

# Space and Missile Systems Center



## GPS Modernization Update

June 2014

Lt Col Brian K. Bailey  
Global Positioning Systems Directorate

# Report Documentation Page

Form Approved  
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE <b>JUN 2014</b>		2. REPORT TYPE		3. DATES COVERED <b>00-00-2014 to 00-00-2014</b>	
4. TITLE AND SUBTITLE <b>GPS Modernization Update</b>				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>Space and Missile Systems Center, Global Positioning Systems Directorate, Los Angeles AFB, CA, 90009</b>				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release; distribution unlimited</b>					
13. SUPPLEMENTARY NOTES <b>Space-based Positioning and Navigation Timing Thirteenth Meeting, 3-4 June 2014, Washington DC.</b>					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT <b>Same as Report (SAR)</b>	18. NUMBER OF PAGES <b>17</b>	19a. NAME OF RESPONSIBLE PERSON
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>			



# GPS Constellation

SPACE AND MISSILE SYSTEMS CENTER

- **Robust constellation**
  - 30 space vehicles currently set healthy
    - 6 GPS IIA, 12 GPS IIR, 7 GPS IIR-M, 5 GPS IIF
  - 5 additional satellites in residual status, 1 in test status
  - SV-6 successfully launched 16 May 14
- **6 more GPS IIFs in pipeline**
  - SV-7 scheduled for Jul 2014 launch
  - SVs 8 and 10-12 in storage; SV-9 pending final testing
- **Extensive International and Civil Cooperation**
  - Agreements with 57 international customers
  - ~2 billion civil/commercial users
- **Global GPS civil service performance commitment met continuously since Dec 1993**
  - Best performance 46.6 cm User Range Error (URE) 8 Jun 13; best weekly average 64.6 cm URE 16 Apr 14
  - Performance improving as new satellites replace older satellites

