

GPS Post Processed Software Using CORS Stations – An Update

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Presentation Topics

- 2010 Census Address Canvassing Field Operations Overview
- NGS Post Processing Software Overview
- SIRF Chip Set GPS Evaluation Data Melbourne, FL
- Test Data Runs with Census Hand Held Computers
- Summary



Address Canvassing

- The Census Bureau used Hand Held Computers (HHCs) to capture GPS structure points for every housing unit during its Address Canvassing field operation
 - ❖ The Address Canvassing operation supports the 2010 Census
 - ❖ Address Canvassing is the first nationwide collection of housing unit structure points using GPS technology to be conducted by the Census Bureau
 - ❖ Field collection occurred in spring 2009
 - ❖ The HHC had Wide Area Augmentation System (WAAS) capability to increase point position accuracy to 3 meters or less in an unobstructed environment



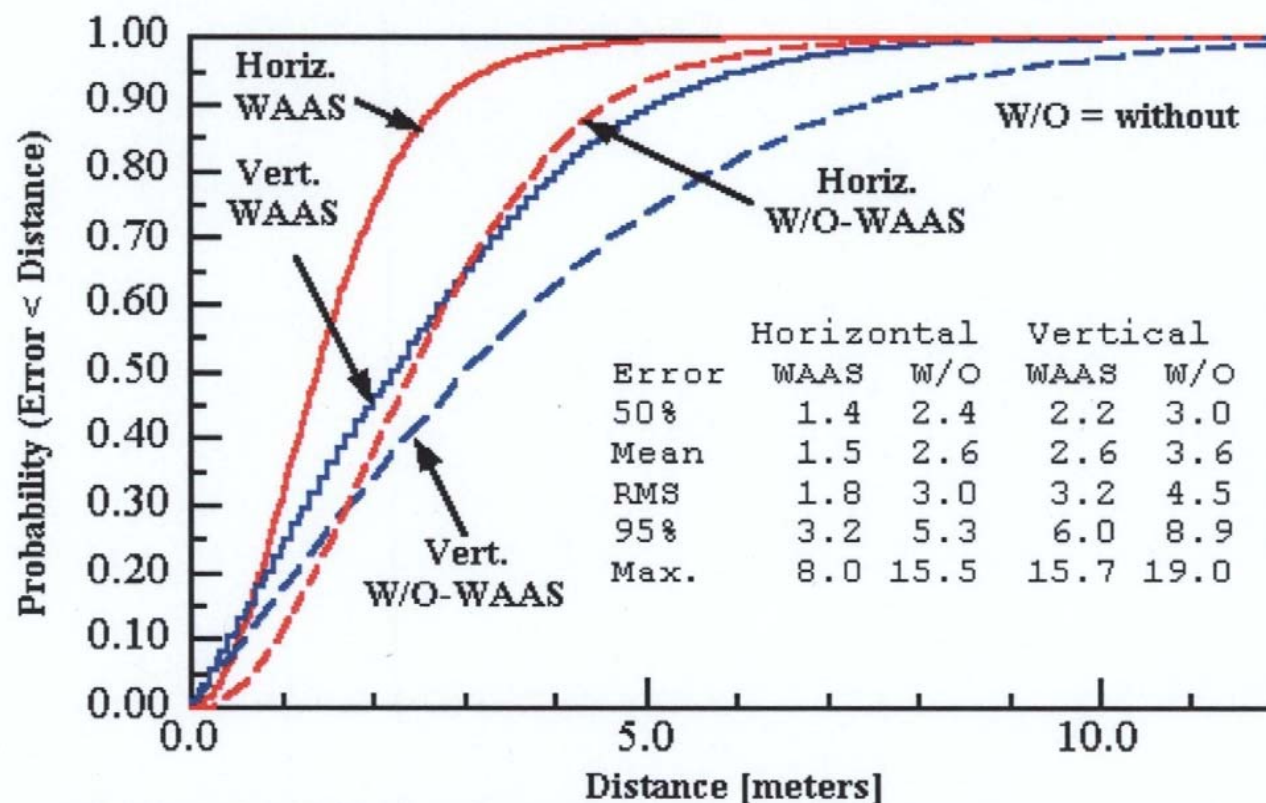
Census Bureau / NGS Partnership

- For this historical undertaking the Census Bureau has partnered with NOAA's National Geodetic survey (NGS) to extend the 3 meter accuracy coverage by post processing HHC data with Continuously Operating Reference Stations (CORS).
- NGS customized post processing software for Census Bureau.
- The NGS – provided Software has been installed on Census Bureau computers
- The Census Bureau plans to post-process the housing unit structure points in the Fall 2009



WAAS VS. NON-WAAS COMPARISON

Garmin GPSMAP 76 with GA29 antenna



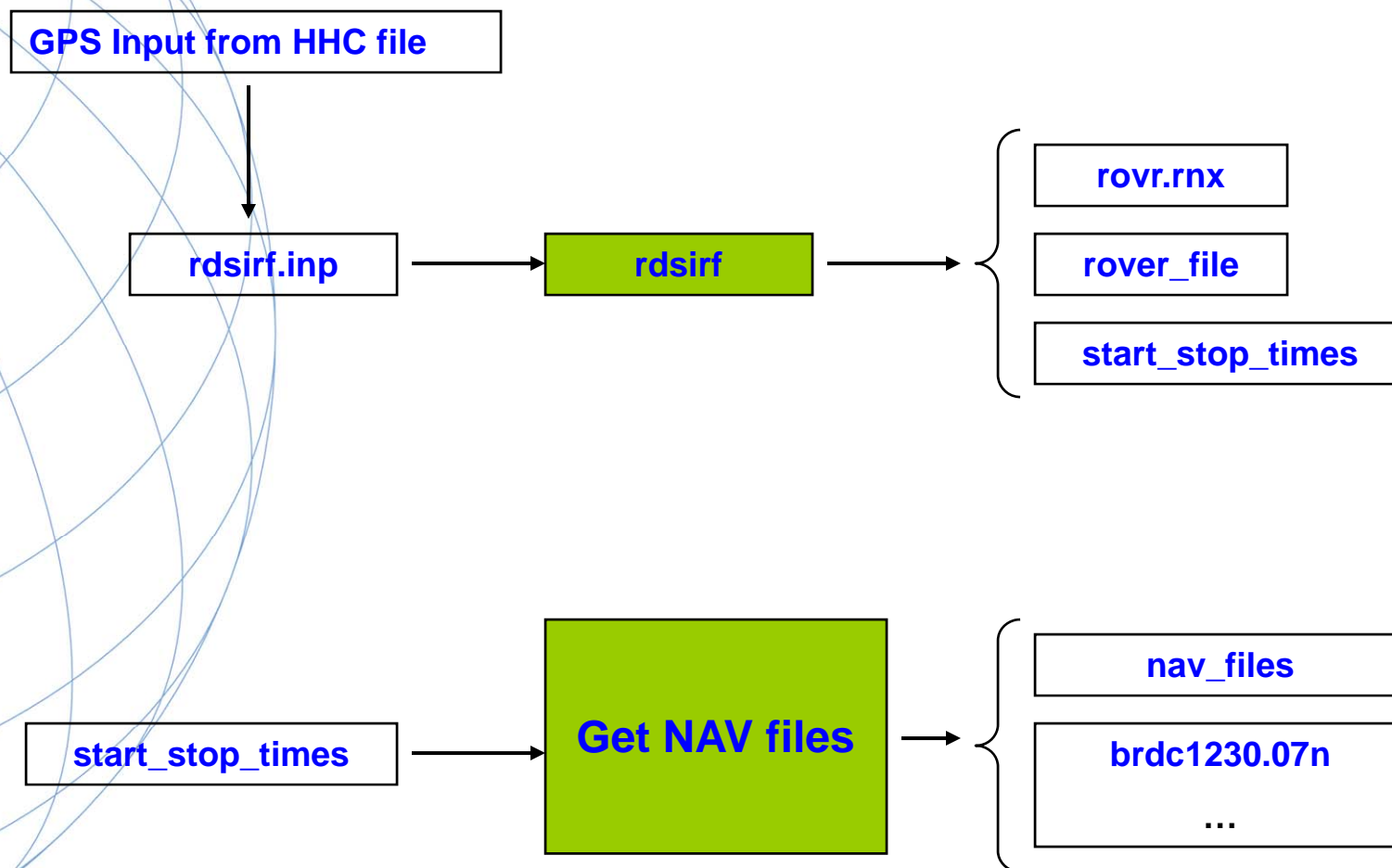
172815 samples (4 days) each session
 WAAS & Non-WAAS non-simultaneous
 Samples every 2 seconds

