White Rabbit
for T&F metrology
(a research proposal to Euramet)

Paul-Eric Pottie

some slides thanks to courtesy of Erik Dierickx, Jeroen Koelmeij, Mikko Merima

What is EURAMET ?

- Regional Metrology Organisation (RMO) of Europe,
- coordinates the cooperation of National Metrology Institutes (NMI) of Europe
- Topics : metrology, traceability of measurements to the SI units, international standards and Calibration

- responsible for the elaboration and execution of the European Metrology Research Programme (EMRP)

- encourage collaboration between NMIs and partners (industry/academia).

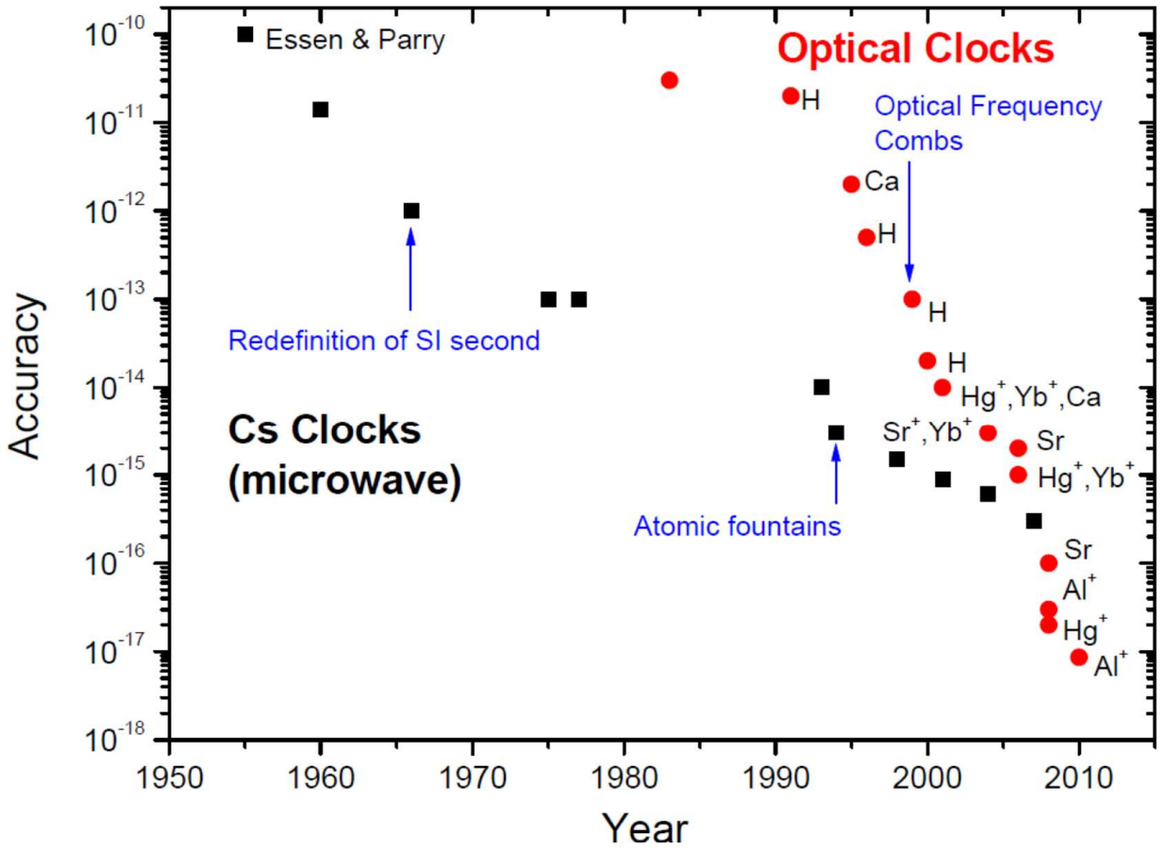
