Oregon DOT Geometronics Unit Update

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Lead Geodetic Surveyor
ODOT Geometronics Unit
16 September 2008
CGSIC States & Localities
Savannah, Georgia

Mission: ODOT Geometronics Unit

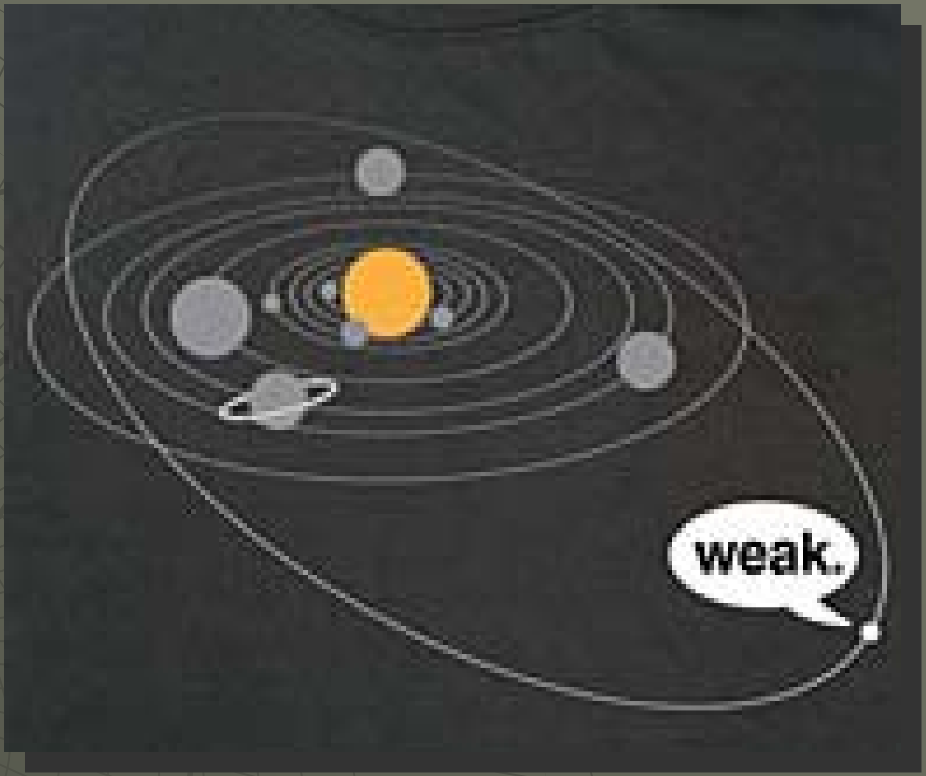
- Preserve and enhance geodetic control in the State of Oregon

Overview

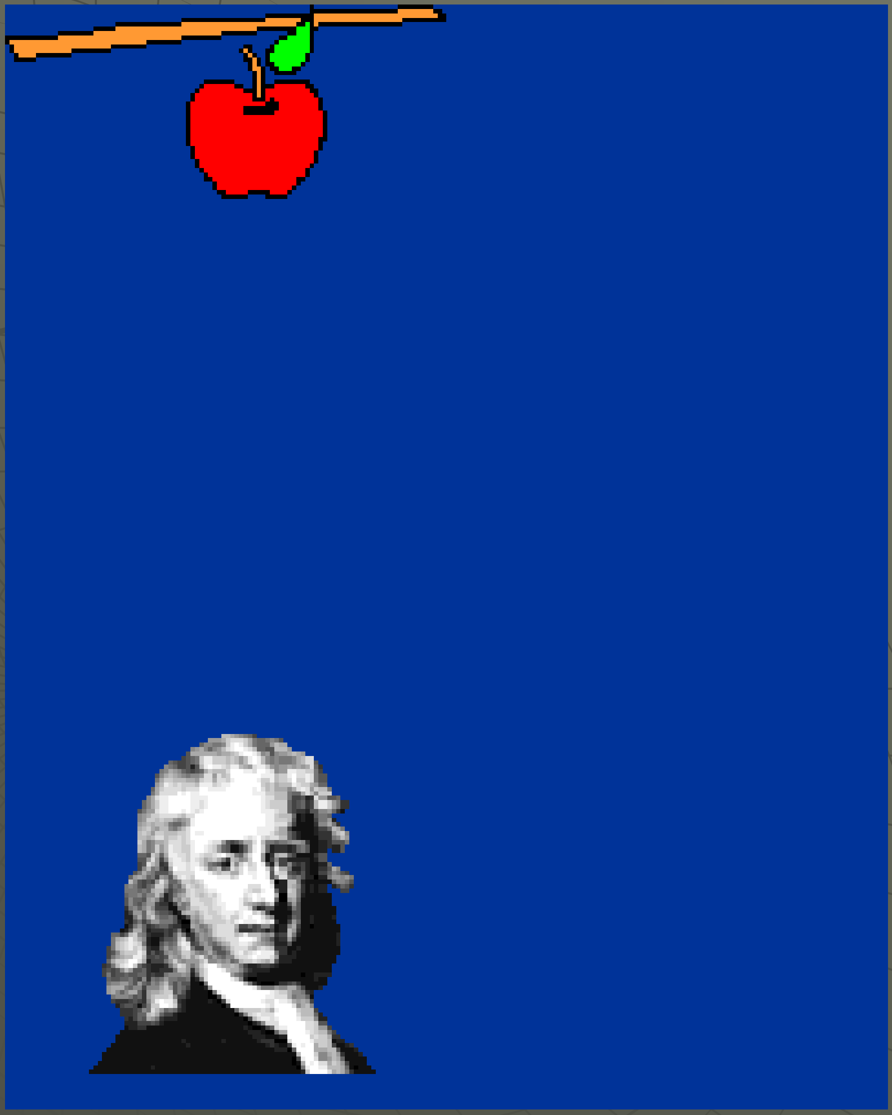
- Gravity Campaign in Oregon
  - NGS National Gravity Survey Plan
  - Oregon Gravity Surveys 2007
- Precise Digital Leveling in Oregon
- Oregon Real-time GPS Network Update
- Outreach/Education

Gravity

- NGS National Gravity Survey Plan
- 2007 Oregon Gravity Survey



Sir Isaac Newton (1643-1727)



GRAVITY
Not just a good idea, it's the law

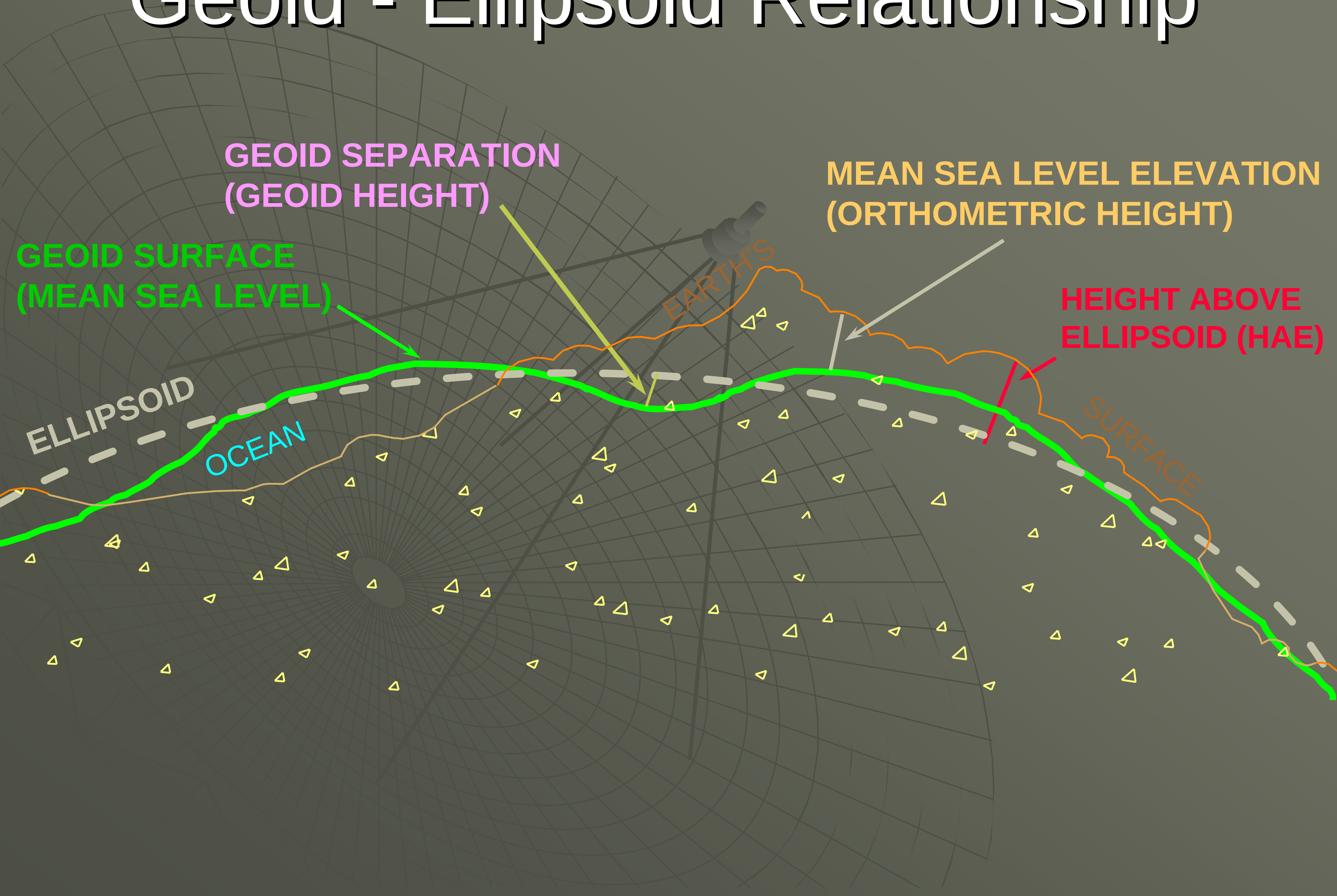
NGS National Gravity Survey Plan

- The GRAV-D Project:
  - Gravity for the Redefinition of the American Vertical Datum
- "Accurate gravity data is the foundation for the Federal government's determination of heights"

