T2L2 on Jason-2

First results of the engineering model

OCA –UMR Gemini
Grasse – FRANCE

CNES
Toulouse – France

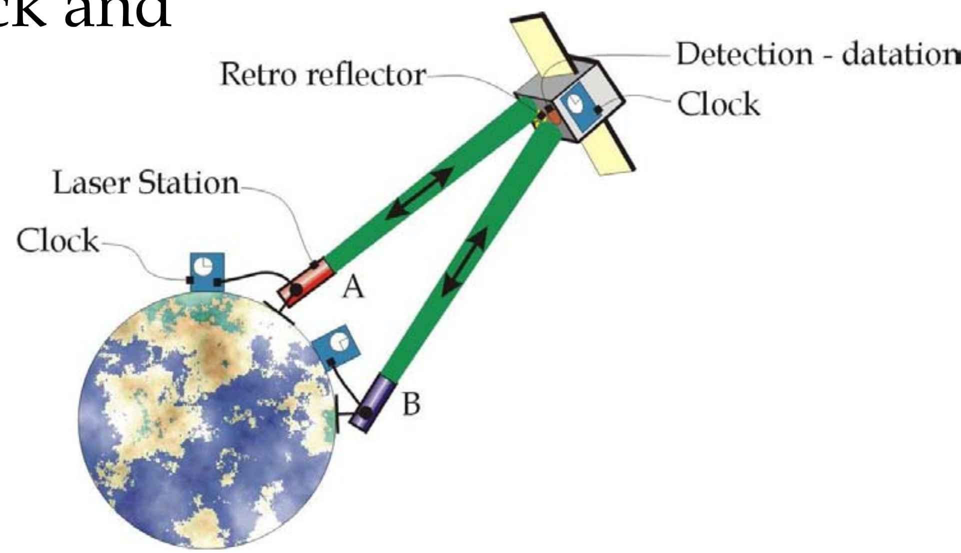
E. Samain: Prime Investigator
D. Albanese: Optique
F. Para: Instrumentation
J.M. Torre: Laser sations ILRS
P. Vrancken: Test benches
J. Weick : error - link Budget - computation

P. Guillemot: System Engineer
S. Leon: Program
I. Petitbon: Project Manager

T2L2 Principle

- Time Tagging of laser pulses emitted from a laser station towards the satellite
  - Start Time at ground station $\mathbf{t_s}$ (ground clock)
  - Arrival time at satellite $\mathbf{t_b}$ (on-board clock)
  - Return Time at ground station $\mathbf{t_r}$ (ground clock)
- Time Transfer between Ground clock and space clock
  - Triplet Construction for each laser pulse ($\mathbf{t_s}$, $\mathbf{t_b}$, $\mathbf{t_r}$)
  - Computation of the time offset :

$$x_{AS} = t_s + \frac{t_r - t_s}{2} - t_b + \tau_{Relativiste} + \tau_{Atmosph} + \tau_{Calib}$$



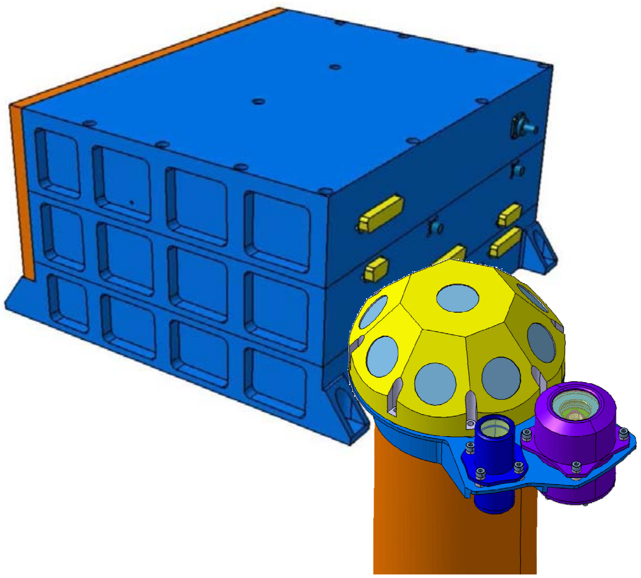
Historical Account

- 1972: Time transfer by laser link concept : LASSO
- 1992: Time transfer between Texas and France: LASSO

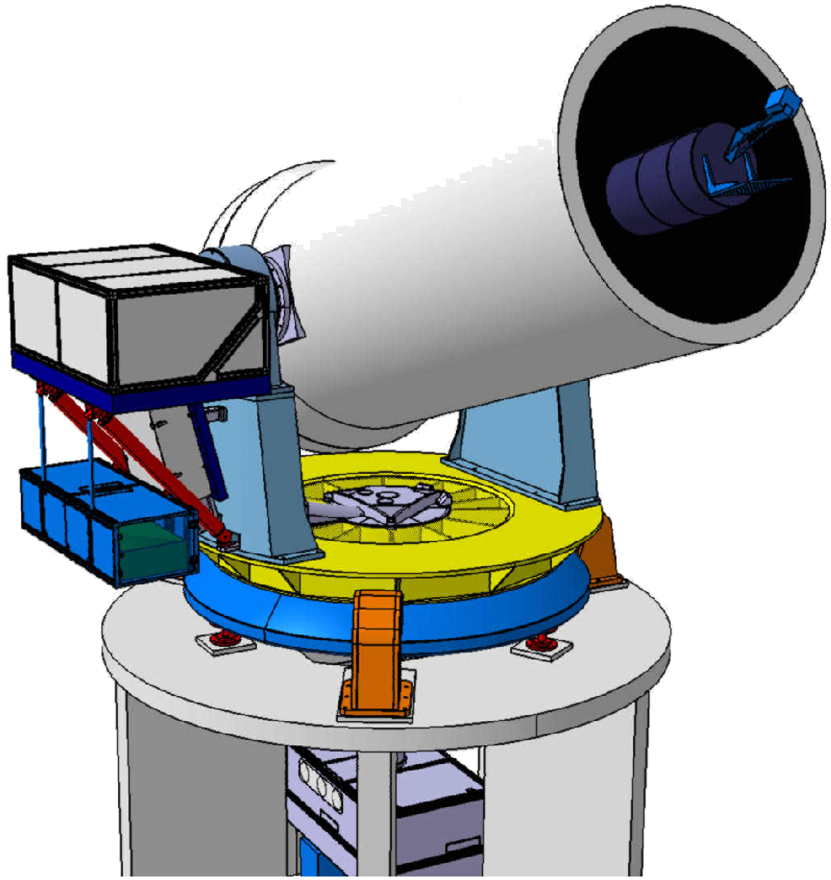
- 1994: T2L2 Proposal (OCA)
- 1996: T2L2 on MIR 99 (A Phase)
- 1997: T2L2 on ISS with ACES (B Phase)
- 2002: T2L2 on a Microsat Myriade CNES

- 2005 : T2L2 accepted on JASON 2 as a passenger instrument
  - Phase B: September to December 2005
  - Instrument delivery: End 2006
  - Jason-2 launch: Mid 2008

