

# **Performance Impacts of the LightSquared ATC Reference Stations on High Precision GPS Receivers**

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NOAA / National Geodetic Survey

## Presentation Overview

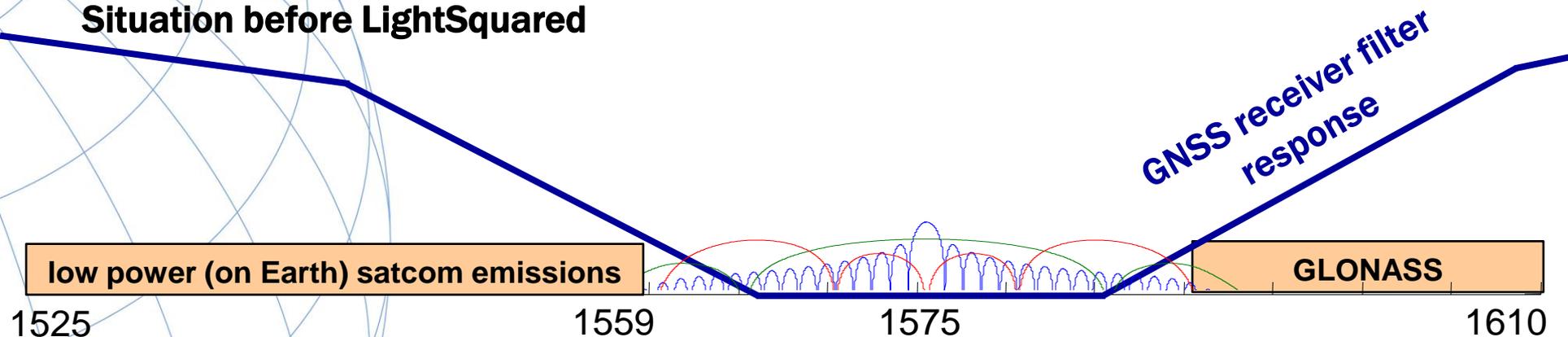
- LightSquared Background & Spectrum Plans
- NOAA Live Sky Summary Test Results
- NOAA Anechoic Chamber Test Results
- Present Status

## Who is LightSquared?

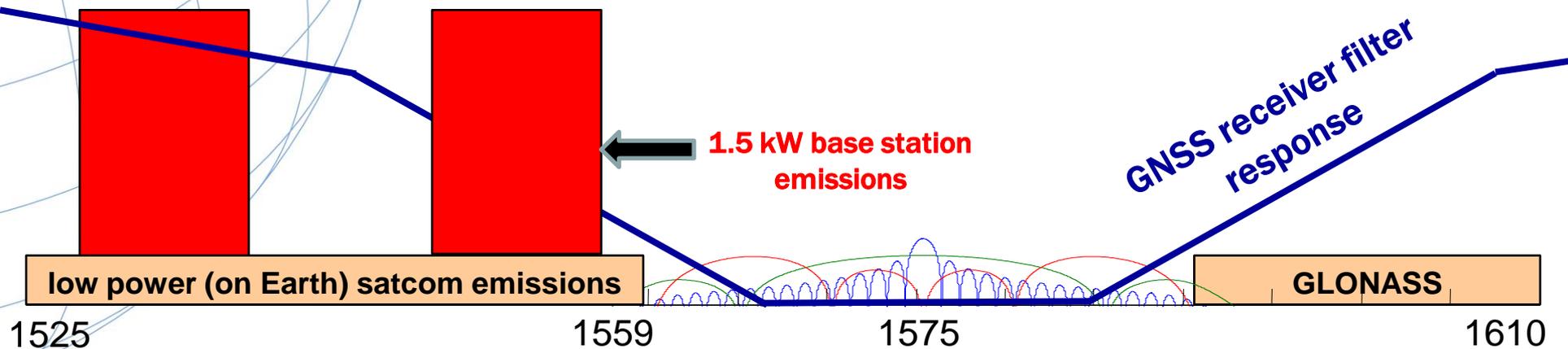
- New Telecom company formed Mid 2010
  - Formerly SkyTerra and before that Mobile Satellite Ventures
- Company formed to create a nationwide 4G LTE (Long Term Evolution) open wireless broadband network
- First wholesale-only broadband network
- Intends to provide coverage to 92% of USA by 2015
- Key Asset
  - Mobile Satellite Service /Ancillary Terrestrial Component license for 1525–1559 MHz; 1626.5-1660.5 MHz

# Illustration of Concerns with LightSquared

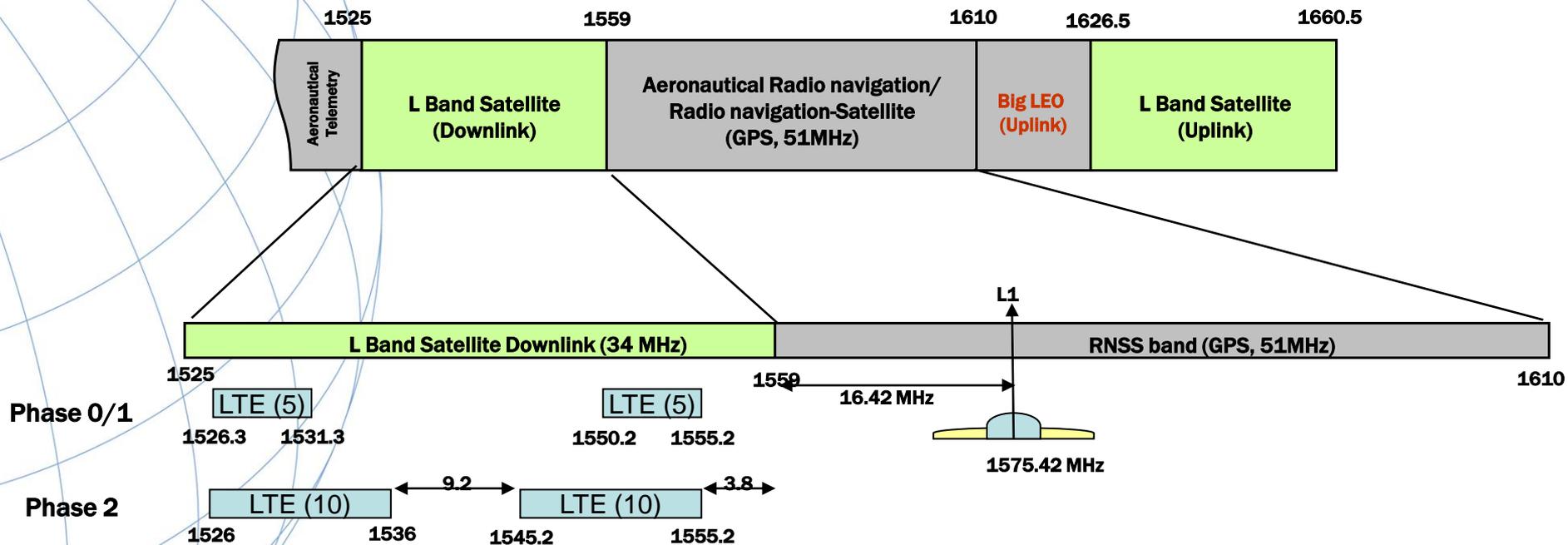
## Situation before LightSquared



## Situation with LightSquared



# Original LightSquared Spectrum Plan



## **NOAA / NGS Configuration For Live Sky Tests at Holloman AFB, April 15, 2011**

- Four high precision geodetic / survey GPS receivers connected through an eight way splitter to a geodetic antenna using magnetic mounts on the vehicle roof
- Another antenna similarly mounted was connected to a single survey receiver with the manufacturer recommended geodetic antenna
- Due to high wind conditions on April 15<sup>th</sup>, the LightSquared Ancillary Terrestrial Component (ATC) reference station could only be raised to 32 ft (9.8 m) instead of the 100 ft (30.48 m) specified operational height
- The NOAA vehicle was approximately positioned 315 m from the LightSquared transmitter for Tests #2, Test #3, and Test #4

