



The NIST Special Calibration Test, Preliminary Results and Future Plans WSTS 2021

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Outline

- Context of the NIST Special Calibration Test
 - Executive Order #13905 of Feb 12, 2020
 - NIST Special Test #78100S
- Fiber-Based, Time-Distribution Reference Architecture
- Results of NIST Collaboration with OPNT
 - Signal from NIST Gaithersburg in Maryland to McLean, VA
 - Signal from McLean, VA to Atlanta GA
 - Performance vs Cost implications
- Potential for Signal from NIST Boulder in Colorado to Silicon Valley, CA
- Conclusions

From U.S. Executive Order 13905 of Feb 12, 2020

Section 4 (i):

“Within 180 days of the date of this order, the Secretary of Commerce shall make available a GNSS-independent source of Coordinated Universal Time, to support the needs of critical infrastructure owners and operators, for the public and private sectors to access.”

Time over Fiber Special Test SKU 78100S

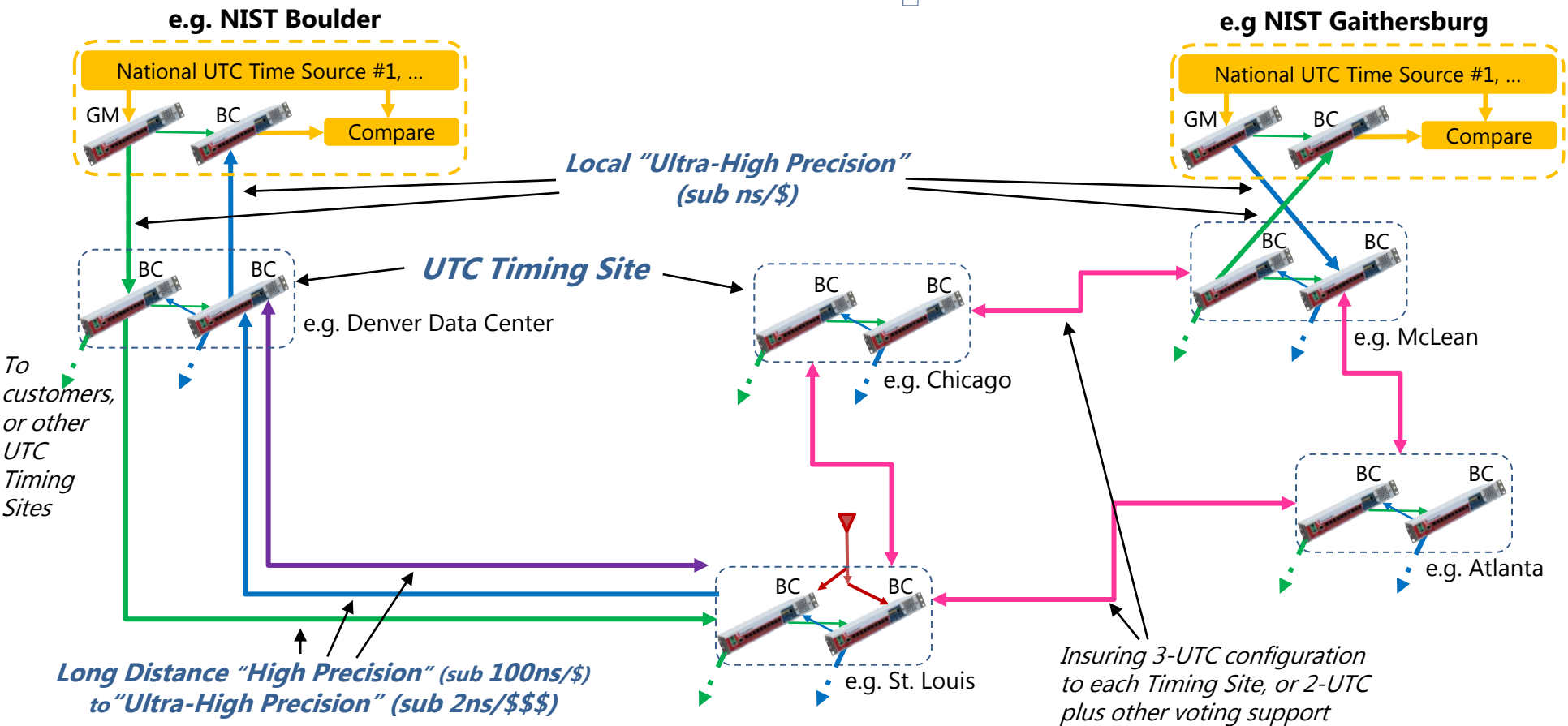
- Provide a signal traceable to UTC(NIST) from NIST Gaithersburg through a third-party optical fiber to a customer’s outside user facility.
- Initial accuracy of 1 μ s and an ultimate accuracy of 100 ns after 6 months of operation.
- https://shop.nist.gov/ccrz_ProductDetails?viewState=DetailView&cartID=&portalUser=&store=&cclcl=en_US&sku=78100S




