Sub-nanosecond GPS Time Transfer; Global Solutions Using Carrier Phase and Pseudorange

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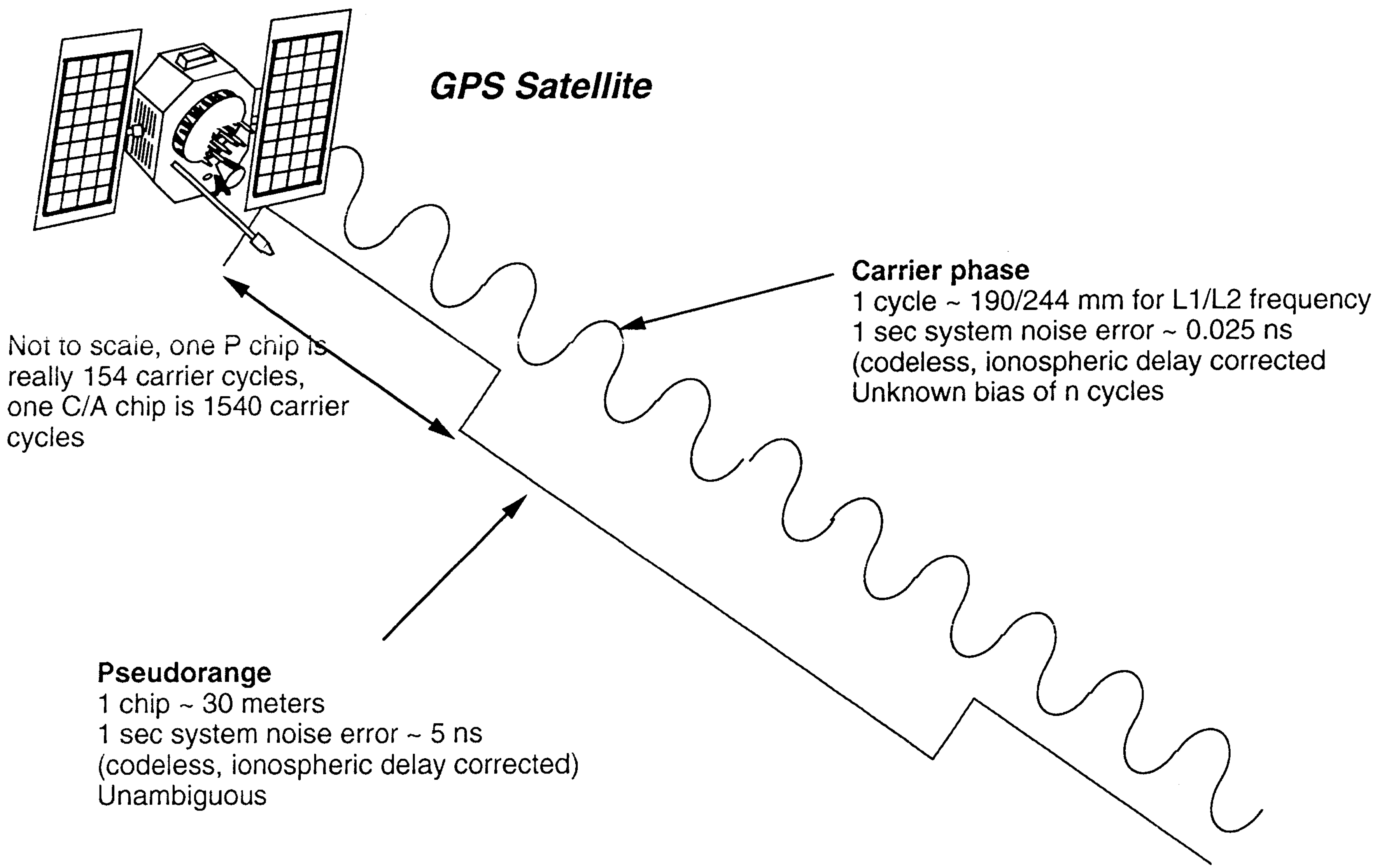
Sub-nanosecond GPS Time Transfer

