



*The Abdus Salam  
International Centre for Theoretical Physics*



**2025-13**

**Satellite Navigation Science and Technology for Africa**

*23 March - 9 April, 2009*

**Introduction to Clocks, GPS time, Precise Time Applications  
(Part 3)**

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U.S.A.*



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# **The U.S. Naval Observatory**

Who, What, When, Why, Where



# Some of us ... 10 years ago



Positions Today (4 vacant)	#
Administration	2
Physical Clock Care	5
Time Scale Mathematicians	2
GPS	6
TWSTT	7
Computer Experts	4
Alternate Master Clock	2
Clock Development	5
Total	32



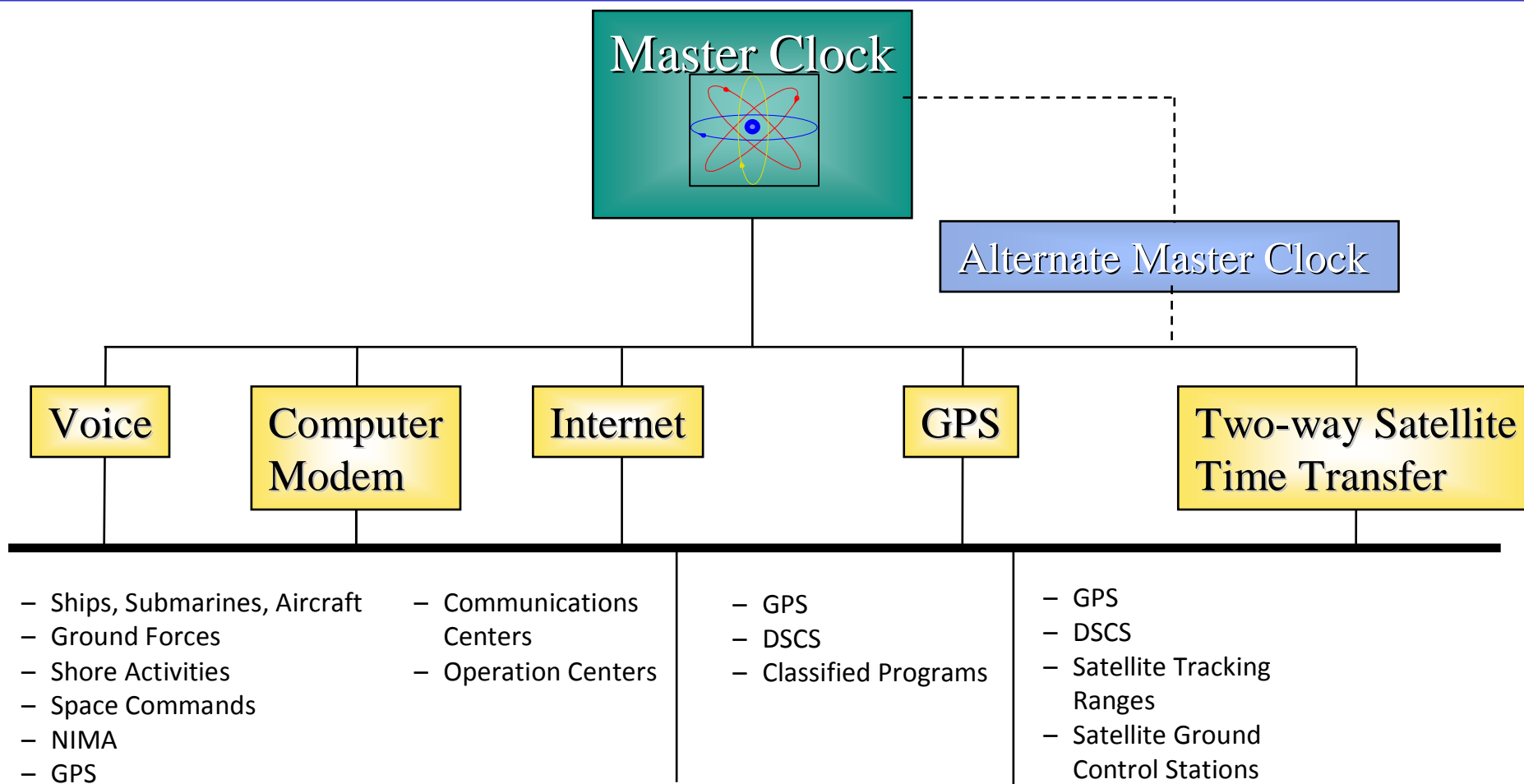
# What the Google Used to Show

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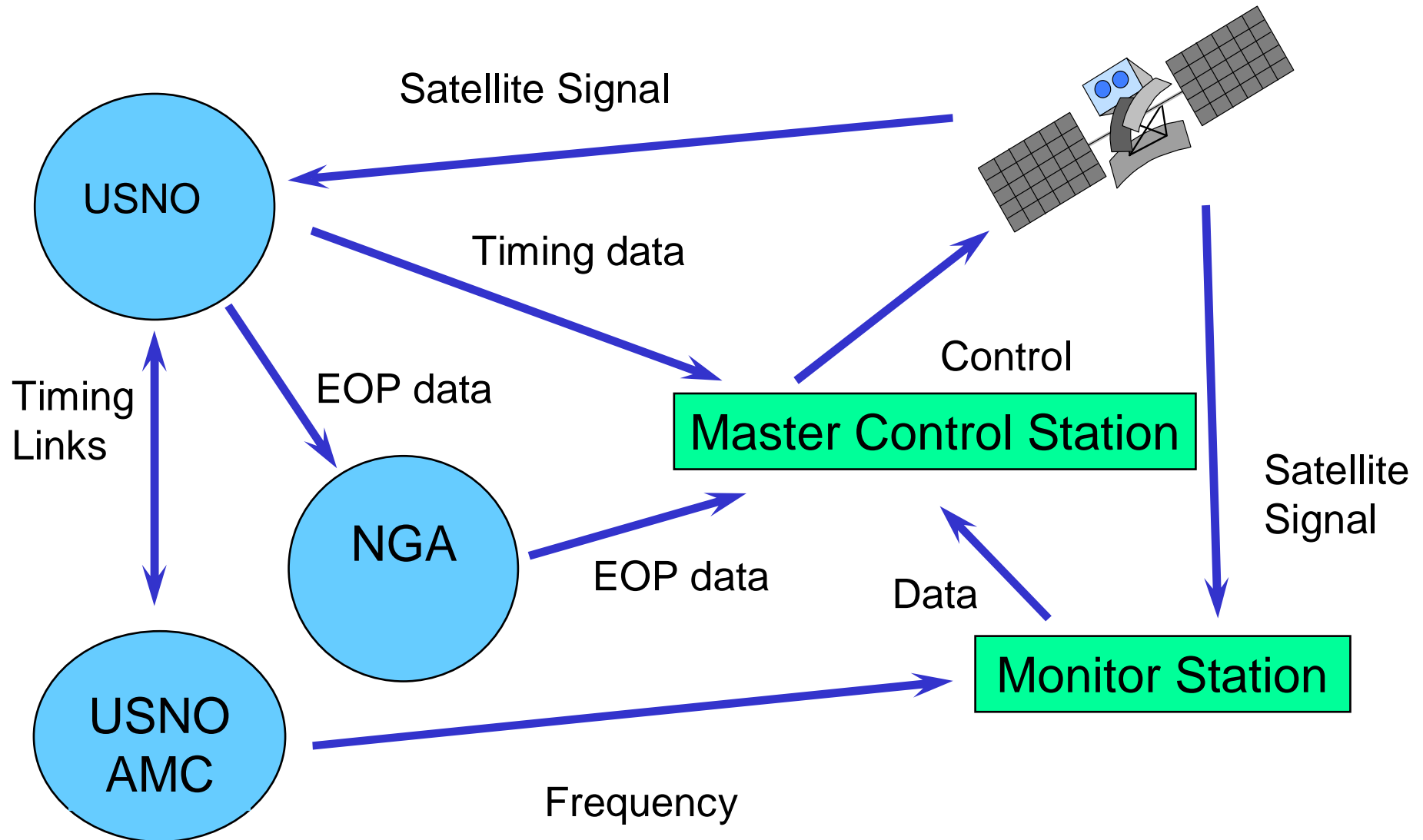
# USNO's Time Dissemination