Fiber-Based, Time-Distribution Reference Architecture

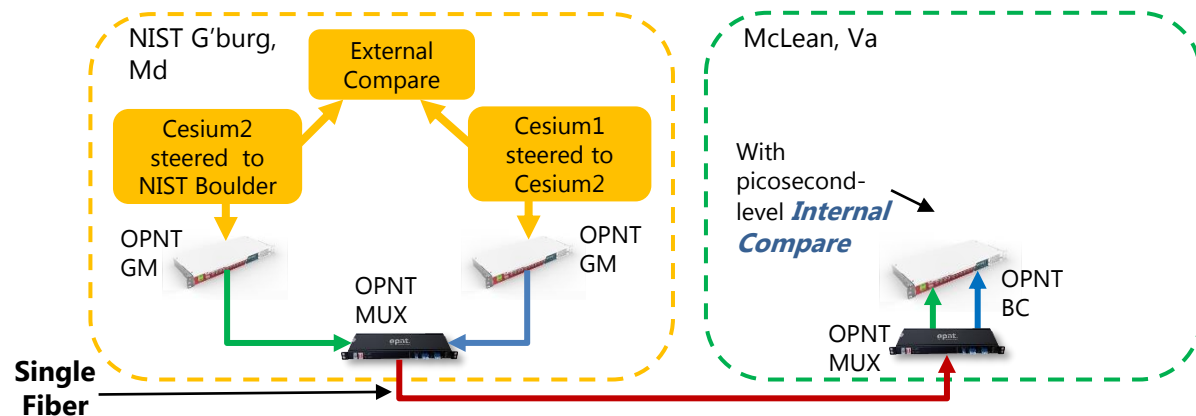
Continuity, Traceability, Accuracy, Affordability

□



NIST G'burg to McLean, Va: Dual Time Sources via Single Fiber

Legend:  Bi-directional Fiber / Ultra-High Precision



Two Cesium clocks located in NIST G'burg

- Each connected to separate GM


Single fiber strand from NIST G'burg to data center in McLean

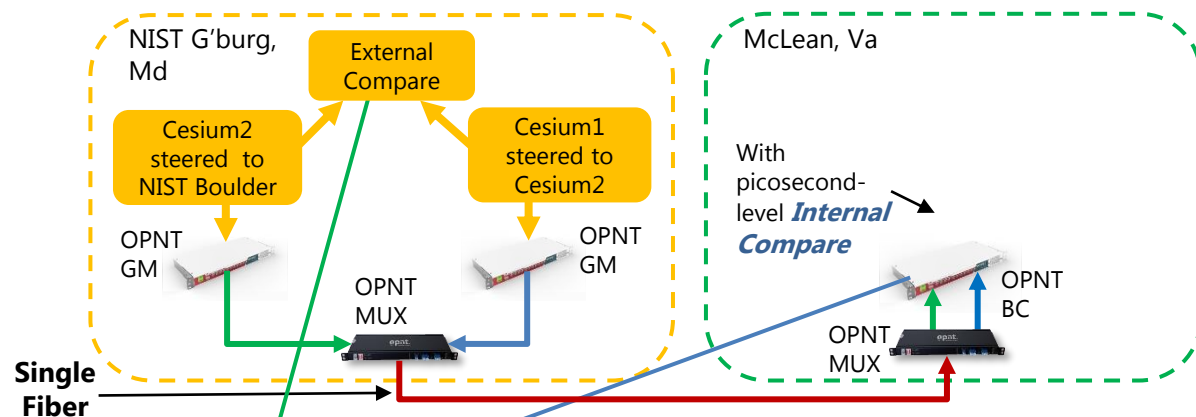
- Optical multiplexer on both ends to accommodate dual timing sources

