Booz | Allen | Hamilton


# HOW TO RECEIVE UTC AND HOW TO PROVE ACCURACY

*Marc Weiss, Ph.D.*

*Independent Consultant to Booz Allen Hamilton*

*Weiss_Marc@ne.bah.com*

JANUARY 23, 2018

# HOW DO YOU GET UTC AND PROVE IT?

- SEC Rule 613: UTC must come from NIST
  - GPS is OK, though it's UTC(USNO): UTC from GPS is continuously measured against NIST – good to much better than 1 microsecond
  - Could get direct from NIST via fiber, but this is not done at this time
  - NTP over a public network cannot be better than 1 millisecond
  - Other methods are possible, but GPS is currently dominant

- Beyond what the GPS (or GNSS) receiver does, need to document and validate transmission delays and calibrations from the satellite to your time server
  - Ensure and document no catastrophic effects in the air, including jamming
  - Document and validate reasonable efforts to detect and mitigate spoofing
  - Document that Receiver is configured properly (a major source of error)
  - Document calibrations of  everything: antenna, antenna cables, receiver, local cables

# DOCUMENT AND VALIDATE TRANSMISSION DELAYS AND CALIBRATIONS

**User Controlled Receiver Issues:**

Multi-path interference – Bad installations

Jamming and Spoofing

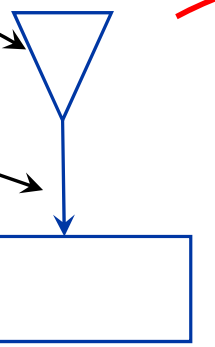
Delay through Antenna

Delays in cables

Delay through receiver

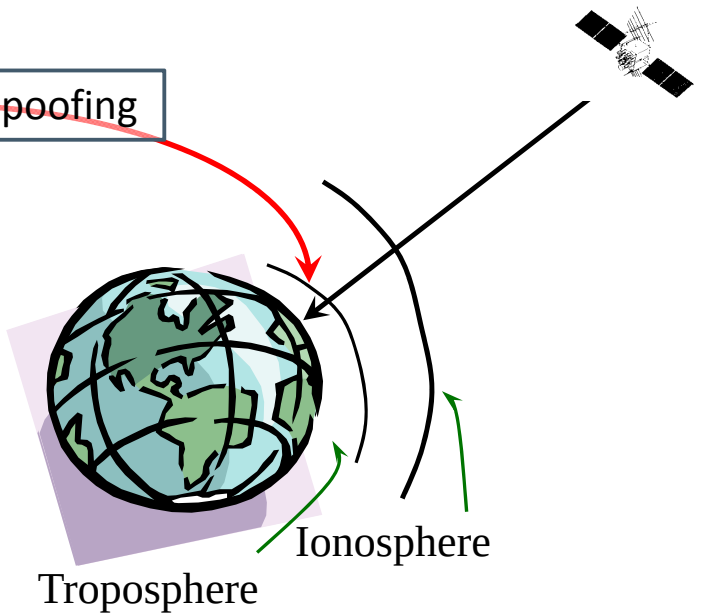
Receiver Configuration:

- Coordinates
- Receiver software



Systems Needed to be Calibrated, Validated and Documented

Jamming, Spoofing




Systems Needed to be Monitored, Mitigated and Documented

# GNSS ARE VERY ACCURATE AND VERY RELIABLE

Perhaps both their greatest advantage and disadvantage:

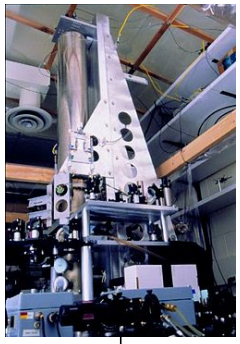
- Very reliable is NOT 100%, but inhibits users from backing up!
- Signals are vulnerable