Outline

- o Precise time transfer at JPL (*a partial history)*
  - *o* VLBI
  - o Common view GPS
  - o Global solution GPS (The topic of this talk)
- o GPS signal. Information content in pseudorange and carrier phase.
- o Global solution approach and errors
- o Results
- o Future prospects

GPS Signal Structure



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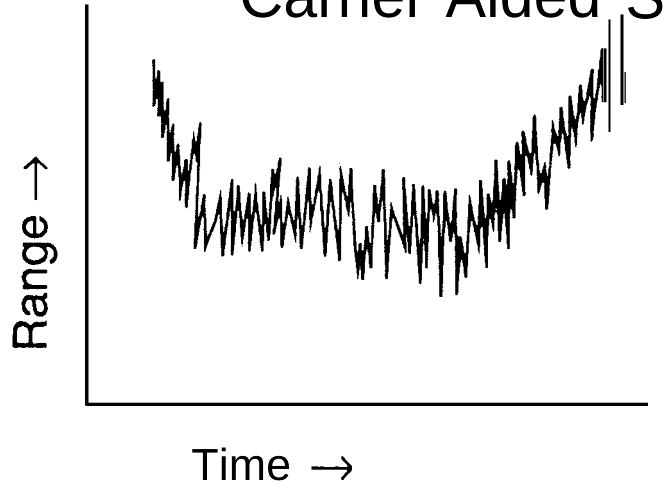
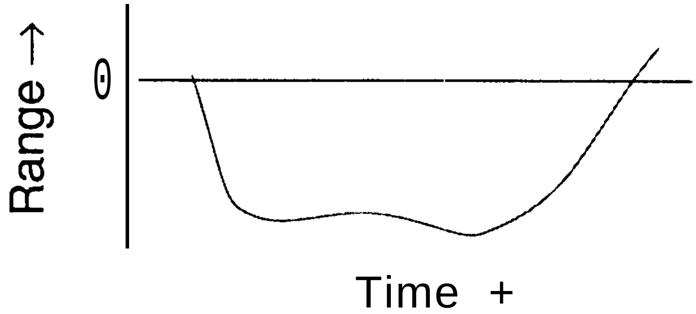
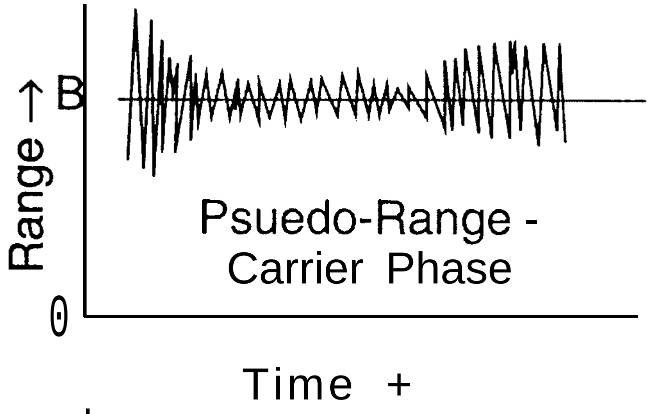
Global GPS Solution
Carrier Aided Smoothing



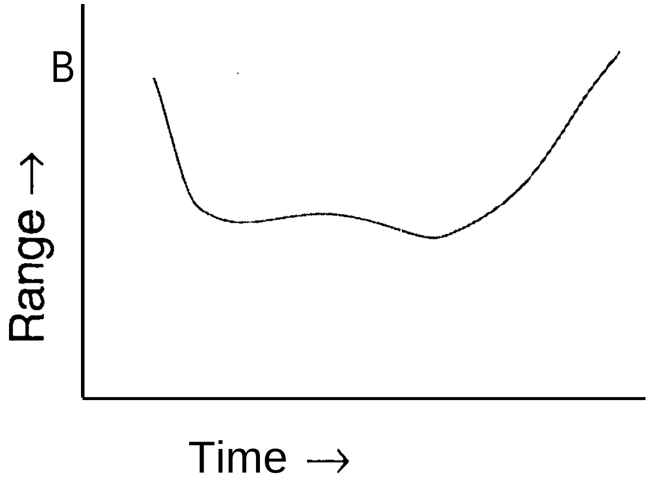
Ionosphere Free
Pseudo-Range
● 5 ns Noise