EMRP

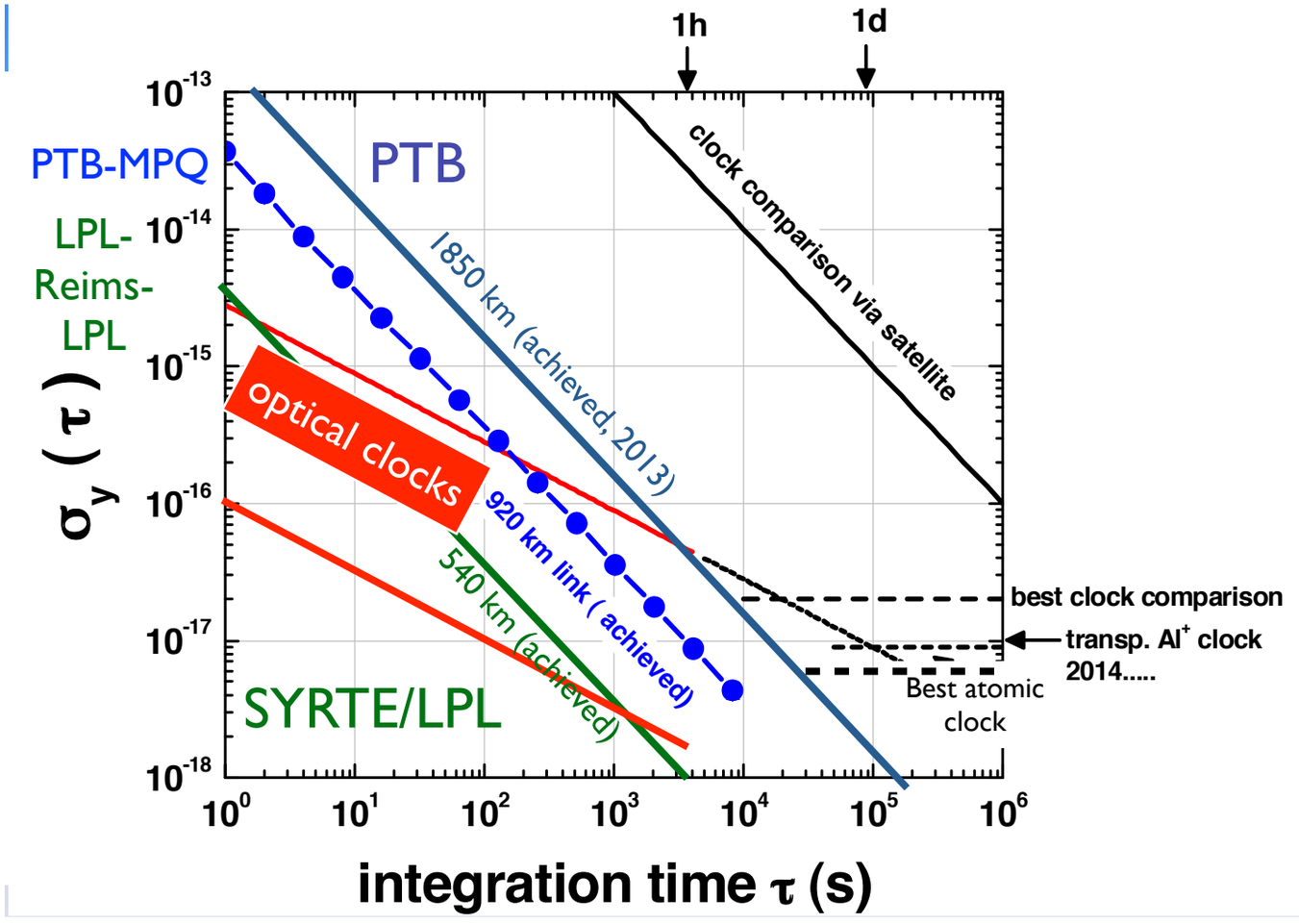
European Metrology Research Programme

Programme of EURAMET

The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union

Fiber links for T&F metrology





- **Satellite links don't meet optical clocks comparisons requirements**
- **International and national clocks comparisons below 10^{-16}**
- **Frequency standard dissemination (for research labs)**

NEAT FT

Aim : phase-coherent comparison of remotely located optical clocks (up to 1500 km)

1. Develop techniques for frequency comparisons at ~10^{-18} at 1 day

(**PTB**, INRIM, NPL, OBSPARIS)

