Below the Sky

Building Resilient Terrestrial Time Networks for Europe

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Camerata Room
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Read the full report:
zenodo.org/records/10688748

tnc26

GÉANT

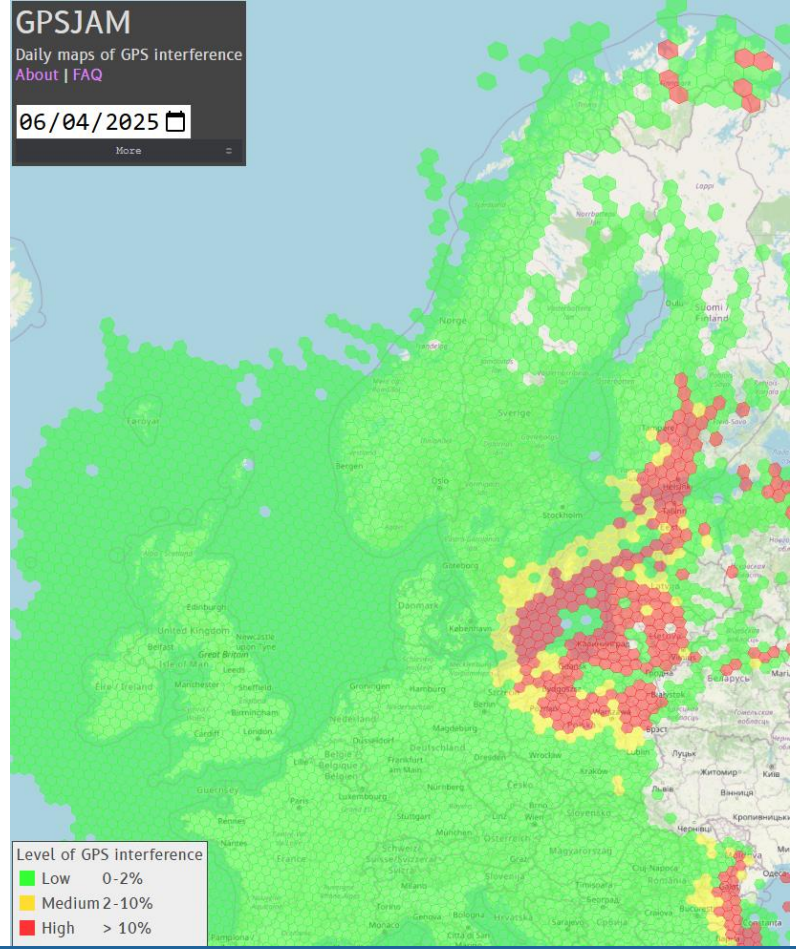
Co-funded by the European Union

Breaking news! 5th June

The New York Times

Russian Satellites Have Been Jamming GPS Signals Across Europe, Scientists Say

Scientists and U.S. military briefers have linked short, widespread interference incidents to Russia, revealing vulnerabilities in a technology essential to everyday society.

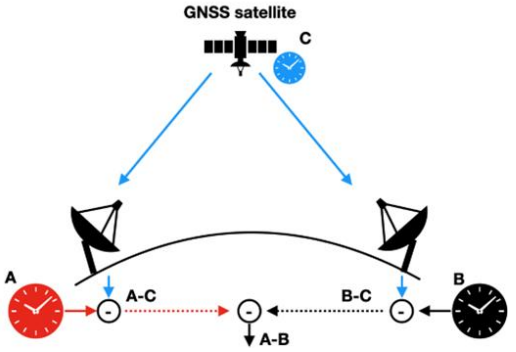


Maintaining the Coordinated Universal Time (UTC)

- Coordinated Universal Time (UTC) is the worldwide reference time scale computed, maintained and improved by BIPM.
  - National Metrology Institutes (NMIs) maintain and distribute the national timescale.
  - Their clocks provide regular measurement data to BIPM, as well as the local real-time approximations of UTC, known as UTC(k), for national use. BIPM compares and gives the NMIs the offset.
- The network of time links used is non-redundant and relies on observation of Global Navigation Satellite System (GNSS) and two-way satellite time and frequency transfer.

But GNSS is no longer reliable!

