OAK RIDGE National Laboratory

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Comparison of Two-Way Satellite Time and Frequency Transfer (TWSTFT) and PTP over long Distances

Presented by:
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U.S. DEPARTMENT of ENERGY

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Comparison of Two-Way Satellite Time and Frequency Transfer (TWSTFT) and PTP over long Distances

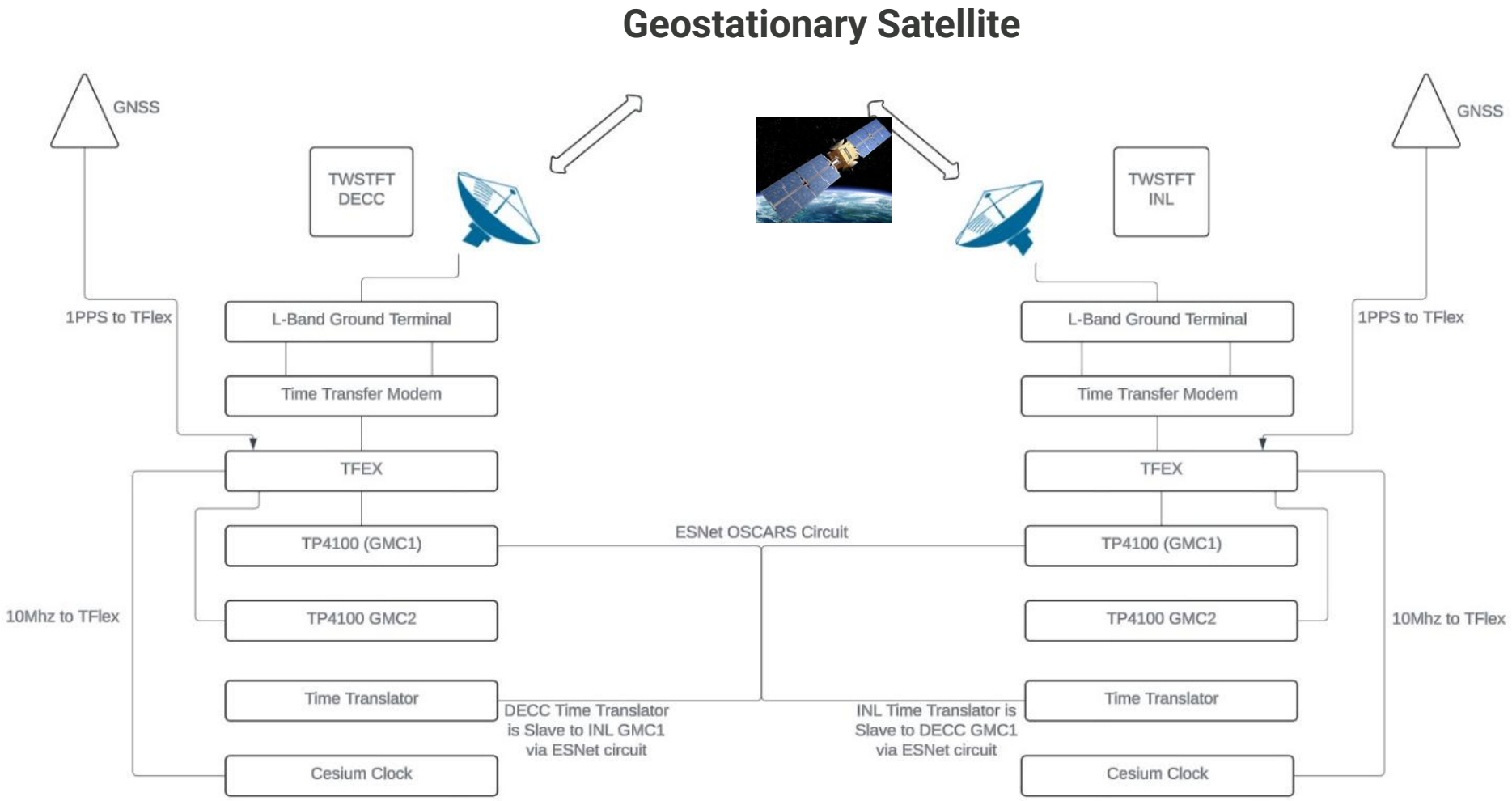
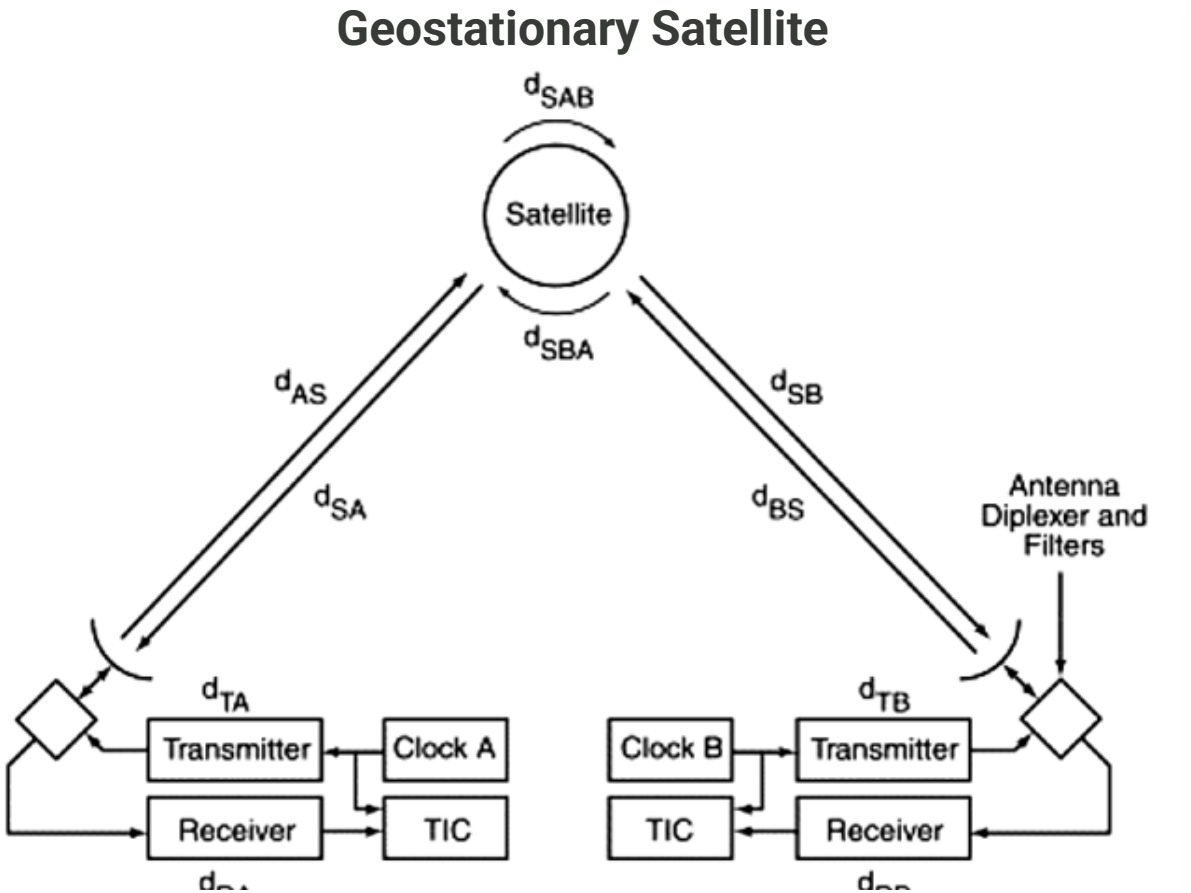