# BACKUP

# THE GENERATION OF UTC

Real Time UTC is only a Prediction, a Phase Lock Loop with a one-month delay…

Accuracy: Laboratory Frequency Standards



Stability: Labs provide clock data


Labs Output UTC(lab): **Predictions of UTC**

delay

delay

BIPM* collects data from labs, computes and outputs TAI and UTC

BIPM

*BIPM is the French acronym for the International Bureau of Weights and Measures

# TIME AND FREQUENCY TRANSFER: HOW TO DELIVER A TIMING REFERENCE

- Time Transfer Accuracy Requires Calibrating Delays
  - Imagine writing a letter: "It is now 2 PM– set your watch"
  - Seal it in an envelope and drop it in a mail box
  - Only useful if you know how long it took to get to you
  - Now suppose you timestamped when you sealed the letter and the receiving person timestamped when he got it…

# ONE-WAY DISSEMINATION OR COMPARISON SYSTEM

Clock 1

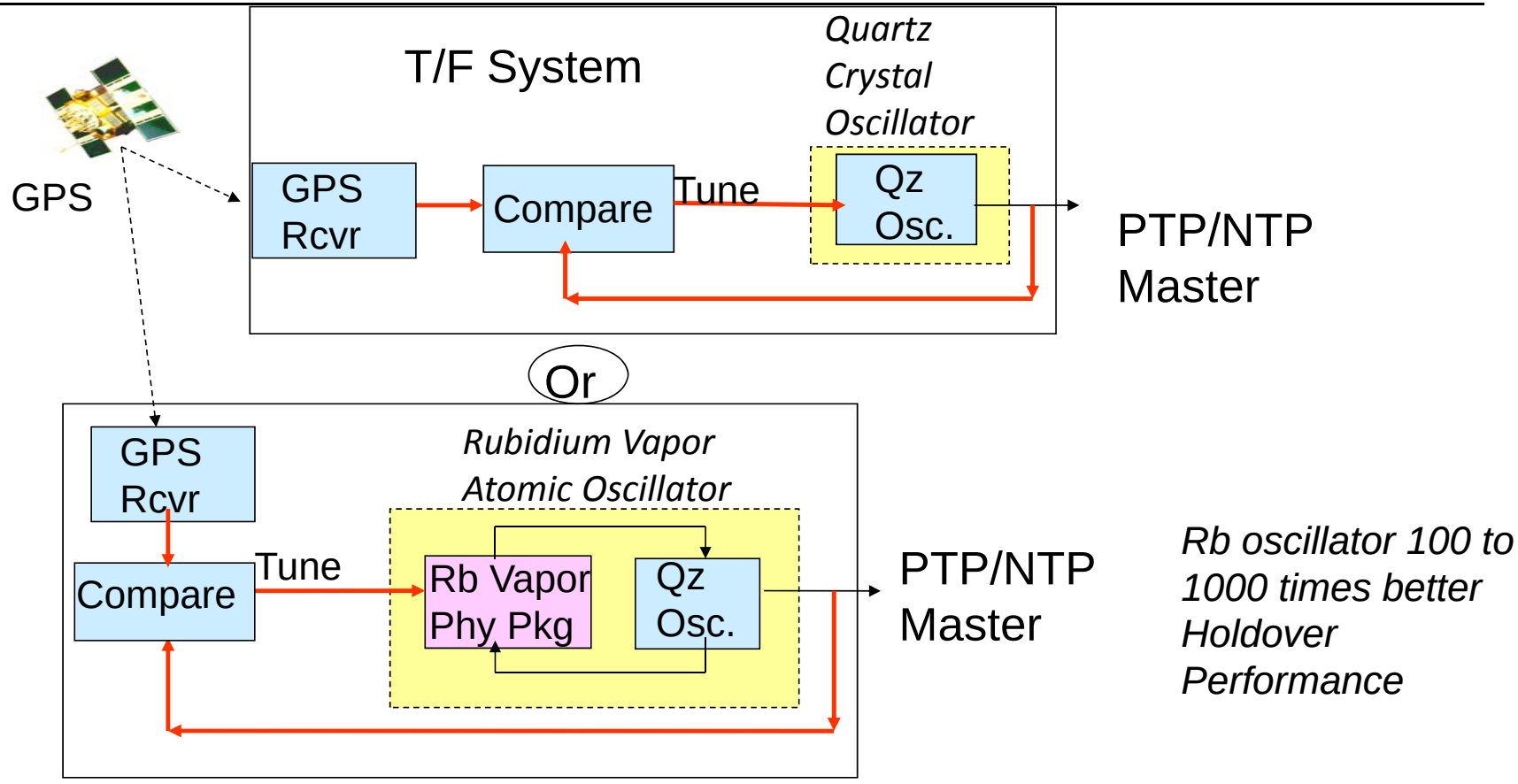
Clock 2


Clock 1 Systematics and Noise

Delay, Measurement Noise and Path Perturbations

Clock 2 Systematics and Noise

# OSCILLATOR IN GPS PTP OR NTP GRAND MASTER



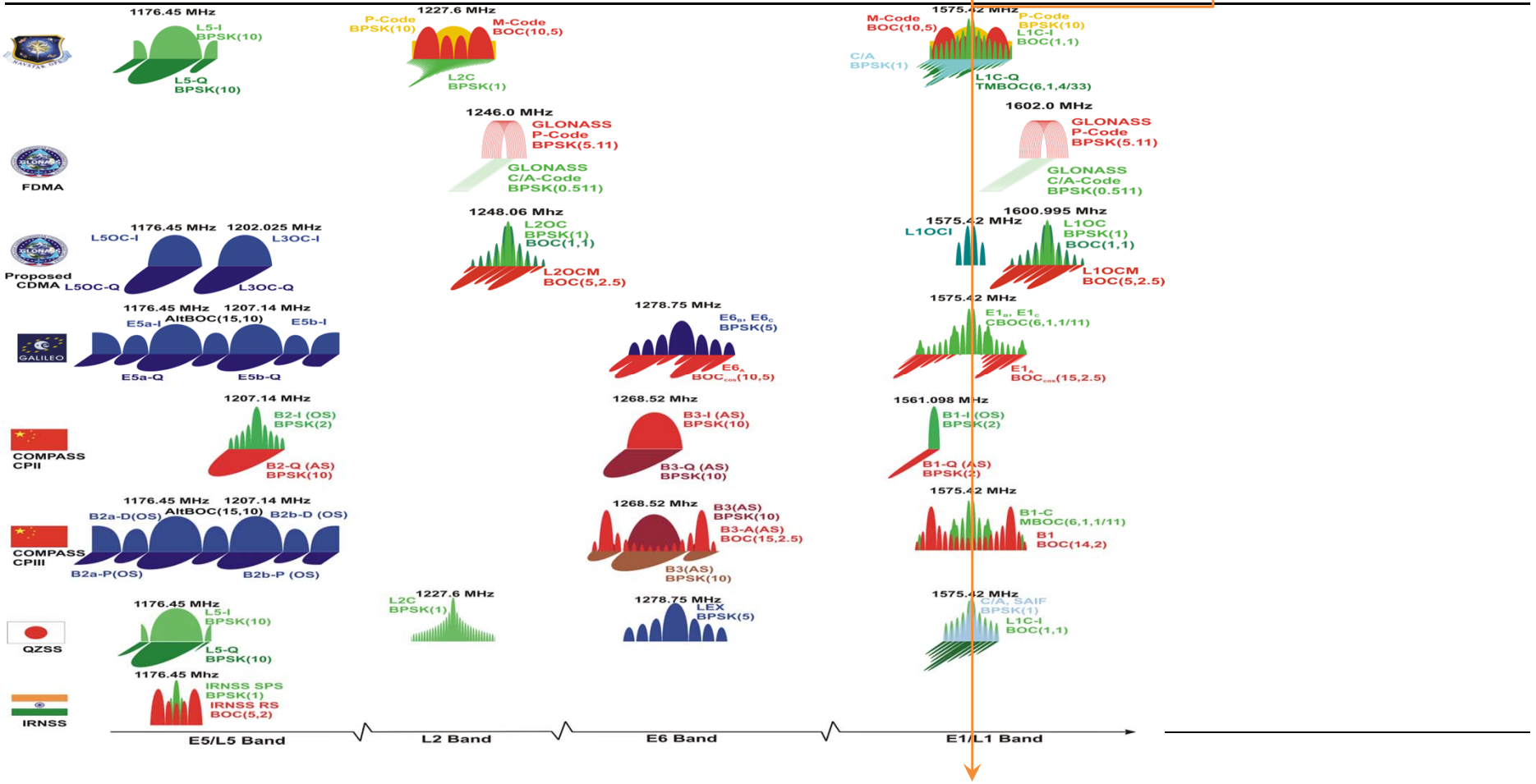
# THE FAMILY OF GLOBAL NAVIGATION SYSTEMS