Note: Max. error depends greatly on the length of the observation period and is generally not a robust statistic.

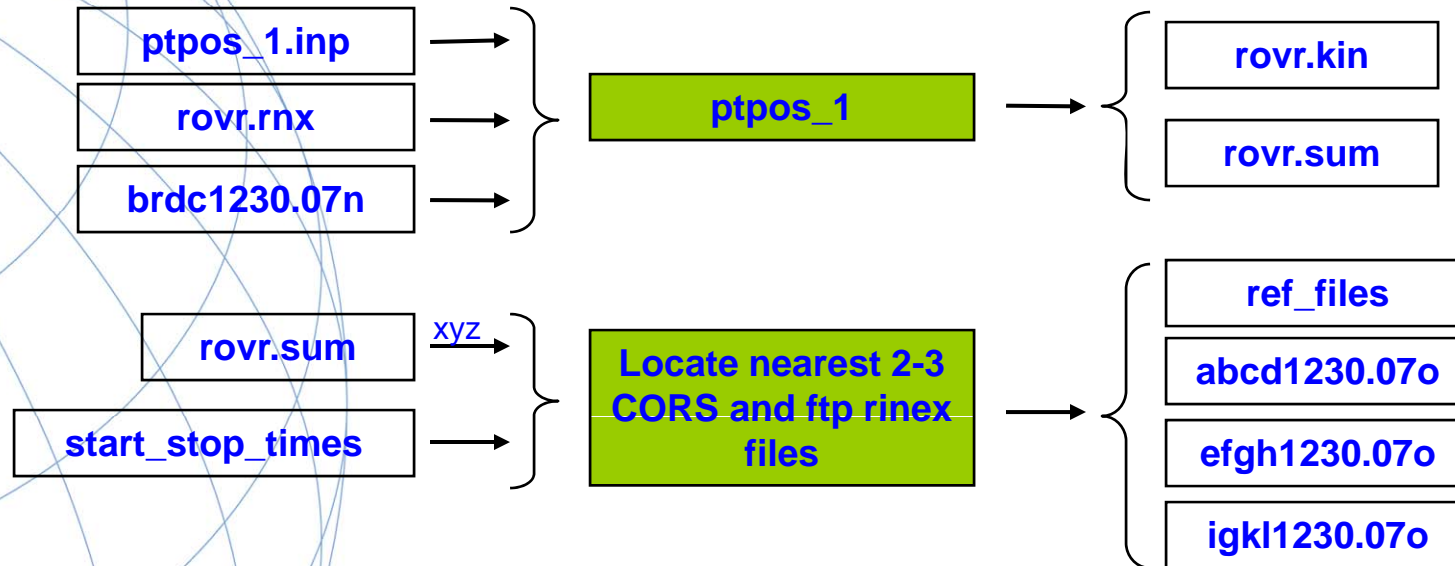
[1] Wilson, David L. *GPS WAAS Accuracy*.
<http://users.erols.com/dlwilson/gpswaas.htm>