Boundary Clock located in McLean, terminating both timing inputs from Gaithersburg

- Contains equivalent of ultra-high precision time interval counter

NIST G'burg to McLean, Va: Dual Time Sources via Single Fiber

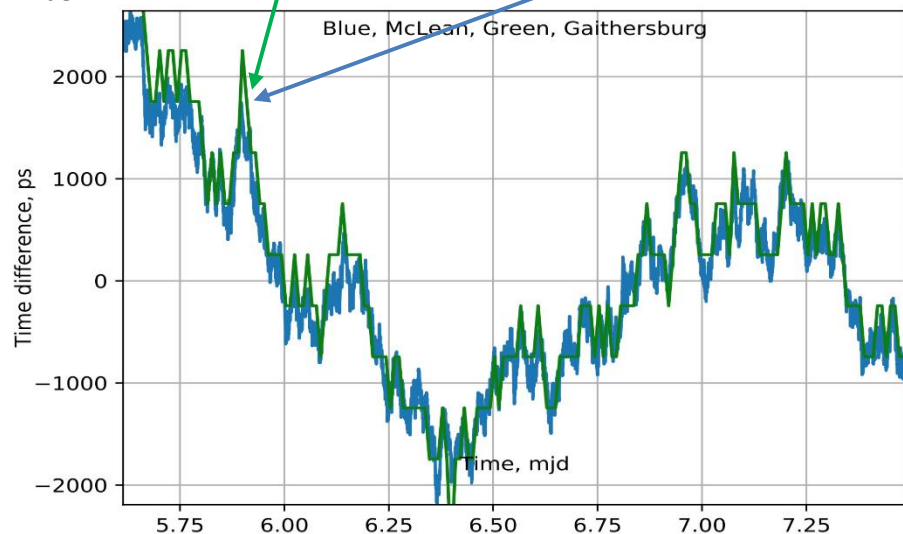
Legend:  Bi-directional Fiber / Ultra-High Precision



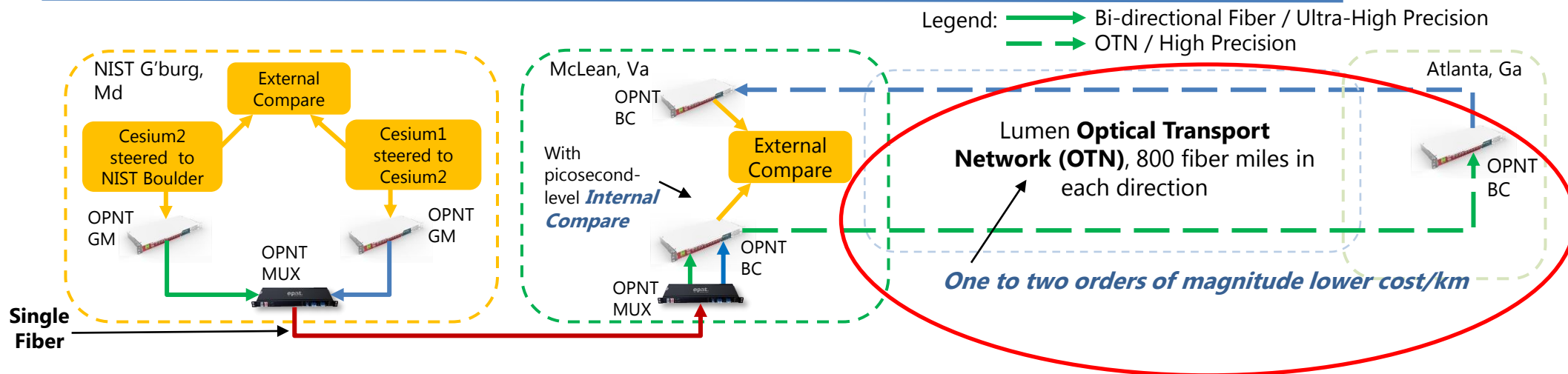
Precision-calibrated links between NIST and McLean