Why a Gravity Survey is Needed

- "GPS Ellipsoid heights cannot be used to determine where water will flow, and therefore are *not* used in topographic/floodplain mapping."
- "Orthometric heights are related to water flow and more useful."
  - **NGS National Gravity Survey Plan**

Geoid - Ellipsoid Relationship



Why a Gravity Survey is Needed

- "In order to transform from ellipsoid heights to orthometric heights, a model of *the geoid* must be computed."
- "Geoid modeling *can only be done with measurements of the acceleration of gravity near the Earth's surface.*"
  - **NGS National Gravity Survey Plan**

Grav-D Project Summary

- I. High resolution snapshot
  - to repair and improve existing gravity holdings
  - a one-time survey with dense spatial coverage but short time frame (7-10 years)
  - Rely heavily on airborne gravity
- II. Low resolution movie
  - to track the temporal changes to the gravity field on a broad scale
  - a re-occurring survey with very coarse spatial coverage and a long time span.
- III. Terrestrial Partnership Surveys
  - to measure and/or track very localized gravity values of particular importance to the fine-scale local determination of heights

Campaign III: Terrestrial Partnership Surveys

- "A 'boots-on-the-ground' re-check of each place where new airborne gravity surveys disagree with existing terrestrial gravity data"
- "In general such surveys are expected to rely heavily upon the partnerships NGS has formed, and will form, through a National Height Modernization program"
- "NGS will engage local partners in the surveys, including loaning equipment and providing training in the use of the equipment, and submittal of processed data to NGS."
- "Potential for localized geoid slopes to be directly determined from field surveys of **co-located (space and time) leveling and GPS**."

From Astoria to Crater Lake….

…..A Story of Bouys & Gals

Unit of Gravity Measurements

- **Gal = 1 cm / sec2**
- **Named in honor of Galileo Galilei**

“Average” Gravity Force on Earth’s Surface

- 32 ft/sec^2 is “average” force on Earth’s surface
- = 9.8 $meters/sec^2$
- = 980 $centimeters/sec^2$ (or 980 Gals)
- = 980,000 milliGals (mGals)
- Typically, gravity observations are recorded in **milliGals** , a milliGal is about 1 millionth of the acceleration of gravity at the earth's surface.

GRAVITY BASE STATION

LATITUDE 43°05.3'N (1)	STATION DESIGNATION ALKALI LAKE
LONGITUDE ~~119°57.5'W~~ 119° 57' 20 (1)	
ELEVATION METERS	COUNTRY/STATE USA/Oregon
REFERENCE CODE NUMBERS	ADOPTED GRAVITY VALUE
DOD 1277-0 IGB 15639	g = 980 033.59 mgals
	ESTIMATED ACCURACY: ± 0.1 mgals
	DATE MONTH/YEAR: July 73

DESCRIPTION AND/OR SKETCH

The observations were made at Alkali Lake Airport in Oregon.

The site is located at the north edge of the landing strip, in line with the center line of the road leading to the landing strip from HWY 395.

(1)