2. Demonstrate long distant fiber link capability

OBSPARIS, INRIM, NPL, PTB

3. Novel techniques for accurate time transfer over fiber

NPL, INRIM, SP, PTB

4. Novel methods and protocols for distant time comparisons

UFE, BEV, MIKES, OBSPARIS, SP, PTB, VSL, CESNET

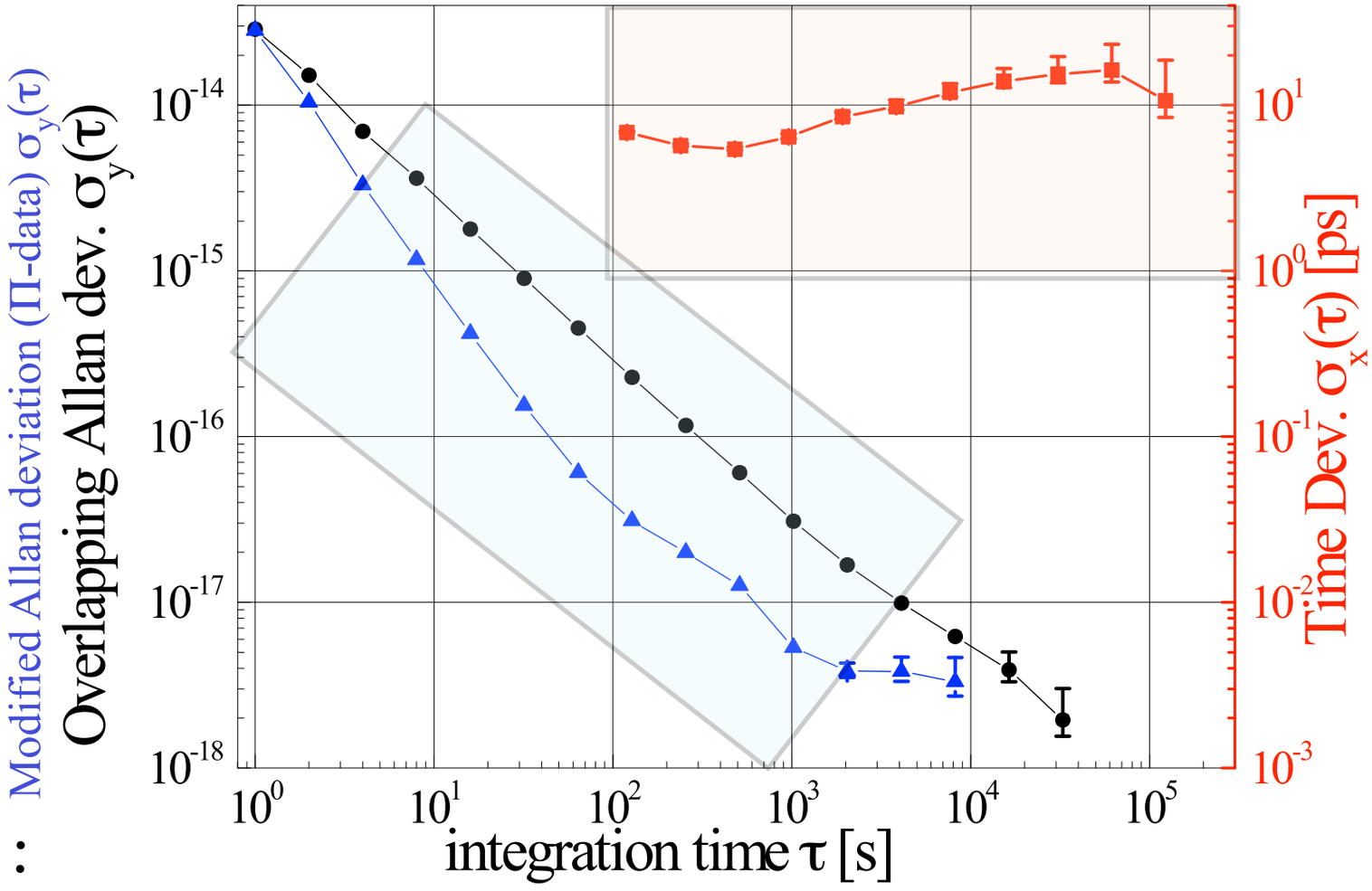
10 partners, 3 partners granted

Some performances of coherent optical fiber links

PTB : 1840 km
SYRTE : 1100 km
INRIM : 2x642 km

PTB, SYRTE, INRIM :
Relative stability
< 5E-19
over >700 km !
(...)