Instrumentations



Space segment

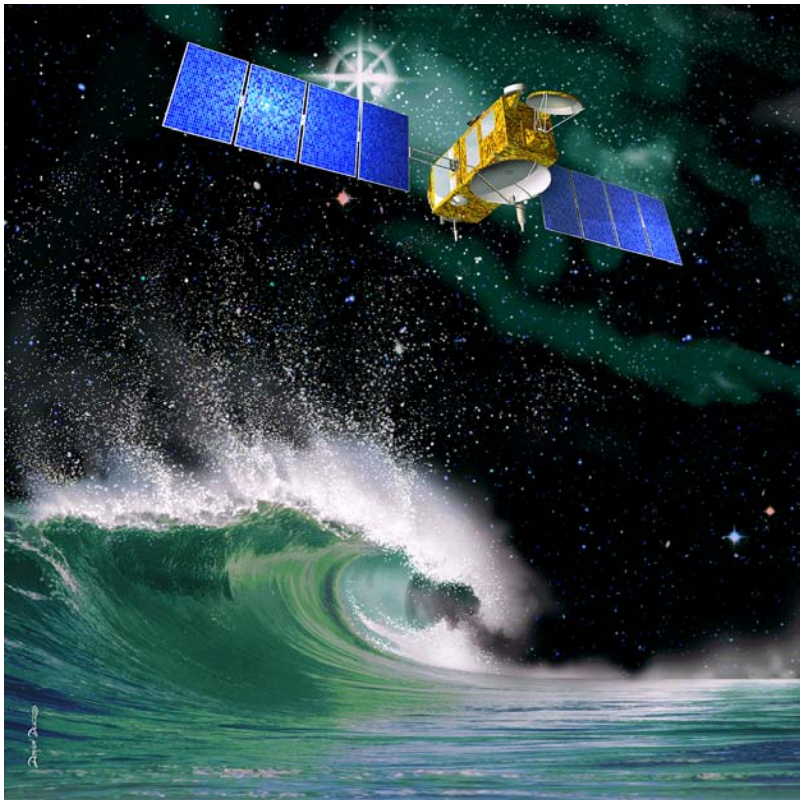


Ground segment:

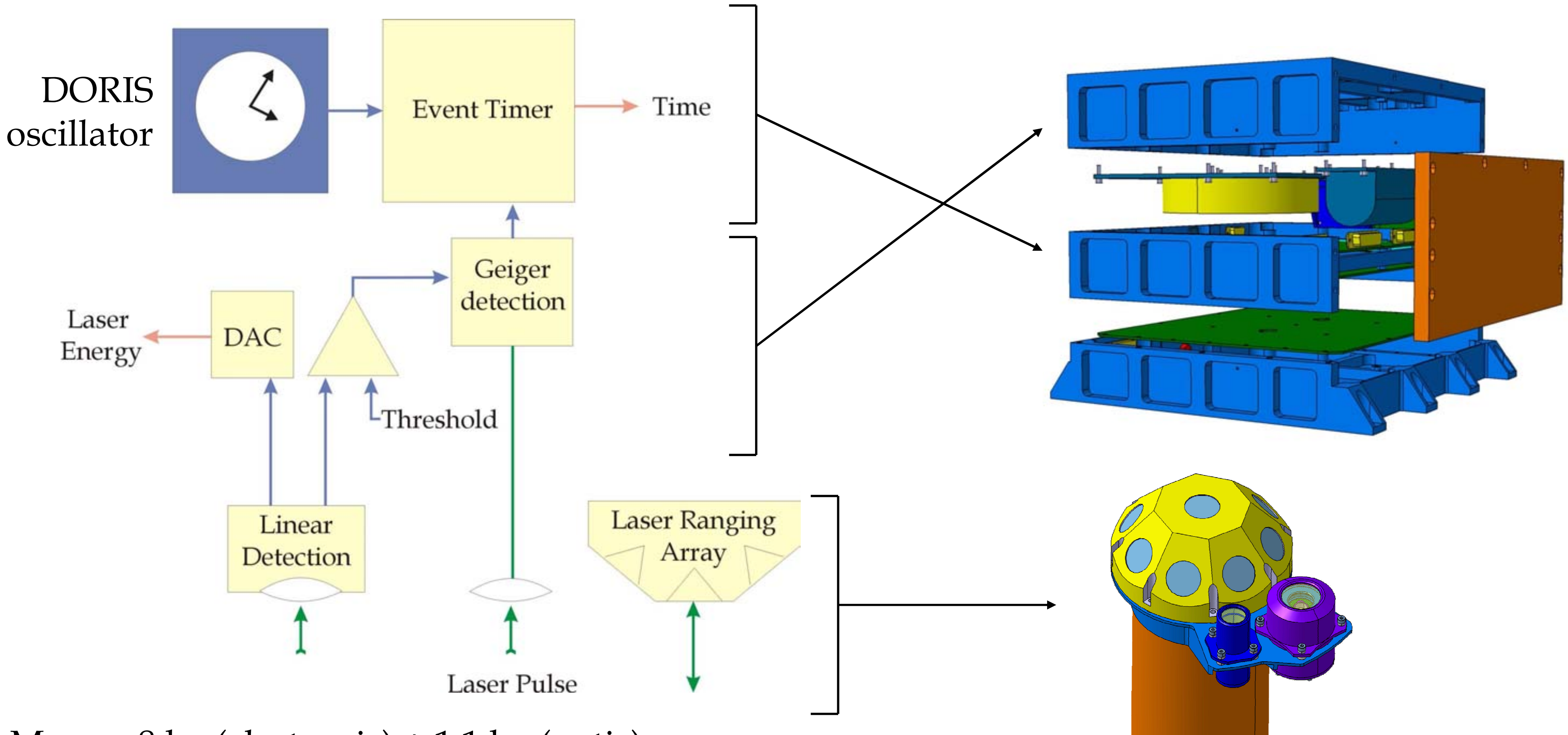
Laser station

Space segment
T2L2 on Jason 2

- Millemetric sea altimetry
- Native instruments
  - » Altimeter : Poseïdon 3
  - » Water vapor measurement
  - » Orbitography: Doris, GPS, Laser
- Passenger instrument
  - » Radiation: Carmen 2, LPT
  - » Time Transfer by Laser Link: T2L2
- Orbit
  - » Altitude 1336 km, i = 66°, P = 6800 s
  - » Max distance in a common view mode : 6500 km
  - » Single pass: ~1000s
  - » Time interval between pass 2h < T < 14h
  - » 3 to 6 passes per day

