



# *Using WAAS for Sub-meter Mapping*

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# *WAAS – What is it?*

- **Wide Area Augmentation System**
- **A Federal Aviation Administration (FAA) program that provides GPS integrity monitoring and improves GPS accuracy.**
- **~\$90M-100M annual budget.**



# WAAS – What is it?

- **What does WAAS do?**

- Provides position integrity. GPS alone isn't reliable enough for aviation navigation.
- The specification when using WAAS is that GPS shouldn't provide an "out of tolerance" position more than 1 in 100,000,000 times.
- Provides user notification within six seconds if a position is "out of tolerance".
- Ionospheric modeling.
- Position corrections.

# *WAAS – What is it?*

- **WAAS addresses three GPS error sources; ionospheric error, satellite clock error, satellite ephemeris error.**
- **Error from the ionosphere is the largest and most dynamic.**
- **WAAS models the effect of the ionosphere that it has on GPS signals passing through it.**

# *WAAS – What is it?*

## **WAAS consists of:**

- **A network of 38 WAAS Reference Stations (WRS) that are dual frequency (L1/L2) GPS receivers.**
- **Processing facilities.**
- **Geostationary satellites.**
- **Control facilities.**

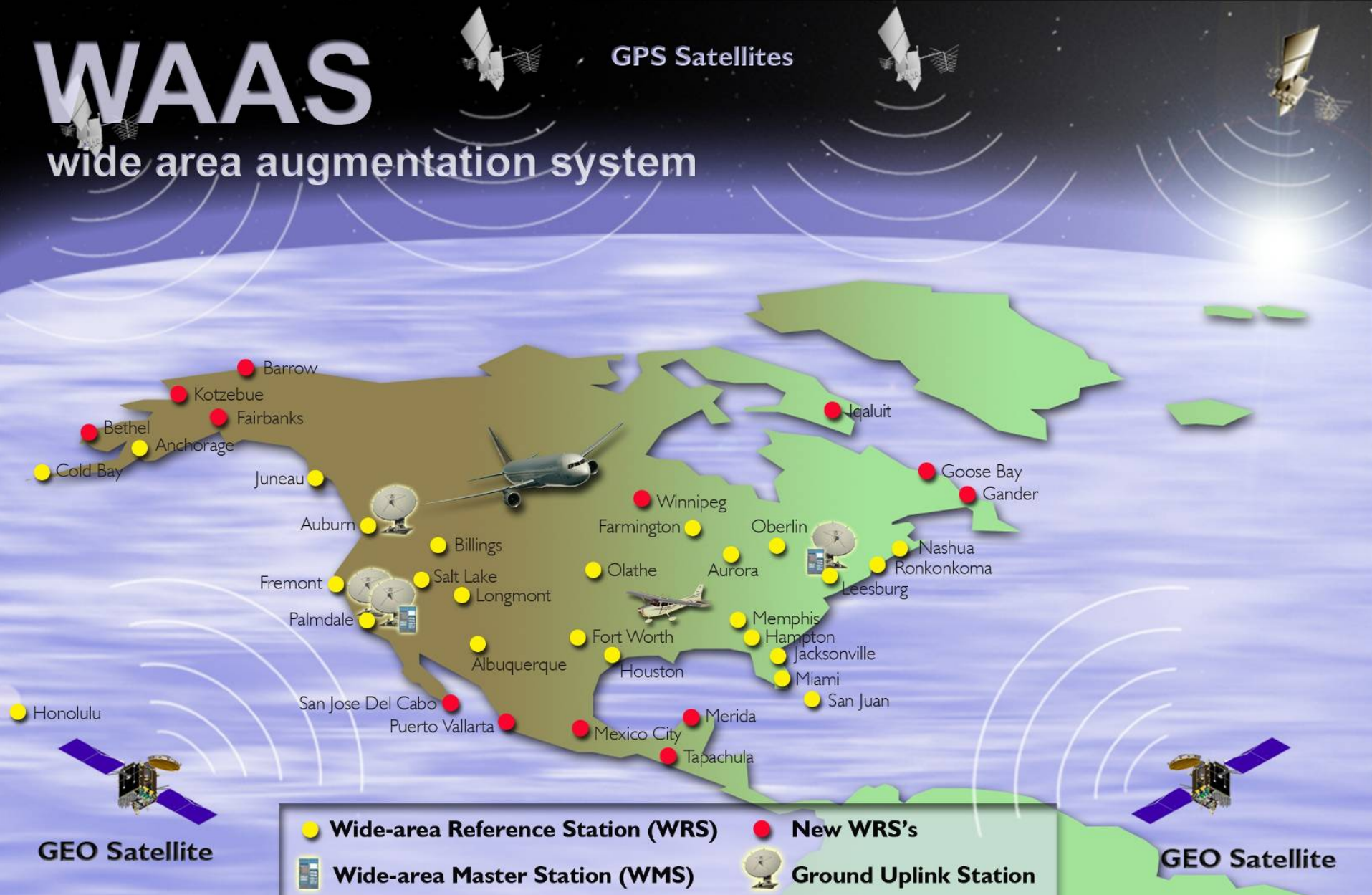


# WAAS - What is it?

## WAAS

wide area augmentation system

GPS Satellites



GEO Satellite

● Wide-area Reference Station (WRS)

