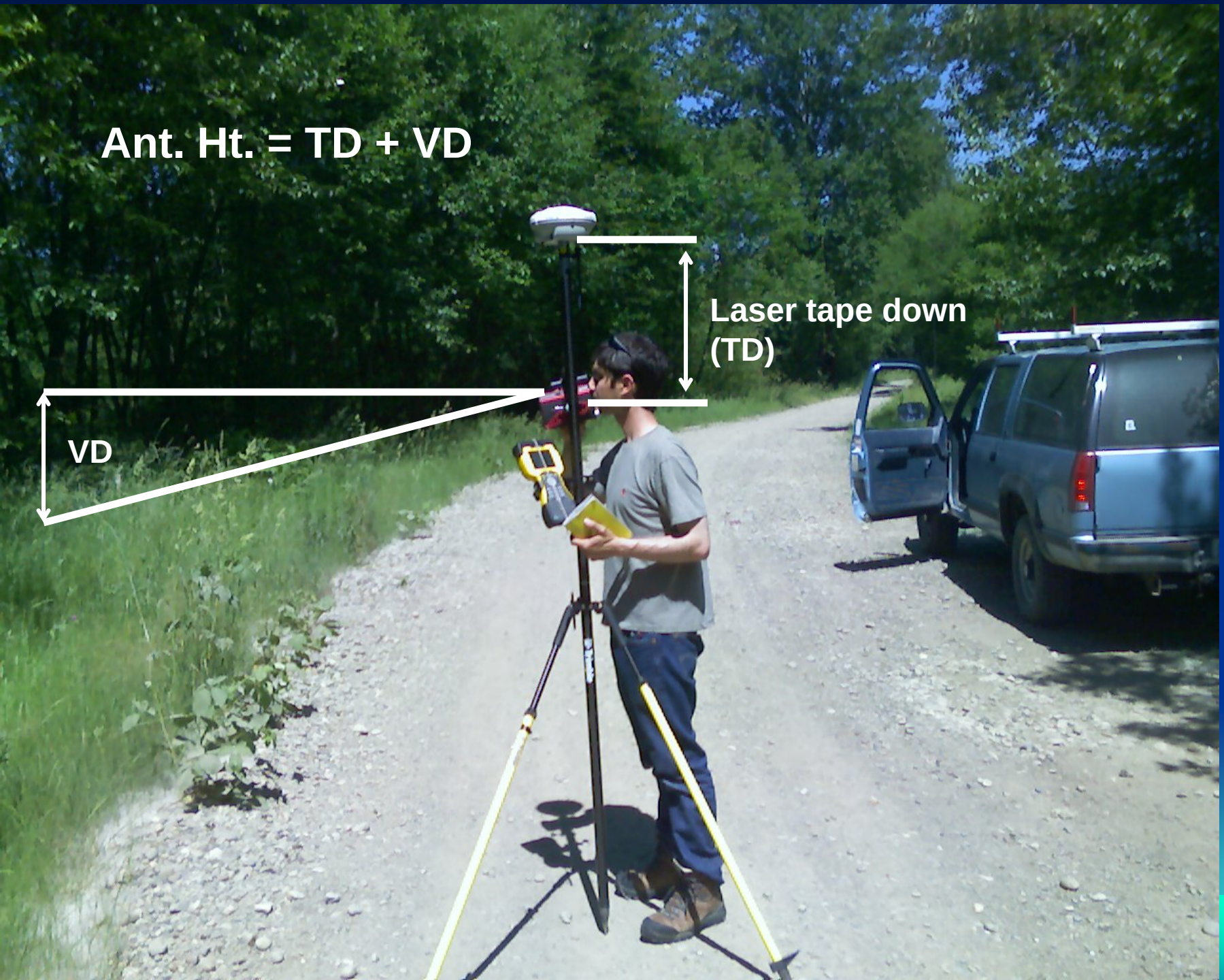
FEMA HWMs Project					
All GPS Checks with WADOT Monuments					
REACH	Monument	Vertical Accuracy	# of checks	Average Error	Maximum Error
Orting	GP27162-86	1 cm	1	0.049	0.049
	ORT-D	1cm	4	0.062	0.099
	ORTING	1cm	12	0.050	0.089
So.Prairie	ORT-J	1cm	3	0.088	-0.102
	ORT-K	1cm	5	0.074	0.109
Snoqualmie	MEAD	1cm	5	0.041	0.069
	IS17109	5cm	4	0.080	0.197
Carnation	2445	1cm	4	0.065	-0.153
	2444	1cm	8	0.090	-0.191
	562	1cm	4	0.065	-0.134
		TOTAL	**50**	**0.066**	**0.197**
VRS GPS Checks with WADOT Monuments					
Carnation	2445	1cm	4	0.065	-0.153
	562	1cm	1	0.001	0.001
		TOTAL	**5**	**0.052**	**0.153**



FEMA HWMs

GPS accessories

- Laser/angle inclinometer 0.1 angular resolution (0.175 ft error in 100 ft)
- TSC2 controller
- Cell phone (data modem)
- Reflector
- Tractor/backhoe


Ant. Ht. = TD + VD
Laser tape down
(TD)
VD

New Total Station

FC2500 w/TopSurv, $2,000

GPT 3103, 3” machine, reflectorless, $7,800

- 3” angle error equates to a 0.0015 ft error in 100 ft
- Old total station is a 5” machine, 0.0024 ft error in 100 ft.
- Levels w/ horizontal ring, 10-minute machines, 0.29 ft error in 100 ft.

EDM error (w/prism) = 2 mm + 2ppm * dist. Or 0.006 ft in 100 ft.

New Digital Levels

TOPCON

DC 101

- Electronic accuracy 0.4 mm (0.0013 ft)
- Optical accuracy 1mm (.0032 ft)