Graph shows tracking between the two locations

Step functions on green graph traces a result of less precise time commercial time interval counter test equipment accuracy at NIST



McLean, Va to Atlanta, Ga: Standard Dual-Fiber Based OTN*



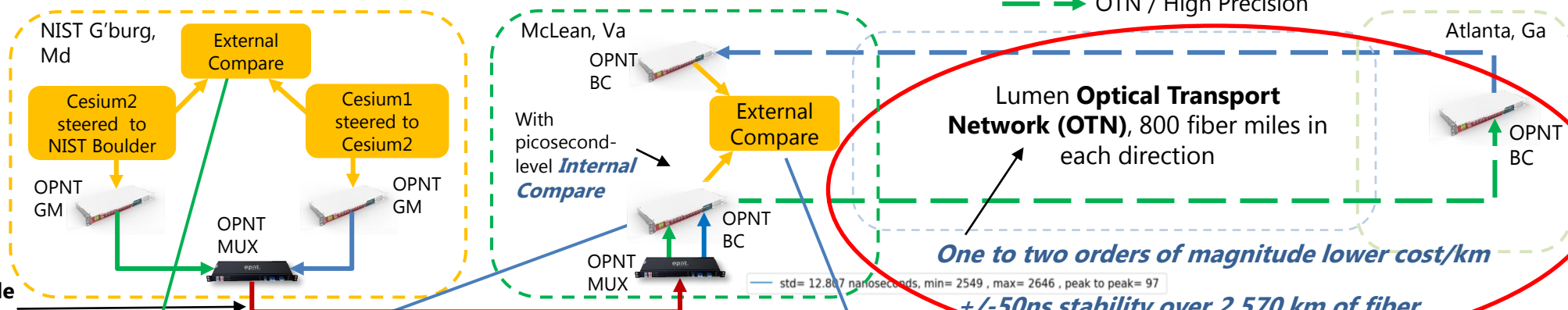
- Deployed two Lumen OTN links from McLean data center to Atlanta data center, each 800 fiber miles
- The two links connected in Atlanta on Boundary Clock
 - One transmitting time from McLean to Atlanta
 - Second transmitting time back from Atlanta to McLean
 - Forming a 1,600-mile loop from McLean to Atlanta and back
- Addition of Boundary Clock in McLean, terminating the return link from Atlanta
- Commercial Time Interval Counter added to McLean to assess full-loop stability