## Live Sky Tests w/ NGS Vehicle @ 315 m From LightSquared ATC Transmitter

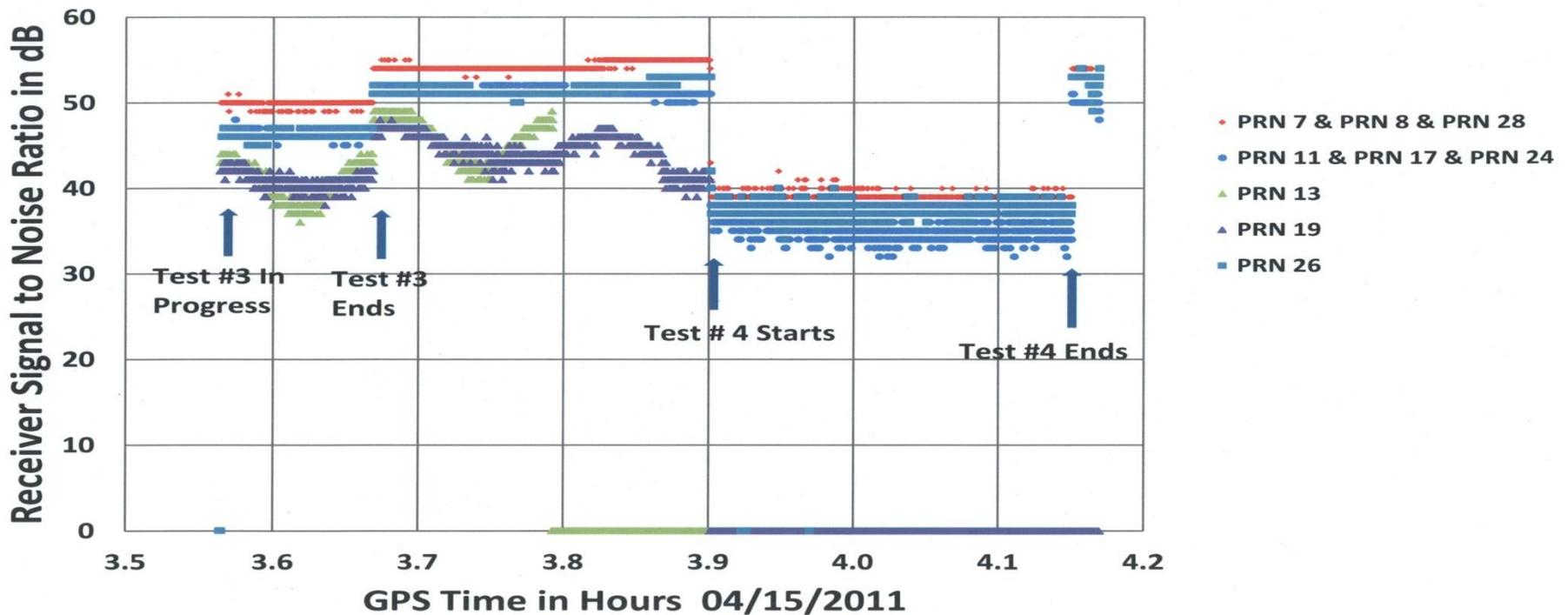
<b>Test #2 – 5 Mhz – High Band- Full Power</b>	Event time (GPS)	Transmitted Power EIRP –Total (dBm)
Start Test	2:39:00	54.1
Added + 3dB to each port	2:42:00	57.1
End Test	3:09:00	57.1
<b>Test #3 – 5 Mhz – Low Band – Full Power</b>		
Start Test	3:25:00	57.2
End Test	3:40:00	57.2
<b>Test #4 – 10 Mhz – Low Band – Full Power</b>		
<b>Start Test</b>	<b>3:54:00</b>	<b>57.2</b>
<b>End Test</b>	<b>4:09:00</b>	<b>57.2</b>

## High Precision Receiver Performance with LightSquared Lower 10MHz Signal

Receiver ID Code	Receiver Performance
Receiver H07007B/A-ant	No SNR degradation or tracking loss
Receiver H07007A/C-ant	SNRs for all PRNs tracked decreased 11 dB at beginning of test and dropped another 4 dB at the end of test
Receiver H80708/B-ant. (in 4 seconds) Receiver H92053/B-ant. (in 6 seconds) Receiver H91389/B-ant. (in 22 seconds)	less than 4 PRNs tracked – no position solution for remainder of test

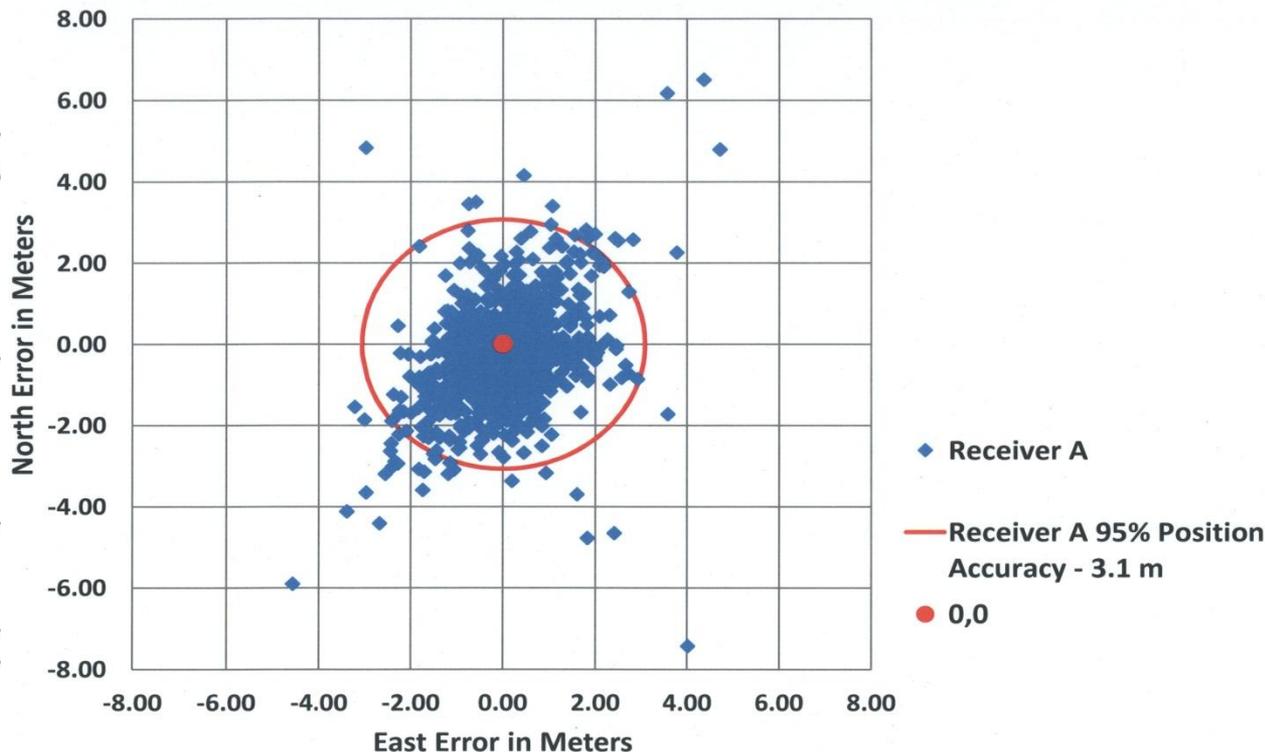
# Receiver H07007A C/N0 (Signal-to-Noise Ratio) During Tests #3 and #4

