National Geodetic Survey

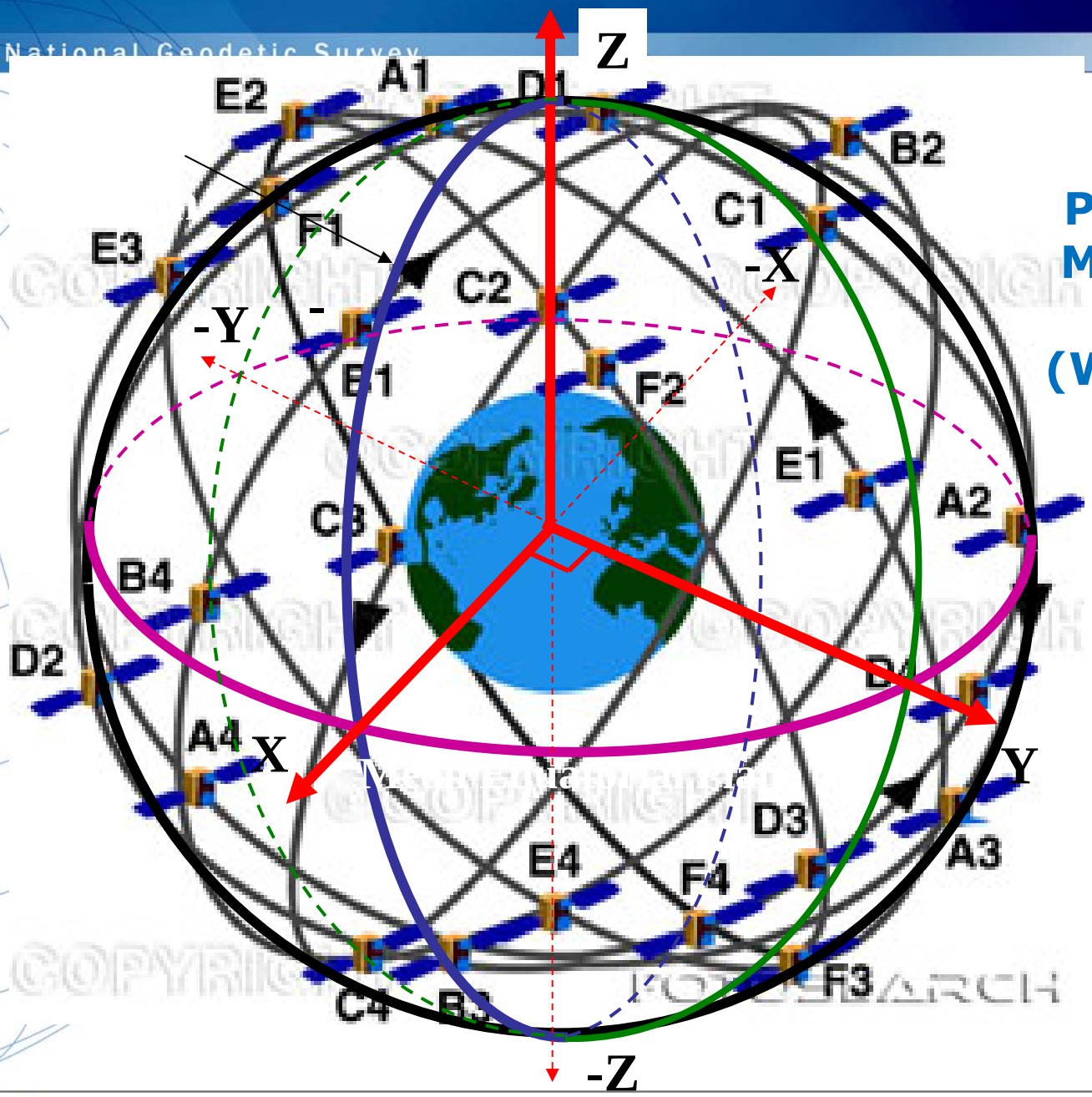
NERRS
APRIL 2012 GEODETIC TRAINING
CORBIN, VA

COMPARING LEVELING , STATIC GNSS, AND RT GNSS FOR HEIGHTS

NATIONAL ESTUARINE RESEARCH RESERVE SYSTEM

BILL HENNING, CHARLEY GEOGHEGAN,
DAVE DOYLE

National Oceanic and Atmospheric Administration



ALL GPS SATELLITES' POSITIONS ARE MAINTAINED IN ECEF X,Y,Z (WGS 84 DATUM)

It takes between 65 and 85 milliseconds for a signal to travel from a GPS satellite to a receiver on the surface of the Earth.

LAUNCH HISTORY

Summary of satellites[12]

Block	Launch Period	Satellite launches				Currently in orbit and healthy
		Success	Failure	In preparation	Planned	
I	1978–1985	10	1	0	0	0
II	1989–1990	9	0	0	0	0
IIA	1990–1997	19	0	0	0	10
IIR	1997–2004	12	1	0	0	12
IIR-M	2005–2009	8	0	0	0	7
IIF	2010–2011	2	0	10	0	2
IIIA	2014–?	0	0	0	12	0
IIIB	Theoretical	0	0	0	8	0
IIIC	Theoretical	0	0	0	16	0
Total		60	2	11	36	31

(Last update: 24 May 2010)

PRN 01 from Block IIR-M is unhealthy
PRN 25 from Block IIA is unhealthy
PRN 32 from Block IIA is unhealthy
[13] For a more complete list, see *list of GPS satellite launches*

GPS frequency overview

Band	Frequency	Description
L1	1575.42 MHz	Coarse-acquisition (C/A) and encrypted precision P(Y) codes, plus the L1 civilian (L1C) and military (M) codes on future Block III satellites.
L2	1227.60 MHz	P(Y) code, plus the L2C and military codes on the Block IIR-M and newer satellites.
L3	1381.05 MHz	Used for nuclear detonation (NUDET) detection.
L4	1379.913 MHz	Being studied for additional ionospheric correction.[*citation needed*]
L5	1176.45 MHz	Proposed for use as a civilian safety-of-life (SoL) signal.

GPS SATELLITES MAINTAIN TIME TO 1 SECOND PRECISION IN A MILLION YEARS! NEW SVNS KEEP PRECISION TO 8 NANOSECONDS – POSSIBLY EVEN BETTER IF HYDROGEN MASER CLOCKS ARE IMPLEMENTED.

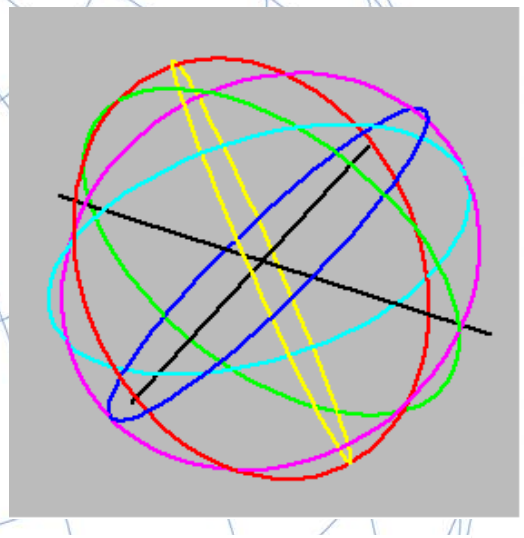
LOCKHEED MARTIN, 2005-2009, #4480, DELTA II, (SNV 41-61)
L2C, NEW M CODES, 10 YEAR LIFE

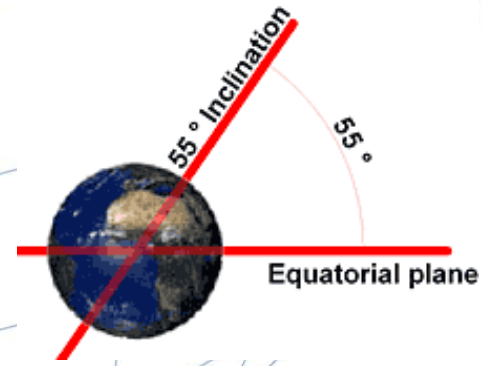
Block IIR-M								
IIR-M-1	53	17	2005-038A	28874	C4	05-09-26	Rb3	05-12-16 23:30 UT
IIR-M-2	52	31	2006-042A	29486	A2	06-09-25	Rb3	06-10-12 22:53 UT
IIR-M-3	58	12	2006-052A	29601	B4	06-11-17	Rb3	06-12-13 03:07 UT
IIR-M-4	55	15	2007-047A	32260	F2-A	07-10-17	Rb3	07-10-31 22:46 UT
IIR-M-5	57	29	2007-062A	32384	C1	07-12-20	Rb3	08-01-02 20:41 UT
IIR-M-6	48	07	2008-012A	32711	A4	08-03-15	Rb3	08-03-24 20:08 UT
IIR-M-7	49	01	2009-014A	34661		09-03-24		11-05-06
IIR-M-8	50	05	2009-043A	35752	E3	09-08-17	Rb1	09-08-27 14:40 UT

BOEING, 2010-X, #3600, DELTA IV, SNV 62-X, L5, 12 YEAR LIFE

Block IIF								
IIF-1	62	25	2010-022A	36585	B2	10-05-28	Rb1	10-08-27 04:10 UT
IIF-2	63	01	2011-036A	37753	D2-A	11-07-16	Rb1	11-10-14 19:53 UT

GPS ORBITAL PLANES & SLOTS

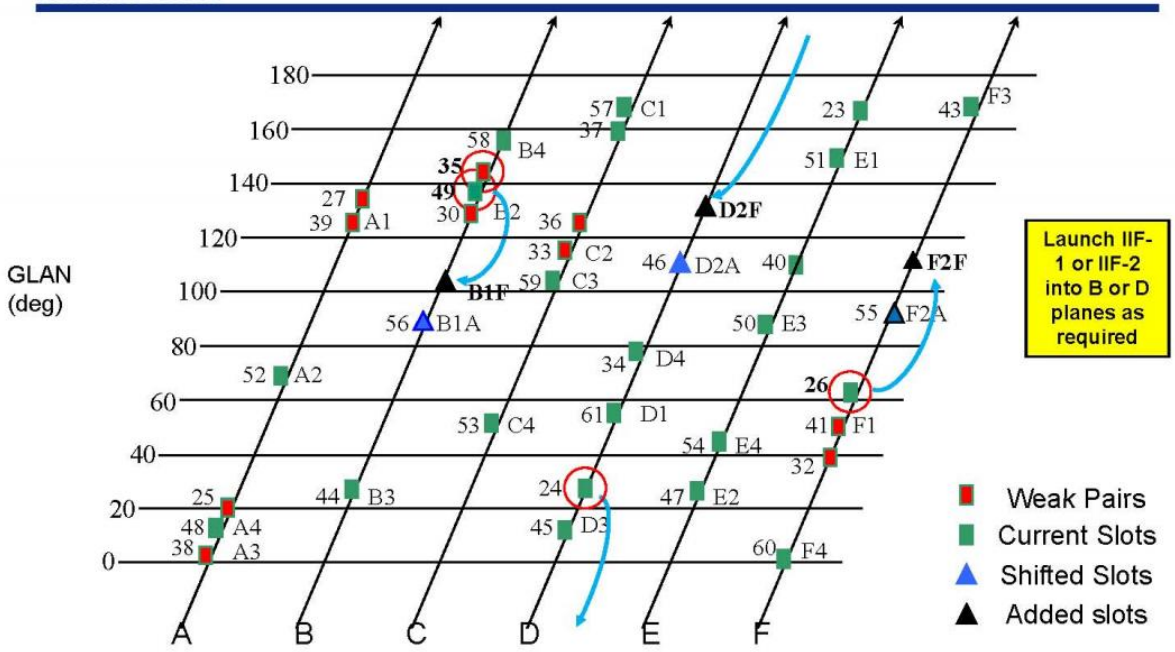




6 PLANES AT 55° DECLINATION, SPACED 60° RIGHT ASCENSION

U.S. AIR FORCE

Expand to 24+3 in B/D/F Planes



Integrity - Service - Excellence

GPS TIME

ORIGIN = JANUARY 1, 1980, ATOMIC TIME

DELAYED 19 SECONDS TO TAI AT ORIGIN (CONSTANT)

UTC IS CURRENTLY DELAYED (BEHIND) 15 SECONDS TO GPS TIME

TIME OF WEEK IN SECONDS FROM SUNDAY MORNING THROUGH SATURDAY NIGHT = 604799 SECONDS

GPS PASSED THROUGH ITS 1 BILLIONTH SECOND SEPTEMBER 14TH (2011). PROCESSING PROBLEMS?

GPS WEEK ROLLOVER: 8/15/99 = WEEK 1023
8/22/99 = WEEK 0
9/18/11 = WEEK 630 (1654)

GNSS Calendar

Click on a date in one of the calendars to display data

Wednesday, February 15, 2012 (UTC)

Julian Day Number: **2455972.5** Day of Year: **46**

GPS Week: **1675** GPS Week Number: **16753**

JANUARY 2012

Su	M	Tu	W	Th	F	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

FEBRUARY 2012

Su	M	Tu	W	Th	F	Sa
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29			

MARCH 2012

Su	M	Tu	W	Th	F	Sa
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

APRIL 2012

Su	M	Tu	W	Th	F	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

JULY 2012

Su	M	Tu	W	Th	F	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

AUGUST 2012

Su	M	Tu	W	Th	F	Sa
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

SEPTEMBER 2012

Su	M	Tu	W	Th	F	Sa
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30						

OCTOBER 2012

Su	M	Tu	W	Th	F	Sa
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

NOVEMBER 2012

Su	M	Tu	W	Th	F	Sa
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

DECEMBER 2012

Su	M	Tu	W	Th	F	Sa
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007
2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021

http://adn.agi.com/GNSSWeb/

http://www.rvdi.com/freebies/gpscalendar.html

endar

lata for each day are as follows:

epoch : day of week number
och : seconds of week at midnight for that day

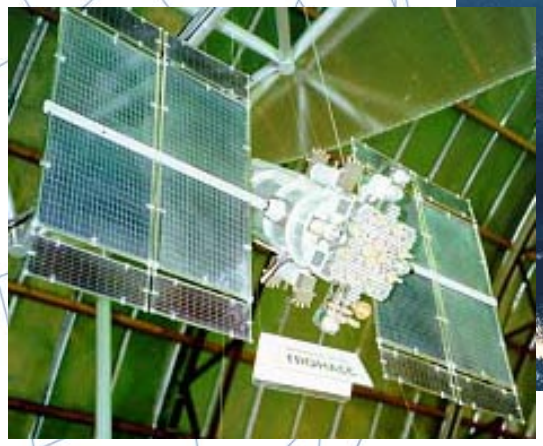
March

Thu	Fri	Sat
2 1673:4 549:345600 33	3 1673:5 649:432000 34	4 1673:6 649:518400 35
9 1674:4 550:345600 40	10 1674:5 650:432000 41	11 1674:6 650:518400 42
16 1675:4 551:345600 47	17 1675:5 651:432000 48	18 1675:6 651:518400 49
23 1676:4 552:345600 5	24 1676:5 652:432000	25 1676:6 652:518400

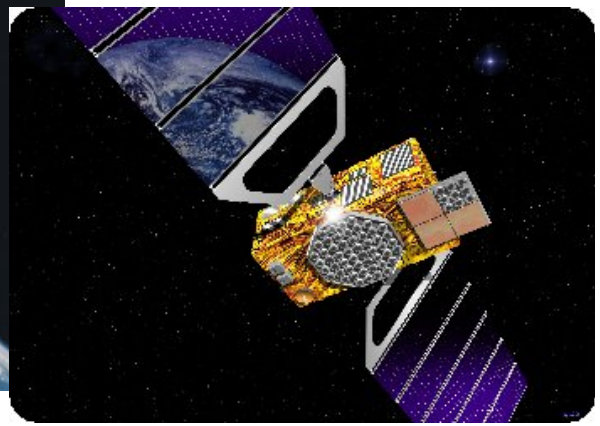
"JULIAN DAY NUMBER" IS TERRESTRIAL TIME SINCE JAN.1, 4713 B.C. AT NOON

"GNSS"

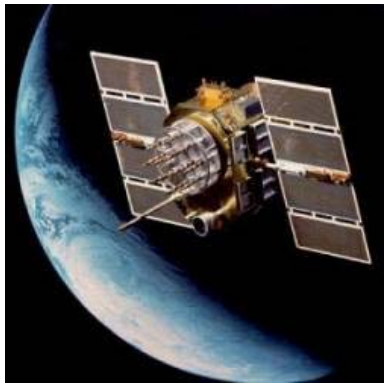
GPS



GLONASS



GALILEO



COMPASS (BEIDOU-2)

Planned GNSS

- Global Constellations
  - GPS (24+) USA
  - GLONASS (24) Russia
  - Galileo (27) EU
  - Compass (35) China
- Regional Constellations
  - QZSS (3) Japan
  - IRNSS (7) India
- Satellite-Based Augmentations
  - WAAS (3) USA
  - MSAS (2) Japan
  - EGNOS (3) EU
  - GAGAN (3) India
  - SDCM (2?) Russia

GLONASS STATUS

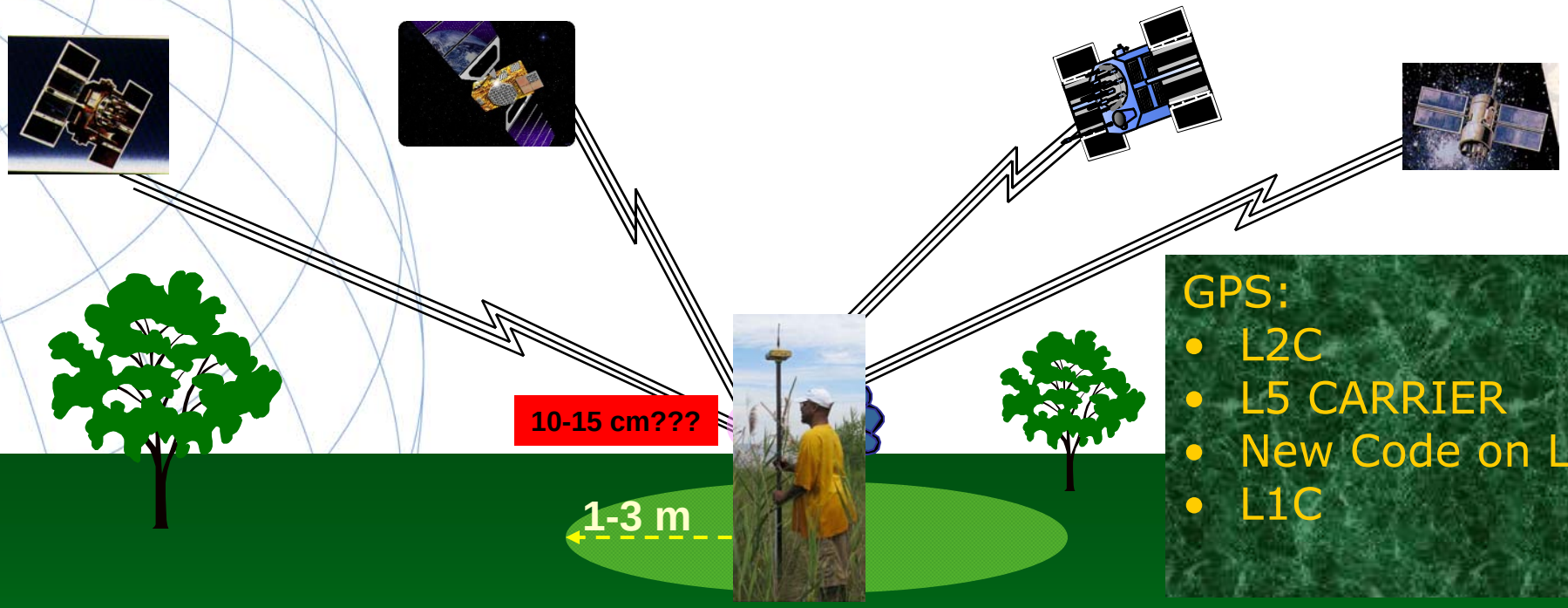
GLONASS Constellation Status at 08.12.2011 based on both the almanac analysis and navigation messages received at 11:00 08.12.11 (UTC) in IAC PNT TsNIImash

Orb. slot	Orb. pl.	RF chnl	# GC	Launched	Operation begins	Operation ends	Life-time (months)	Satellite health status		Comments
								In almanac	In ephemeris (UTC)	
1	1	01	730	14.12.09	30.01.10		23.8	+	+ 11:45 08.12.11	In operation
2	1	-4	728	25.12.08	20.01.09		35.4	+	+ 11:45 08.12.11	In operation
3	1	05	744	04.11.11	08.12.11		1.1	+	+ 09:59 08.12.11	In operation
4	1	06	742	02.10.11	25.10.11		2.2	+	+ 09:59 08.12.11	In operation
5	1	01	734	14.12.09	10.01.10		23.8	+	+ 09:59 08.12.11	In operation
6	1	-4	733	14.12.09	24.01.10		23.8	+	+ 09:59 08.12.11	In operation
7	1	05	712	26.12.04	07.10.05		83.4	+	+ 09:59 08.12.11	In operation
8	1	06	729	25.12.08	12.02.09		35.4	+	+ 11:15 08.12.11	In operation
9	2	-2	736	02.09.10	04.10.10		15.2	+	+ 11:30 08.12.11	In operation
10	2	-7	717	25.12.06	03.04.07		59.5	+	+ 11:44 08.12.11	In operation
11	2	00	723	25.12.07	22.01.08		47.5	+	+ 11:45 08.12.11	In operation
12	2	-1	737	02.09.10	12.10.10		15.2	+	+ 09:59 08.12.11	In operation
13	2	-2	721	25.12.07	08.02.08		47.5	+	+ 09:59 08.12.11	In operation
14	2	-7	715	25.12.06	03.04.07		59.5	+	+ 09:59 08.12.11	In operation
15	2	00	716	25.12.06	12.10.07		59.5	+	+ 10:30 08.12.11	In operation
16	2	-1	738	02.09.10	11.10.10		15.2	+	+ 11:15 08.12.11	In operation
17	3	04	714	25.12.05	31.08.06		71.5	+	+ 11:45 08.12.11	In operation
18	3	-3	724	25.09.08	26.10.08		38.4	+	+ 11:45 08.12.11	In operation
19	3	03	720	26.10.07	25.11.07		49.4	+	+ 09:59 08.12.11	In operation
20	3	02	719	26.10.07	27.11.07		49.4	+	+ 09:59 08.12.11	In operation
21	3	04	725	25.09.08	05.11.08		38.4	+	+ 09:59 08.12.11	In operation
22	3	-3	731	02.03.10	28.03.10		21.2	+	+ 09:59 08.12.11	In operation
23	3	03	732	02.03.10	28.03.10		21.2	+	+ 10:30 08.12.11	In operation
24	3	02	735	02.03.10	28.03.10		21.2	+	+ 11:45 08.12.11	In operation
2	1	-4	743	04.11.11			1.1			Commissioning Phase
7	1	05	745	04.11.11			1.1			Commissioning Phase
17	3	04	746	28.11.11			0.3			Commissioning Phase
21	3		701	26.02.11			9.4			Flight Tests
14	2		722	25.12.07	25.01.08	12.10.11	47.5			Spares
3	1		727	25.12.08	17.01.09	08.09.10	35.4			Maintenance
22	3		726	25.09.08	13.11.08	31.08.09	38.4			Maintenance

GALILEO- OFF THE GROUND OCTOBER 21, 2011

2 IOV SATELLITES, EUROPEAN SPACEPORT, FRENCH GUIANA, RUSSIAN SOYEZ ROCKET (SPUTNIK, YURI GREGARIN)

CHANGES IN GNSS



GPS:
- L2C
- L5 CARRIER
- New Code on L5
- L1C

GLONASS- FULL OPERATIONAL CAPABILITY 2011
EUROPEAN UNION - GALILEO
CHINA – COMPASS/BEIDOU

= 115 SATELLITES?