Figure shows the details on the TWSTFT setup between ORNL and INL as well as PTP over ESnet for the comparison purpose.

Two-Way Satellite Time and Frequency Transfer (TWSTFT): Why is it Important?

- Ability to synchronize timing systems over a large geographic area where traditional terrestrial communications mediums may either not be available or may not b practical from a performance standpoint.
- Pros: good timing accuracy (less than 50 ns) over large geographic areas and ability to synchronize multiple sites
- Cons: cost and complicated setup

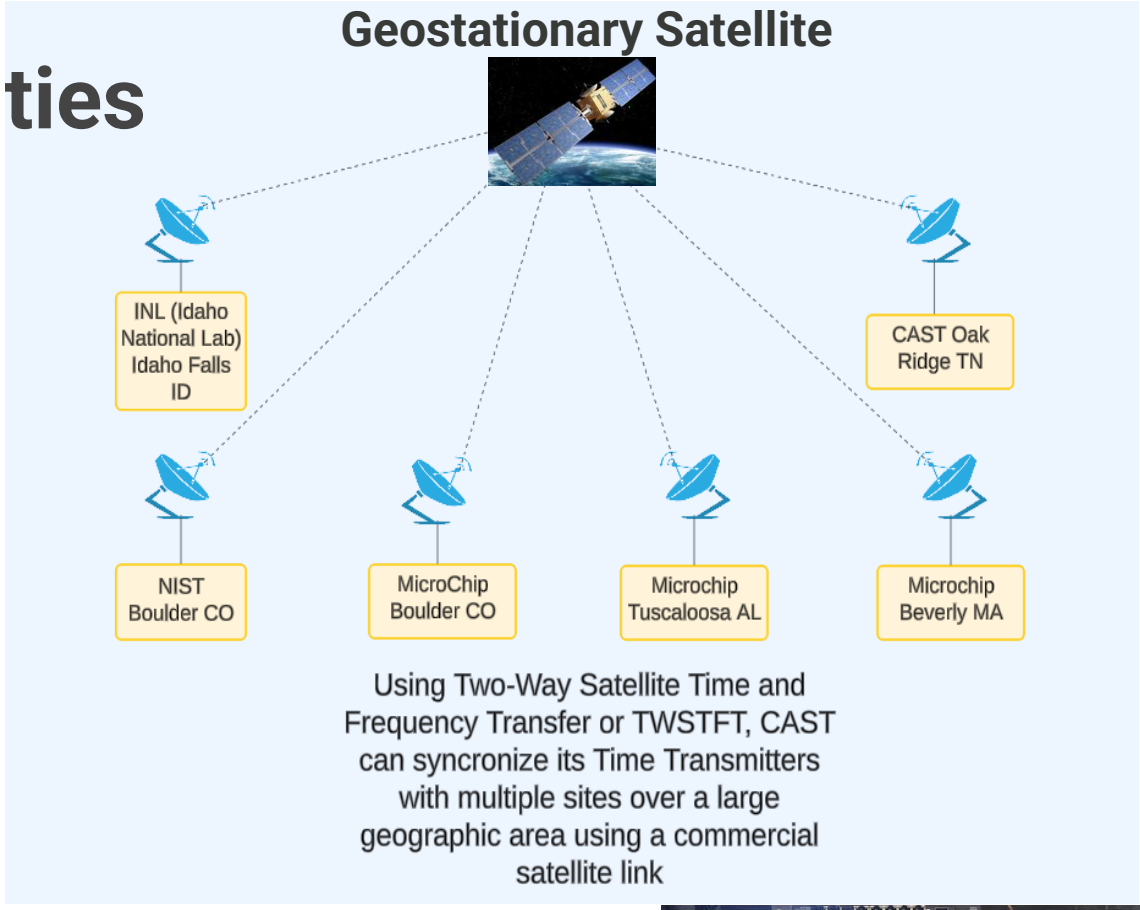


$$TIC(A) = A - B + d_{TB} + d_{BS} + d_{SBA} + d_{SA} + d_{RA} + S_B \quad (1)$$

$$TIC(B) = B - A + d_{TA} + d_{AS} + d_{SAB} + d_{SB} + d_{RB} + S_A \quad (2)$$

CAST/MicroChip TWSTFT Capabilities

- Transfer time from a master node with atomic clock to other sites without atomic clocks.
- Benchmarking long distance PTP over EsNet using TWSTFT as reference.
- Greater resilience against jamming and spoofing compared to GNSS.
- Loss of connection at one site does not affect others, providing a robust and redundant time transfer solution.
- TWSTFT use as regional hub, providing timing to local sites.