Time & RF transfer by AGH :
Relative stability
1E-17 over 420 km !
sub ps resolution
100 ps uncertainty



Bi-directional
high coherence laser
C-band

APPL. PHYS. B, **110** (1) , PP 3-6 (2013)

Need for F&T metrology : dissemination

Frequency metrology:

Access to ultra precise reference frequencies for remote user.

Applied dimensional measurements:

Traceability of the unit of length for interferometric measurements.

Astronomy:

Phase traceable signals for the synchronization of radio telescopes

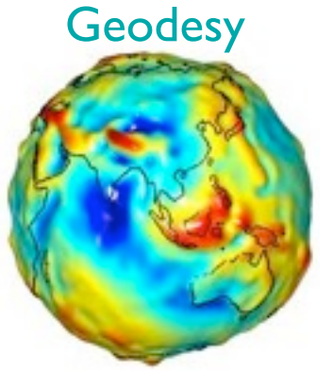
Several projects are going on (REFIMEVE+, LIFT...)

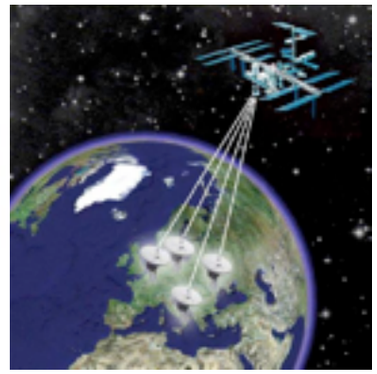
Broadband communication technology:

Provision of reference signals with low-jitter for synchronization

ESA, DESY, CERN, GSI:

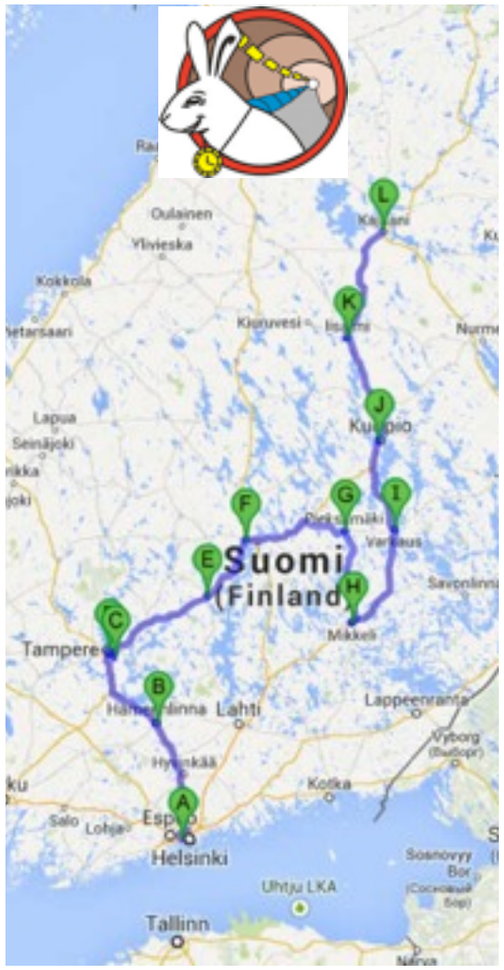
Time and frequency dissemination in ground stations