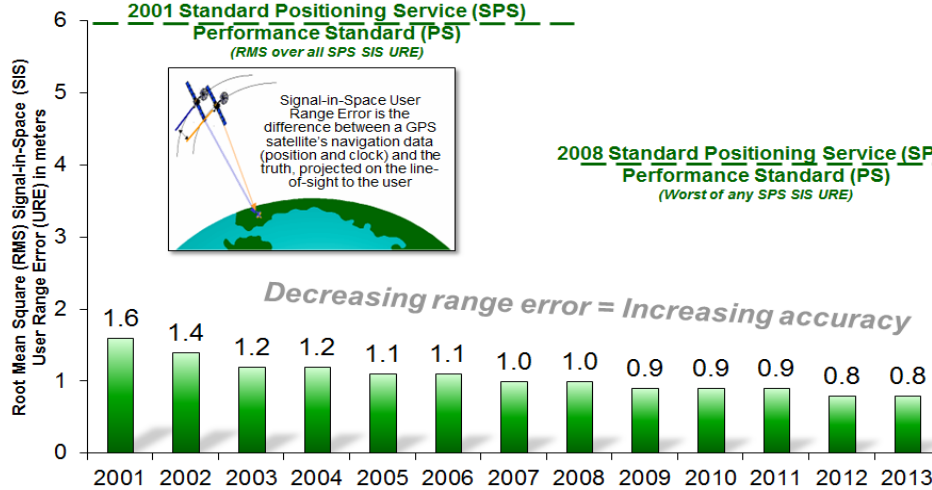




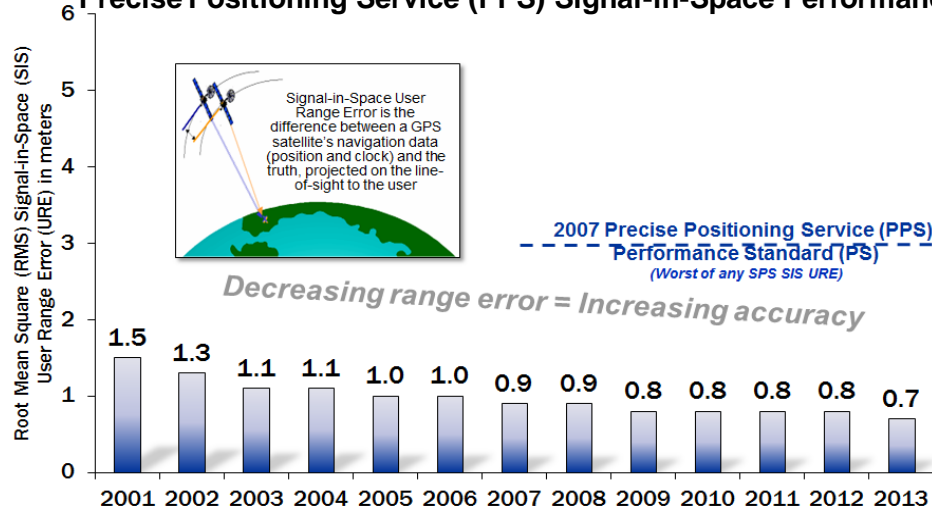
# GPS Signal in Space Performance

SPACE AND MISSILE SYSTEMS CENTER

## Standard Positioning Service (SPS) Signal-in-Space Performance



## Precise Positioning Service (PPS) Signal-in-Space Performance



**System accuracy exceeds published standard**



# GPS Modernization Program

SPACE AND MISSILE SYSTEMS CENTER

## Legacy GPS IIA/IIR

- Single Frequency (L1)
- Coarse acquisition (C/A) code
- Y-Code (L1Y & L2Y)

## GPS IIR-M

- 2<sup>nd</sup> Civil Signal (L2C)
- M-Code (L1M & L2M)

## GPS IIF

- 3<sup>rd</sup> civil signal (L5)
- 2 Rb + 1 Cs Clocks
- 12 year design life

## GPS III

- 4<sup>th</sup> civil signal (L1C)
- 4x better User Range Error than GPS IIF
- Increased availability
- Increased integrity
- 15 year design life



## Legacy Operational Control Segment (OCS)

- Mainframe system
- Command & Control
- Signal monitoring

## Architecture Evolution Plan (AEP)

- Distributed architecture
- Increased signal monitoring
- Security & Accuracy
- Launch and disposal ops

## Next Generation Operational Control System (OCX) Block 0

- Launch & On-Orbit Checkout of GPS III
- Fly legacy constellation

## OCX Block 1

- Transition from OCS to OCX for all GPS command and control operations

**Increasing system capabilities - Increasing user benefit**



# CNAV Pre-Operational Deployment

*SPACE AND MISSILE SYSTEMS CENTER*

- Initiated continuous CNAV message broadcast (L2C & L5) on 28 Apr 14
- CNAV Data message uploaded twice a week initially; with daily uploads expected by Dec 2014
- Position accuracy not guaranteed during pre-operational deployment of CNAV signals; “use at own risk”
  - L2C message currently set “healthy”
  - L5 message set “unhealthy” until sufficient monitoring capability established (signal verification)
- Expected Performance for users:
  - During first 24 hours after upload, CNAV performs as LNAV
  - Expect divergence between CNAV & LNAV as CNAV data ages until next CNAV upload



# GPS III

SPACE AND MISSILE SYSTEMS CENTER

- Newest block of GPS satellites
  - 4 civil and 4 military signals:  
L1 C/A, L1C, L2C, L5; L1/L2 P(Y), L1/L2M
  - First satellite to broadcast common L1C signal
  - Three improved Rubidium atomic clocks
- GPS Satellite Simulator delivered to support Next Generation Operational Control System (OCX) & cross-segment testing
- GPS III Non-Flight Satellite Testbed accomplished launch processing at Cape Canaveral; reduced risk for integration & test and launch processing
- SV07/08 contract awarded 31 Mar 14



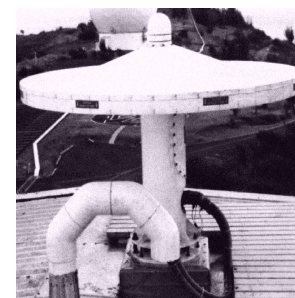
Lockheed-Martin (Waterton, CO) – Prime



# Ground Segment

*SPACE AND MISSILE SYSTEMS CENTER*

- Current system Operational Control Segment (OCS)
  - Flying GPS constellation on Architecture Evolution Plan (AEP) and Launch & Early Orbit, Anomaly, and Disposal Operations (LADO) software systems
  - Cyber security enhancements in progress
- Next Generation Operational Control System (OCX)
  - Modernized command & control system with M-Code, modern civil, signal monitoring, info assurance infrastructure and improved PNT performance
  - OCX Block 0 supports launch & checkout for GPS III and is in integration & test; Raytheon (Aurora, CO) - Prime
  - OCX Block 1 supports transition from OCS in 2017
  - Successfully completed 3 GPS III launch exercises



**Monitor Station**



**Ground Antenna**



*SPACE AND MISSILE SYSTEMS CENTER*

# Spectrum Allocation and Sharing Initiatives



# Spectrum Allocation and Sharing Initiatives

SPACE AND MISSILE SYSTEMS CENTER

- International & Domestic push to reallocate or share spectrum on L-Band for mobile services
- Domestically, Presidential Memo regarding providing 500 MHz of spectrum for mobile services
  - Adjacent-Band Capability (ABC) study initiated to ensure GPS receiver performance
- Internationally, working through the World Radiocommunication Conference to identify spectrum allocation opportunities and to ensure Global Navigation Satellite System (GNSS) performance