| GPS | Galileo | GLONASS | Beidou/Compass |
|---|---|---|---|
| US | EU | Russia | China |
| (24+, Now 30 | (27, Now 11-15 | (24, Now 24-27) | (35, Now 21) |
| 12 IIR | IOC) | | |
| 6 IIR-M | | | |
| 12 IIF) | | | |

# TIME FROM GNSS

- Clocks on Satellite Vehicles (SVs) are free-running
  - Data provides the offset in Time and Frequency
  - System time is offset from UTC
- The positions of the satellite and receiver are needed for the delay
- SV Clocks and positions are ***predicted*** and uploaded, for GPS about once per day

# SPECTRA OF GNSS



# GNSS VULNERABILITY TO JAMMING

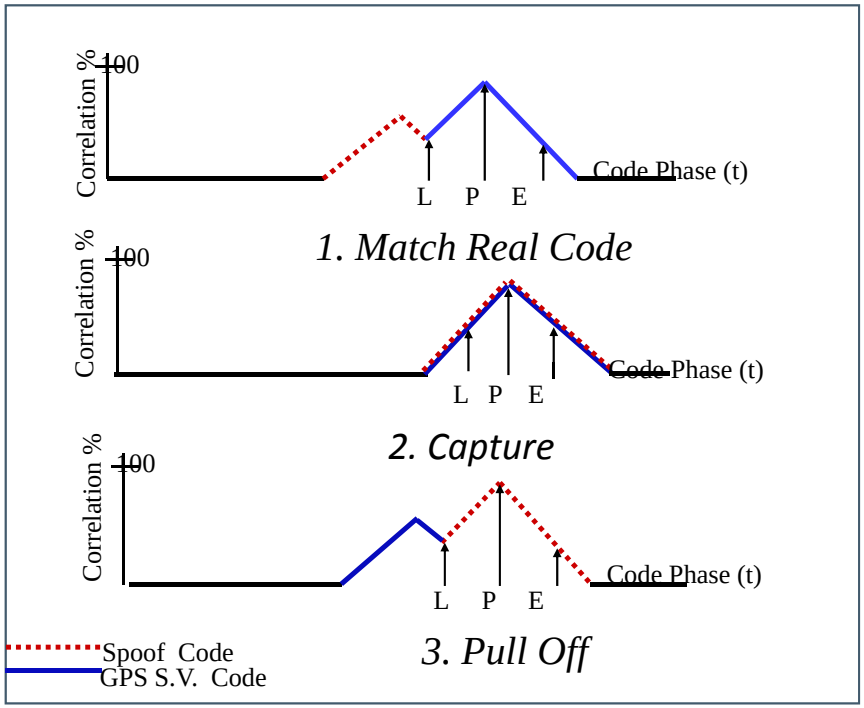
- GNSS best feature and worst problem: it is extremely reliable
- Jamming Power Required at GPS Antenna
  - On order of a Picowatt ($10^{-12}$ watt)
- Many Jammer Models Exist
  - Watt to MWatt Output – Worldwide Militaries
  - Lower Power (<100 watts); "Hams" Can Make