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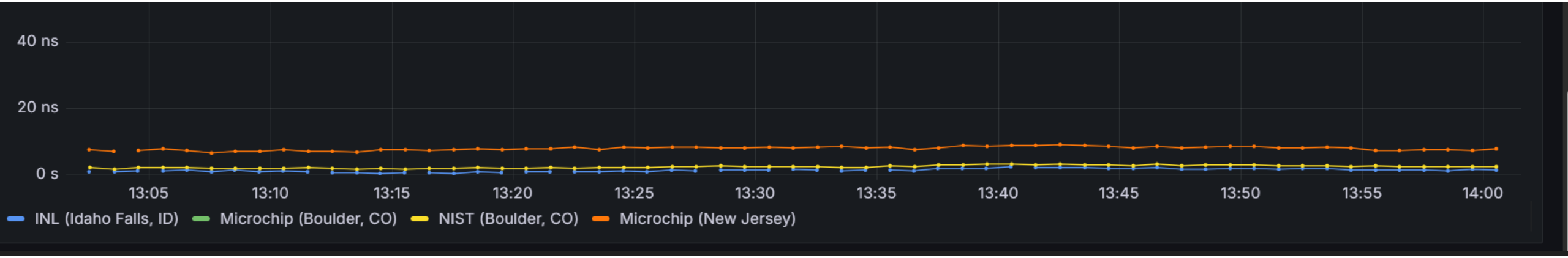
TWSTFT Experiment Phases with NIST, INL, and MicroChip

- **Phase 1 (FY 24)** – Established satellite communications and connecting CAST and NIST. Once connected we validated the stability and accuracy of the timing signal.
- **Phase 2 (FY 25)** – Added 3 MicroChip sites and confirmed the stability and accuracy of the timing signal.
- **Phase 3 (FY 25)** – Added INL, confirmed the stability and accuracy of the timing signal and compare the performance to each site.

TWSTFT Current Performance NIST, INL, and Microchip



Achieve Synchronization with NIST UTC Within 10 Nanoseconds

Challenges Faced during the TWSTFT Experiments

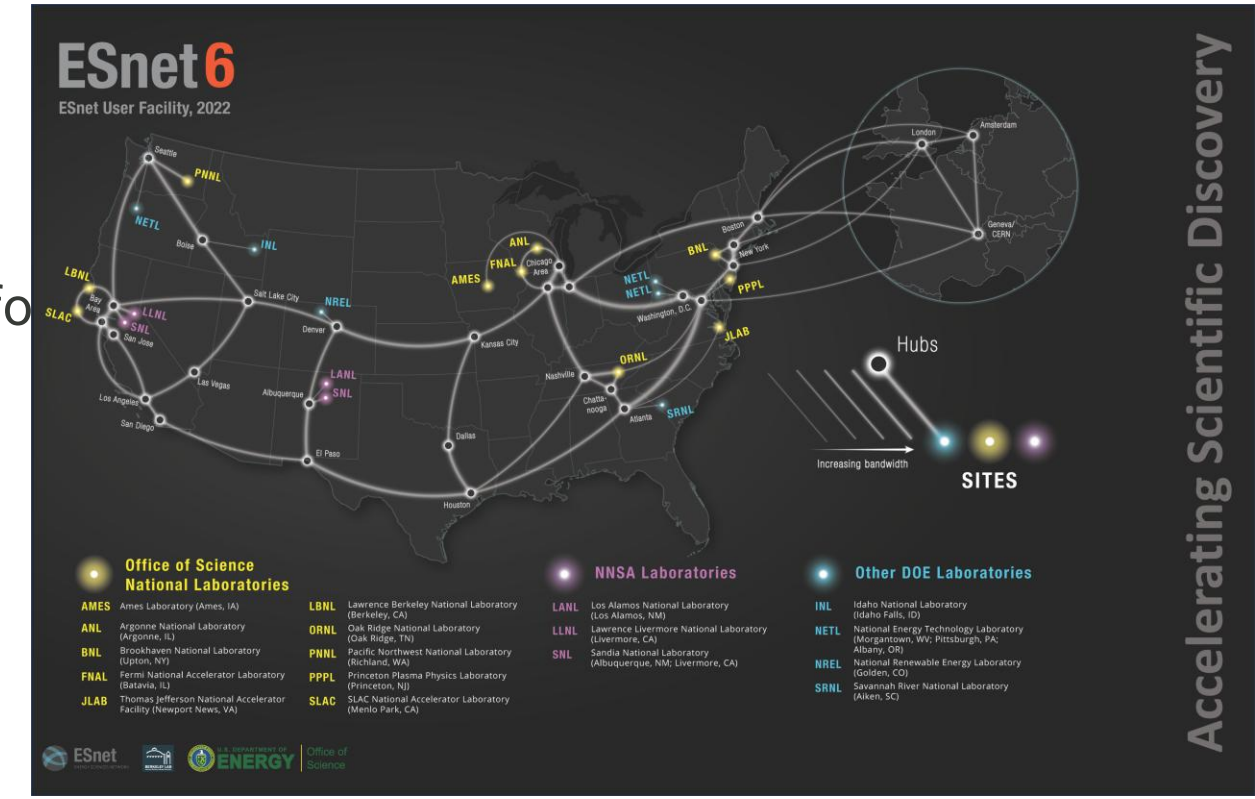
- Some of the equipment was less than user friendly
- Site outages due to equipment failure and severe weather (which required dish repointing)
- Pointing the dish to the correct satellite azimuth and elevation
- Resyncing different sites when we changed from one satellite provider to another