Receiver H07007A with Geodetic Antenna C  
 L1 C/A PRN 7, 8, 11, 13, 17, 19, 24, 26 & 28  
 NOAA Vehicle Approximately 315 m from LightSquared ATC  
 Reference Station (Tower at 9.8 m Elevation)



# Post Processed Pseudorange and Carrier Phase Accuracy with LightSquared Transmitter On

Receiver H07007A / Antenna C - Position Error During LightSquared Transmitter Test #4 (10 Mhz Low Band 57.2 dBm)



	95% Predicted Position Accuracy	95% Measured Position Accuracy
Receiver H07007A/C-ant. Test site #1	2 cm.	1.2 cm Test # 4 (898 Data Points)

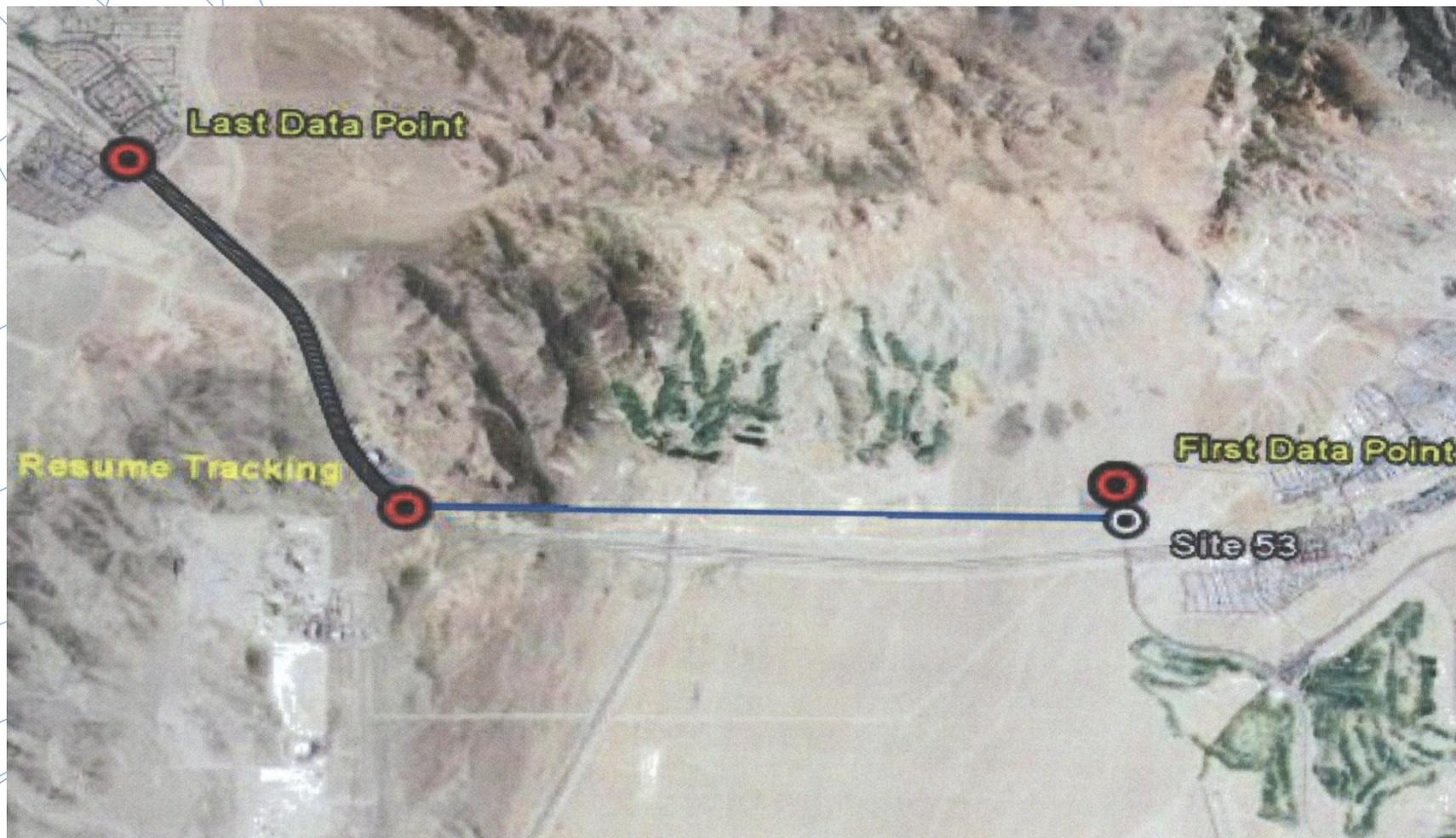
## TWG Live Sky Tests in Las Vegas

- NOAA / NGS and several law enforcement agencies were the only federal organizations participating in the Lightsquared sponsored Live Sky Testing
  - ❖ Law enforcement agencies conducted an operational test of their equipment
  - ❖ NOAA /NGS conducted a more detailed evaluation of percent of tracking loss for each receiver during LightSquared transmissions and tracking loss ranges from the LightSquared ATC reference station for each receiver

# Typical East –West NOAA / NGS Vehicle Test Track May 19 -20, 2011



# High Percentage Tracking Loss - GPS Receiver H33451 - Resume Tracking @ 3753 m. from the LightSquared Transmitter



## East – West Maximum GPS Receiver Tracking Loss Distances

Receiver ID	Tracking Loss Range - East	Tracking Loss Range - West
H07007 w/ Antenna 2	1101 m.	1339 m.
H41591 w/ Antenna 5	1025 m.	1303 m.
H80708 w/ Antenna 5	No Tracking Loss	775 m.
H33451 w/ Antenna 5	1125 m.	3753 m.
H84576 w/ Antenna 5	<u>2012 m.</u>	<u>3995 m.</u>

May 19, 2011 – 5 MHz Upper Band

Receiver ID	Tracking Loss Range - East	Tracking Loss Range - West
H07007 w/ Antenna 5	520 m.	362 m.
H41591 w/ Antenna 1	1868 m.	2981 m.
H33451 w/ Antenna 1	1886 m.	3133 m.
H84576 w/ Antenna 1	2015 m.	<u>3151 m.</u>
H47596 w/ Antenna 1	1153 m.	2094 m.
H91389 w/ Antenna 1	<u>2027 m.</u>	2119 m.