"Personal Privacy" Device


Military Jammer

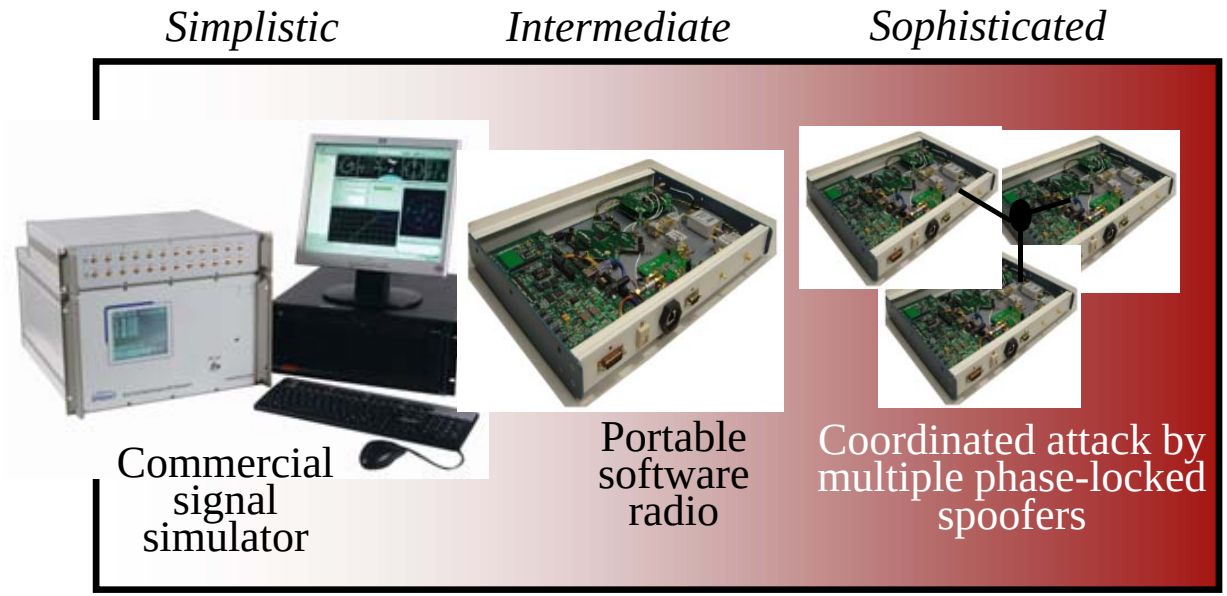
# DISRUPTION MECHANISMS - SPOOFING/MEACONING

- Spoof – Counterfeit GNSS Signal
  - C/A Code Short and Well Known
  - Widely Available Signal Generators
- Meaconing – Delay & Rebroadcast
- Possible Effects
  - Long Range Jamming
  - Injection of Misleading PVT Information
- No “Off-the-Shelf” Mitigation




