

Space and Missile Systems Center



GPS Modernization Update

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GPS Constellation

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- **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

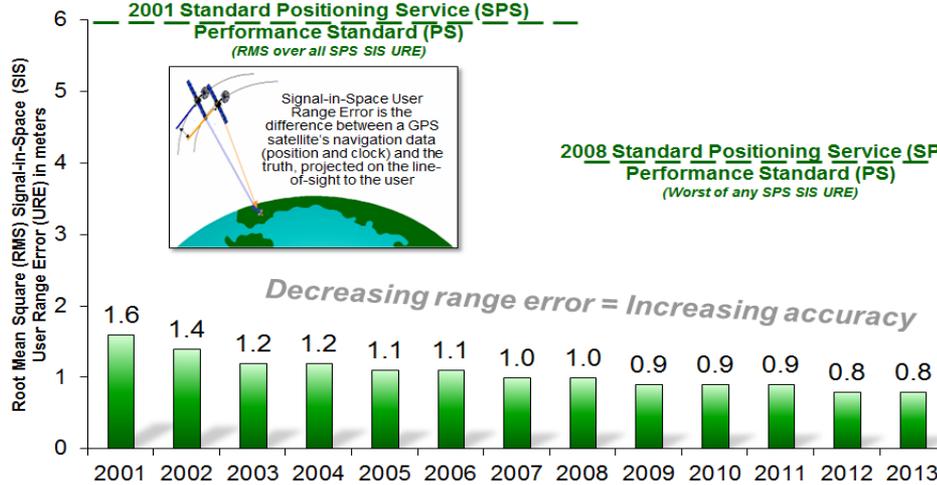




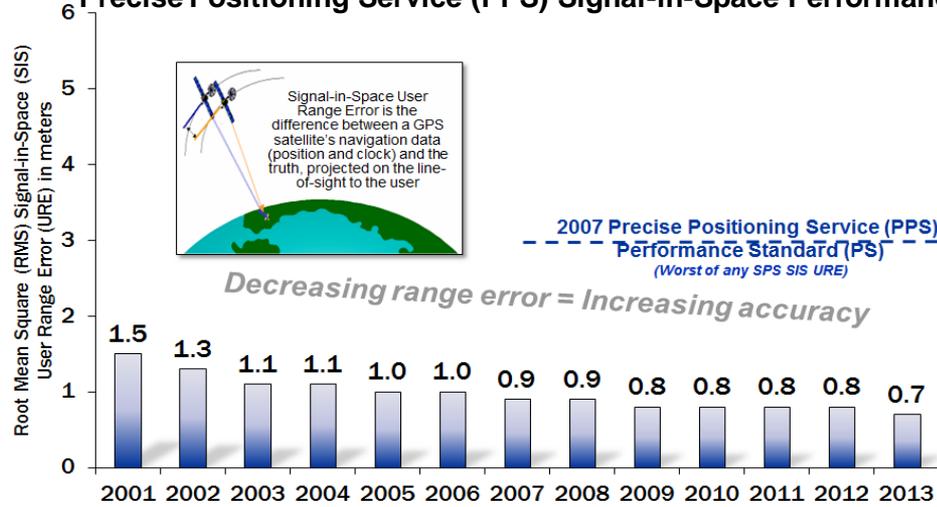
GPS Signal in Space Performance

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



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



System accuracy exceeds published standard



GPS Modernization Program

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Legacy GPS IIA/IIR

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

GPS IIR-M

- 2nd Civil Signal (L2C)
- M-Code (L1M & L2M)

GPS IIF

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

GPS III

- 4th 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

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- 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

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- 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

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- 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



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Spectrum Allocation and Sharing Initiatives



Spectrum Allocation and Sharing Initiatives

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- 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

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- 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