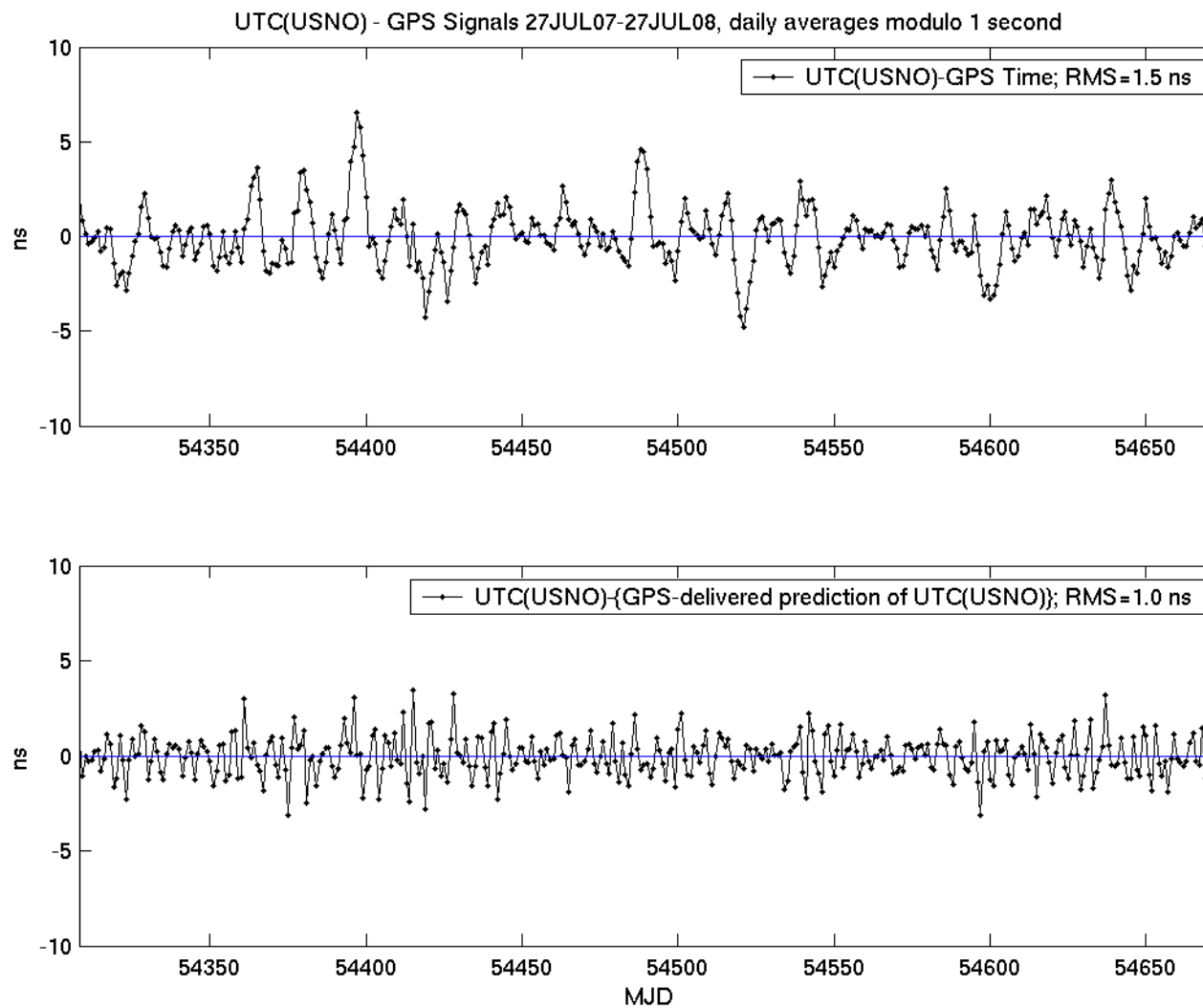


# USNO Contribution to GPS





# GPS Time and UTC(USNO)





# USNO Master Clock

## Master Clock Washington, DC

- 57 High Performance Cesiums
- 24 Cavity-Tuned Masers



## Alternate Master Clock Schriever AFB

- 12 High Performance Cesiums
- 3 Cavity-Tuned Hydrogen Masers





# Environmental Chambers

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# Master Clock Must Improve

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- Order of Magnitude Needed
  - More robust (reliable)
  - More precise (more self-consistent)