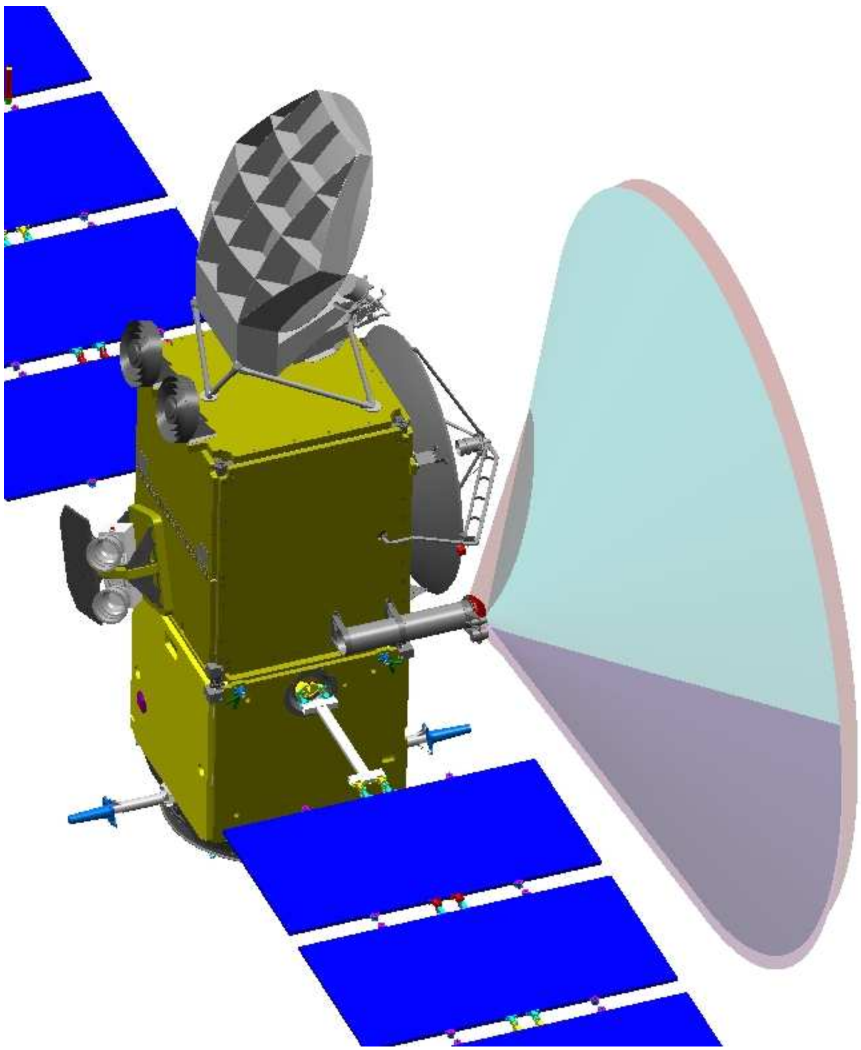


T2L2 Space Instrument Synoptic



- ⇨ Masse : 8 kg (electronic) + 1.1 kg (optic)
- ⇨ Power Consumption: 42 W
- ⇨ Volume : 270x280x250 mm^3 // Ø 30x95 // Ø62x100

T2L2
External payload



- From Space: +/- 55° for both T2L2 detection and LRA
- From ground: 5° in elevation (no atmosphere uncertainty)

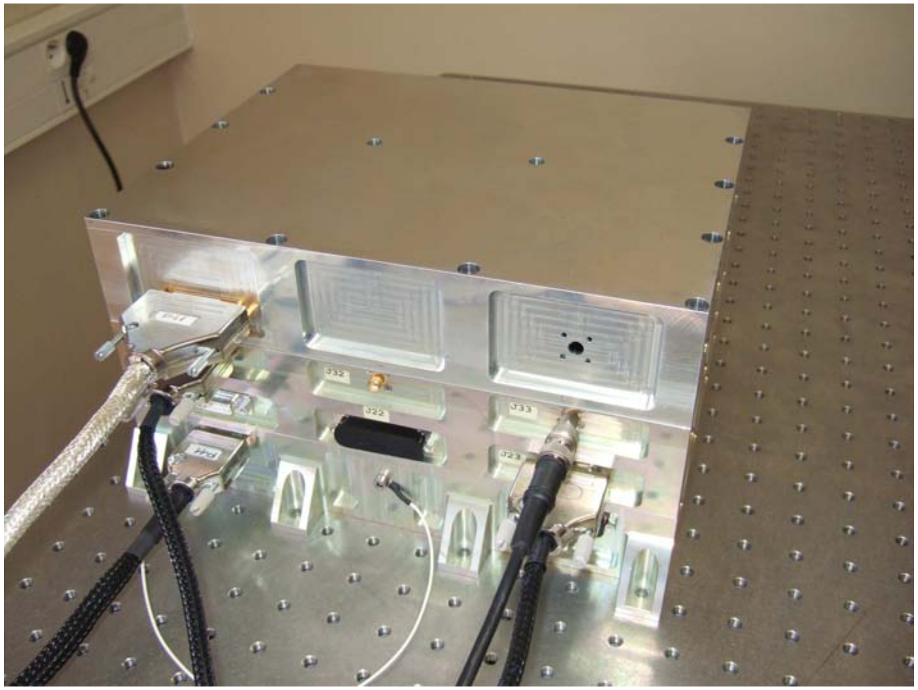
T2L2 Space instrument Development plan

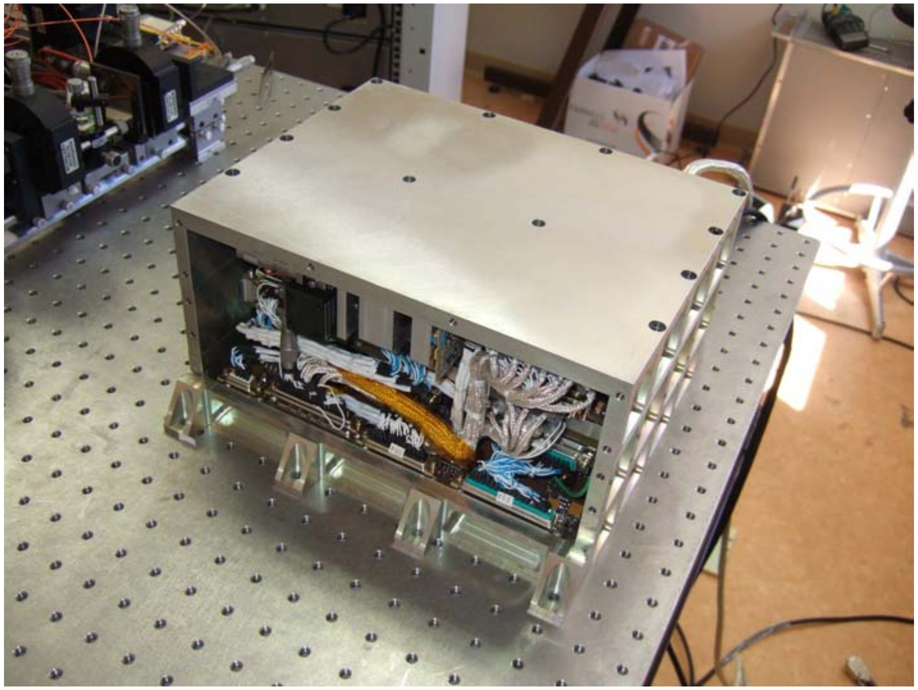
- B Phase: 09/2005 → 02/2006
- CD phases : 03/2006 → 12/06
- Performance tests: 01/07
- T2L2 integration on Jason 2: 02/2007

