T2L2 on Jason-2

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Grasse – FRANCE

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D. Albanese: Optique
P. Berio: Analysis Working Group
F. Deleflie: Validation Working group
F. Para: Instrumentation
F. Pierron: Laser station
J.M. Torre: Laser sations Working group
P. Vrancken: Test benches
J. Weick : error - link Budget - computation

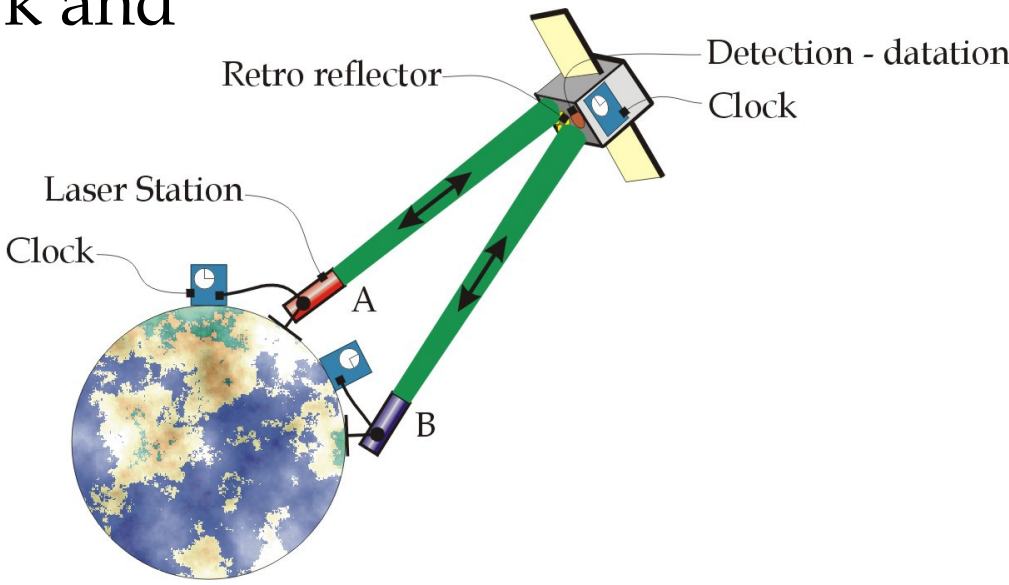
CNES
Toulouse – France

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 :

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



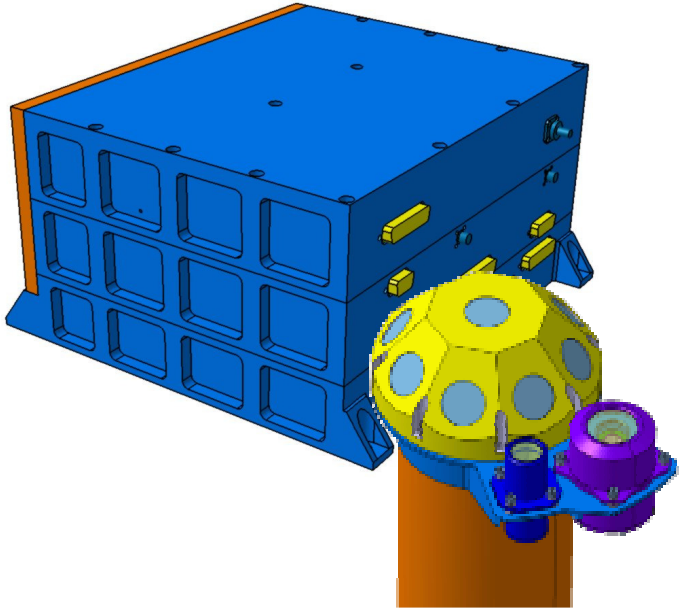
Historical Account

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

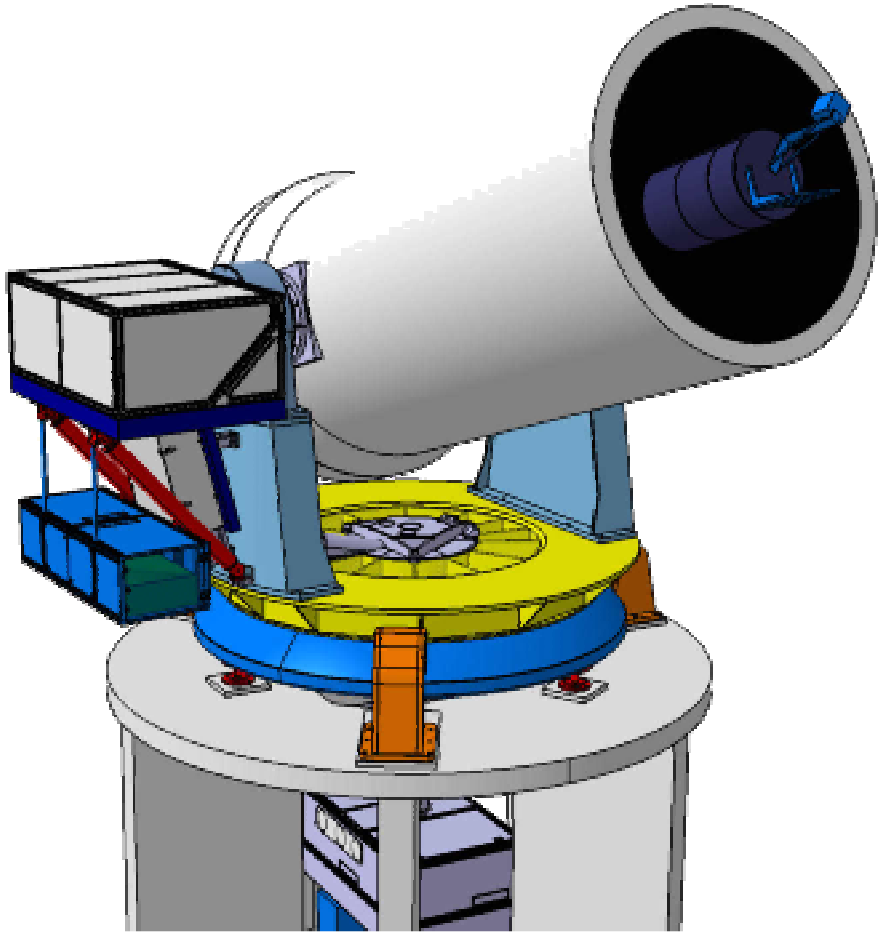
- 1994: T2L2 Proposal (OCA)
- 1996: T2L2 on MIR 99 (A Phase)
- 1997: T2L2 on ISS with ACES (B Phase)
- 2002: T2L2 on a Microsat Myriade CNES

- 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

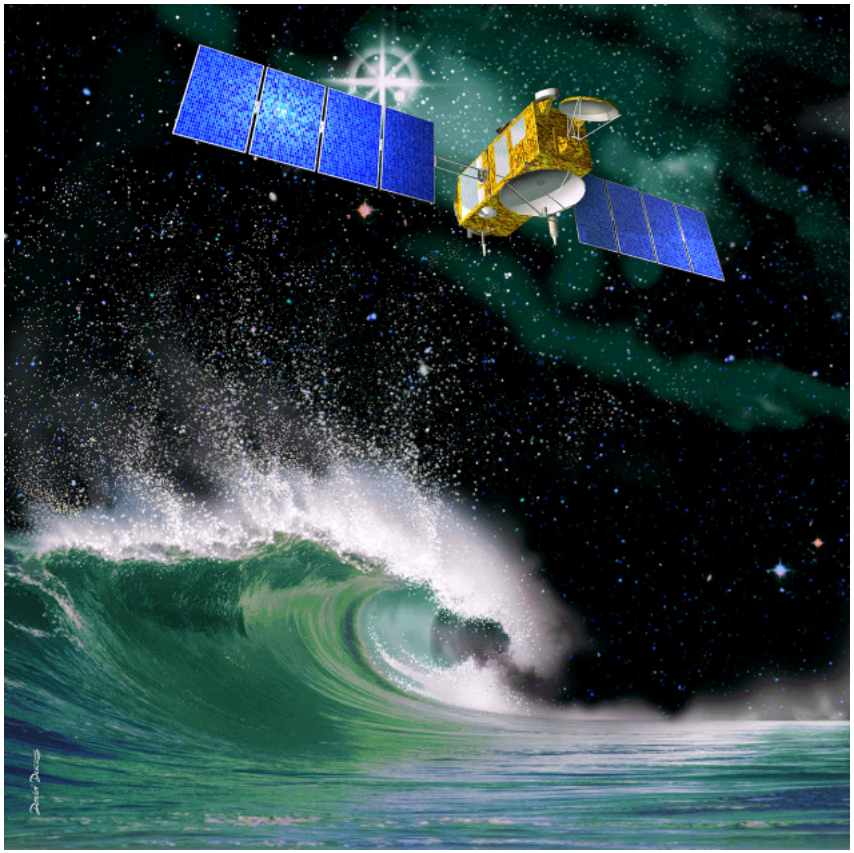


Ground segment:

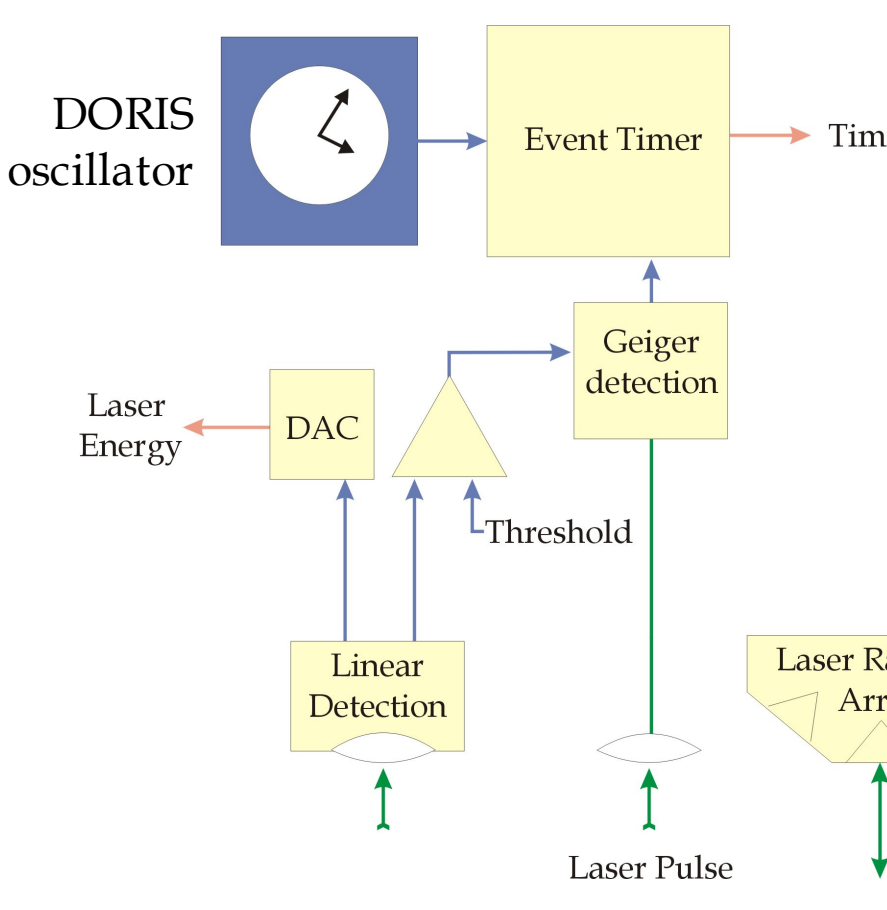
Laser station

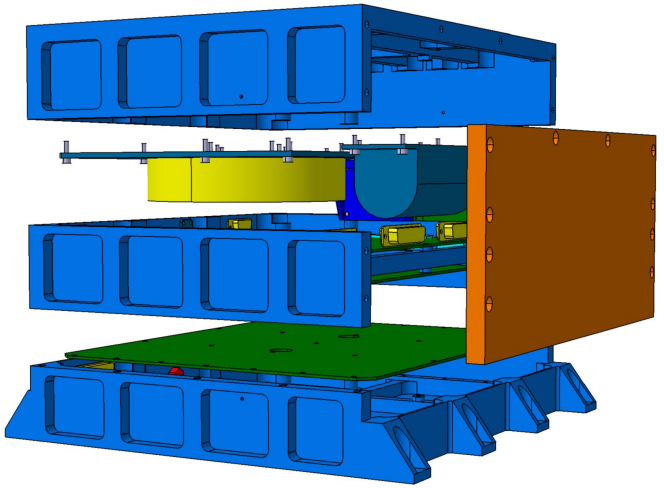
Space segment
T2L2 on Jason 2

- 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



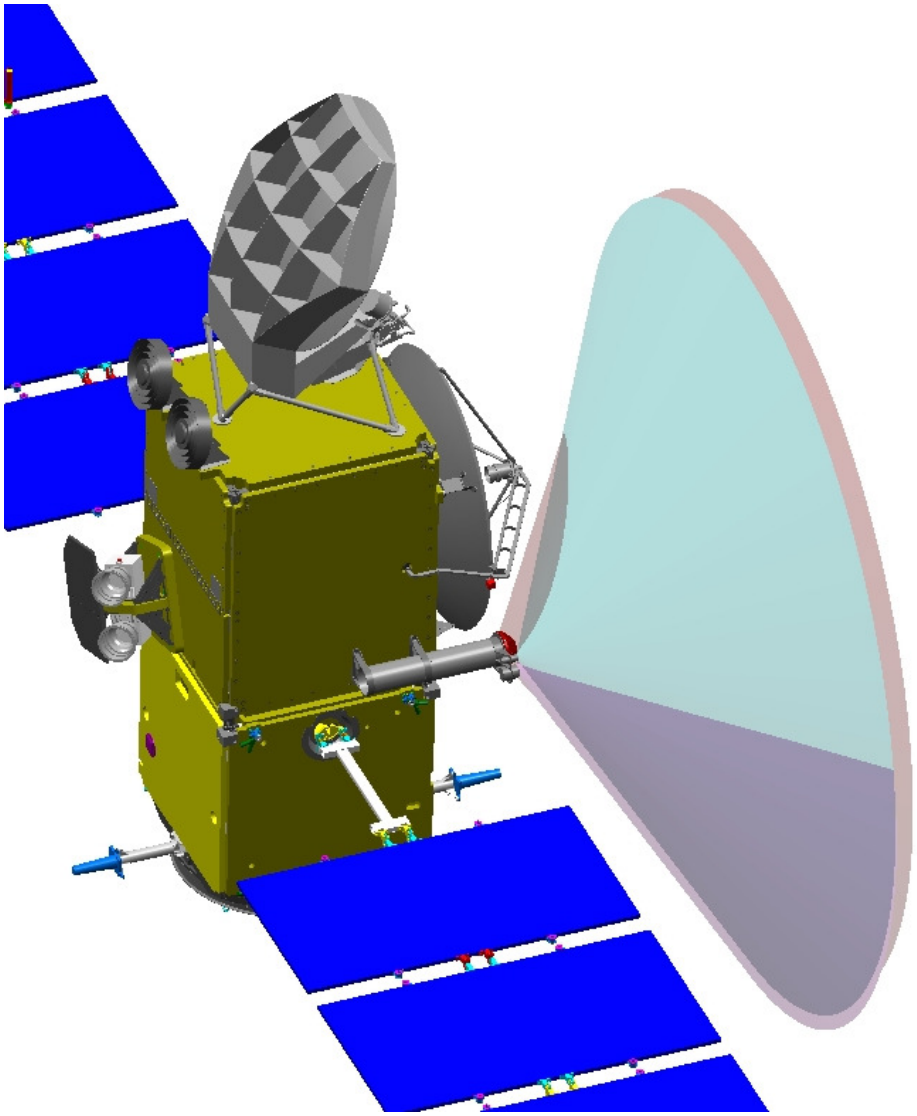
T2L2 Space Instrument Synoptic





- ⇨ 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)