Ionosphere Free
Carrier Phase
--0.025 ns Noise
unknown bias



Noise on B is ~5 ns/sqrt(t), where t is length of track



Carrier with bias
estimated with
smoothed
Pseudo-Range

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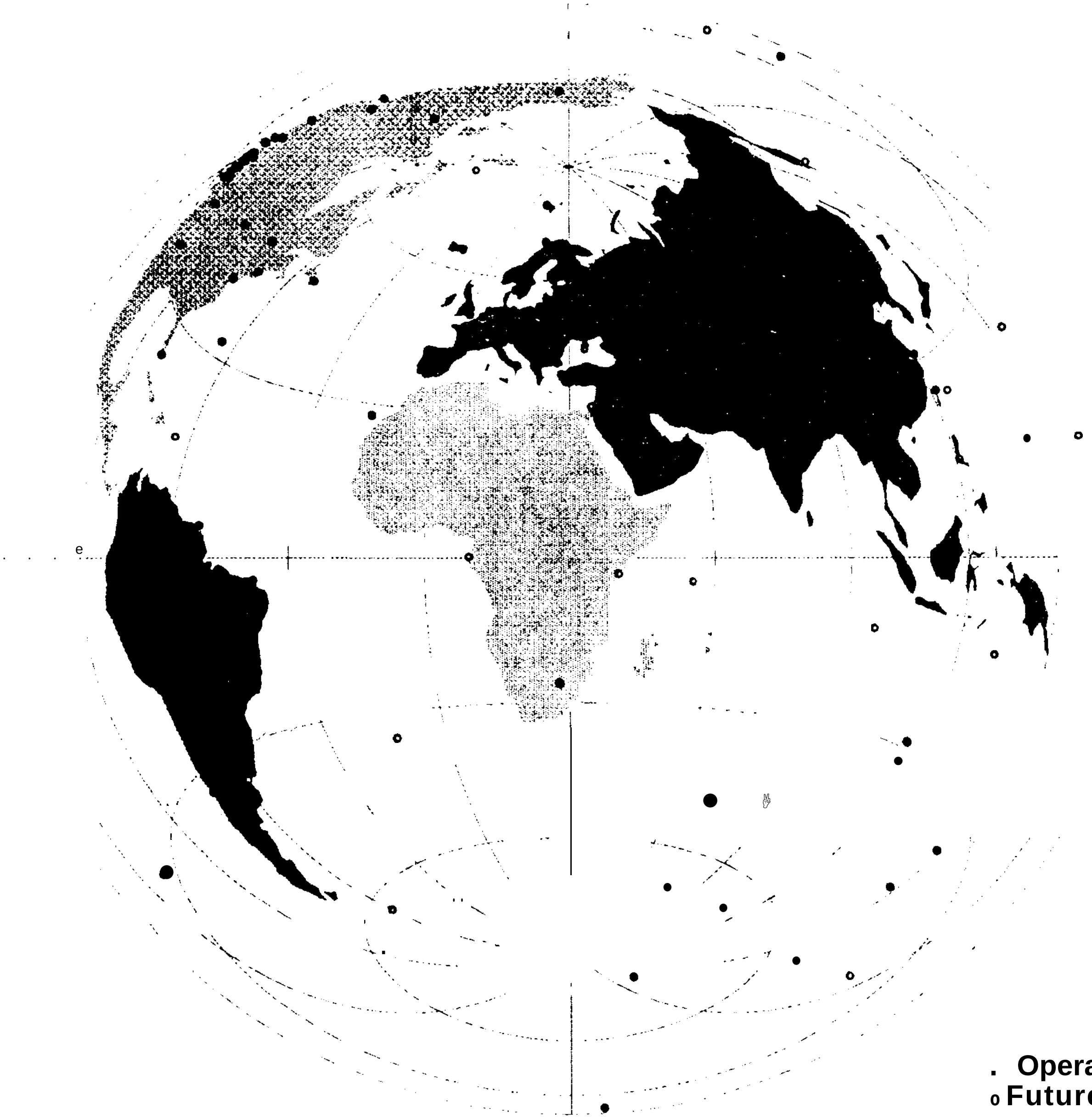
IGS STATIONS