REGIONAL:
(JAPAN- QZSS FIRST LAUNCH 2010)
(INDIA – GAGAN)

BETTER RESISTANCE TO INTERFERENCE

FASTER AMBIGUITY RESOLUTION

AUGMENTED CODE APPLICATIONS

KNOWING DATUMS AND PROJECTIONS CAN HELP WITH ANALYZING ERRORS

GPS IS MAINTAINED BY THE DoD IN WGS 84

GLONASS IS MAINTAINED IN PZ 90.02

GALILEO IS MAINTAINED IN ITRS

OUR NATIONAL GEOMETRIC DATUM IS NAD 83 – BASED ON CORS ANTENNAS IN THE AIR

OUR NATIONAL VERTICAL DATUM (ORTHOMETRIC HEIGHTS) IS NAVD 88 - BASED ON NAVD 88 BENCH MARKS IN THE GROUND

WE WORK IN MAP PROJECTIONS: UTM, SPC, LDP

DATUM DEFINITIONS IN THE USA

HORIZONTAL/ GEOMETRIC:

- NAD 83- USA
- ITRS- "OLD"CORS/WORLD
- WGS 84- GPS (DoD)
- IGS 08 – "NEW" CORS
- NRS 22 (?) – NEW GEOCENTRIC

VERTICAL/GEOPOTENTIAL:

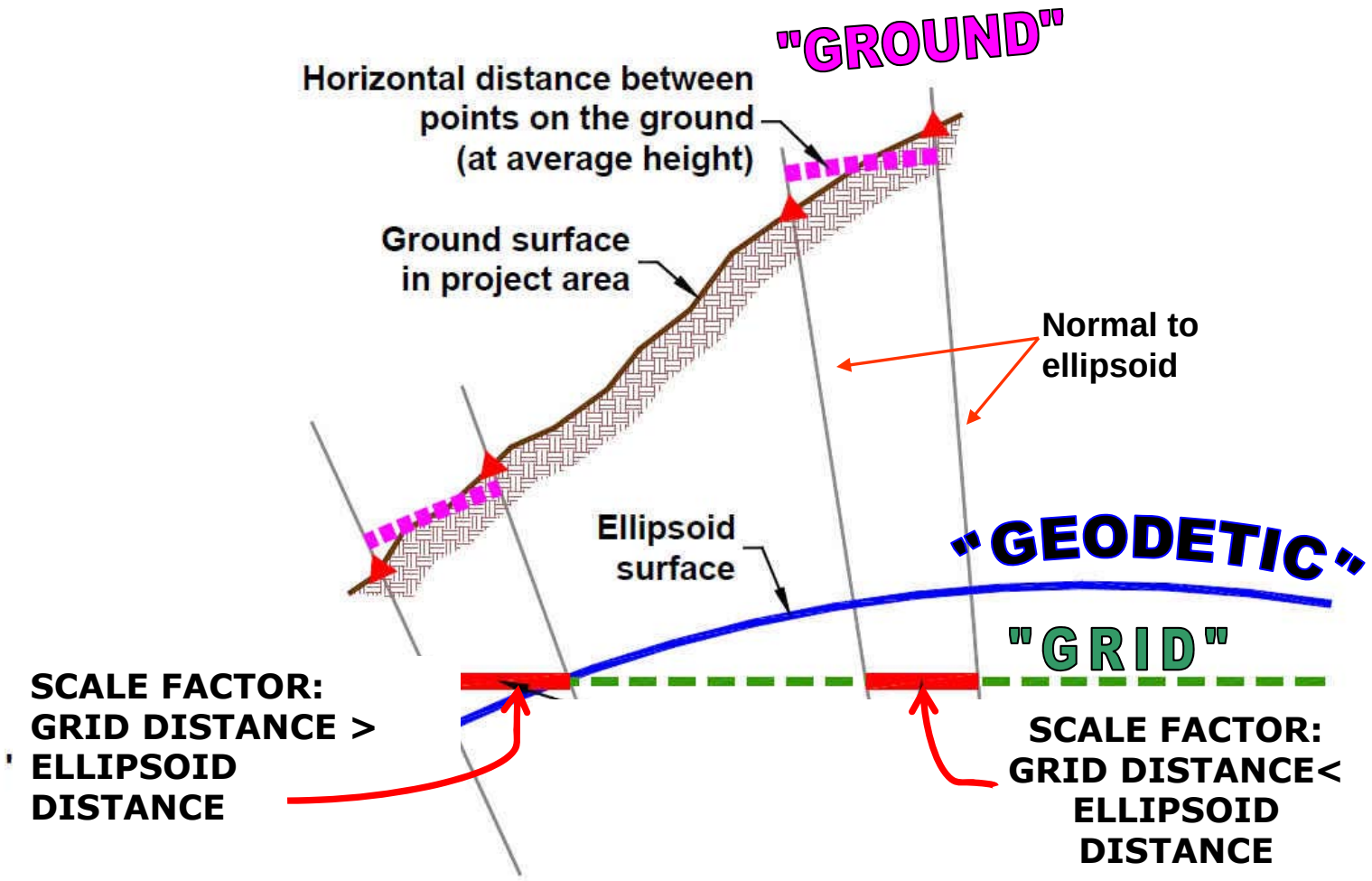
- NGVD 29
- NAVD 88
- NAVD 22 (?)

PROJECTIONS FROM DATUMS:

- SPC
- UTM
- LDP

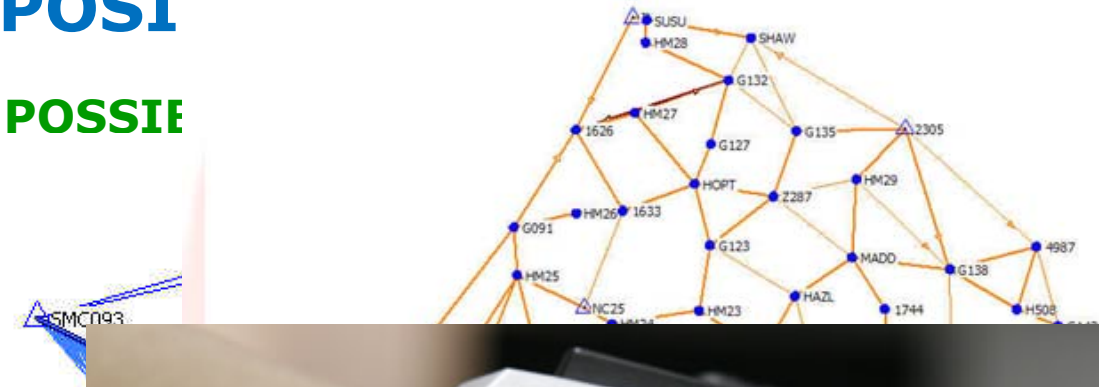
GRID/GROUND ISSUE

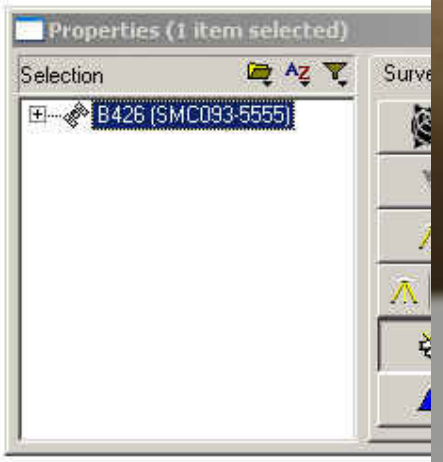
Linear distortion due to ground height above ellipsoid



GNSS POSI

STATIC – BEST POSSIE





for raw navigation for point recovery. Note: future GNSS constellations & signals may yield near decimeter accuracy.

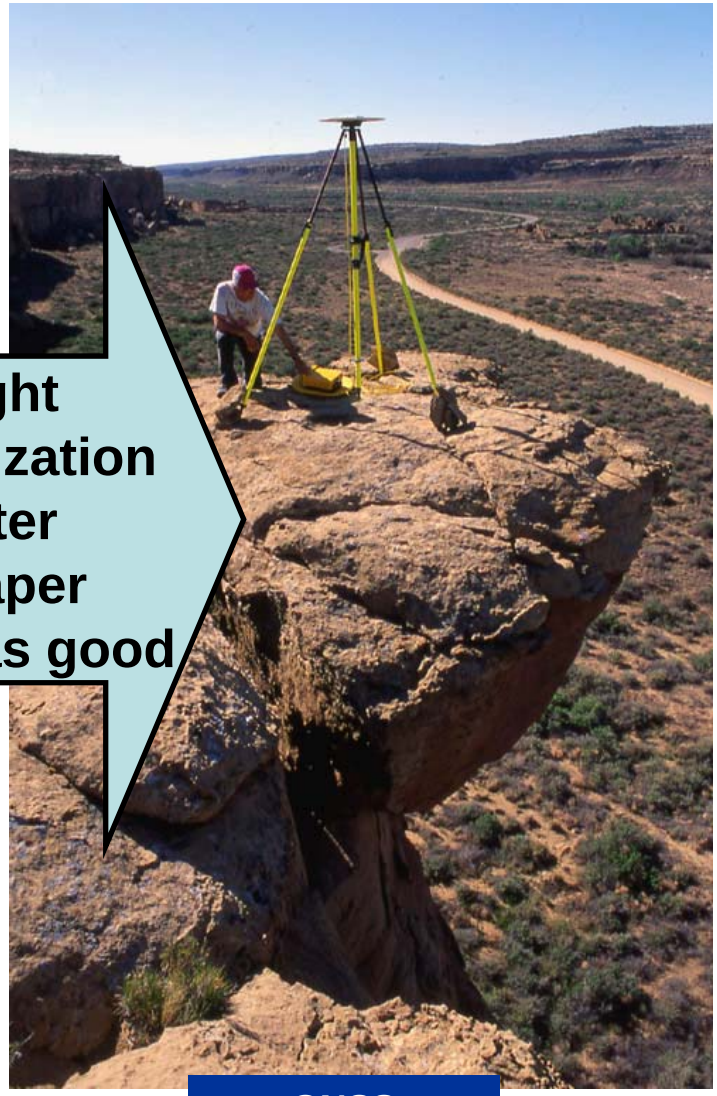
EXPECTED PRECISIONS FROM VARIOUS GNSS POSITIONING METHODS

GNSS METHOD	95% PRECISION: HORIZONTAL	95% PRECISION: VERTICAL	TIME ON POINT	NOTES
STATIC: CORS	2 CM	3 CM	≥ 2 HOURS	
	1.5 CM	2 CM	≥ 4 HOURS	
STATIC: OPUS-S	2 CM	3 CM	≥ 2 HOURS	
	1.5 CM	2 CM	≥ 4 HOURS	
STATIC: OPUS-RS	2 CM	5 CM	≥ 15 MINUTES	SEE OPUS RS MAP
OPUS-RS AVG. OF 2 OR MORE	1.5 CM	2.5 CM		
STATIC: MULTI RECEIVER	≤ 1 CM	≤ 1.5 CM	≥ 30 MINUTES	USING HTMOD GUIDELINES
				CONNECTED SESSIONS
RTK	1.5 CM	2.5 CM	1 SECOND-5 MINUTES	TO LOCAL BASE
				USING NGS GUIDELINES
RTN	2 CM	3-5 CM		
GEODETIC LEVELING	N/A	3 MM	N/A	3RD ORDER

HEIGHT MODERNIZATION- BACKGROUND

differential leveling

Height Modernization
-faster
-cheaper
-Nearly as good



GNSS

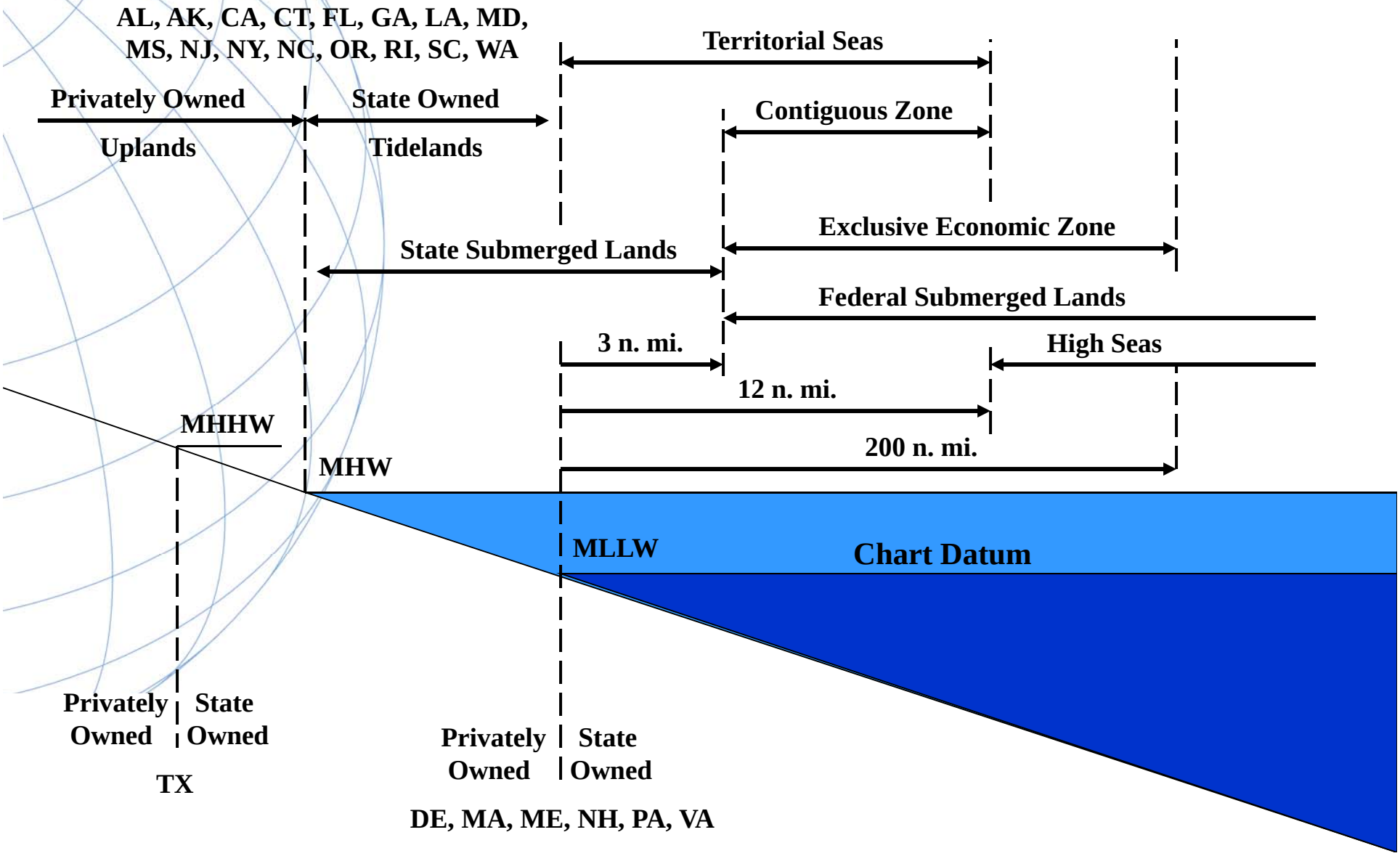
CHA - CHING $$$$$$$

♪♪♪

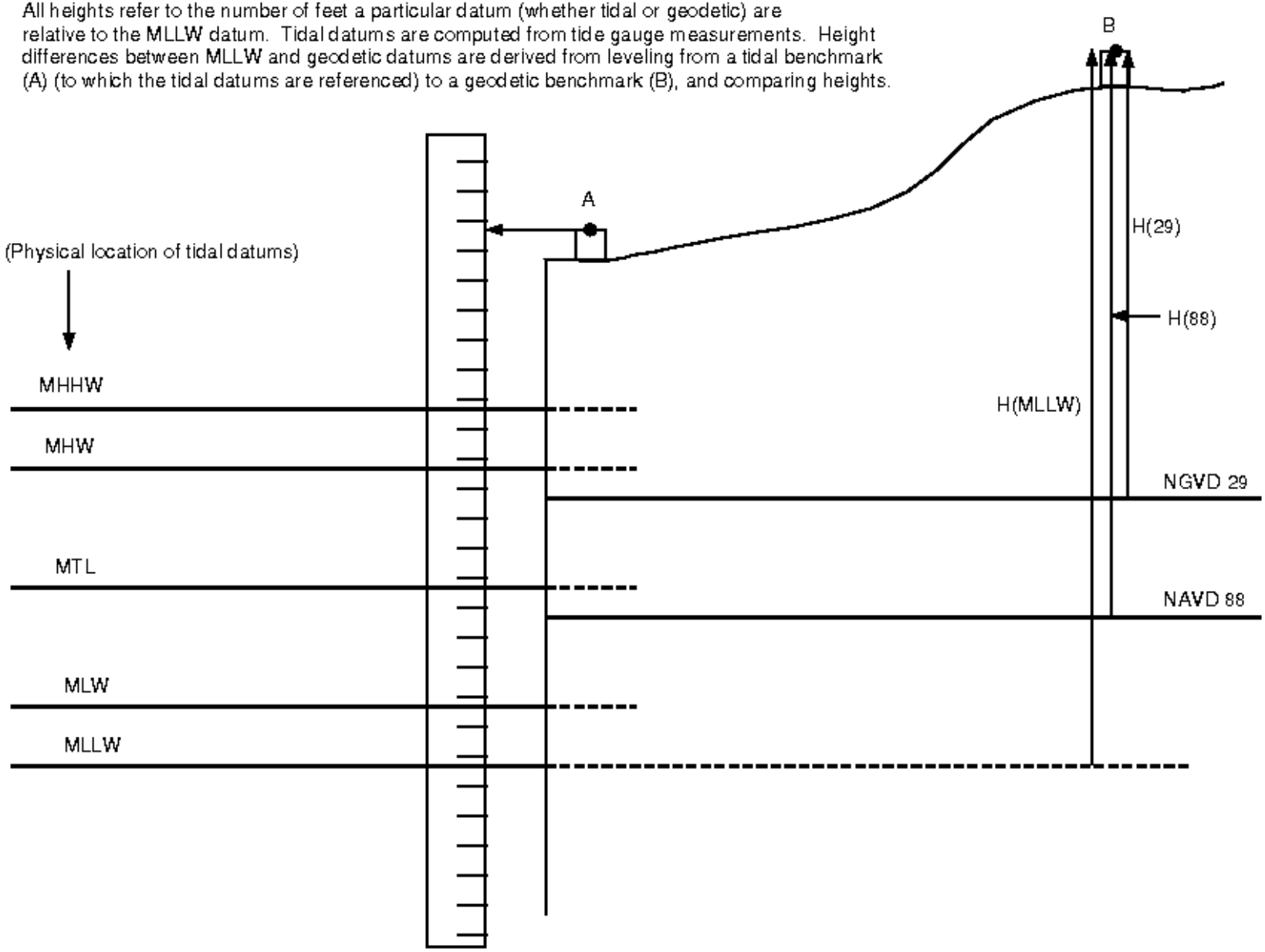
HEIGHTS MATTER!

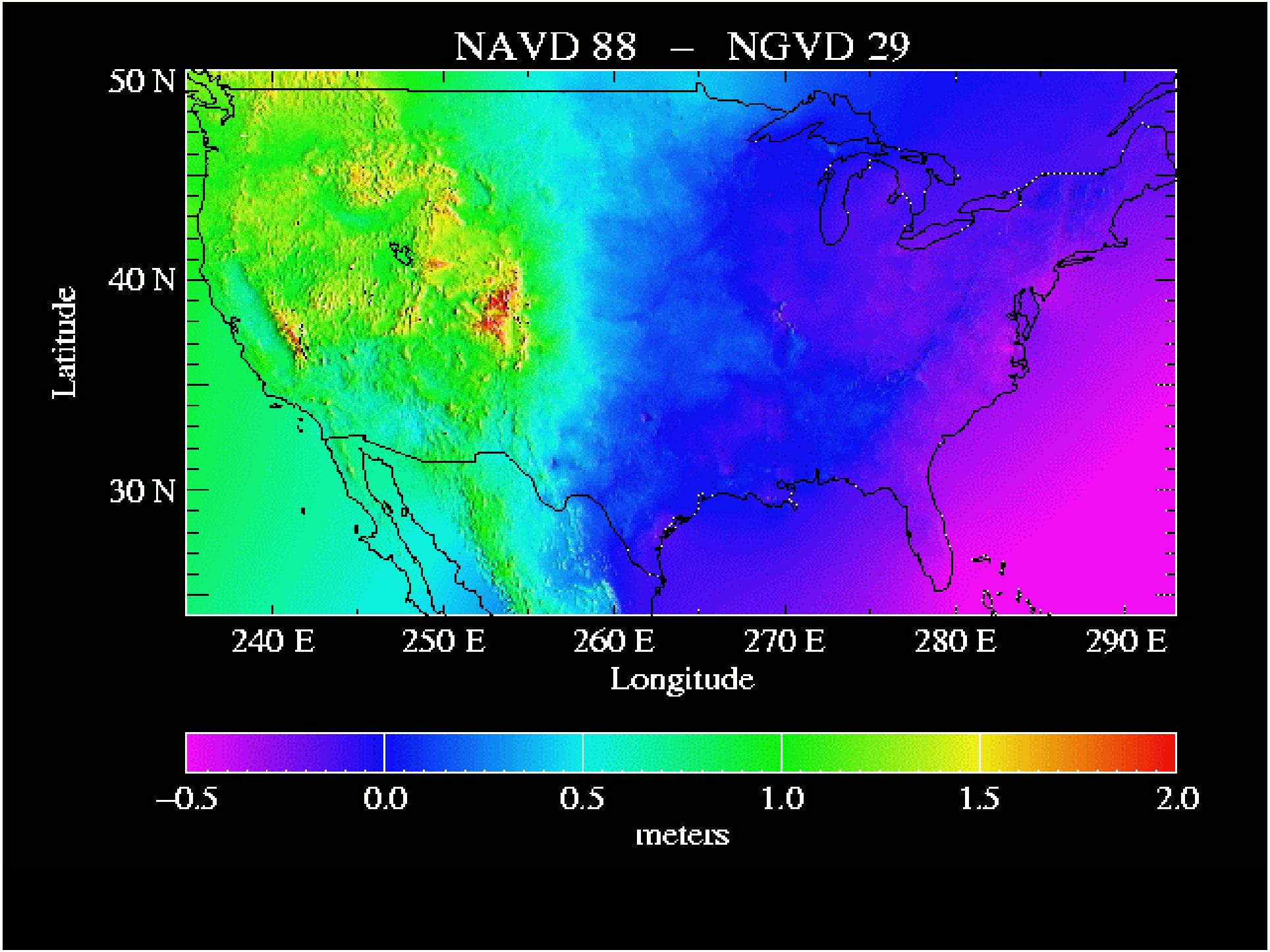
GUESS WHO PAID FOR THIS DISASTER?

Importance of Shoreline



All heights refer to the number of feet a particular datum (whether tidal or geodetic) are relative to the MLLW datum. Tidal datums are computed from tide gauge measurements. Height differences between MLLW and geodetic datums are derived from leveling from a tidal benchmark (A) (to which the tidal datums are referenced) to a geodetic benchmark (B), and comparing heights.