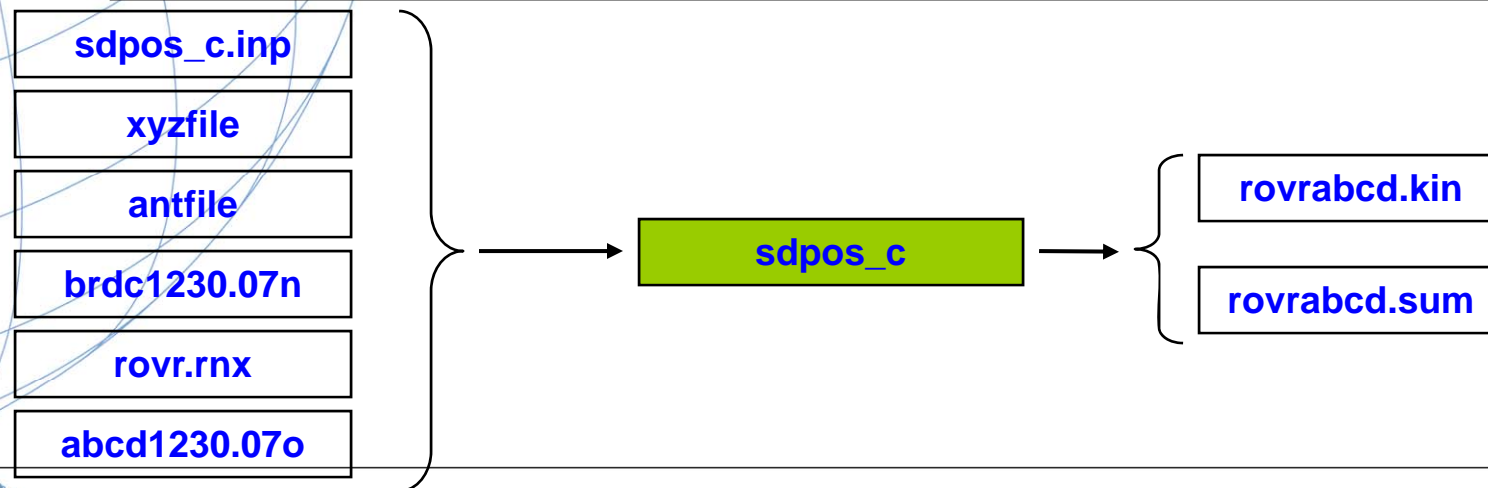
NGS Post Processing Block Diagram

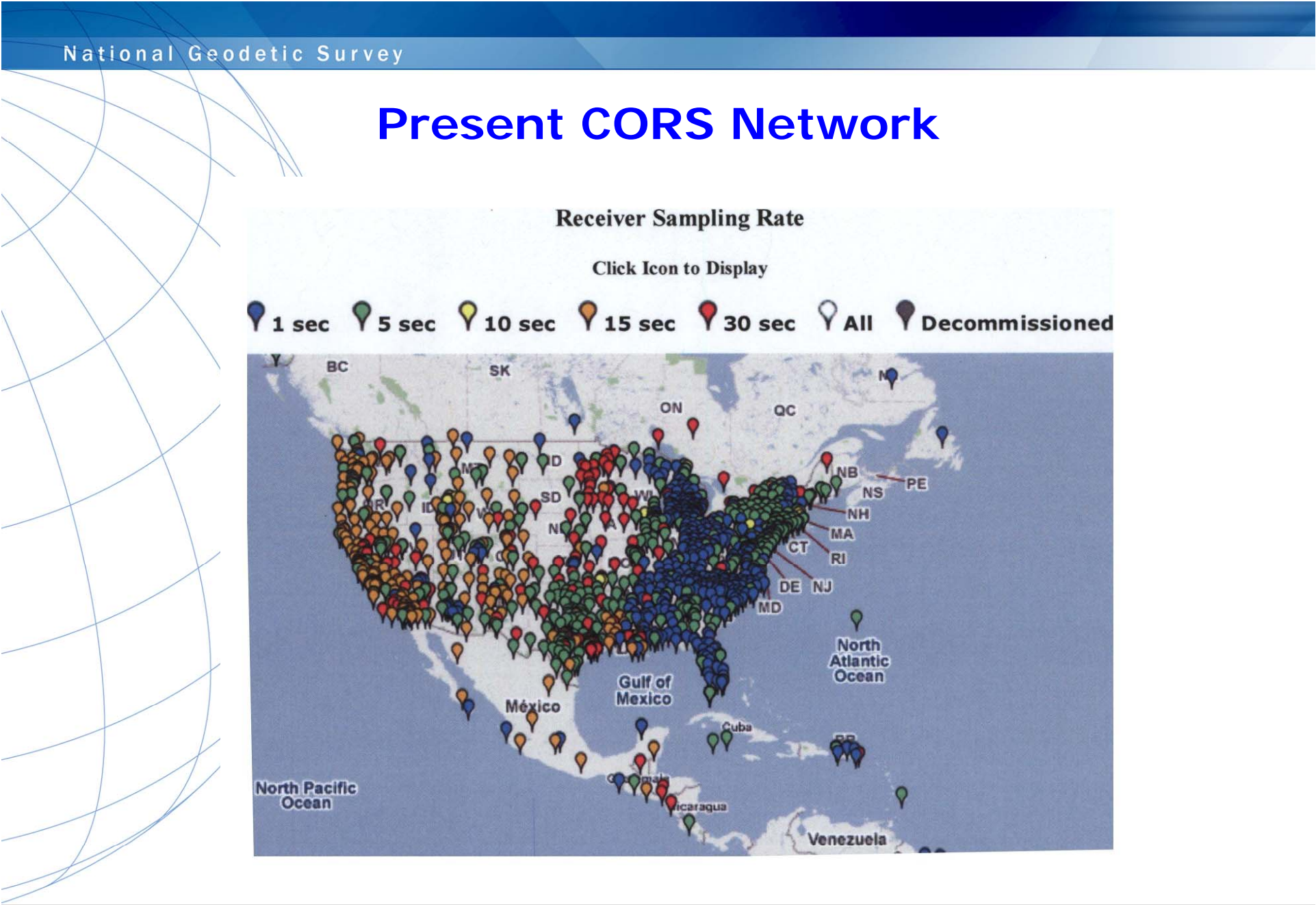



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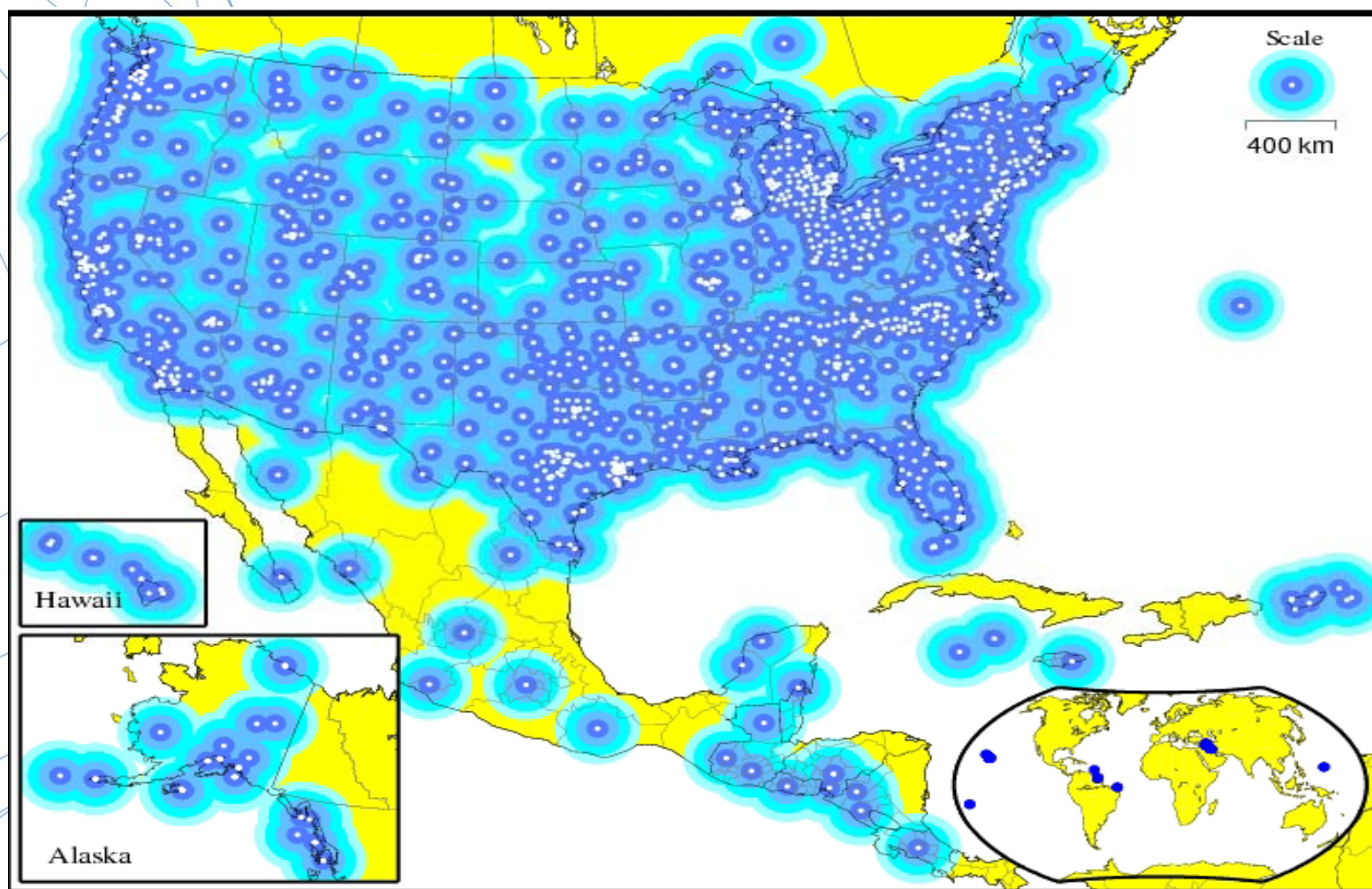