***Fully support the allocation and sharing of spectrum through robust analysis, testing and specification development***



# AFSPC Contribution to Adjacent-Band Compatibility (ABC) Study

*SPACE AND MISSILE SYSTEMS CENTER*

- Setup / provide representative receiver hardware to model interference scenarios
- Provide subject matter experts as required to conduct analysis & testing
- Use existing GPS public forums to involve receiver community

***Partnership with DOT to ensure successful spectrum allocation & sharing***



# International Spectrum Reallocations for Mobile Sources

*SPACE AND MISSILE SYSTEMS CENTER*

- Working through the 2012 World Radiocommunication Conference (WRC-12)
  - Consider additional spectrum allocations for the mobile service on a primary basis
  - Identify additional frequency bands for International Mobile Telecommunications (IMT) operations
- GPS Directorate Goal: monitor all GPS bands and adjacent bands being proposed as candidate bands for reallocation or sharing with IMT
- Various US agencies and international GNSS providers share this interest to help protect GPS



# GPS Summary

SPACE AND MISSILE SYSTEMS CENTER

- Modernized signal development in progress
  - 12 L2C, 5 L5 and 12 M-Code capable SVs on orbit
  - OCX will implement full C2 of L1/L2M, L2C, L5
  - Continuous L2C, L5 CNAV message broadcast began Apr 2014
  - Expect the first L1C SV launch in 2016
  - Continued progress to M-Code early use ~2017
- Modernization of all GPS Segments making progress but still with technical challenges commensurate with the advanced tech
- Working domestically, internationally and with Industry to simultaneously protect GNSS services and release spectrum for mobile services