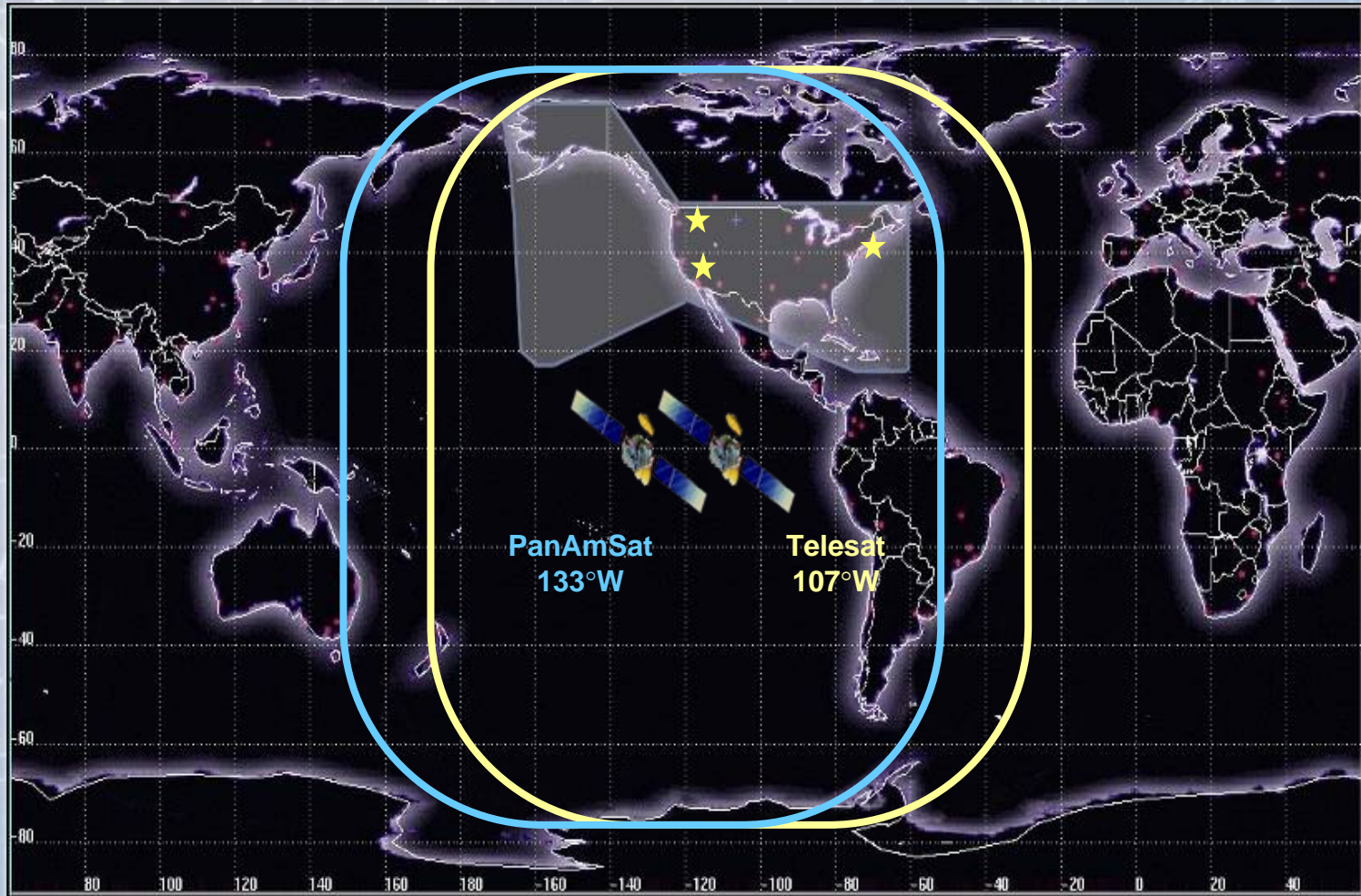
● New WRS's

■ Wide-area Master Station (WMS)

● Ground Uplink Station

GEO Satellite

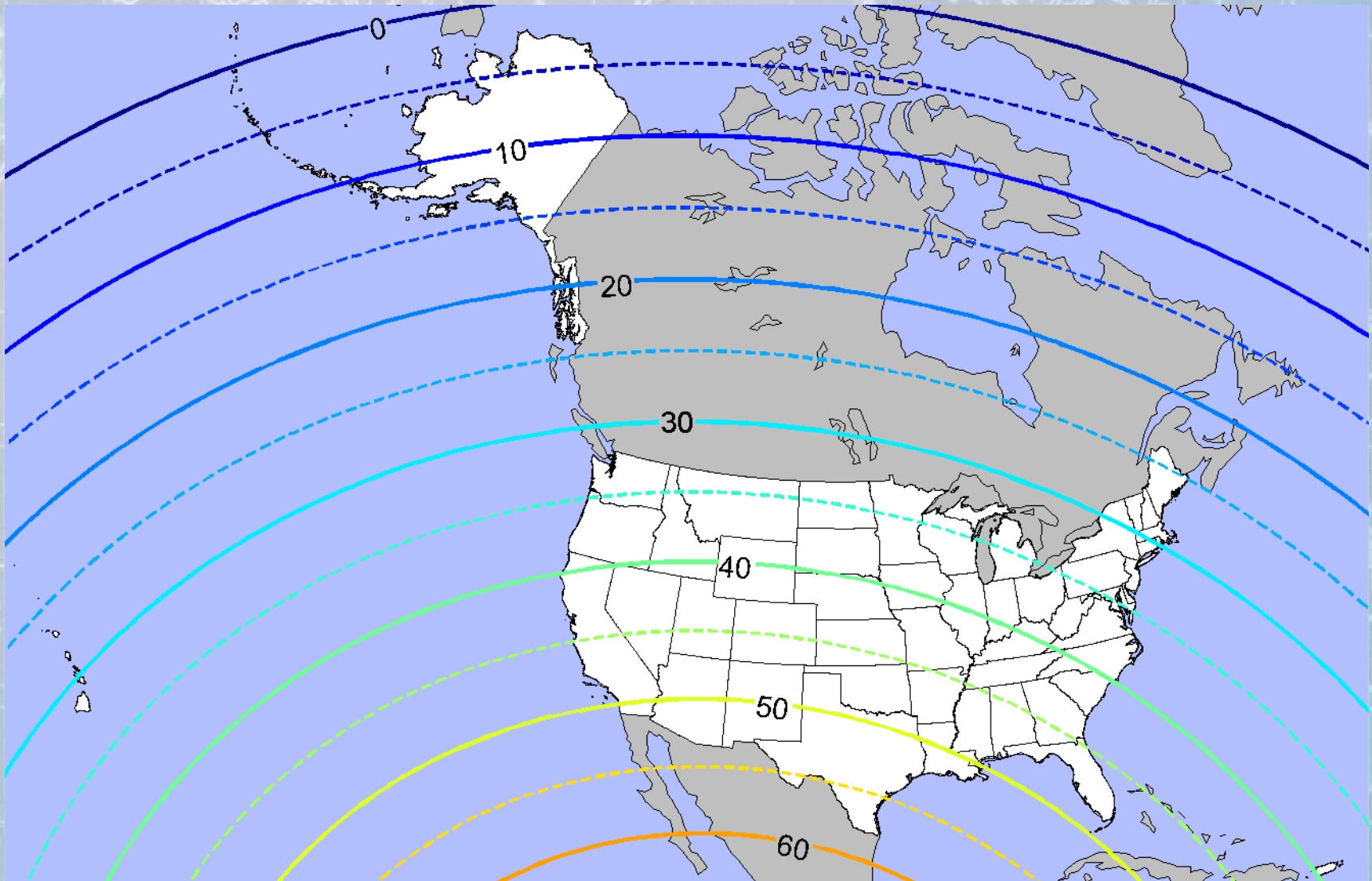
# WAAS - What is it?





