Why Leap Seconds are Difficult for a Vendor
Multiple Notification Sources

- Inconsistencies in notification date
  - GPS  < 6 months
  - NTP  needs 24 hours
  - IRIG IEEE-1344 2 – 64 seconds
  - Manual input IERS sends out Bulletin C ~ 6 months in advance

- 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

- Leap-second sources added to instrument code sequentially

- Customer desires for prioritization may be inconsistent
  - Is GNSS primary (which GNSS in the future)?
  - Is the user primary?

- Serving NTP using an IRIG reference needs manual leap second entry

- Approach is to rewrite software to a standard leap-second centric view
The Problem of Testing

- Leap-second information is an ephemeral resource
- Instrument software using leap seconds developed over decades by multiple developers
- 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
- Leap-second test scenarios don’t identify code dependencies that later show up in unusual circumstances
- 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
Fast Startup Requirements

- 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
- Instruments are forced to gather information from multiple, possibly incorrect, or out of date information
- Use of leap-second file to supplement time source
- Leap-second files are out of date when an instrument sits on the shelf for 6 months (and less in the future)
- Leap-second information may appear out of date due to ICD-GPS-200 implementation errors in GPS engines
- These are all issues of the ephemeral nature of leap-second information and the difficulty of dealing with it
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

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

- 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

- 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.
Bad Scenarios
Possible Corrupt Download Data

- Turn on in the first ~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

- 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
Bad Scenarios
Possible Corrupt Download Data

- 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

- 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

- The use of 2 days is arbitrary and is not guaranteed
Conclusions

- Problems with vendors simply not understanding how to implement leap seconds are principally a thing of the past
- 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
- Modern instruments are designed around leap-seconds from the start
- Most leap-second problems will go away as legacy hardware, firmware, and software are updated
- But, it will still take quite a long time...