* Optical Transport Network

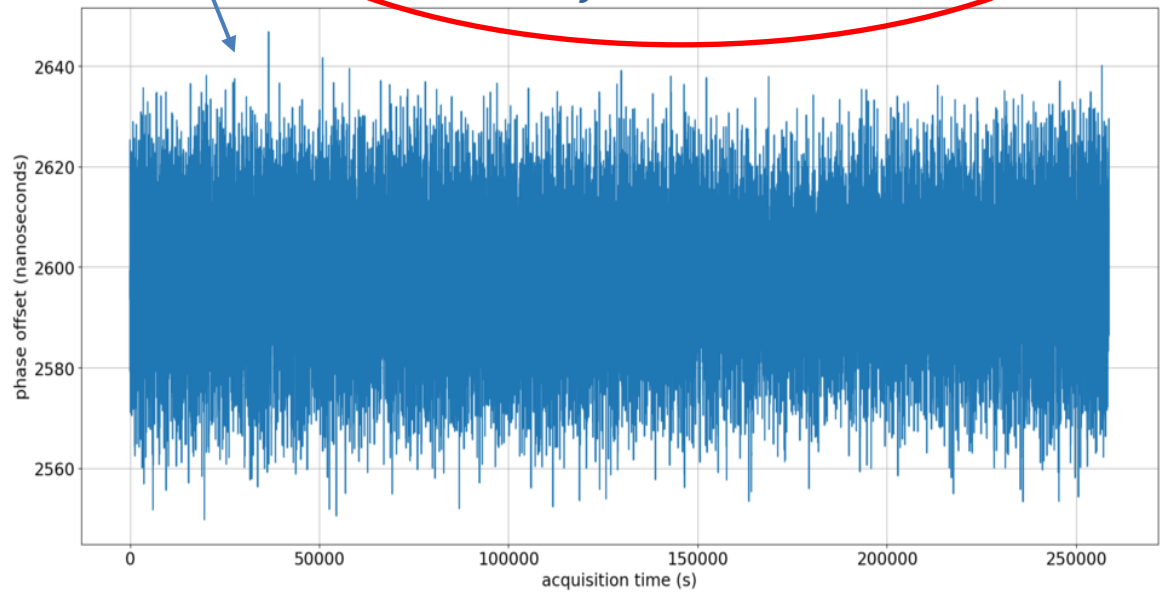
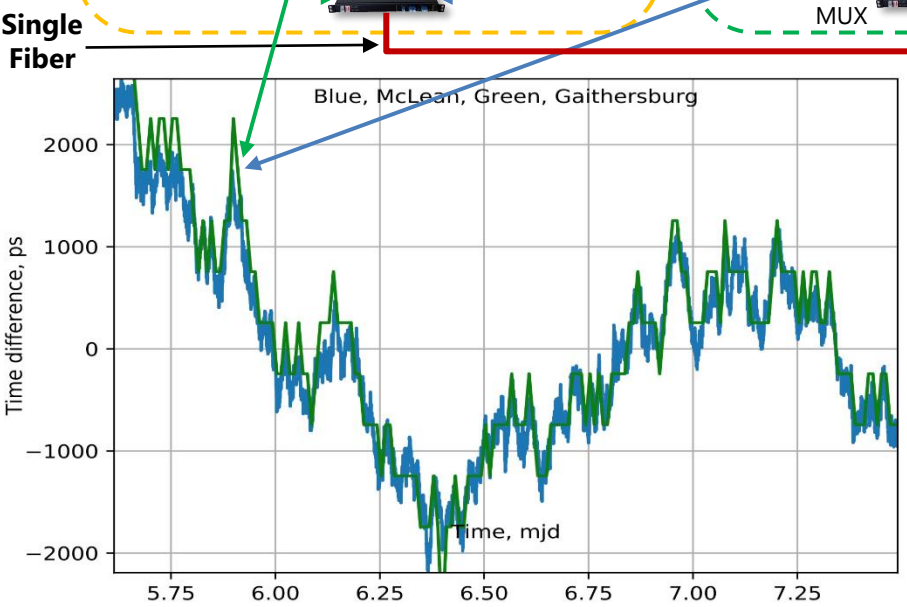