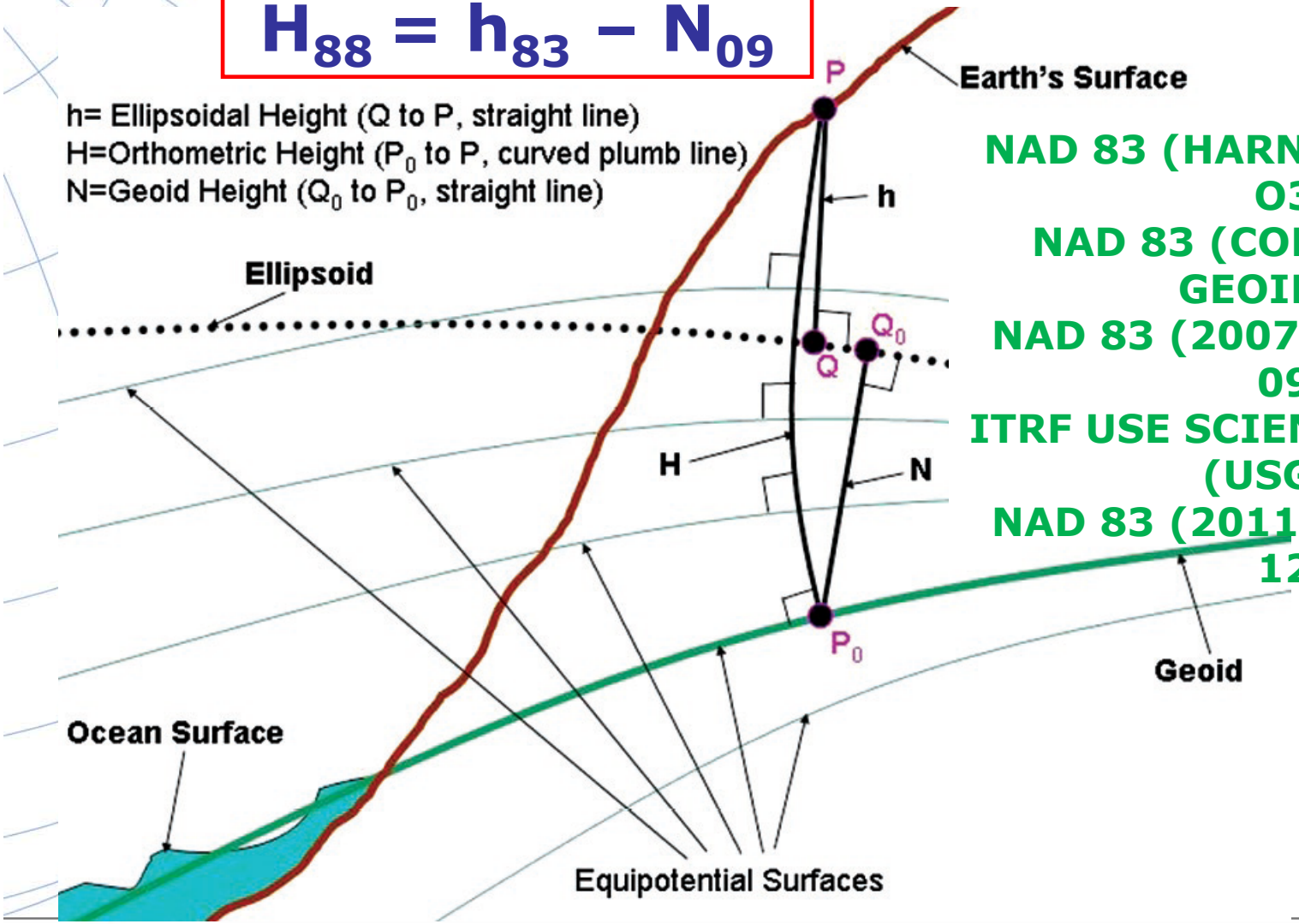

NAVD 88 – NGVD 29
50 N
40 N
30 N
Latitude
240 E
250 E
260 E
270 E
280 E
290 E
Longitude
–0.5
0.0
0.5
1.0
1.5
2.0
meters

FAIRFAX COUNTY, VA: HTMOD PROJECT & NEW NAVD 88 ORTHOMETRIC HEIGHTS

Adobe Acrobat Document

USING NAD 83 ELLIPSOID HEIGHTS WITH THE HYBRID GEOID FOR ORTHO HEIGHTS

$$H_{88} = h_{83} - N_{09}$$



NAD 83 (HARN) USE GEOID O3

NAD 83 (CORS 96) USE GEOID 09

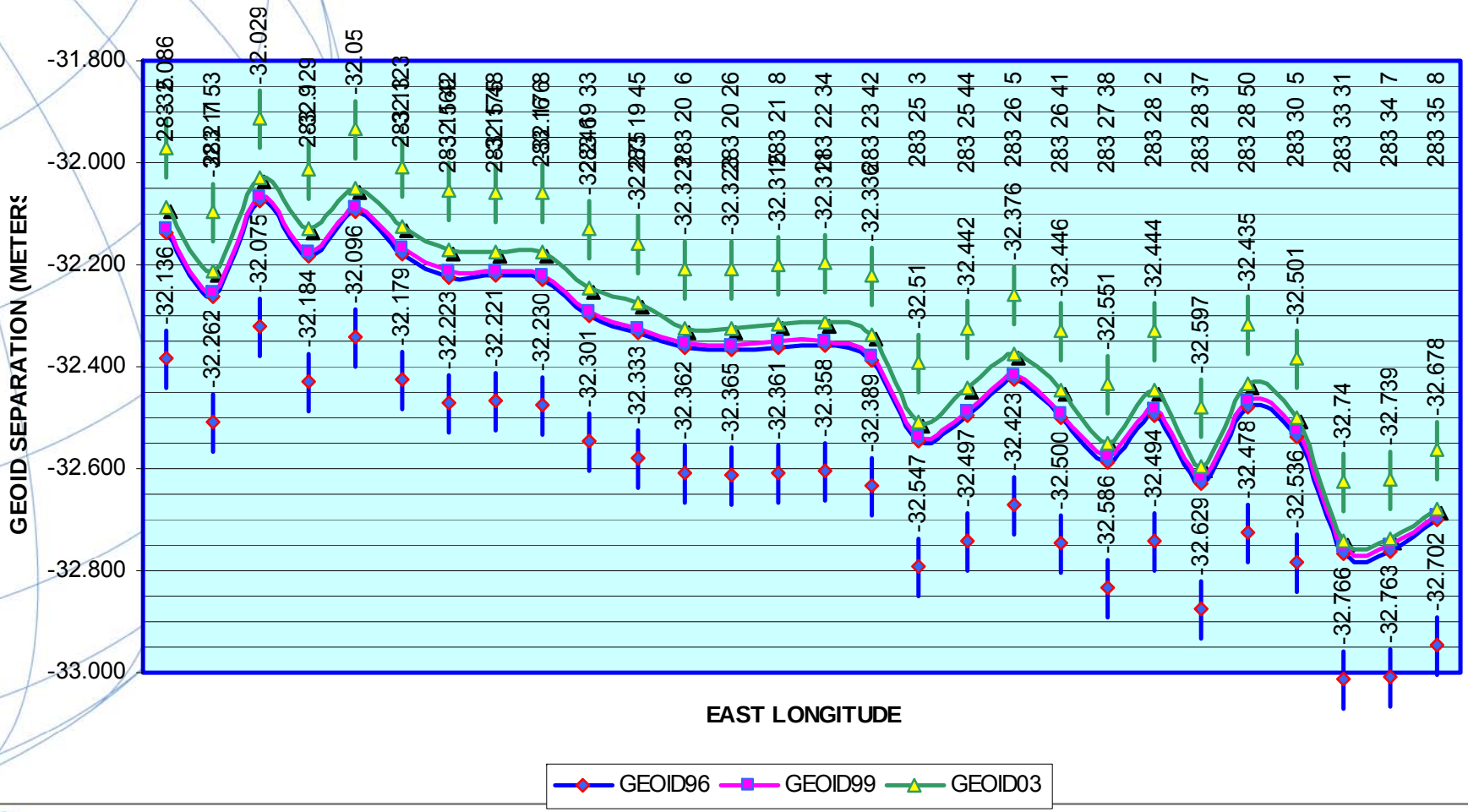
NAD 83 (2007) USE GEOID 09

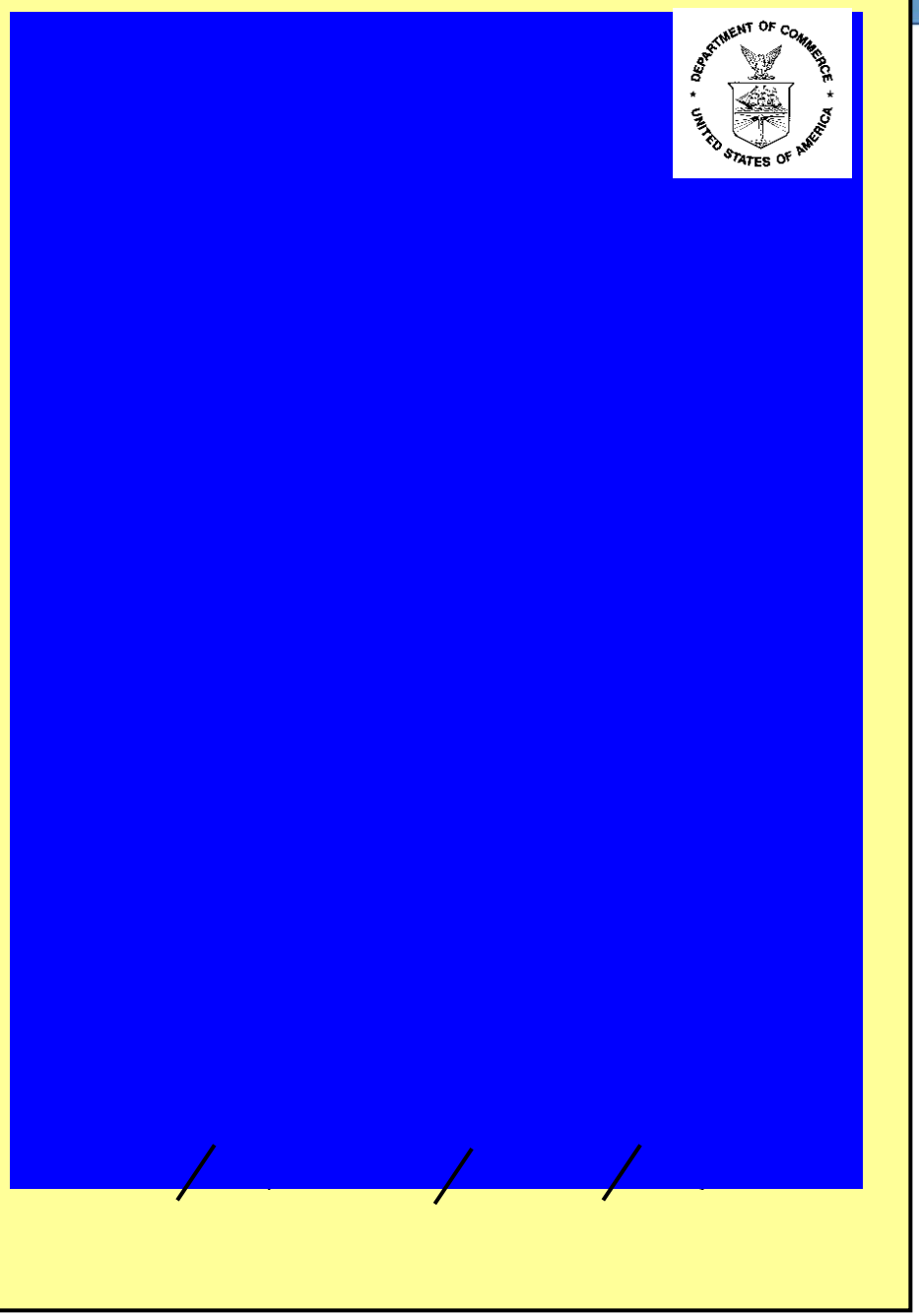
ITRF USE SCIENTIFIC GEOID (USGG)

NAD 83 (2011) USE GEOID 12

GEOID SEPARATIONS

GEOID COMPARISONS-VARIOUS BENCHMARKS-
BALTIMORE COUNTY AREA
WEST TO EAST





Available “On-Line” at
the NGS Web Site:

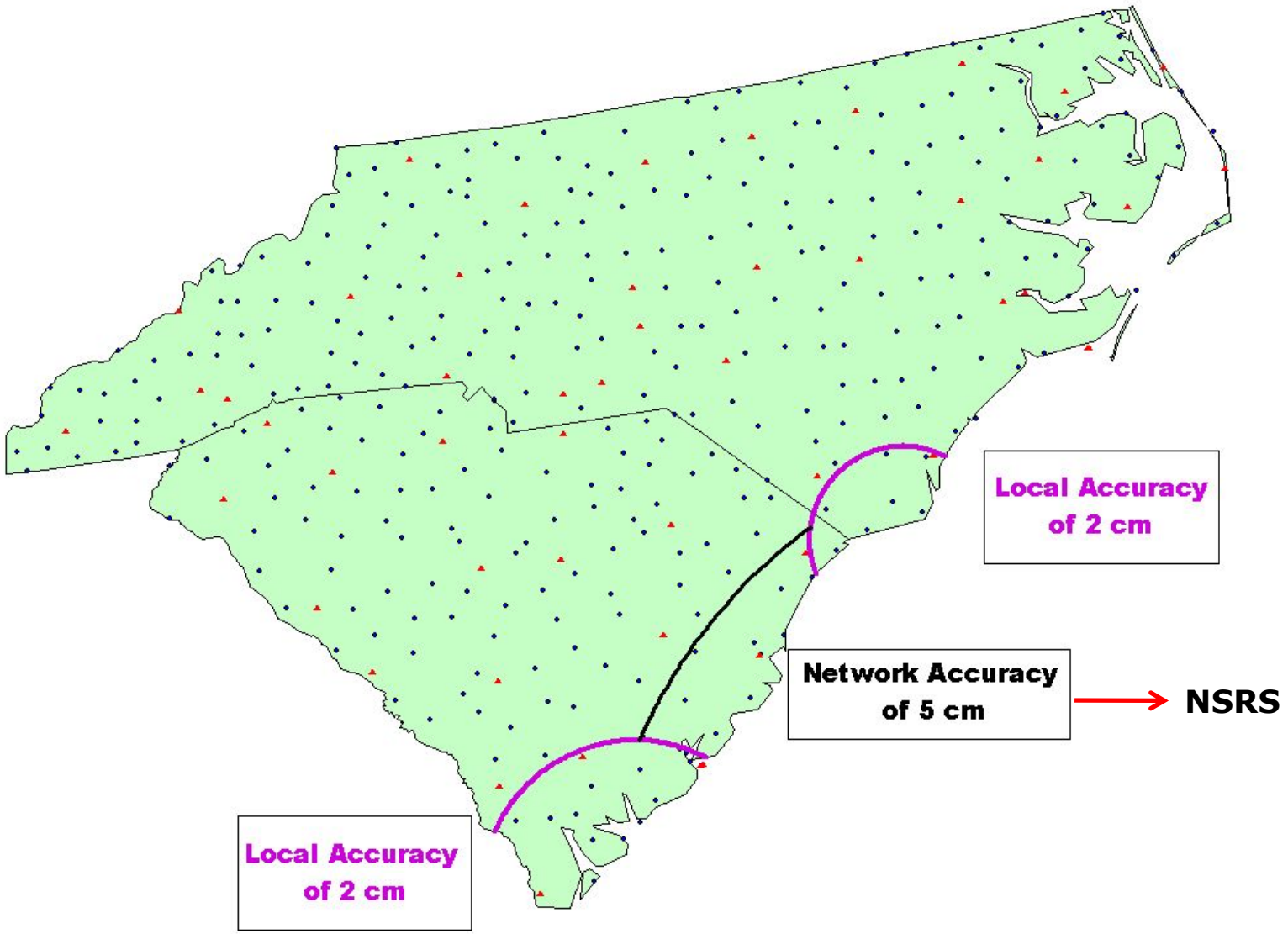
www.ngs.noaa.gov

SEARCH: “NGS 58”

BASIC CONCEPT OF GUIDELINES

- **Stations in local 3-dimensional network connected to NSRS to at least 5 cm uncertainty**
- **Stations within a local 3-dimensional network connected to each other to at least 2 cm uncertainty**
- **Stations established following guidelines are published to centimeters by NGS**
- **Quality is shown by: REPEATABILITY, RMS, & LOOP CLOSURES**

Network / Local Accuracy

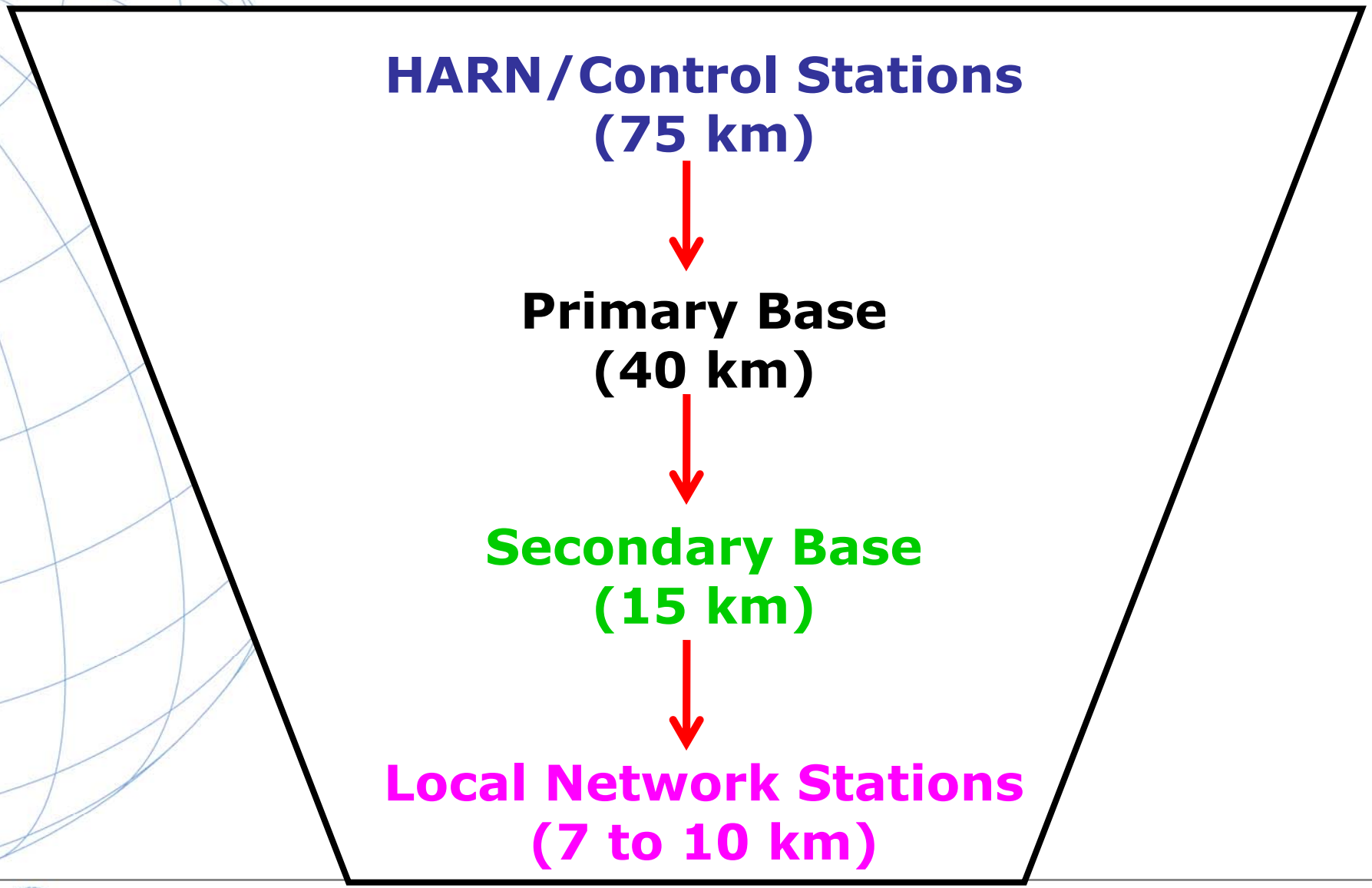


PLANNING FOR THE FIELD OBSERVATIONS

PLANNING

- LOGISTICS- MINIMIZE COST, MAXIMIZE EFFICIENCY
- REDUNDANCY
- BASELINE LENGTH
- PARTICULAR PROJECT REQUIREMENTS (E.G., FLIGHT LINE PROXIMITY)
- MONUMENT CONSTRUCTION
- MONUMENT RECOVERY
- NEW GEODETIC LEVELING

GPS ELLIPSOID HEIGHT HIERARCHY



STATION SELECTION AND RECONNAISSANCE

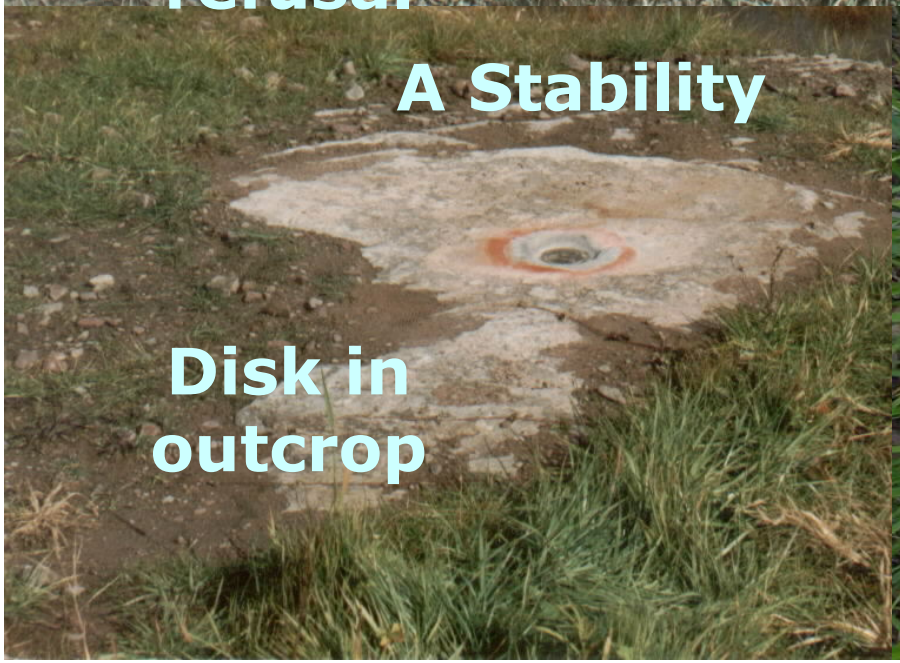
- **ASSURE ACCURATE CONNECTIONS TO CONTROL STATIONS**
  - NGS approved CORS
  - TCORS (temporary or project CORS)
  - HARN
    - Federal Base Network (FBN)
    - Cooperative Base Network (CBN)
    - User Densified Network (UDN)
  - NAVD 88 Bench Marks
- **NGS DATABASE AND DATA SHEETS**
- **IDENTIFY GPS-USABLE STATIONS**

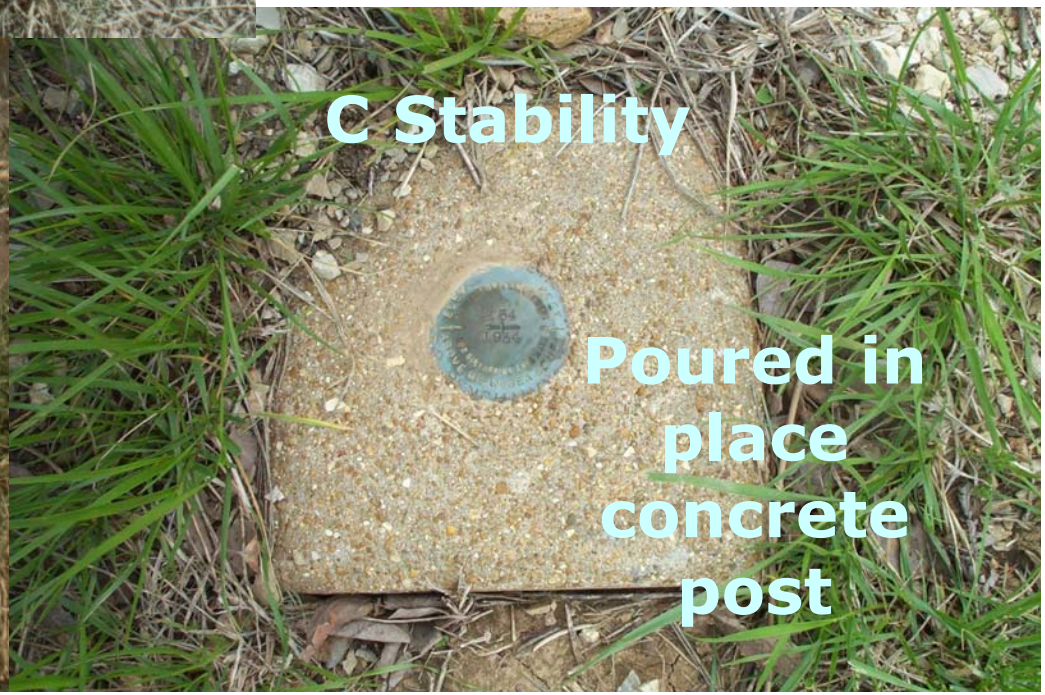
PRIMARY OR SECONDARY STATION SELECTION CRITERIA

1. **HARN either FBN or CBN**
   - Level ties to A or B stability bench marks during this project
2. **Bench marks of A or B stability quality**
   - Or HARN previously tied to A or B stability BMs
3. **UDN stations**
   - Level ties to A or B stability bench marks during this project
4. **Bench marks of C stability quality**