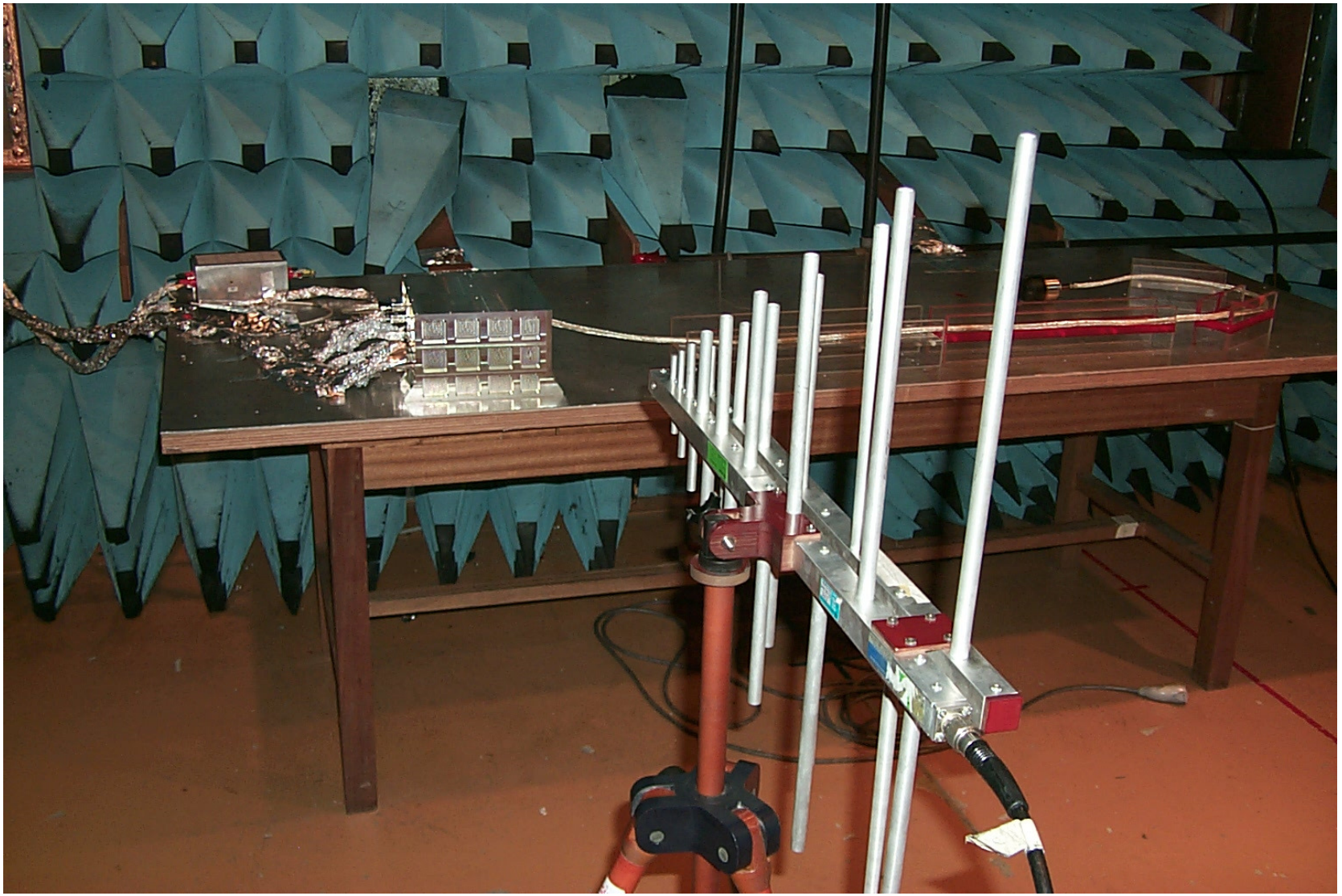
T2L2 Space instrument Development plan

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

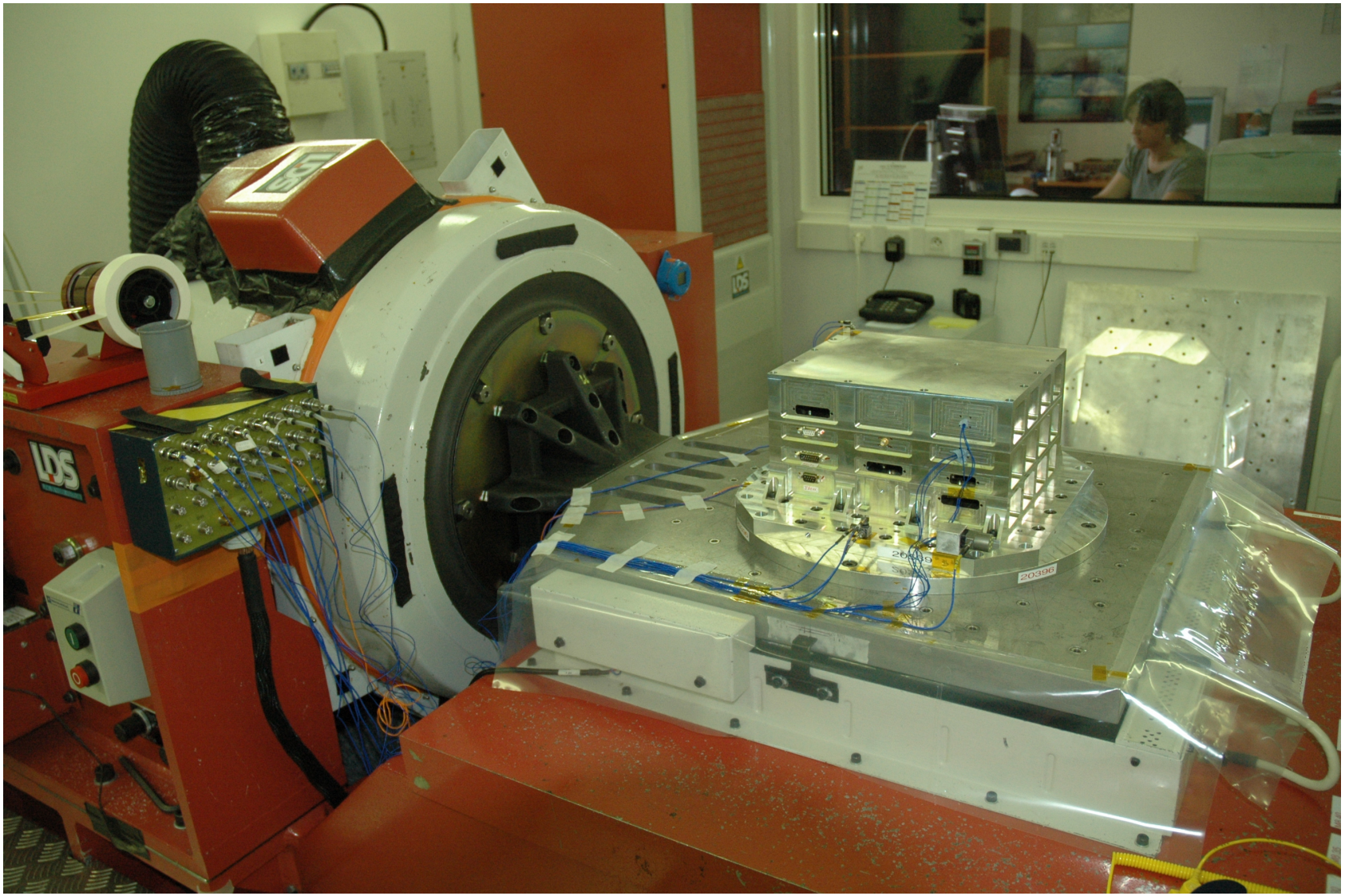
- Jason 2 launch: 06/08

- Exploitation: 06/2008 → 06/2010