DOE's Energy Sciences Network (ESNet) OSCARS

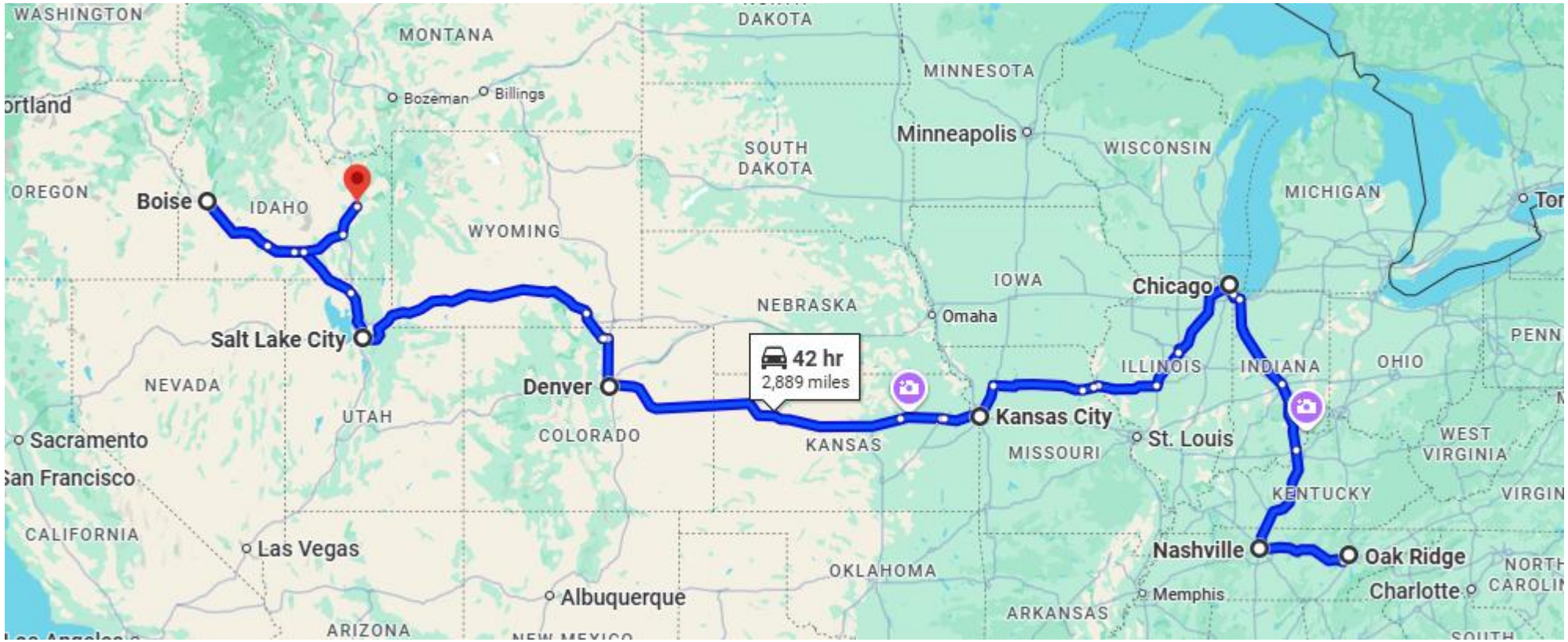
- Funded by the U.S. Department of Energy (DOE) Office of Science and managed by Lawrence Berkeley National Laboratory, the Energy Sciences Network (ESnet) was created in 1986 to provide dedicated high-performance network connectivity fo DOE researchers.