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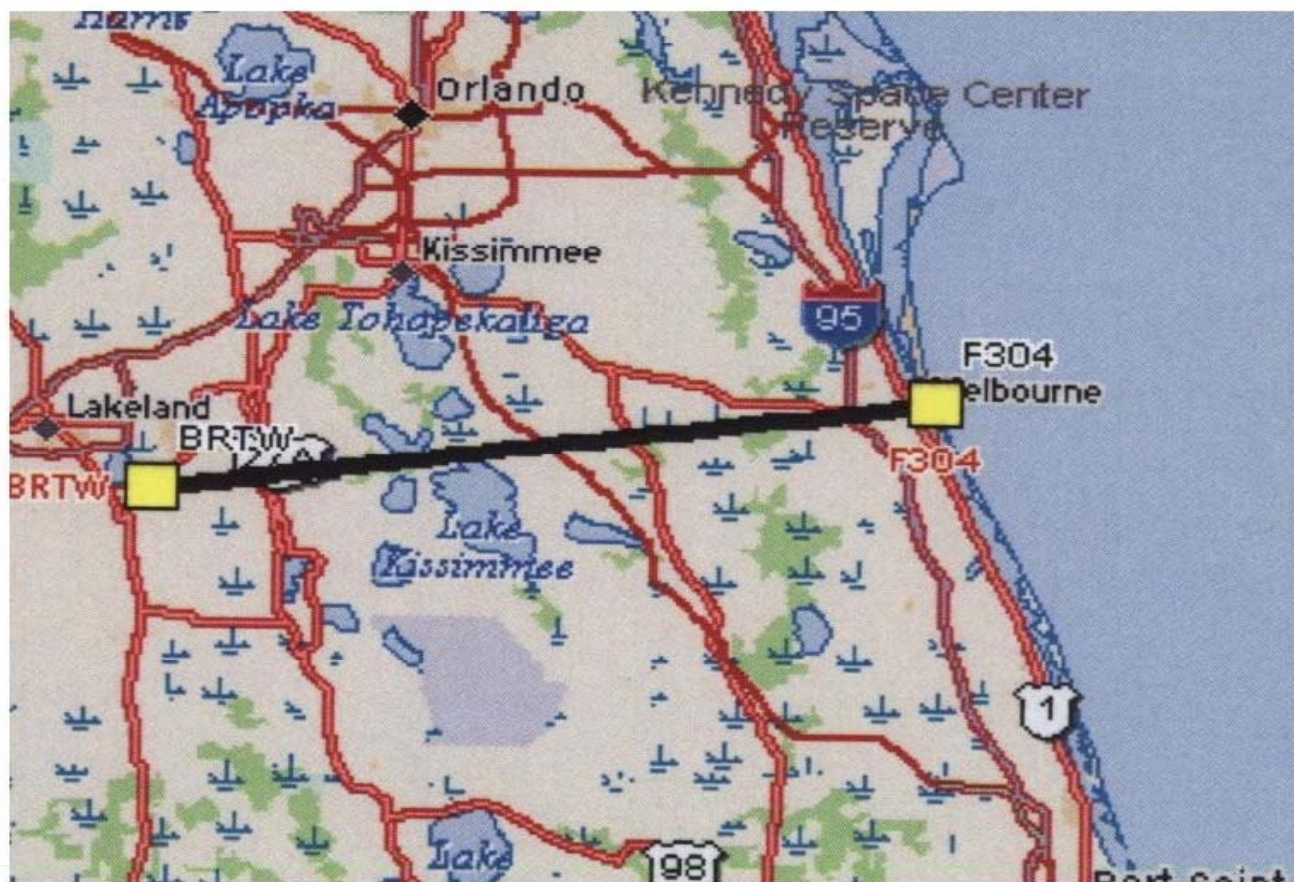


[illegible]

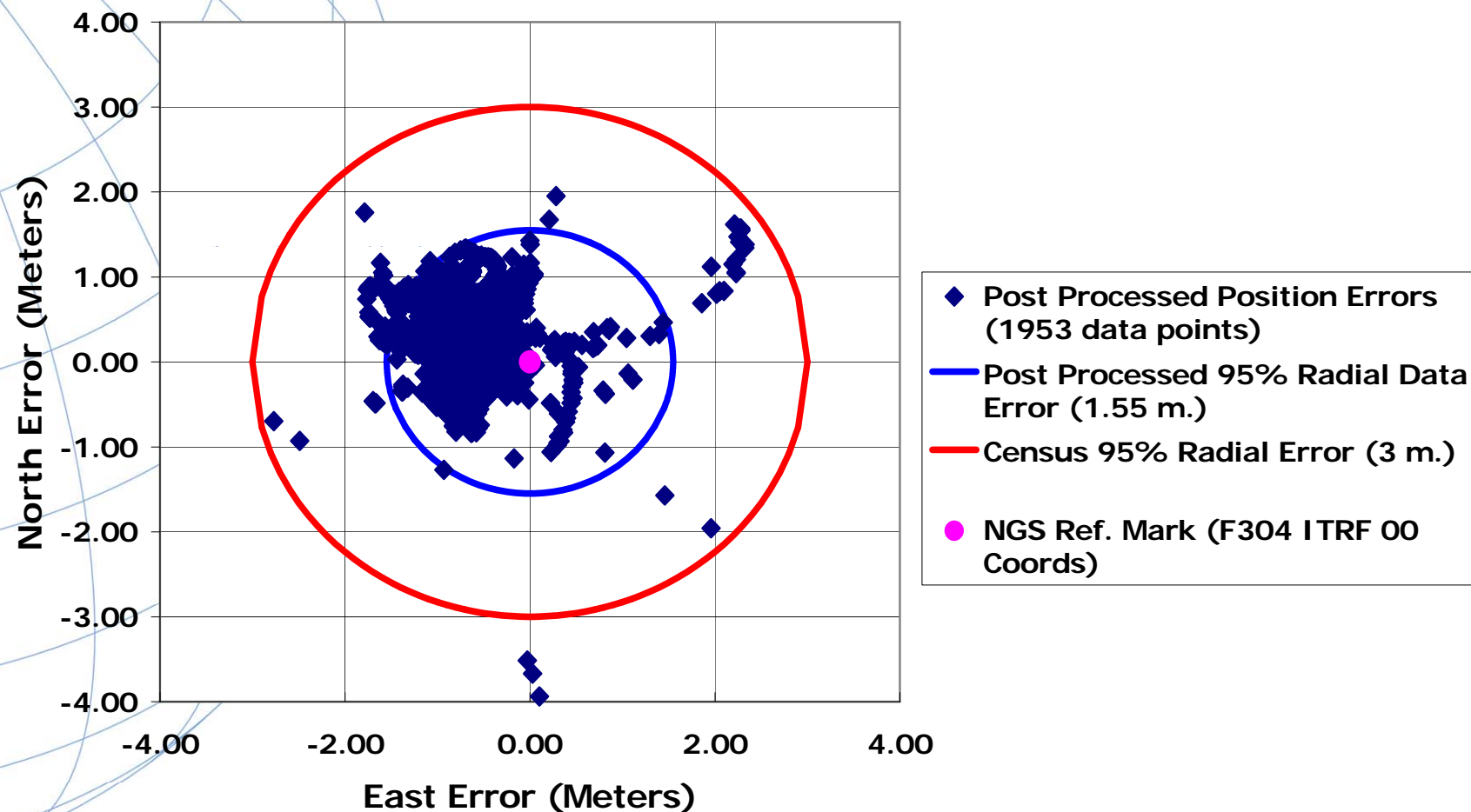
CORS Network Coverage with Reference Station Range of 200Kms



