



NATIONAL GEOSPATIAL-INTELLIGENCE AGENCY
Know the Earth... Show the Way... Understand the World

NGA's Relationship With GPS

Presented to the PNT Advisory Board 14-15 August 2012

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NATIONAL GEOSPATIAL-INTELLIGENCE AGENCY

Know the Earth... Show the Way... Understand the World

NGA MISSION



To provide timely,
relevant, and accurate
GEOINT in support of
national security.

NGA is the lead federal agency responsible
for Geospatial Intelligence – or **GEOINT**



What *is* GEOINT?



- **Where am I?**
- **Where are the natural and man-made structures? How do I navigate them?**
- **What does the area look like now? What activities are taking place there?**
- **What might it look like after an event?**



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OUR HISTORY

AMERICAN
Revolution

CIVIL WAR

WWII

COLD WAR

NIMA

NGA

Balloons



**Aerial
Imagery**

Satellites



**1996
Imagery
& Mapping**

2003



**Geospatial
Intelligence**

Surveying





TYPES OF DATA

Remotely Sensed Data

Panchromatic



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Infrared



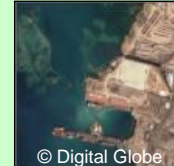
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Radar



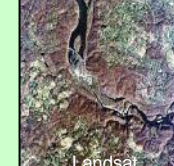
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Multispectral



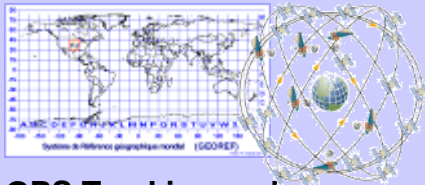
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Hyperspectral