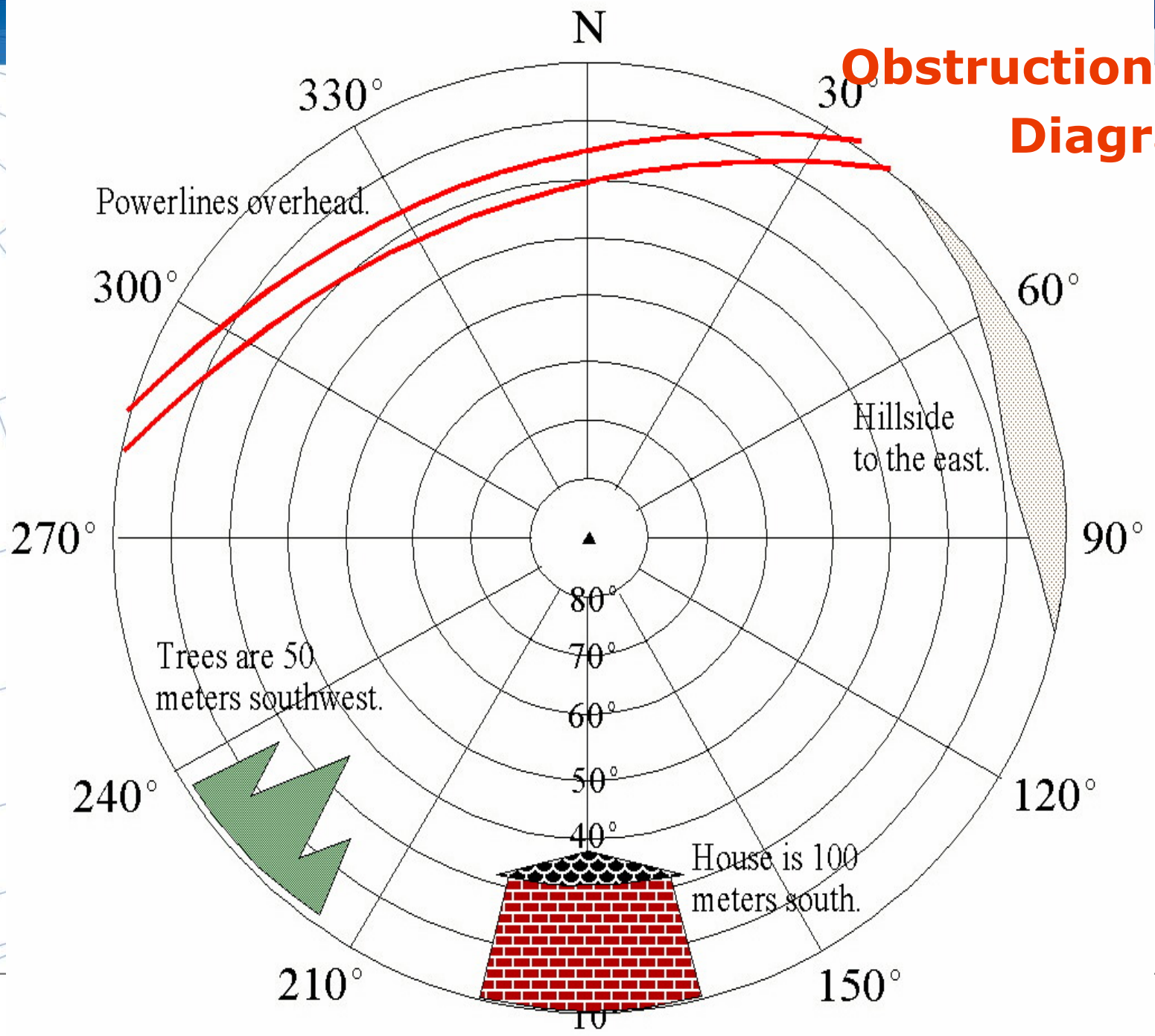
- **Special guidelines for areas of subsidence or uplift**

Physically Monumented Points = "PASSIVE MONUMENTATION"





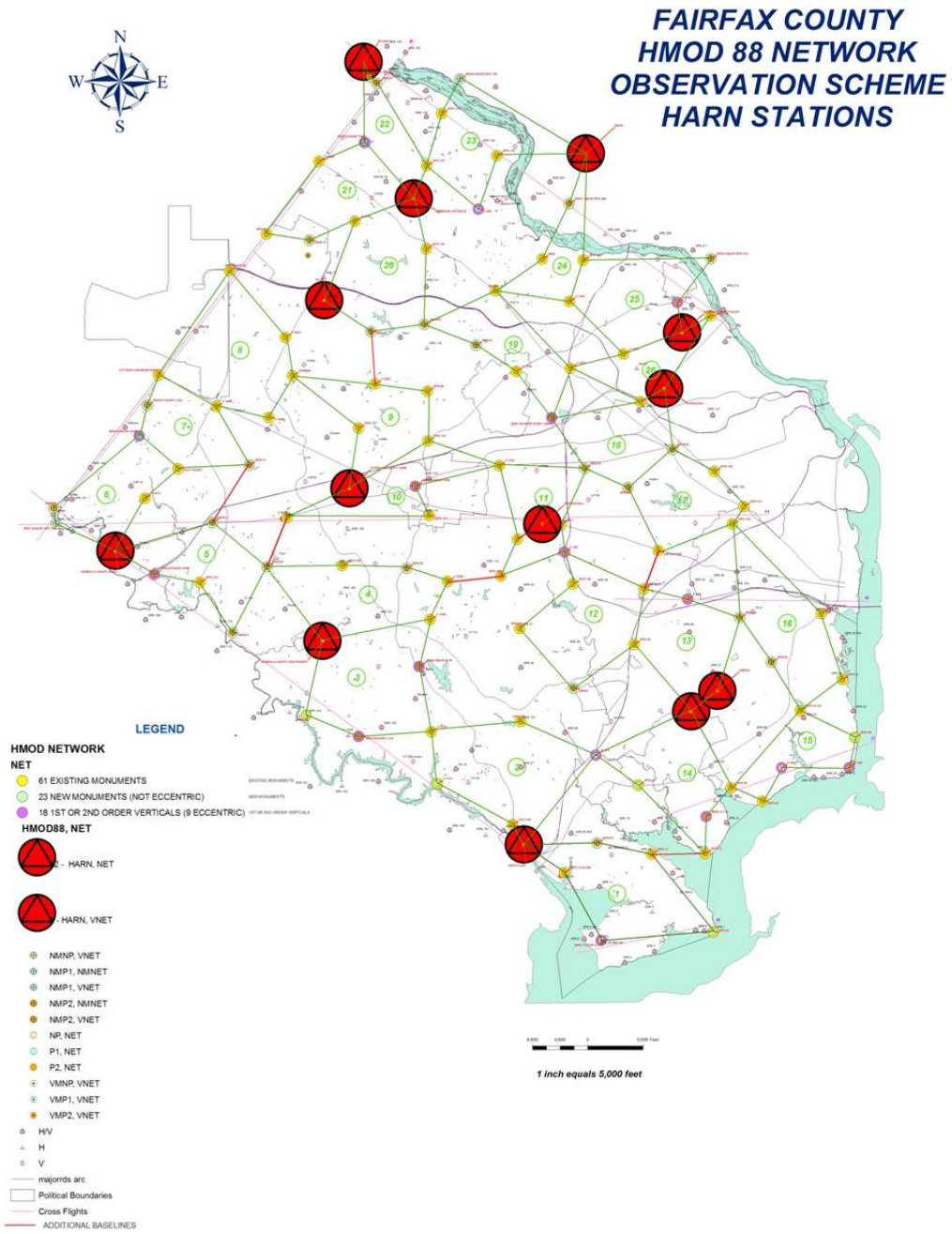
Obstruction Visibility Diagram




ESTABLISH A STABLE ECCENTRIC POINT AND TRANSFER THE ORTHOMETRIC HEIGHT USING PROPER LEVELING TECHNIQUES
Bench Mark
G 506

PRIMARY BASE STATIONS

- **Basic Requirements:**
  - **5 Hour Sessions / 3 Days**
  - **Spacing between PBS cannot exceed 40 km**
  - **Each PBS must be connected to at least its nearest PBS neighbor and nearest control station**
  - **PBS must be traceable back to 2 control stations along independent paths**

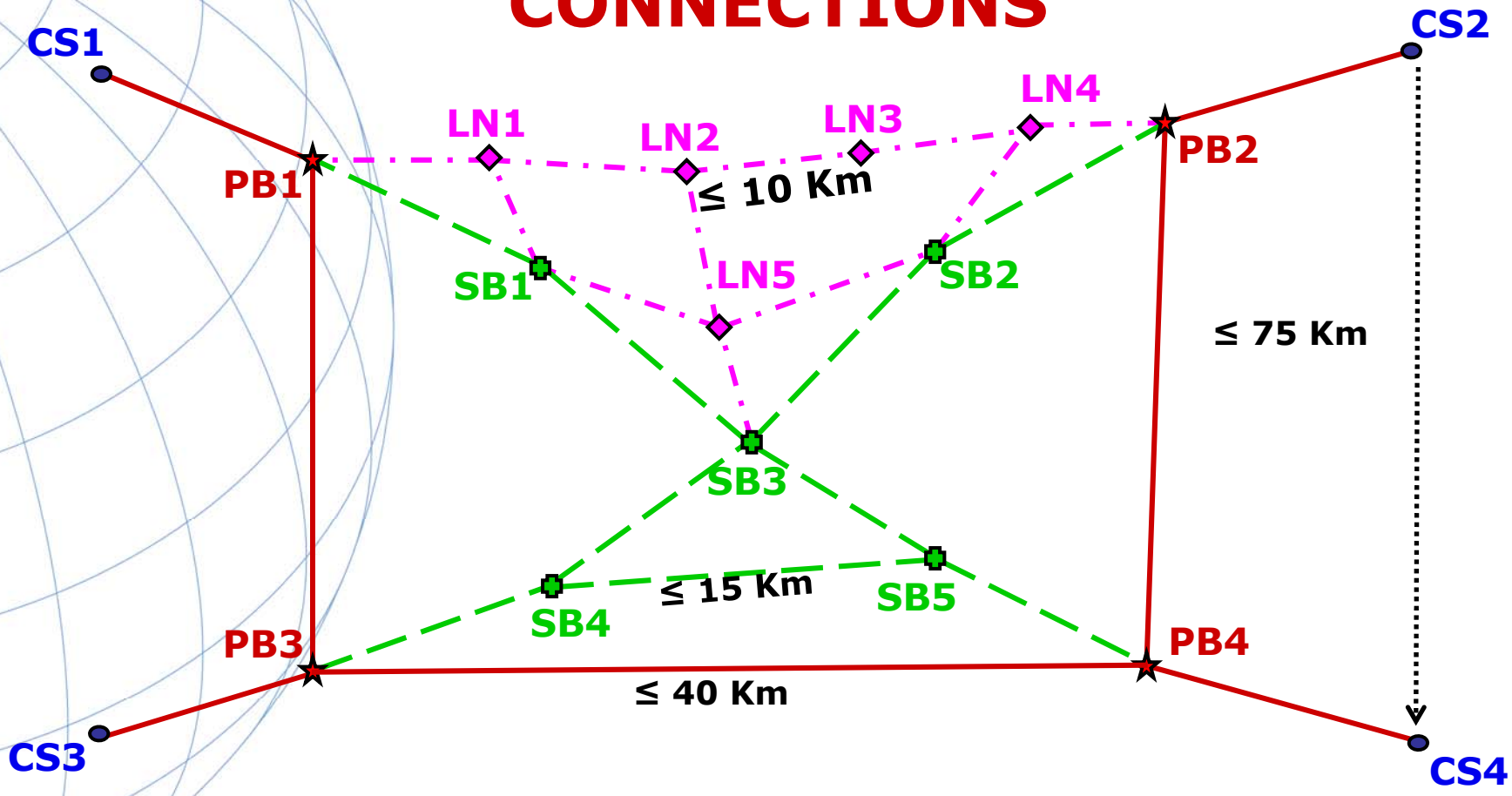


FAIRFAX COUNTY CONTROL & PRIMARY STATIONS

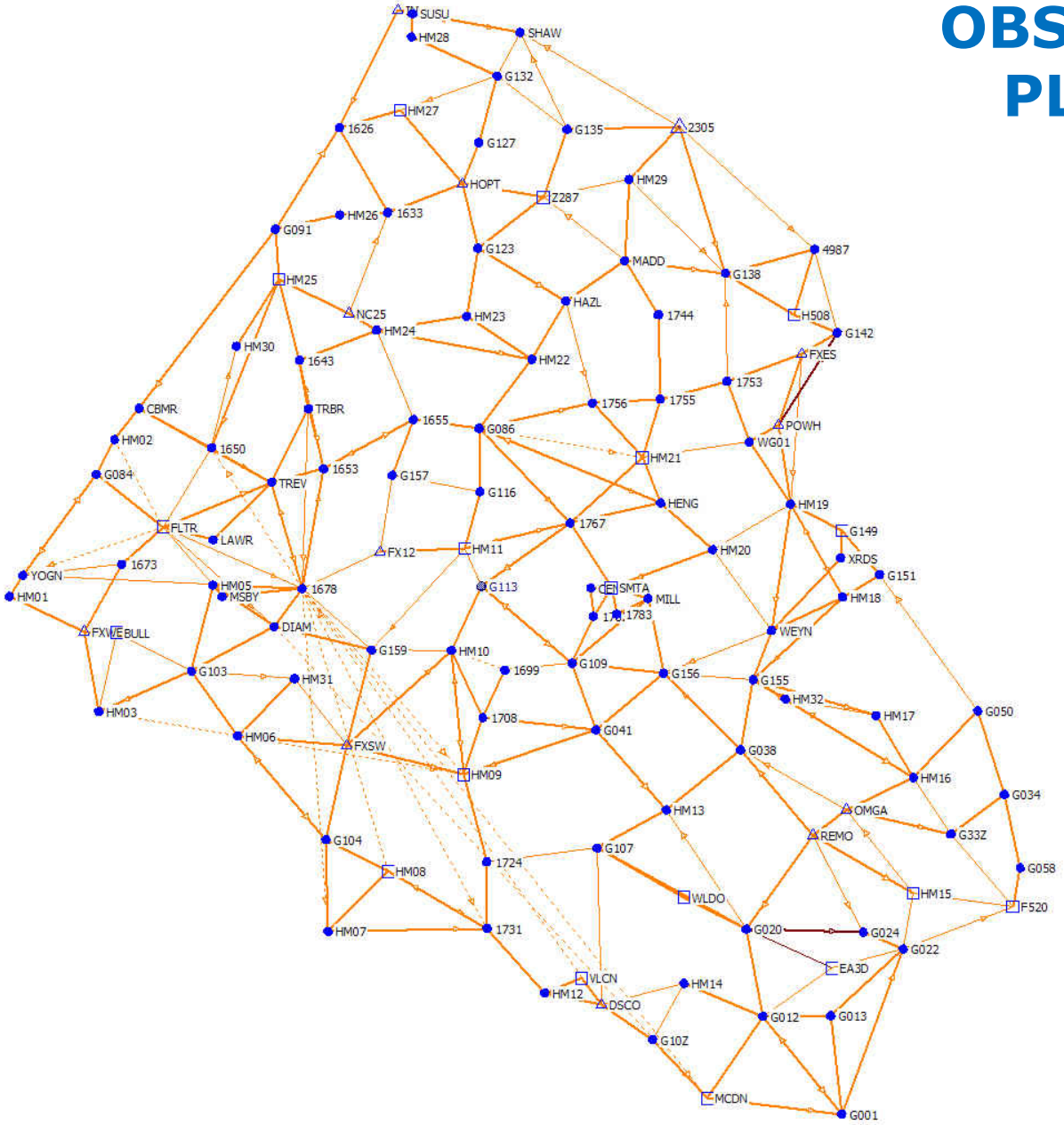
LOCAL NETWORK STATIONS

- **Basic Requirements:**
  - **30 Minute Sessions / 2 Days / Different times of the day**
  - **Spacing between LNS (or between base stations and local network stations) cannot exceed 10 km**
  - **All LNS must be connected to at least its two nearest neighbors**
  - **LNS must be traceable back to 2 primary base stations along independent paths**

SAMPLE PROJECT SHOWING CONNECTIONS



OBSERVATION PLANNING



ME	NAME
UG	ERIC
TION	STATION
24	1731
03	G159
03	FXWE
TR	FXWE
TR	1650
43	1653
43	1653

FIELD OBSERVATIONS

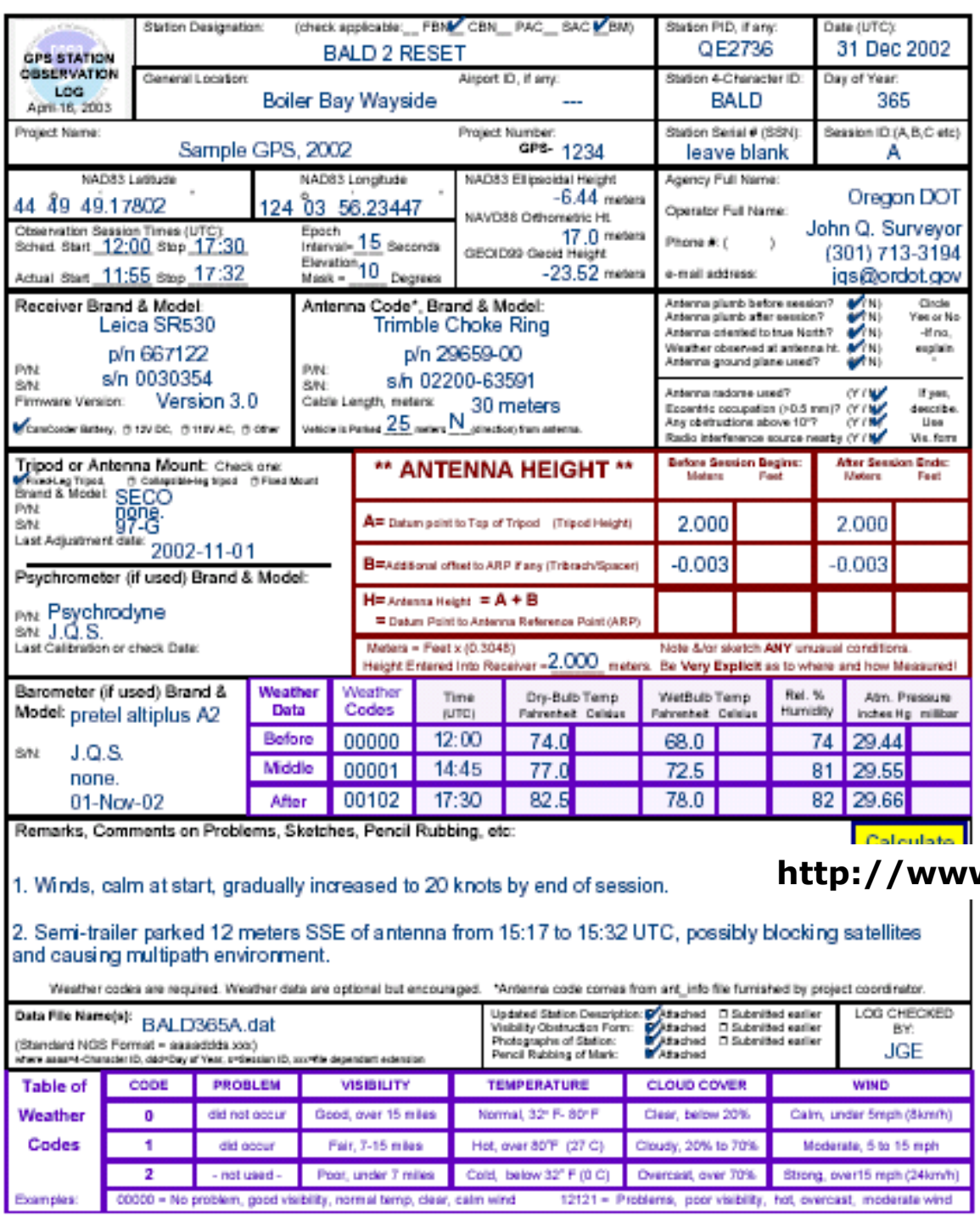
- **Observation logs**
  - Record complete receiver/antenna manufacturer, model part number, and serial numbers
  - Record meteorological data and unusual conditions
  - Record station and observer information
  - Record height of antenna and measurement computations

- **Obtain a clear station rubbing**
  - Rubbing for each occupation of station
  - Make complete plan sketch of mark when rubbing not feasible
  - OR – Take digital snapshots

METEOROLOGICAL DATA

- **Weather data must be collected at control, primary, and secondary base stations at height of antenna PC**
  - **Wet and dry temperatures, atmospheric pressure**
    - **Sessions > 2 hrs; record beginning, midpoint, ending**
    - **Sessions < 2 hrs > 30 min; record beginning and ending**
    - **Sessions < 30 min; record at midpoint**
- **Note on obs log where recorded and unusual conditions**
- **Stabilize equipment to ambient conditions**
- **Check equipment prior to observations**

Sample Observation Log



GPS STATION OBSERVATION LOG
April 16, 2003

Station Designation: (check applicable: __ FBN ✔ CBN __ PAC __ SAC ✔ BM)
BALD 2 RESET

Station PID, if any: QE2736
Date (UTC): 31 Dec 2002
General Location: Boiler Bay Wayside
Airport ID, if any: ---
Station 4-Character ID: BALD
Day of Year: 365
Project Name: Sample GPS, 2002
Project Number: GPS- 1234
Station Serial # (SSN): leave blank
Session ID (A,B,C etc): A

NAD83 Latitude: 44 ° 49 ' 49.17802 "
NAD83 Longitude: 124 ° 03 ' 56.23447 "
NAD83 Ellipsoidal Height: -6.44 meters
NAVD88 Orthometric Ht: 17.0 meters
GEOID99 Geoid Height: -23.52 meters

Observation Session Times (UTC):
Sched. Start 12:00 Stop 17:30
Actual Start 11:55 Stop 17:32
Epoch Interval= 15 Seconds
Elevation Mask = 10 Degrees

Agency Full Name:
Operator Full Name: Oregon DOT
Phone #: ( ) John Q. Surveyor (301) 713-3194
e-mail address: jqs@ordot.gov

Receiver Brand & Model: Leica SR530
P/N: p/n 667122
S/N: s/n 0030354
Firmware Version: Version 3.0
✔ CaneCoder Battery; ☐ 12V DC; ☐ 110V AC; ☐ Other

Antenna Code*, Brand & Model: Trimble Choke Ring
P/N: p/n 29659-00
S/N: s/n 02200-63591
Cable Length, meters: 30 meters
Vehicle is Parked 25 meters N (direction) from antenna.

Antenna plumb before session? ✔ (Y) (N)
Antenna plumb after session? ✔ (Y) (N)
Antenna oriented to true North? ✔ (Y) (N)
Weather observed at antenna ht. ✔ (Y) (N)
Antenna ground plane used? ✔ (Y) (N)
Circle Yes or No -If no, explain
Antenna radome used? (Y) ✔ (N)
Eccentric occupation (>0.5 mm)? (Y) ✔ (N)
Any obstructions above 10°? (Y) ✔ (N)
Radio interference source nearby (Y) ✔ (N)
If yes, describe. Use Vis. form

Tripod or Antenna Mount: Check one:
✔ Fixed-Leg Tripod; ☐ Collapsible-leg tripod; ☐ Fixed Mount
Brand & Model: SECO
P/N: none.
S/N: 97-G
Last Adjustment date: 2002-11-01

Psychrometer (if used) Brand & Model:
P/N: Psychrodyne
S/N: J.Q.S.
Last Calibration or check Date:

** ANTENNA HEIGHT **

	Before Session Begins: Meters	Feet	After Session Ends: Meters	Feet
A= Datum point to Top of Tripod (Tripod Height)	2.000		2.000	
B= Additional offset to ARP if any (Tribrach/Spacer)	-0.003		-0.003	
H= Antenna Height = A + B = Datum Point to Antenna Reference Point (ARP)				

Meters = Feet x (0.3048)
Height Entered Into Receiver = 2.000 meters.
Note &/or sketch ANY unusual conditions. Be Very Explicit as to where and how Measured!

Barometer (if used) Brand & Model: pretel altiplus A2
S/N: J.Q.S.
none.
01-Nov-02

Weather Data	Weather Codes	Time (UTC)	Dry-Bulb Temp Fahrenheit	Celsius	WetBulb Temp Fahrenheit	Celsius	Rel. % Humidity	Atm. Pressure Inches Hg	millibar
Before	00000	12:00	74.0		68.0		74	29.44	
Middle	00001	14:45	77.0		72.5		81	29.55	
After	00102	17:30	82.5		78.0		82	29.66	

Remarks, Comments on Problems, Sketches, Pencil Rubbing, etc:

1. Winds, calm at start, gradually increased to 20 knots by end of session.

2. Semi-trailer parked 12 meters SSE of antenna from 15:17 to 15:32 UTC, possibly blocking satellites and causing multipath environment.

Weather codes are required. Weather data are optional but encouraged. *Antenna code comes from ant_info file furnished by project coordinator.