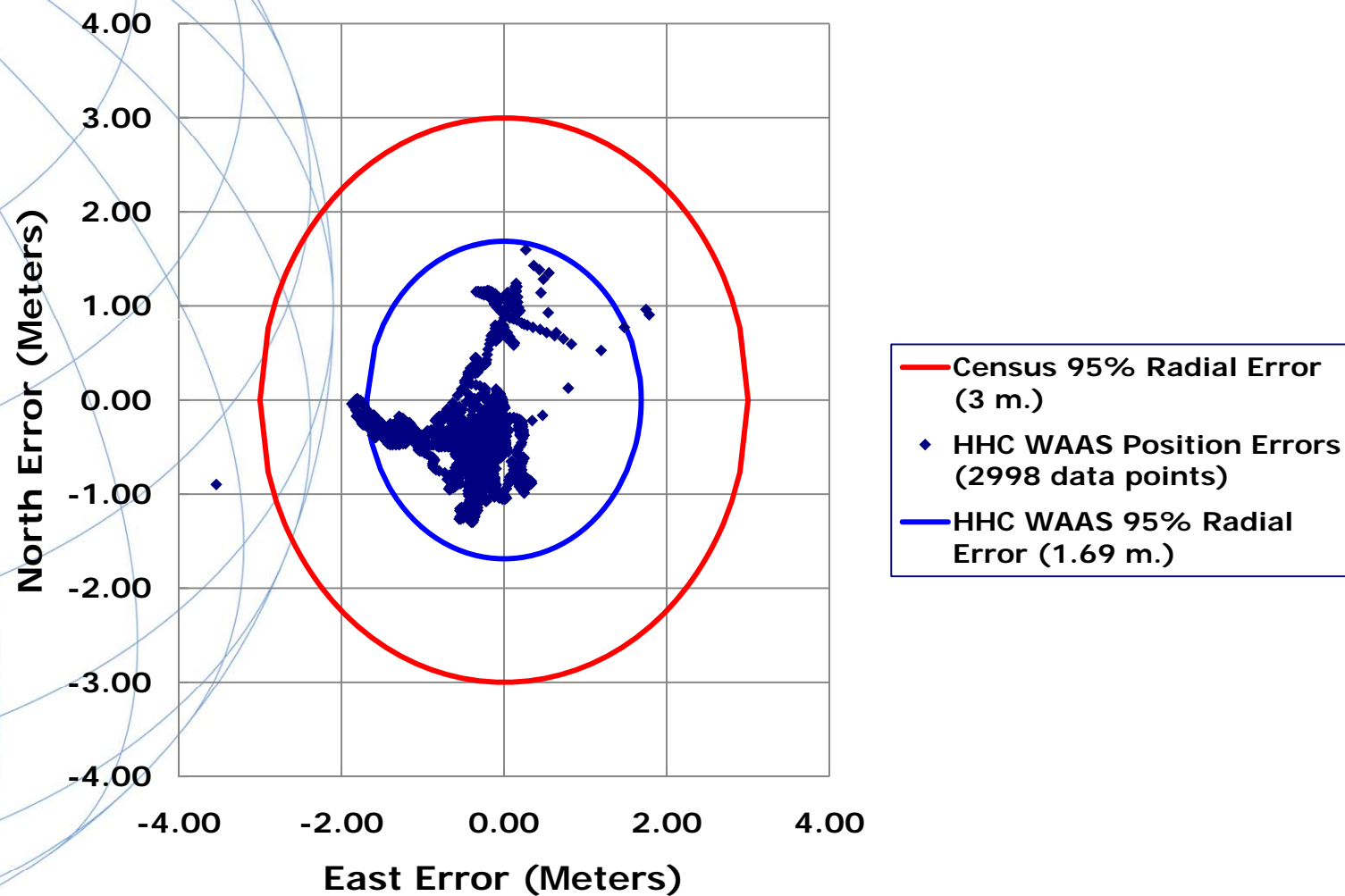
HHC Evaluation Unit Testing in Melbourne, FL 10/17/2006



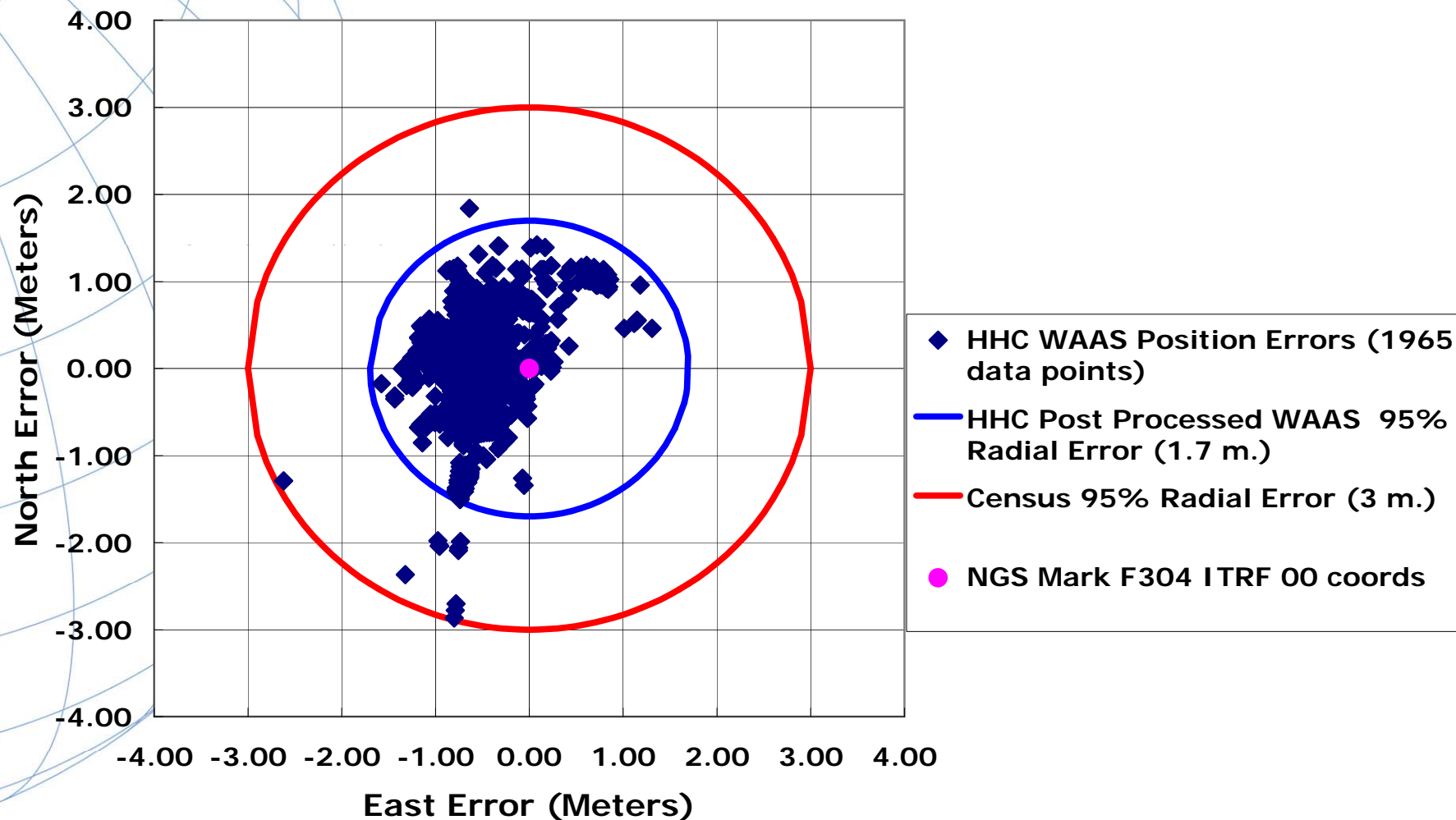
Post Processed Position Errors at NGS MARK F304 (Melbourne, FL) re CORS BRTW Ref. Station @ 120 Km.