# WAAS - What is it?

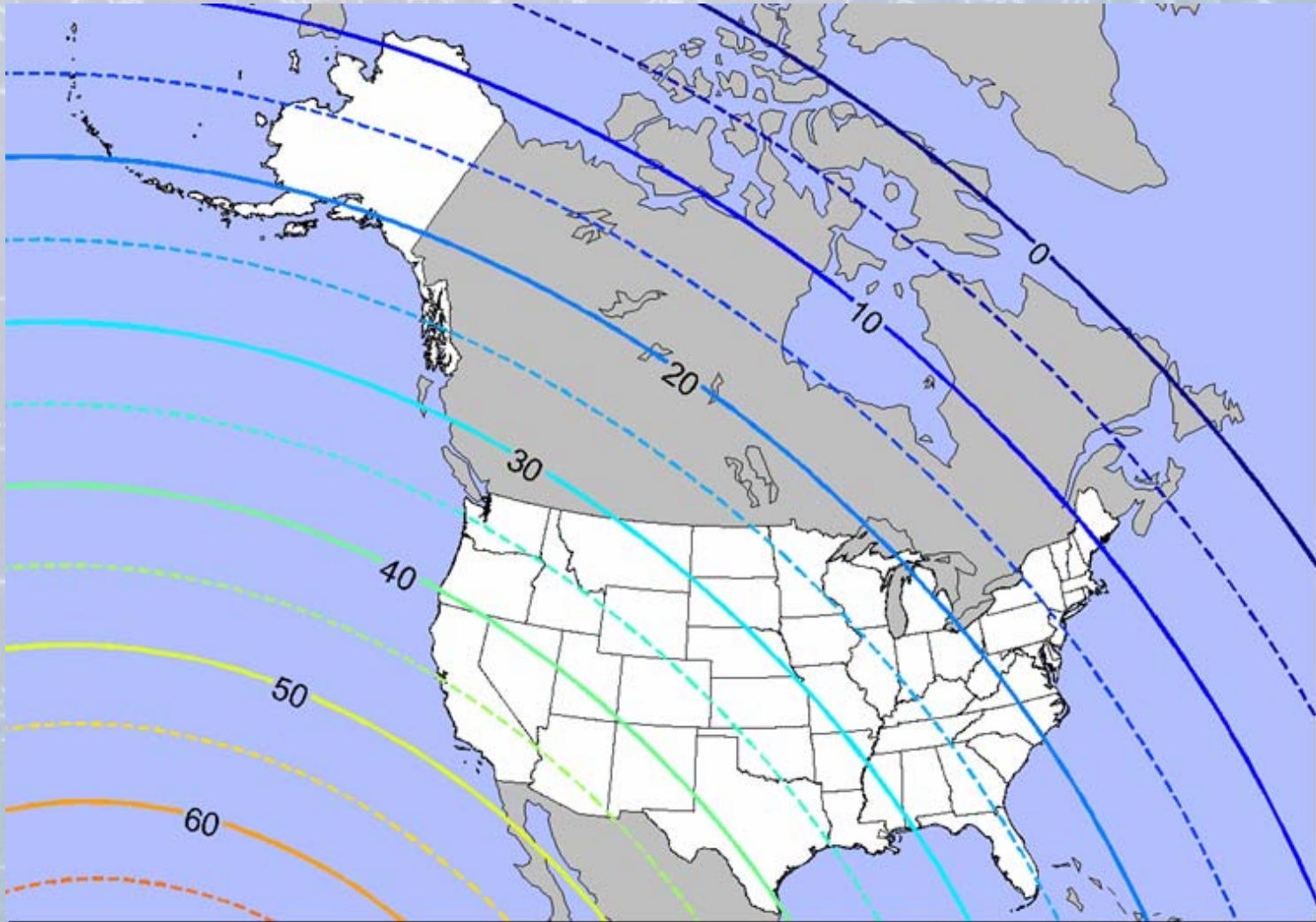
- **Elevation of WAAS PRN 138/SV 51**



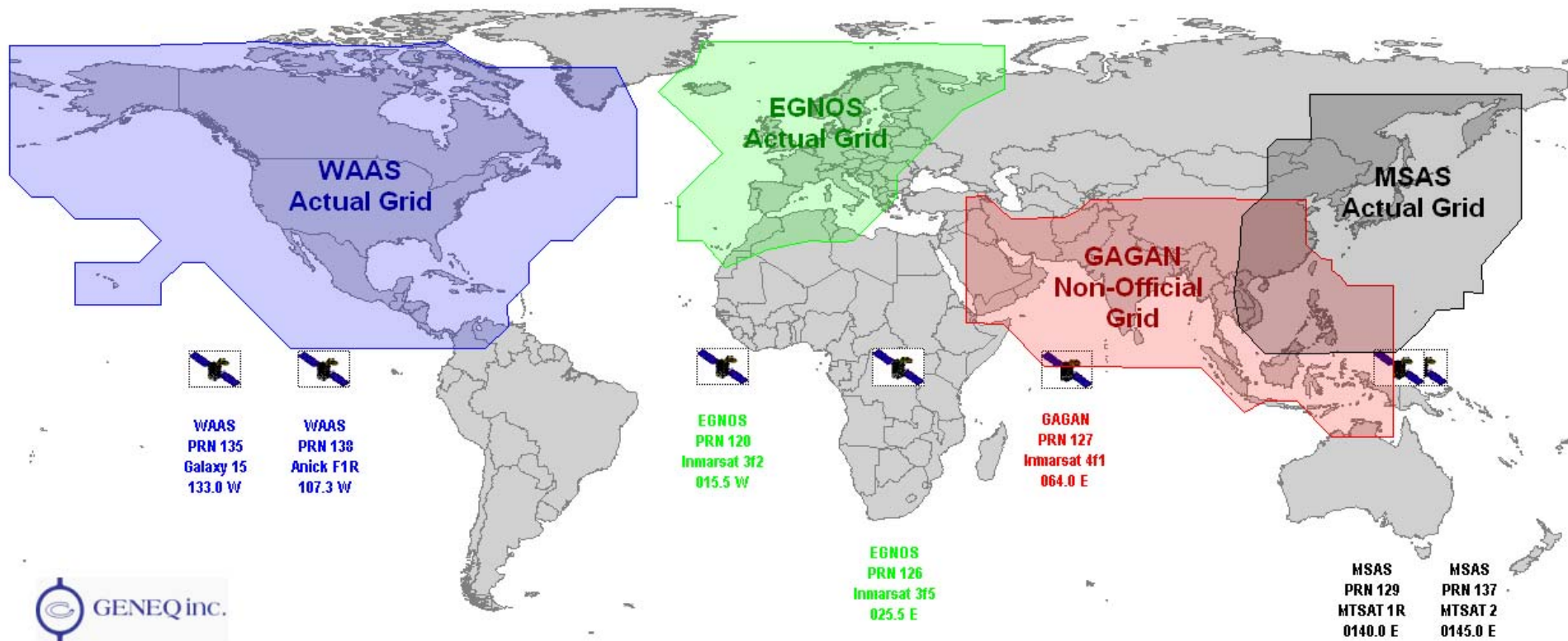


# WAAS - What is it?

- Elevation of WAAS PRN 135/SV 48



# World-wide compatibility





# *Trends in GPS mapping*

**It seems that WAAS is all about aviation.**

**How does the surveying/mapping community benefit from WAAS?**

# *Trends in GPS mapping*

- **The survey/mapping community expects smaller, simpler, cheaper GPS sub-meter mapping equipment.**
- **The user community is moving away from post-process differential correction and towards real-time corrections.**
- **What are the choices for real-time DGPS corrections?...**



# Real-time Correction Sources

- **WAAS (SBAS):**

- free, accurate, North American coverage (US/Alaska, Hawaii, Canada, Mexico), Western Europe (EGNOS), MSAS (Japan). India and Russia in planning stage.

- **Radio-beacon DGPS/NDGPS:**

- free, accurate, USA coverage (parts of Canada), coastlines of 40+ other countries, extra hardware required.