- Jason 2 launch: 06/08

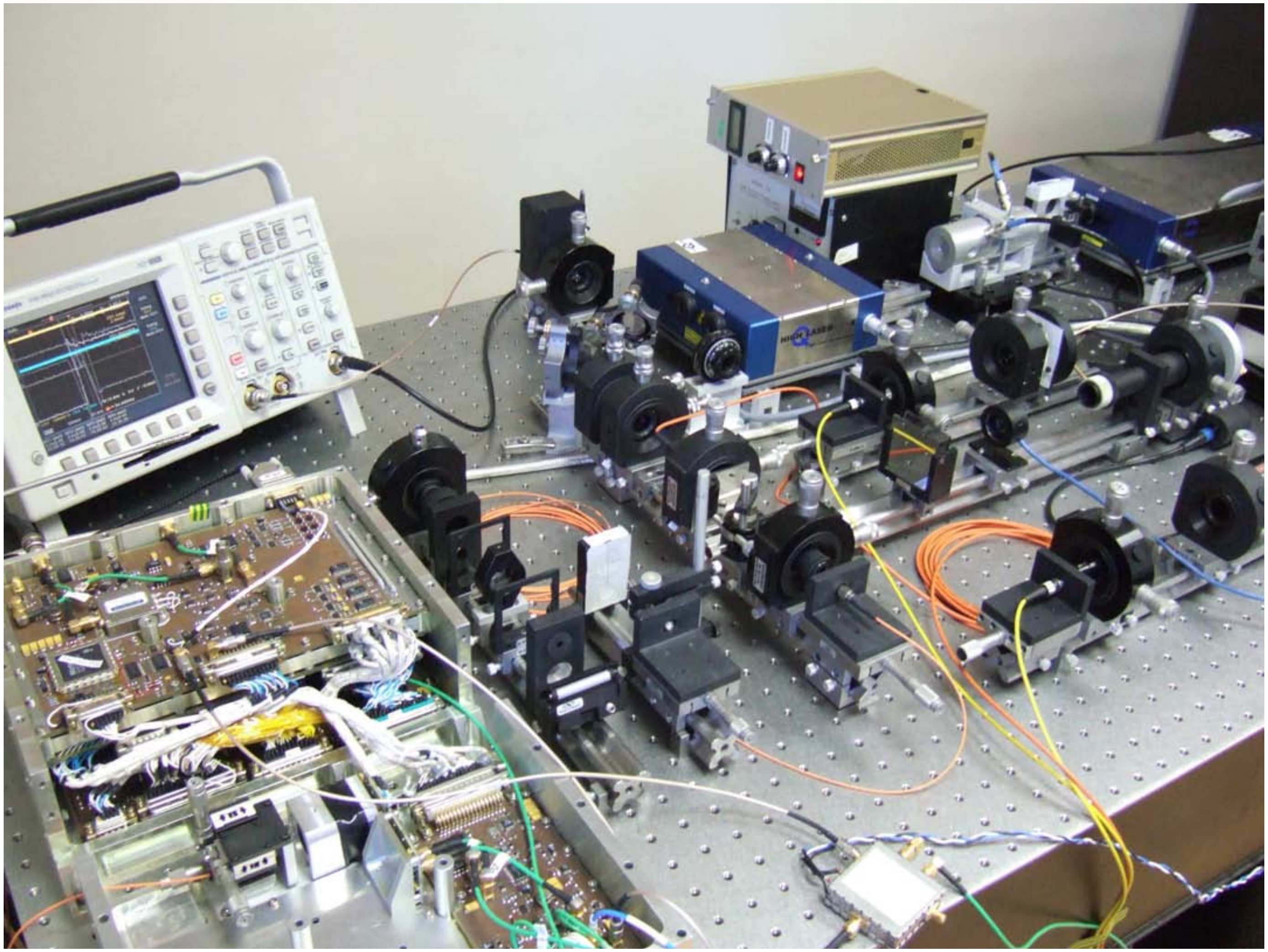
- Exploitation: 06/2008 → 06/2010

T2L2 Engineering model (Electronic)





Optical test bench



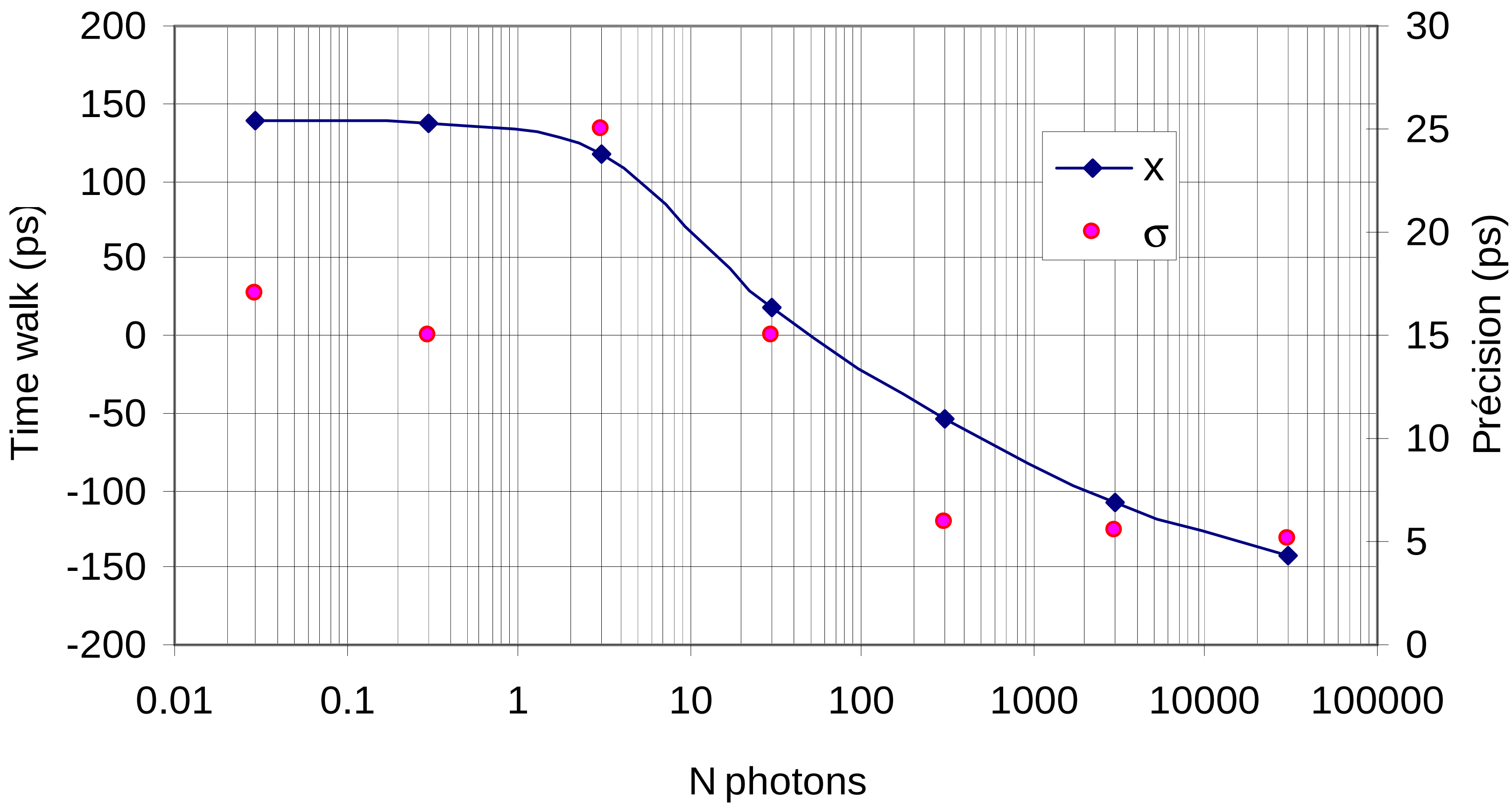
T2L2 Engineering model
Photo detection Threshold

Energie (fJ)	N photons	Probabilité %
0.32	880	98
0.16	440	33
0.09	264	7.5

Detection dynamic > 80 dB (static)

Detection dynamic > 100 dB (Whole)