HHC WAAS Position Errors at NGS F304 (Melbourne, FL) Ref. Mark



HHC WAAS Post Processed Position Errors at NGS mark F304 (Melbourne, FL) re CORS BRTW Ref. Station @ 120 Km.



GPS Post Processed & WAAS Accuracy at Melbourne, FL NGS Reference Marks

Post Processed with 120 Km Ref. Station	1.55 m. (95%) @ F304
WAAS @ F304	1.69 m. (95%)
WAAS @ 5062 (THRON)	1.50 m. (95%)
WAAS Post Processed with 120 Km Ref. Station	1.70 m. (95%) @ F304

Church Parking Lot Test Area (Mt. Vernon, VA) 3/20 & 4/13/2009



Table 1 Post Processed Results – Church Parking Lot

RMS (m.)	WAAS? Yes=2 No=1	East Error (m.)	North Error (m.)	Time HH/MM/SS	Data Point Desig.
19.6	2	-10.29	8.66	140851	T2
2.6	2	-0.61	-1.14	141027	T4
9.9	1	-2.04	1.04	141107	T5
5.6	1	-1.91	-0.52	141149	T6
3.2	1	-1.57	-0.85	141237	T7
2.7	2	-0.47	-0.66	141812	T14
2	2	-1.38	1.42	141856	T15
2.4	2	0.01	-3.63	141938	T16
10.2	2	7.94	-10.5	142101	T18
8.8	2	-7.21	7.47	142146	T19
24	2	0.61	-4.08	142235	T20
1.2	2	0.72	0.27	142317	T21

About 60% of post processed data within 3 m. of a parking lot reference stripe in a good GPS signal environment.

Data taken 04/13/2009 using CORS station “gode” located at the NASA Goddard Space Flight Center.



Table 2 Post Processed “Church II” Results

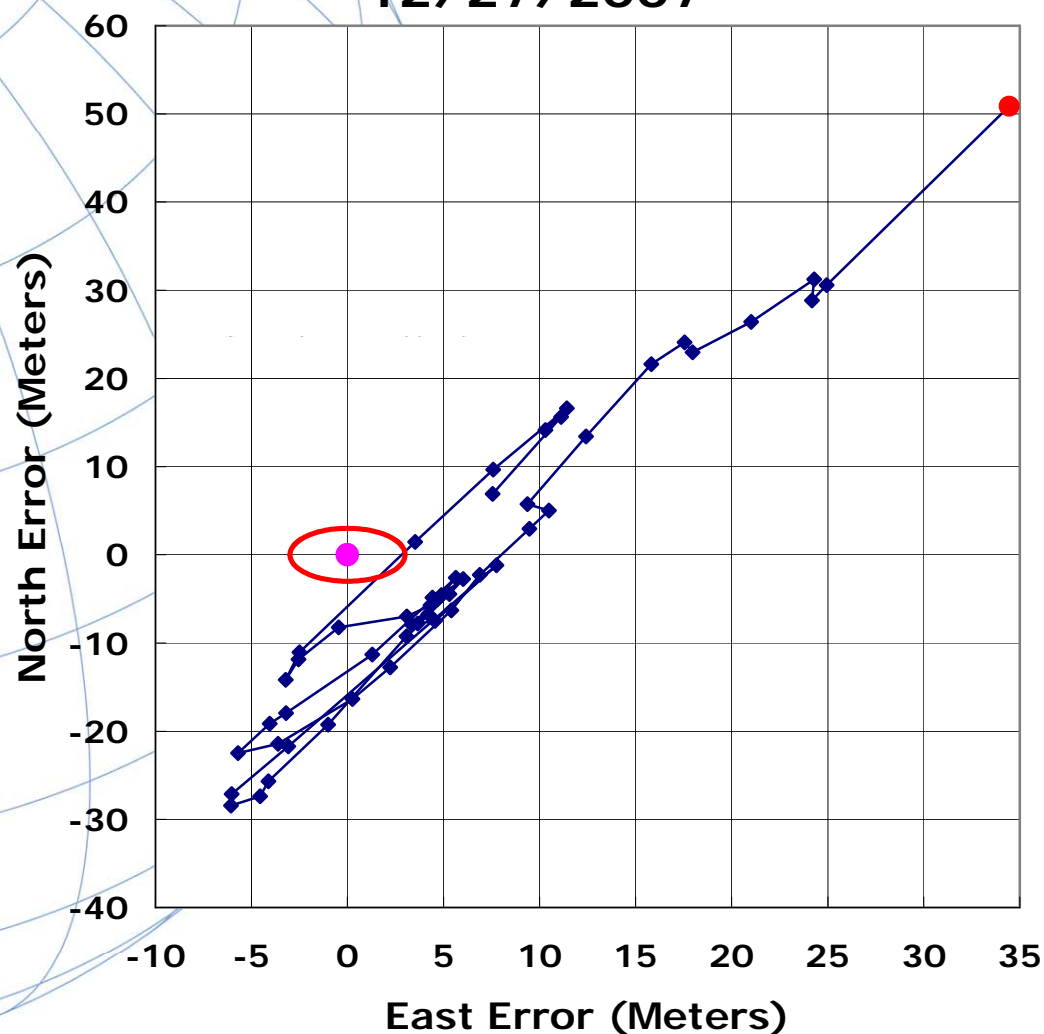
RMS (m.)	WAAS? Yes=2 No=1	East Error (m.)	North Error (m.)	Time HH/MM/S S	Data Point Desig.
25.5	1	2.09	-1.74	143343	H1
32.5	1	2.58	-0.46	143514	H2
35.7	1	5.82	-5.5	143914	H5
18.2	1	1.85	-0.78	144015	H6
12.8	1	4.54	1.66	144111	H7
2.1	1	-3.5	5.3	144214	H8
3.5	1	2.19	-3.4	144325	H9
13.1	1	-8.23	3.56	144431	H10
13.6	1	-3.9	1.33	144600	H11
16.2	1	-0.1	0.47	144709	H12
6.6	1	-9.91	7.3	144809	H13
47.9	1	-4.59	1.82	144908	H14
20	1	-22.17	6.93	145108	H15
20.7	1	-15.84	6.51	145206	H16

About 30% of Post
Processed Data Within
3 m. of Map Spot

About 60% of Data
Within 5 m. of Map Spot
in a partially obstructed
environment.