Landsat

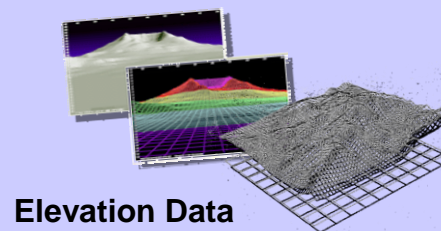
Physical Geography



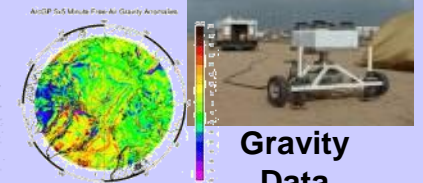
GPS Tracking and Coordinate Systems



Geology

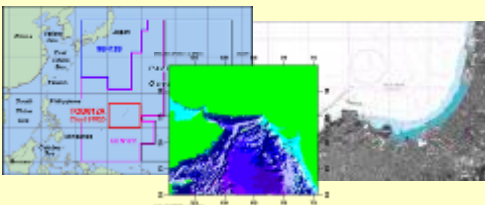


Elevation Data



Gravity Data

Land Cover and Cultural Data



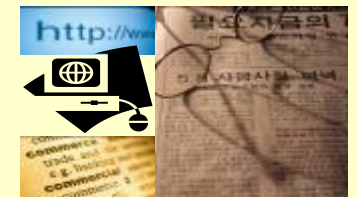
Hydrographic Data



Vegetation



Boundaries, Transportation and Infrastructure

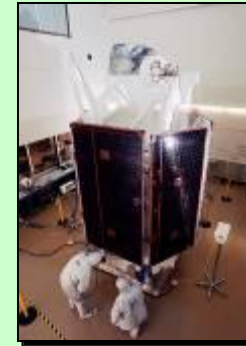


Open Source



VARIETY OF PLATFORMS

**Classified
Systems**



**Commercial
Satellites**