Data File Name(s): BALD365A.dat
(Standard NGS Format = aaaadddx.xxx)
where aaaa=4-Character ID, ddd=Day of Year, s=Session ID, xx=file dependant extension

Updated Station Description: ✔ Attached ☐ Submitted earlier
Visibility Obstruction Form: ✔ Attached ☐ Submitted earlier
Photographs of Station: ✔ Attached ☐ Submitted earlier
Pencil Rubbing of Mark: ✔ Attached

LOG CHECKED BY: JGE

Table of Weather Codes

CODE	PROBLEM	VISIBILITY	TEMPERATURE	CLOUD COVER	WIND
0	did not occur	Good, over 15 miles	Normal, 32° F- 80° F	Clear, below 20%	Calm, under 5mph (8km/h)
1	did occur	Fair, 7-15 miles	Hot, over 80°F (27 C)	Cloudy, 20% to 70%	Moderate, 5 to 15 mph
2	- not used -	Poor, under 7 miles	Cold, below 32° F (0 C)	Overcast, over 70%	Strong, over15 mph (24km/h)

Examples: 00000 = No problem, good visibility, normal temp, clear, calm wind. 12121 = Problems, poor visibility, hot, overcast, moderate wind

http://www.ngs.noaa.gov/PROJECTS/FBN/

Table 1. -- Summary of Guidelines

	Control 2 and 5 cm	Primary Base 2 cm	Primary Base 5 cm	Secondary Base 2 cm	Secondary Base 5 cm	Local Network 2 cm	Local Network 5 cm
Dual Frequency Required	Yes, if base line is greater than 10 km	Yes, if base line is greater than 10 km	Yes, if base line is greater than 10 km	Yes, if base line is greater than 10 km	Yes, if base line is greater than 10 km	Yes, if base line is greater than 10 km	Yes, if base line is greater than 10 km
Geodetic Quality Antenna with Ground Plane	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Minimum Number of Stations	3	3	3	No Minimum	No Minimum	No Minimum	No Minimum
Occupation Time	5 Hours	5 Hours	5 Hours	30 Minutes [1]	30 Minutes [1]	30 Minutes [1]	30 Minutes [1]
Number of Days Station is Occupied	3	3	3	2[2]	2[2]	2[2]	2[2]
Maximum Distance Between Same or Higher Order Stations	75 km	40 km	50 km	15 km	20 km	10 km	20 km

[1] Analyses have indicated that when following all guidelines in this document, 30 minutes of observations over base lines that are typically less than 10 kilometers will meet the standards. For base lines greater than 10 km, but less than 15 km, 1 hour sessions should meet the standards. For observing sessions greater than 30 minutes, collect data at 15-second epoch interval. For sessions less than 30 minutes, collect data at 5-second epoch interval. Track satellites down to at least 10-degree elevation cut-off.

[2] Base lines must be re-observed on different days with significantly different satellite geometry.

Table 1. -- Summary of Guidelines (continued)

Table 1. (Continued)	Control 2 and 5 cm	Primary Base 2 cm	Primary Base 5 cm	Secondary Base 2 cm	Secondary Base 5 cm	Local Network 2 cm	Local Network 5 cm
Average Distance Between Stations	No Maximum	No Maximum	No Maximum	No Maximum	No Maximum	7 km	10 km
Repeat Base Line	Yes [3]	Yes [3]	Yes [3]	Yes [3]	Yes [3]	Yes [3]	Yes [3]
Collect Met. Data	Yes	Yes	Yes	Yes	Yes	No	No
Fixed Height Pole Req.	Yes	Yes	No	Yes	No	Yes	No
Rubbing of Mark	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Precise Ephemerides	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fix Integers	Yes[4]	Yes[5]	Yes[5]	Yes	Yes	Yes	Yes

[3] The observing scheme requires that all adjacent stations have base lines observed at least twice on two different days with significantly different geometry.

[4] If base line is greater than 40 kilometers, a partially fixed or float solution is permitted.

[5] For all station pairs except for those involved with control stations (see note 4).

FIELD REQUIREMENTS SUMMARY

- DUAL FREQUENCY RECEIVERS
- GEODETIC ANTENNAS
- FIXED HEIGHT TRIPODS, VERIFY HEIGHT
- 5 HOUR PRIMARY CONTROL OCCUPATIONS WITH MET DATA
- REDUNDANT 30 MINUTE NETWORK CONTROL OCCUPATIONS
- OCCUPY CLOSEST NEIGHBORS
- OCCUPY BENCH MARKS ≤ 20 KM SPACING
- SET ECCENTRICS AS NEEDED
- BASELINES ≤ 10 KM, AVG. 7 KM
- PDOP ≤ 4.0
- PICTURES AND TIES TO MONUMENTS
- COMPLETE LOG FOR EACH OCCUPATION

BASELINE PROCESSING

BASELINE PROCESSING

- "MULTI-STATION" PROCESSING MODE
- DOUBLE DIFFERENCING (ELIMINATES SAT/RECEIVER CLOCK, HARDWARE BIASES, REDUCES NOISE PARAMETERS)
- PRECISE EPHEMERIS
- 15° CUT OFF
- FIX ALL INTEGERS FOR BASELINES LESS THAN 40 KM
- USE A TROPO MODEL RATHER THAN FIELD MET DATA UNLESS PROVEN BETTER
- USE RELATIVE TROPO SCALE PARAMETER FOR STATIONS OVER 15 KM AND FOR LARGE INTERSTATION RELIEF
- BASELINE RMS ≤ 1.5 CM
- REDUNDANT BASELINES DIFFER BY ≤ 2.0 CM

National Geodetic Survey

GPS Orbits

National Geodetic Survey

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Orbit Naming Convention
Analysis Strategy
Orbit Data
Contact Us

GPS Orbit Data

IGS Orbit Availability
IGS Product Information
SP3 Conversion (sp3c --> sp3a)

The SP3-c format was developed to allow one to put GPS, GLONASS, and Galileo satellites all in the same file, and also to give standard deviations for the satellite XYZ coordinates and clock offset at each epoch

Ultra-rapid (iguWWWWD.sp3)
6-hour latency
constrained (no-net rotation, no-net translation) 24-hour file – sp3

Rapid (igrWWWWD.sp3)
13-hour latency
constrained (no-net rotation, no-net translation) 24-hour file – sp3

Final (igsWWWWD.sp3)
12 to 14 day latency
minimally constrained (no-net rotation) 24 hour file - sp3

files named by GPS Week number and Day of Week

Website Owner: National Geodetic Survey - ORBITS / Last modified by Don Haw Feb 10 2012

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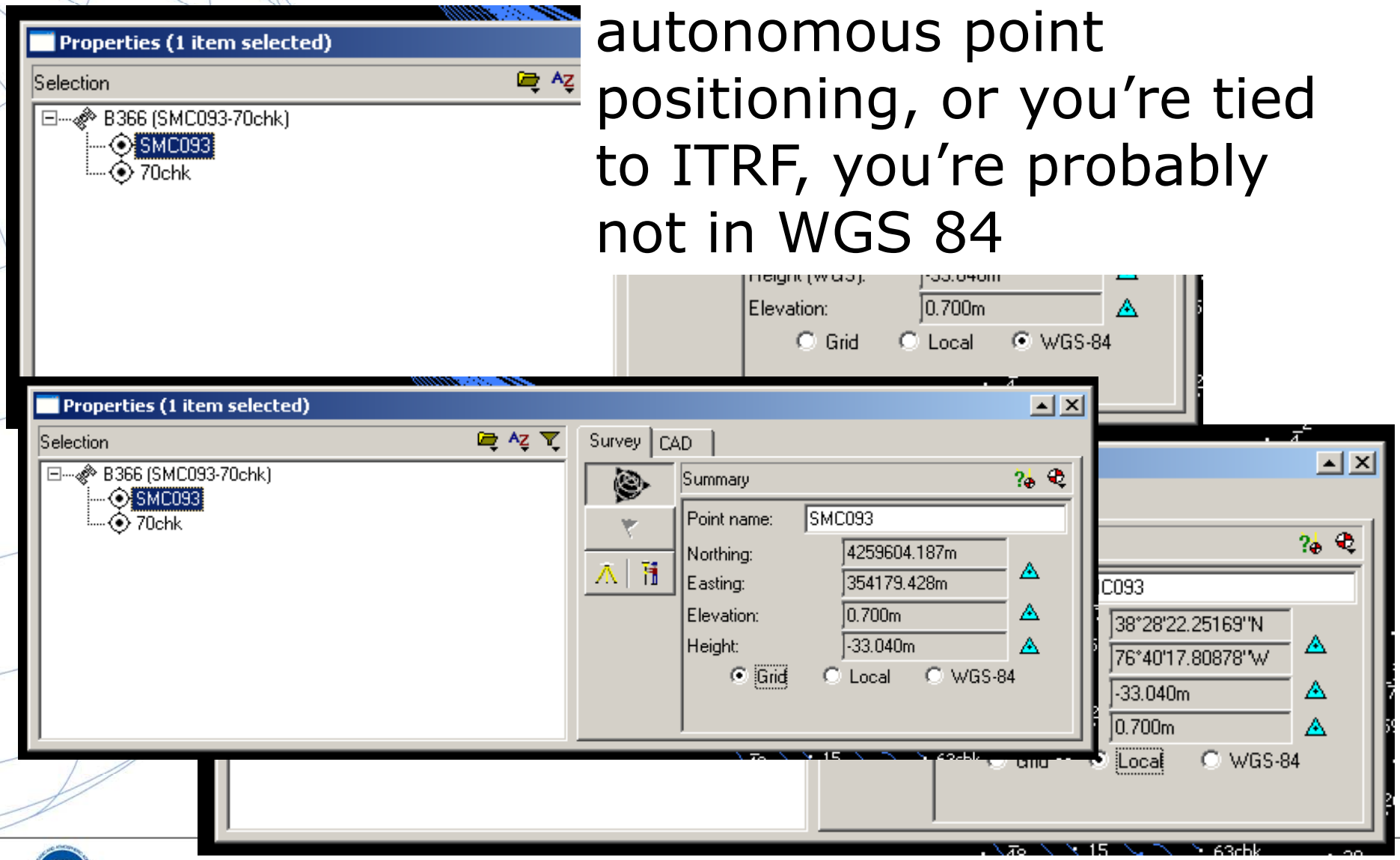
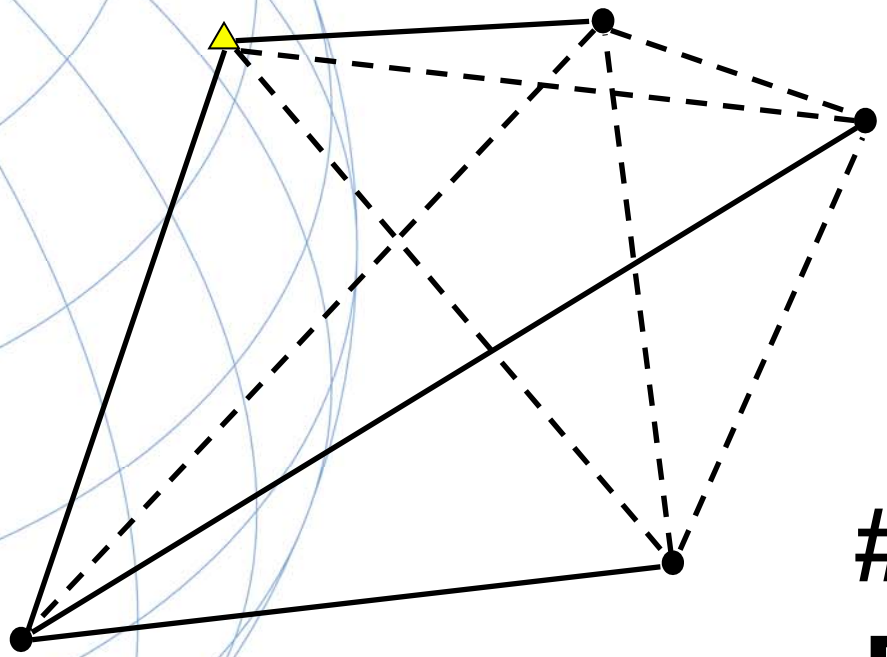
http://www.ngs.noaa.gov/orbits/orbit_data.shtml

"WGS84" OR IS IT?

Unless you're doing autonomous point positioning, or you're tied to ITRF, you're probably not in WGS 84



Independent Baselines in GPS



$$\text{\# of Baselines} = \frac{N(N-1)}{2}$$

# of Independent Baselines =(N-1)

N = Number of receivers observing simultaneously

BASELINE PROCESSING

Processing Summary

ID	From	To	Baseline Length	Solution Type	Ratio	Reference Variance	RMS
B154	HM11	G159	5897.495m	Iono free fixed	12.5	1.821	0.014m
B157	G123	Z287	3548.072m	L1 fixed	3.1	28.119	0.017m
B616	G123	Z287	3548.073m	L1 fixed	11.4	18.318	0.012m
B159	HM20	FXTO	4635.366m	L1 fixed	25.7	3.488	0.006m
B602	HM20	FXCL	4635.373m	L1 fixed	24.5	3.198	0.007m
B163	FX12	HM11	3625.558m	L1 fixed	12.4	4.809	0.008m
B169	FX12	HM11	3625.556m	L1 fixed	77.0	4.647	0.008m

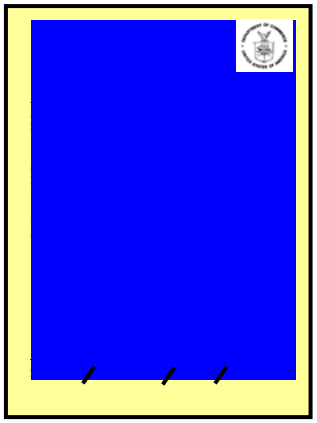
G123	Z287	2473.193m	1922.277m	1666.430m	3548.073m	0.012m	11.4	18.318
HM20	SMTA	-4032.768m	-1942.532m	-1204.147m	4635.366m	0.006m	25.7	3.488
HM20	SMTA	-4032.771m	-1942.548m	-1204.136m	4635.373m	0.007m	24.5	3.198
FX12	HM11	3519.639m	866.896m	72.858m	3625.558m	0.008m	12.4	4.809
FX12	HM11	3519.637m	866.892m	72.856m	3625.556m	0.008m	77.0	4.647
FX12	HM11	3519.631m	866.891m	72.862m	3625.550m	0.006m	25.1	2.694
HM09	1708	503.900m	1670.938m	1902.549m	2581.790m	0.014m	10.4	17.268
HM09	1708	503.893m	1670.926m	1902.557m	2581.787m	0.015m	11.0	18.123
HM09	1708	503.922m	1671.004m	1902.523m	2581.818m	0.006m	31.9	2.385
HM09	1708	503.905m	1670.982m	1902.523m	2581.801m	0.008m	29.7	4.627
WEYN	G156	-4285.395m	-2112.848m	-1368.869m	4970.165m	0.009m	10.8	5.854
REMO	G020	-2283.433m	-3070.416m	-3102.733m	4926.305m	0.009m	14.5	6.216
REMO	G020	-2283.446m	-3070.392m	-3102.745m	4926.303m	0.008m	10.5	5.465
REMO	G020	-2283.433m	-3070.406m	-3102.725m	4926.293m	0.013m	12.7	14.934
G041	G156	2514.143m	2092.052m	1854.454m	3759.867m	0.008m	20.1	4.364
G041	G156	2514.141m	2092.062m	1854.454m	3759.870m	0.007m	11.0	3.571

B196	G109	G041	3022.732m
B512	G109	G041	3022.742m
B197	G041	HM13	4559.339m
B513	G041	HM13	4559.341m
B198	G020	HM13	6126.512m
B205	G156	G109	3926.192m

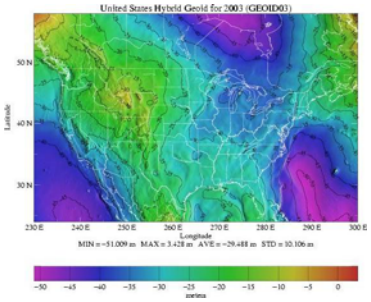
B610	1767	FXCL	3279.360m	L1 fixed	31.5	11.784	0.011m
B220	1699	G109	2882.987m	L1 fixed	10.7	27.727	0.015m
B228	1699	1708	2232.017m	L1 fixed	8.3	19.278	0.015m

EXPECTED HEIGHT ACCURACIES

- **GPS-Derived Ellipsoid Heights**
  - 2 centimeters (following NOS NGS-58 Guidelines)



- **Geoid Heights (GEOID09)**
  - Relative differences typically less than 1 cm in 10 km
  - 2.4 cm RMS about the mean nationally
  - 0.5 cm error in 10 Km



- **Leveling-Derived Heights**
  - Less than 1 cm in 10 km for third-order leveling

VECTOR PROCESSING ACCOMPLISHED

- **Elevation Mask - 15 degrees**
- **Ephemeris - Precise (typ. 14 days latency)**
- **Tropospheric Correction Model**
- **Iono Corrections - All baselines longer than 5 km.**
- **Fix Integers**

  Baselines less than 5 km: L1 fixed solution

  Baselines greater than 5 km: Iono free (L3) solution
- **Baselines must have RMS values ≤ 1.5 cm**
- **Baselines must have difference in "up" ellipsoid height ≤ 2.0 cm**

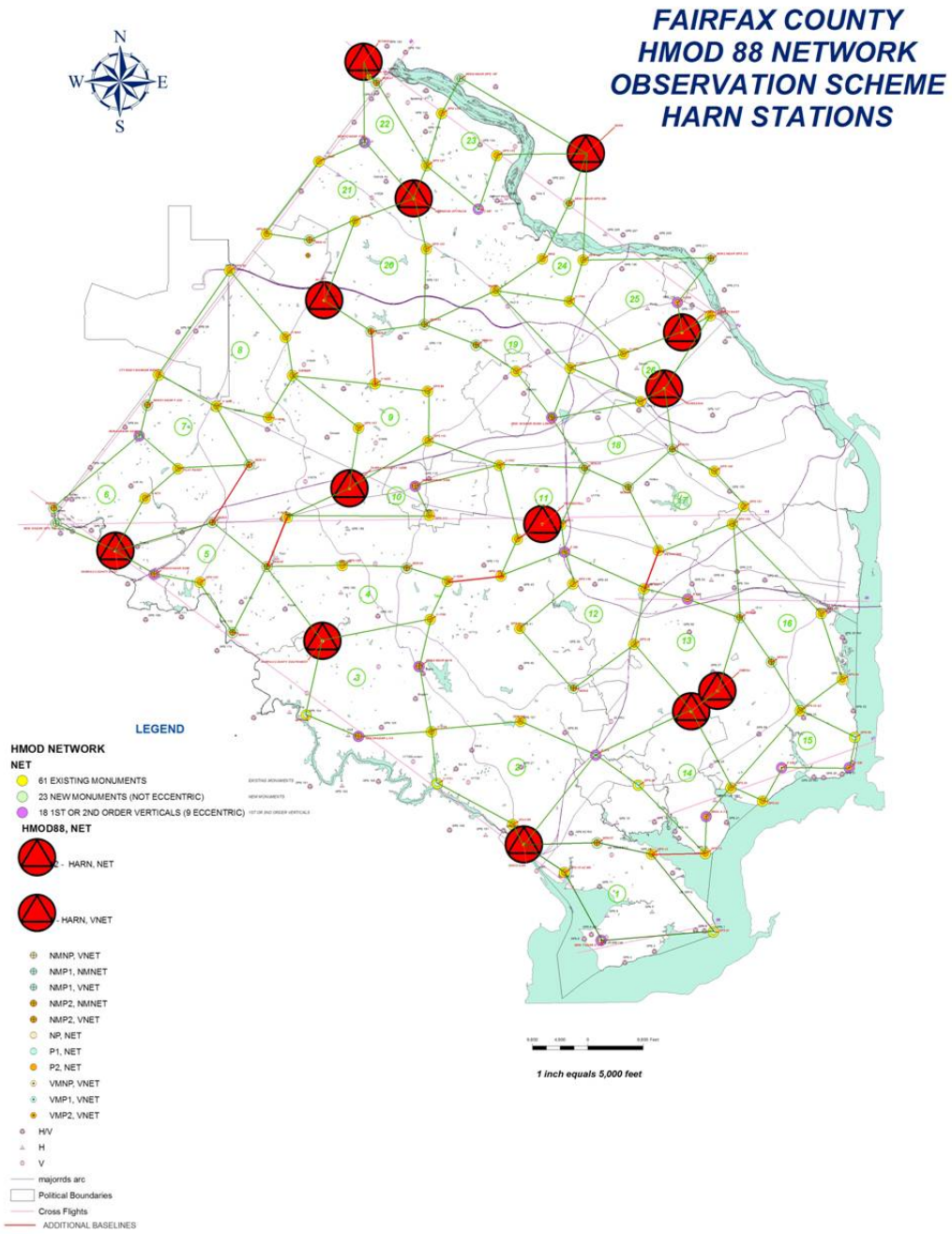
ADJUSTMENT OF PRIMARY NETWORK STATIONS FROM CONTROL

Horizontal Adjustment

(Latitude, Longitude, Ellipsoid Heights)

- **Minimum Constrained [One fixed station]**
  - **Fix latitude, longitude and ellipsoid height at one station**
  - **Resolve all blunders and large residuals**
  - **Determine which Control and known Primary Base Station coordinates should be fixed**
- **Constrained [All suitable stations fixed]**
  - **Fix latitude, longitude, and ellipsoid heights at Control and known Primary Base Stations**
  - **Make sure the constraints did not distort the project**

NOTE - Geoid model NOT applied at this time



FAIRFAX COUNTY CONTROL & PRIMARY STATIONS

ADJUSTMENT OF LOCAL NETWORK STATIONS

Horizontal Adjustment

(Latitude, Longitude, Ellipsoid Heights)

- **Minimum Constrained [One fixed station]**
  - Fix latitude, longitude and ellipsoid height at one station
  - Resolve all blunders and large residuals
  - Evaluate coordinates at Control and Primary Base Station
    - should not be greatly affected by Local Station baselines
- **Constrained [All suitable stations fixed]**
  - Fix latitude, longitude, and ellipsoid heights at Control and Primary Base Stations
  - Make sure the constraints did not distort the project

NOTE - Geoid model NOT applied at this time

National Geodetic Survey

BASELINE ADJUSTMENT SUMMARY

Statistical Summary

Successful Adjustment in 1 iteration(s)

Network Reference Factor : 1.00
Chi Square Test (α=95%) : PASS
Degrees of Freedom : 1027.00

GPS Observation Statistics

Reference Factor : 1.00
Redundancy Number (r) : 1027.00

Individual GPS Observation Statistics

Observation ID	Reference Factor	Redundancy Number
B20	1.28	3.00
B21	1.49	2.29
B24	0.15	2.32
B25	0.53	2.55
B26	0.57	1.95
B35	1.18	2.06
B42	0.34	2.49
B43	1.67	2.40
B45	0.94	2.51
B51	0.90	2.29
B52	0.81	2.31
B53	0.54	2.06
B56	2.37	2.39
B58	0.72	1.76

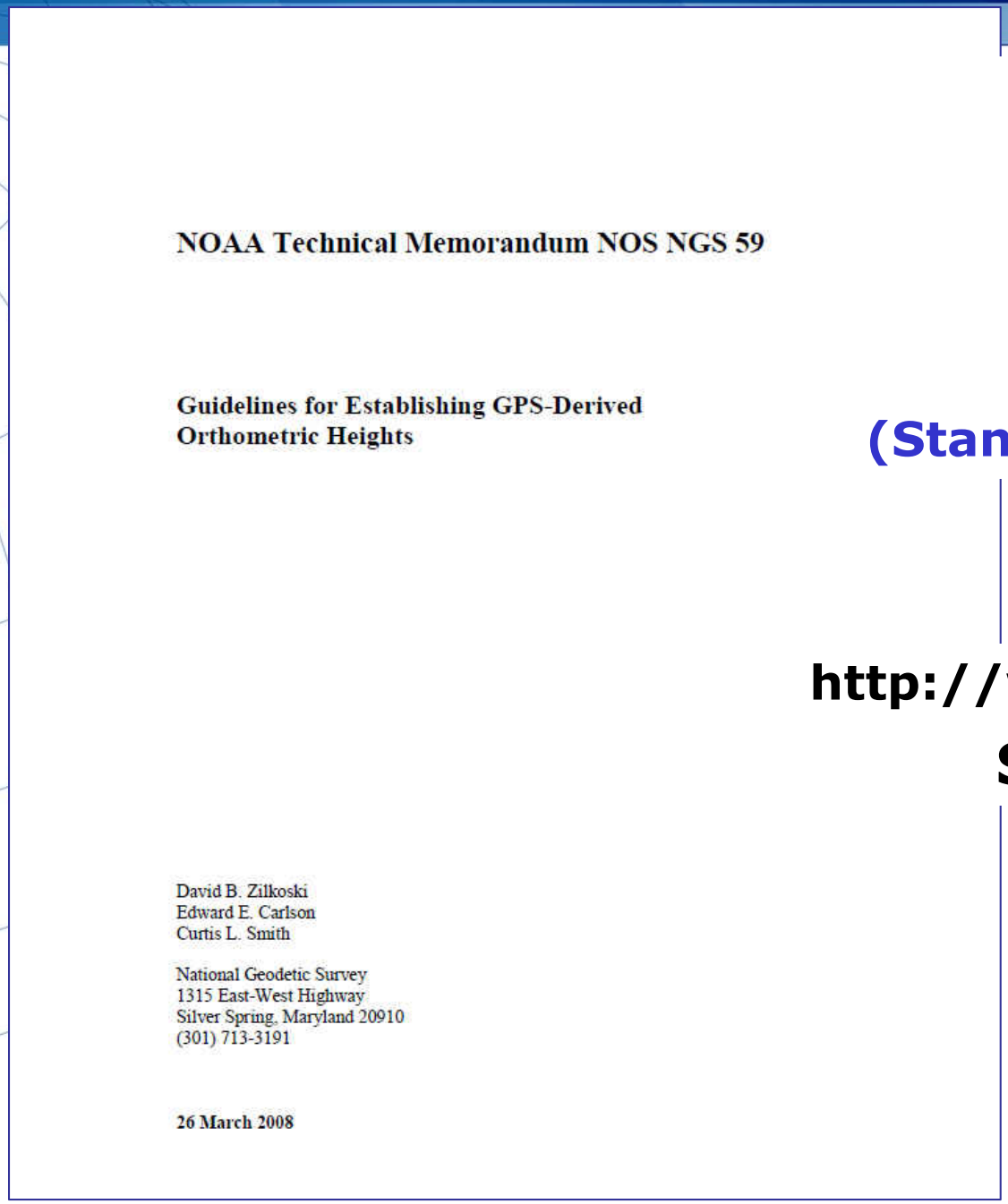
Adjusted Geodetic Coordinates

Errors are reported using 2.58s.