Astoria

```
SC1055  CBN            -  This is a Cooperative Base Network Control Station.
SC1055  TIDAL BM       -  This is a Tidal Bench Mark.
SC1055  DESIGNATION    -  943 9040 TIDAL 12
SC1055  STATE/COUNTY-  OR/CLATSOP
SC1055  USGS QUAD      -  ASTORIA (1984)
SC1055                         *CURRENT SURVEY CONTROL
SC1055* NAD 83(1998)-  46 12 26.45816(N)    123 46 01.25297(W)    ADJUSTED
SC1055* NAVD 88       -          5.495  (meters)       18.03   (feet)  ADJUSTED
SC1055  ELLIP HEIGHT-          -17.468 (meters)            (03/21/00) GPS OBS
SC1055  GEOID HEIGHT-          -22.94  (meters)                       GEOID03
SC1055  DYNAMIC HT   -           5.496 (meters)        18.03   (feet)  COMP
SC1055  MODELED GRAV-     980,713.5    (mgal)                         NAVD 88
SC1055                          SUPERSEDED SURVEY CONTROL
SC1055  NAD 83(1991)-  46 12 26.45592(N)    123 46 01.25507(W) AD(         ) B
SC1055  ELLIP H (10/13/99)  -17.347   (m)                      GP(         ) 3 1
SC1055  NAD 83(1991)-  46 12 26.46255(N)    123 46 01.21573(W) AD(         ) 3
SC1055  NAD 27      -  46 12 27.08765(N)    123 45 56.70363(W) AD(         ) 3
SC1055  NAVD 88 (10/13/99)    5.50    (m)         18.0     (f) LEVELING    3
SC1055_MARKER: DJ = TIDAL STATION DISK
SC1055_SETTING: 37 = SET IN A MASSIVE RETAINING WALL
SC1055_STAMPING: TIDAL NO 12 1962
SC1055_MARK LOGO: CGS
SC1055_MAGNETIC: N = NO MAGNETIC MATERIAL
SC1055_STABILITY: B = PROBABLY HOLD POSITION/ELEVATION WELL
SC1055_SATELLITE: THE SITE LOCATION WAS REPORTED AS SUITABLE FOR GPS
SC1055
SC1055  HISTORY     - Date      Condition          Report By
SC1055  HISTORY     - 1962      MONUMENTED         CGS
SC1055  HISTORY     - 20070325  GOOD               USPSQD

RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1998 (CLS)
THE STATION IS LOCATED ABOUT 4.0 KM (2.50 MI) EAST OF ASTORIA, AT THE U.S. COAST GUARD BASE
TONGUE POINT, IN TOP OF THE EAST END OF THE CONCRETE SEAWALL ON THE SOUTH SIDE OF THE PIER.
OWNERSHIP--U.S. COAST GUARD, TONGUE POINT FACILITY, ASTORIA, OR 97103-2099.  CONTACT OFFICER
THE DAY PHONE 503-325-2378.  TONGUE POINT JOB CORPS CENTER MANAGER IS GEORGE SABOL, PHONE 503
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N

#7

25-

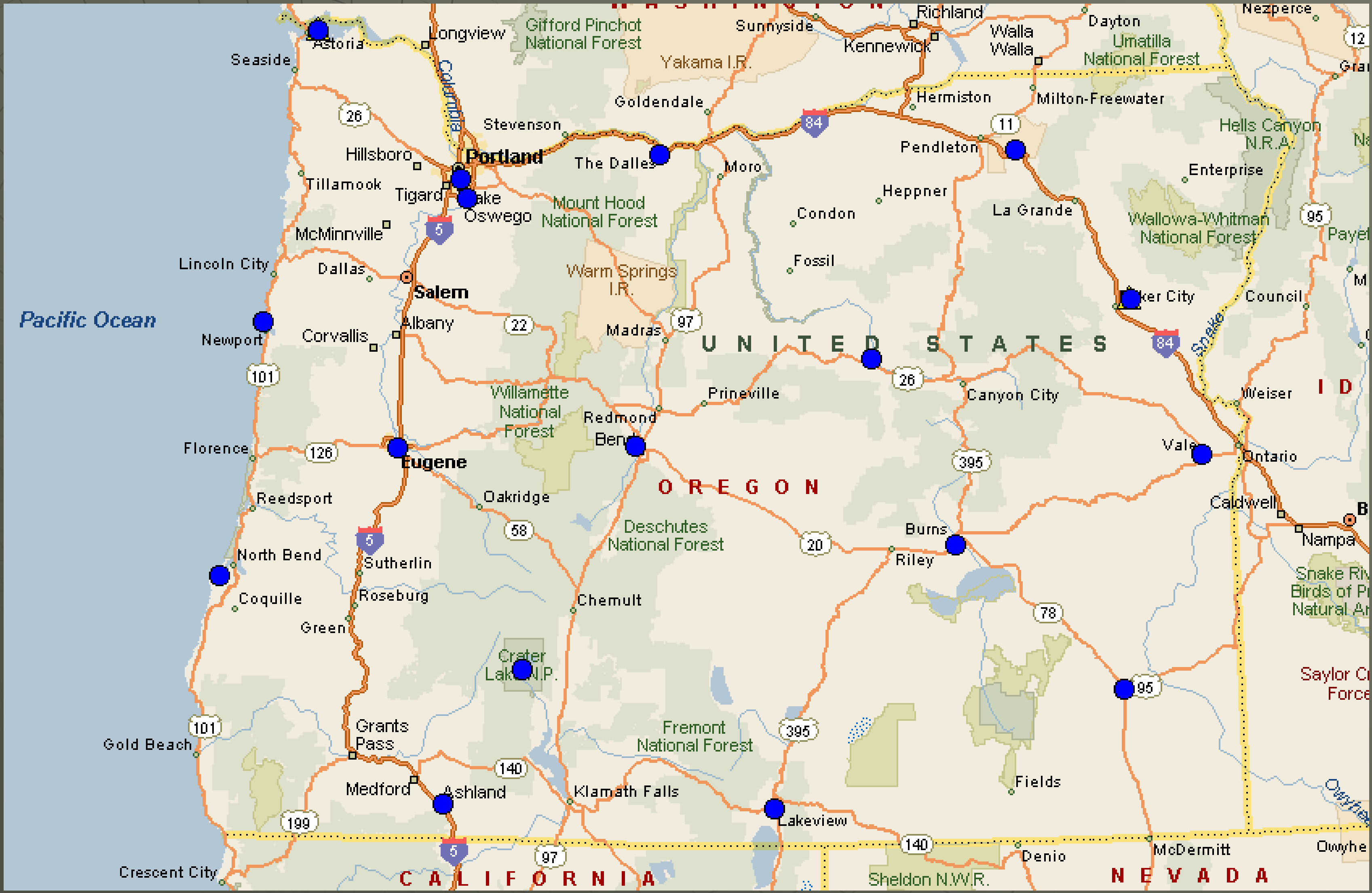
old flag pole down, but distance from base of flag pole correct

station is 2.6 m NW of NEW FLA

The Process

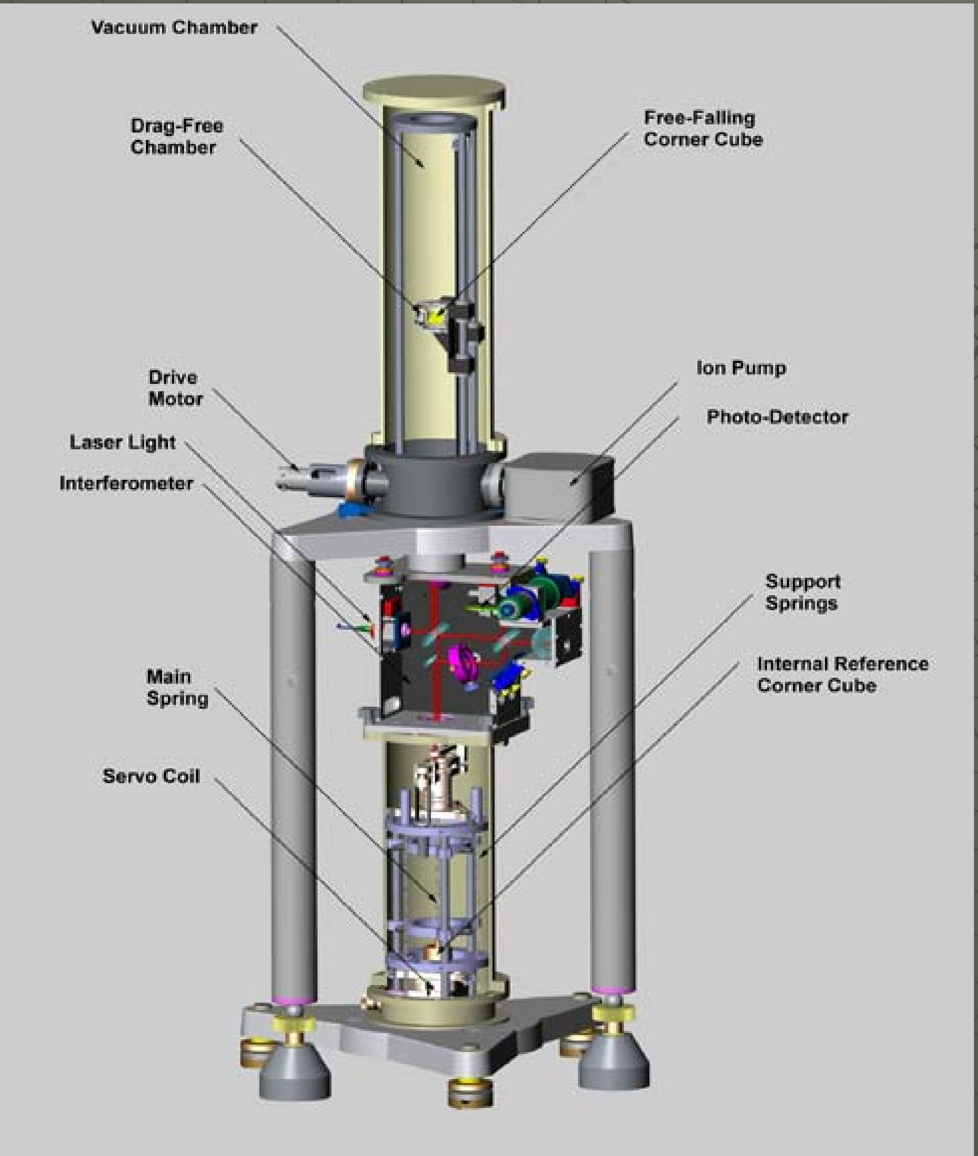
- Absolute gravity measured by Dan Winester, NGS
- Transfer absolute gravity reading to ground w/relative meter
- Transfer absolute ground to Excenter
- Search for Old Gravity Stations
- Run relative loops from Excenter to previously observed stations (double run)

Absolute Sites



Absolute Gravimeter

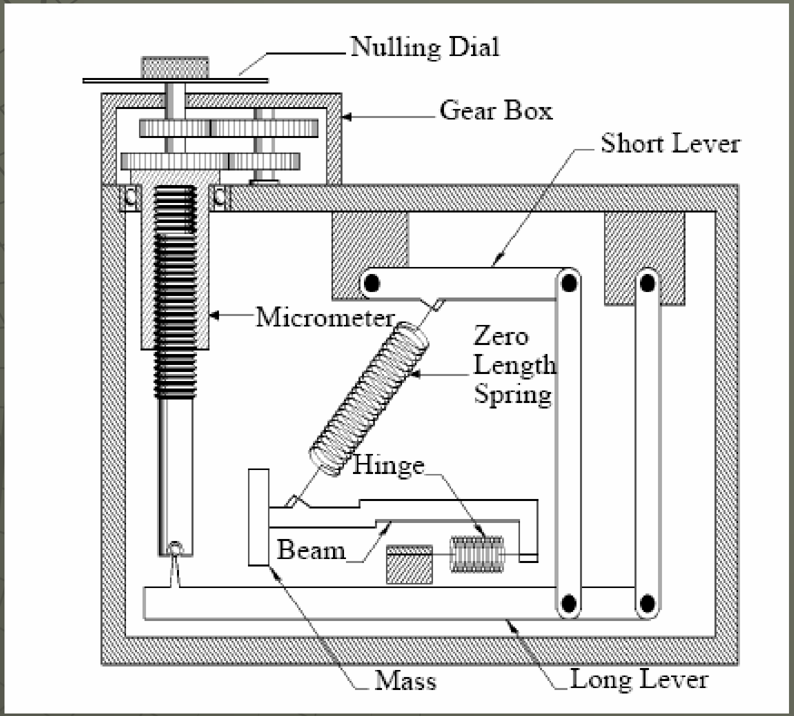
Absolute Gravimeter



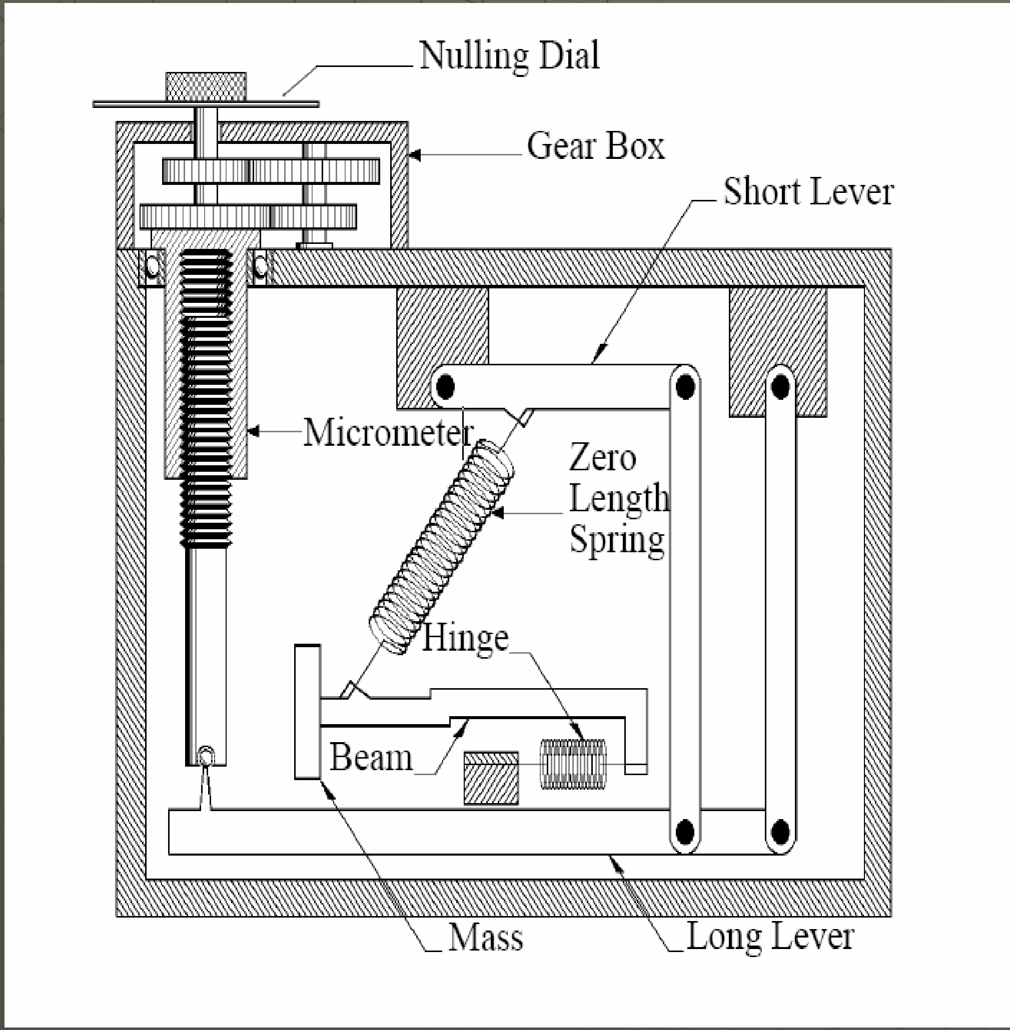
