UTC Leap Seconds: The GPS Directorate Perspective

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  - Precise Timing Applications
- **GPS Timing Service**
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Global Positioning Systems Directorate

Mission:

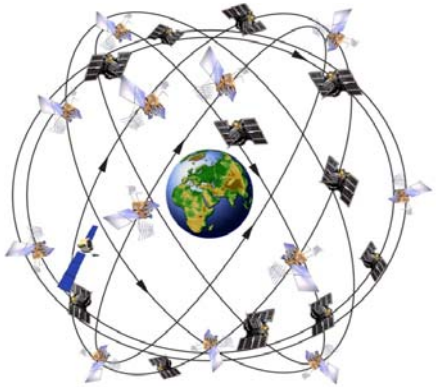
Acquire, deliver and sustain reliable GPS capabilities to America's warfighters, our allies, and civil users

New GPS Program Director: Col Bill Cooley

Deliver and Sustain Global Navigation and Timing Service

GPS Overview

Civil Cooperation
- 1+ Billion civil & commercial users
- Search and Rescue
- Civil Signals
  - L2C (2nd Civil Signal)
  - L5 (Safety of Life)
  - L1C (International)



Spectrum
- World Radio Conference
- International Telecommunication Union
- Bilateral Agreements
- Adjacent Band Interference

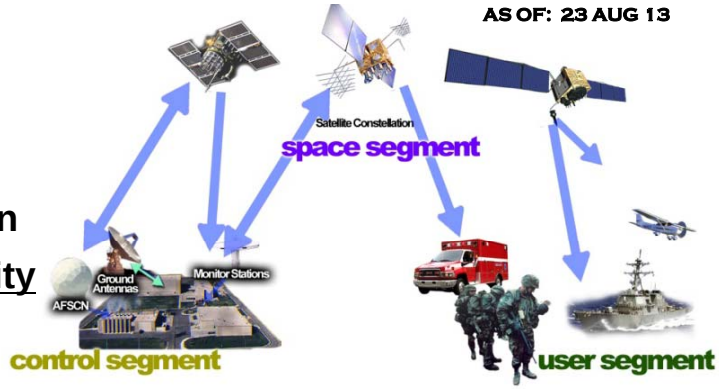
Department of Transportation
- Federal Aviation Administration

Department of Homeland Security
- U.S. Coast Guard

36 Satellites/ 31 Set Healthy
Baseline Constellation: 24 Satellites

Satellite	Quantity	Avg Life	Oldest
GPS IIA	8	19.2	22.7
GPS IIR	12	11.6	16.1
GPS IIR-M	7	6.1	7.9
GPS IIF	4	1.6	3.2
Constellation	31	11.0	22.7

AS OF: 23 AUG 13



Department of Defense
- Services (Army, Navy, AF, USMC)
- Agencies (NGA & DISA)
- US Naval Observatory
- PNT EXCOMS
- GPS Partnership Council

Maintenance/Security
- All Level I and Level II
  - Worldwide Infrastructure
  - NATO Repair Facility
- Develop & Publish ICDs Annually
  - ICWG: Worldwide Involvement
- Update www.GPS.gov Webpage
- Load Operational Software on over 1 million SAASM Receivers
- Distribute PRNs for the World
  - Including 90 for GNSS

International Cooperation
- 55 Authorized Allied Users
  - 25+ Years of Cooperation
- GNSS
  - Russia - GLONASS
  - Europe - Galileo
  - China - BeiDou
  - Japan - QZSS
  - India - IRNSS