May 20, 2011 5 MHz Upper & Lower Band

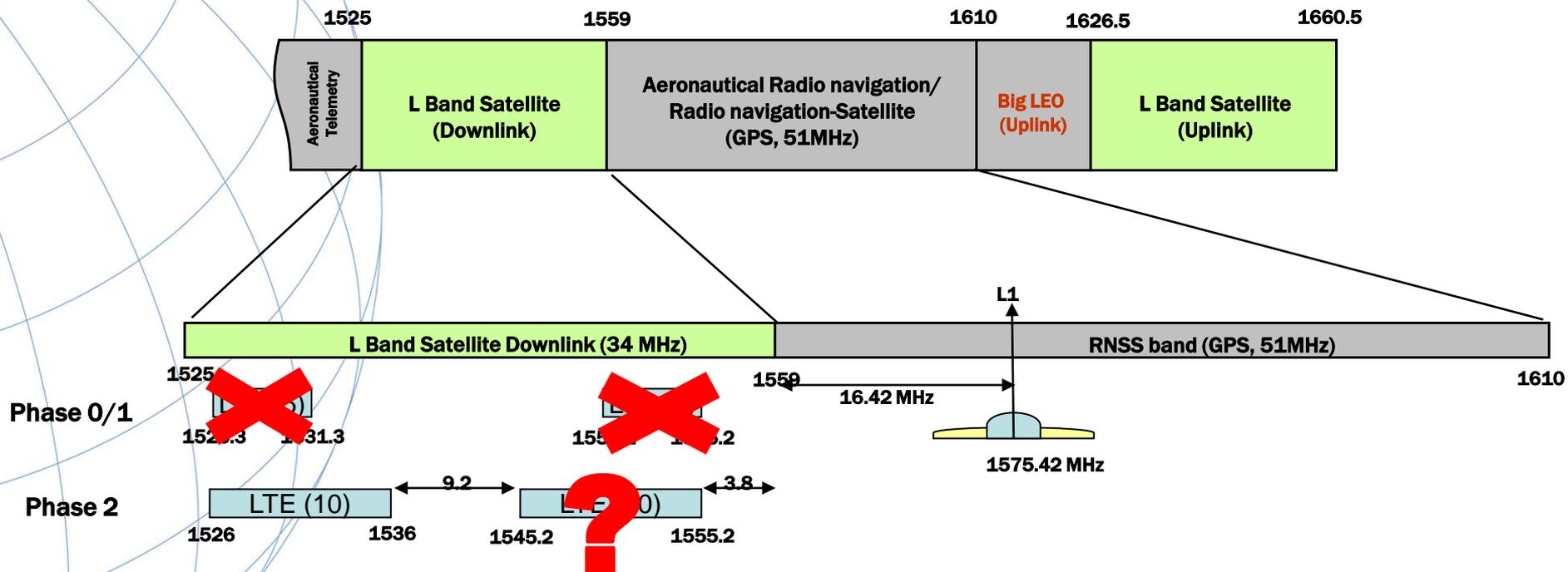
## LightSquared & Federal Working Groups Completed Activities

- TWG Final report filed with the FCC June 30
  - LightSquared also filed a modified deployment plan on the same date as the TWG report
- NPEF Final Report public version filed with the FCC on July 06
- RTCA report focusing on aviation receivers available to the public on the FCC website

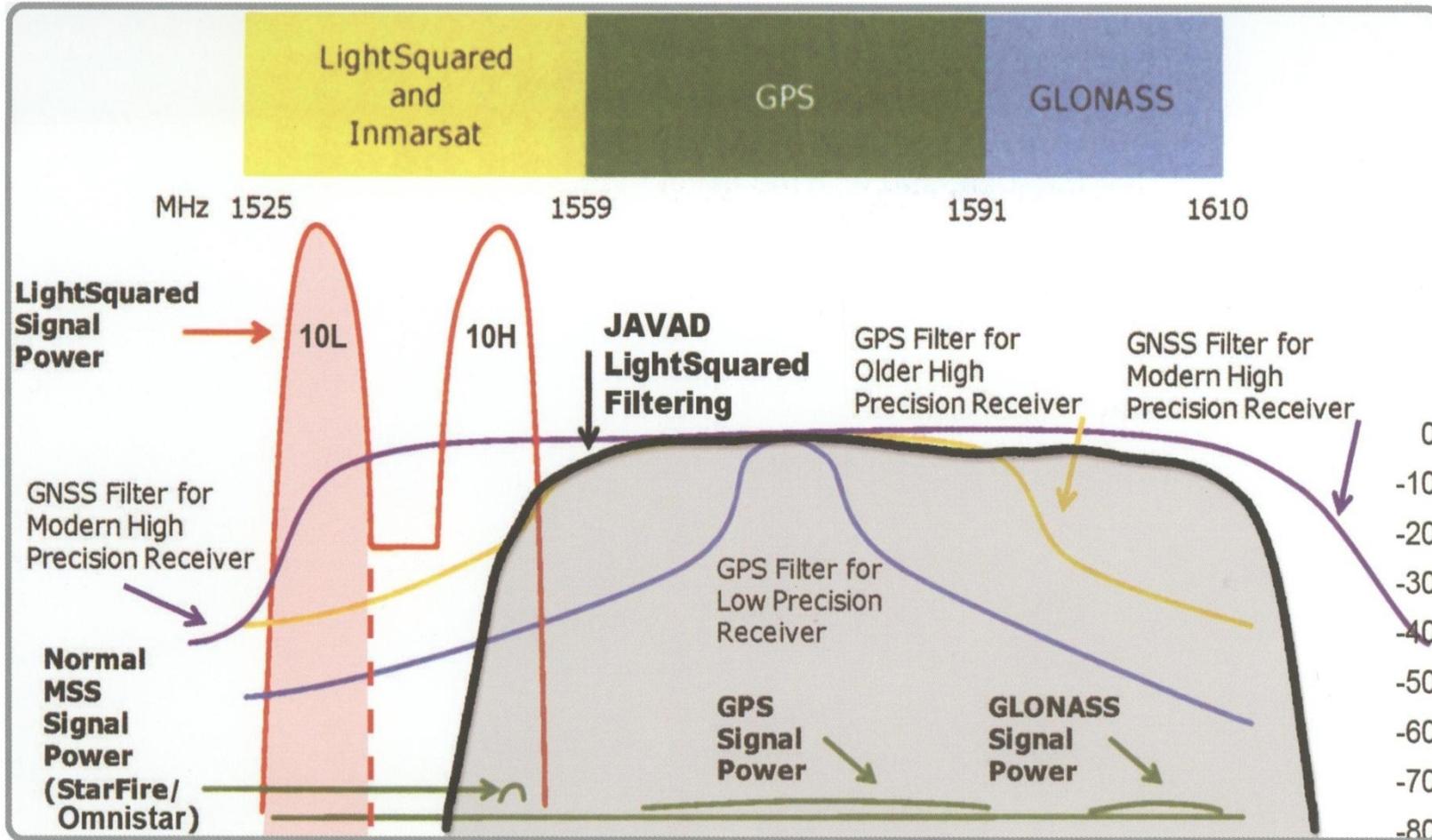
## LightSquared Modified Spectrum Plan

- LightSquared will commence terrestrial commercial operations only on the lower 10 MHz portion of its spectrum
  - ❖ They will coordinate and share the cost of underwriting a workable solution with GPS manufacturers of legacy precision measurement devices that may be at risk
  - ❖ A filter solution for the Lower 10 MHz band has been developed by Javad, Topcon, Hemisphere, Partron America and PCTEL in partnership with LightSquared for high precision receivers

# Current LightSquared Spectrum Plan End Spectrum State Undefined



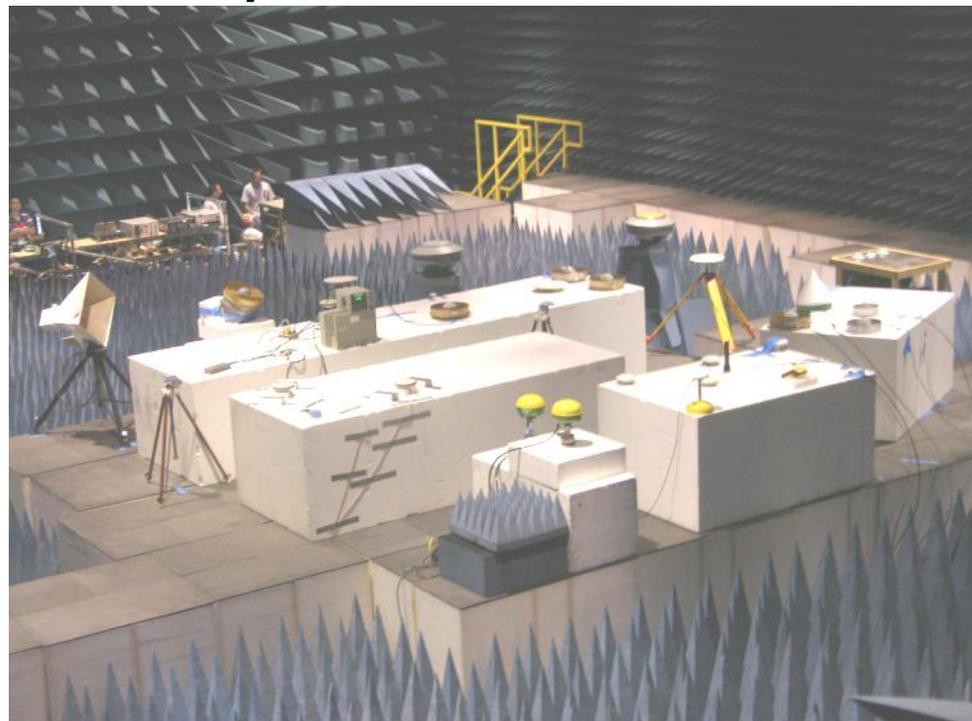
# Javad Filter Response to Mitigate the Lower 10 MHz LightSquared Signal