. Operational
o Future

March 1995

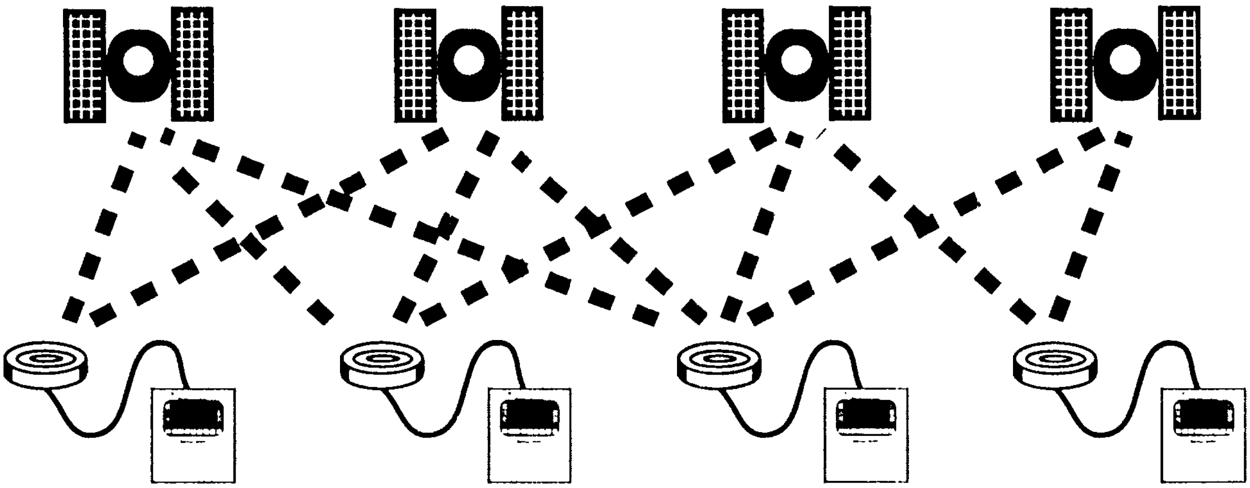
Global GPS Solution

JPL

Estimation Strategy

☞ Common GPS Satellites are tracked by **-35** Ground Sites.

☞ Sub-ns clock sync obtained between sites with no common view



☞ This allows simultaneous solutions of:

- Satellite Ephemerides & Clocks (white noise)
- Ground Positions & Clocks (white noise)
- Random Walk Tropospheric Delays
- Earth Orientation
- Solar Radiation Pressure
- -1,500 non-clock parameters each day
- ~ 22,000 station and satellite clock parameters
- using -100,000 measurements/day

☞ Calibrated effects include:

- General & Special Relativity
- Ionospheric Delay

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APL

Global GPS Solution

Estimation Strategy (contd)

☞ Measurement precision is 0.01 ns every 5 minutes.

☞ Error sources:

- Noise
- Signal Multipath
- Orbit Error
- UncalibratedTroposphere Delay
- Ionosphere Calibration Error
- Variations in instrumental delay

☞ Inferred Time Transfer Error: 100-200 ps
(Intercontinental distances, 30 hour segments)