- **Commercial DGPS services:**

- subscription-based, accurate, world-wide coverage, extra hardware required.

- **RTK networks:**

- some free/some subscription-based, very accurate, very limited coverage, extra hardware required.

# WAAS

- **All WAAS-enabled receivers aren't created equal.**
- **WAAS was designed for aviation, but GPS receivers can be designed to optimize WAAS for ground users.**
- **Some manufacturers have introduced high performance GPS L1 mapping receivers that exploit WAAS for ground users.**

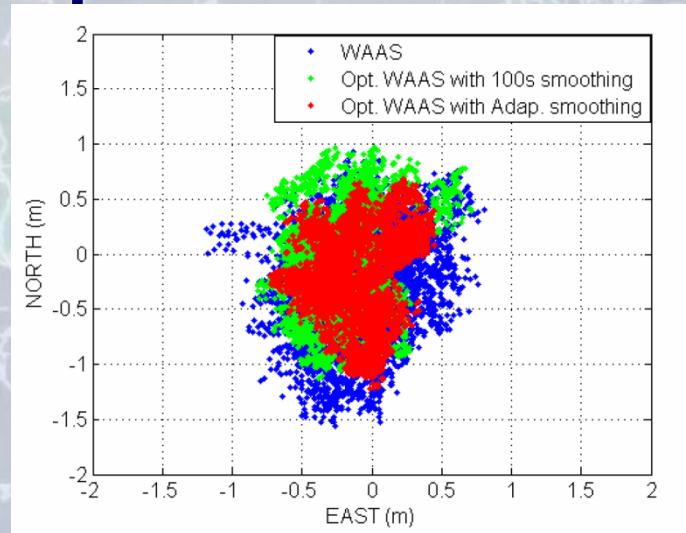


# WAAS

- **The position integrity bounds (horizontal and vertical) required by the FAA is 99.99999%. Therefore, integrity trumps accuracy.**
- **If that level of integrity is not required, then integrity can be traded for accuracy.**

# WAAS performance

- “Optimizing WAAS Accuracy/Stability For a Single Frequency Receiver.” Kim, Euiho, Walter, T., and Powell, J.D. - Stanford University.
- Presented September 2006 at ION 2006.