Predator



Global Hawk



Constant Hawk



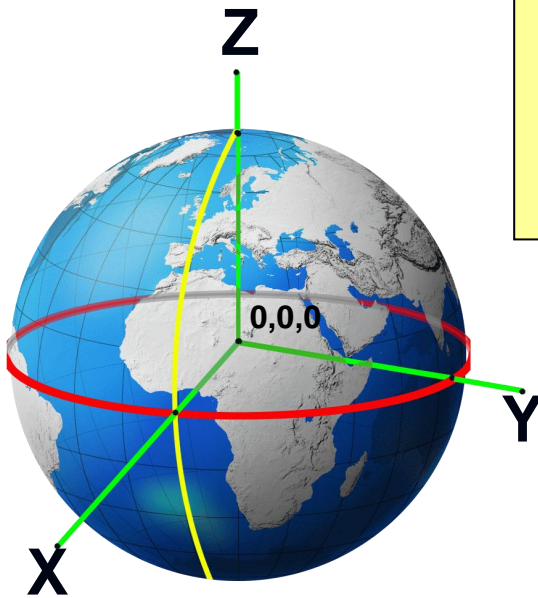
U-2

Airborne



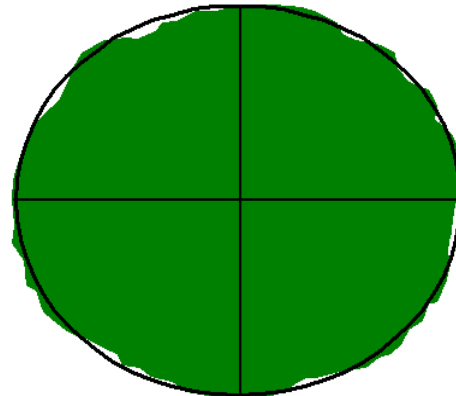
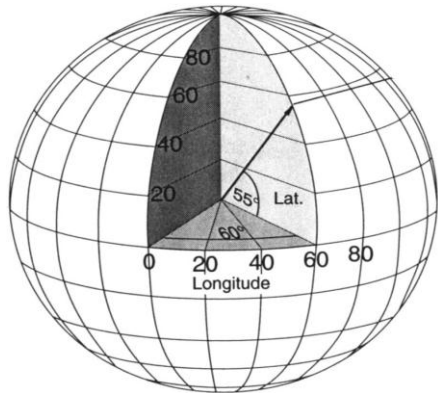
World Geodetic System 1984

NGA –Developed the Global Reference Frame and Geophysical Models for all Modern Geospatial Information



Global Reference Frame Accuracy

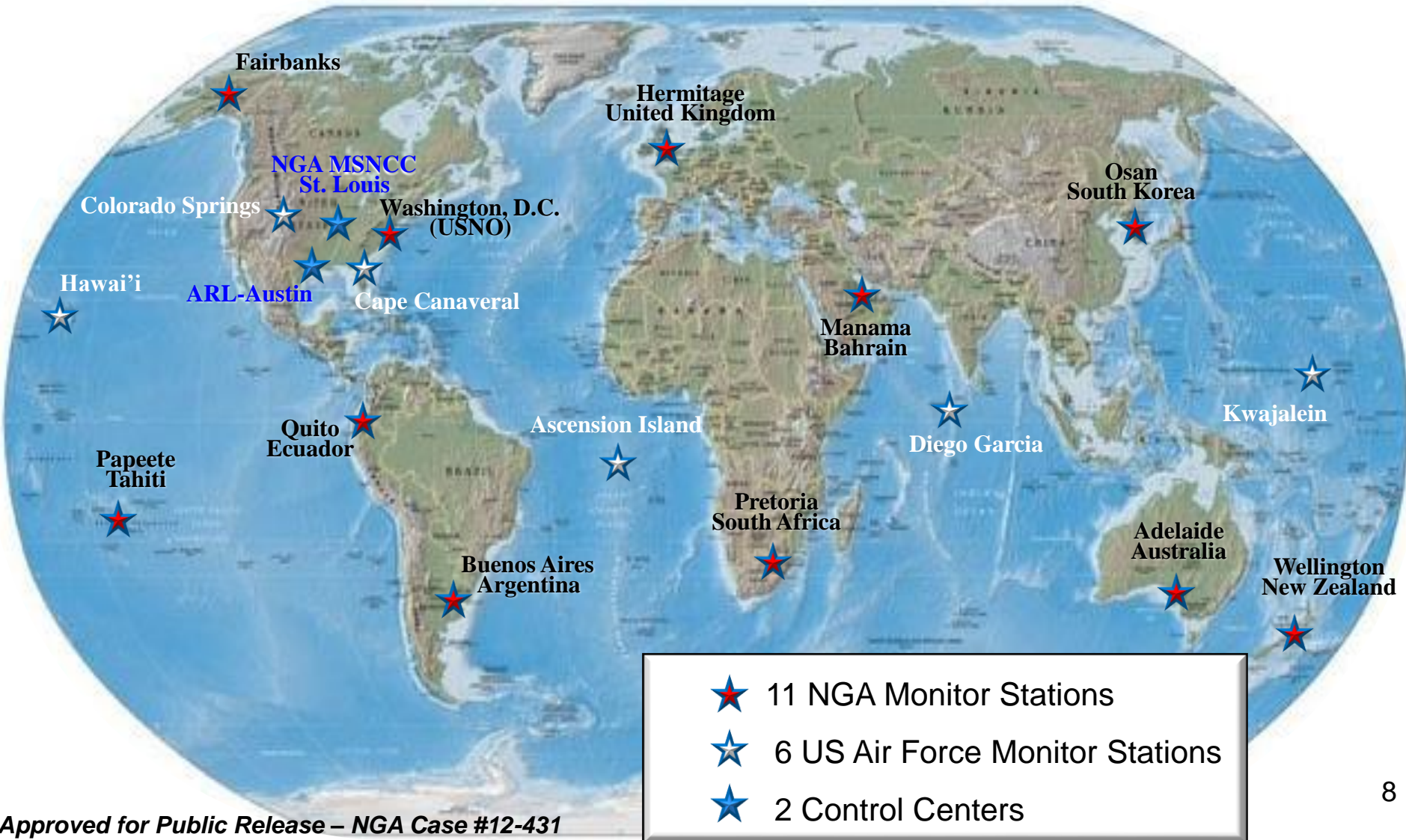
Transit (1 - 2 m)	Jan 1987
G730 (10 cm)	Jun 1994
G873 (5 cm)	Jun 1997
G1150 (1-2 cm)	Jan 2002
G1674 (1 cm)	Feb 2012