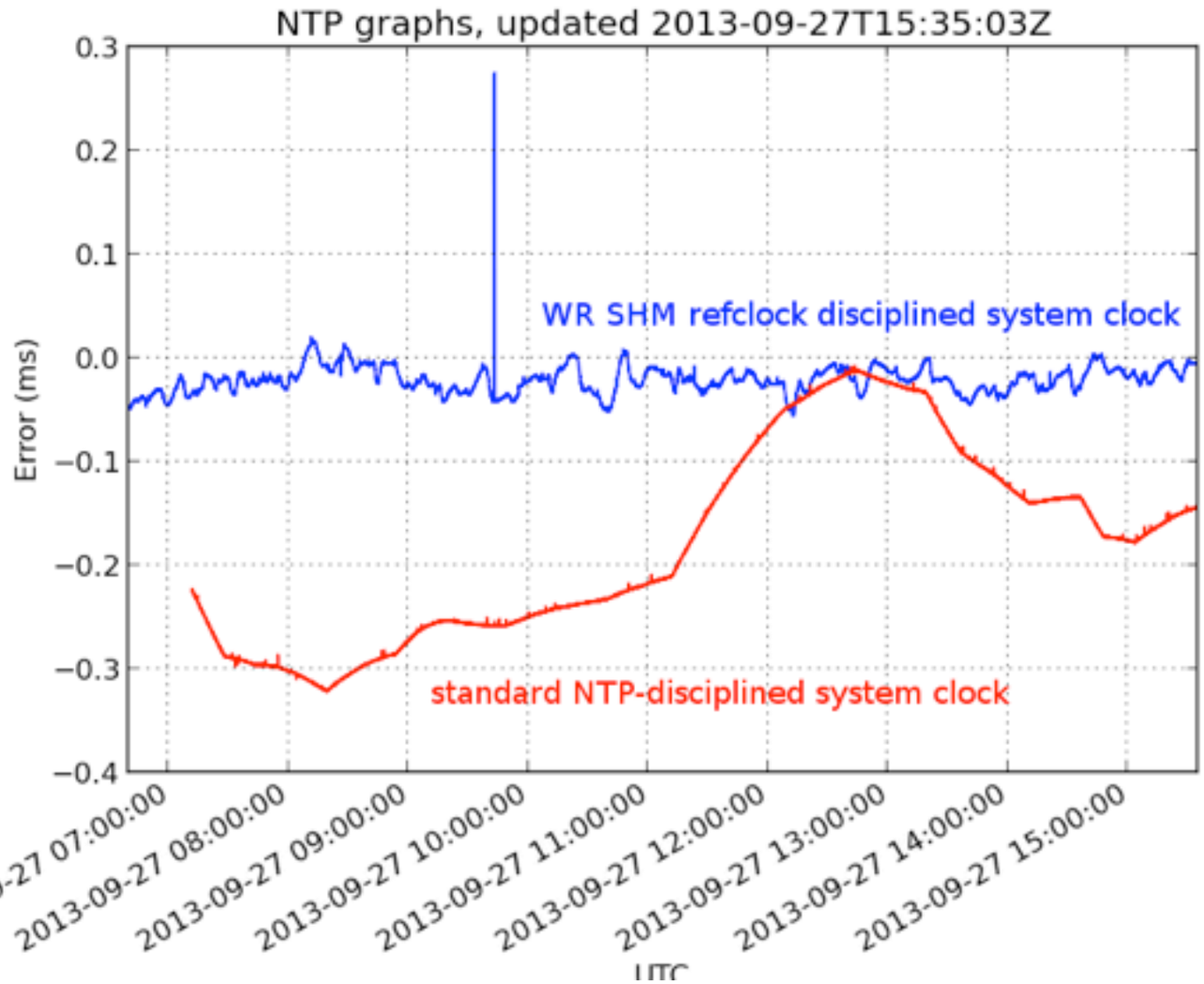


2013 : two experiments starts with WR on long hauls

MIKES experiment



1000 km



Courtesy Mikko Merimaa

MIKES – CSC WR time link at Espoo

Frequency stability measurements@MIKES

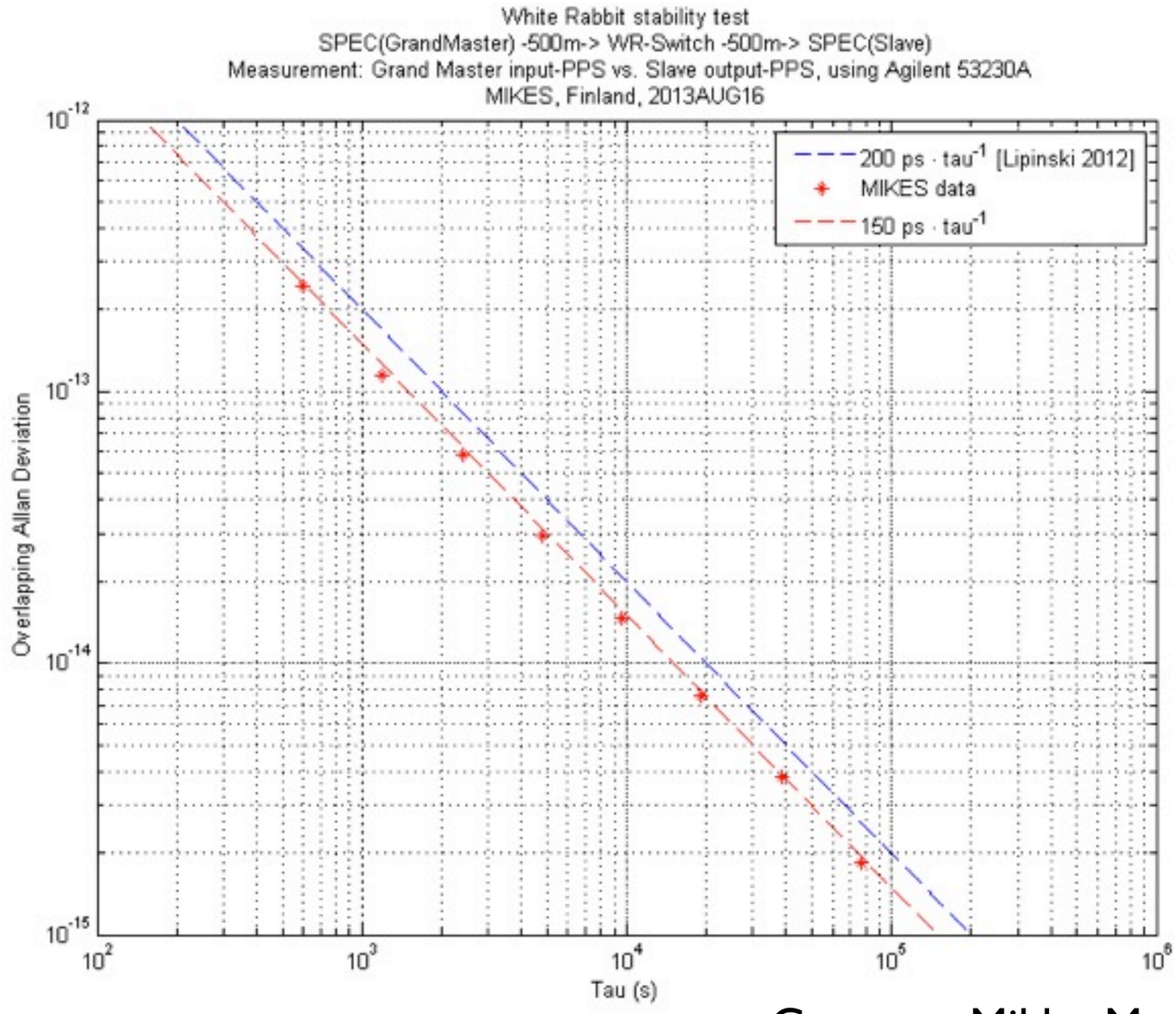
White Rabbit switch @ CSC

1.2 km

1.2 km

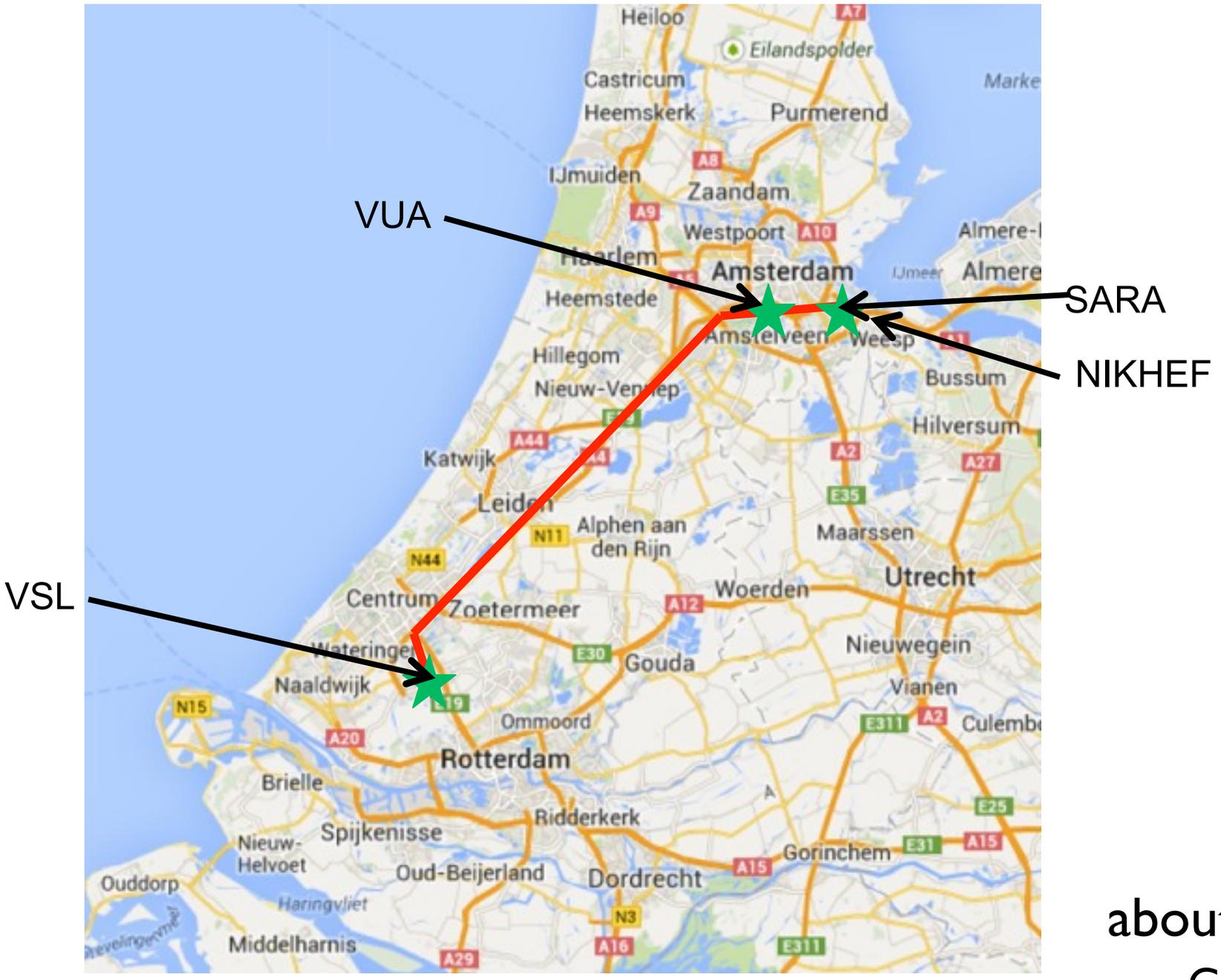
WR master @ MIKES

WR slave @ MIKES



Courtesy Mikko Merimaa

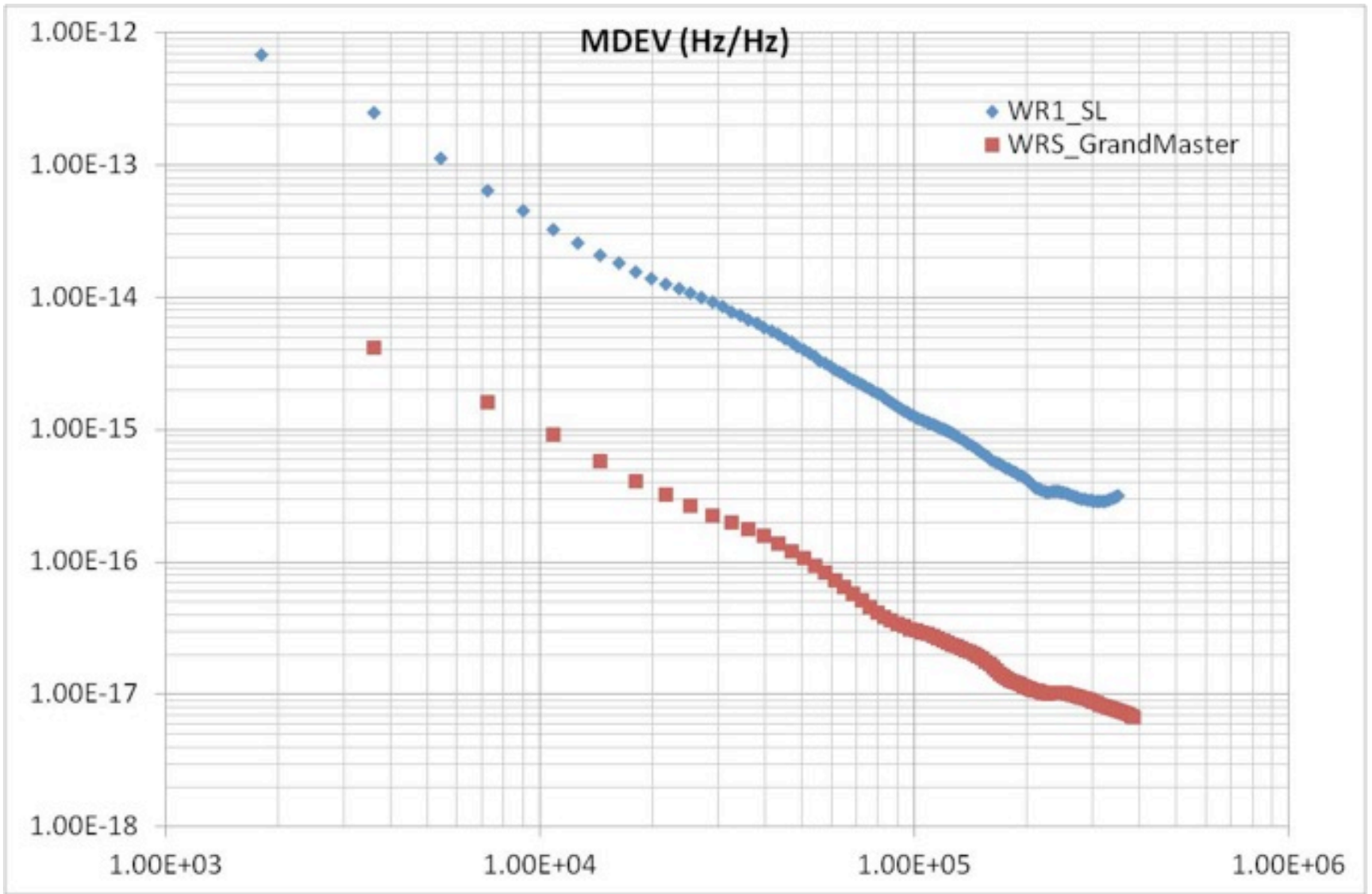
VSL- NIKHEF



about 150 km

Courtesy Erik Dierickx

WR link VSL- NIKHEF / Results



VSL
Dutch Metrology Institute

See talk yesterday, Jeroen Koelmeij

Courtesy Erik Dierickx