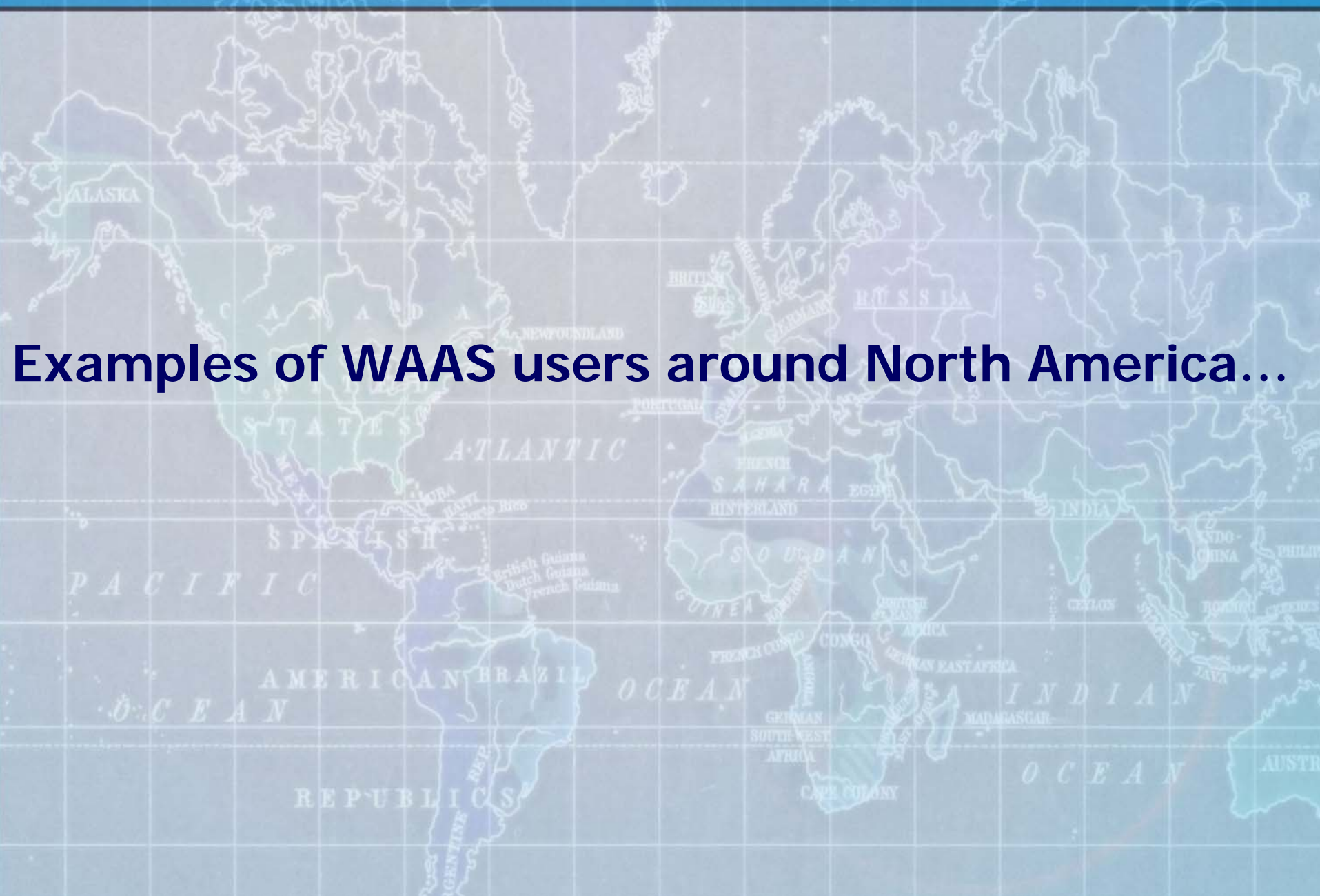


- Modifying the weighting matrix, adaptive carrier smoothing, and nullifying range rate correction.



# *Examples of WAAS Mapping users*

**Examples of WAAS users around North America...**



# WAAS Mapping users

- J.D. Irving Ltd.
- 15,000 employees
- Industry: Forest Products
- Location: Eastern Canada
- Application: Harvesting timber.
- 300+ high performance WAAS receivers.

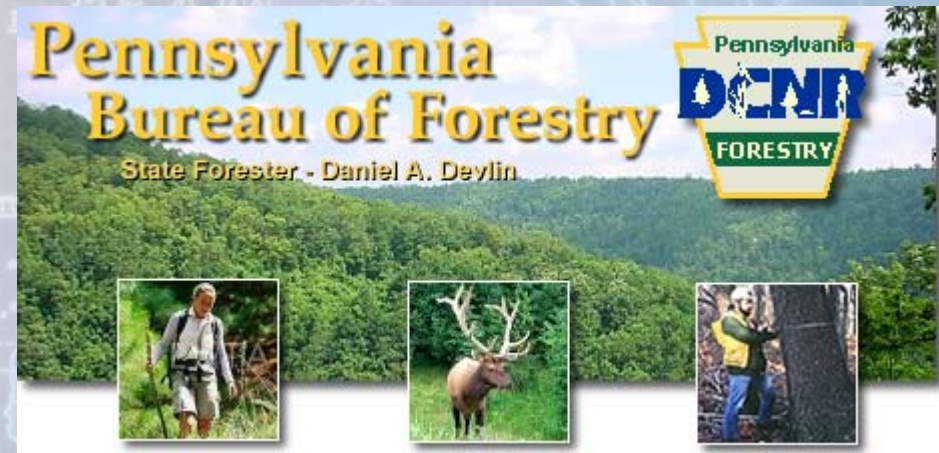


"Initially, a number of DGPS options were tested, and WAAS proved to penetrate our forest canopy type the best."