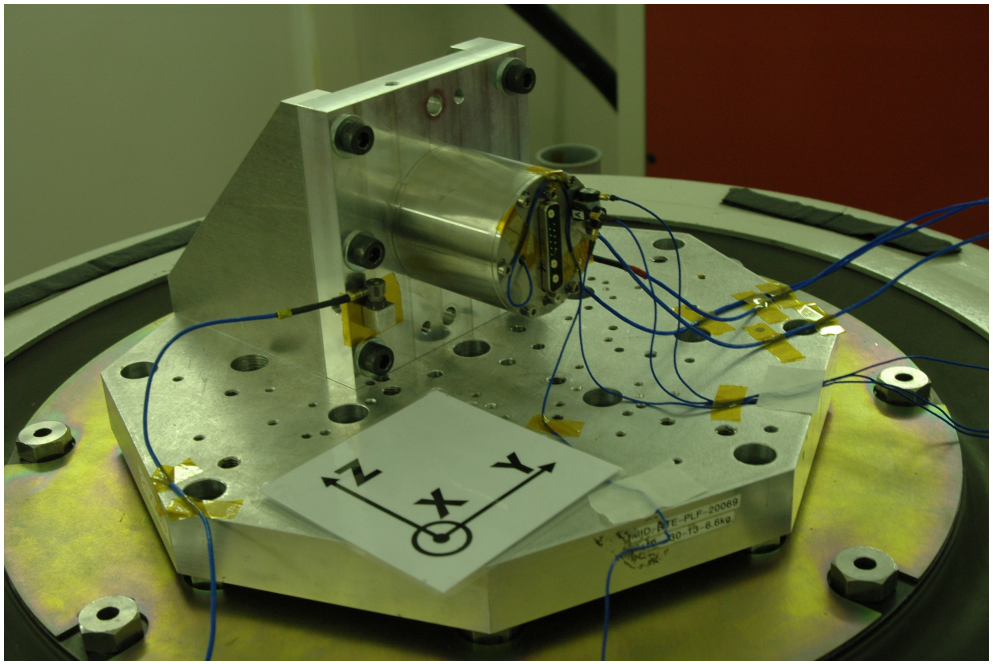
EMC Tests
T2L2 Electronic

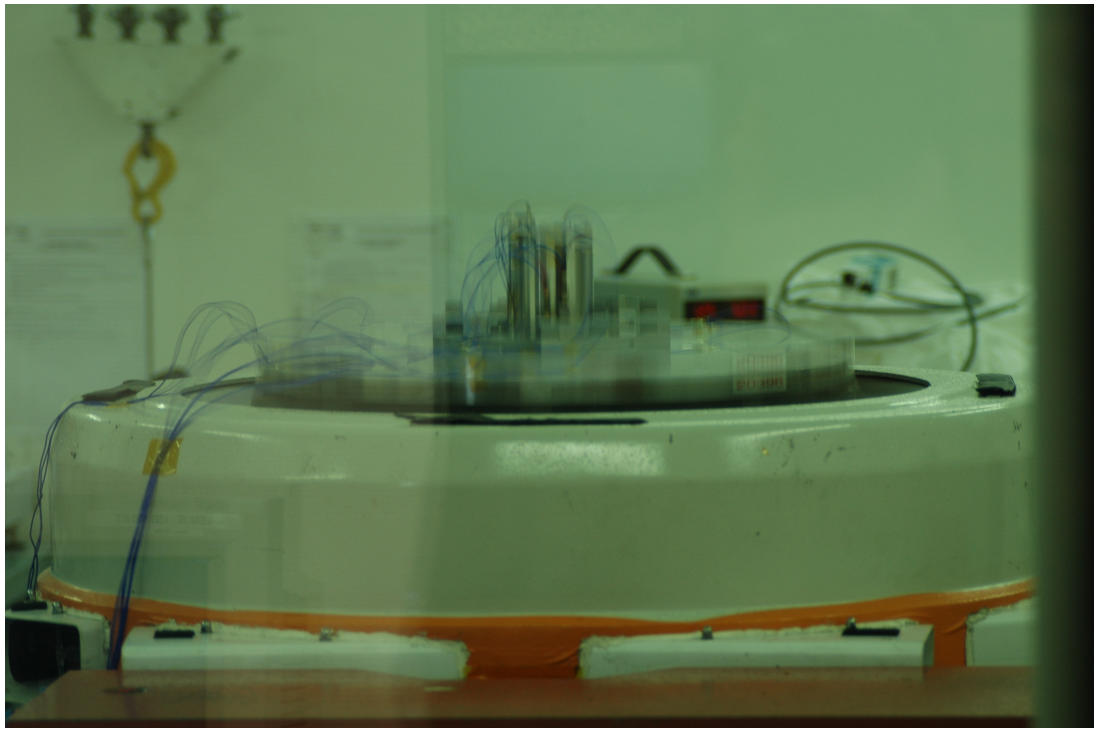


Mechanical tests
T2L2 Electronic

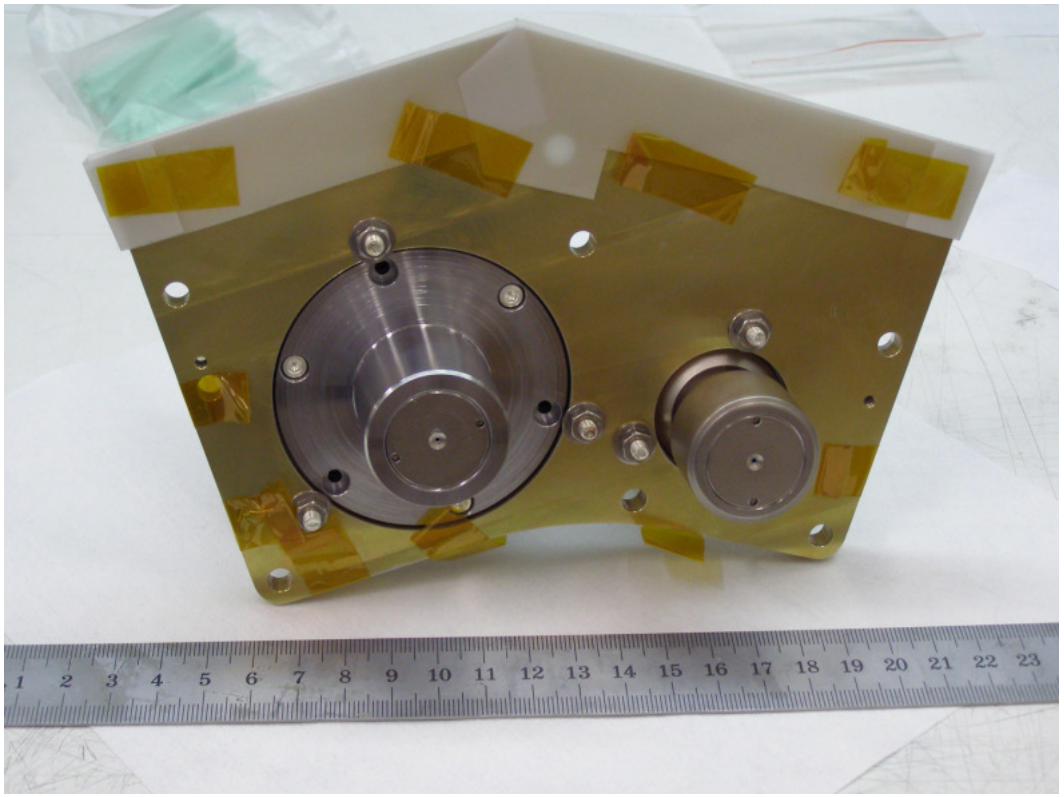


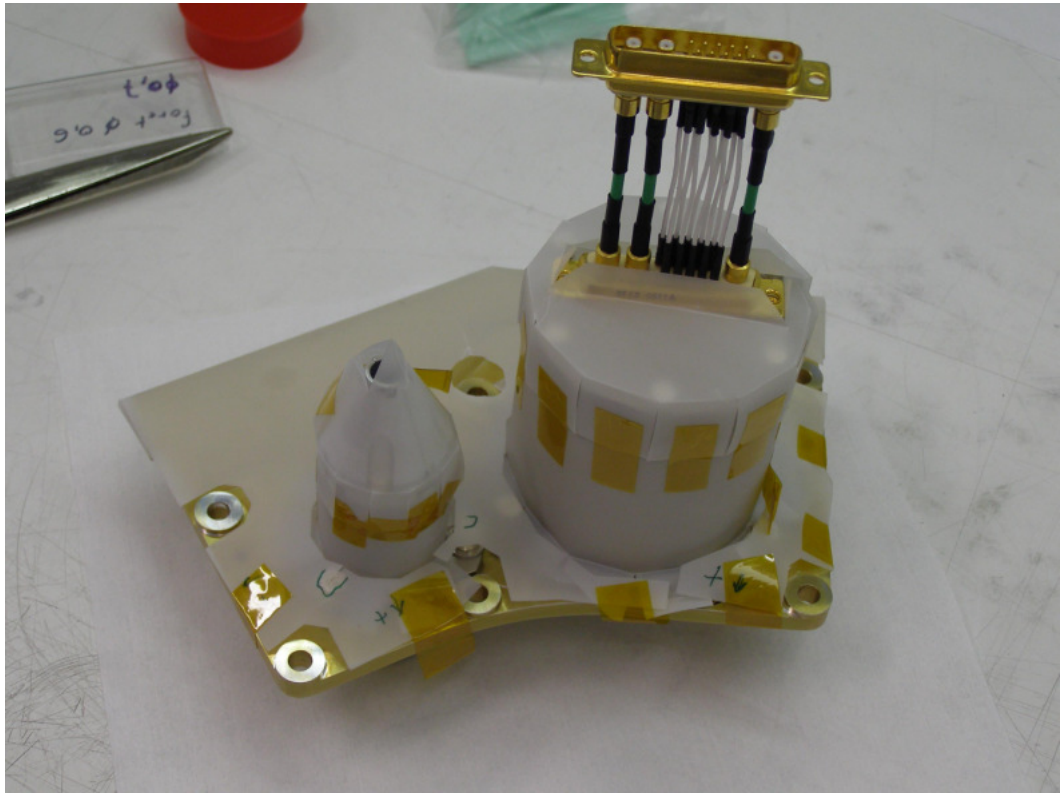