**Maintaining the world's "Gold Standard" PNT service is Job #1**

# Backup



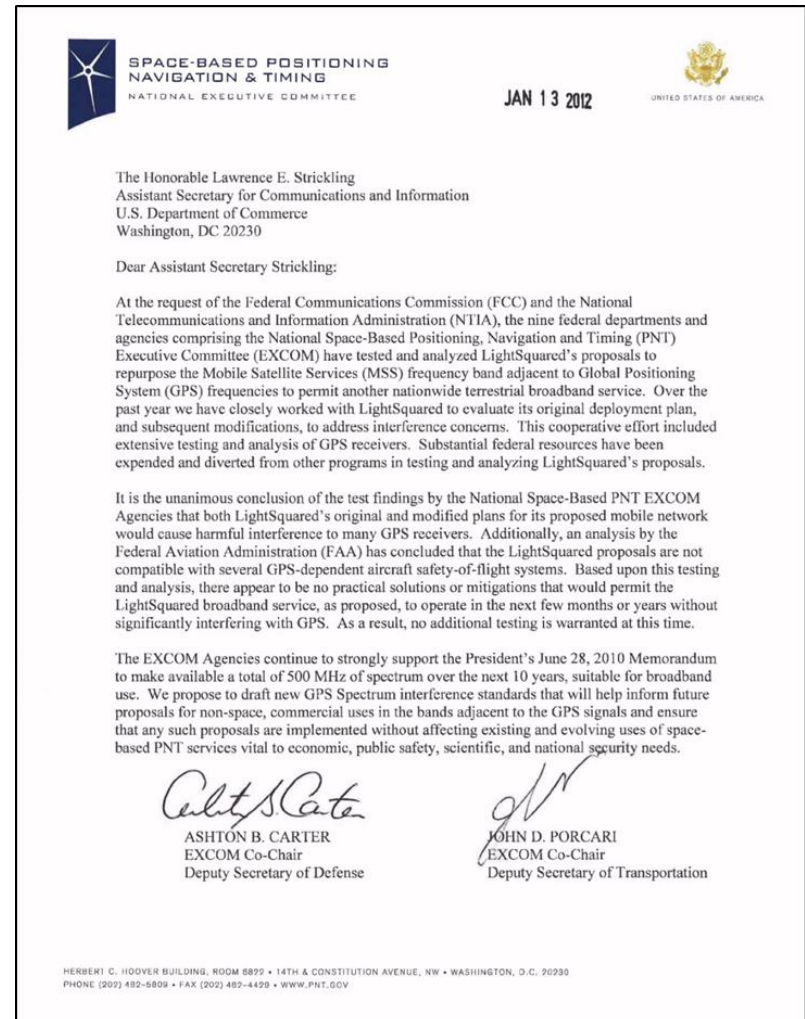
*SPACE AND MISSILE SYSTEMS CENTER*



# Space-Based PNT EXCOM Spectrum Interference Standards

SPACE AND MISSILE SYSTEMS CENTER

- 13 Jan 12, National Space-Based Positioning, Navigation, and Timing (PNT) Executive Committee (EXCOM) co-chair letter to National Telecommunications and Information Administration (NTIA) proposed to draft new Global Positioning System (GPS) spectrum interference standards:
  - Inform future proposals for non-space, commercial uses in the bands adjacent to the GPS signals.
  - Ensure such proposals are implemented without affecting existing and evolving uses of space-based PNT that are vital to economic, public safety, scientific, and national security needs

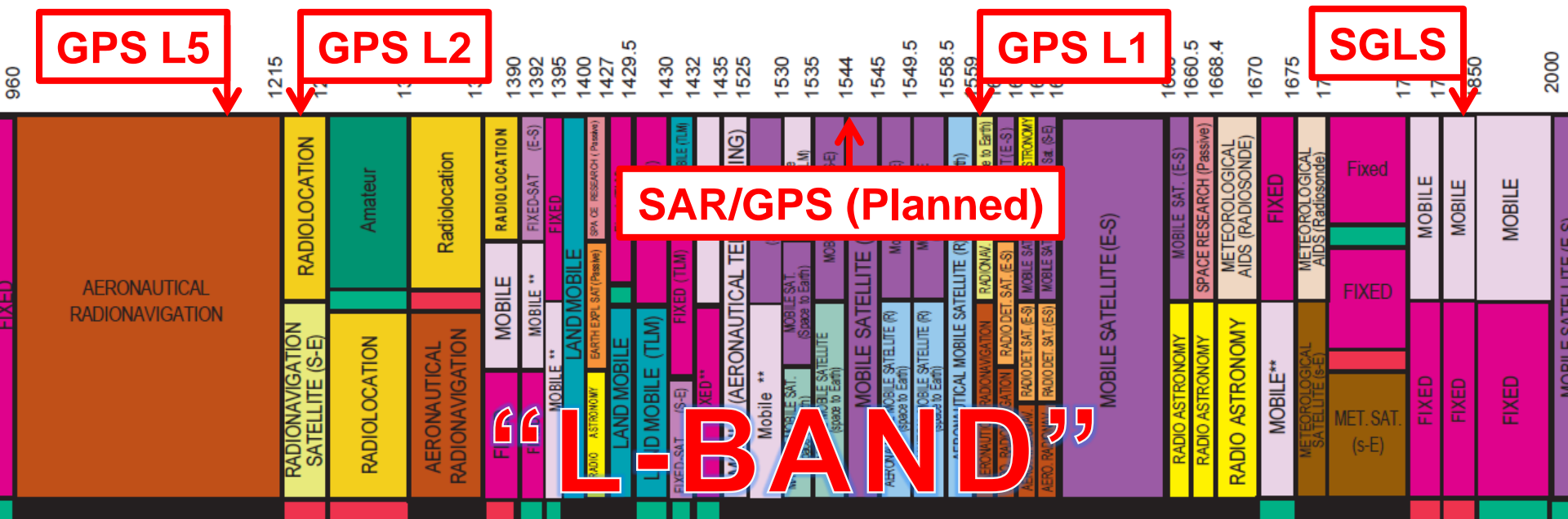




# Adjacent-Band Compatibility (ABC)

SPACE AND MISSILE SYSTEMS CENTER

- A signal's ability to operate free of harmful degradation (interference) from other transmissions in the nearby areas of the electromagnetic spectrum
- Adjacent-band interference (ABI) can occur as the result of an adjacent band's power and proximity to a signal as well as inadequate filtering and/or tuning



\*National Telecommunications and Information Administration (NTIA) Table of Allocations in the L-Band (1-2GHz, IEEE)