# WAAS Mapping users

- State of Pennsylvania
- Industry: Forestry
- Location: PA
- Application: Forestry mapping.
- 30 hi-performance WAAS receivers.

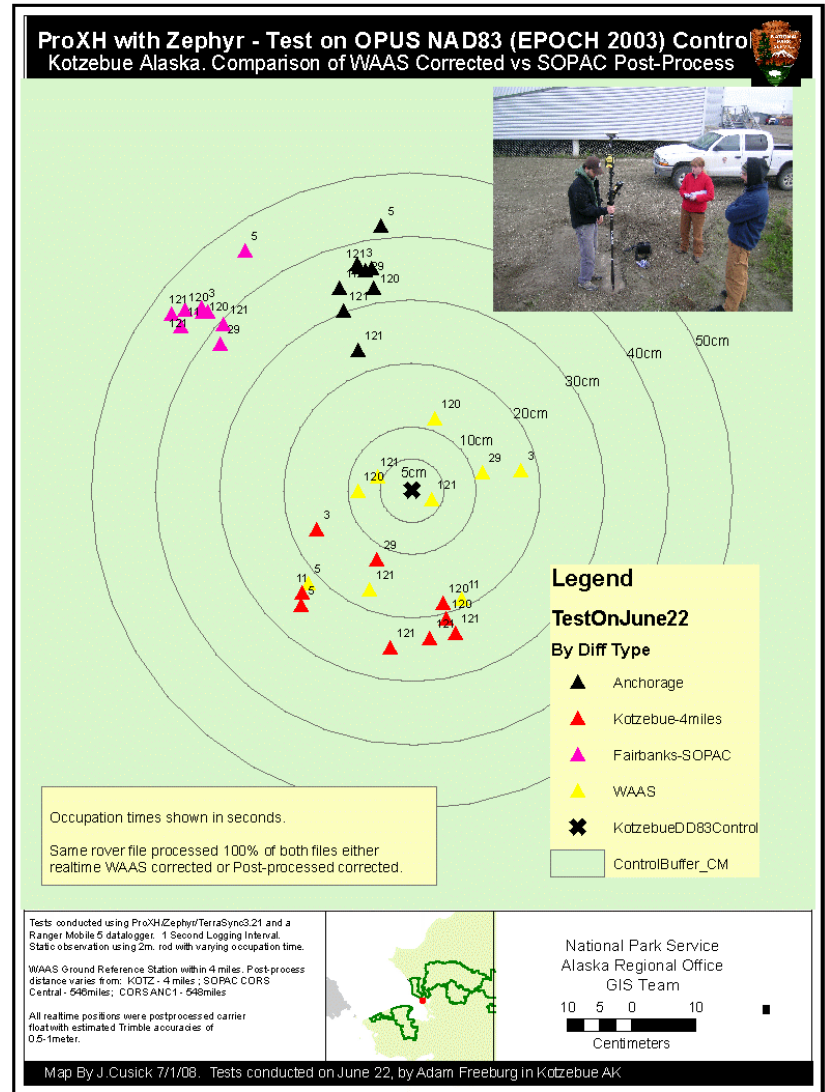


"We tested against post-processing units in some of the toughest forestry environments we know of. We are extremely pleased with WAAS performance."

# WAAS Mapping users

AdGIF UNREGISTERED - www.gf-animator.com

- US Nat'l Park Service
- Industry: Gov't
- Location: Sub-Arctic Alaska
- Application: Map archaeological sites
- 45 high performance WAAS receivers

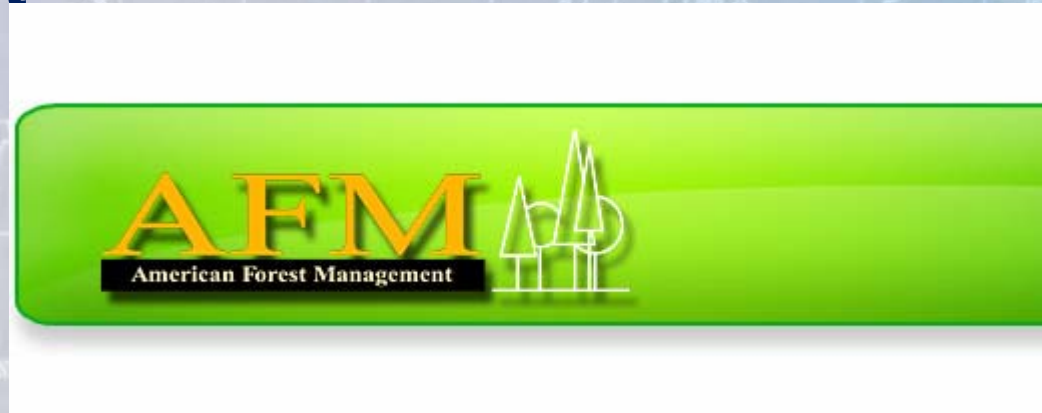


"Many mapping grade GPS users still do not feel good about relying on WAAS. You can always post-process, but after reading these numbers, some may ask *why bother?*"



# WAAS Mapping users

- American Forest Mgt
- 250 employees
- Industry: Forestry
- Location: VA to TX, ME to MI.
- Application: Area calcs, road work, land owner mapping.
- 25 hi-performance WAAS receivers.



“Our field efficiency has drastically increased due to reliable reception and ease of use...office productivity also increased because of real-time correction.”