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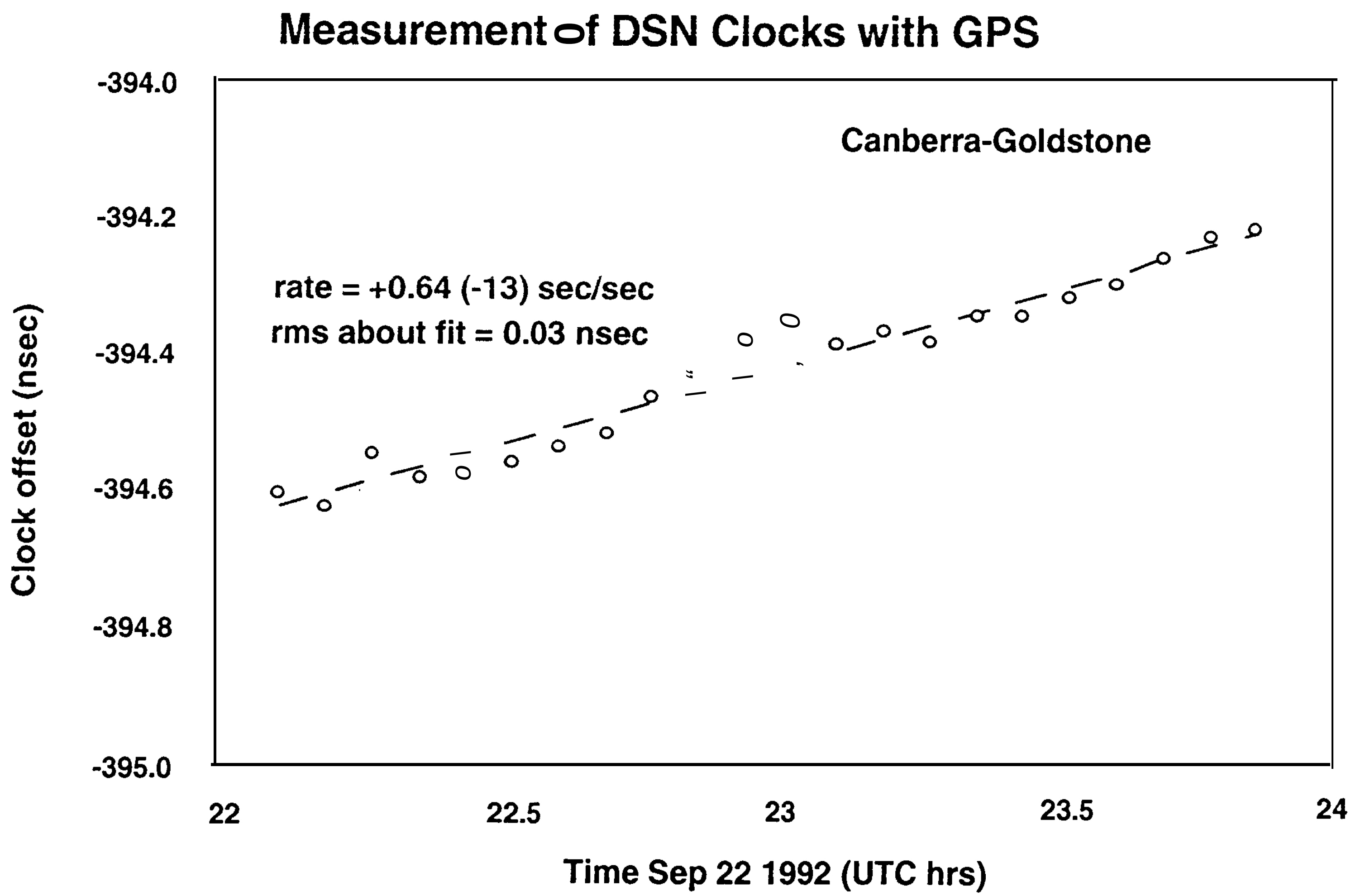
Global GPS Solution
(0.030 ns clock offset precision)