The geoid is used as a surrogate for mean sea level, the vertical datum for traditional 'elevations'



DoD GPS Ground Station Network

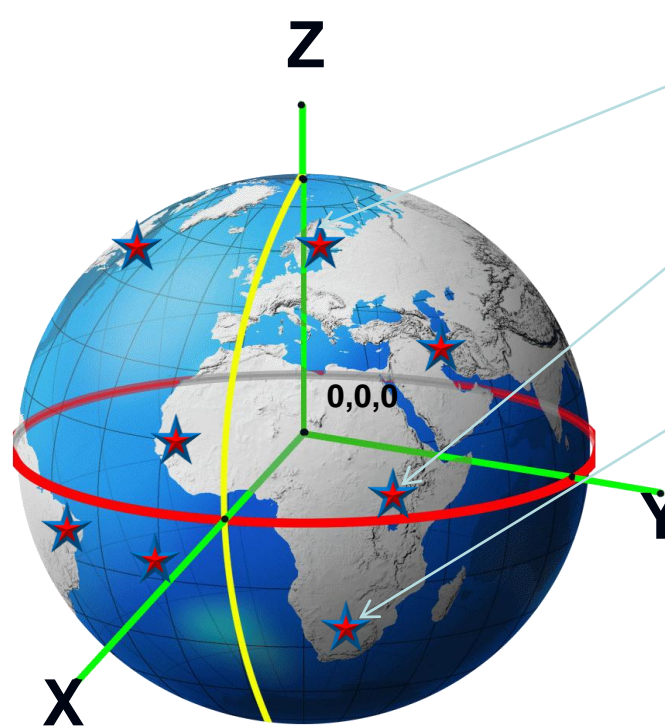
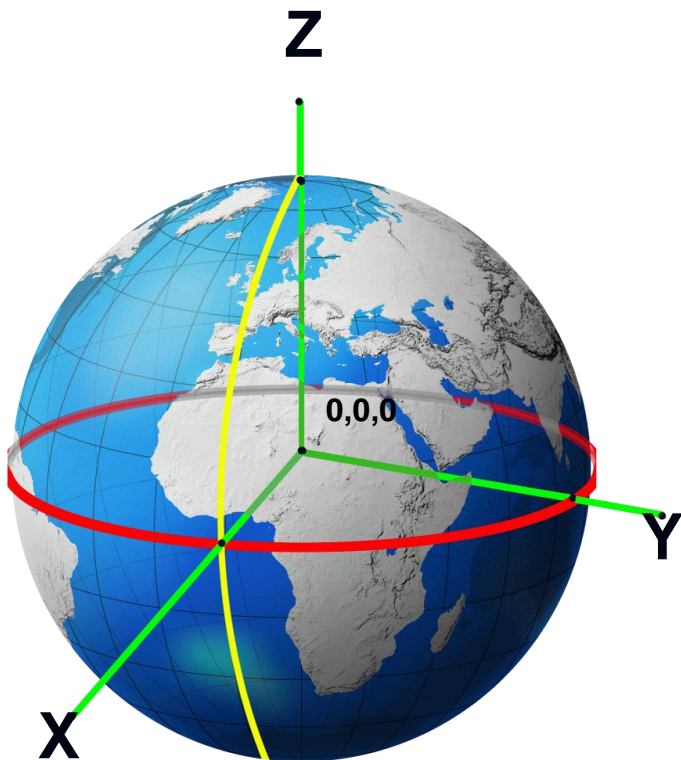