- Basically an accelerometer
- The descent of a free-falling object inside of the absolute gravimeter is monitored very accurately with an accurately timed laser interferometer
- Accuracy: 2 microGal (observed agreement between FG5 instruments)

Transferring Gravity to the Ground

Relative Gravimeter

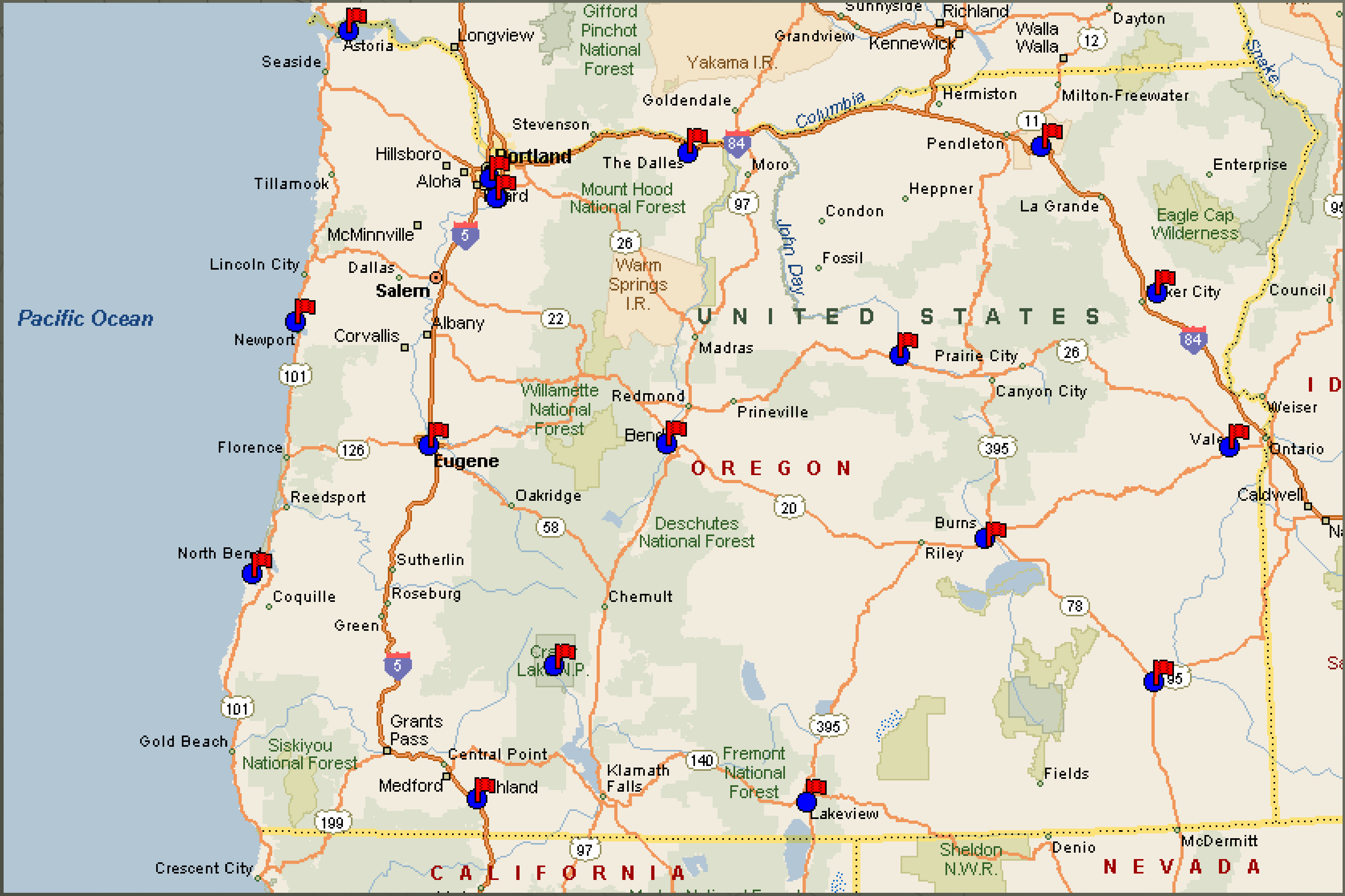


Relative Gravimeter



- A spring used to counteract the force of gravity pulling on an object.
- The change in length of the spring may be calibrated to the force required to balance the gravitational pull on the object.

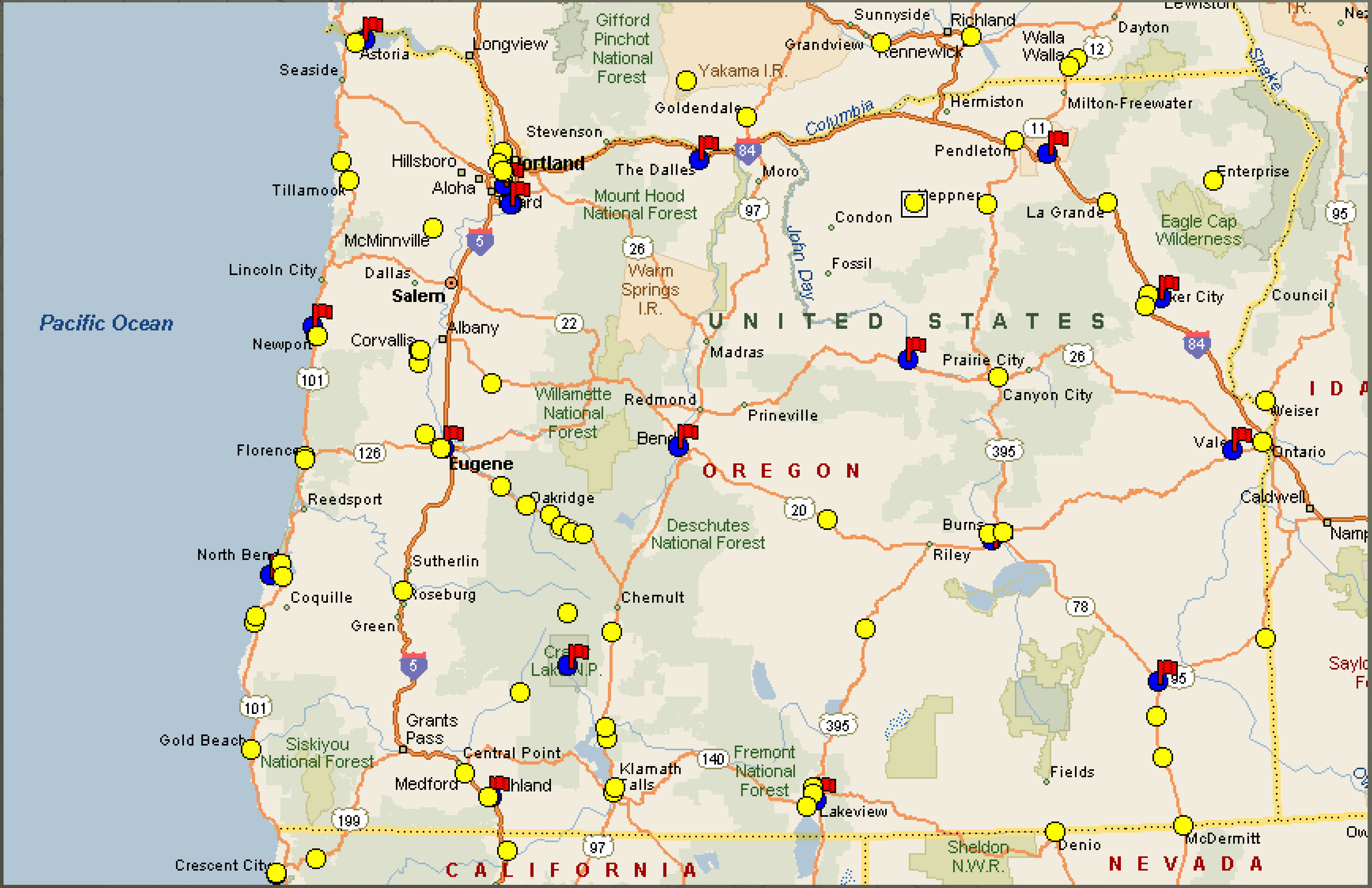
Excenters



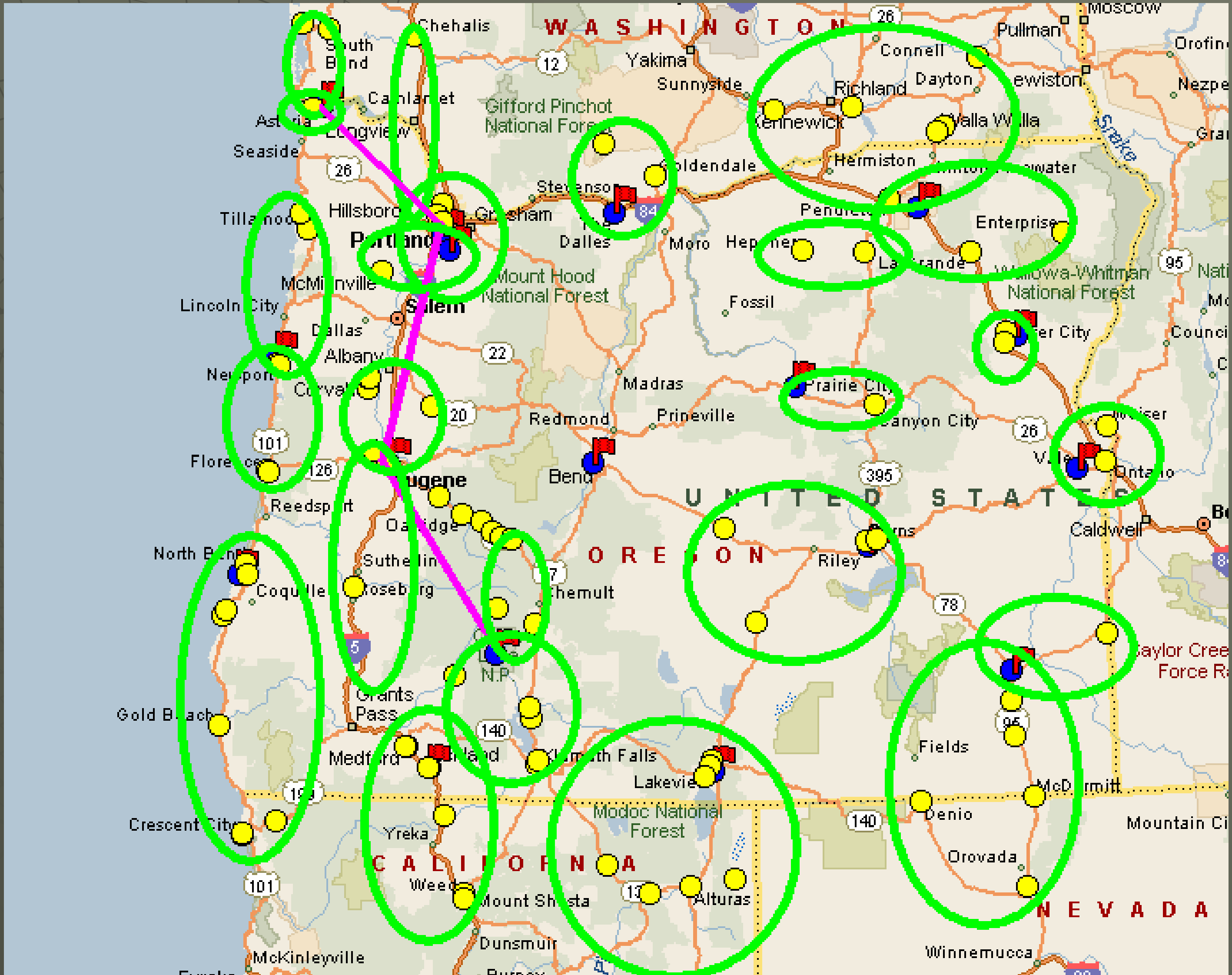
Pacific Ocean
Astoria
Seaside
Longview
Gifford Pinchot National Forest
Yakama I.R.
Richland
Kennewick
Grandview
Walla Walla
Dayton
Hermiston
Milton-Freewater
Goldendale
Stevenson
Columbia
Pendleton
Portland
Hillsboro
Aloha
Tillamook
The Dalles
Moro
Mount Hood National Forest
Heppner
Condon
La Grande
Enterprise
Eagle Cap Wilderness
McMinnville
Lincoln City
Dallas
Salem
Fossil
John Day
Warm Springs I.R.
Newport
Corvallis
Albany
Madras
UNITED STATES
Prairie City
Canyon City
Council
Weiser
Ontario
Caldwell
Willamette National Forest
Redmond
Prineville
Florence
Eugene
OREGON
Reedsport
Oakridge
Deschutes National Forest
Burns
Riley
North Bend
Coquille
Sutherlin
Roseburg
Chemult
Green
Grants Pass
Gold Beach
Siskiyou National Forest
Central Point
Medford
Klamath Falls
Fremont National Forest
Lakeview
Fields
Sheldon N.W.R.
Denio
McDermitt
Crescent City
CALIFORNIA
NEVADA

Transferring Absolute to Excenter

Relative Sites



2007 Planning



Searching for Gravity Stations

- Very Old Poorly Written Descriptions
- Many were not Monumented
- 100+ Stations to Measure
- Lots of Driving and Long Days
- Three Months to Complete the State

The elevation of the knife edge was 2,091 feet, based on city bench mark 2,089.7.
The knife edge was 2 feet below the ground surrounding the building.

U. S. 79, Boise, Idaho (Ada County, H. D. King, 1910).—Station is located at Boise, in the new (1908) east wing of the high school at Tenth and Washington Streets, in the boys' dressing room in the south part of basement, directly beneath the Tenth Street entrance. The receiver was mounted on three bricks, each cemented to the concrete floor. use of room?

The elevation of the knife edge was 2,697 feet, based on the elevation of the Oregon Short Line Railroad tracks in front of depot. The knife edge was about 10 feet below the surface of the ground surrounding the building.

U. S. 80, Astoria, Oreg. (Clatsop County, H. D. King, 1910).—Station is located at Astoria, at the southeast corner of the intersection of Lafayette and Chemanus Streets, in the Federal building (customhouse and post office), in the northwest part of the basement. The receiver was mounted on three bricks, each cemented to the concrete pier in a temporary room.

