ASTRIUM AN EADS COMPANY

GeoAzur TERRE - OCÉAN - ESPACE

Observatoire de la CÔTE d'AZUR

Demonstration and Interest of Laser Ranging on space debris, from the Grasse SLR station

Credit photo : Jacques Beilin

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Overview

I. Specific technical development

1. MéO telescope
2. The 2J pulsed laser
3. Photo-detection and laser Event-Timer
4. Some technical points

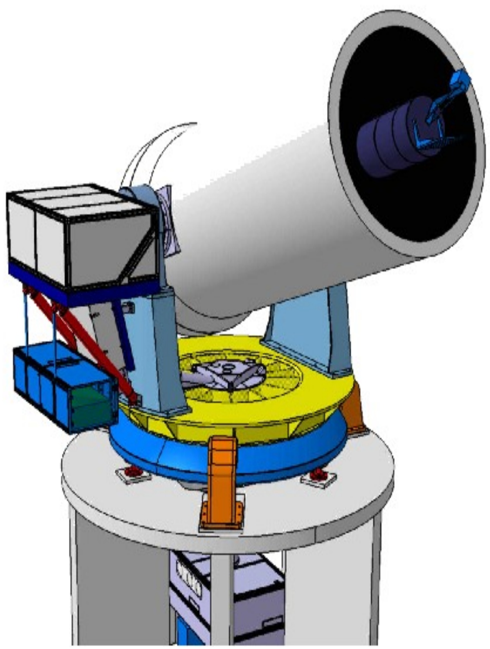
II. Observation campaigns

1. First echoes
2. The final campaign results obtained
3. The Link budget
4. Future work

The aim of those activities is to:

- Find complementary solution for space debris observation. Fast growing population, need of accurate measurement at reasonable cost.
- Validate the dimensioning studies concerning a laser ranging station dedicated to the active tracking on orbital debris.
- Prove the ability to perform laser ranging on non-cooperative objects.
- Demonstrate the interest of **simultaneous** laser ranging and imagery measurements : accurate orbit determination.

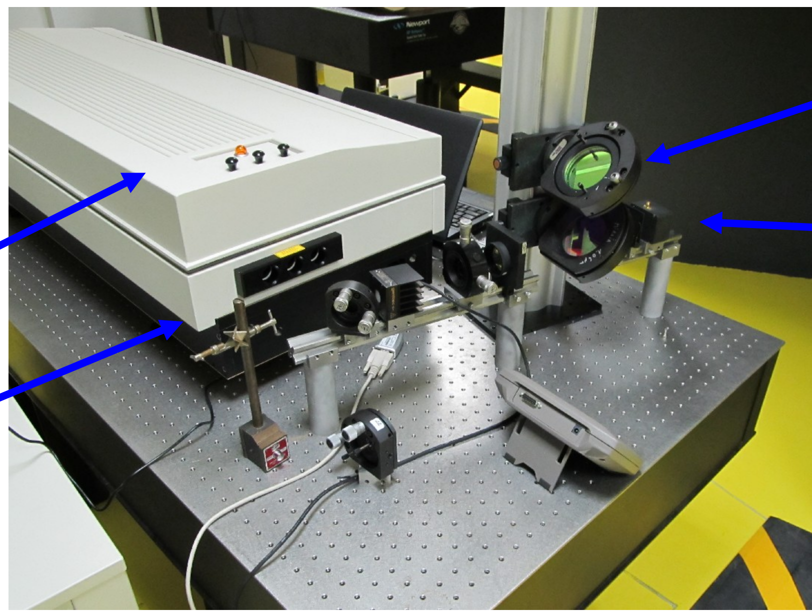
- **MéO** (Métrologie Optique) telescope dedicated for **Satellite and Lunar Laser Ranging**
- **Fork mount altaz with direct drive tracking using Etel motors**
  → allows tracking orbiting satellites
- Fully renovated in 2009



- Azimuth axis speed: **5°/s;**
  Azimuth axis acceleration: **1°/s^{-2}**
- Pointing accuracy: **± 5 arcsec**

FoV camera = 3 arcmin
FoV photodetection = 28 arcsec
Laser divergence = 3 arcsec
Diameter 152 cm
EMCCD camera

- Laser **Continuum DLS 2J** integrated in 2011:
  - Energy : 2.1 J/pulse
  - Repetition rate : 10 Hz
  - Pulse width : 5 ns
  - Wavelength : 532 nm
- The laser is **synchronized** by a **control module** developed specifically → Generates control signals of the Q-Switch flash from optical synchronization signal.