# New NPEF Testing at WSMR

## Oct. 31 – Nov. 4, 2011

- Targeted Testing
  - Navigation/Cellular Devices
  - Low 10 MHz
  - Handset (LSQ Cell Phone) simulation to be included
  - NOAA Participants
    - NOS / NGS – 4 Precision survey /geodetic receivers
    - NOS / Office of Coast Survey – 4 marine navigation receivers
    - NWS – 3 general location / navigation receivers and 1 timing receiver



# NPEF Testing at WSMR

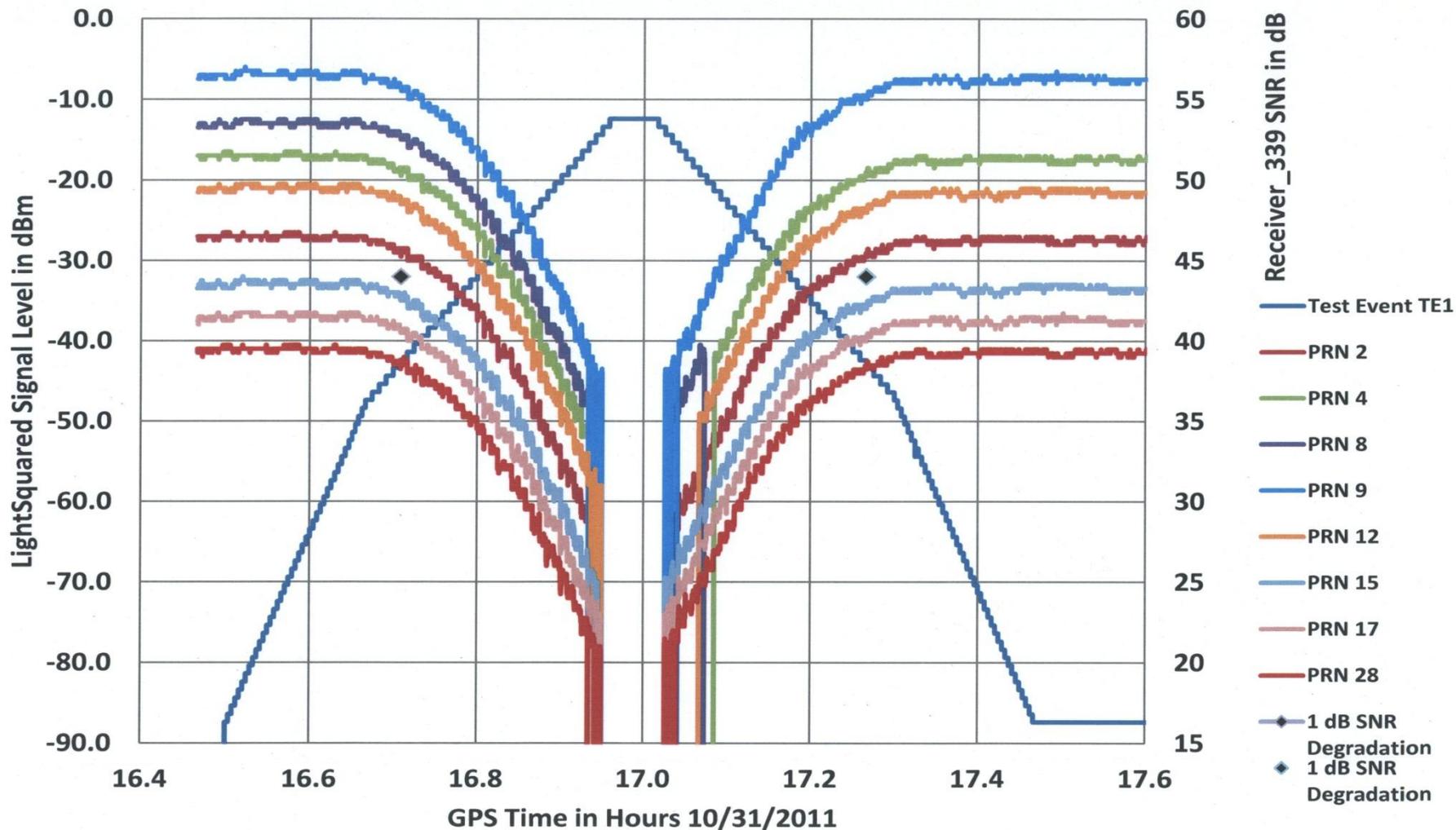
## Oct. 31 – Nov. 4, 2011

- Testing focused on General Navigation / Location receivers and Cellular Devices
- 37 other receivers (including high precision receivers) were also tested
- NGS objective in participating in the White Sands Missile Range (WSMR) testing was to:
  - ❖ Test the best and worst performing receiver with a legacy “robust” antenna from the Live Sky tests (Holloman, April 2011 and Las Vegas, May 2011)
    - ❖ CORS management requested another receiver be added to the test suite
  - ❖ A Javad receiver from the NGS CORS Foundation network was also added with the possibility of testing a modified JAVAD antenna to mitigate the LightSquared lower 10 MHz signal
  - ❖ A total of six receivers were tested (four different manufacturers and two spares)