# WAAS Mapping users

- **Portland General Electric**
- **2,600 employees**
- **Industry: Utility**
- **Location: Oregon**
- **Application: Utility pole mapping**
- **15 hi-performance WAAS receivers.**

Utility Asset Management



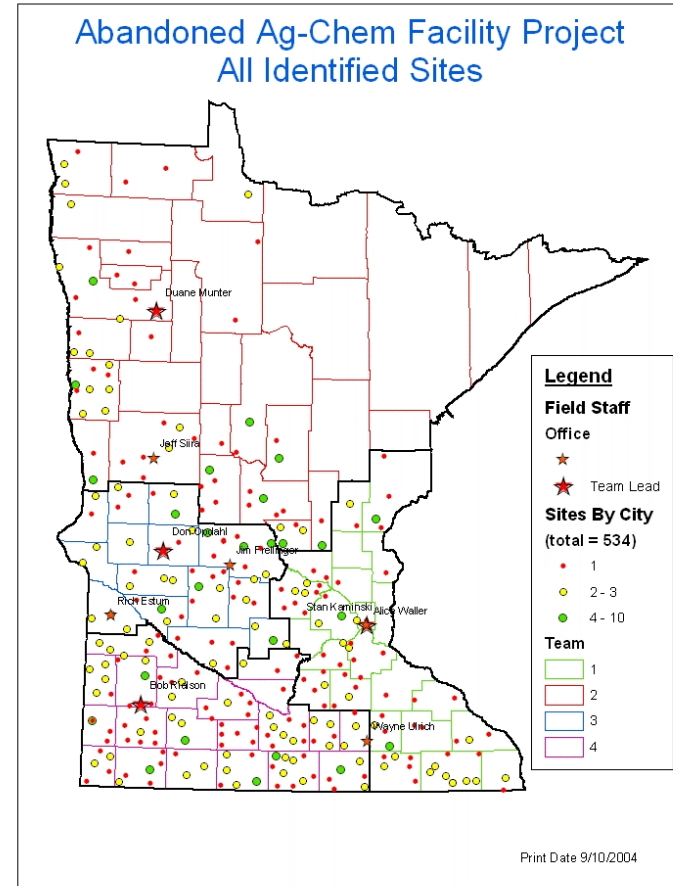
“Four years ago, we started out using low-end WAAS receivers, but switched to mapping-grade WAAS receivers after 60 days due to accuracy problems. 225,000 poles and four years later, we are still using the same WAAS receivers.”



# WAAS Mapping users

- State of Minnesota
- Industry: Gov't
- Location: Minnesota
- Application: Mapping abandoned chem bldgs
- 5 hi-performance WAAS receivers.

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Approximately 500 facilities were mapped using a bluetooth, submeter WAAS GPS and a windows mobile data collector. Wireless technology eliminated connectivity problems and the receivers had Coast technology, consistently giving us submeter, real-time results, even in areas that had poor visibility.

# WAAS Mapping users

- US Forest Service
- Industry: Forestry
- Location: N. Mexico
- Application: Forestry mapping.
- 5 hi-performance WAAS receivers.

The logo for the US Forest Service, featuring the text "US FOREST SERVICE" in white capital letters on a dark green rectangular background.A banner for the Southwestern Region of the US Forest Service. It features a landscape photograph of mountains and a river. The text "Southwestern Region" is written in a large, bold, yellow serif font. Below it, the slogan "Caring for the land and serving the people" is written in a smaller, yellow serif font.

## Southwestern Region

"Caring for the land and serving the people"

"Signal reliability is probably 95%. Great reception along a forest road. A differentially-corrected file with no post-processing. That is a HUGE timesaver."