  - More accurate (closer to target)
- We know how to do it
  - Better clocks, better care, better time transfer
- We know why
  - GPS III
  - Space
  - 1 ns equals 1 foot
  - 3 ns equals 1 meter



## USNO portion of the GPS III Error Budget

All values 1 $\sigma$	Threshold	Objective
Signal in Space	0.75 ns	0.25 ns
GPS Reception at USNO	0.625 ns	0.275 ns
UTC(USNO)	0.25 ns/day	.05 ns/day
TOTAL	1.0 ns (1 $\sigma$ )	.375 ns (1 $\sigma$ )



# A Database At Your Fingertips







# New Clock Building

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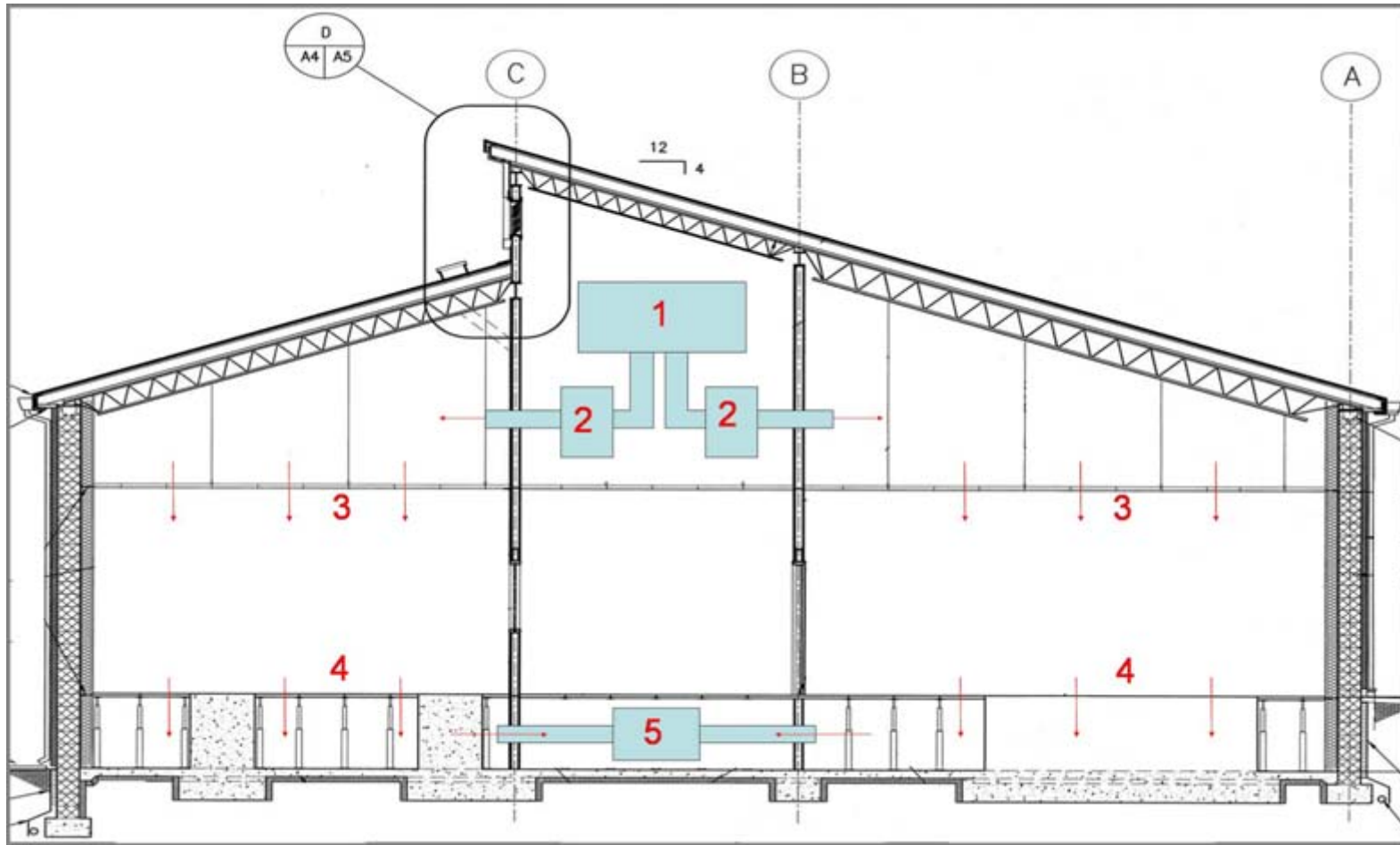