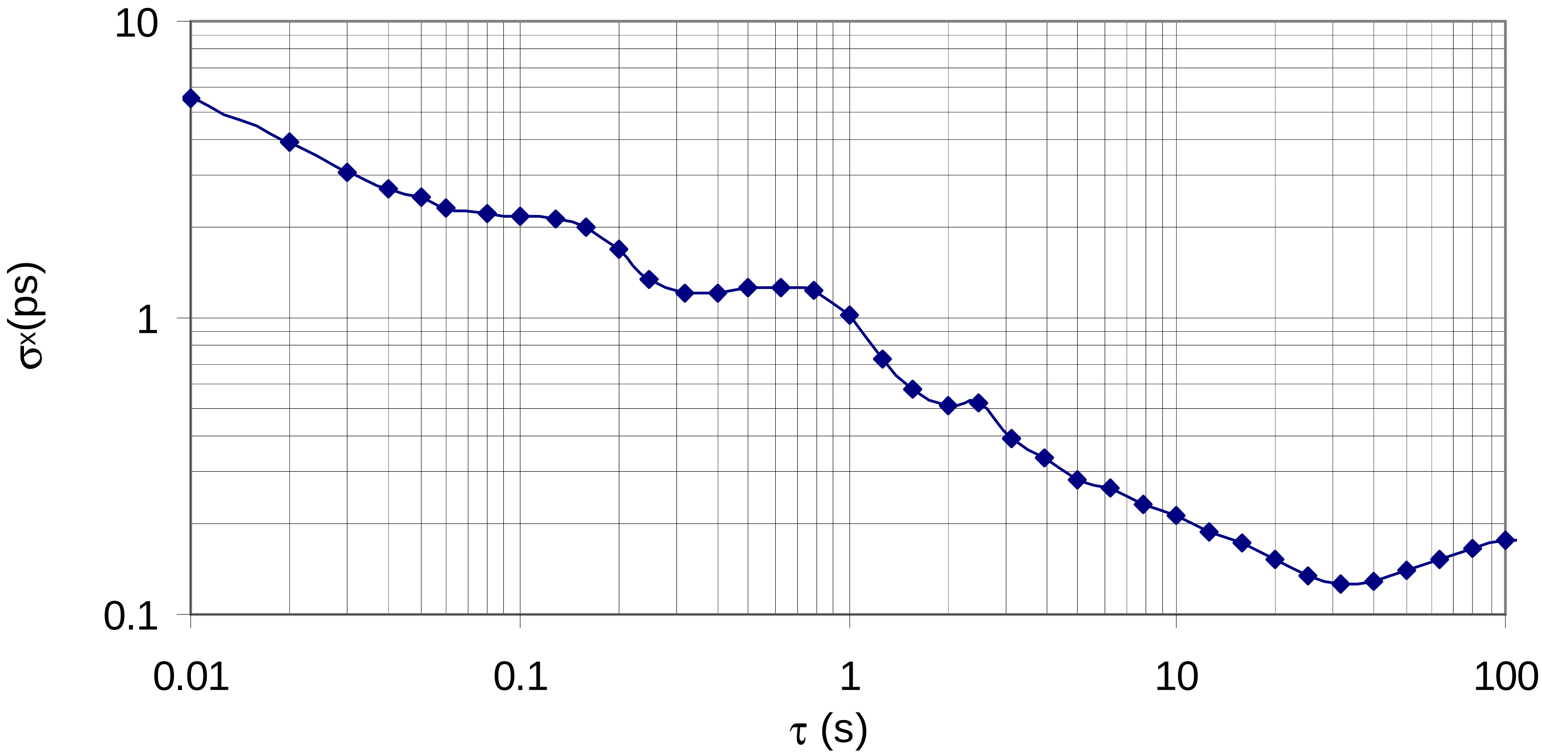
T2L2 Engineering model
Photo detection Precision –Time Walk