The elevation of the knife edge was 8.4 feet above mean half tide.
The knife edge was 5 feet below the surface of the ground immediately surrounding the building.

– station destroyed
this 1873 bldg. replaced at same location in 1923

U. S. 81, Sisson, Calif. (Siskiyou County, H. D. King, 1910).—Station is located at Berryvale, at the Sisson Tavern about 1 mile west and ¼ mile south of Sisson railroad station, in the basement under the southwest corner of the main part of the building. The receiver was mounted on a concrete pier in a temporary room.

The elevation of the knife edge was 3,439 feet, based on the elevation of the railroad track at Sisson.
The knife edge was 1 foot above the surface of the ground on the west side of the building and 4 feet below the surface on the east side.

U. S. 82, Rock Springs, Wyo. (Sweetwater County, H. D. King, 1910).—Station is located at Rock Springs, at the city hall, in the basement, in a room just east of boiler room near the middle of the southeast side.

The receiver was mounted on a low concrete pier.
The elevation of the knife edge was 1,909.5 meters, based on bench mark N 3 (on the city hall). MQ 6160
The knife edge was 2 feet below the ground surrounding the building.

U. S. 83, Paxton, Nebr. (Keith County, H. D. King, 1910).—Station is located at Paxton, at the Globe Hotel, in the southeast corner of the cellar under the storehouse at the rear. The receiver was mounted on three bricks, each cemented to the concrete floor.

The elevation of the knife edge was 3,056 feet, based on bench mark 3060 (U.S.G.S.). MM 0208
The knife edge was 1.5 feet below the surface of the ground surrounding the hotel.

U. S. 84, Bureau of Standards, D. C. (Washington, D. C., W. H. Burger, 1910).—Station is located at Washington, in room No. 16 in the Physical Laboratory or Main Building of the Bureau of Standards. The room is near the center of the basement and without windows, its only door being almost directly opposite the

Excenter to Existing Gravity Stations around the state

ODOT put us up in some of the best places

Precise Leveling in Oregon

- Preservation and replacement of Benchmarks in Oregon
- Run levels to stations of the Oregon Real-time GPS Network as part of Height Modernization program.
- "Potential for localized geoid slopes to be directly determined from field surveys of **co-located (space and time) leveling and GPS**." NGS National Gravity Survey Plan

Precise Leveling

- Acquired all equipment
  - First order Leica DNA-03 level
  - Invar rods
  - Invar 60 cm strip (for vertical Bm's)
  - Thermisters
  - Turtles
  - Turning Pins
- Acquired Training
  - NGS Precise Leveling Workshop
  - Curt Smith, NGS State Advisor tutorial provided on-project training

Stanford Linear Accelerator Center