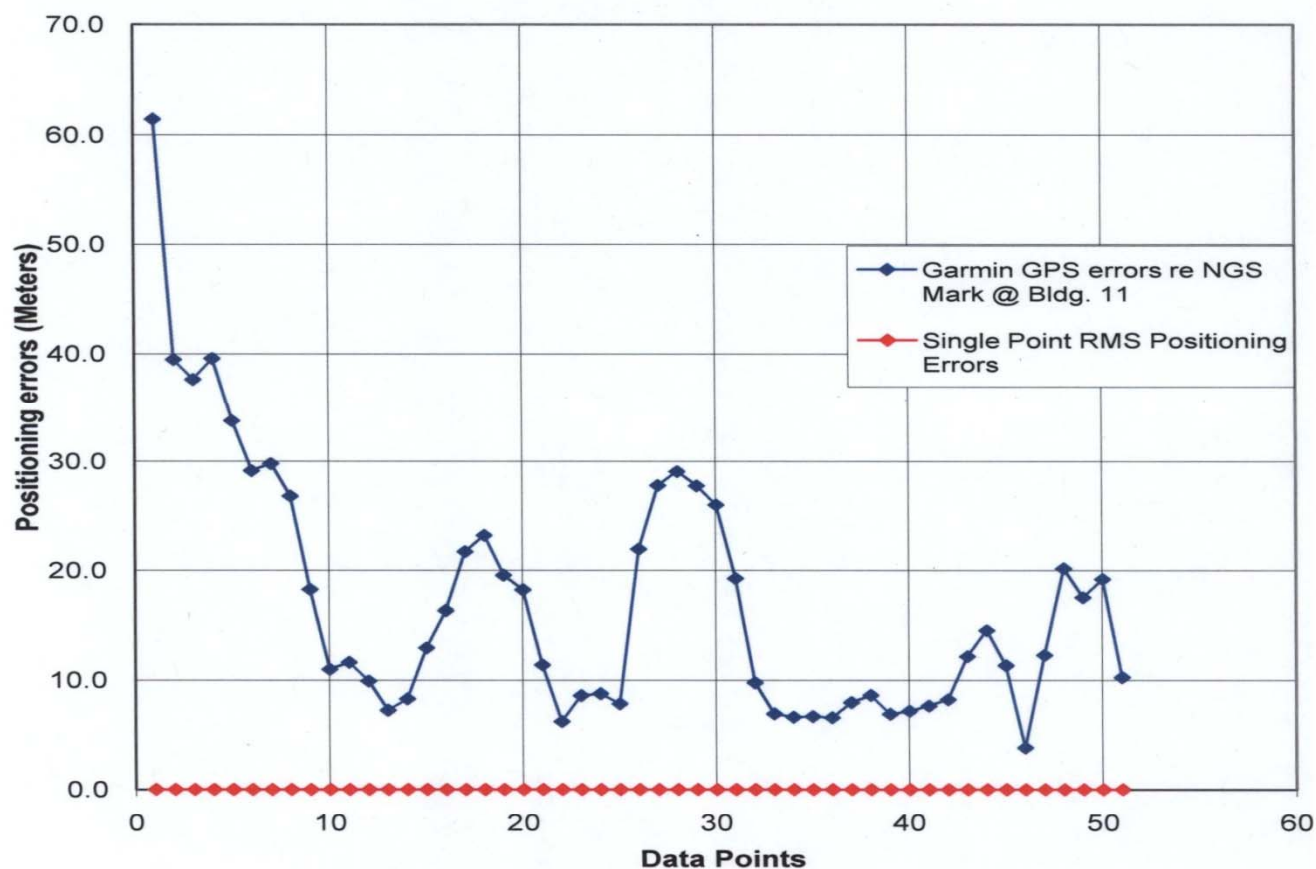
Garmin Post Processed GPS Errors re NGS Mark @ GPS Bldg. #11 Corbin, VA 12/27/2007

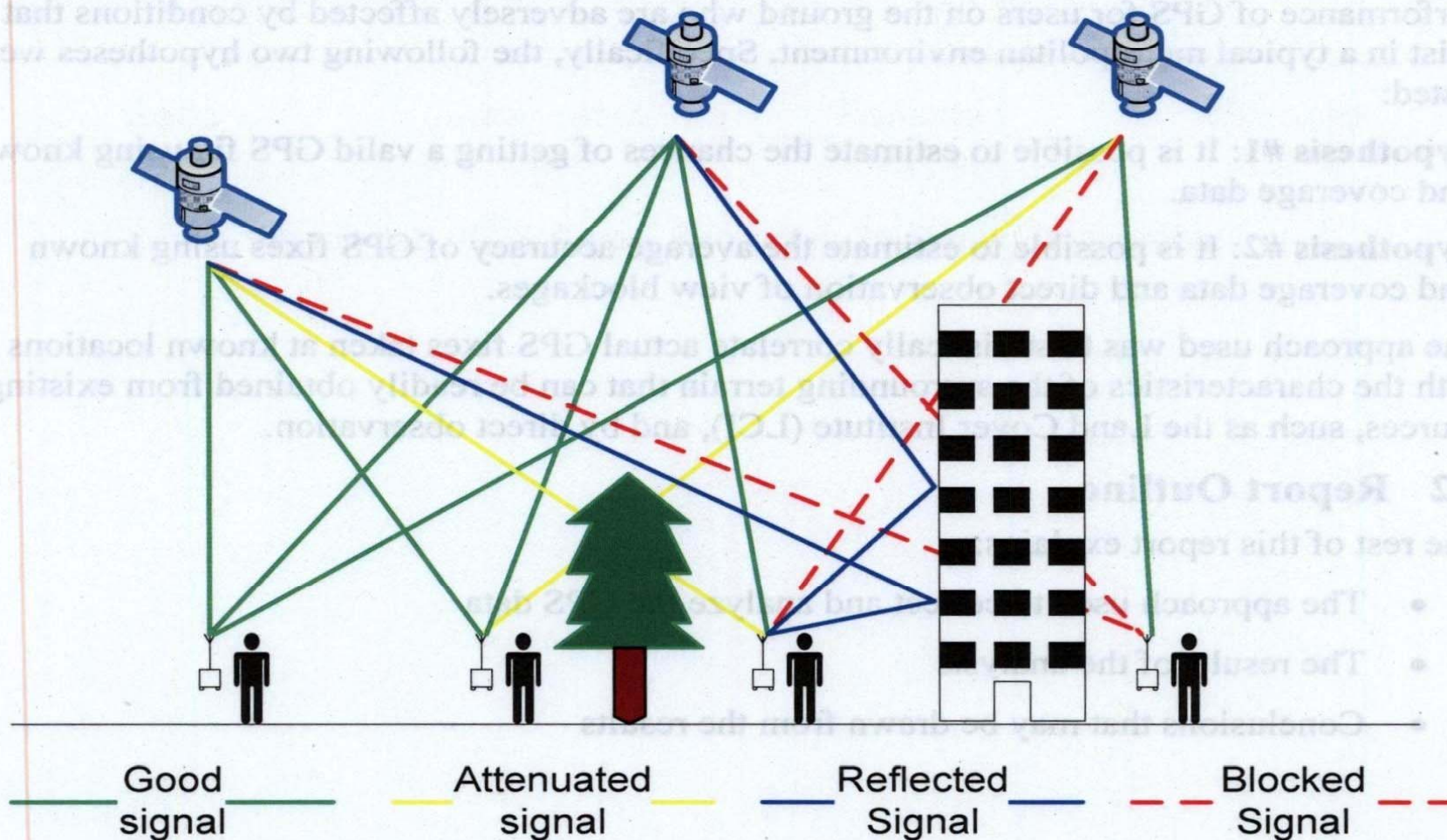


- ◆ Garmin GPS Errors re NGS mark at Bldg. #11 - 9/60 (15%) Missing Data
- Census 95% Radial error (3 m.) - No Data Within Census Accuracy
- NGS Mark @ Building # 11
- Tap & Go - First Data Point

Possible Use of RMS Post Processed Parameter as a Data Quality Indicator

Garmin GPS Errors re NGS Mark @ Bldg. 11
Corbin, VA 12/27/2007





GPS Signal Reception Problem Illustration

Bohne, Paul F. & Nobile, Marc P. MITRE Technical Report MTR070200, "Average GPS signal Availability Estimation", pp. 1-1, September 2007.