Precise Timing Applications

Communications

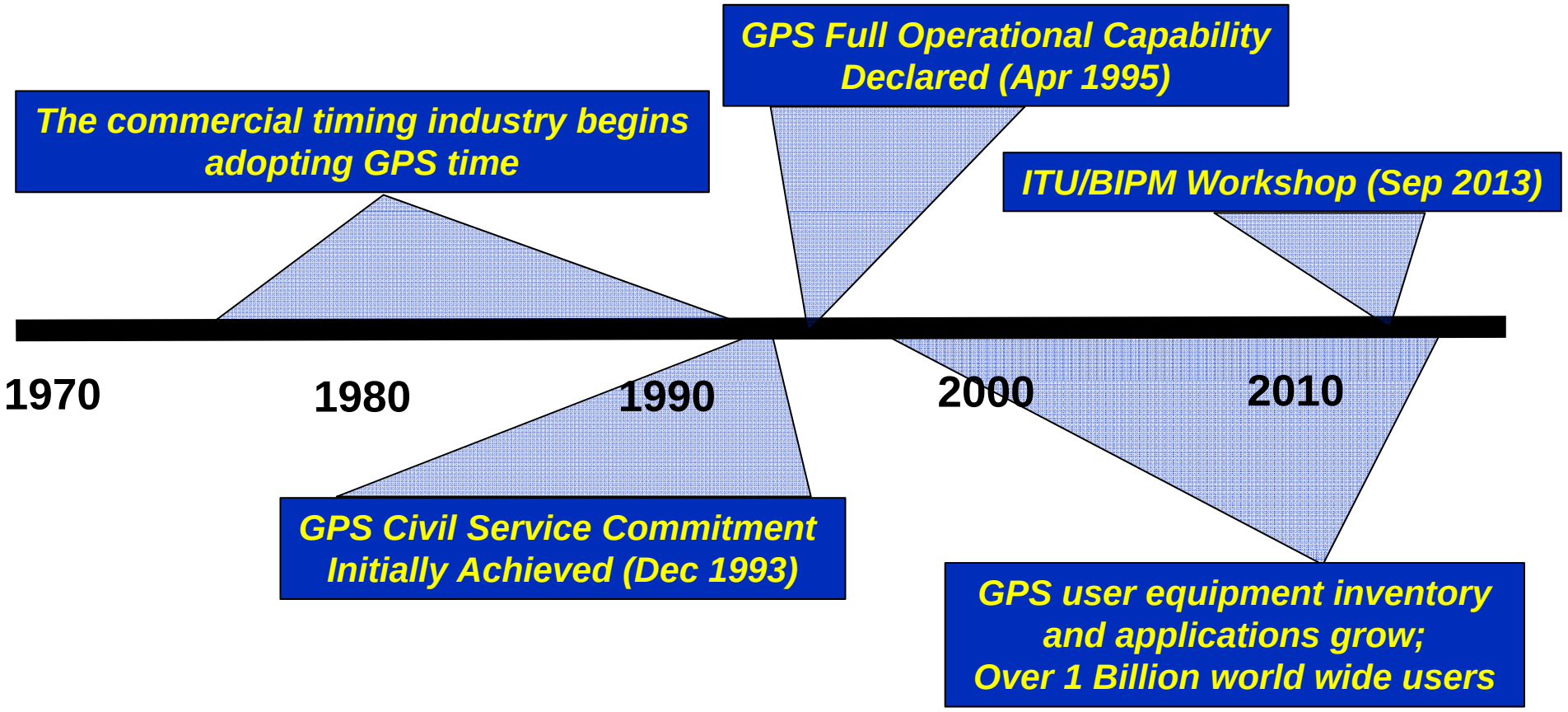
Power Grid

Financial

Scientific

GPS timing service is critical to the infrastructure of the modern world

Early Usage of GPS Timing Service

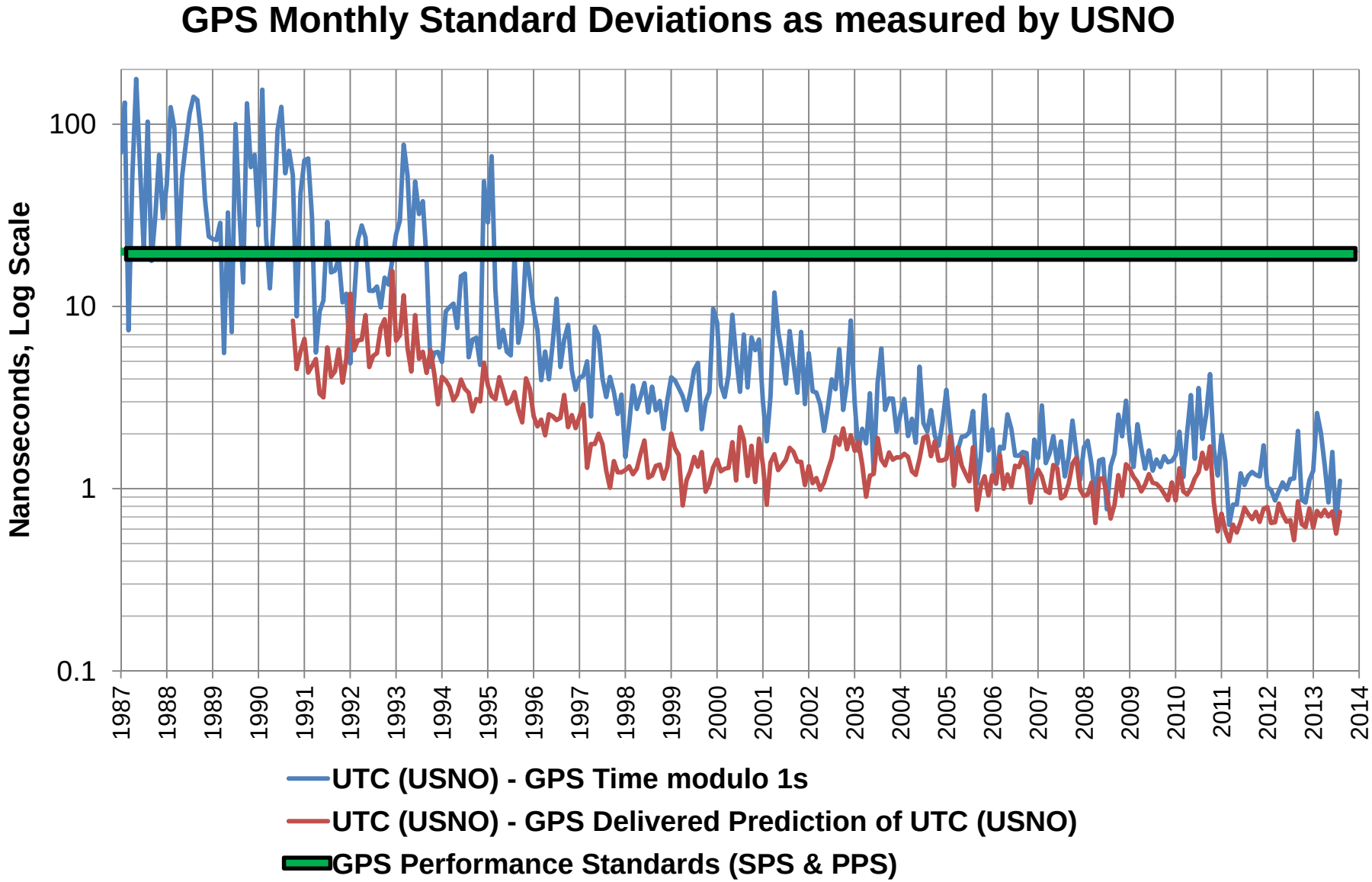


GPS Time Keeping Function

There are two purposes for timing in GPS:

- **Navigation Timekeeping:**
  - Critical for navigation mission
  - Needed for orbit determination/prediction & internal satellite clock synchronization
  - Not intended for timing applications.
- **Metrological Timekeeping:**
  - Not critical for navigation
  - Needed to provide UTC timing services (time dissemination)

