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- u Inconsistencies in notification date
 - § GPS < 6 months
 - § NTP needs 24 hours
 - § IRIG IEEE-13442 – 64 seconds
 - § Manual input IERS sends out Bulletin C □ 6 months in advance
- u Inconsistencies in data presentation
 - § GPS leap-second current, leap second pending, effective date
 - § NTP Effective date and sign
 - § IRIG sign
 - § Manual Effective date and sign
- u Leap-second sources added to instrument code sequentially
- u Customer desires for prioritization may be inconsistent
 - § Is GNSS primary (which GNSS in the future)?
 - § Is the user primary?
- u Serving NTP using an IRIG reference needs manual leap second entry
- u Approach is to rewrite software to a standard leap-second centric view

The Problem of Testing

- u Leap-second information is an ephemeral resource
- u Instrument software using leap seconds developed over decades by multiple developers
- u A software engineer working on instrument code today may add innocuous functionality having no obvious connection with leap seconds (or even timing) and introduces a leap second bug
 - § Function produces an event that needs to be logged
 - § Logging calls the time stamper
 - § The time stamper translates TAI to UTC using leap seconds
 - § The function may block if valid information is not available
- u Leap-second test scenarios don't identify code dependencies that later show up in unusual circumstances
- u The problem is being addressed by instrumenting code to identify calls from leap-second aware and leap-second unaware functions
 - § Warnings and errors are produced and logged for unaware function calls

- u Use of GPS almanac before checksum computed
 - § Takes up to 26 minutes to get full almanac with validity checking
 - § Potential to use invalid data
 - § Different engines output leap-second information after varying intervals
- u Instruments are forced to gather information from multiple, possibly incorrect, or out of date information
- u Use of leap-second file to supplement time source
- u Leap-second files are out of date when an instrument sits on the shelf for 6 months (and less in the future)
- u Leap-second information may appear out of date due to ICD-GPS-200 implementation errors in GPS engines
- u These are all issues of the ephemeral nature of leap-second information and the difficulty of dealing with it

- u ICD-GP-S200 misinterpretations by engine manufacturers cause incorrect GPS week downloads
 - § Novatel, M12 and other Motorola designs
 - § These engines periodically transmit incorrect effectivity dates
 - § Failure to pass validity checking in instrument code leads to unexpected behavior
- u First 48 hours of the year
 - § GPS satellites are uploaded sequentially, some transmitting out of date information
 - § No problem for a device that transitioned through the leap second
 - § Instruments that start shortly after a leap-second opportunity must make a best guess whether to use leap second current or pending
 - § This guess is made with the knowledge that the effectivity date might be wrong due to the ICD-GPS-200 problem
 - § Leap-second files are used to aid startup, but easily get out of date and may be corrupted

Incorrect Vendor Assumptions Based on Reverse Engineering



- u That the leap second is effective at the next quarterly opportunity
 - § GPS CONOPS had always conformed
 - § It did not appear necessary to use the effectivity date
 - § Some instruments executed a leap second early due to GPS announcement of the leap second prior to Sept 30 2008
- u That GPS would advance the current leap second after the leap second and **move the effectivity date to the future**
 - § GPS CONOPS had always conformed
 - § Validity testing of the leap-second information depended on the consistency and currency of the leap-second date
 - § Last year, GPS started to leave the effectivity date equal to the last implementation date
 - § On June 29 last year, some instruments invalidated GPS broadcast leap-second information due to age and did not update the leap-second file
 - § Restarts following that date led to failures due to the lack of an current leap second file.

- u Turn on **in** the first \square 2 days following a leap second opportunity (December 31 and June 30)
 - § Expired leap-second file
 - § Leap second future = leap second current + 1
 - § Effectivity date not the next opportunity
 - § Can't tell if effectivity date is correct or if the effectivity date has been corrupted by ICD-GPS-200 misinterpretation
 - § Can't tell if the SV providing the leap-second information hasn't been uploaded
- u The possibility of mistakes can't be avoided
 - § Guess that the satellite has not been uploaded
 - § Use the leap-second future value to set the instrument time
 - § This is wrong if the information represents a future scheduled leap second

- u Turn on **after** ▪ 2 days following a leap-second opportunity
 - § Expired leap-second file
 - § Leap second future = leap second current + 1
 - § Effectivity date not the next opportunity
 - § Can't tell if effectivity date is correct or if the effectivity date has been corrupted by ICD-GPS-200 misinterpretation
 - § Can't tell if the SV providing the leap-second information hasn't been uploaded
 - § We assume that the effectivity date is corrupt
- u The possibility of mistakes can't be avoided
 - § Guess and use leap second current to set the instrument time
 - § Schedule a leap second at the next opportunity
 - § This is wrong if the satellite has not been uploaded
- u The use of 2 days is arbitrary and is not guaranteed

- u Problems with vendors simply not understanding how to implement leap seconds are principally a thing of the past
- u Current leap-second issues primarily result from
 - § Legacy code that was not designed for leap seconds from the ground up
 - § Un-testable leap second issues due to unsuspected leap-second dependencies
 - § Errors in legacy GNSS engines
 - § Ambiguities resulting from operational difficulties that prevent timely GNSS satellite uploads
- u Modern instruments are designed around leap-seconds from the start
- u Most leap-second problems will go away as legacy hardware, firmware, and software are updated
- u But, it will still take quite a long time...