Mechanical tests
T2L2 Optics



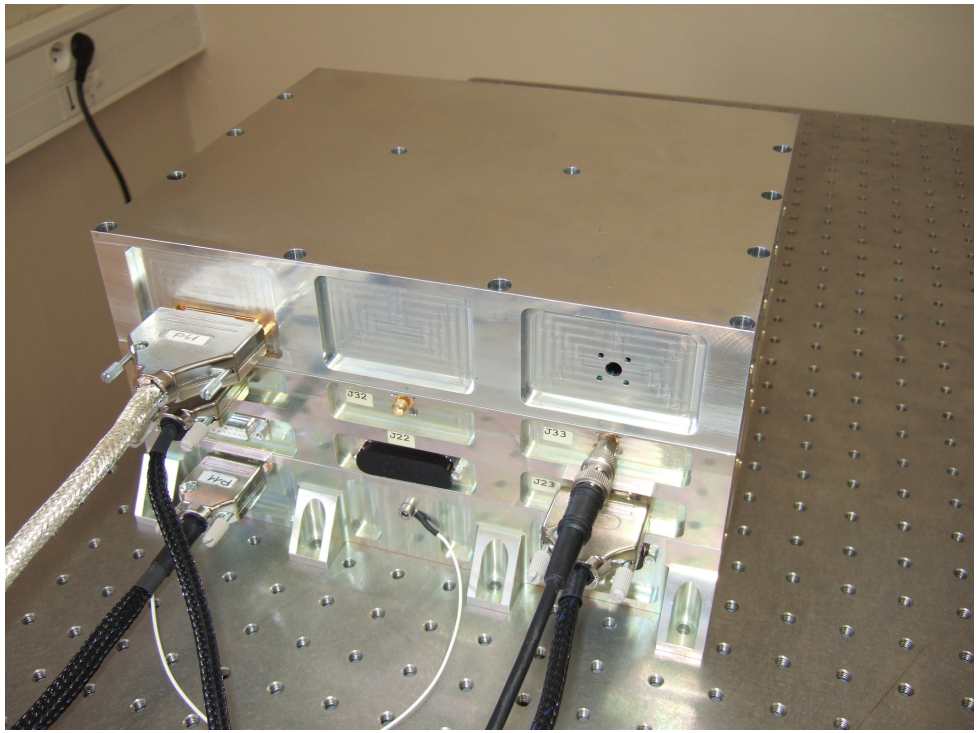


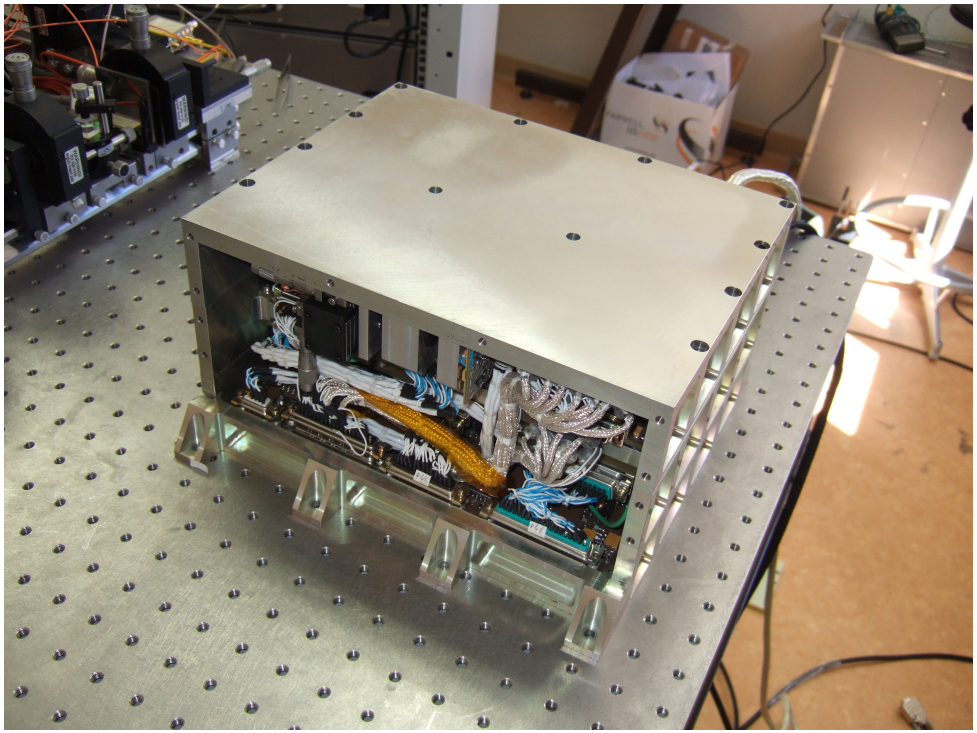
T2L2 Optics
MLI tests



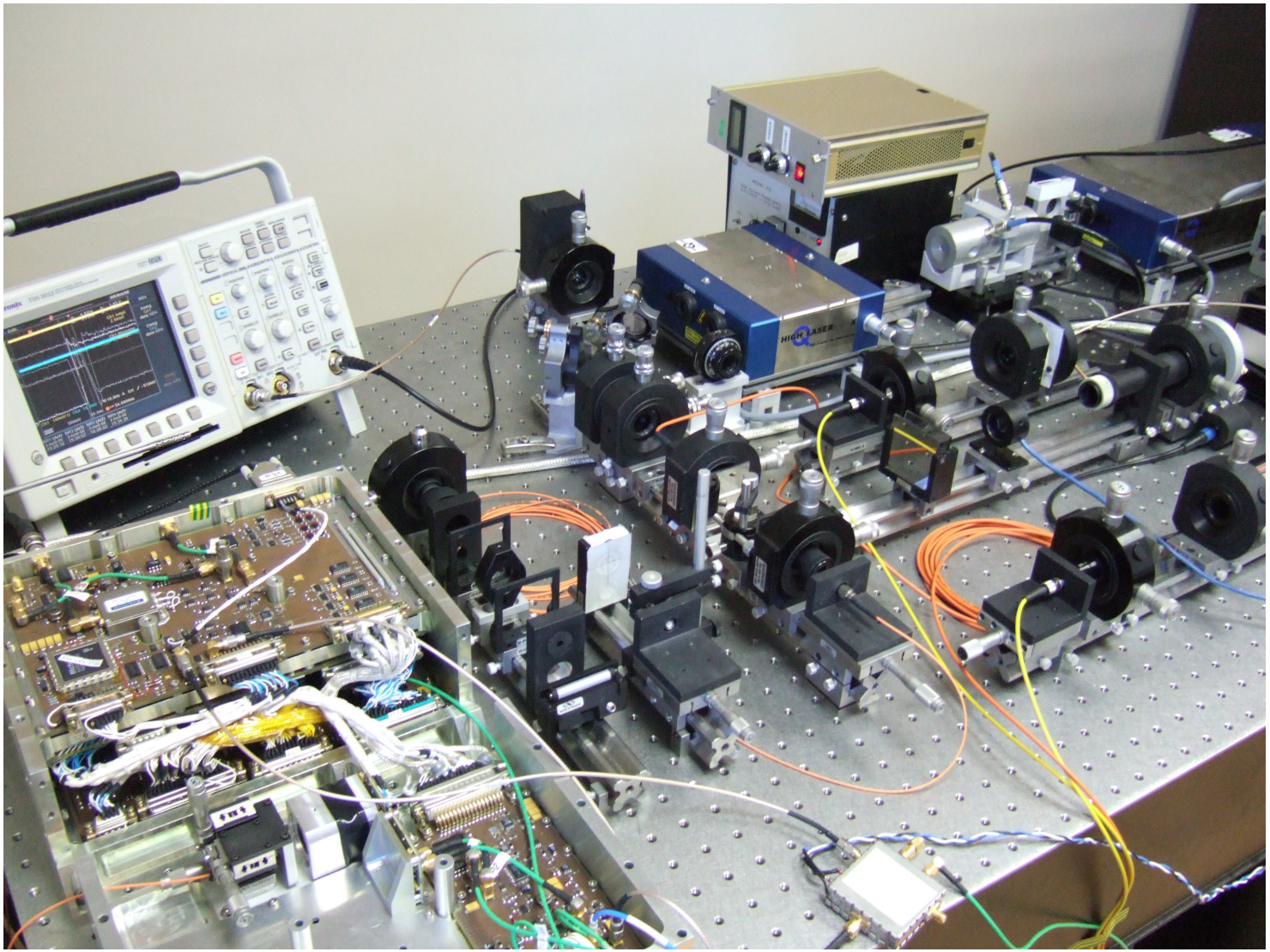


T2L2 Engineering model (Electronic)