# LightSquared Background

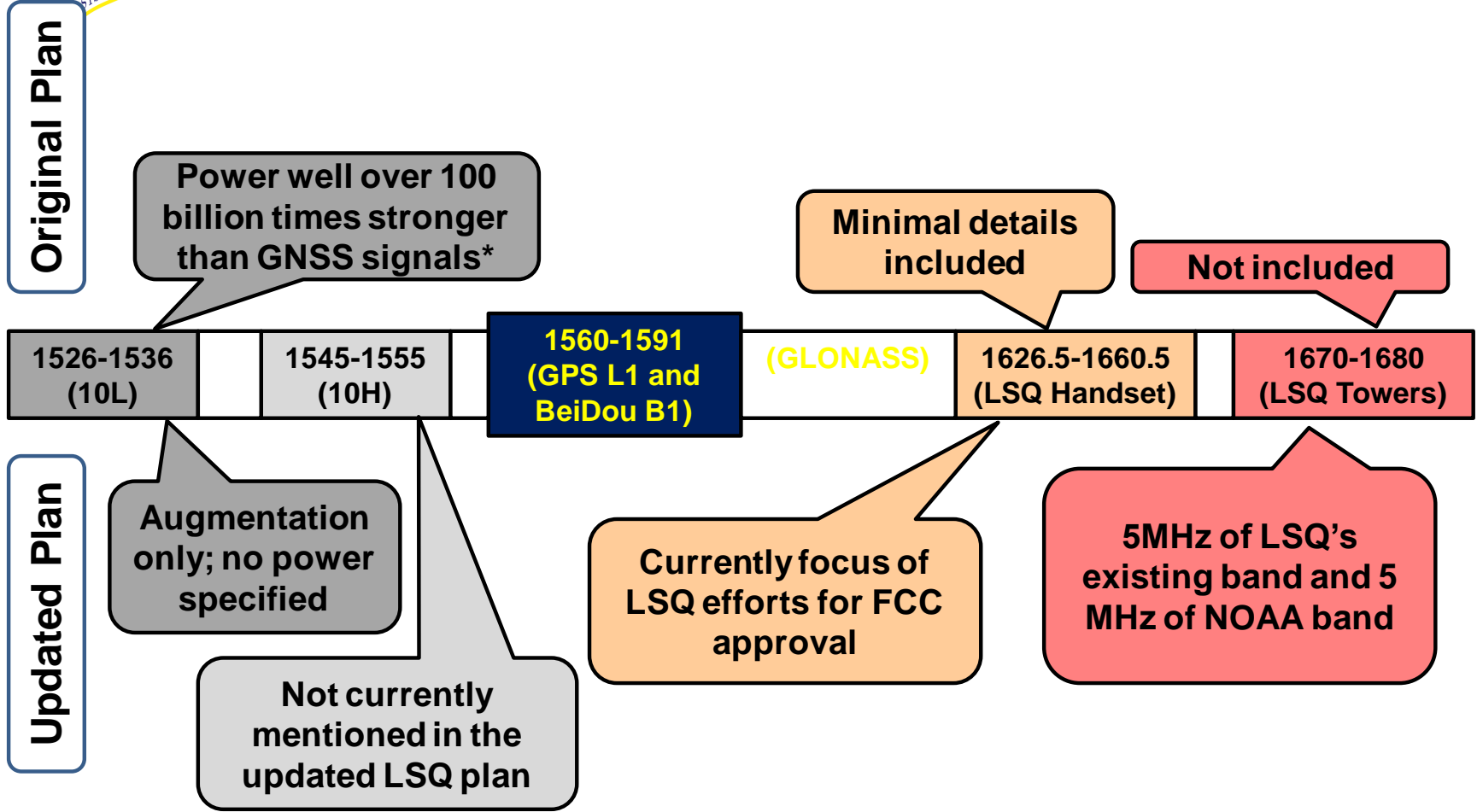
*SPACE AND MISSILE SYSTEMS CENTER*

- LightSquared (LSQ) – a company seeking to develop a 4G LTE wireless broadband system using a block of frequencies adjacent to GPS
- Timeline of LSQ evolution:
  - 2001 – Mobile Satellite Ventures (Satcom only with desire for ATC)
  - 2004 – FCC authorized Satcom with Ancillary Terrestrial Component (ATC)
  - Jan 2011 – FCC granted conditional waiver to offer increased terrestrial 4G service (40K ATC) only if harmful interference to GPS was resolved
  - Feb 2011 – Oct 2011 – Testing commences and LSQ begins to modify their operational plan as the results indicate negative impacts to GPS
  - Nov 2011 – Jan 2012 – Further testing and analysis is conducted on the various changes being made to the LSQ plan
  - Feb 2012 – NTIA memo to FCC declaring that LSQ will impact GPS services and that there is no practical method for mitigation at this time
  - 14 May 12 – LSQ filed for bankruptcy
  - Present – LSQ bankruptcy decisions on-going; handset plan moving forward with concerns expressed from Department of Transportation and other US federal agencies



# Real World Example: LightSquared (LSQ)

SPACE AND MISSILE SYSTEMS CENTER



**Concerns over 10L power level remain**

\*Power at a distance of 100 meters from a LSQ tower