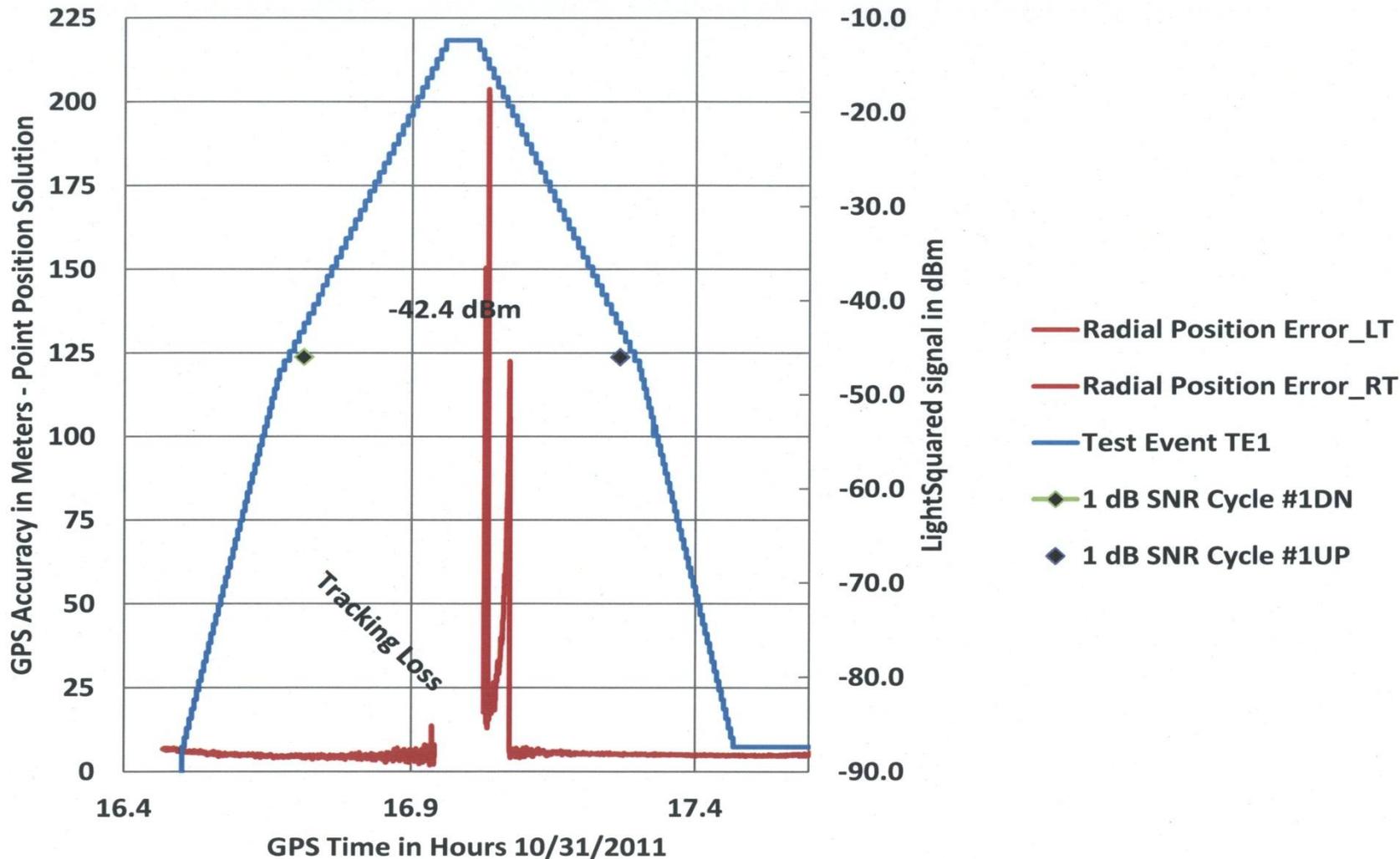
## **NOAA /NGS Configuration for the Lower 10 MHz at WSMR on Day One (10/31/2011) of Testing**

- Five high precision geodetic / survey GPS receivers connected through an eight way splitter to a “robust” legacy geodetic antenna in the Anechoic Chamber
- A single survey receiver with the manufacturer recommended geodetic antenna at a different grid location in the chamber

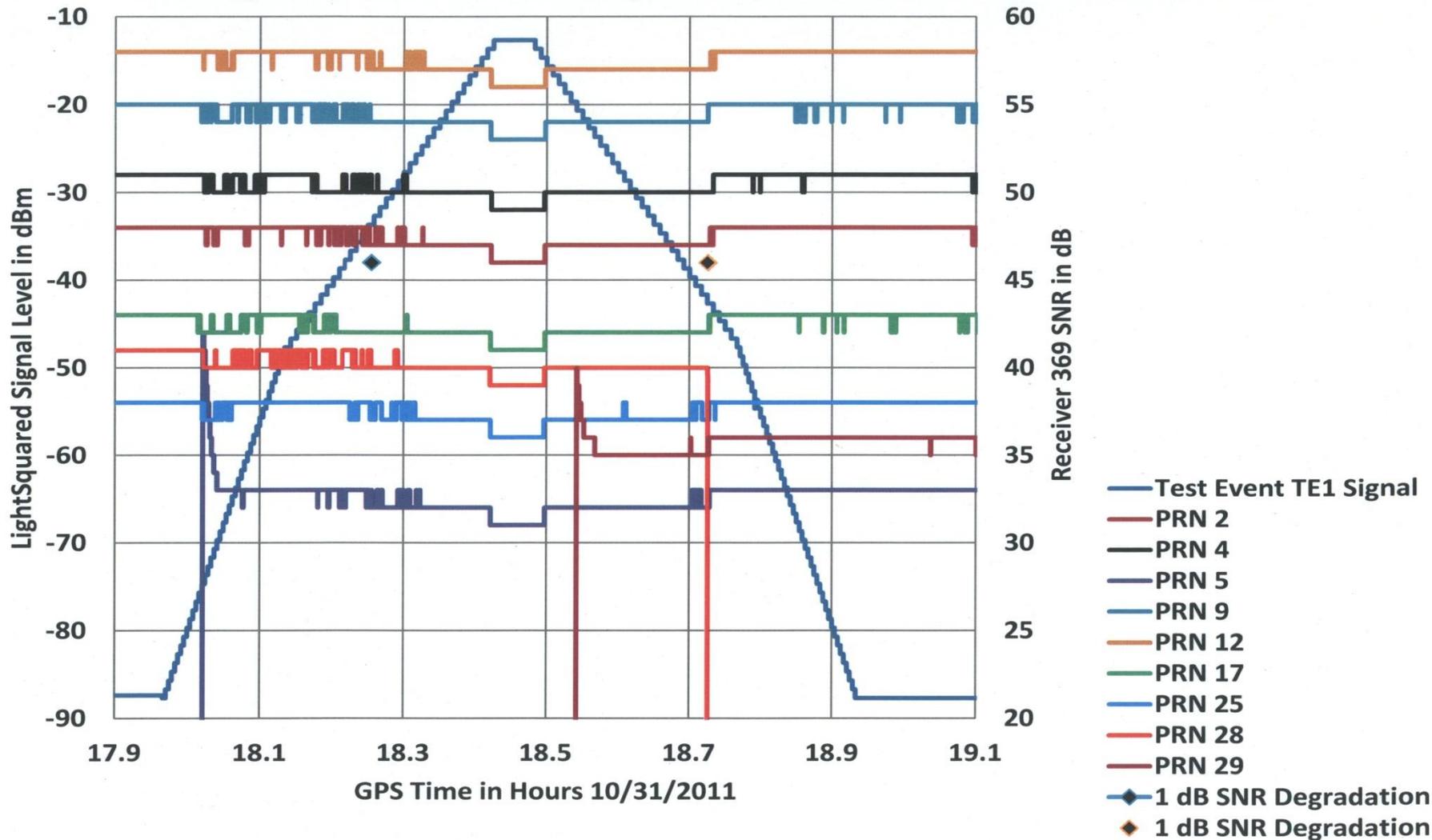
### Receiver 339 / Ant. #369/ SNR Degradation / LightSquared Lower 10 MHz Signal / Cycle #1 / WSMR Anechoic Chamber Tests