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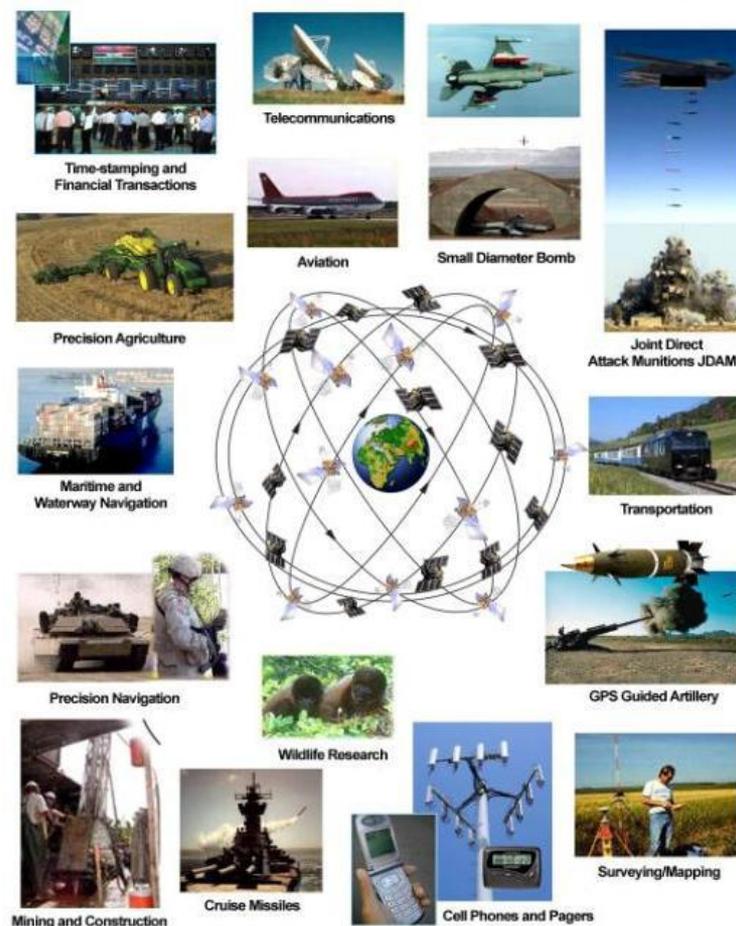
- Working through the 2012 World Radiocommunication Conference (WRC-12)
 - Consider additional spectrum allocations for the mobile service on a primary basis
 - Identify additional frequency bands for International Mobile Telecommunications (IMT) operations
- GPS Directorate Goal: monitor all GPS bands 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

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- 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



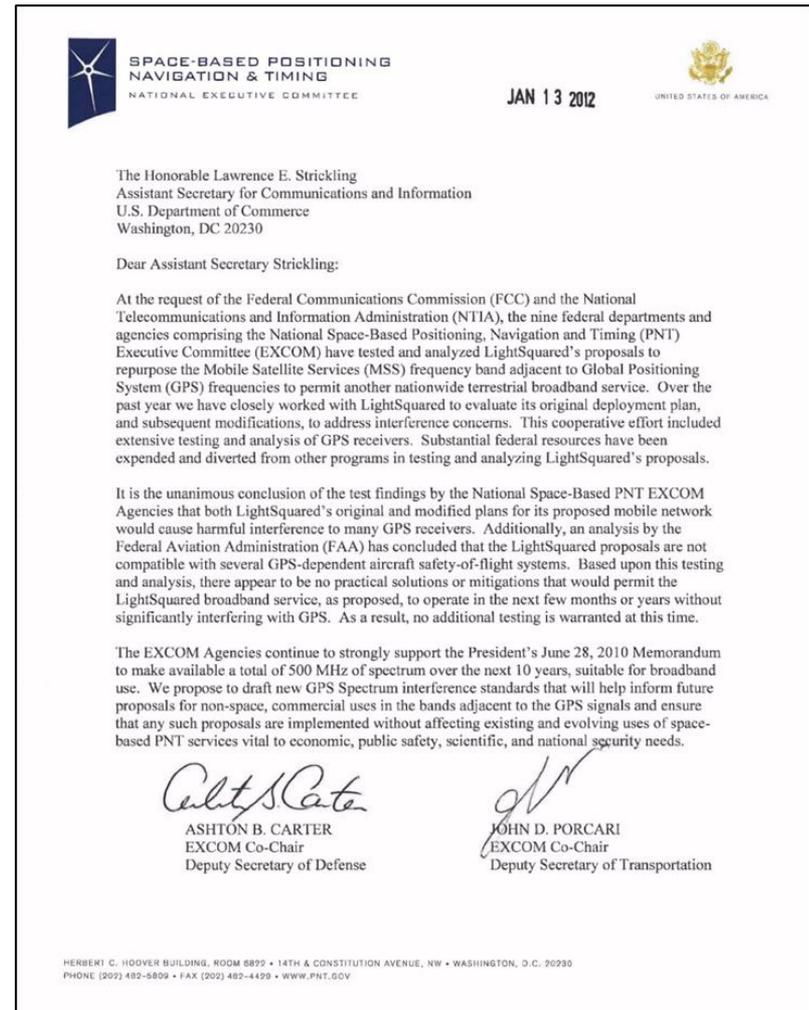
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Space-Based PNT EXCOM Spectrum Interference Standards