GPS Timing Service Performance Over the Past 25 Years



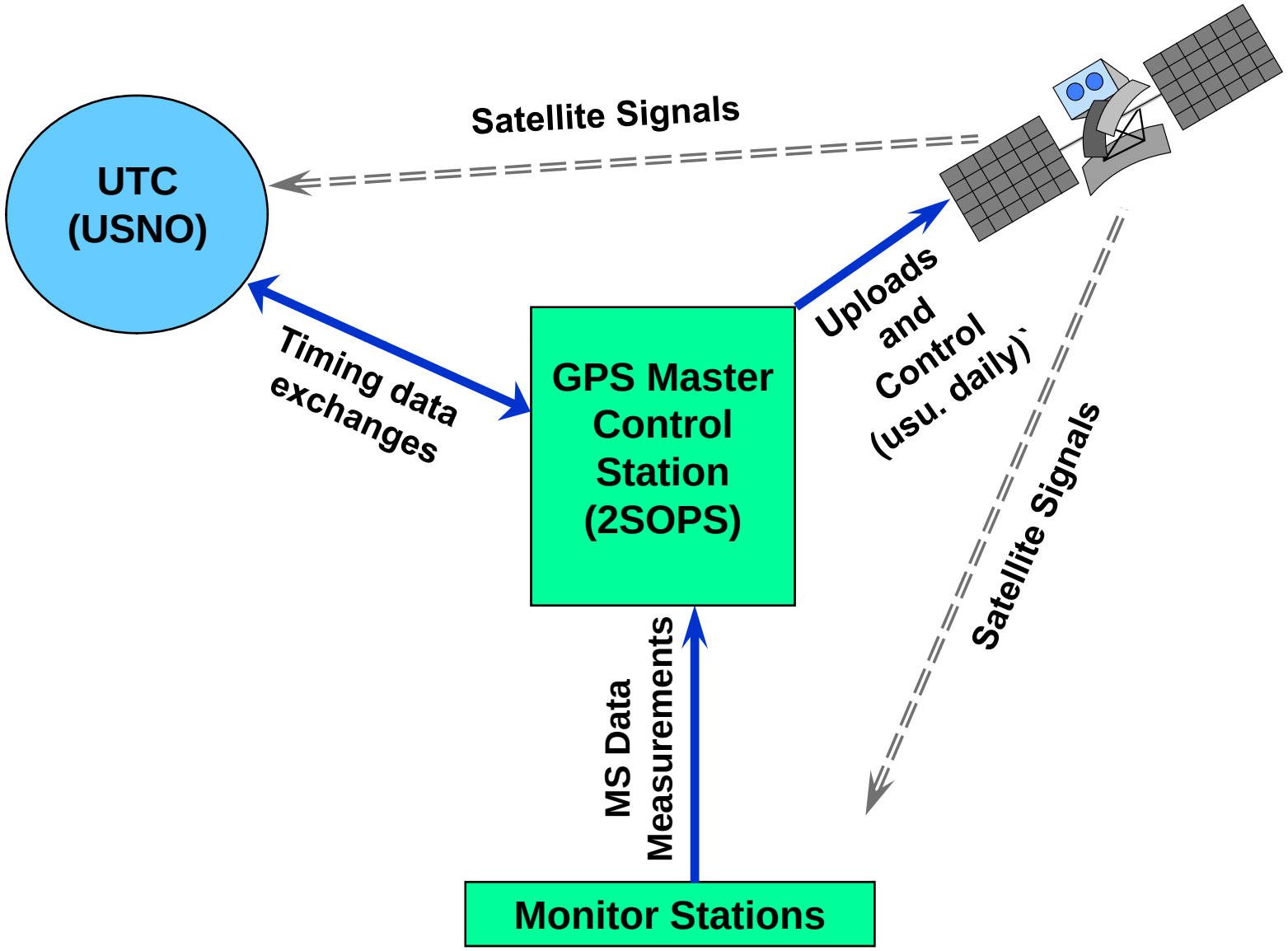
GPS Timescale

- **GPS time is expressed as follows:**
  - A count of weeks with time zero at 0h on 6 Jan 1980
  - Z-counts (1.5 seconds) from the start of each week
- **GPS time is formed as a "paper clock" consisting of the weighted average of the following:**
  - GPS satellite and ground station clocks, including the master clocks contributed from USNO and the MCS
- **The broadcast message content, scheduling, and payload functions on all GPS satellites use this concept of time**