GNSS time-transfer



Common View GNSS Time Transfer

Source: NIST

Comparing remote clocks, A and B with a common GPS clock (C). The time differences are computed using measurements logged by GNSS receivers that are referenced to local clocks A and B.

Mixing data and White Rabbit on long-haul DWDM systems

- White Rabbit Ethernet switches have been developed to distribute timing with up to 1 nS precision
- With careful planning time can be distributed using WR on DWDM transmission networks without interfering with internet data.
- Guard-bands are needed – discuss with your DWDM equipment provider
- Three types or regeneration are possible:
  - 1R: all optical regeneration using optical amplifiers
  - 2R: Optical-Electrical-Optical (OEO) regeneration
  - 3R: (OEO) + re-timing, can be done with a WR switch

The GEANT C-TFN Incubator Report

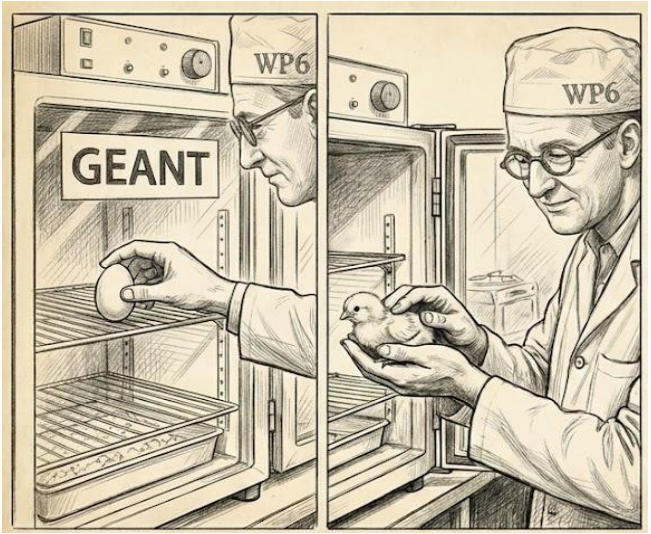
✓Three regeneration architectures compared (1R bidir amps, 2R OEO, 3R WR switches) — with performance data

✓Cost modelling: interactive calculator for your network topology

✓Spectrum planning: C-band vs L-band, guard-band sizing

✓Operational design, calibration, and support model recommendations

✓Field-trial results: 498 km Prague-Vienna link, ±100 ps stability



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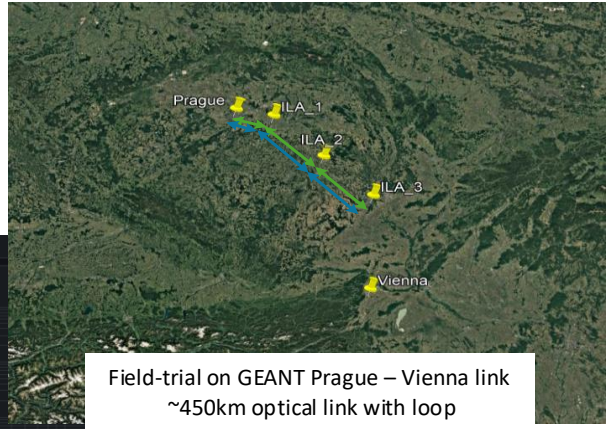
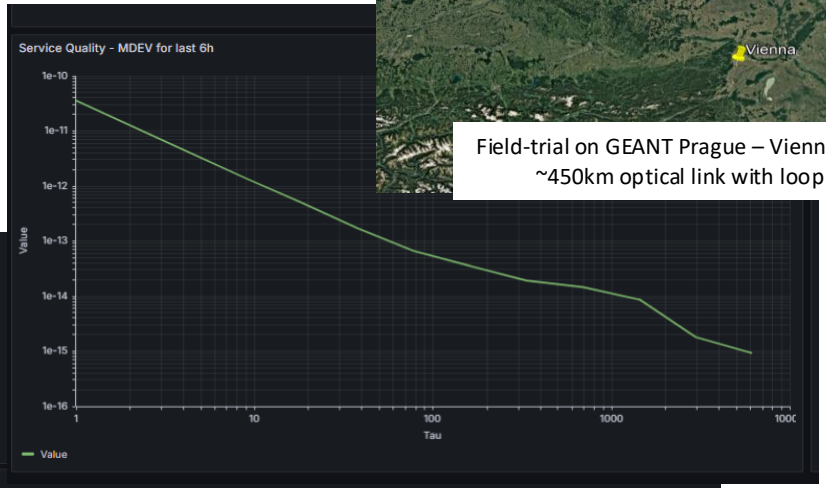
Long-haul White Rabbit Trial