NIST Gaithersburg to McLean, Va: Dual Time Sources

Legend: Bi-directional Fiber / Ultra-High Precision
 OTN / High Precision

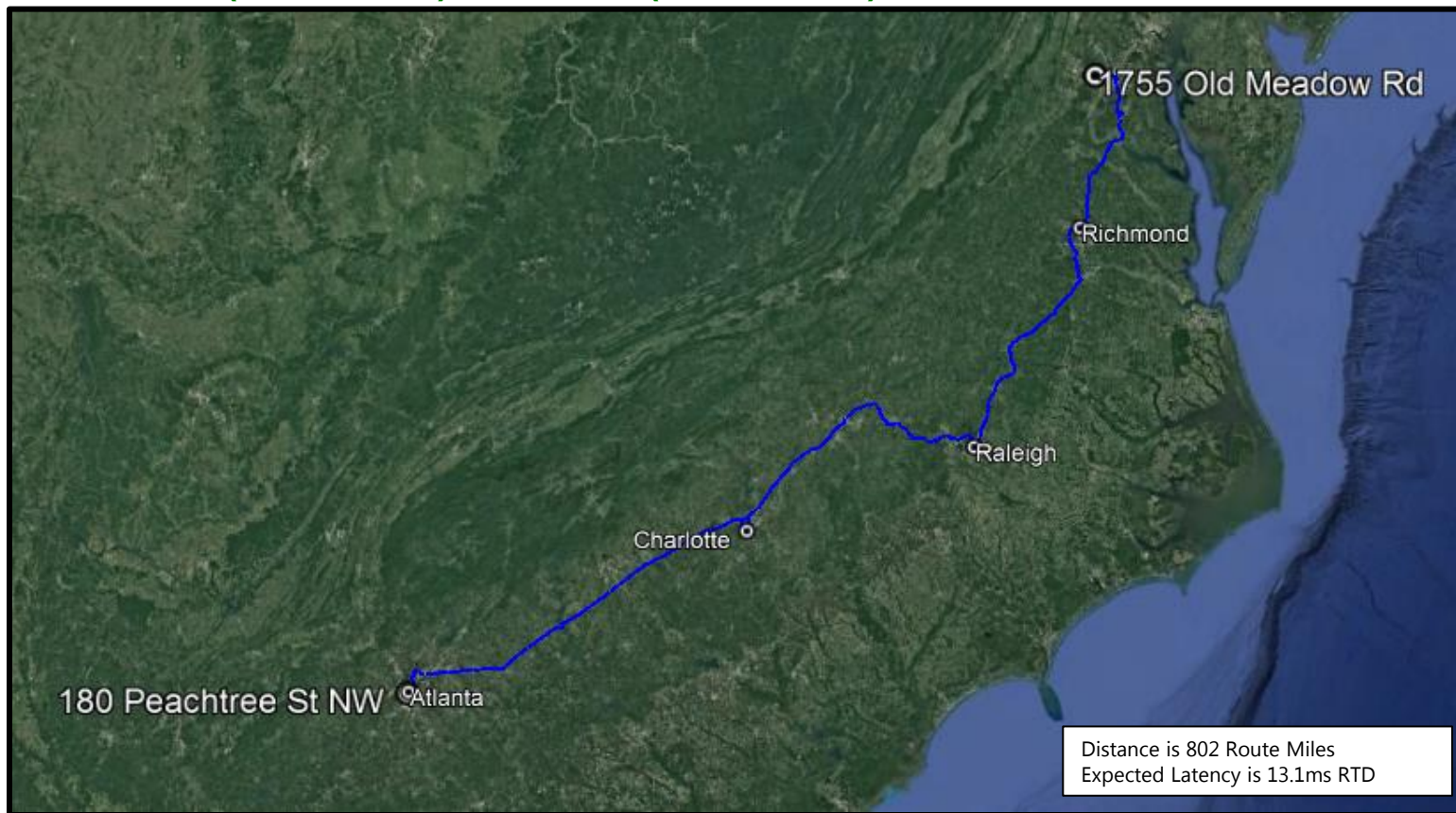


std= 12.807 nanoseconds, min= 2549 , max= 2646 , peak to peak= 97

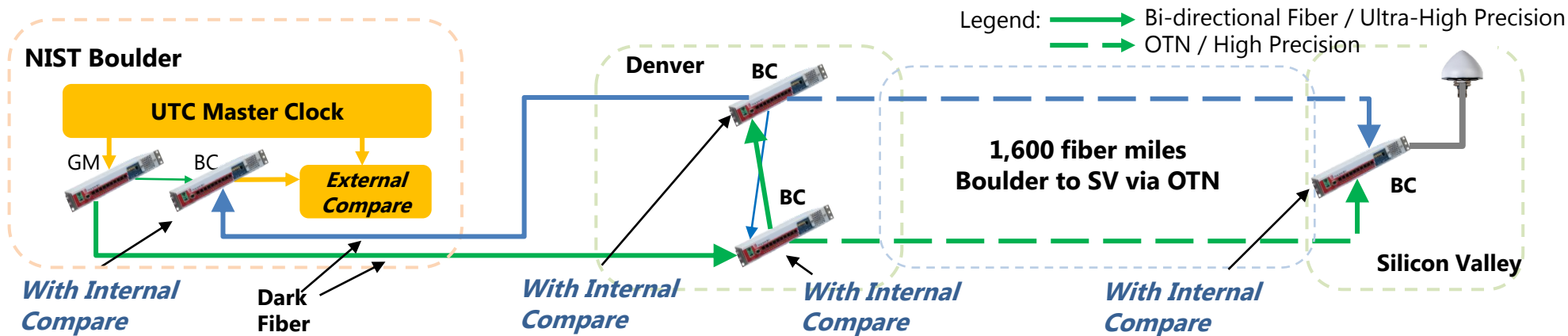


Lumen OTN Links from McLean, Va to Atlanta, Ga

OPNT – Custom Routed GigE Waves:
McLean (MCLNVA23) to Atlanta (ATLDGAUY)