Optical test bench



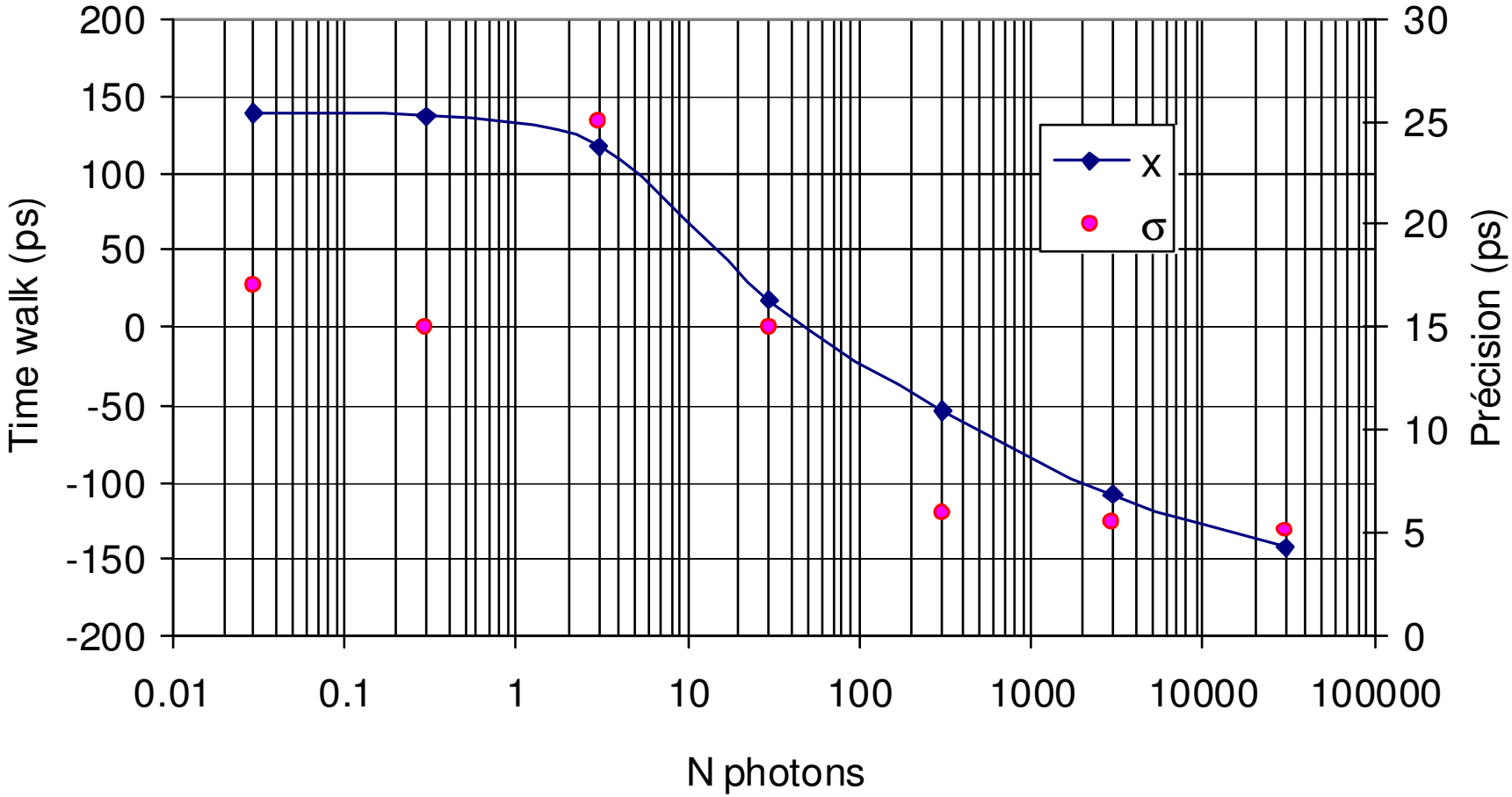
T2L2 Engineering model
Photo detection Threshold

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)

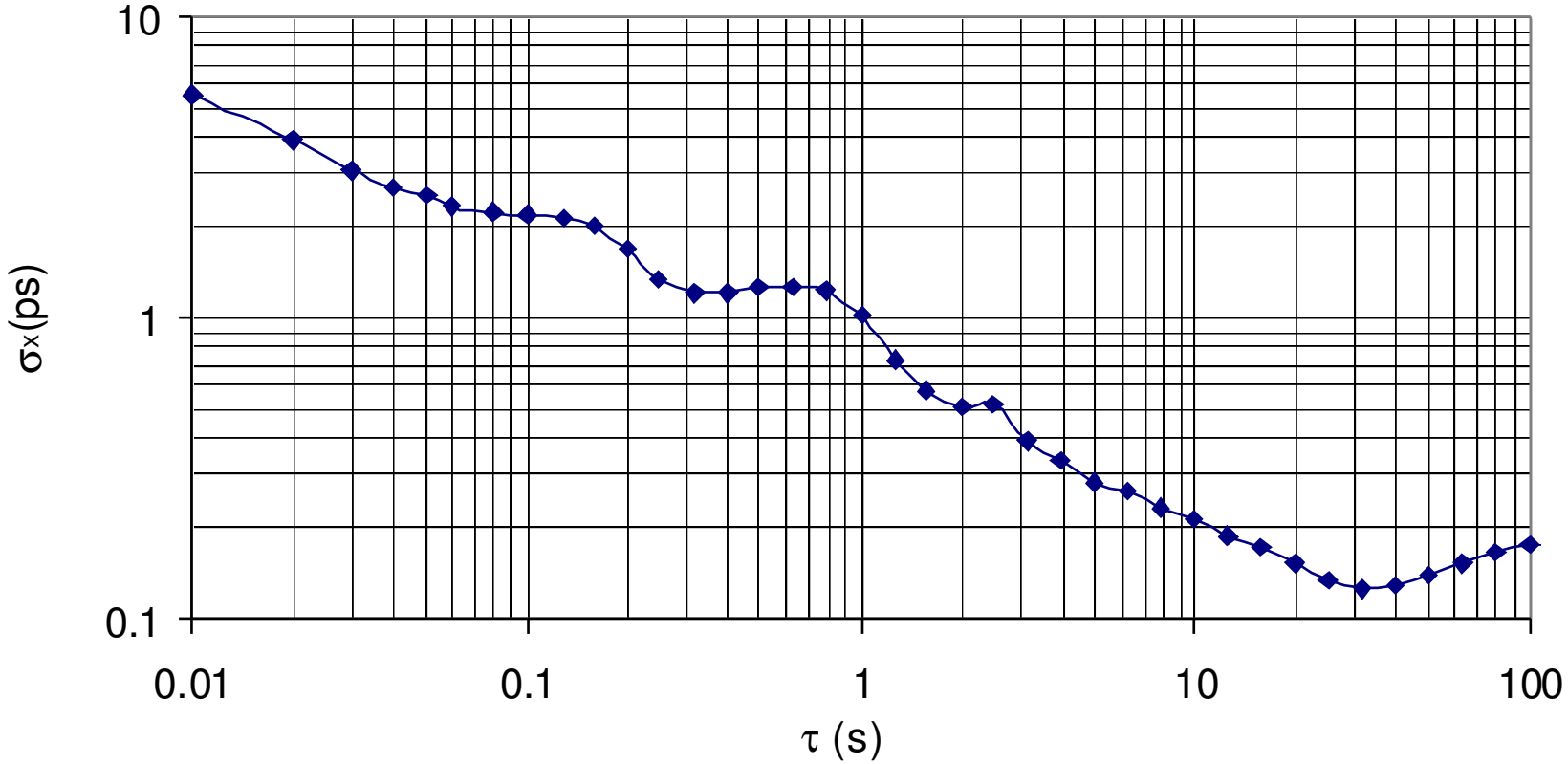
T2L2 Engineering model
Photo detection Precision –Time Walk