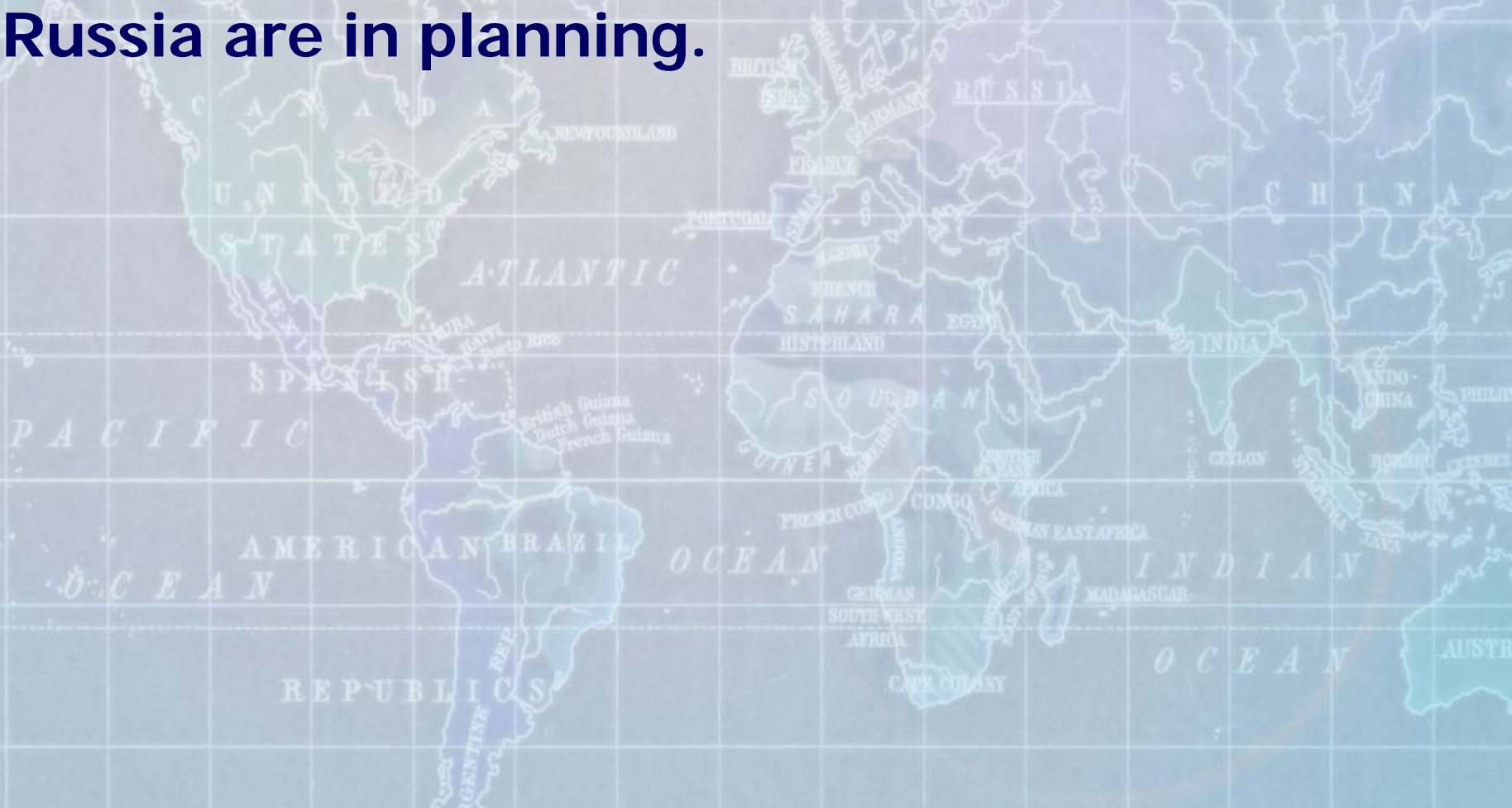
# *Watch the manufactures*

- **Both mapping and survey GPS receivers have been introduced that exploit WAAS and the WAAS GEO observables.**



# Take away messages

- **WAAS, when exploited for ground users, is an effective source of GPS corrections throughout North America, Europe and Japan. India and Russia are in planning.**





# Take away messages

- WAAS, when exploited for ground users, is an effective source of GPS corrections throughout North America, Europe and Japan. India and Russia are in planning.
- **The survey/mapping user community clearly prefers a low overhead solution such as WAAS that requires no additional receiver and antenna hardware.**

# *Take away messages*

- WAAS, when exploited for ground users, is an effective source of GPS corrections throughout North America, Europe and Japan. India and Russia are in planning.
- The survey/mapping user community clearly prefers a low overhead solution such as WAAS that requires no additional receiver and antenna hardware.
- **WAAS, when exploited for ground users, meets the sub-meter accuracy requirements expected of today's high performance mapping systems.**



# QUESTIONS?



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# *Backup slides*



**BACKUP SLIDES**



# WAAS performance report

WAAS Performance Analysis Report

April 2008

## 75cm

- Ave. horizontal accuracy with 95% confidence throughout North America based on more than 7 million measurements per site over a 3 month period.

Jan-Mar 2008

Table 2-2 PA 95% Horizontal and Vertical Accuracy

Location	Horizontal (HAL=40m) (Meters)	Horizontal (HAL=556m) (Meters)	Vertical (VAL=50m) (Meters)	Percentage in PA mode (%)	SPS Accuracy	
					95% Horizontal (Meters)	95% Vertical (Meters)
Atlantic City	1.193	1.193	1.215	99.99738	*	*
Arcata	0.852	0.852	0.912	99.99603	*	*
Oklahoma City	0.664	0.664	1.009	99.99695	*	*
Albuquerque	0.643	0.643	0.757	99.99712	2.233	4.038
Anchorage	0.505	0.506	0.772	99.96967	*	*
Atlanta	0.717	0.717	0.990	99.99814	2.439	4.552
Barrow	0.608	0.611	1.428	99.98066	*	*
Bethel	0.524	0.524	0.789	99.99728	1.960	4.897
Billings	0.706	0.706	0.857	99.99710	2.277	4.205
Boston	0.718	0.718	0.831	99.99614	2.470	4.253
Chicago	0.735	0.735	0.791	99.99652	*	*
Cleveland	0.719	0.719	0.813	99.99636	2.502	4.334
Cold Bay	0.843	0.845	0.996	99.99654	*	*
Dallas	0.665	0.665	1.107	99.99698	*	*
Denver	0.665	0.665	0.824	99.99712	*	*
Fairbanks	0.465	0.465	0.919	99.99838	1.823	4.893
Gander	0.895	0.897	0.961	99.96394	*	*
Gouse Bay	0.662	0.663	1.079	99.96368	*	*
Houston	0.691	0.691	1.224	99.99693	2.256	4.264
Iqaluit	0.733	0.736	1.641	99.96634	*	*
Jacksonville	0.707	0.707	1.234	99.99974	*	*
Juncau	0.580	0.580	0.960	99.99775	*	*
Kansas City	0.734	0.734	0.809	99.99670	2.407	4.414
Kotzebue	0.523	0.524	1.065	99.98108	1.856	4.946
Los Angeles	0.703	0.703	0.993	99.99729	2.218	4.651
Memphis	0.682	0.682	0.889	99.99670	*	*
Merida	0.812	0.812	1.239	99.99672	*	*
Mexico City	0.986	0.985	1.306	99.99700	*	*
Miami	0.764	0.764	1.325	99.99636	2.302	4.558
Minneapolis	0.689	0.689	0.846	99.99670	2.360	4.272
New York	0.743	0.743	0.871	99.99480	*	*
Oakland	0.678	0.678	0.945	99.99753	2.207	4.813
Puerto Vallarta	0.949	0.964	1.810	99.99714	*	*
Salt Lake City	0.659	0.659	0.724	99.99729	2.301	4.296
San Jose Del Cabo	0.910	0.914	1.829	99.99729	*	*
Seattle	0.879	0.880	0.801	99.99752	2.342	4.636
Tapachula	1.253	1.272	1.917	98.71394	*	*
Washington DC	0.721	0.721	0.822	99.99355	2.520	4.515
Winnipeg	0.719	0.719	1.070	99.99670	*	*

\* SPS accuracy not computed for this location.