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- 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

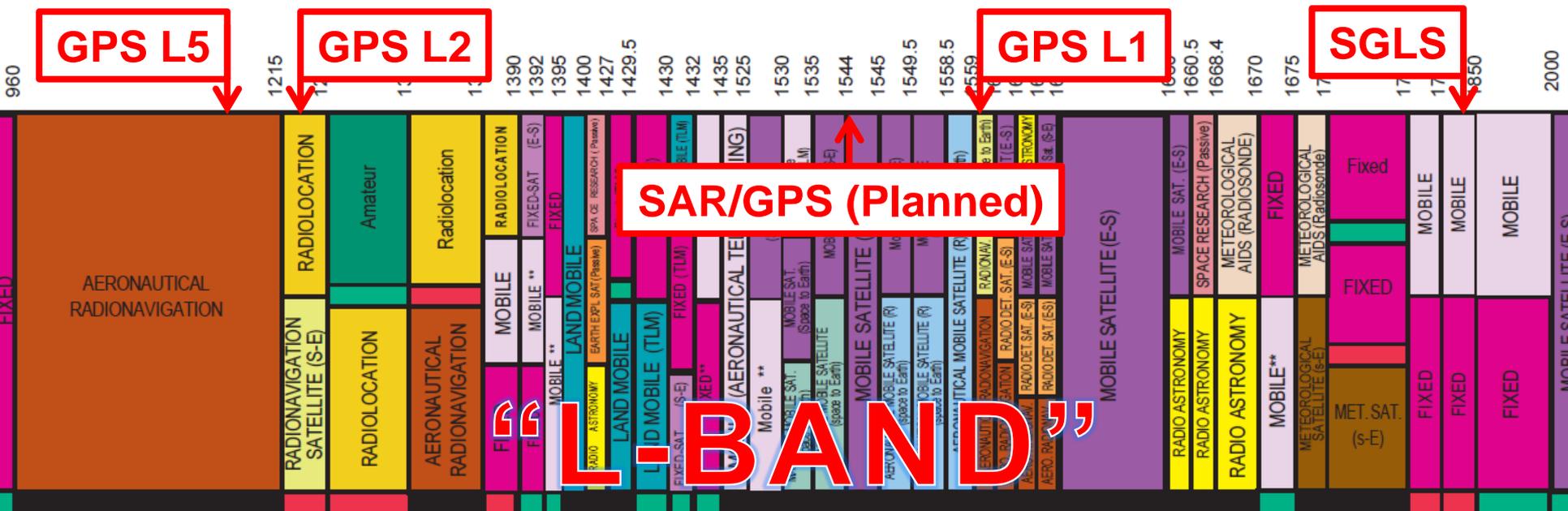




Adjacent-Band Compatibility (ABC)

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- 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