Point Name	Latitude	N error	Longitude	E error	Height	h error	Fix
REMO	38°44'36.39173"N	0.000m	77°08'39.87408"W	0.000m	-5.450m	0.000m	Lat Long h
OMGA	38°45'11.31240"N	0.000m	77°07'40.60426"W	0.000m	-21.040m	0.000m	Lat Long h
HM16	38°45'54.07930"N	0.013m	77°05'40.71817"W	0.013m	5.888m	0.011m	
H508	38°56'37.39647"N	0.016m	77°08'59.04358"W	0.016m	46.238m	0.014m	
4987	38°58'07.78368"N	0.016m	77°08'21.72380"W	0.016m	14.670m	0.016m	
2305	39°01'00.31786"N	0.000m	77°12'18.26226"W	0.000m	79.640m	0.000m	Lat Long h
HM29	38°59'48.45697"N	0.014m	77°13'49.40683"W	0.014m	82.378m	0.015m	
SHAW	39°03'14.23347"N	0.012m	77°16'59.27011"W	0.012m	61.641m	0.011m	
SUSU	39°03'41.88033"N	0.015m	77°20'09.97882"W	0.015m	27.358m	0.011m	
G135	39°00'59.14966"N	0.014m	77°15'37.89183"W	0.013m	57.170m	0.015m	
G155	38°48'12.99850"N	0.013m	77°10'21.50124"W	0.012m	45.195m	0.011m	
WEYN	38°49'20.65533"N	0.015m	77°09'47.77481"W	0.015m	50.322m	0.013m	
1753	38°55'06.87691"N	0.013m	77°11'00.36937"W	0.013m	63.610m	0.016m	
WG01	38°53'42.37345"N	0.012m	77°10'22.53814"W	0.012m	75.428m	0.012m	
G142	38°56'12.22613"N	0.014m	77°07'43.73568"W	0.014m	39.849m	0.010m	
MADD	38°57'55.78125"N	0.014m	77°13'59.26970"W	0.013m	84.311m	0.013m	
G132	39°02'14.20563"N	0.015m	77°17'40.89637"W	0.014m	57.165m	0.012m	
G127	39°00'42.11843"N	0.017m	77°18'15.24052"W	0.016m	85.473m	0.013m	
G33Z	38°44'34.89660"N	0.018m	77°04'35.79334"W	0.018m	-20.678m	0.018m	
G038	38°46'35.99529"N	0.012m	77°10'45.52104"W	0.011m	43.496m	0.011m	
HM19	38°52'15.29584"N	0.011m	77°09'11.03572"W	0.011m	77.654m	0.011m	
G050	38°47'25.04517"N	0.020m	77°03'45.00930"W	0.020m	-28.921m	0.018m	
HM18	38°50'05.64604"N	0.016m	77°07'41.37354"W	0.016m	36.500m	0.014m	
G151	38°50'35.77432"N	0.019m	77°06'35.17729"W	0.018m	23.995m	0.015m	
HOPT	38°59'45.18521"N	0.000m	77°18'45.84871"W	0.000m	80.550m	0.000m	Lat Long h
HM27	39°01'28.58699"N	0.015m	77°20'33.86629"W	0.014m	96.598m	0.012m	
HM28	39°03'09.79941"N	0.019m	77°20'12.24386"W	0.019m	69.516m	0.014m	
1633	38°59'07.22725"N	0.017m	77°20'57.96047"W	0.015m	94.499m	0.023m	
F520	38°42'53.08709"N	0.021m	77°02'48.60023"W	0.021m	-24.042m	0.024m	
HM17	38°47'20.55764"N	0.016m	77°06'45.34079"W	0.016m	40.546m	0.013m	
G149	38°51'37.91057"N	0.017m	77°07'39.95309"W	0.017m	44.700m	0.014m	
INTK	39°03'46.55701"N	0.000m	77°20'34.73047"W	0.000m	27.110m	0.000m	Lat Long h
NC25	38°56'48.06097"N	0.000m	77°22'09.84060"W	0.000m	91.430m	0.000m	Lat Long h
HM25	38°57'36.61450"N	0.013m	77°24'12.90930"W	0.013m	88.844m	0.011m	
FXES	38°55'43.18409"N	0.000m	77°08'47.67513"W	0.000m	52.410m	0.000m	Lat Long h
HM24	38°56'24.22205"N	0.014m	77°21'20.58815"W	0.013m	103.526m	0.012m	
Z287	38°59'25.41926"N	0.013m	77°16'21.55524"W	0.013m	67.913m	0.015m	
HM11	38°51'19.95979"N	0.012m	77°18'48.59078"W	0.011m	84.482m	0.010m	
G159	38°49'01.15743"N	0.012m	77°21'36.80383"W	0.012m	73.412m	0.011m	

STATIC PROCESSING VARIABLES TO TRY

- USE OTHER REDUNDANT BASELINES
- INDEPENDENT BASELINES (N-1)- DON'T USE BAD BASELINES
- PRECISE EPHEMERIS- ESPECIALLY FOR VERTICALS
- CUT OFF ANGLE- DON'T CUT OUT TOO MUCH DATA
- EDIT SATELLITE DATA- DISABLE NOISY SATS, DATA
- REOBSERVE WITH BETTER PLANNING, HIGHER ANTENNA



Guidelines for Establishing GPS-Derived Orthometric Heights

(Standards: 2 cm and 5 cm)

http://www.ngs.noaa.gov/

SEARCH: "NGS 59"

A GUIDE FOR ESTABLISHING GPS-DERIVED ORTHOMETRIC HEIGHTS (STANDARDS: 2 CM AND 5 CM)

3-4-5 System

- THREE BASIC RULES
- FOUR BASIC CONTROL REQUIREMENTS
- FIVE BASIC PROCEDURES

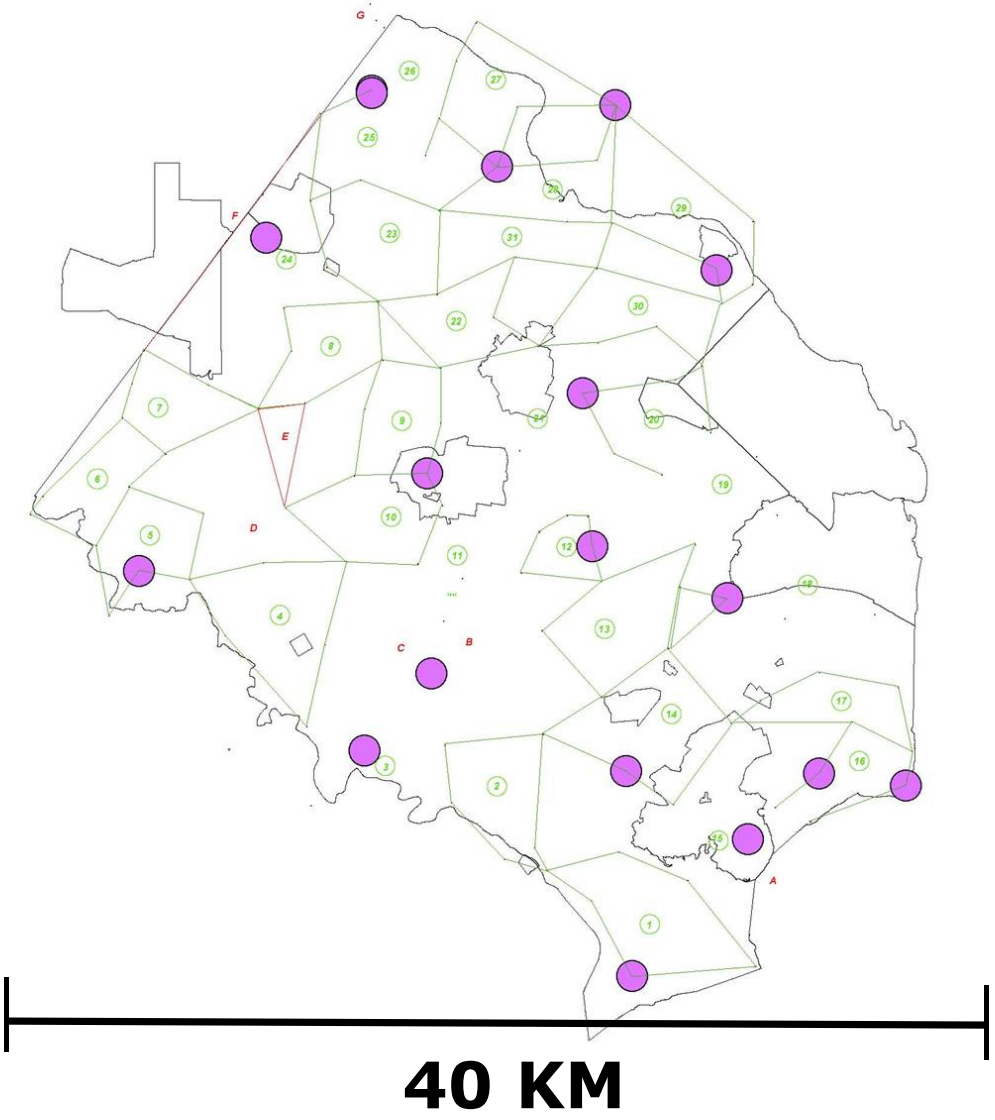
THREE BASIC RULES

- **RULE 1:**
  - **FOLLOW NGS' GUIDELINES FOR ESTABLISHING GPS-DERIVED ELLIPSOID HEIGHTS (NGS 58:STANDARDS: 2 CM AND 5 CM)**
- **RULE 2:**
  - **USE *LATEST* NATIONAL GEOID MODEL, I.E., GEOID09**
- **RULE 3:**
  - **USE *LATEST* NATIONAL VERTICAL DATUM, I.E., NAVD 88**

FOUR BASIC CONTROL REQUIREMENTS

- **BCR-1: Occupy stations with known NAVD 88 orthometric heights**
  - **Stations should be evenly distributed throughout project**
- **BCR-2: Project areas less than 20 km on a side, surround project with NAVD 88 bench marks**
  - **i.e., minimum number of stations is four; one in each corner of project**
- **BCR-3: Project areas greater than 20 km on a side, keep distances between GPS-occupied NAVD 88 bench marks to less than 20 km**
- **BCR-4: Projects located in mountainous regions, occupy bench marks at base and summit of mountains, even if distance is less than 20 km**

FAIRFAX COUNTY VERTICALS USED



FIVE BASIC PROCEDURES

- **BP-1: PERFORM 3-D MINIMUM-CONSTRAINT LEAST SQUARES ADJUSTMENT OF GPS SURVEY PROJECT**
  - **CONSTRAIN 1 LATITUDE, 1 LONGITUDE, 1 ORTHOMETRIC HEIGHT (RECALL THAT ELLIPSOID HEIGHTS HAVE ALREADY BEEN ANALYZED AND ADJUSTED)**
  - **CURRENT HYBRID GEOID MODEL IS APPLIED**
- **BP-2: ANALYZE ADJUSTMENT RESULTS FROM BP-1**
  - **DETECT AND REMOVE ALL DATA OUTLIERS**

FIVE BASIC PROCEDURES (CONTINUED)

- **BP-3: COMPUTE DIFFERENCES BETWEEN GPS-DERIVED ORTHOMETRIC HEIGHTS FROM MINIMUM-CONSTRAINT ADJUSTMENT IN BP-2 AND PUBLISHED NAVD88 ORTHOMETRIC HEIGHTS FOR ALL KNOWN BENCH MARKS**

CONTROL COMPARISON

Values shown are control coord minus adjusted coord.

Point Name	ΔNorthing	ΔEasting	ΔElevation	ΔHeight
REMO	0.010m	0.018m	N/A	-0.019m
OMGA	-0.006m	0.016m	N/A	-0.017m
H508	N/A	N/A	N/A	N/A
2305	0.005m	0.017m	N/A	-0.009m
HOPT	-0.020m	-0.010m	N/A	0.014m
F520	N/A	N/A	N/A	N/A
INTK	0.003m	0.010m	N/A	N/A
NC25	0.014m	0.015m	N/A	-0.026m
FXES	0.013m	0.015m	N/A	-0.042m
Z287	N/A	N/A	N/A	N/A
FX12	N/A	N/A	N/A	N/A
1708	N/A	N/A	N/A	N/A
DSCO	0.009m	0.003m	N/A	-0.024m
FXSW	0.005m	-0.005m	N/A	-0.033m
1650	N/A	N/A	N/A	N/A
TRBR	0.004m	0.024m	N/A	N/A
1724	N/A	N/A	N/A	N/A
FLTR	0.009m	0.047m	N/A	N/A
FXWE	0.006m	0.003m	N/A	-0.023m
EA3D	N/A	N/A	N/A	N/A
POWH	0.013m	0.011m	N/A	0.017m
VLCN	N/A	N/A	N/A	N/A

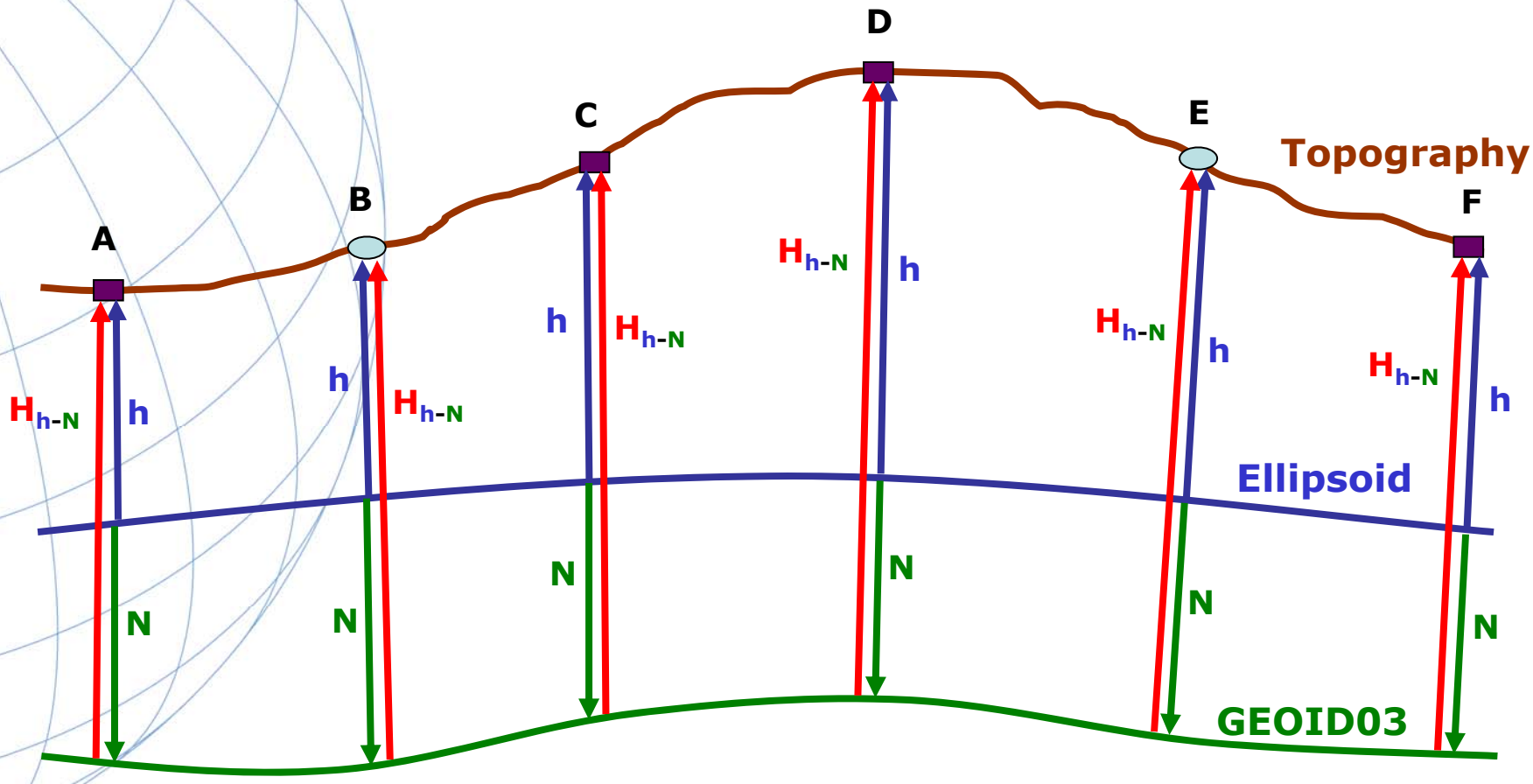
OUTLIERS ?

- **PASSIVE CONTROL QUALITY (OVER TIME)**
- **GEOID MODEL QUALITY**

FIVE BASIC PROCEDURES (CONTINUED)

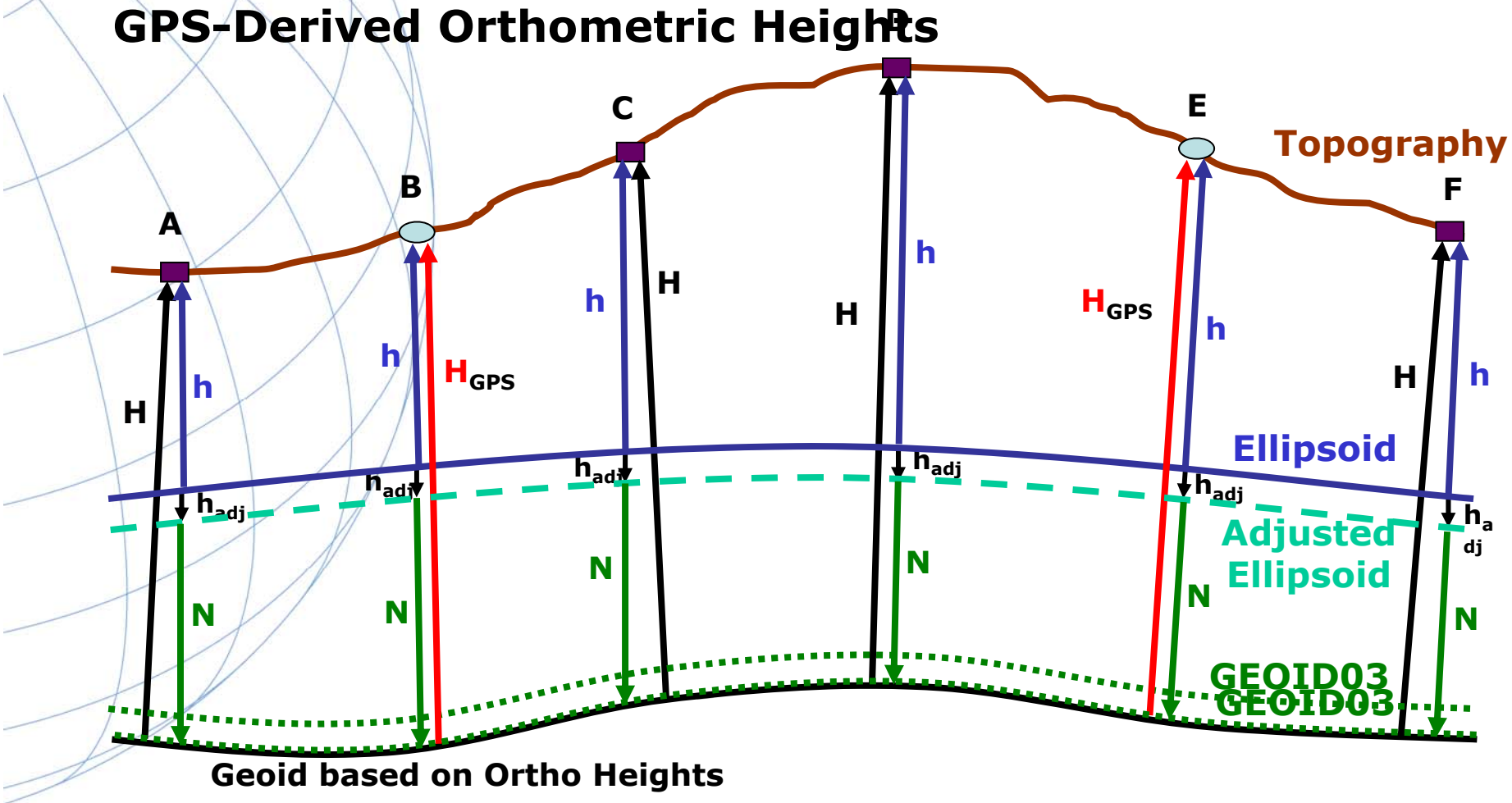
- **BP-4: Determine which BMs have *valid* NAVD88 height values from results from BP-3 and should be fixed**
  - **Differences need to agree 2 cm for 2 cm survey**
  - **Differences need to agree 5 cm for 5 cm survey**
  - **May detect systematic tilt over large areas**
    - **Solve for geoidal slope and scale**
- **BP-5: Perform constrained adjustment with results from BP-4**
  - **Constrain 1 latitude, 1 longitude, all valid orthometric height values**
  - **Ensure final heights not distorted in adjustment**

GPS-DERIVED HEIGHTS FROM GEOID03 SEPARATION



Constrained Vertical Adjustment

Ellipsoid Height Adjusted to Fit Constrained Orthometric Heights



■ = Published NAVD88 Orthometric Height ⬭ = New Control

Adjusted Geodetic Coordinates

Errors are reported using 2.58s.