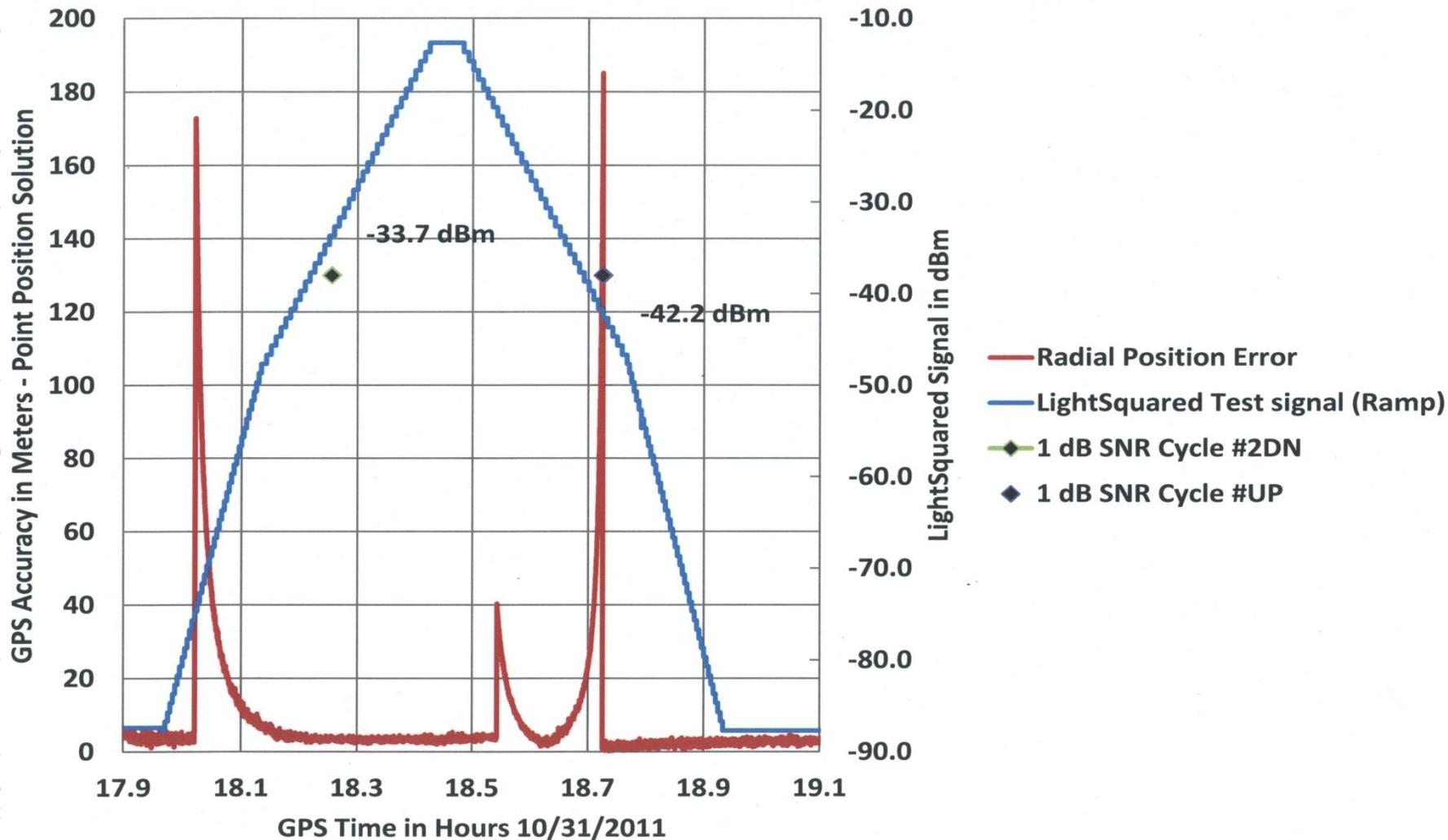
### Receiver 339 W/ #369 Geodetic Antenna / Radial Position Error / Test Event TE1 / Cycle #1 / WSMR Anechoic Chamber Tests



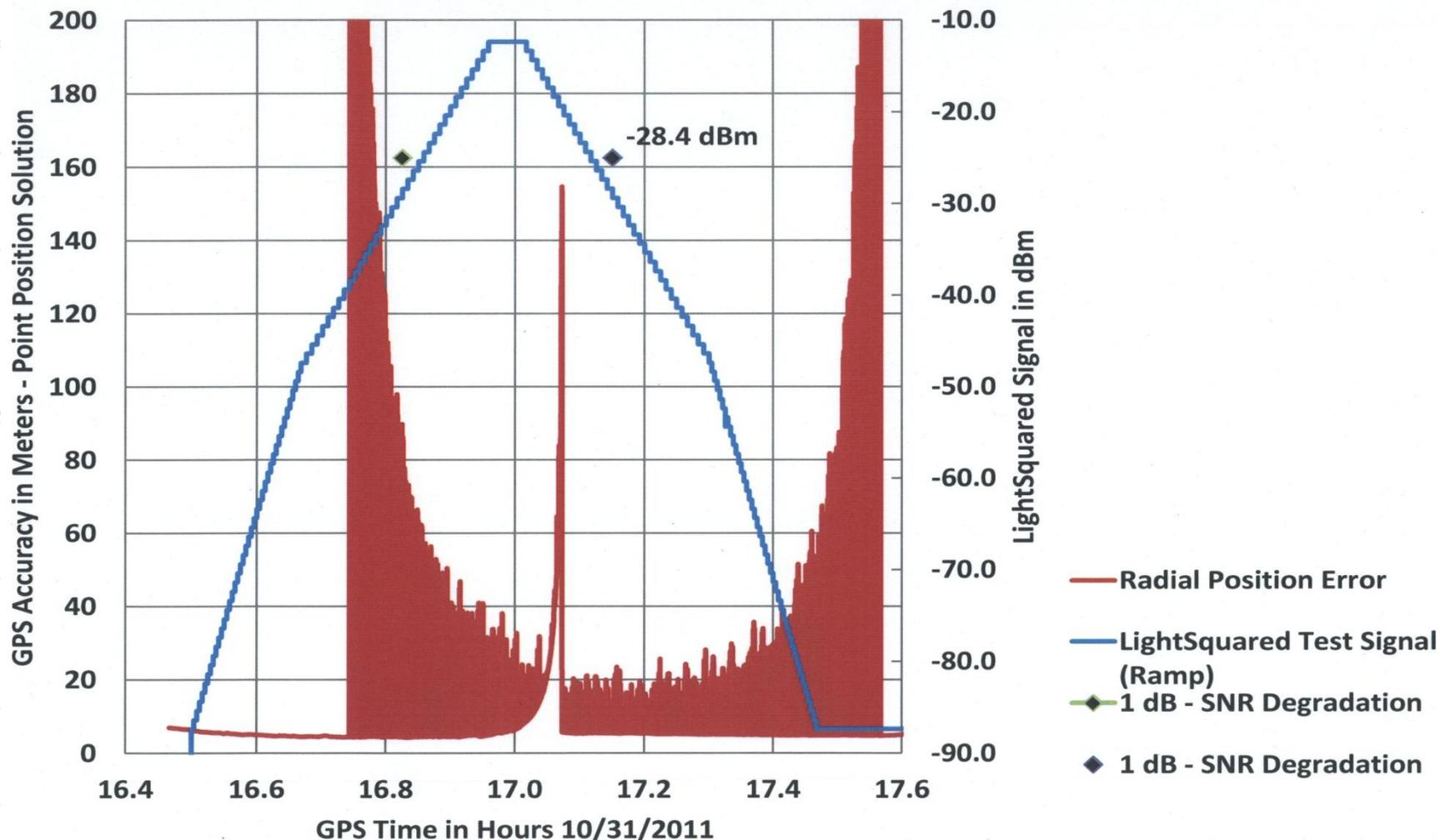
### Receiver 369 / Ant. #369 / SNR Degradation / LightSquared Lower 10 MHz Signal / Test Event TE1 / Cycle # 2 / WSMR Anechoic Chamber Tests