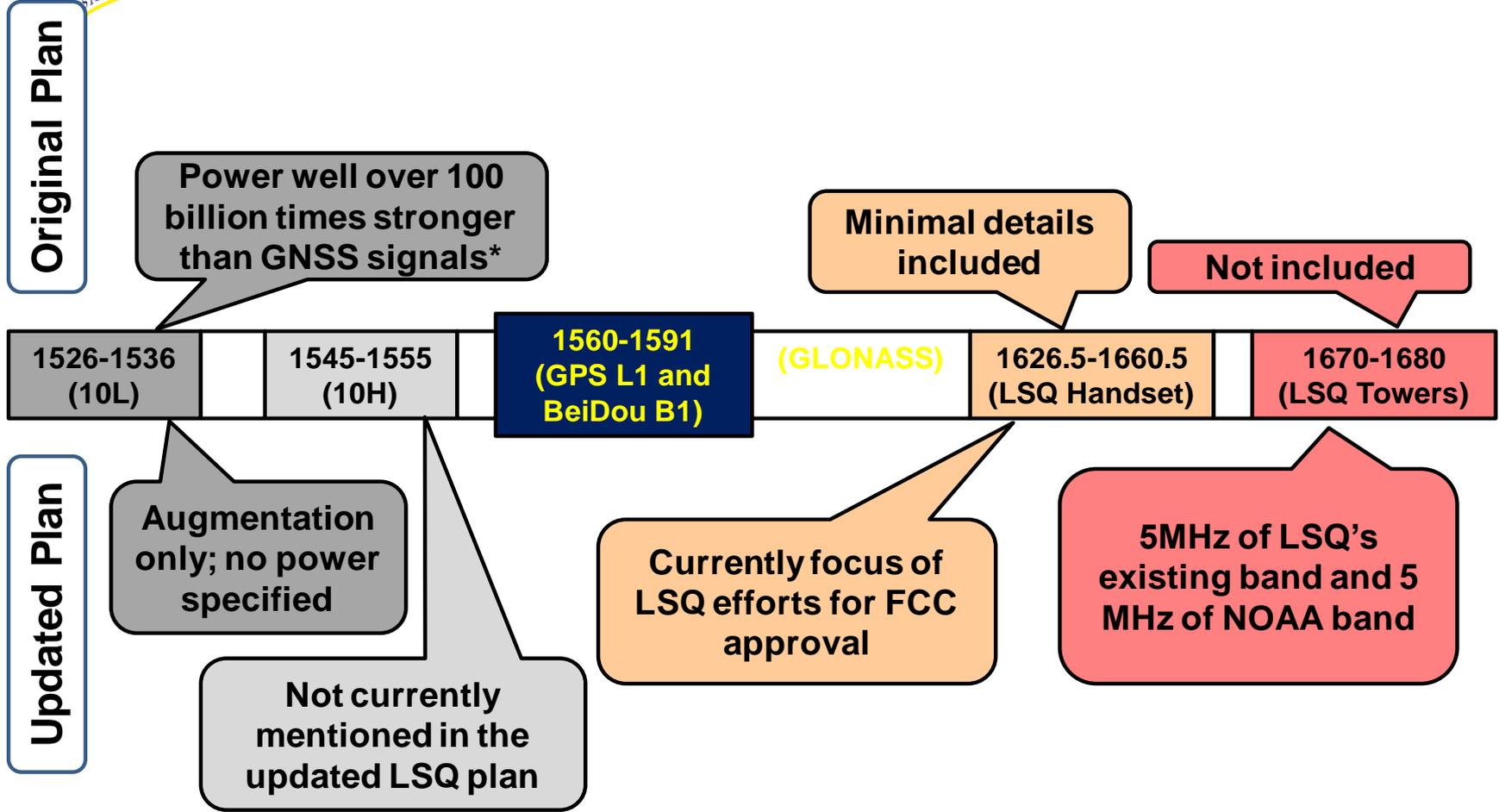
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- LightSquared (LSQ) – a company seeking to develop a 4G LTE wireless broadband system using a block of frequencies adjacent to GPS
- Timeline of LSQ evolution:
 - 2001 – Mobile Satellite Ventures (Satcom only with desire for ATC)
 - 2004 – FCC authorized 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)

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Concerns over 10L power level remain

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