Precision Single photon: 17 ps

Precision @ 1000 photons: 2 ps

Short term Time stability @ 532 nm



Mode Locked Vanadate laser @ 532 nm

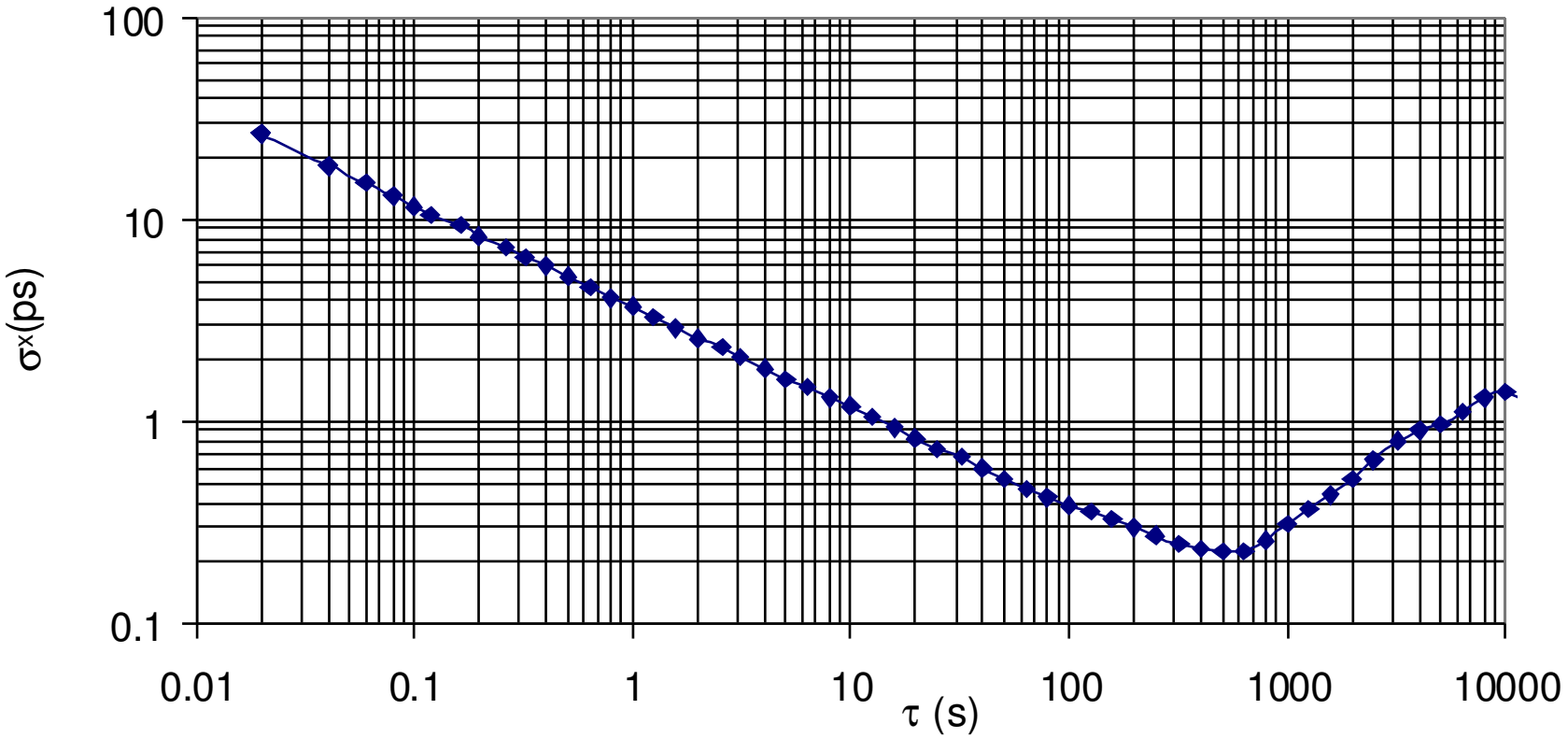
Pulse Width: 20 ps

Repetition 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
Repetition 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

Mobile Laser Stations

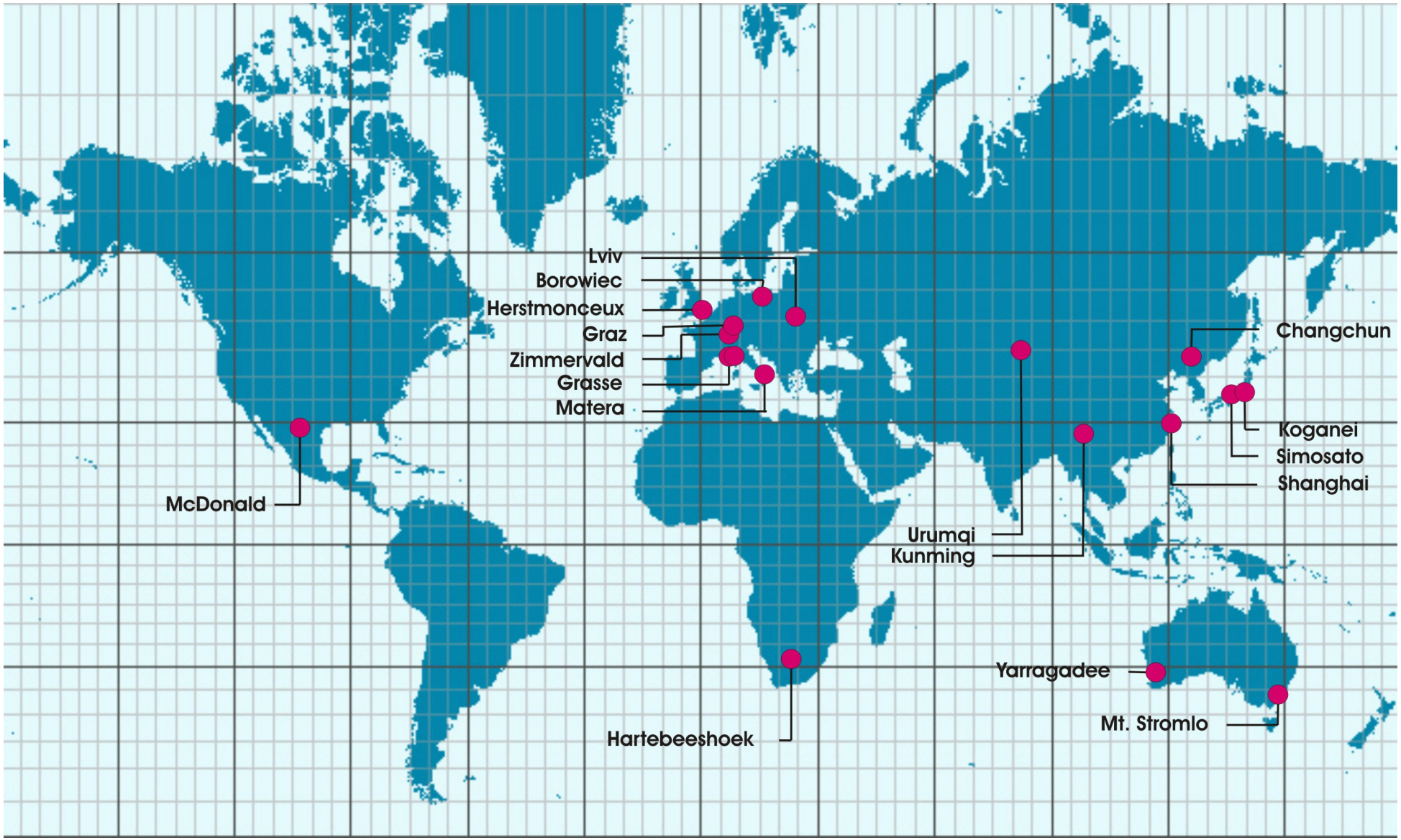
FTLRS (France)

Transportable SLR (Russia)

TROS (China)

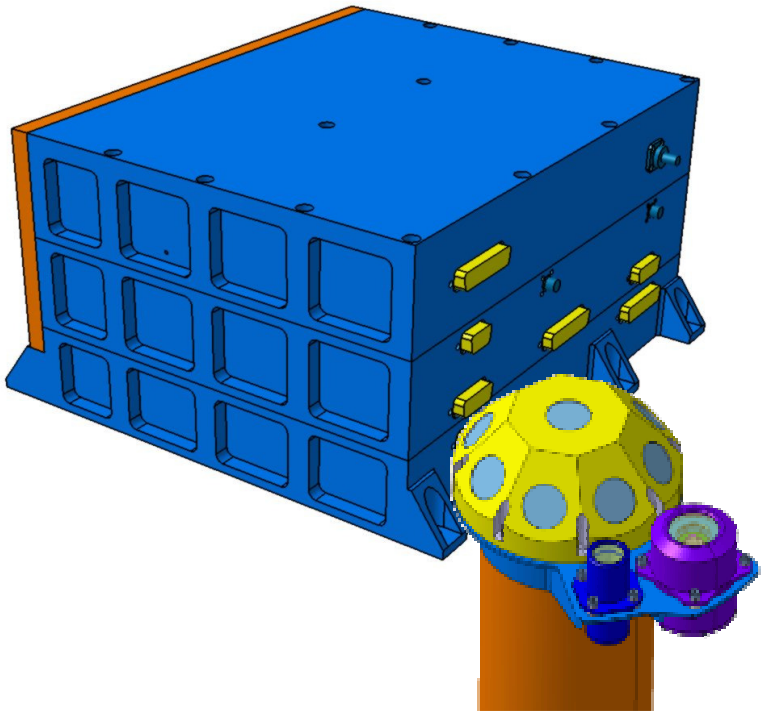
Miniature Modular SLR (Russia)