The 'Realization' of an Earth-Centered, Earth-Fixed Global Reference Frame

Definition

Realization



X=-1248597.295m
Y=-4819433.239m
Z= 3976500.175m

X= 6118524.122m
Y=-1572350.853m
Z= -876463.990m

X= 1916197.142m
Y= 6029999.007m
Z= -801737.366m

⋮
⋮
⋮

NGA also provides Earth-orientation parameter predictions to the GPS OCS on a routine basis



NGA GPS Tracking Station at the US Naval Observatory



The NGA GPS Tracking Station at USNO uses a frequency standard tied to UTC(USNO)



NGA Monitoring Station Receivers

- Texas Instruments TI 4100
Dec 1985 - Jan 1994
L1 C/A, L1/L2 P
4 SVs, No A-S capability
- Ashtech Z(Y)-12
Jan 1994 – 2010
L1 C/A, L1/L2 P(Y)
12 SVs, PPS-SM
- ITT MSN SAASM Receiver
2010 – current
L1 C/A, L2C, L1/L2 P(Y)
12 SVs, SAASM





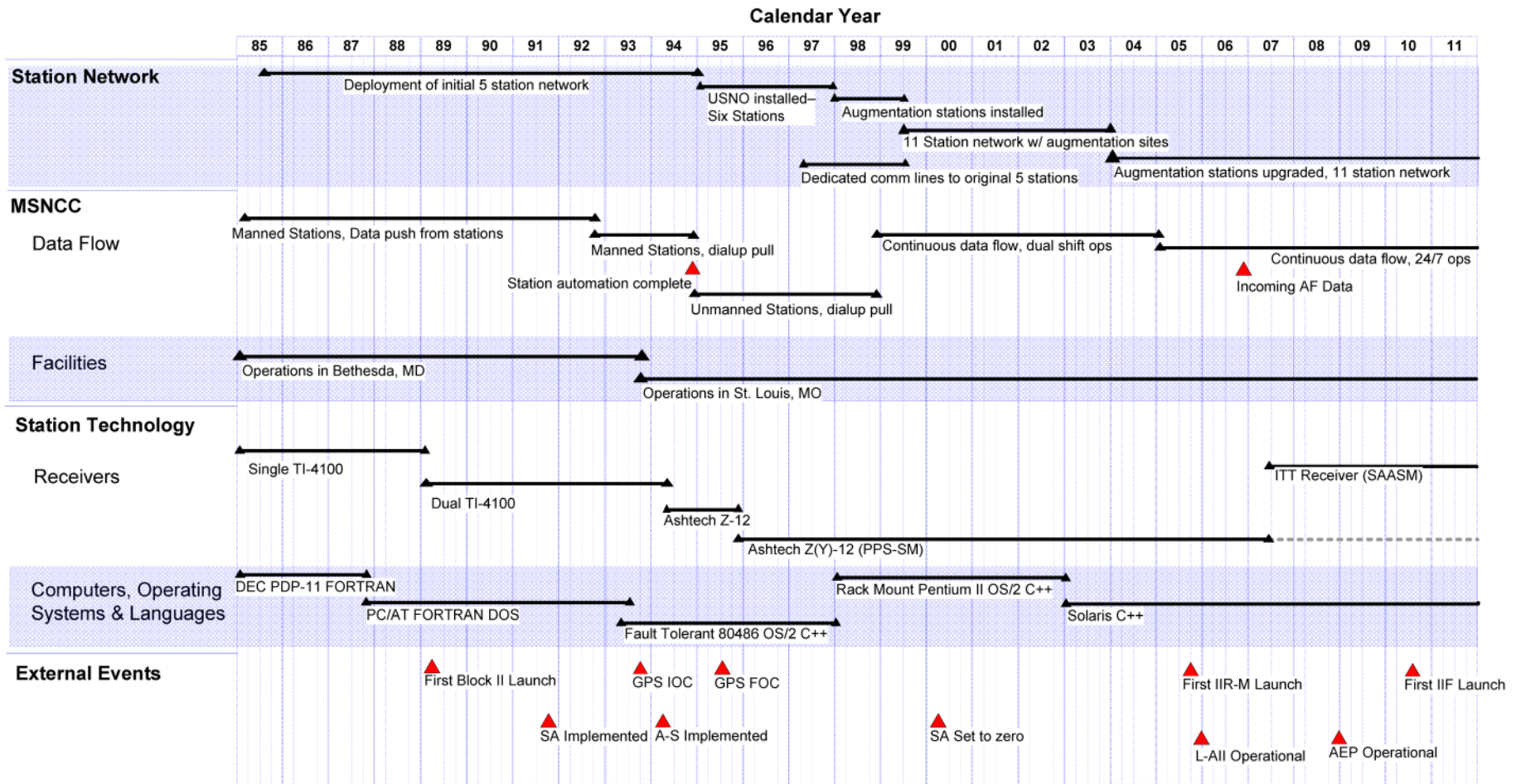
Current NGA Monitor Station Technology



- ITT SAASM Receiver
(above, upper left rack),
- SUN computer,
(center right)
- HP-5071A Frequency Standard.
(upper right rack)