Point Name	Latitude	N error	Longitude	E error	Height	h error	Fix
REMO	38°44'36.39173"N	0.000m	77°08'39.87408"W	0.000m	-5.450m	0.000m	Lat Long
OMGA	38°45'11.31240"N	0.000m	77°07'40.60426"W	0.000m	-21.040m	0.000m	Lat Long
HM16	38°45'54.07930"N	0.013m	77°05'40.71817"W	0.013m	5.888m	0.011m	
H508	38°56'37.39647"N	0.016m	77°08'59.04358"W	0.016m	46.238m	0.014m	
4987	38°58'07.78368"N	0.016m	77°08'21.72380"W	0.016m	14.670m	0.016m	
2305	39°01'00.31786"N	0.000m	77°12'18.26226"W	0.000m	79.640m	0.000m	Lat Long
HM29	38°59'48.45697"N	0.014m	77°13'49.40683"W	0.014m	82.378m	0.015m	
SHAW	39°03'14.23347"N	0.012m	77°16'59.27011"W	0.012m	61.641m	0.011m	
SUSU	39°03'41.88033"N	0.015m	77°20'09.97882"W	0.015m	27.358m	0.011m	
G135	39°00'59.14966"N	0.014m	77°15'37.89183"W	0.013m	57.170m	0.015m	
G155	38°48'12.99850"N	0.013m	77°10'21.50124"W	0.012m	45.195m	0.011m	
WEYN	38°49'20.65533"N	0.015m	77°09'47.77481"W	0.015m	50.322m	0.013m	
1753	38°55'06.87691"N	0.013m	77°11'00.36937"W	0.013m	63.610m	0.016m	
WG01	38°53'42.37345"N	0.012m	77°10'22.53814"W	0.012m	75.428m	0.012m	
G142	38°56'12.22613"N	0.014m	77°07'43.73568"W	0.014m	39.849m	0.010m	
MADD	38°57'55.78125"N	0.014m	77°13'59.26970"W	0.013m	84.311m	0.013m	
G132	39°02'14.20563"N	0.015m	77°17'40.89637"W	0.014m	57.165m	0.012m	
G127	39°00'42.11843"N	0.017m	77°18'15.24052"W	0.016m	85.473m	0.013m	
G33Z	38°44'34.89660"N	0.018m	77°04'35.79334"W	0.018m	-20.678m	0.018m	
G038	38°46'35.99529"N	0.012m	77°10'45.52104"W	0.011m	43.496m	0.011m	
HM19	38°52'15.29584"N	0.011m	77°09'11.03572"W	0.011m	77.654m	0.011m	
G050	38°47'25.04517"N	0.020m	77°03'45.00930"W	0.020m	-28.921m	0.018m	
HM18	38°50'05.64604"N	0.016m	77°07'41.37354"W	0.016m	36.500m	0.014m	
G151	38°50'35.77432"N	0.019m	77°06'35.17729"W	0.018m	23.995m	0.015m	
HOPT	38°59'45.18521"N	0.000m	77°18'45.84871"W	0.000m	80.550m	0.000m	Lat Long
HM27	39°01'28.58699"N	0.015m	77°20'33.86629"W	0.014m	96.598m	0.012m	
HM28	39°03'09.79941"N	0.019m	77°20'12.24386"W	0.019m	69.516m	0.014m	
1633	38°59'07.22725"N	0.017m	77°20'57.96047"W	0.015m	94.499m	0.023m	
F520	38°42'53.08709"N	0.021m	77°02'48.60023"W	0.021m	-24.042m	0.024m	
HM17	38°47'20.55764"N	0.016m	77°06'45.34079"W	0.016m	40.546m	0.013m	
G149	38°51'37.91057"N	0.017m	77°07'39.95309"W	0.017m	44.700m	0.014m	
INTK	39°03'46.55701"N	0.000m	77°20'34.73047"W	0.000m	27.110m	0.000m	Lat Long
NC25	38°56'48.06097"N	0.000m	77°22'09.84060"W	0.000m	91.430m	0.000m	Lat Long
HM25	38°57'36.61450"N	0.013m	77°24'12.90930"W	0.013m	88.844m	0.011m	
FXES	38°55'43.18409"N	0.000m	77°08'47.67513"W	0.000m	52.410m	0.000m	Lat Long
HM24	38°56'24.22205"N	0.014m	77°21'20.58815"W	0.013m	103.526m	0.012m	
Z287	38°59'25.41926"N	0.013m	77°16'21.55524"W	0.013m	67.913m	0.015m	
HM11	38°51'19.95979"N	0.012m	77°18'48.59078"W	0.011m	84.482m	0.010m	
G159	38°49'01.15743"N	0.012m	77°21'36.80383"W	0.012m	73.412m	0.011m	
F520	2117335.990m	0.022m	3626374.862m	0.021m	8.330m	0.000m	e
HM17	2125493.974m	0.017m	3620531.730m	0.017m	72.652m	0.017m	

Adjusted Geodetic Coordinates

Errors are reported using 2.58s.

Point Name	Latitude	N error	Longitude	E error	Height	h error	Fix
REMO	38°44'36.39173"N	0.000m	77°08'39.87408"W	0.000m	-5.449m	0.038m	Lat Long
OMGA	38°45'11.31240"N	0.000m	77°07'40.60426"W	0.000m	-21.044m	0.038m	Lat Long
HM16	38°45'54.07930"N	0.014m	77°05'40.71817"W	0.014m	5.881m	0.039m	
H508	38°56'37.39647"N	0.017m	77°08'59.04362"W	0.017m	46.242m	0.038m	e
4987	38°58'07.78369"N	0.016m	77°08'21.72385"W	0.016m	14.670m	0.041m	
2305	39°01'00.31786"N	0.000m	77°12'18.26226"W	0.000m	79.622m	0.039m	Lat Long e
HM29	38°59'48.45698"N	0.015m	77°13'49.40686"W	0.015m	82.374m	0.040m	
SHAW	39°03'14.23349"N	0.013m	77°16'59.27010"W	0.013m	61.643m	0.043m	
SUSU	39°03'41.88034"N	0.016m	77°20'09.97882"W	0.016m	27.368m	0.045m	
G135	39°00'59.14967"N	0.016m	77°15'37.89184"W	0.015m	57.166m	0.041m	
G155	38°48'12.99852"N	0.013m	77°10'21.50123"W	0.013m	45.199m	0.036m	
WEYN	38°49'20.65534"N	0.016m	77°09'47.77481"W	0.016m	50.326m	0.036m	
1753	38°55'06.87692"N	0.013m	77°11'00.36937"W	0.013m	63.621m	0.039m	
WG01	38°53'42.37346"N	0.012m	77°10'22.53814"W	0.012m	75.439m	0.037m	
G142	38°56'12.22612"N	0.014m	77°07'43.73569"W	0.014m	39.856m	0.040m	
MADD	38°57'55.78125"N	0.014m	77°13'59.26971"W	0.014m	84.316m	0.038m	
G132	39°02'14.20565"N	0.016m	77°17'40.89637"W	0.015m	57.166m	0.042m	
G127	39°00'42.11844"N	0.018m	77°18'15.24052"W	0.017m	85.472m	0.041m	
G33Z	38°44'34.89661"N	0.019m	77°04'35.79334"W	0.019m	-20.691m	0.042m	
G038	38°46'35.99530"N	0.012m	77°10'45.52104"W	0.012m	43.502m	0.036m	
HM19	38°52'15.29584"N	0.012m	77°09'11.03572"W	0.012m	77.662m	0.037m	
G050	38°47'25.04517"N	0.020m	77°03'45.00932"W	0.020m	-28.931m	0.042m	
HM18	38°50'05.64603"N	0.017m	77°07'41.37354"W	0.017m	36.502m	0.038m	
G151	38°50'35.77431"N	0.020m	77°06'35.17728"W	0.019m	23.995m	0.039m	
HOPT	38°59'45.18521"N	0.000m	77°18'45.84871"W	0.000m	80.548m	0.039m	Lat Long
HM27	39°01'28.58702"N	0.016m	77°20'33.86631"W	0.015m	96.605m	0.039m	e
HM28	39°03'09.79942"N	0.020m	77°20'12.24386"W	0.020m	69.525m	0.044m	
1633	38°59'07.22728"N	0.017m	77°20'57.96058"W	0.016m	94.520m	0.043m	
F520	38°42'53.08711"N	0.022m	77°02'48.60016"W	0.021m	-24.062m	0.040m	e
HM17	38°47'20.55764"N	0.017m	77°06'45.34079"W	0.017m	40.540m	0.038m	
G149	38°51'37.91057"N	0.018m	77°07'39.95308"W	0.018m	44.703m	0.038m	
INTK	39°03'46.55701"N	0.000m	77°20'34.73047"W	0.000m	27.123m	0.045m	Lat Long
NC25	38°56'48.06097"N	0.000m	77°22'09.84060"W	0.000m	91.471m	0.038m	Lat Long
HM25	38°57'36.61454"N	0.014m	77°24'12.90939"W	0.014m	88.885m	0.038m	e
FXES	38°55'43.18409"N	0.000m	77°08'47.67513"W	0.000m	52.422m	0.039m	Lat Long
HM24	38°56'24.22205"N	0.014m	77°21'20.58821"W	0.014m	103.556m	0.038m	
Z287	38°59'25.41928"N	0.015m	77°16'21.55516"W	0.014m	67.909m	0.040m	

```
DH3699  HT_MOD       -  This is a Height Modernization Survey Station.
DH3699  DESIGNATION  -  3688E82
DH3699  PID          -  DH3699
DH3699  STATE/COUNTY-  MO/PEMISCOT
DH3699  USGS QUAD    -  STEELE (1976)
DH3699
DH3699                          *CURRENT SURVEY CONTROL
DH3699
DH3699* NAD 83(1997)-  36 00 00.84824(N)     089 49 52.22461(W)      ADJUSTED
DH3699* NAVD 88      -         77.54    (meters)      254.4     (feet)  GPS OBS
DH3699
DH3699  X            -      15,222.070  (meters)                        COMP
DH3699  Y            -  -5,166,000.892  (meters)                        COMP
DH3699  Z            -   3,728,241.823  (meters)                        COMP
DH3699  LAPLACE CORR-            0.42   (seconds)                       DEFLEC99
DH3699  ELLIP HEIGHT-           49.33   (meters)           (05/31/05)   GPS OBS
DH3699  GEOID HEIGHT-          -28.19   (meters)                        GEOID03
DH3699
DH3699  HORZ ORDER   -  FIRST
DH3699  ELLP ORDER   -  FOURTH    CLASS II
DH3699
DH3699.The horizontal coordinates were established by GPS observations
DH3699.and adjusted by the National Geodetic Survey in May 2005..
DH3699
DH3699.The orthometric height was determined by GPS observations and a
DH3699.high-resolution geoid model using precise GPS observation and
DH3699.processing techniques.
DH3699
DH3699.The X, Y, and Z were computed from the position and the ellipsoidal ht.
DH3699
DH3699.The Laplace correction was computed from DEFLEC99 derived deflections.
DH3699
DH3699.The ellipsoidal height was determined by GPS observations
DH3699.and is referenced to NAD 83.
DH3699
DH3699.The geoid height was determined by GEOID03.
DH3699
DH3699;                     North          East      Units Scale Factor Converg.
DH3699;SPC MO E      -    18,724.696   310,300.091    MT  0.99997812   +0 23 35.3
DH3699;UTM  16       - 3,987,682.411   244,801.459    MT  1.00040255   -1 39 54.1
DH3699
DH3699!              -  Elev Factor  x  Scale Factor =   Combined Factor
DH3699!SPC MO E      -   0.99999226  x   0.99997812  =   0.99997038
DH3699!UTM  16       -   0.99999226  x   1.00040255  =   1.00039480
```

Identified as Height Mod survey station

Elevation published to centimeters

Orthometric height determined by GPS

NGS Data Sheet - GEOID03 Published NAVD88 to GPS Derived

$H = h - N$

$102.431 = 69.78 - (-32.60)$

$102.431 \neq 102.38$

102.429 GEOID 09

```
HT2268  DESIGNATION -  S 1320
HT2268  PID         -  HT2268
HT2268  STATE/COUNTY-  CA/SAN FRANCISCO
HT2268  USGS QUAD   -  SAN FRANCISCO NORTH (1975)
HT2268
HT2268                      *CURRENT SURVEY CONTROL
HT2268
HT2268* NAD 83(1992)-  37 45 25.30727(N)    122 28 36.34687(W)     ADJUSTED
HT2268* NAVD 88     -       102.431  (meters)     336.06   (feet)  ADJUSTED
HT2268
HT2268  EPOCH DATE  -         1997.30
HT2268  X           -  -2,711,121.437 (meters)                     COMP
HT2268  Y           -  -4,259,419.310 (meters)                     COMP
HT2268  Z           -   3,884,200.262 (meters)                     COMP
HT2268  LAPLACE CORR-            5.53  (seconds)                  DEFLEC03
HT2268  ELLIP HEIGHT-           69.78  (meters)                   GPS OBS
HT2268  GEOID HEIGHT-          -32.60  (meters)                   GEOID03
HT2268  DYNAMIC HT  -          102.363 (meters)        3
HT2268  MODELED GRAV-      979,964.0   (mgal)
HT2268
HT2268  HORZ ORDER  -  FIRST
HT2268  VERT ORDER  -  FIRST      CLASS I
HT2268  ELLP ORDER  -  FOURTH     CLASS I
HT2268
```

GEOID96 = 0.17 m
GEOID99 = 0.11 m
GEOID03 = 0.05 m
GEOID 09 = 0.002 m

POSITIONAL ACCURACY
REPLACING DISTANCE CORRELATED ACCURACY

```
NE1027 ************************************************************************
NE1027  CBN          -  This is a Cooperative Base Network Control Station.
NE1027  DESIGNATION  -  F 337
NE1027  PID          -  NE1027
NE1027  STATE/COUNTY-  MI/WAYNE
NE1027  USGS QUAD    -  YPSILANTI EAST (1983)
NE1027
NE1027                        *CURRENT SURVEY CONTROL
NE1027
NE1027* NAD 83(2007)-   42 13 10.41682(N)     083 30 40.50685(W)      ADJUSTED
NE1027* NAVD 88      -       212.637  (meters)      697.63   (feet)   ADJUSTED
NE1027
NE1027  EPOCH DATE   -         2002.00
NE1027  X            -     534,616.161 (meters)                       COMP
NE1027  Y            -  -4,700,472.689 (meters)                       COMP
NE1027  Z            -   4,263,815.954 (meters)                       COMP
NE1027  LAPLACE CORR-          -1.96  (seconds)                       DEFLEC09
NE1027  ELLIP HEIGHT-         178.286 (meters)          (06/10/07)   ADJUSTED
NE1027  GEOID HEIGHT-         -34.35  (meters)                       GEOID09
NE1027  DYNAMIC HT   -         212.570 (meters)      697.41  (feet)   COMP
NE1027
NE1027                    SUPERSEDED SURVEY CONTROL
NE1027                                                                cm) --------
NE1027                                                                 East  Ellip
NE1027  ELLIP H (02/10/07)   178.277   (m)                    GP(        )      ------------
NE1027  ELLIP H (06/11/02)   178.311   (m)                    GP(        )  4 1   0.31   0.94
NE1027  NAD 83(1994)-   42 13 10.41653(N)     083 30 40.50656(W) AD(        )  B   ------------
NE1027  ELLIP H (09/20/95)   178.321   (m)                    GP(        )  1 2      NAVD 88
NE1027  NAD 83(1986)-   42 13 10.42375(N)     083 30 40.53514(W) AD(        )  1      GRAV_OBS
NE1027  NAD 83(1986)-   42 13 10.42214(N)     083 30 40.53071(W) AD(        )  1
NE1027  NAVD 88 (09/30/94)   212.64    (m)          697.6     (f) LEVELING     3
NE1027  NGVD 29 (01/19/93)   212.768   (m)          698.06    (f) ADJUSTED     1 2 vations
NE1027                                                                          2007.
NE1027
```

PROCESSING & ADJUSTMENT REQUIREMENTS SUMMARY

- RMS ELLIPSOID HEIGHTS ≤ 1.5 CM
- REPEAT BASELINES ≤ 2.0 CM
- USE TROPO MODEL
- EVALUATE VERTICAL CONTROL
- USE IONO-FREE (L3) SOLUTION FOR BASELINES ≥ 5 KM
- USE L1 SOLUTION FOR ALL OTHERS
- MINIMALLY CONSTRAINED ADJUSTMENT – VERIFIES FIELD DATA CONSISTENCY
- FULLY CONSTRAINED ADJUSTMENT – PLACES PROJECT ON NAVD 88/NAD 83
- GOAL IS 2 CM NAVD 88 HEIGHTS BETWEEN NETWORK MONUMENTS

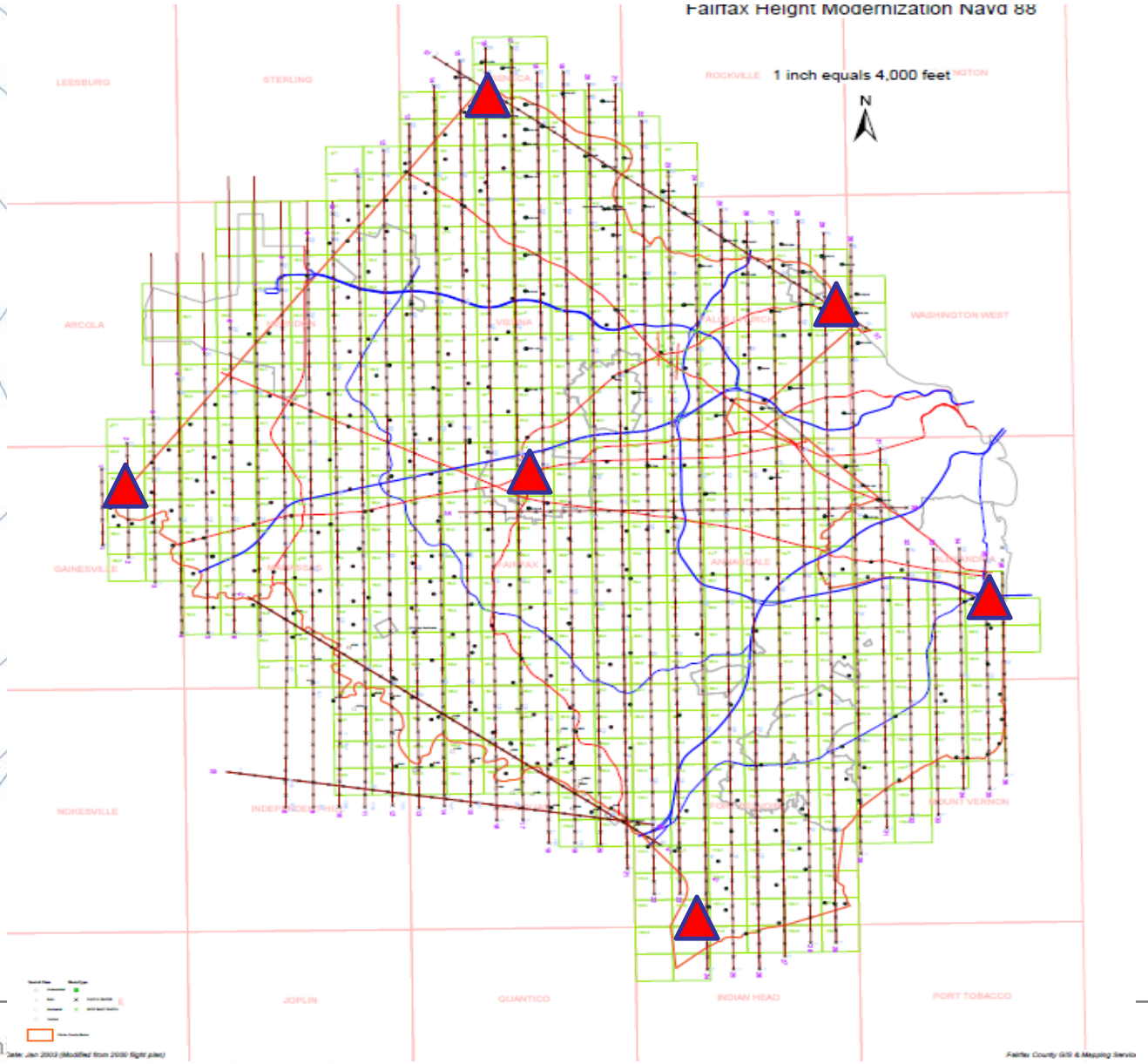
SUMMARY

- ***Mistakes*** **and** ***systematic errors*** **must be removed before the adjustment**
- **A least squares adjustment handles** ***random errors*** **and provides a single solution (Try to eliminate all systematic errors)**
- **The Minimally Constrained adjustment checks the internal consistency of the network**
- **The Constrained adjustment checks the existing control and references the network to the datum**
- **The vertical adjustment estimates GPS-derived Orthometric heights- Approaching 3rd order leveling accuracies**

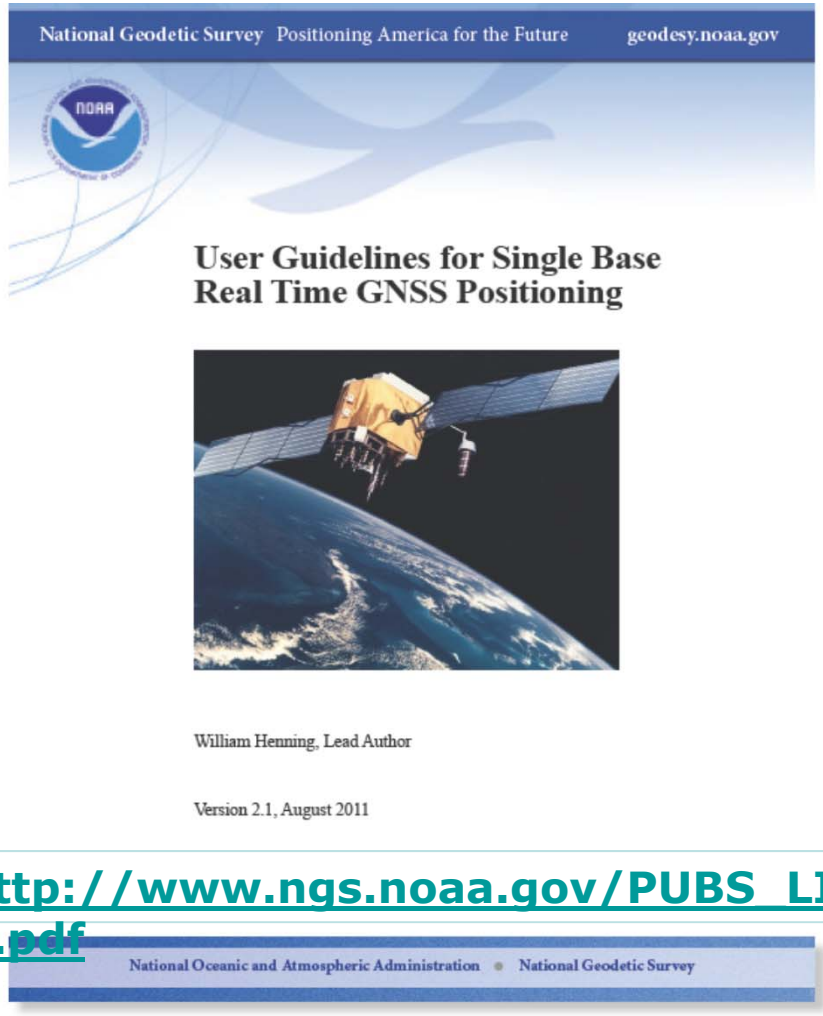
POSSIBLE ALTERNATIVE = RTN APPROACH

- EVALUATE GEOID MODEL ACROSS THE COUNTY
- REFINE AS NECESSARY (GEODETIC LEVELING)
- CONSTRUCT ACTIVE STREAMING STATIONS CONFORMING TO NGS GUIDELINES SPACED AT A MAXIMUM OF 50 KM
- SEED COORDINATES ON THE STATIONS WITH 10 DAYS OF OPUS-DB OR OPUS-PROJECTS SOLUTIONS
- PERFORM A LEAST SQUARES ADJUSTMENT WEIGHTING (NGS) CORS TO 1 CM IN EACH HORIZONTAL COMPONENT AND 2 CM IN THE ELLIPSOID HEIGHT
- EVALUATE RESULTS – THEY SHOULD ALL BE VERY CLOSE TO THE OPUS POSITIONS. IF THE RTN HAS A MAXIMUM DELTA BELOW 2 CM HORIZONTALLY AND 4 CM ELLIPSOID HEIGHT, THE RTN IS SUCESSFULLY ALIGNED TO THE NSRS.
- BEGIN WORK!