Target Extension from NIST Boulder to Silicon Valley

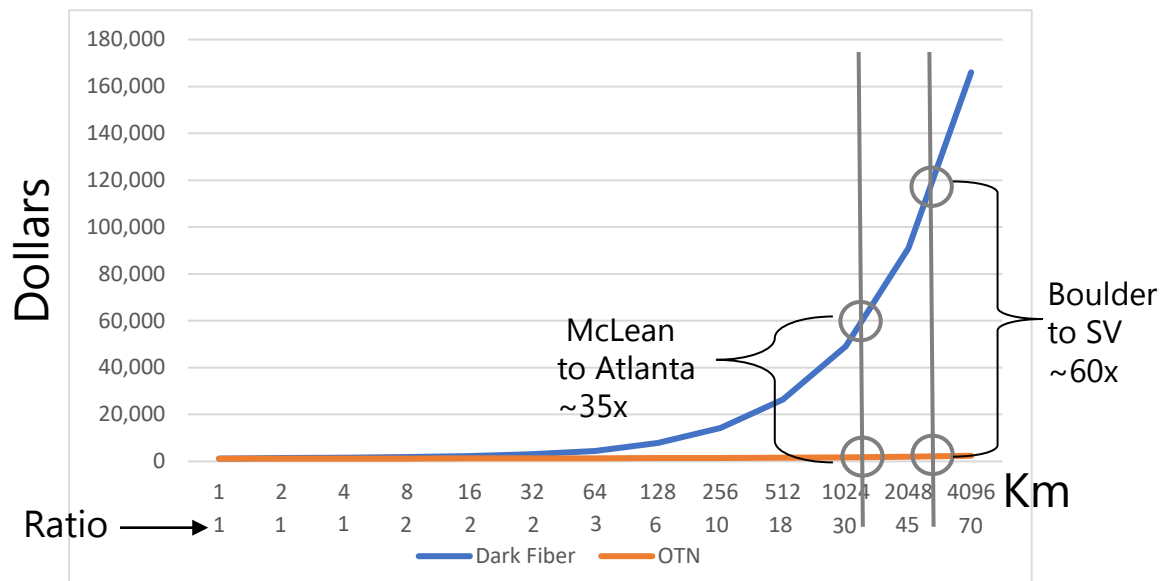


- Repeat “NIST Special Calibration Service” arrangement from NIST Boulder to Silicon
 - The dark fiber from NIST Boulder to local data center configured as verification loop
- Deploy OTN pair from Boulder data center to Santa Clara data center
 - 1,600 fiber miles (2x the McLean to Atlanta distance)
 - Test with both links directed from Denver to Silicon Valley (redundant configuration)
 - Also test with second link in return configuration (3200 mile loop)
- Silicon Valley site includes GPS receiver
 - Supports calibration, monitoring, 3-way voting, “fail-safe” fault detection and automatic, real-time recovery
- Pico-second level “Internal Compare” results reportable at every Boundary Clock

Connectivity Cost Comparisons (\$/KM)

From example market prices; Dark fiber cases highly variable

Monthly Cost/Link



- Cost/km increasingly comparable at short distances given increased deployment of multi-strand dark fiber between buildings, lowering that cost/km
E.g. The cost ratio in the 1 to 3 range
- Cost/km increasingly diverging as distances increase, driven by benefit of extensive customer sharing of fiber assets through the power of DWDM and data switching electronics, lowering that cost/km
E.g. The cost ratio in the 20 to 70+ range

Conclusions

- NIST successfully met its EO commitment, based on the OPNT/NIST collaboration associated with the NIST Special Calibration Test
 - Doubled in performance the six-month benchmark at initiation
- Both White Rabbit/Ultra-High Precision plus cost-effective/OTN-based High Precision were successfully incorporated
- Looking forward to connecting UTC from NIST Boulder and extending to the West Coast
 - Covid has presented up-planned challenges
- NIST Boulder to McLean, Va is also on the radar

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