Toyon Research Prototype SBIR Phase II Antenna

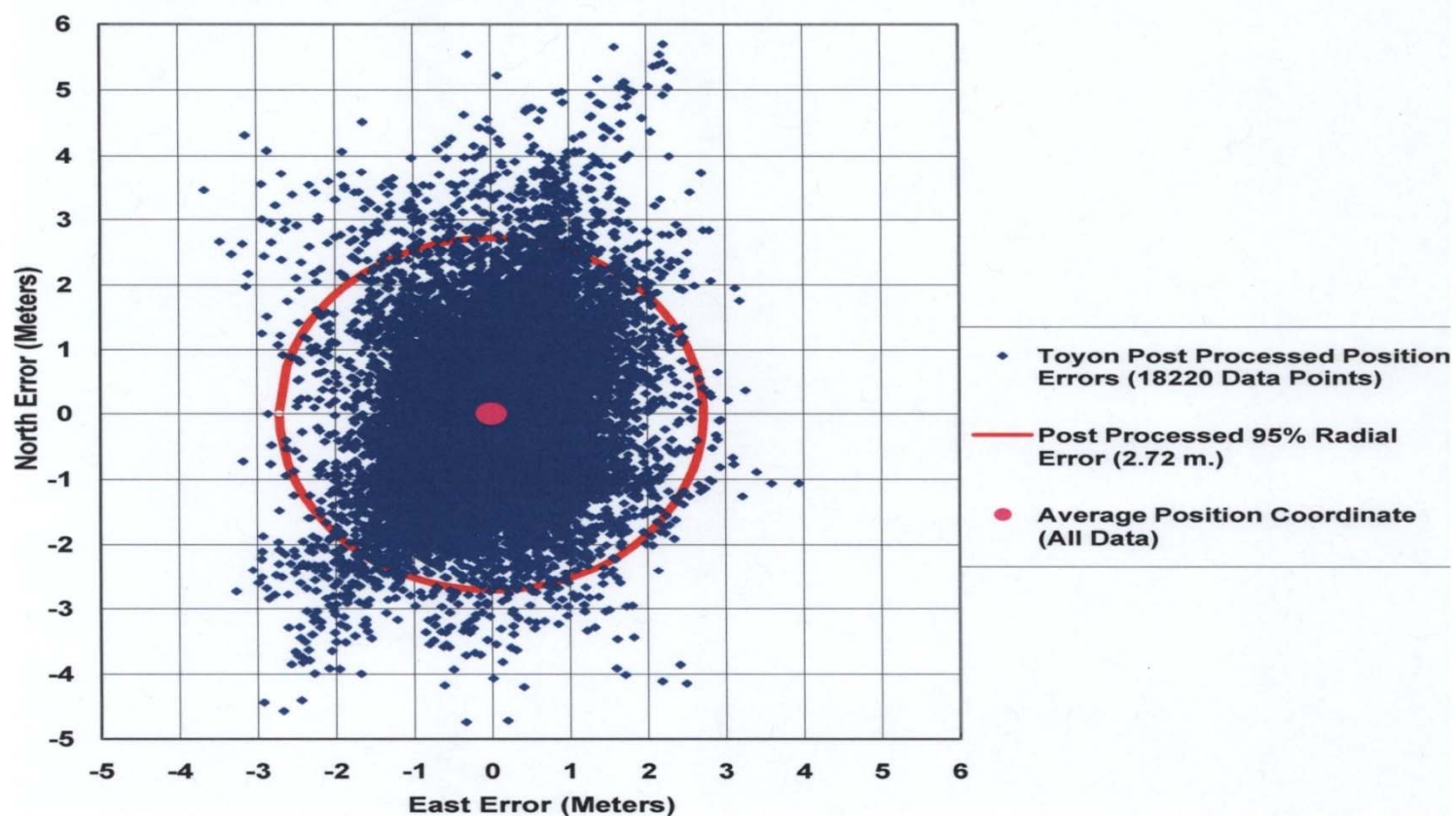


TOYON SBIR Phase II Multipath Mitigation Antenna



Post Processed Accuracy Using a Multipath Mitigation Antenna About 3.5 m. from Residence

Toyon Antenna Configuration # 1 (No Radome) in a Multipath Environment Goleta CA, June 23, 2008



Automated Map Spot Accuracy Analysis



National Positioning, Navigation, and Timing (PNT) Architecture Study

- In 2006 the Assistant Secretary of Defense for Networks and Information Integration (ASD/NII) and the Under Secretary of Transportation for Policy (UST/P) sponsored a National Positioning, Navigation, and Timing (PNT) Architecture Study to “provide more effective and efficient PNT capabilities focused on the 2025 time frame...”¹
- Several NOAA organizations, including the National Geodetic Survey (NGS), participated on the Architecture Development Team (ADT) and are, additionally, members of the Architecture Transition Team (ATT).
- The PNT Joint Capabilities Document (JCD) identified a number of validated gaps in capability which are projected to exist in the 2025 timeframe.

¹ National Positioning, Navigation, and Timing Architecture Study, Final Report, September 2008---This Document Is Cleared For Public Release



National Positioning, Navigation, and Timing (PNT) Architecture Study

- The team identified 7 gaps and the key gap related to this presentation was:
- ***Assured and real-time PNT in physically impeded environments.¹***
- The large data set gathered (approximately 140 Million data points) during the Address Canvas by Census can provide a very good assessment of what are the PNT capabilities of GPS in a partially impeded physical environment in the 2009 time frame.

Caveats:

- Data is Title 13 data.
- Statistical data analysis procedures must be negotiated and approved by the Census Bureau.

1 National Positioning, Navigation, and Timing Architecture Study, Final Report, September 2008---This Document Is Cleared For Public Release



Summary Test Conclusions

- NGS Post Processing accuracy using CORS Reference stations was less than 3 meters (95%) in unobstructed environments.
- 3 meter GPS accuracy may not be achievable at all map spots due to multipath & blocked signals; Census Bureau has a partnership in place to obtain the best possible GPS coordinate under these conditions.
- Post processed coordinates minus map spot coordinates in partially obstructed environments less than 3 meters and meet the Census accuracy specification may range from 30% to 60% in a given address block from preliminary data.
- The Census Bureau and NGS are working together to ensure the highest quality of GPS collected data.



Next Steps

- Evaluate the effectiveness of post processing of housing unit structure points captured using GPS technology in Address Canvassing.
- Recommend possible improvements (both hardware, software, and new GPS signals) to improve coordinate accuracy data quality percentage.