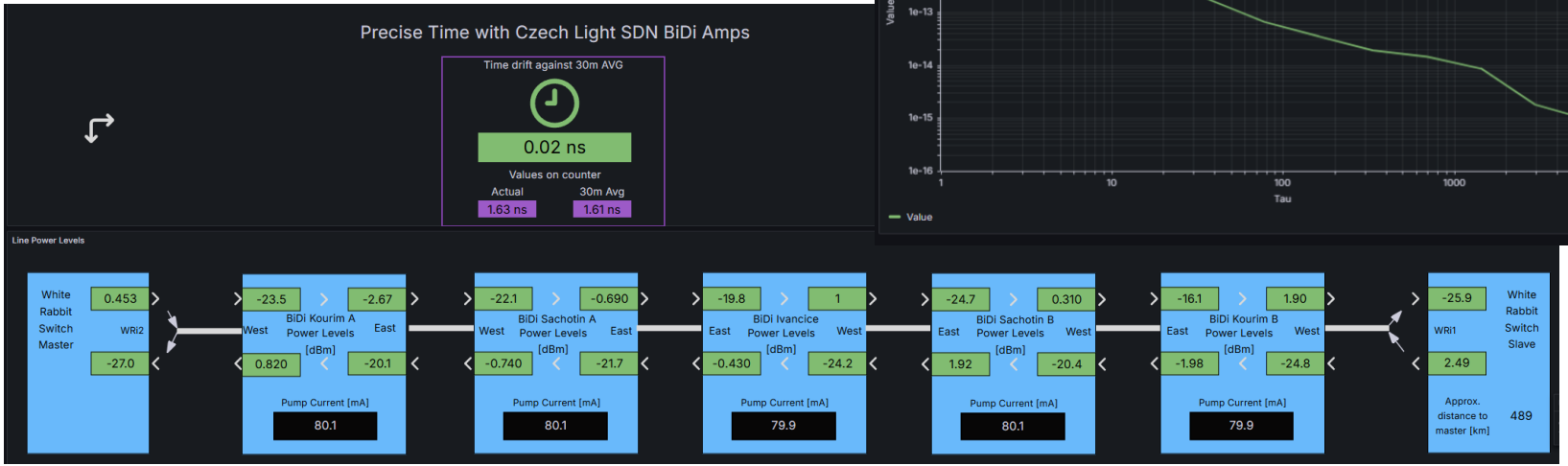
- Trial to demonstrate the high precision WR time distribution over the L-band in GEANT network
- Link built over 498km and 6 hops from Prague towards Vienna
- Typical time drift of 0.02ns compared to reference