Precision Single photon: 17 ps

Precision @ 1000 photons: 2 ps

Short term Time stability @ 532 nm



Mode Locked Vanadate laser @ 532 nm

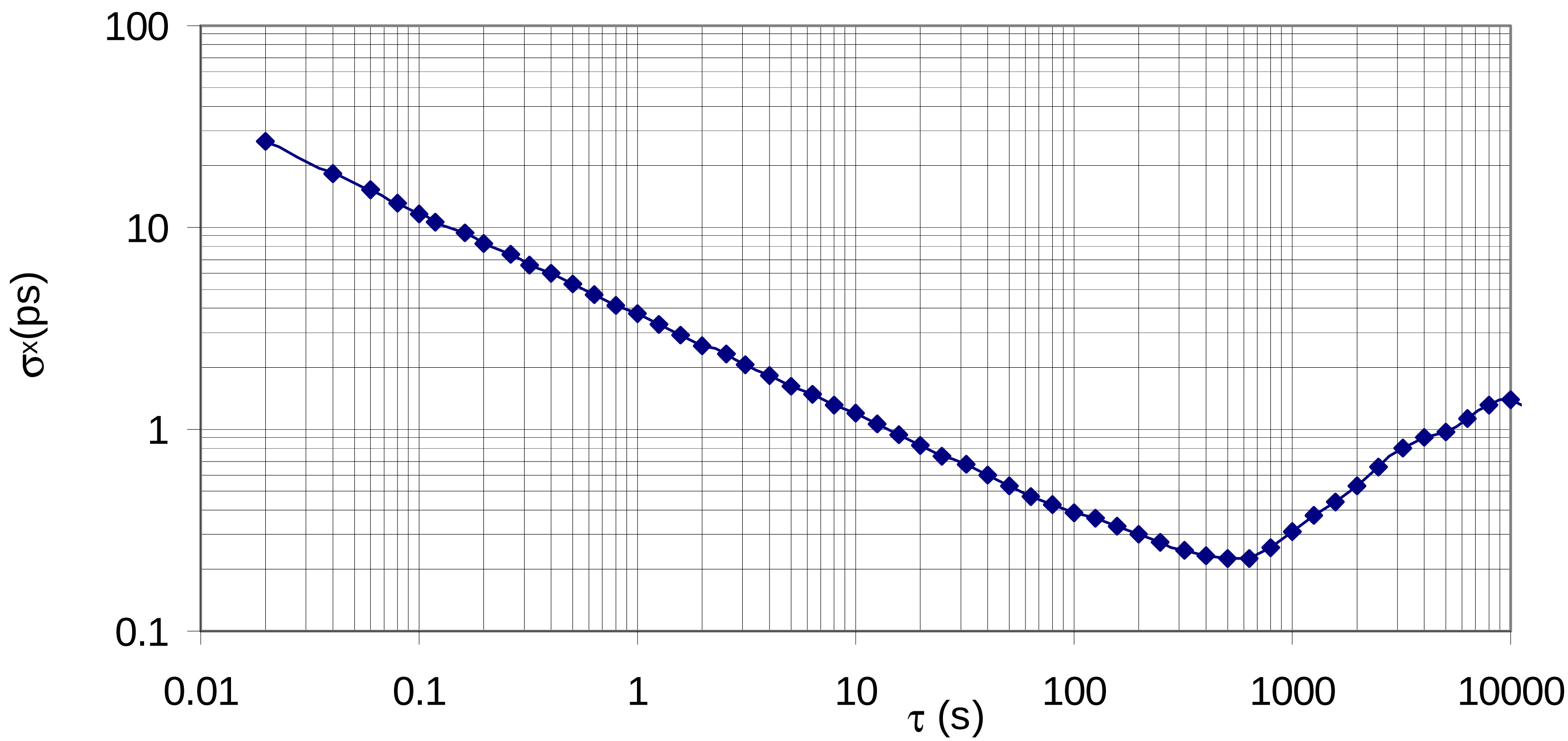
Pulse Width: 20 ps

Repetion rate: 100 Hz

White phase noise: $0.01 < \tau < 100$ $\sigma_x = 0.8\ 10^{-12}\ \tau^{-1/2}$ s

Flicker phase noise: $\tau > 100$ s $\sigma_x = 100\ 10^{-15}$ s

Mid term Time stability @ 778 nm



Pulsed laser diode @ 778 nm

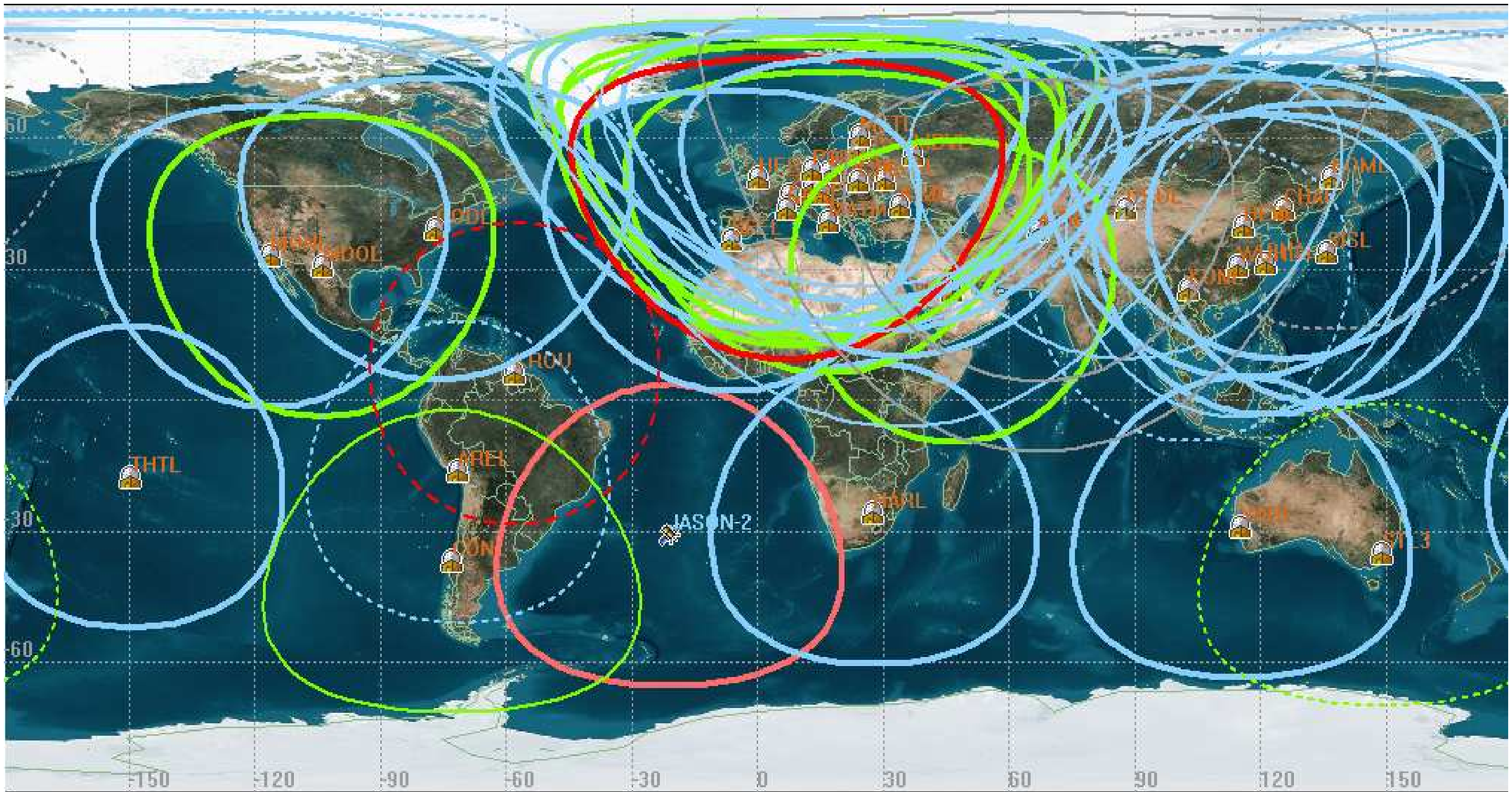
Pulse Width: 30 ps

Repetion rate: 50 Hz

White phase noise: $0.02 < \tau < 500$ $\sigma_x = 3.8\ 10^{-12}\ \tau^{-1/2}$ s

Flicker phase noise: $500 < \tau < 10000$ s $\sigma_x = 2.\ 10^{-14}\ \tau^{+1/2}$ s

Laser ranging stations Network



— Jason-1 : High activity

— Jason-1 : Poor activity

- - Jason-1 : No activity

Mobile Laser Stations

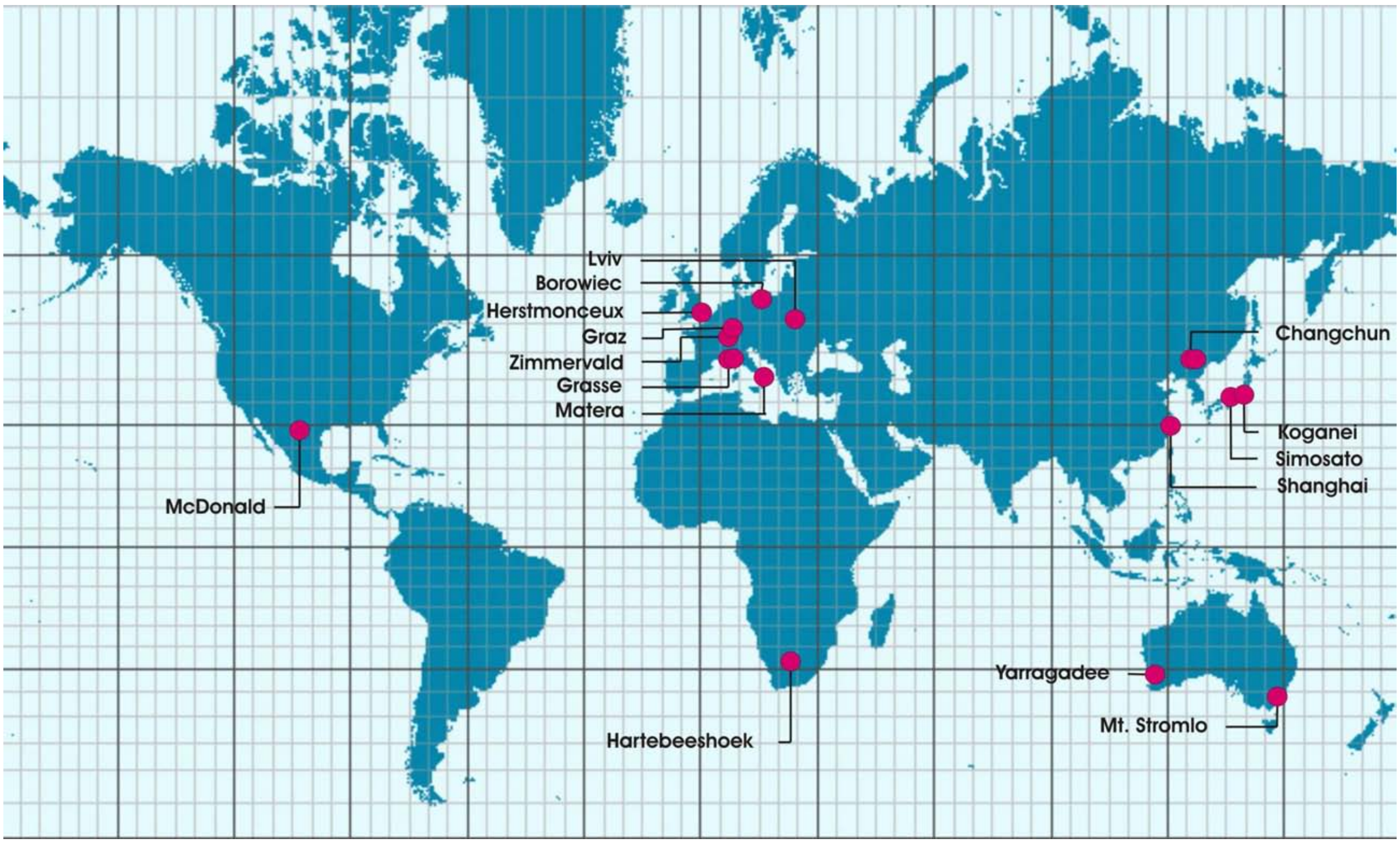
FTLRS (France)