Vertical Comparator for the Calibration of Leveling Equipment

- A fully automated vertical comparator for the calibration of digital levels and invar staffs
- Developed by the Metrology Department in cooperation with the Institute of Engineering Geodesy and Measurement Systems at the Graz University of Technology.
- The vertical comparator was built in 2003 in the SLAC Metrology laboratory

Oregon Real-time GPS Network

www.TheORGN.net

Administrator

- Oregon Department of Transportation
  - Geometronics Unit
- Program Manager: Ron Singh
- Technical Manager: Ken Bays
- ORGN Support: Randy Oberg

Administrator Responsibilities

- Network quality control
- Network software operation
- Network software maintenance and upgrades
- User support

Major Cooperators & Support

- NGS
- UNAVCO Plate Boundary Observatory
- Washington State Reference Network
  - Exchange of raw GPS data streams across the Columbia River.
- California and Idaho as their networks develops

Partners

- Partners will provide sites, GPS equipment, and other major infrastructure to the network.
  - Government agencies
    - Inter-Governmental Agreements
  - Private entities
    - Public-Private Partnerships

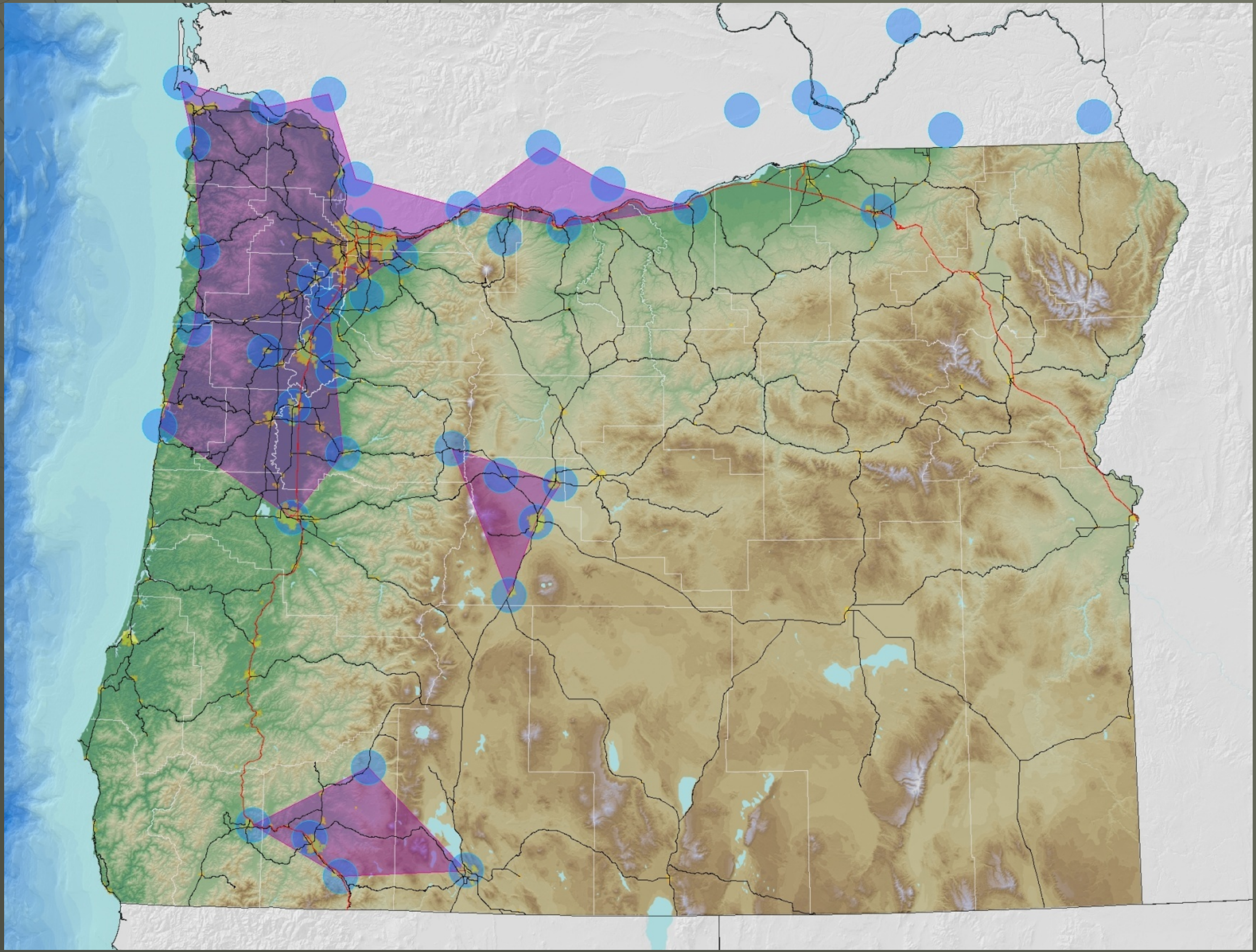
Some, but not all, of our Interested Partners

OBEC Consulting Engineers	Yamhill County
Polk County	City of Salem
Deschutes County	Clackamas County
EWEB	Marion County OR
City of Beaverton	Jackson County
City of Newberg	Lane County
Washington County	Tualatin Valley Water District
City of Springfield	Port of Portland
Curry County	Oregon State University
Washington DOT	City of Wilsonville
City of Bend	Clatsop County
Linn County	Douglas County
David Evans & Associates	Portland Water Bureau
Lincoln County	Benton County
Multnomah County	Oregon Parks and Recreation Department
Oregon Division of Aviation	

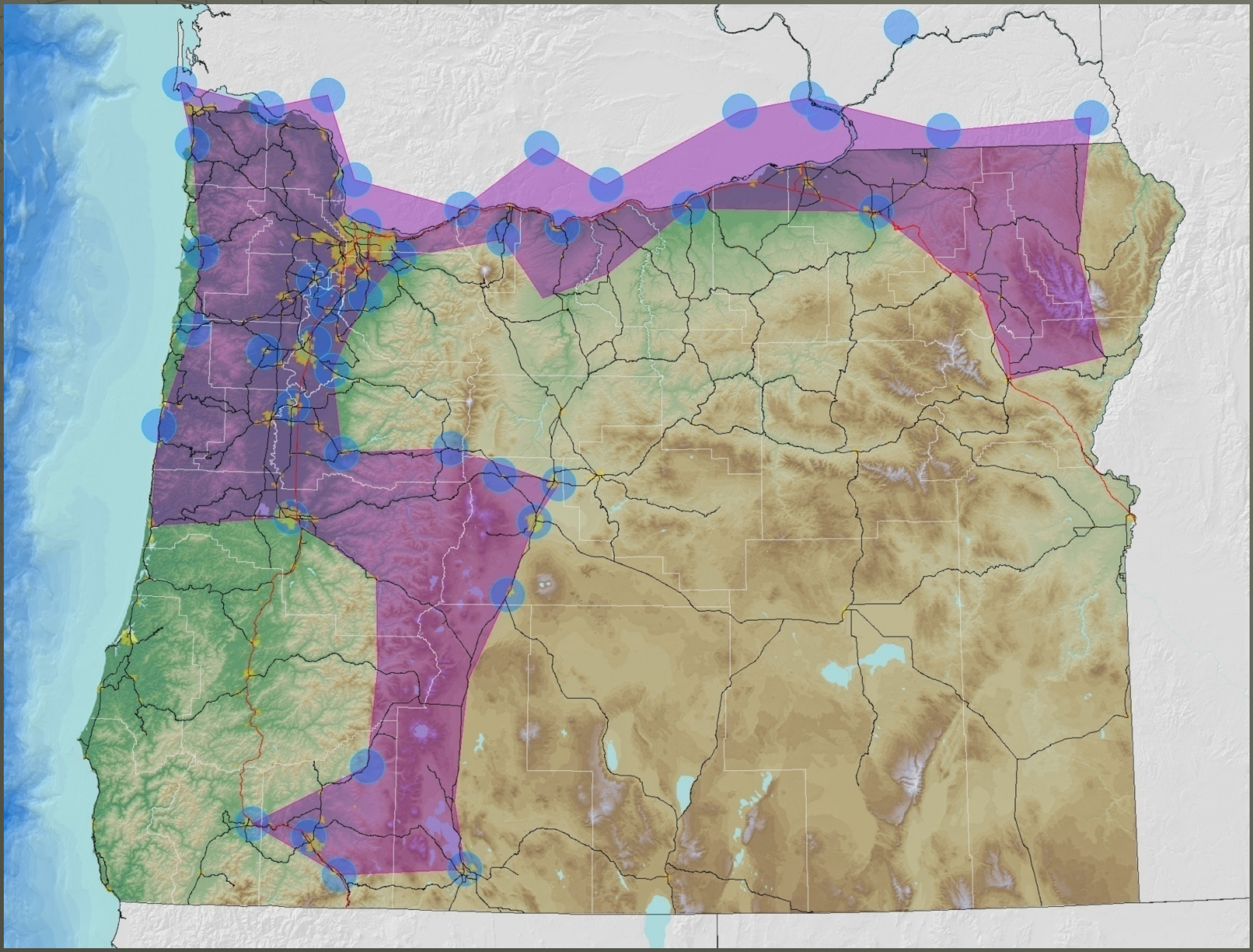
Subscribers

- Anyone who is not a partner and wants access to RTK correctors data from the ORGN.
- Must have rover account set up
  - No direct fee at this time
  - Online rover account application at www.TheORGN.net
- May have minimal fee in future to cover operation, maintenance, and upgrades, but not to cover the build of the infrastructure of the network.

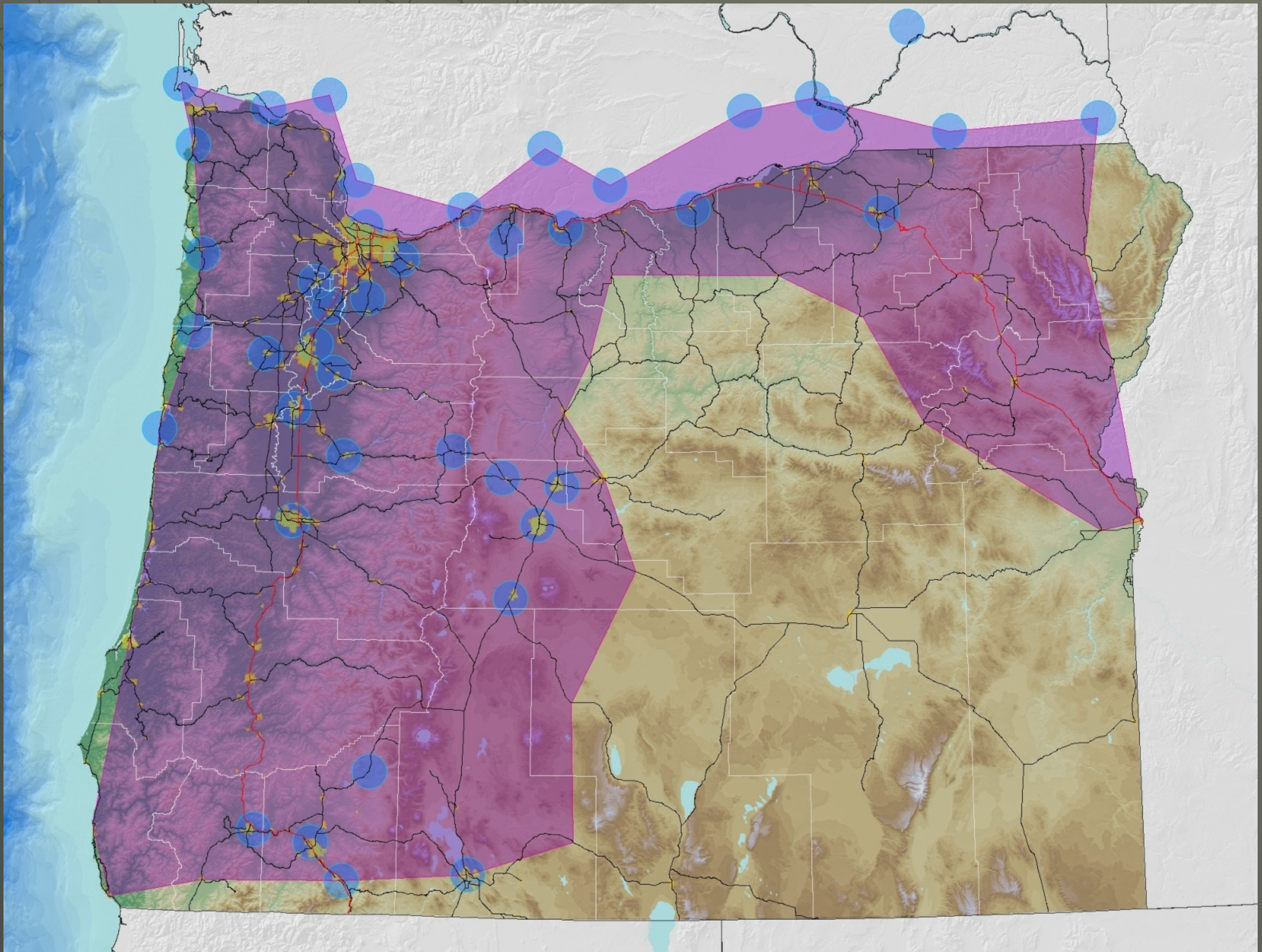
September 2008



December 2008



July 2009



Can I Trust the ORGN for Accurate GPS Positions?

Installation

- Pre-testing of Positions
- Extreme Care
- Sturdy Antenna Mounts

- Carefully Calculated Positions
- Constant Monitoring of Antenna Positions
- Precise Emphemeris used for Correctors

Site Criteria Standards

- 60 Km Station Spacing
- Satellite visibility: clear view of sky
- No electromagnetic interference
- Pre-installation data quality sets: 3 days of GPS data
- Continuous power w/ backup
- Internet connectivity

Quality Testing:

```
CycleSlips:          Pass   (Value 142 slips, Threshold 240 slips)
Multipath:              Pass   (Value 0.25m MP1 / 0.26m MP2, Threshold 1.5 m
DataCompleteness:       Pass   (Value 99.4 %, Threshold 95.0 %)
EpochsWithData:      Pass   (Value 100.0 %, Threshold 99.0 %)
NavData:             Pass
Format:              Pass
RX Clock:            Pass
Other:               Pass
```

Quality Testing:

CycleSlips:	Fail	(Value 420, Threshold 199)
Multipath:	Pass	(Value 0.21m MP1 / 0.26m MP2, Threshold 1.5 m)
DataCompleteness:	Pass	(Value 99.7 %, Threshold 95.0 %)
EpochsWithData:	Pass	(Value 100.0 %, Threshold 99.0 %)
NavData:	Pass	
Format:	Pass	
RX Clock:	Pass	
Other:	Pass	

Solid Antenna Mounts

ORGN Coordinates

NAD83(CORS96)(Epoch2002)

	A	B	C	D	E	F	G	H	I	J	K
1	ORGN CORS NETWORK										
2		ASHL	LEIAT504 LEIS								
3		2006-07	N 42-10	W 122-40	(meters)	ERROR (reading-mean)					
4	Ephem	JulianDay	LAT	LONG	ELLIP. EL.	N(v)	E(v)	El.(v)	N(v2)	E(v2)	EL.(v2)
5	P	318	50.47055	12.55213	609.16000	0.0000	0.0000	0.0052	0.00000	0.00000	0.00003
6	P	321	50.47062	12.55210	609.15300	0.0000	0.0000	-0.0018	0.00000	0.00000	0.00000
7	P	330	50.47058	12.55207	609.15600	0.0000	0.0000	0.0012	0.00000	0.00000	0.00000
8	P	334	50.47056	12.55201	609.16100	0.0000	-0.0001	0.0062	0.00000	0.00000	0.00004
9	P	335	50.47056	12.55202	609.15800	0.0000	-0.0001	0.0032	0.00000	0.00000	0.00001
10	P	340	50.47056	12.55206	609.15100	0.0000	0.0000	-0.0038	0.00000	0.00000	0.00001
11	P	344	50.47043	12.55208	609.15400	-0.0001	0.0000	-0.0008	0.00000	0.00000	0.00000
12	P	347	50.47058	12.55208	609.15300	0.0000	0.0000	-0.0018	0.00000	0.00000	0.00000
13	P	350	50.47057	12.55209	609.15500	0.0000	0.0000	0.0002	0.00000	0.00000	0.00000
14	P	359	50.47062	12.55217	609.15500	0.0000	0.0001	0.0002	0.00000	0.00000	0.00000
15	P	1	50.47066	12.55208	609.14700	0.0001	0.0000	-0.0078	0.00000	0.00000	0.00006
16											
17	11-day	mean	50.47057	12.55208	609.15482	USE		sum v2	0.0000	0.0000	0.0001
18	4-day		50.47065	12.55213	609.15			/N-1	0.0000	0.0000	0.0000
19			-0.00008	-0.00005	0.00482				√ Northing	√ Easting	√ Elevation
20								Sigma =	0.0001	0.0000	0.0031
21								3 Sigma	0.0002	0.0001	0.0094
22											
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31											
32											
33											
34											

Direction and Distance - [inverses]

General

From Point Id: ASHL 11 day

To Point Id: ASHL 4 day 2006

Geodetic Azimuth:	337° 37' 26.0"
Ellipsoidal Distance:	0.0030 m
Ellipsoidal Height Diff.:	-0.0048 m
Slope Distance:	0.0057 m

Comparison of Ephemerides

- Broadcast (predicted) Ephemeris
  - Sent from GPS satellites as part of the navigation message when you are collecting data.
- Precises Emphemerides
  - Ultra-rapid Ephemeris
    - ORGN Spider software grabs Ultra Rapid Emphemeris every few hours and applies to RT correctors transmitted by the ORGN.
  - Rapid Ephemeris
  - Final Precise Ephemeris

IGS Product Table [GPS Broadcast values included for comparison]					
		Accuracy	Latency	Updates	Sample Interval
GPS Satellite Ephemerides/ Satellite & Station Clocks					
Broadcast	orbits	~160 cm	real time	--	daily
	Sat. clocks	~7 ns			
Ultra-Rapid (predicted half)	orbits	~10 cm	real time	four times daily	15 min
	Sat. clocks	~5 ns			
Ultra-Rapid (observed half)	orbits	<5 cm	3 hours	four times daily	15 min
	Sat. clocks	~0.2 ns			
Rapid	orbits	<5 cm	17 hours	daily	15 min
	Sat. & Stn. clocks	0.1 ns			5 min
Final	orbits	<5 cm	~13 days	weekly	15 min
	Sat. & Stn. clocks	<0.1 ns			5 min

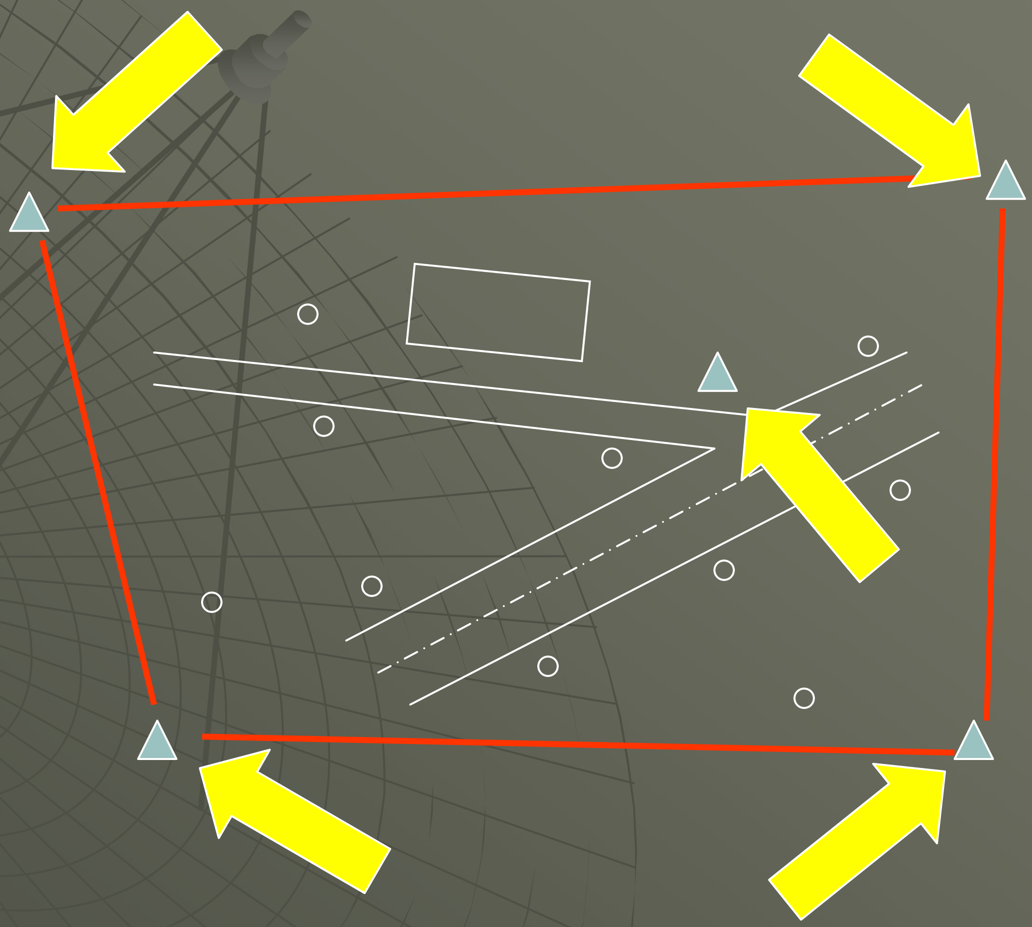
FAQ: Why am I not Hitting my Old Control Points when using correctors from the ORGN?