- ESnet's high-performance network connects 17 national laboratories, 28 user facilities, and 270 research & education and commercial networks.

- OSCARS On-Demand Secure Circuits and Advance Reservation System

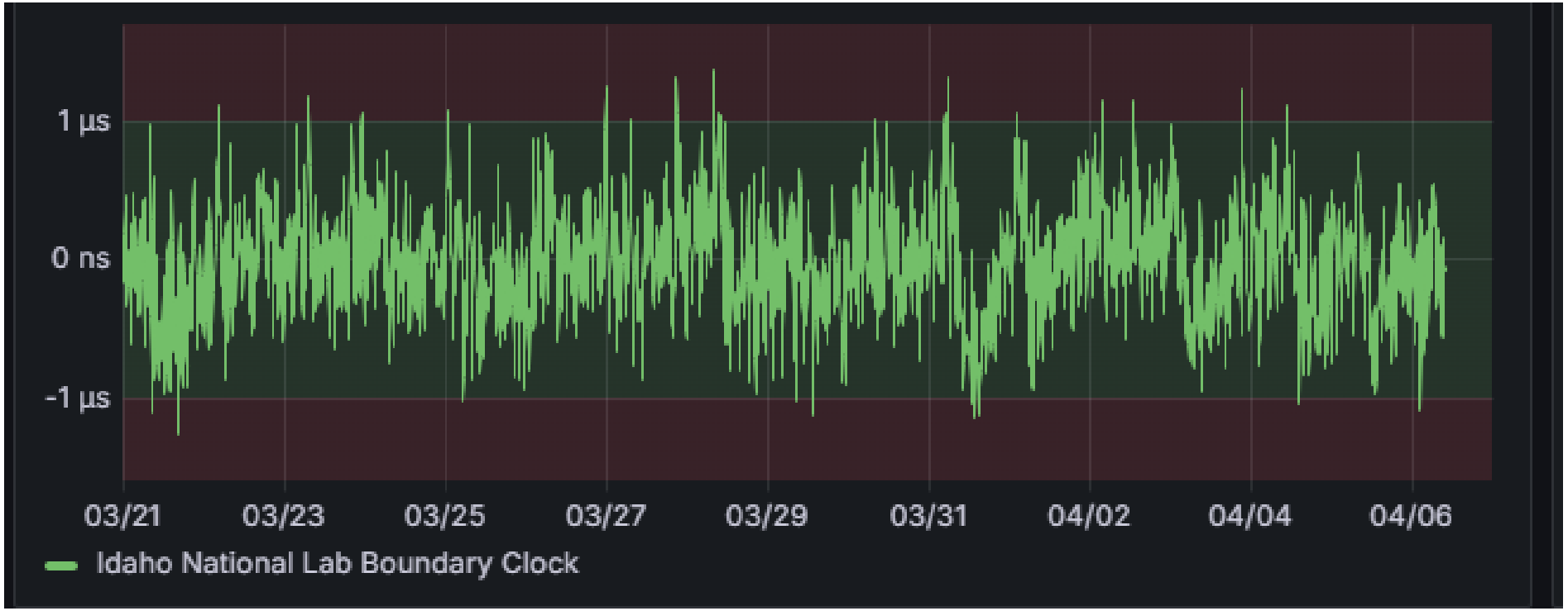


ORNL<>INL PTP performance



Esent fiber link between ORNL-NL ~3000 Miles

ORNL<>INL PTP performance



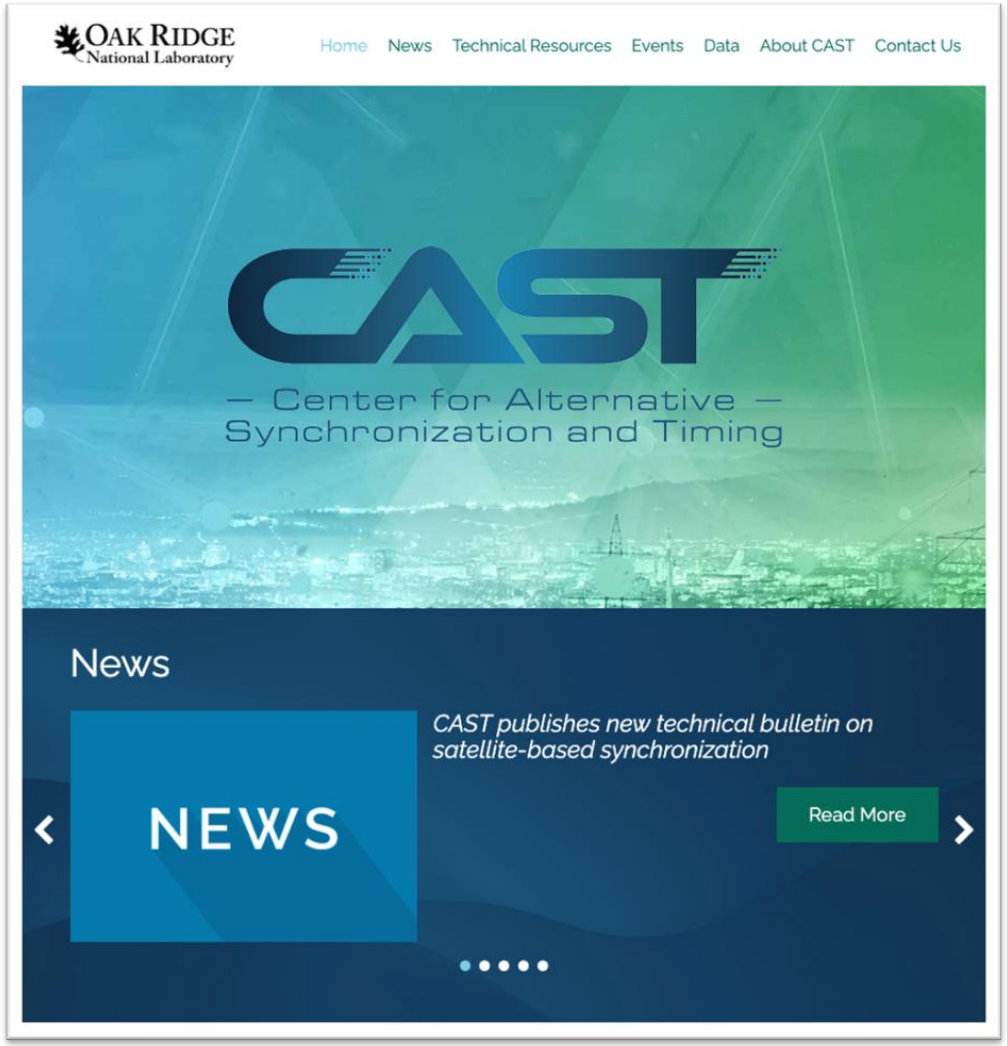
PTP Performance between ORNL<> INL < 1us

Conclusions

- TWSTFT is excellent for wide-area synchronization and achieves on average10 nanoseconds accuracy
- Distributing time (terrestrially) using PTP can be a reliable alternative to GPS/GNSS, even over long terrestrial distances. offering less than 1 microseconds accuracy.
- CAST can provide synchronization and timing without relying on GNSS

Building a Community through Partnerships & Engagement

Webpage: https://cast.ornl.gov



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