Industrial needs for F&T metrology

Optical fibre links found to be a reliable way to transfer time and frequency (T&F) with unprecedented stability and accuracy.

Technology needs to be transferred to industry

<u>Industry areas that push optical fiber links development</u> :

1) wireless telecommunications

2) electrical power grids

3) optical telecommunications technology (new services)

4) Galileo GNSS ground segment

Ground Mission Control Centre (Telespazio)

Next generation Industry time and frequency Dissemination through optical Fibers

VSL Dutch Metrology Institute · vrije Universiteit amsterdam · MIKES Centre for metrology and accreditation · l'Observatoire de Paris – SYRTE Systèmes de Référence Temps-Espace · SEVEN Solutions · cnrs · ugr Universidad de Granada

INRiM Istituto Nazionale di Ricerca Metrologica

20 partners
8 NMIs
12 non NMI (+CNRS)
1.6 million € budget

NOKIA · ThalesAlenia Space · NPL National Physical Laboratory · SP · inλ · Institute of Scientific Instruments Academy of Sciences of the Czech Republic · ūfe · CESNET · SIQ Slovenski institut za kakovost in meroslovje Slovenian Institute of Quality and Metrology · AGH

Next generation Industry time and frequency Dissemination through optical Fibers

Call : «Metrology for industry»

Aims :

Continuous synchronization over long haul networks, uncertainty better than 1 ns;

Advanced T&F service for industry (1e-15 to 1e-17 @1d relative frequency stability)

Traceability to SI units : (GALILEO, ESTEC, cross-checks)

Calibration, T&F instrumentation

1. Equipment development & Transfer to industry

OP, **7S, UGR, VSL, VU, MIKES**, AGH, NPL, INRIM, TAS-I

2. Traceability and Dissemination to industry

SP, SP, INRIM, NPL, TAS-I, AGH, VSL, VU, ISI, UFE, CESNET

3. Synchronization of Advanced Networks

MIKES, NOKIA, VSL, VU, 7S, UGR, SP, VSK, SIQ, INLAMBDA, ELEC

Thank you for attention

Questions ?