Outreach/Education

- OSU Workshop: Using the ORGN: Feb 2008
- PLSO Conference: Getting Started with the ORGN:March 2008
- ODOT Surveyors Conference: April 2008

Site Calibration

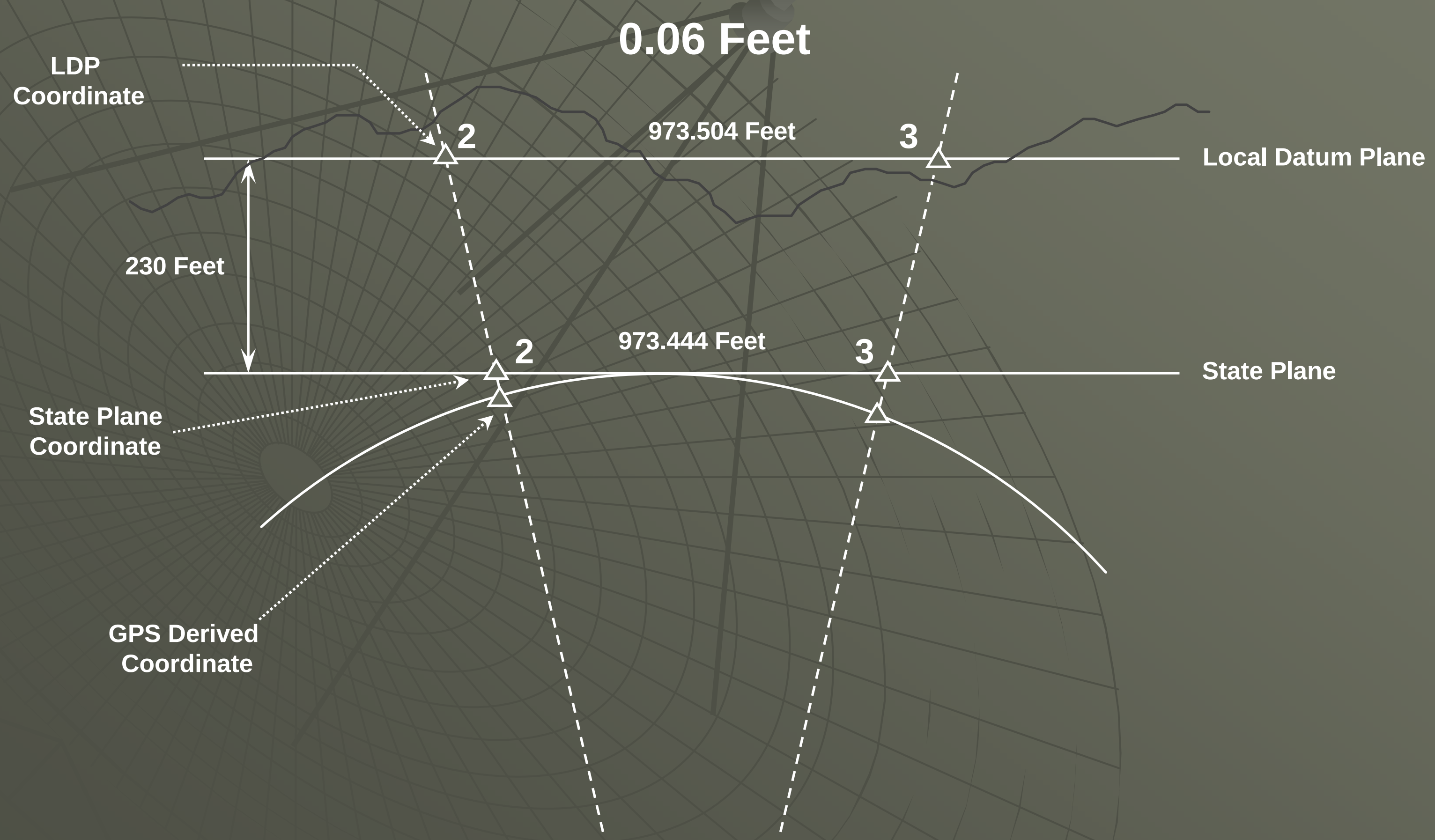
- Calibrate to points that surround the project that have coordinates known in the local system.
- Occupy calibration points with GPS while receiving real-time correctors from the ORGN, then calibrate to the local system.



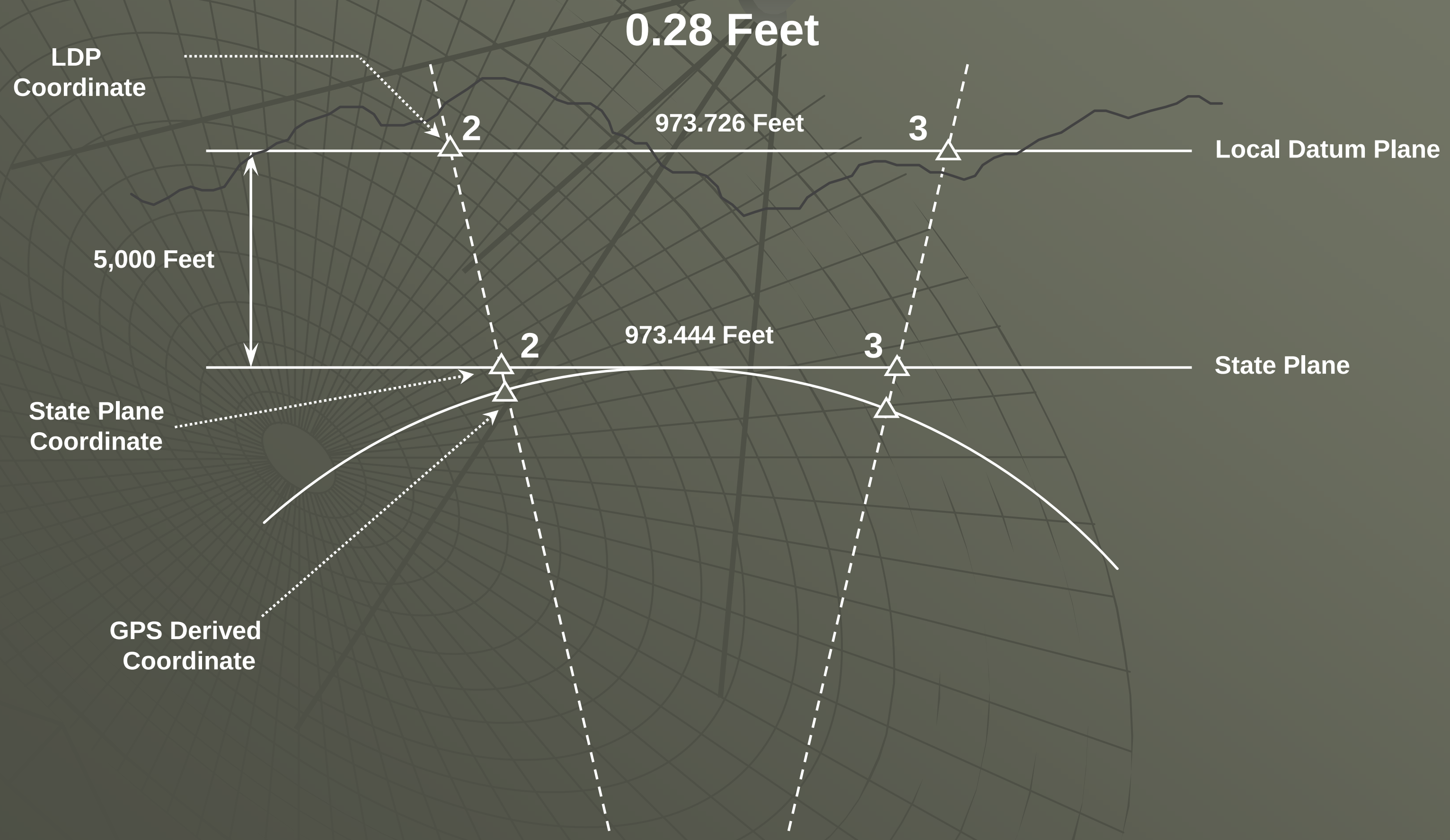
FAQ: Why am I not hitting published HARN positions when I use correctors from the ORGN?

- NGS has adopted a realization of NAD 83 called NAD 83 (NSRS 2007) for over 70,000 passive monuments (HARN brass caps).
- “This realization approximates (but is not, and can never be equivalent to) the more rigorously defined NAD 83 (CORS 96) in which CORS and OPUS (and Oregon Real-time GPS Network) coordinates are distributed.” NGS

Distortion Due to Elevation



Distortion Due to Elevation



Low Distortion Projections Workshop

November 4, 2008

Albany, Oregon

Co-sponsors:

- Oregon GPS Users Group
- Oregon DOT Geometronics Unit

- More info: www.ogug.net

- Ken Bays
- kenneth.bays@odot.state.or.us
- 503-986-3543
- www.TheORGN.net

NAD 83(CORS 96) and NAD 83(NSRS2007)

- NGS has adopted a realization of NAD 83 called NAD 83(NSRS2007) for the distribution of coordinates of the High Accuracy Reference Networks (HARN) ~70,000 passive geodetic control monuments.

- This realization *approximates* (but is not, and can never be, equivalent to) the more rigorously defined NAD 83 (CORS 96) realization in which Continuously Operating Reference Station (CORS) coordinates are and NGS Online Positioning User Service (OPUS) coordinates are distributed.

- NAD 83(NSRS2007) was created by adjusting GPS data collected during various campaign-style geodetic
- surveys performed between the mid-1980's and 2005.

- For this adjustment, NAD 83 (CORS 96) positional coordinates for ~700 CORS were held fixed (predominantly at the 2002.0 epoch. for the stable north American plate, but 2007.0 in Alaska and western CONUS) to obtain consistent positional coordinates for the ~70,000 passive marks, as described by Vorhauer [2007]. Derived NAD 83(NSRS2007) positional coordinates should be consistent with corresponding NAD 83(CORS 96) positional coordinates to within the accuracy of the GPS data used in the adjustment and the accuracy of the corrections applied to these data for systematic errors, such as refraction.

- In particular, there were no corrections made to the observations for vertical crustal motion when converting from the epoch of the GPS survey into the epoch of the adjustment, while the NAD 83 (CORS 96) coordinates do reflect motion in all three directions at CORS sites. For this reason alone, there can never be total equivalency between NAD 83(NSRS2007) and NAD 83(CORS 96).

- Note: NGS has not computed NAD 83(NSRS2007) velocities for any of the ~70,000 passive marks involved in this adjustment. Also, the positional coordinates of a passive mark will make reference to an “epoch date”. Epoch dates are the date for which the positional coordinates were adjusted, and are therefore considered “valid” (within the tolerance of not applying vertical crustal motion). Because a mark's positional coordinates will change due to the dynamic nature of the earth's crust, the coordinate of a mark on epochs different than the listed “epoch date” can only be accurately known if a 3-dimensional velocity has been computed and applied to that mark.