Transportable SLR (Russia)

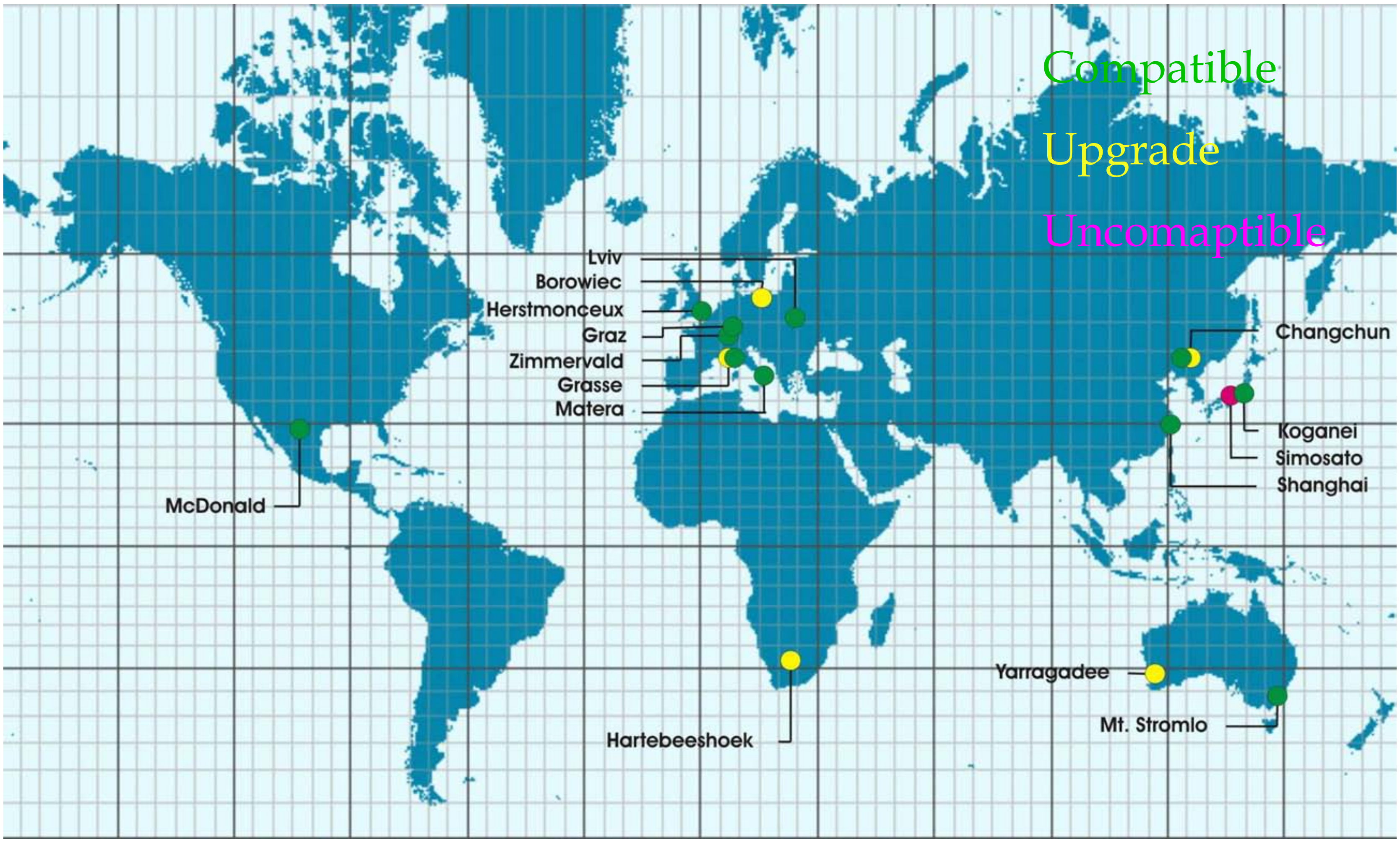
TROS (China)

Miniature Modular SLR (Russia)