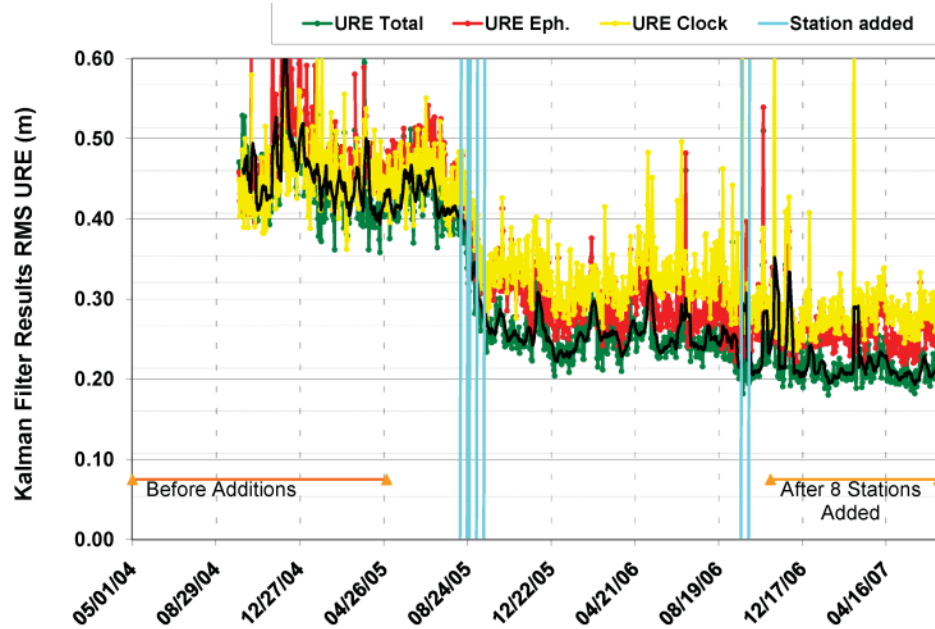
The Timeline



NGA Monitor Station Data Begins to Feed OCS



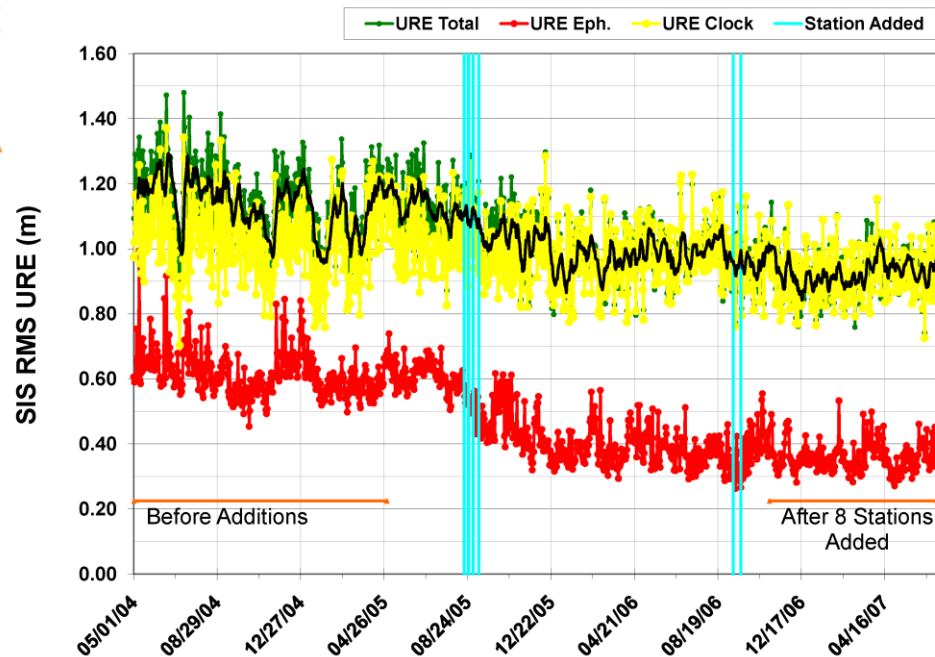
Impact on User Range Error (URE)



- Zero Age of Data URE
- Additional stations results in 51% improvement.