Successful Spoof

# CIVIL GPS SPOOFING THREAT CONTINUUM*

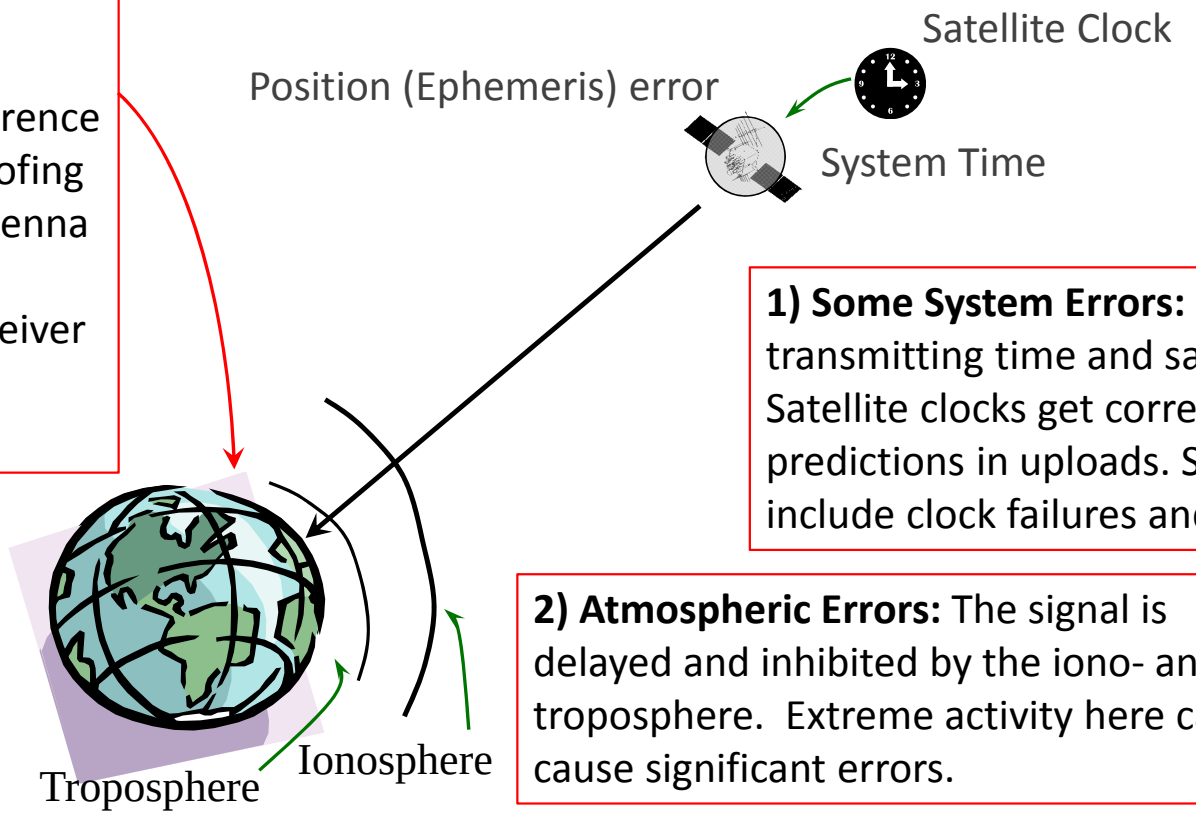



* Courtesy of Coherent Navigation, Inc

# UTC FROM GNSS ERROR SOURCES ALL DELAYS MUST BE ACCOUNTED FOR

**3) User Controlled Receiver Issues:**

- Multi-path interference
- Jamming and Spoofing
- Delay through antenna
- Delays in cables
- Delay through receiver
- Coordinates
- Receiver software




**1) Some System Errors:** GPS works by transmitting time and satellite position. Satellite clocks get corrections as predictions in uploads. System errors include clock failures and upload errors

**2) Atmospheric Errors:** The signal is delayed and inhibited by the iono- and troposphere. Extreme activity here can cause significant errors.

# HOW DO YOU PROVE YOU GOT UTC?

- SEC Rule 613: UTC must come from NIST
  - Document traceability, e.g. UTC from GNSS vs UTC from NIST

- Need to account for the delay from the satellite to your time server
  - Document iono- and tropospheric conditions
  - Document reasonable efforts to detect and mitigate spoofing
  - Document receiver configuration and performance
  - Document calibrations of delays in: antenna, antenna cable, receiver, local cables