Laser ranging Network Participation

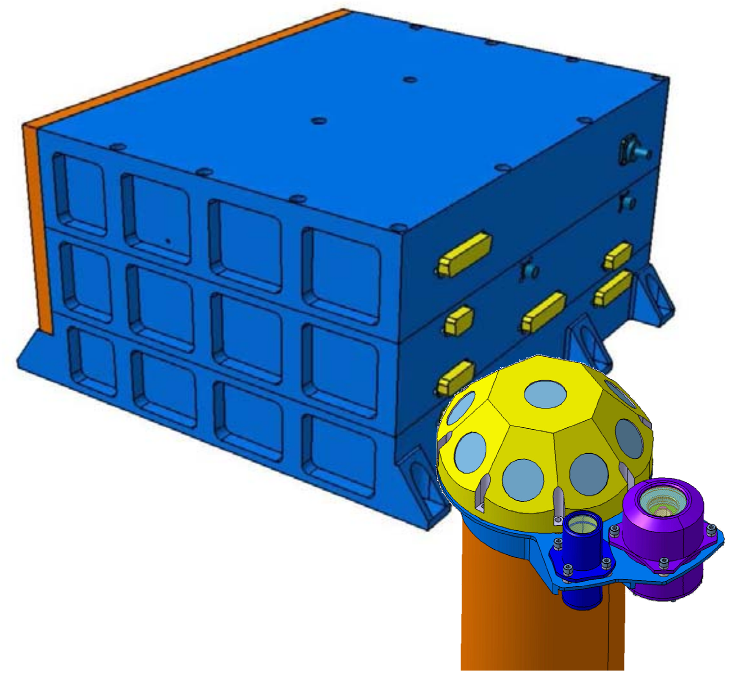


Laser ranging Network
Status 25/09/06

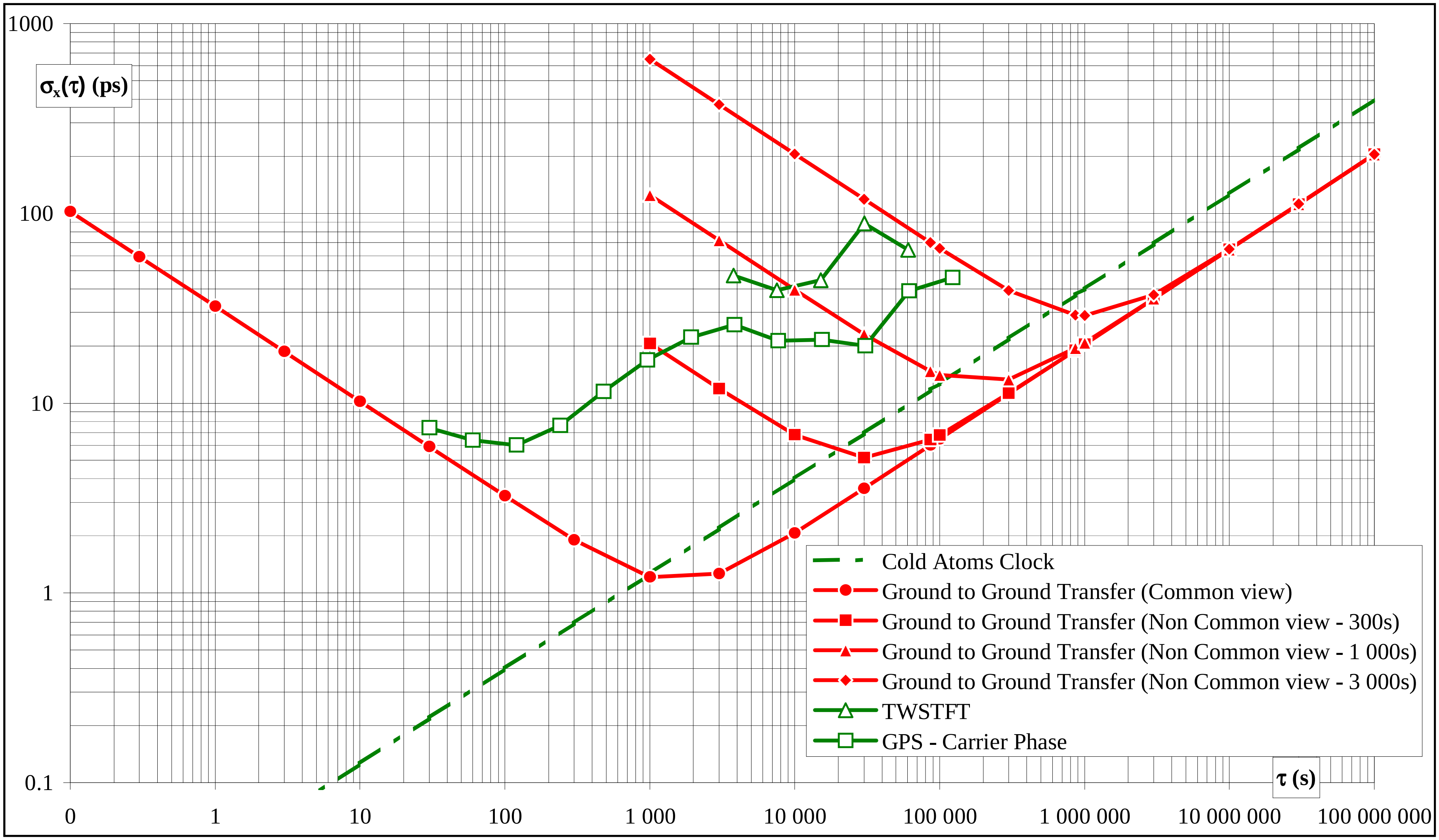


Scientific Objectives
Time and frequency metrology

- T2L2 Validation
  - » $\sigma_x^2(\tau) = \left(28.10^{-12} \times \tau^{-½}\right)^2 + \left(17.10^{-15} \times \tau^{+½}\right)^2 \quad \tau_0 = 0.1\,\mathrm{s}$
  - » $\sigma_y(\tau) = 0.4\,10^{-13}\,\tau^{-1/2}$ pour $\tau > 1000$ s
  - » Uncertainty < 100 ps
- Ground clock synchronisation
  - » Well suited to synchronize the best atomic fontains
- Time scale participation



Scientific Objectives
Microwave links: Inter-comparison



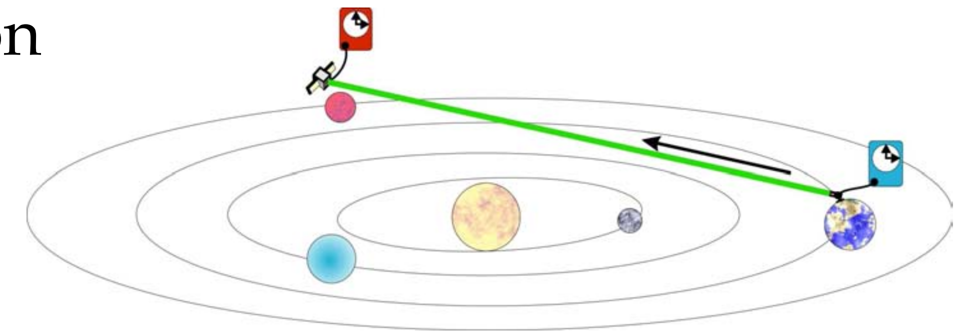
Scientific Objectives
Fondamental Physic

- Anisotropy of the speed of light
  - Measurement of the difference between the up link and the down link for some different orientation of the beam
  - Possibility to use several ground stations to eliminate the noise coming from the space oscillator
  - ≈ $\Delta c/c = 3\ 10^{-10}$

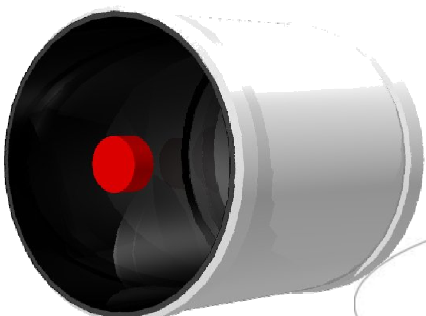
- Drift of $\alpha = e^2/hc$
  - Comparison of several ultra stable ground clocks using different atoms
  - Possibility to compare frequency at a few 10^{-17} over 10 days
  - Measurement limited by ground clocks

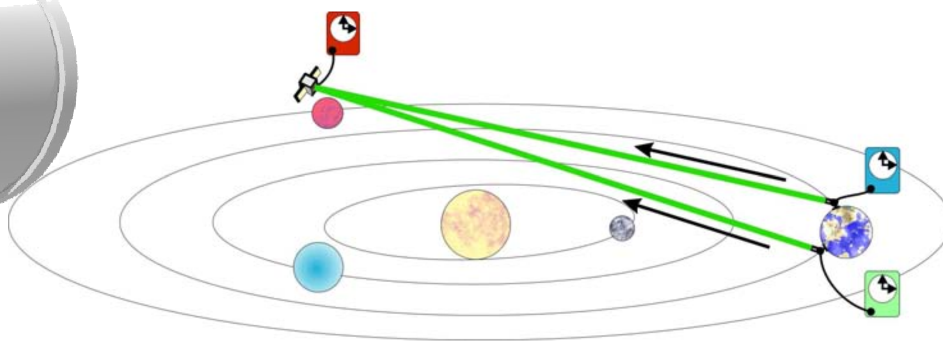
Scientific Objectives
One way interplanetary telemetry

- Distance is computed from the difference between the arrival time andd the strat time of a laser pulse emitted by a ground station
- One Way = Long distance



Radial measurement





Angular measurement

- Shapiro effect
- Planetary telemetry
- Asteroid mass
- Pioneer effect
- Navigation

Scientific Objectives
Jason-2

- Caracterisation of the DORIS Oscillator
- Improvement of the DORIS positioning system (South Atlantic Anomaly)
- One way telemety to improve the accuracy

Conclusions

- Engineering Model Results in very good accordance with expectations
- T2L2 should permit time transfer at the ps level: one or two orders of magnitude better than the existing RF Link
- The development plan of the flight model is actualy nominal
- The delivery of the flight model is sheduled for 01/07

- **Launch of Jason 2: June 2008**