SIS RMS URE represents:

- Ephemeris and clock performance delivered to the user after the orbit predicted forward in time and broadcast from the SVs.
- Improvement is more modest (about 19%)





NGA Network



NGA Network Control Center

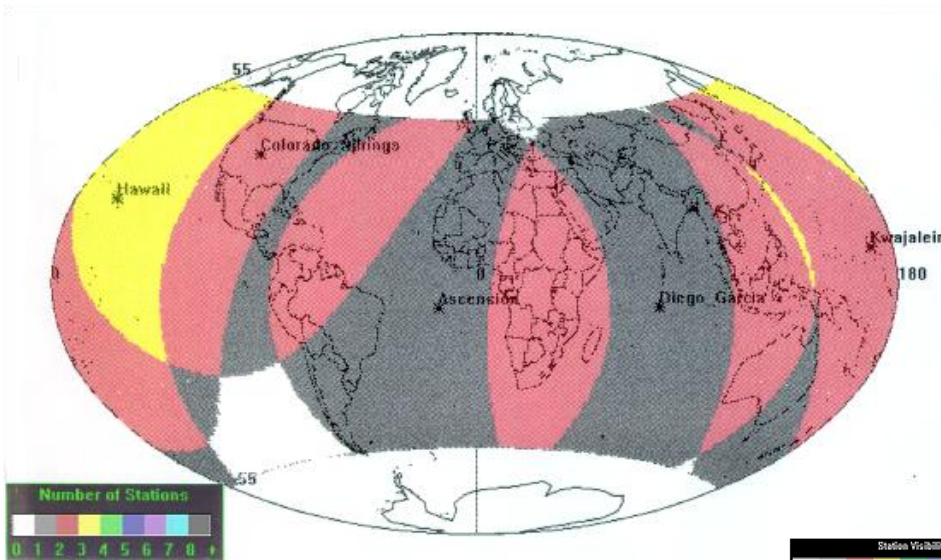




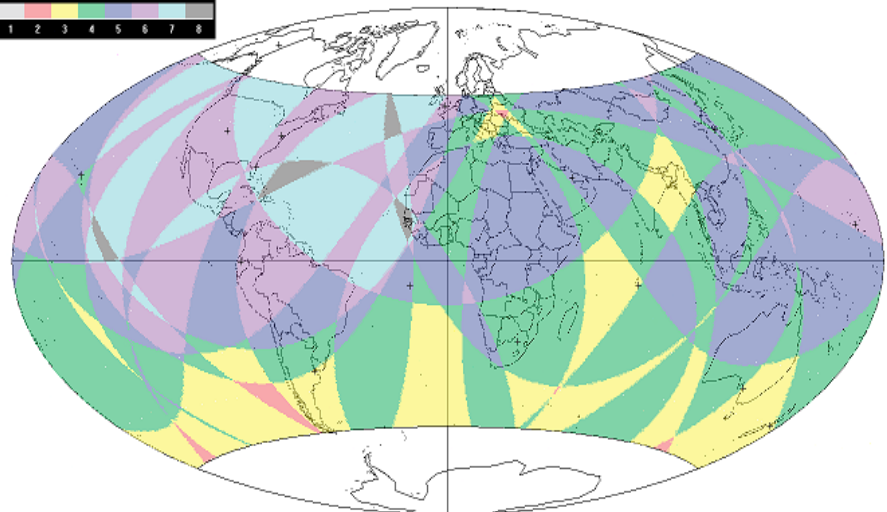
Impact on Satellite Visibility

Co-visibility plotted along ground track projection of SV orbit

Co-visibility plot for five original OCS monitor stations

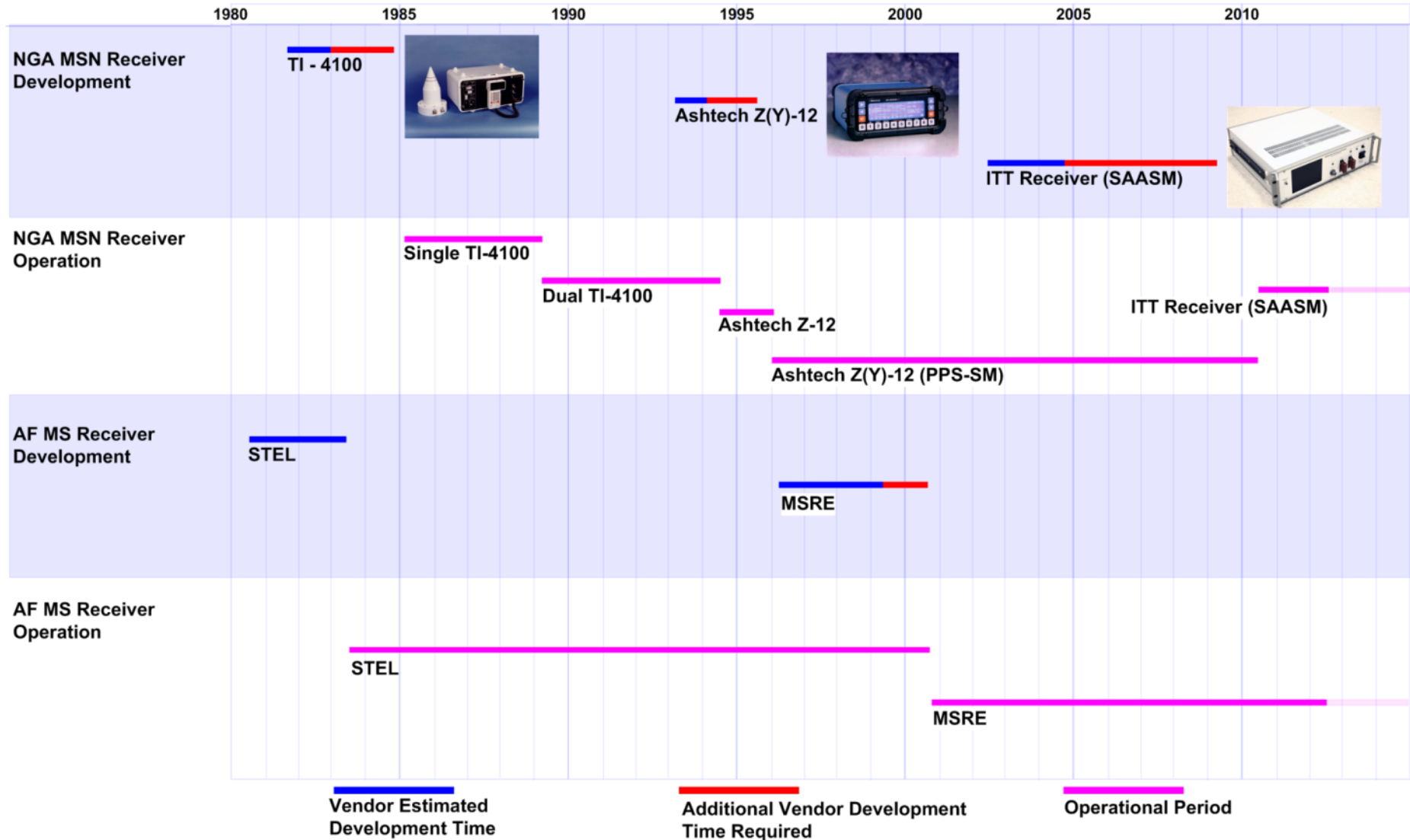


Co-visibility plot for 6 OCS + 10 NGA station network





Monitor Station Development/Deployment



Vendor Estimated Development Time

Additional Vendor Development Time Required

Operational Period



High Rate Tracking Receiver (HRTR)

- A software-defined receiver architecture
 - Designed to JMSRE requirements and interfaces
 - IP Licensed such that government pays for development of features *once* instead of for each procurement
- Digitizing Front End (DFE)
 - Directly samples entire L-band
 - At 2 gigasamples/s with digital downconversion
- Baseband processing
 - Tracks GNSS signals in real-time using FPGAs
- Software reconfigurable
 - Supports new frequency bands and new signals via remote firmware update
 - Supports both traditional observations and detailed signal observations
- HRTRs deployed to four NGA sites in 2011