With integration period of 10,000 s can achieve accuracy of one part in 1e15

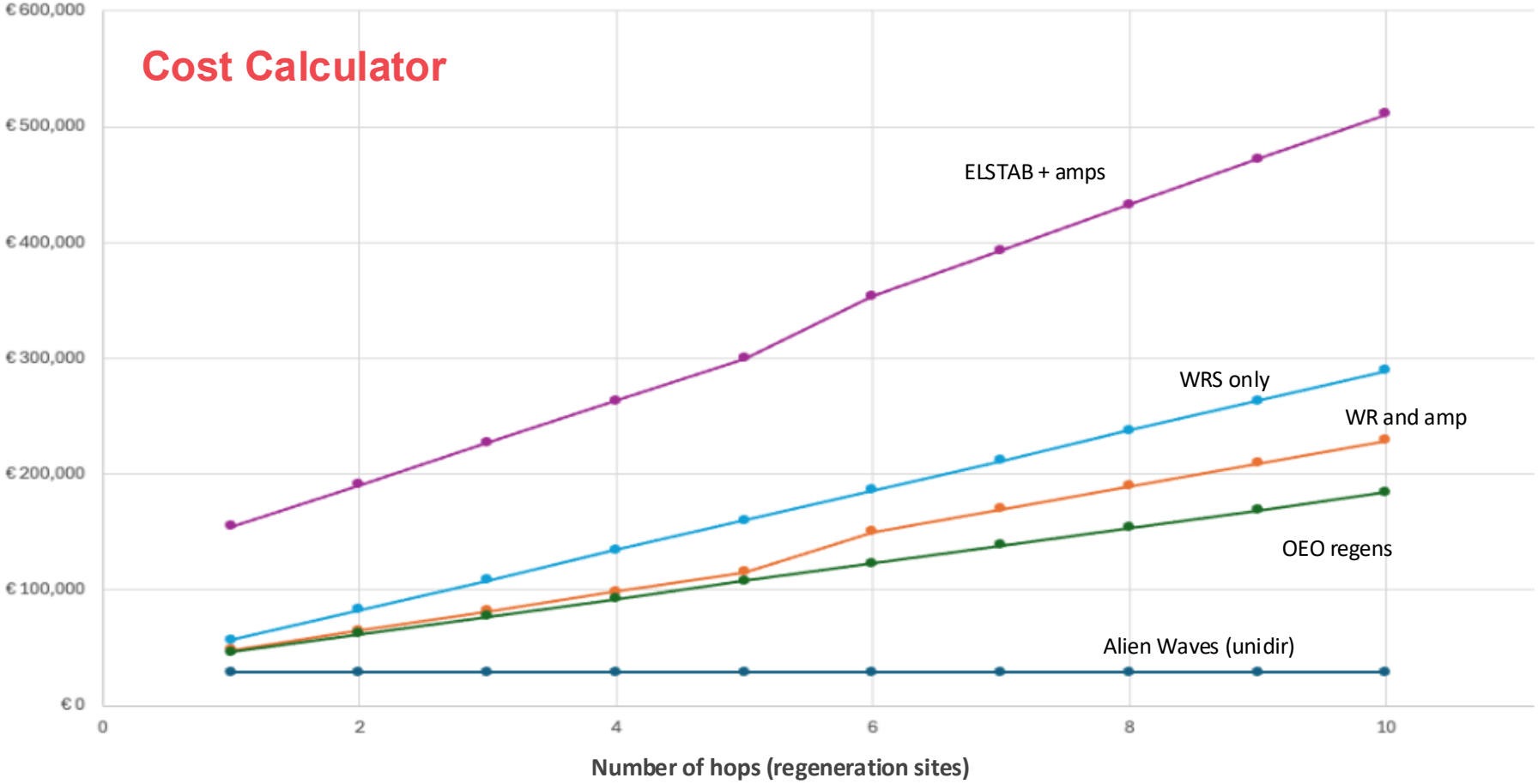


Field-trial on GEANT Prague – Vienna link
~450km optical link with loop





Cost Calculator



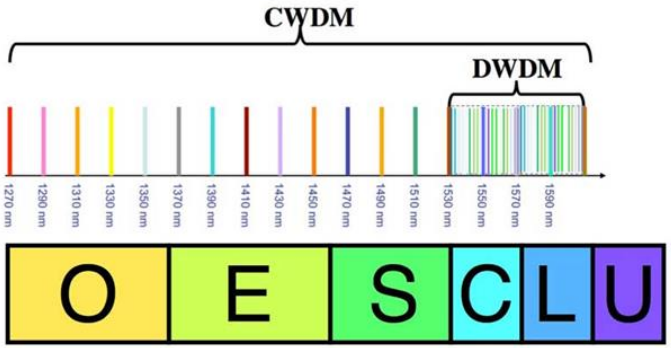
Choosing your regeneration option: 1R vs 2R vs 3R

Criterion	1R Bidir Amps	2R OEO Regens	3R WR Switches
Timing performance	⭐ Best	✓ Good	⚠ More jitter
Cost (long systems)	✓ Medium	✓ varies by vendor	⚠ Highest
Wavelength flexibility	Fixed per span	✓ Can change	⭐ Full flex
Carrier-grade OAM	✓ Standard	⚠ Varies by vendor	⚠ Open-HW gaps
Best for	Accuracy-critical links	Most NRENs 👍	Flexible topologies

Full technical and cost comparison in the GEANT C-TFN Incubator Report → zenodo.org/records/10688748

Where on the optical spectrum should the WR go?