T2L2 Participation (13/10/06)

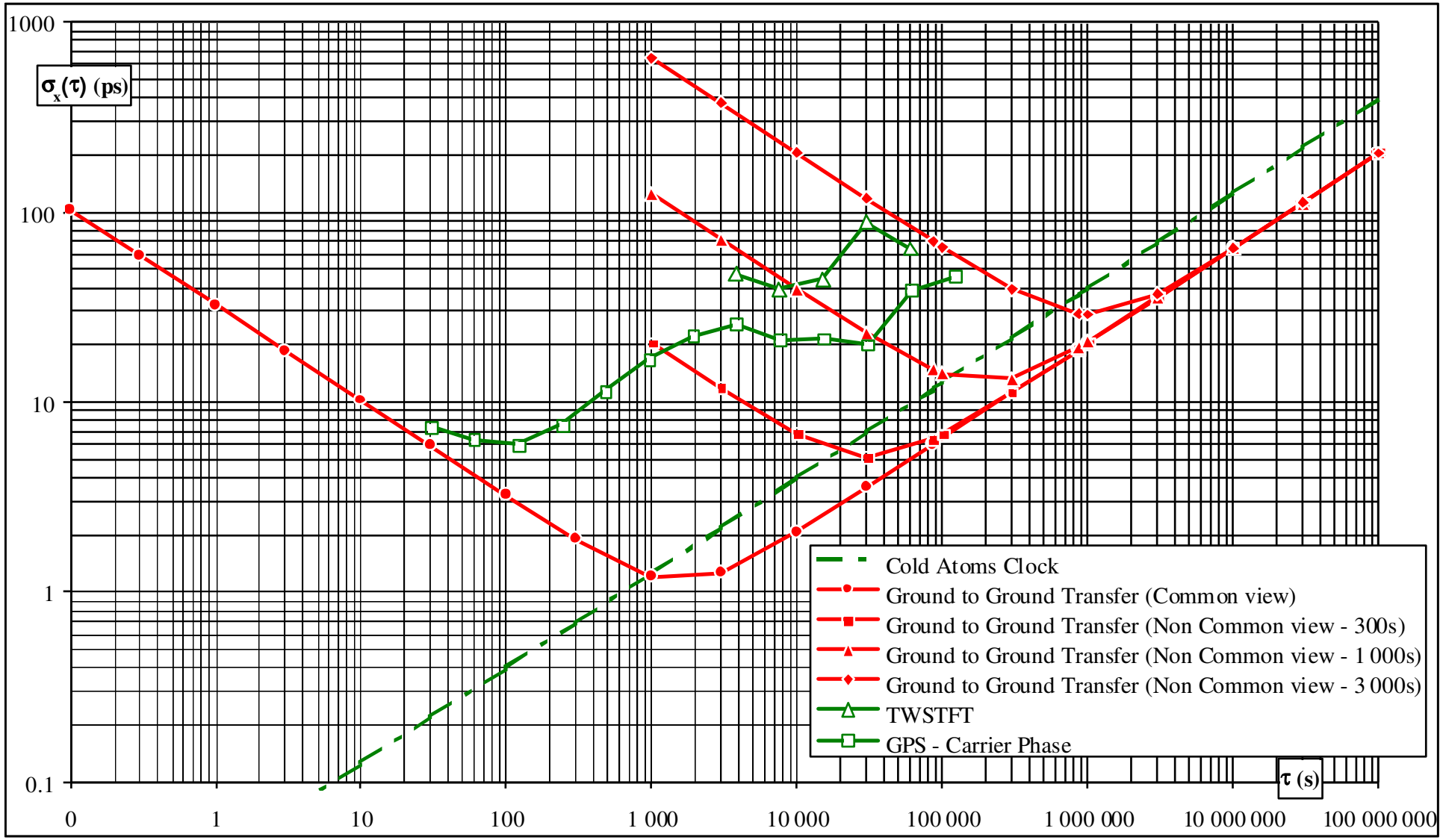


Scientific Objectives
Time and frequency metrology

- T2L2 Validation
  - $\sigma_x^2(\tau) = \left(28.10^{-12} \times \tau^{-½}\right)^2 + \left(17.10^{-15} \times \tau^{+½}\right)^2 \qquad \tau_0 = 0.1\,s$
  - $\sigma_y(\tau) = 0.4\,10^{-13}\tau^{-1/2}$ 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

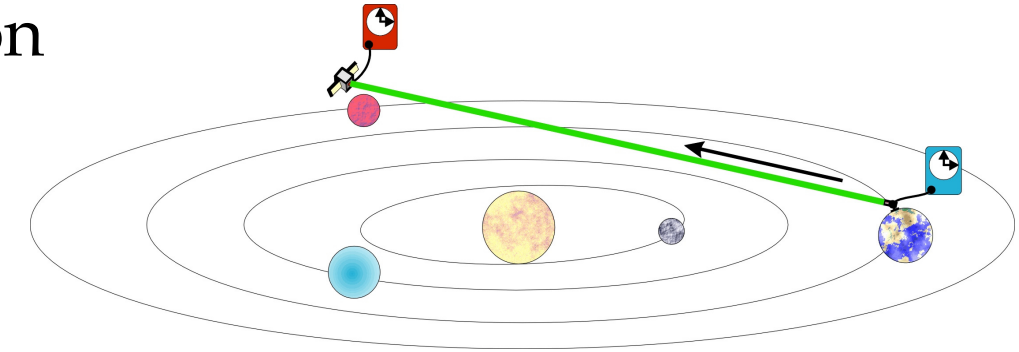


Scientific Objectives
Fondamental Physic

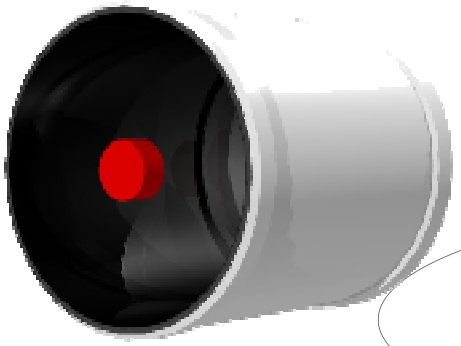
- Anisotropy of the speed of light
  - » Measurement of the difference between the up link and the down link for some different orientation of the beam
  - » Possibility to use several ground stations to eliminate the noise coming from the space oscillator
  - ≈ $\Delta c/c = 3\ 10^{-10}$
- Drift of $\alpha = e^2/hc$
  - » 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

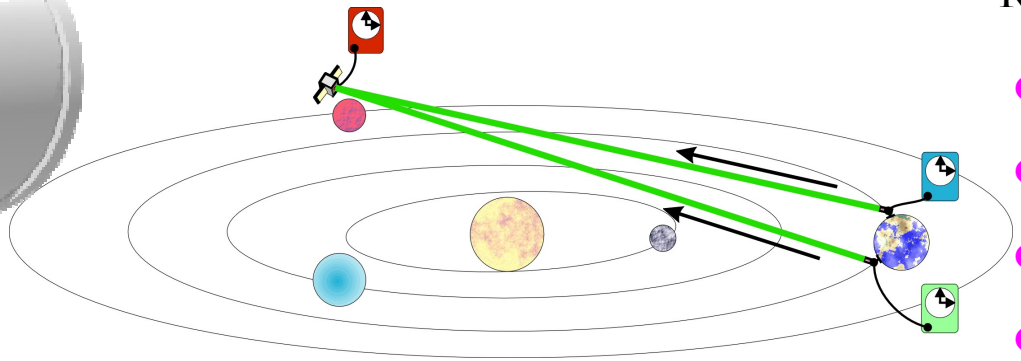
Scientific Objectives
One way interplanetary telemetry

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



Radial measurement



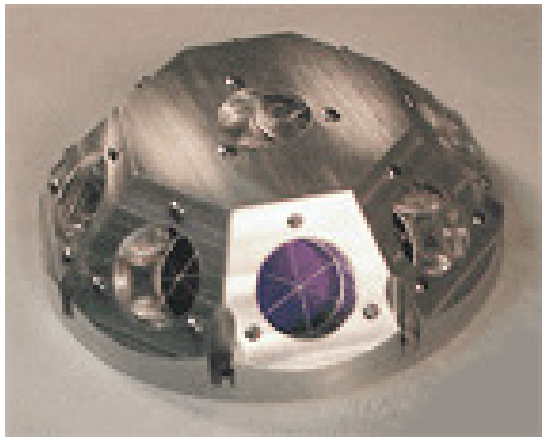


Angular measurement

- 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**