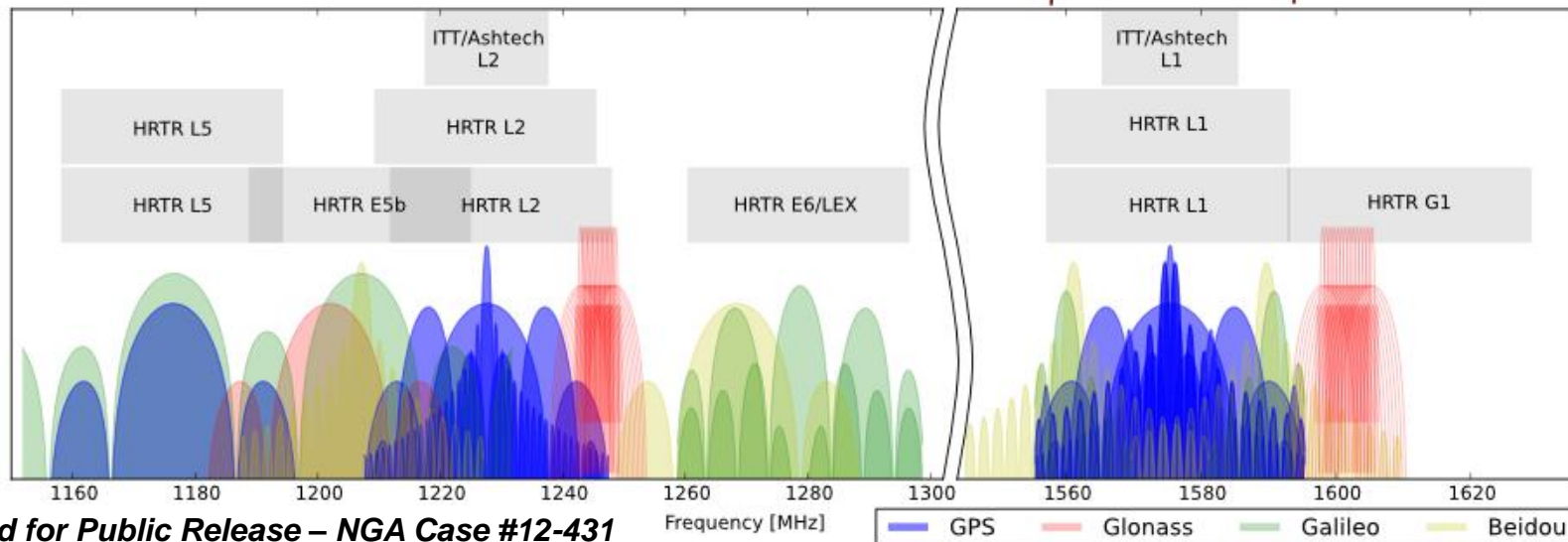
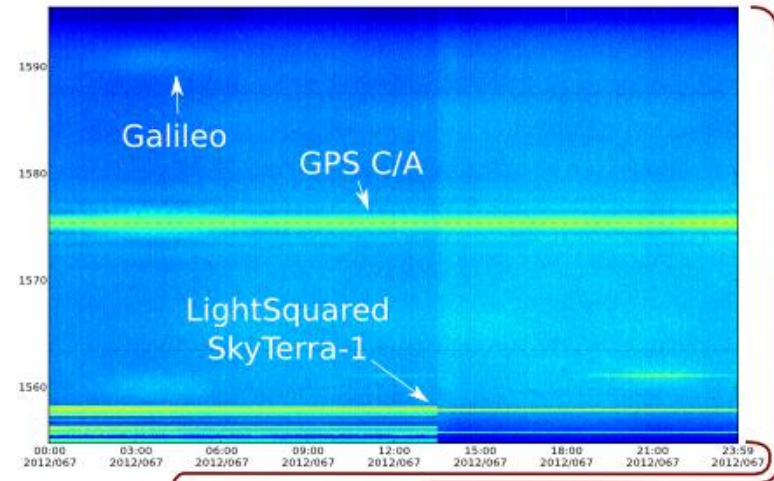
HRTR at NGA Station in Alaska, deployed in 2011





Spectrum Awareness

- L-Band spectrum is heavily used
- 100+ SVs expected for GNSS alone
- High Rate Tracking Receiver (HRTR) well suited to globally monitor ICD compliance and spectral incursions





Contrast Between MS Receivers and Typical GNSS Navigation Receivers

- Requirements of navigation receivers not relevant to monitoring
- Requirements of navigation receivers in conflict with monitoring
- Track signals "outside the envelope" of the specifications
- MS collect full compliment of codes and carriers
- Long-term continuous operation
- Different handling of signal anomalies
- Focus on providing low level raw measures of highest quality rather than accurate PVT solutions



Challenges Faced by Modernization

Develop a receiver that:

- Can track all required signals
- Supports expanded constellation (30+)
- Supports development, test and SV initialization work
- Supports payload anomaly recovery actions
- Supports tighter accuracy requirements in future
- Meets security requirements
- Is sustainable and maintainable over the long haul
- Meets schedule constraints for development and deployment



Summary

- NGA Monitor Stations directly support the operation of the GPS constellation
- Monitor Station Receivers
 - Have unique capabilities
 - Require long timelines to develop, test and deploy
 - Are critical for the operation and performance of the constellation
- GPS is critical for virtually ALL modern Geospatial data collected within NGA and the National System for Geospatial Intelligence (NSG)

NSG Members	NSG Partners
DNI, DIA, NRO, CIA, NSA, CG, DOS, DOE, DHS, DEA, FBI, OUSD(I), DOJ, Services, Joint Staff, COCOMS	USACE, DOA, DOC, DHS, DOI, DOT, EPA, FEMA, NASA, NSF, DISA, DLA, CAC, Australia, Canada, UK, NZ, Industry, Academia, Intl. Entities



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