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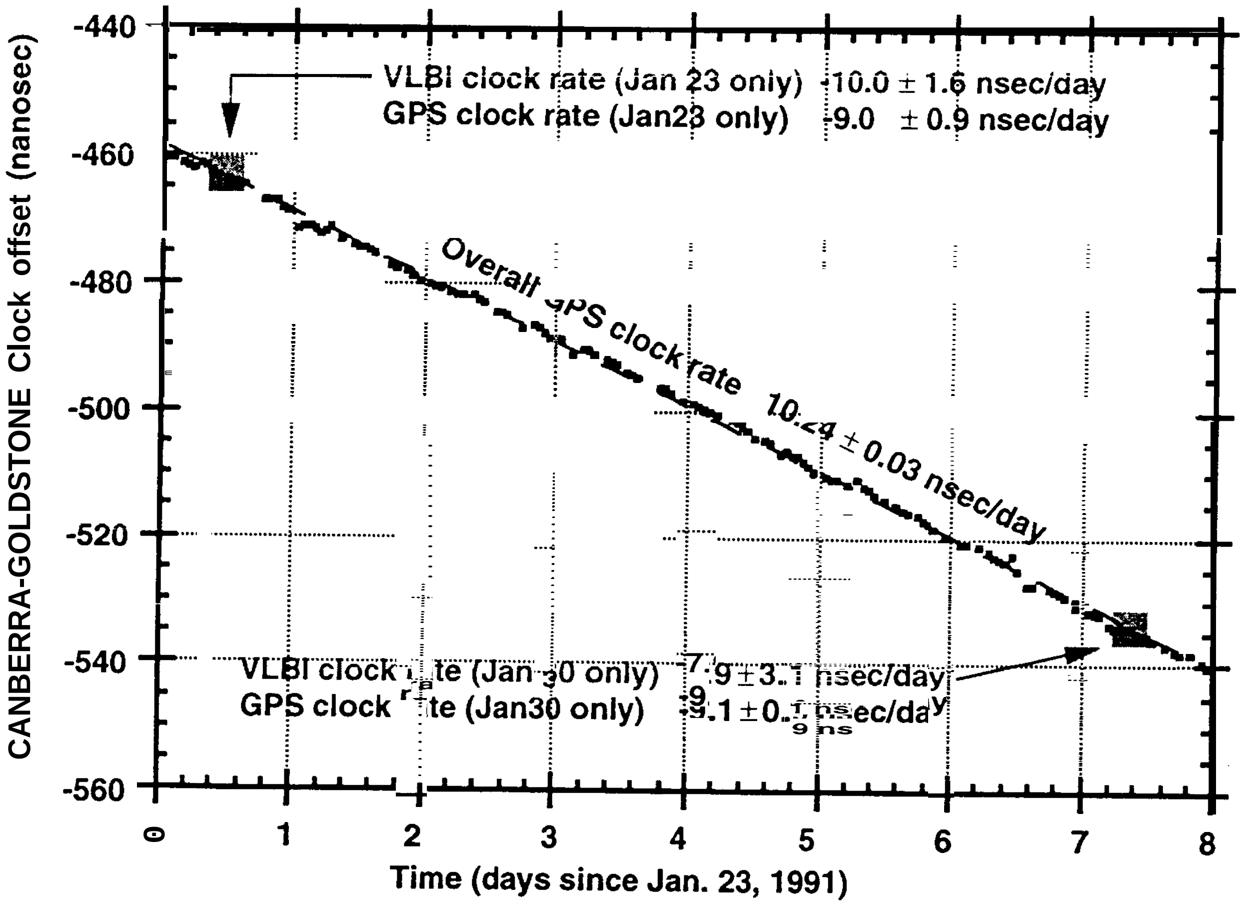
Global GPS Solution

(3.5 × 10-16 clock rate precision)

GPS DSN Clock Offset Determination



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Sub-nanosecond GPS Time Transfer
Status & Future Prospects

- o Status summary
  - o Short-term precision of GPS time transfer over intercontinental distances is about 30 picosecon
  - o GPS time transfer over one week can measure clock rates to a few parts in 10^{16}
- o Future prospects for improvements in GPS time transfer
  - o Improved antennas and receivers to reduce multipath errors.
  - 0 Improved models/estimation of media delays.
  - 0 Improved GPS dynamic models (attitude, solar pressure, ..) will lead to more accurate orbits.
  - 0 Combined GPS/GLONASS time transfer.
  - o Enhancements to the GPS satellites
    - 0 Autonav (with formation of tightly coupled ensemble of satellite clocks)
    - 0 Reduction or elimination of SA
    - 0 Second frequency with non-encrypted code
    - 0 Better clocks on satellites
    - 0 Additional satellites, perhaps in GEO or LEO
    - o Realtime differential systems such as WAAS