- Reserving WR channels in the C-band reduces the spectrum available for revenue-generating data channels
- The L-band is still amplifiable by EDFA but is typically unused for data — making it an attractive home for WR
- Choose the band based on:
  - New-build vs. retrofit — new builds can readily add L-band filters and save C-band spectrum
  - Whether the DWDM platform already includes built-in L-band filters
  - Whether the C-band is running short of available spectrum
- Guard-band tip: placing WR at the edge of the C-band halves the guard-band cost vs. placing it in the middle

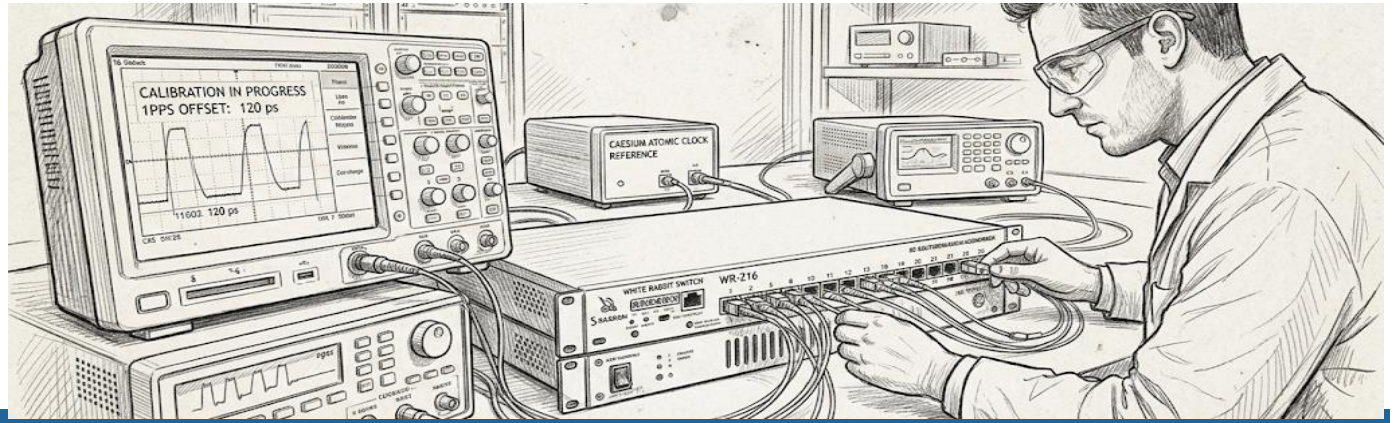


Designing for operations from day one

- A long-haul WR network must be operable and maintainable — design these features in from the start:
  - Dual power supplies, SNMP traps, CLI/API for monitoring and configuration
  - OSC channel for management — a WR switch works well here
  - Temperature monitoring and fan-failure alarms from day one
- Support model matters: decide early — in-house staff, outsourced, or an integrator with a spare-parts depot
- Note: SNMP management of open-source WR switches is still being defined by the WR consortium

Calibration is essential — plan for it

- Calibration is an inevitable requirement of deploying WR - see section 2.4 of the whitepaper
- Excellent documentation on methodology is available from the WR collaboration (use QR code)
- Any Tx/Rx asymmetries need to be measured and accounted for - ideally before the equipment is installed
- Practical NREN guidance: start with manual calibration but plan to migrate to automated calibration rigs as your time network scales
- Beware of Tx/Rx on different fibres - calibration will be needed after every fibre repair



Conclusions

- *Beware: GPS can no longer be relied upon!*
- Coexistence works: 1 Gbps WR signals can share fibre with 400G coherent channels with no measurable BER impact, given a suitable guard-band
- Stability achieved: ±100 ps time transfer stability over a 498 km field-installed loop using five bidirectional amplifiers — well inside the 1 ns target
- Three regeneration options compared:
  - Bidirectional optical amps (1R) — best performance
  - OEO media converters (2R) — strong cost-performance trade-off
  - WR switches (3R) — flexible, but more jitter in cascade
- Optimal solution will be a trade-off between budget and performance

Thank you

Any questions?

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