### Receiver 369 / Ant. # 369 / Radial Position Error / Test Event TE1 Cycle #2 / WSMR Anechoic Chamber Tests



### Receiver 114 / Ant. # 369 / Radial Position Error / Test Event TE1 Cycle # 1 / WSMR Anechoic Chamber Tests



# GPS WSMR Receiver Performance

Receiver ID	Antenna MR/ LR- More/Less Robust	1 dB SNR Avg. dBm	Test Day	GPS Accuracy Events			Tracking Loss
				Test Cycles			
				<u>1</u>	<u>2</u>	<u>3</u>	
369	369-MR	-33.8	Day 1	1	3	1	No
202	369-MR	-14.7	Day 1	1	3	2	No
114	369-MR	-28.8	Day 1	2	3	3	No
339	369-MR	-42.3	Day 1	2	4	3	Cycle #1 Only
399	399- LR	-42.1	Day 1	3	3	3	No
219	369-MR	None	Day 3	2	2	2	No
234	369-MR	None	Day 3	2	2	2	No
246	399- LR	-25.2	Day 3	1	2	1	All Cycles
215	399- LR	-55.4	Day 3	2	2	0	All Cycles
231	399- LR	-41.9	Day 3	3	2	2	All Cycles

## Anechoic Chamber Conclusions

- Preliminary Test Results indicate that the legacy “robust” antenna combined with a number of high precision receivers is not sufficient to mitigate the LightSquared lower 10 MHz signal
  - ❖ Significant degradation to point position accuracy during all cycles of the LightSquared ramp test signal
  - ❖ A filter solution developed specifically for the lower 10 MHz is required and needs to be independently tested
    - The Javad modified filter was not available for WSMR Anechoic Chamber testing last November

## Present Status

- The NPEF test report focusing on General Location and Navigation devices is under review and will be released to the public shortly.
- Based on the test results for General Location and Navigation receivers and aviation analysis, the EXCOM has notified the NTIA that further testing is not warranted at this time.

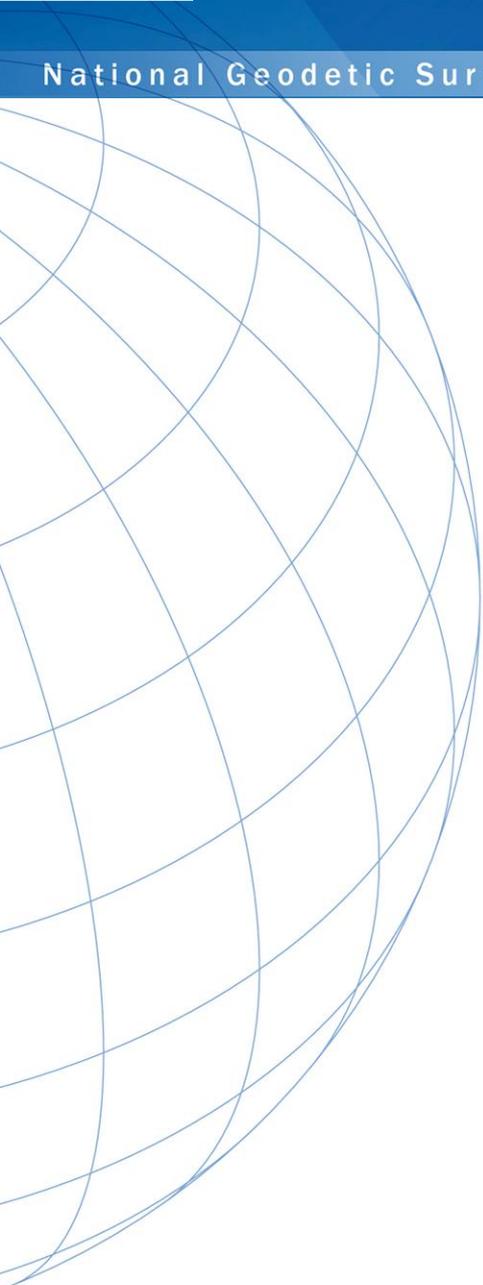
# Questions?

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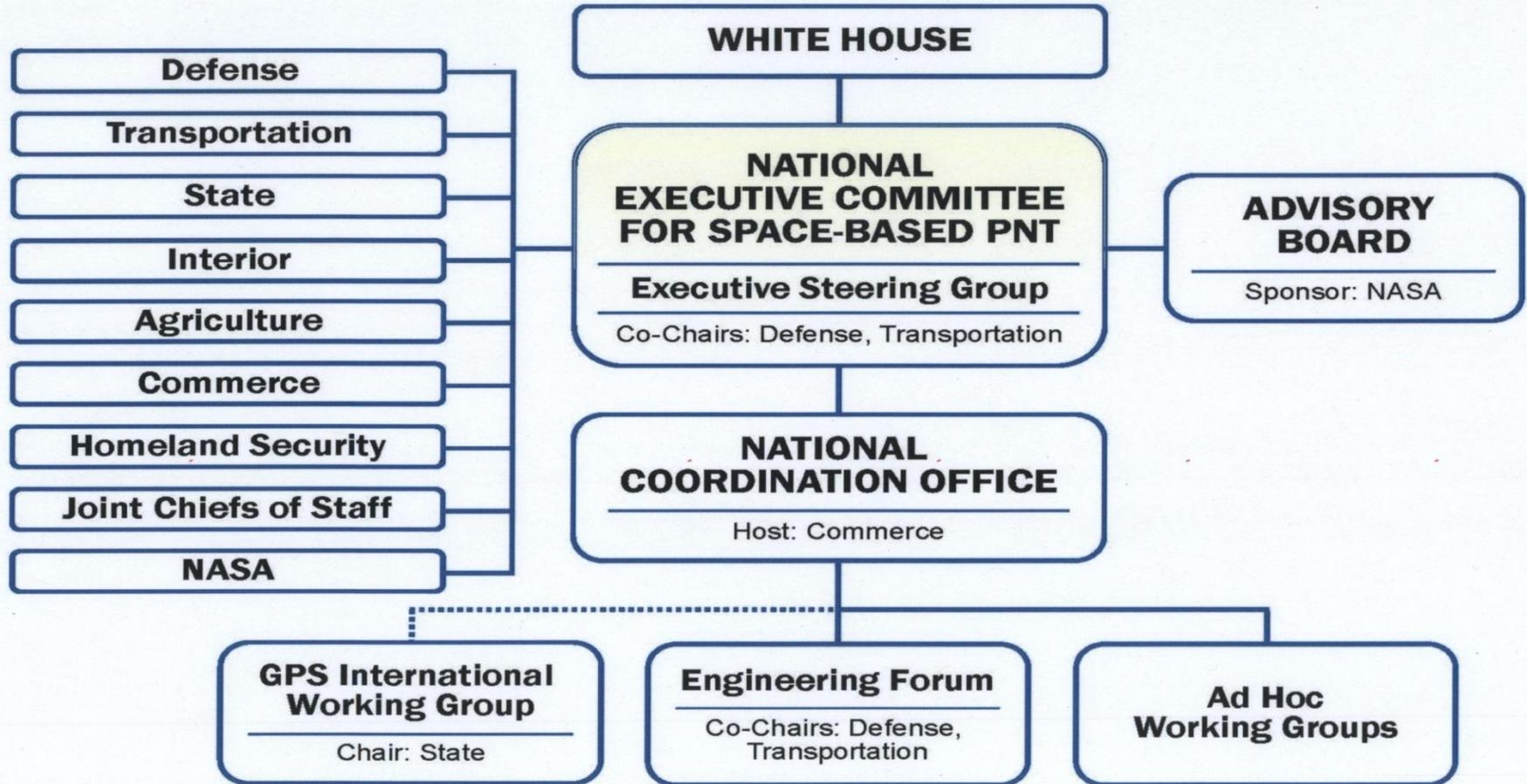
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# Backup Slides

# US Space-Based PNT Organization Structure



NATIONAL COORDINATION OFFICE FOR SPACE-BASED POSITIONING, NAVIGATION & TIMING



# JAVAD & TOPCON Filter Results Alcatel Lucent Bell Labs