Specifications: Temperature  $\pm 0.1$  C Humidity  $\pm 3\%$  RH \*ALWAYS\*





# “Pompidou on the Potomac”





# Fail-safe HVAC





# Clock Room in New Building

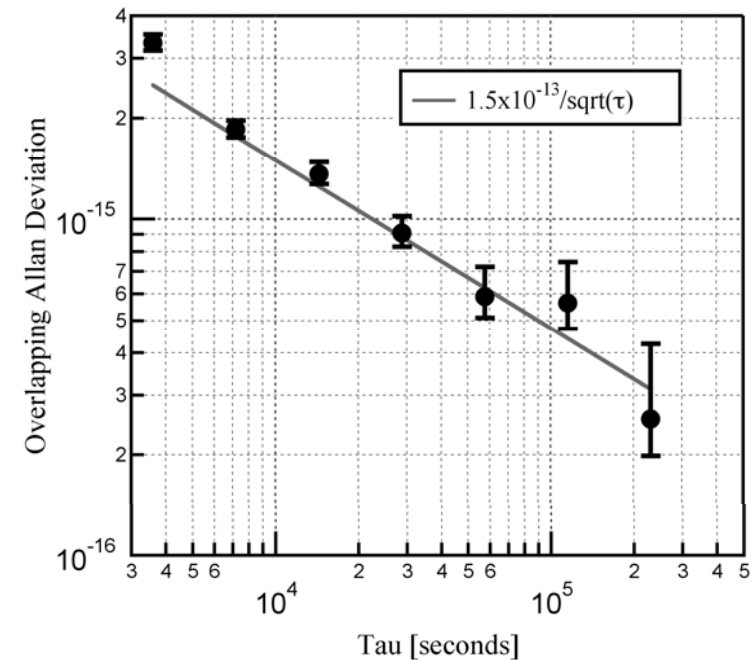
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# Two Rubidium Fountains Installed