GPS Relation to UTC

- **GPS time is "steered" to maintain a close tie to UTC(USNO) through modulo-whole second offsets (due to leap seconds)**
  - Via daily input of UTC(USNO) time into MCS
- **The Legacy (C/A) navigation message broadcast by every GPS satellite provides information to convert between GPS time and UTC(USNO)**
    - Contains fine error corrections in GPS time and leap second data including notification of pending leap seconds
- **The modernized CNAV message (L2C, L5, and L1C) will provide improved correction data supporting sub-nanosecond accuracies between GPS and UTC**
    - Also provides conversion between UT1 and UTC

UTC(USNO) to GPS Interface



GPS and Leap Seconds

- **GPS Time (GPS Internal Navigation Time Scale) established in the late 1970s to be a continuous time scale**
  - Avoided complexity with affecting many internal and external elements (space vehicles, control segment, and user equipment) that make up GPS
- **GPS Time not intended to be used directly for external timing applications**
- **GPS navigation message includes UTC offset**
  - Includes the total number of leap seconds since time zero on 6 Jan 1980
  - GPS time currently differs from UTC by roughly 16 seconds
- **The last leap second was input on 20 June 2012**

Impact of Discontinuing Leap Seconds on GPS

- **Impacts of ending leap second operations on each of the key segments of GPS:**
  - **GPS Space Vehicle**
  - **GPS Control System**
  - **GPS User Equipment**

Impacts on GPS Space Vehicle

Expected Impact: None

- **Current orbit modeling, estimation, prediction and upload generation software operates entirely on GPS time**
- **Navigation payloads on blocks IIA, IIR, IIR-M, and IIF satellites already work entirely on GPS time**
- **Navigation payloads on GPS III will use GPS time when launched**
- **All satellite software will be tested and reviewed for any kind of minor change to ensure a smooth transition**

Impacts on GPS Control System

Expected Impact: Minimal

- **If leap seconds are discontinued, minor GPS software changes will likely be necessary in the Control Segment**
- **One change will be to relax the constraint on UT1 – UTC**
  - System needs to allow UT1 – UTC to grow beyond 1 second
  - Affects interfaces concerned with Earth Orientation Parameter (EOP) Data, primarily from NGA
- **The new system currently in development (OCX) will be examined more closely to make sure all potential impacts are identified**

Impacts to GPS User Equipment

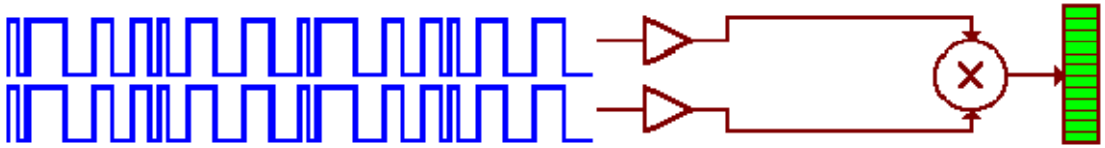
Expected Impact: Varies depending on user equipment, likely minimal

- **User Equipment requires closer look**
  - Should not have any direct impact, as core functions all use GPS time
  - External output of UTC, usage by downstream equipment
- **Individual user equipment manufactures will have to review software for instances that may be affected by this change**

Conclusion

- **GPS has provided a revolutionary timing service that has supported the world's infrastructure for over 20 years**
- **GPS time was implemented without leap seconds to avoid operational problems associated with leap seconds**
- **Minor changes to GPS systems (space vehicle, control system and user equipment) may be implemented to accommodate eventual elimination of leap seconds, with no operational impacts expected**

GPS Directorate is positioned to support continuation or discontinuation of leap seconds



Thank You!

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