POSSIBLE FAIRFAX COUNTY RTN



REAL TIME GNSS GUIDELINES


National Geodetic Survey Positioning America for the Future geodesy.noaa.gov

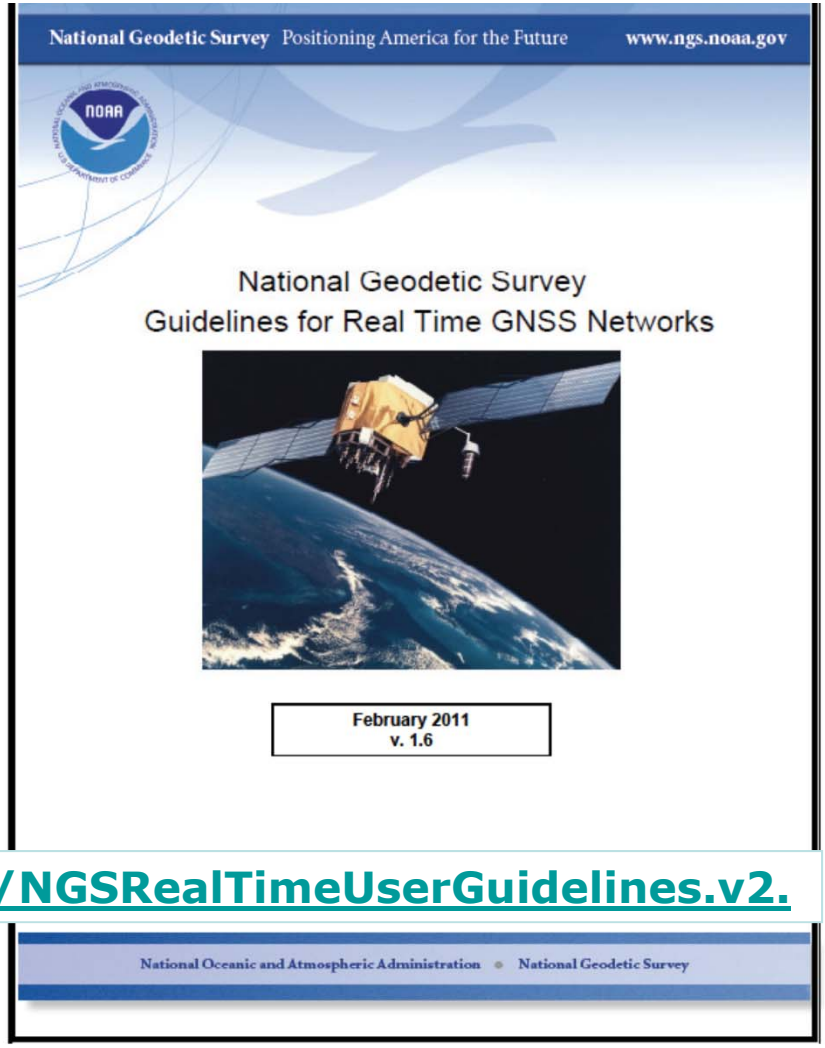
User Guidelines for Single Base Real Time GNSS Positioning

William Henning, Lead Author

Version 2.1, August 2011

National Oceanic and Atmospheric Administration • National Geodetic Survey

http://www.ngs.noaa.gov/PUBS_LIB/NGSRealTimeUserGuidelines.v2.1.pdf


National Geodetic Survey Positioning America for the Future www.ngs.noaa.gov

National Geodetic Survey
Guidelines for Real Time GNSS Networks

February 2011
v. 1.6

National Oceanic and Atmospheric Administration • National Geodetic Survey

http://www.ngs.noaa.gov/PUBS_LIB/NGS.RTN.Public.v2.0.pdf

RT FOR ORTHO HEIGHTS

ADVANTAGES:

- **LESS TIME- SECONDS ON POINT**
- **LESS LABOR- NO POST PROCESSING, MINIMAL PERSONNEL**
- **LESS EQUIPMENT – ONLY ONE RT UNIT NECESSARY WITH RTN**
- **= LESS $$$**

- **USER KNOWS POSITION HAS BEEN CAPTURED AT REQUIRED PRECISION**

- **"GOOD" *RELATIVE* PRECISION IN HOMOGENEOUS TERRAIN AND USING THE SAME INITIALIZATION**

- **NEW GEOPOTENTIAL DATUM WILL BE ACCESSED THROUGH ACTIVE STATIONS**

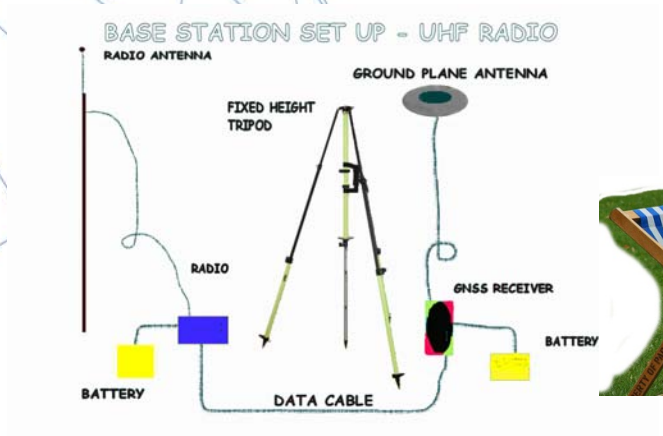
DISADVANTAGES:

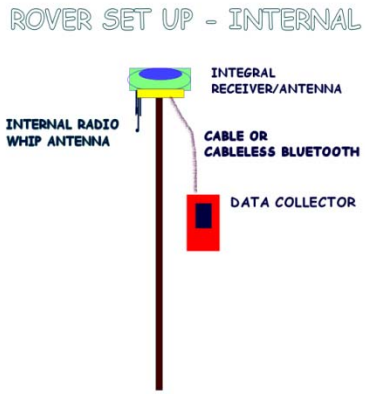
- **LESS ACCURACY THAN LEVELING OR STATIC GNSS**
- **REQUIRES ADEQUATE USER KNOWLEDGE OF ALL EFFECTS ON RT GNSS POSITIONING**

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

RTK VS. RTN

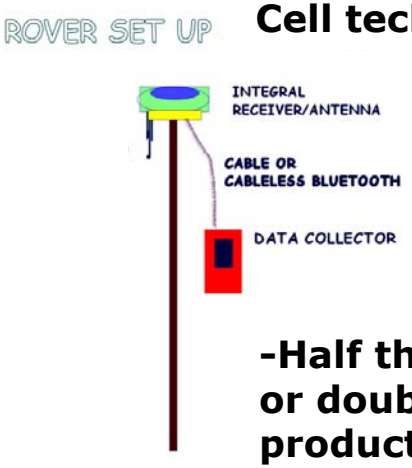




RTK

Plus:
Easy alignment to the NSRS
No ppm (1ST ORDER) ERROR
Extended range
Homogeneous Data
Easy datum updates

Cell technology



RTN

-Half the equipment or double the production
-No monument reconnaissance/ recovery
- No set/break down time
-No base baby sitting

SO – WHAT CAN I EXPECT FROM An RTN?

MOST RTN PRODUCE "GOOD" HORIZONTAL VALUES – TO A FEW CM. OUR HORIZONTAL SYSTEM IS BASED ON ACTIVE REFERENCE STATIONS (NGS CORS), AS ARE THE RTN STATIONS.

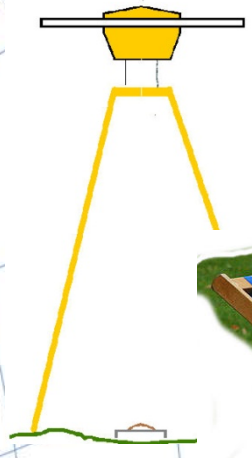
BECAUSE ORTHOMETRIC HEIGHTS ('ELEVATIONS') ARE BASED ON PASSIVE MONUMENTS WITH NAVD 88, THE RTN USER SHOULD, FOR THE MOST PART, CONSTRAIN THE PASSIVE MARK VALUES IN A LOCALIZATION.

CHOOSE THE RTN WITH A BUSINESS MODEL THAT BEST FITS YOUR NEEDS.

USERS CONCERNS WITH RTN

- What Datum is the RTN using?
- What adjustment of the Datum is the RTN using?
- What epoch of the Datum adjustment is the RTN using?
- How Does The RTN Align To The NSRS?
- Can Users Use Any Manufacturers' Equipment In The RTN?
- Do Overlapping Networks Give The Same Coordinates?
- What Are The Field Accuracies?

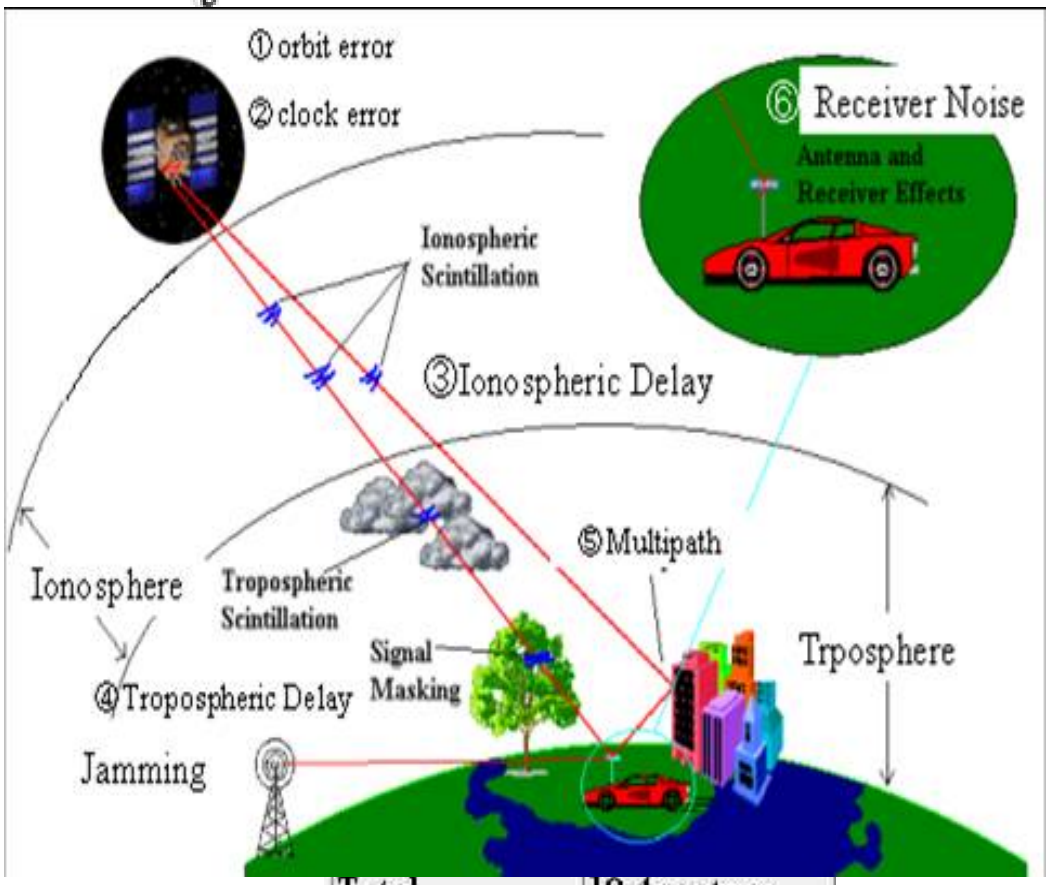
WHAT CAN AFFECT THE GPS SIGNAL? WHAT SHOULD I BE CONCERNED ABOUT WHEN COLLECTING DATA?



UNDIFFERENCED PHASE OBSERVABLE (CYCLES)

$$\varphi_k^p(t) = \frac{f}{c}\rho_k^p(t) - f dt_k(t) + f dt^p(t) + N_k^p - I_{k,\varphi}^p(t) + \frac{f}{c}T_k^p(t) + d_{k,\varphi}(t) + d_{k,\varphi}^p(t) + d_\varphi^p(t) + \varepsilon_\varphi$$

ERROR	VALUE
Ionosphere	4.0 METERS
Ephemeris	2.1 METERS
Clock	2.1 METERS
Troposphere	0.7 METERS
Receiver	0.5 METERS
Multipath	1.0 METERS
TOTAL	10.4 METERS
UNCORRELATEDERROR	5.15 m (square root of sum of errors squared)



MULTIPATH = NOISE
SPECULAR(DISCRETE) & DIFFUSE

INSIDE GNSS

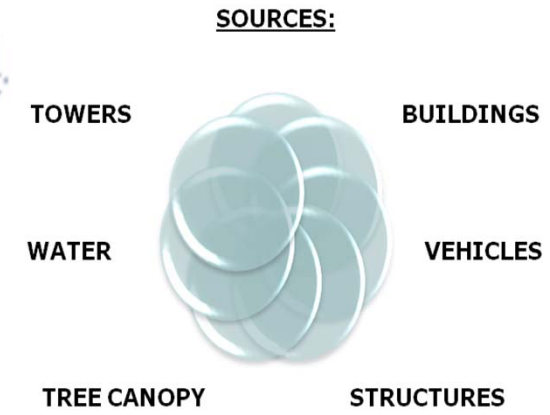
NOVEMBER-DECEMBER 2008

"MULTIATH-MITIGATION TECHNIQUES USING MAXIMUM-LIKELIHOOD PRINCIPLE"

MOHAMED SAHMOUDI AND

RENE JR. LANDRY

WWW.INSIDEGNSS.COM



NEWER GNSS GEAR & FIRMWARE IS BETTER!

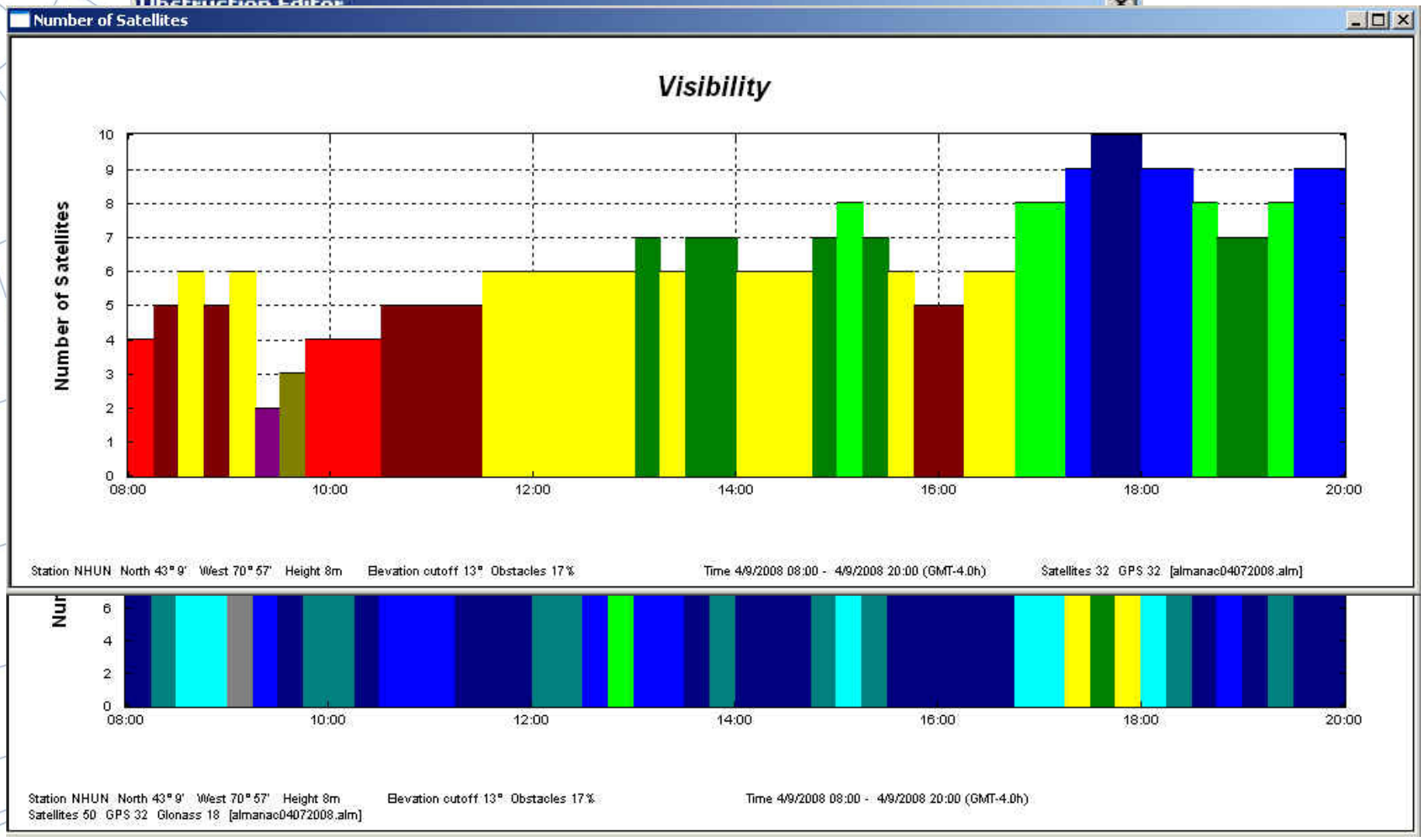
$$\phi\lambda = \rho - c\delta^s + c\delta_r + \rho_{trop} - \rho_{ion} + \rho_{multi} + \rho_{rel} + N\lambda + \varepsilon$$

$$\varphi_k^p(t) = \frac{f}{c}\rho_k^p(t) - fdt_k(t) + fdt^p(t) + N_k^p - I_{k,\varphi}^p(t) + \frac{f}{c}T_k^p(t) + d_{k,\varphi}(t) + d_{k,\varphi}^p(t) + d_\varphi^p(t) + \varepsilon_\varphi$$

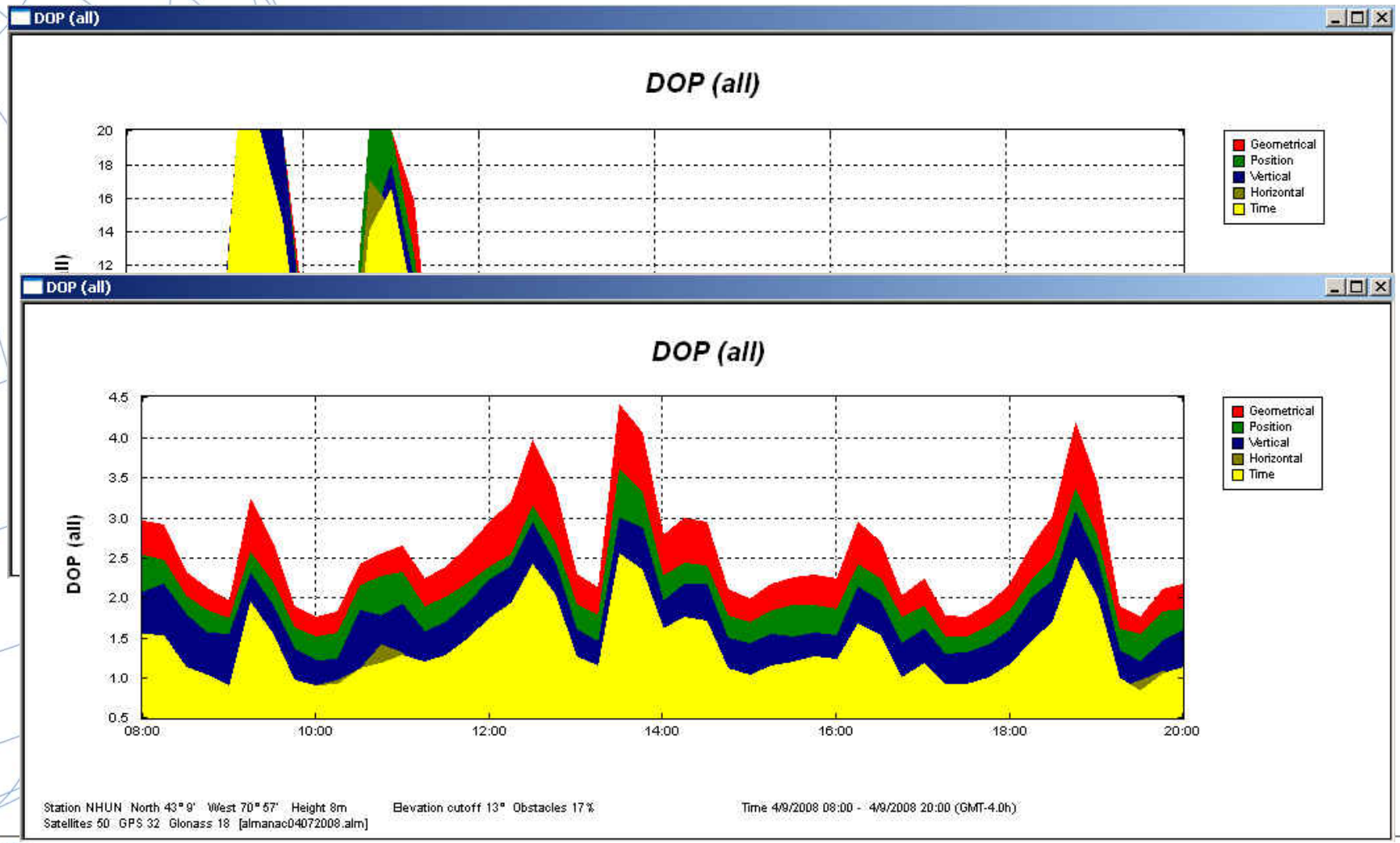
PLAN YOUR GNSS CAMPAIGNS TO AVOID DOWN TIME

- SPACE WEATHER
- DOP
- SATS
- GNSS?

SATELLITES/ DOP WITH OBSTRUCTIONS



SATELLITES/ DOP WITH OBSTRUCTIONS



WHAT ABOUT GLONASS?

GPS AND GLN

Table 1 Comparison of GLONASS and GPS Characteristics

Parameter	Detail		GLONASS	GPS
Satellites	Number of satellites		21 + 3 spares [a]	21 + 3 spares [a]
	Number of orbital planes		3	6
	Orbital plane inclination (degrees)		64.8	55
	Orbital radius (kilometers)		25 510	26 560
Signals	Fundamental clock frequency (MHz)		5.0	10.23
	Signal separation technique [b]		FDMA	CDMA
	Carrier frequencies (MHz)	L1	1598.0625 - 1609.3125 [c]	1575.42
		L2	1242.9375 - 1251.6875	1227.6
	Code clock rate (MHz)	C/A	0.511	1.023
		P	5.11	10.23
	Code length (chips)	C/A	511	1 023
		P	5.11×10^6	6.187104×10^{12}

DUAL CONSTELLATION RT POSSIBILITIES:

GPS ≥ 5, GLN = 0
GPS = 4, GLN = 2
GPS = 3, GLN = 3
GPS = 2, GLN = 4
(Can't initialize with only GLN Sats.)

BEST SCENARIO = 7 OR MORE GPS

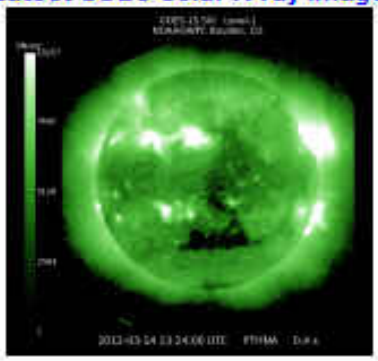
GLN "K" SATS WILL HAVE A CDMA (L3) FORMAT SIGNAL

WWW.SWPC.NOAA.GOV

Current Space Weather Conditions

------- Satellite Displays ------- ------- Popular Pages -------

Latest GOES Solar X-ray Image

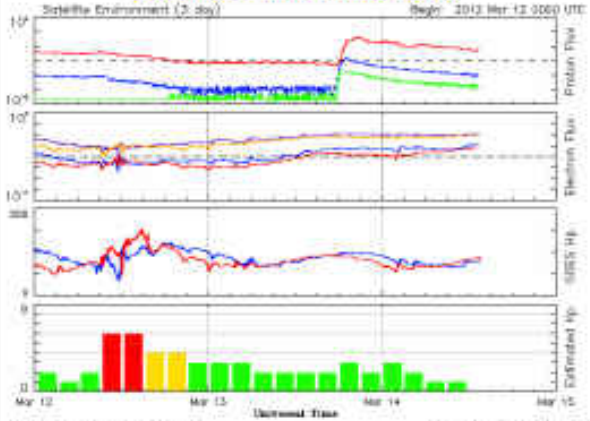


NOAA Scales Activity

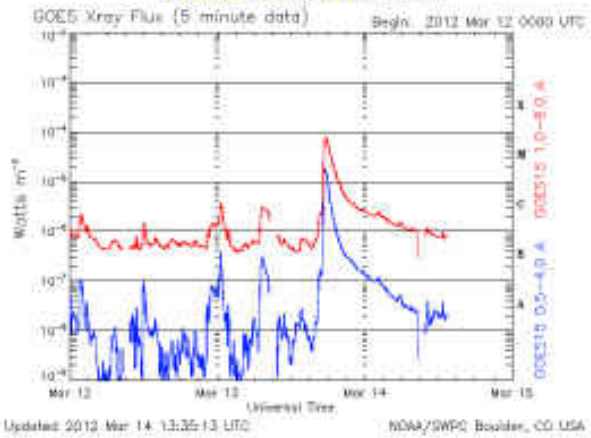
Range 1 (minor) to 5 (extreme)

NOAA Scale	Past 24 hours	Current
Geomagnetic Storms *	none	none
Solar Radiation Storms	S2	S1
Radio Blackouts	R2	none

Satellite Environment Plot



GOES Solar X-ray Flux



SWPC WARNING

SWPC Product Subscription Service SWPC.Products@noaa.gov Mar 9 (5 days ago)

to me

Space Weather Message Code: WARK07
Serial Number: 36
Issue Time: 2012 Mar 09 1146 UTC

EXTENDED WARNING: Geomagnetic K-index of 7 or greater expected
Extension to Serial Number: 35
Valid From: 2012 Mar 09 0700 UTC
Now Valid Until: 2012 Mar 09 1500 UTC
Warning Condition: Persistence

NOAA Space Weather Scale descriptions can be found at
www.swpc.noaa.gov/NOAAscales

Potential Impacts: Area of impact primarily poleward of 50 degrees Geomagnetic Latitude.
Induced Currents - Power system voltage irregularities possible, false alarms may be triggered on some protection devices.
Spacecraft - Systems may experience surface charging; increased drag on low Earth-orbit satellites and orientation problems may occur.
Navigation - Intermittent satellite navigation (GPS) problems, including loss-of-lock and increased range error may occur.
Radio - HF (high frequency) radio may be intermittent.
Aurora - Aurora may be seen as low as Pennsylvania to Iowa to Oregon.

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