## Goal: 3 at USNO, 3 at AMC







# Secure Computing

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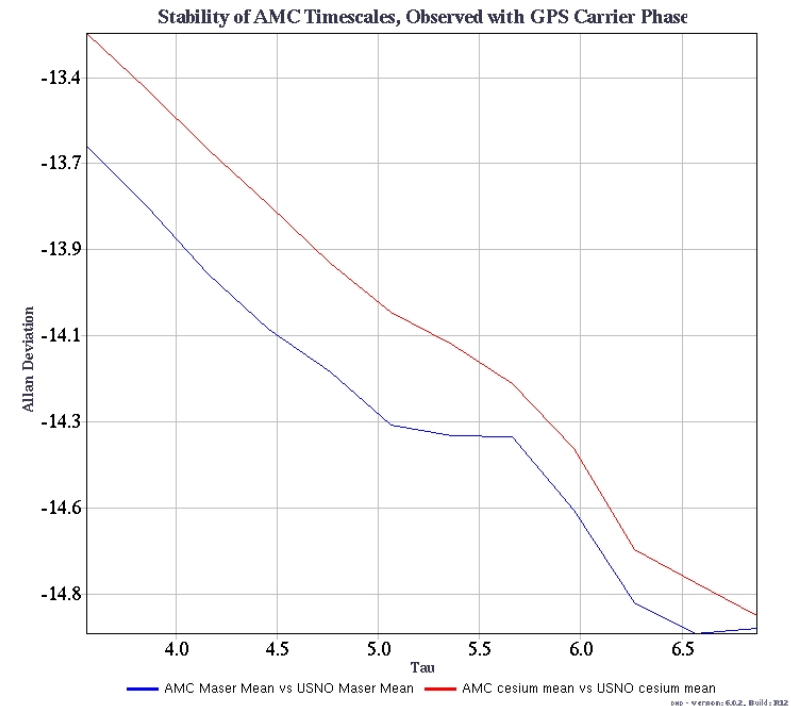
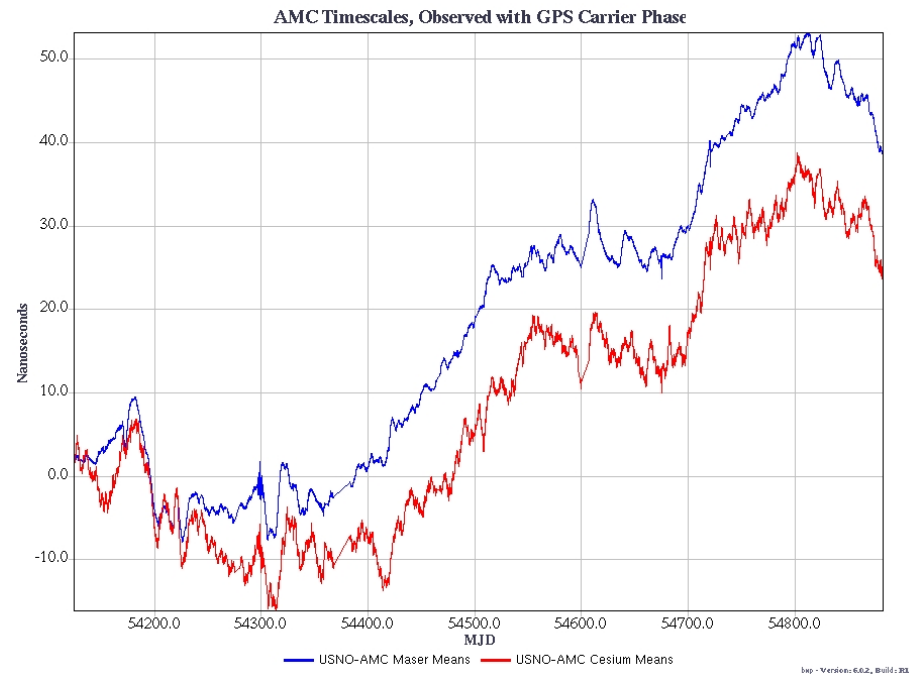






# How Good is the AMC?

## (with 3 masers, 12 cesiums)



- Blue is unsteered AMC maser mean against unsteered USNO maser mean
- Red is unsteered AMC cesium mean against unsteered USNO cesium mean
- Masers do not contribute to long-term stability
  - Since they are characterized against cesium average
- Short-term stability includes measurement and time-transfer noise
- Timescales of other labs (Lab\_k) with comparable numbers of clocks can be inferred from the TA(Lab\_k) values published in the Circular T



# AMC Upgrades

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- New Chambers (\$69,000 each)
  - Fewer Parts
    - Eliminated the relays, a system that had 1-year mtbf
  - Primary and backup share same in/out ports
    - Eliminates gradient change when shift to backup