Coupling mirrors

Single-phase autotransformer

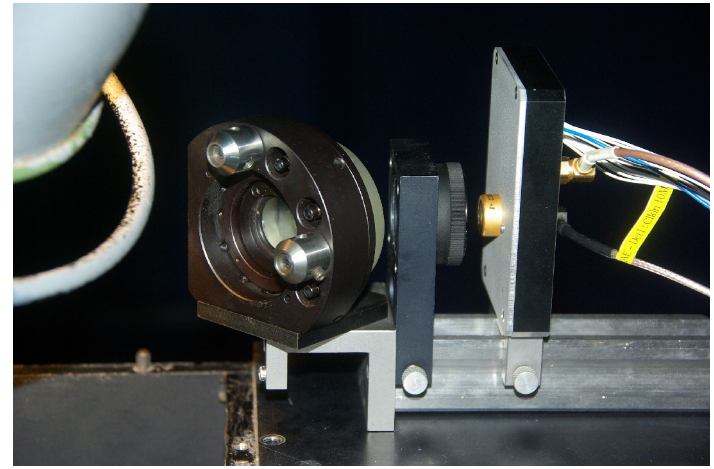
Photo detection that measures the starting tops laser pulses

Chilled water distribution

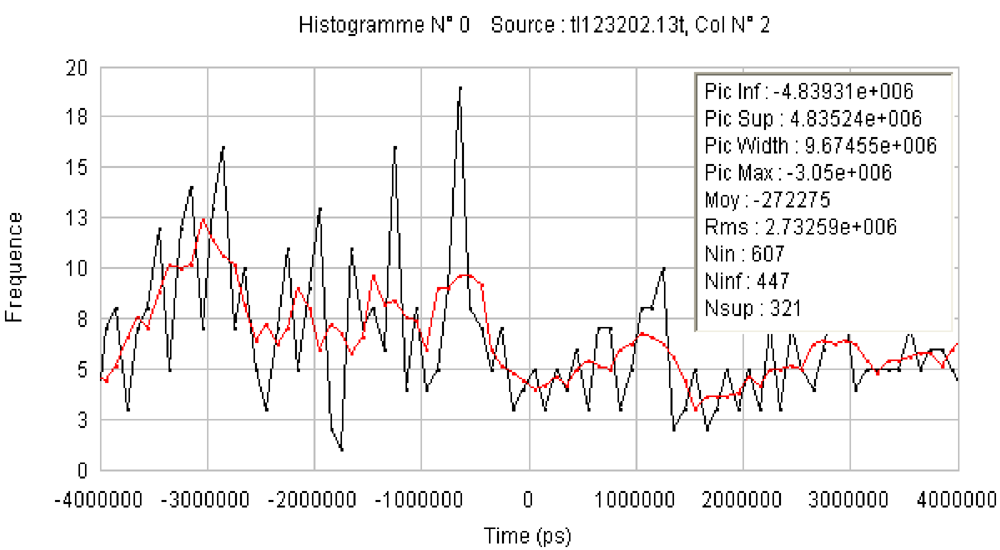
MéO Event Timer

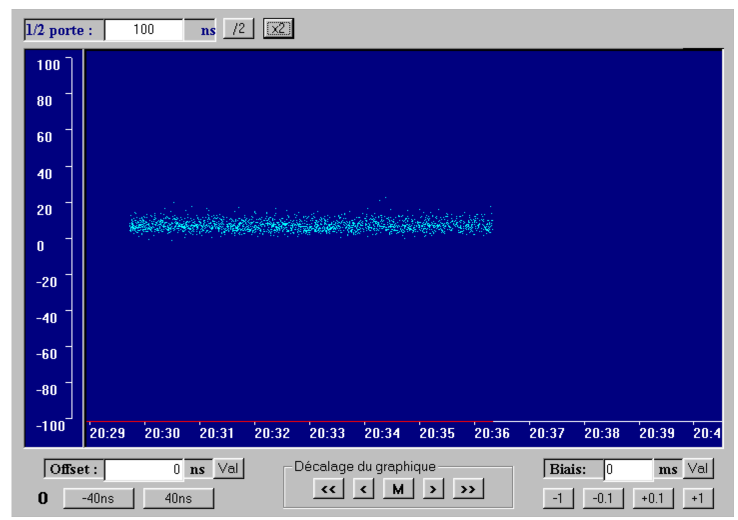
The low noise photo-detection:

- Global field of view : 28 arc sec (~ 280 m @ 2000 km)
- Spectral filter : 0.12 nm
- Photo detector: SAP500 in Geiger Mode
  - Active diameter: 500 µm
  - Quantum efficiency measured: 40 %
  - Noise measured (real pass) : 55 event / µs @ 20° C
  - Repeatability error: 1 ns rms



Experimental setup



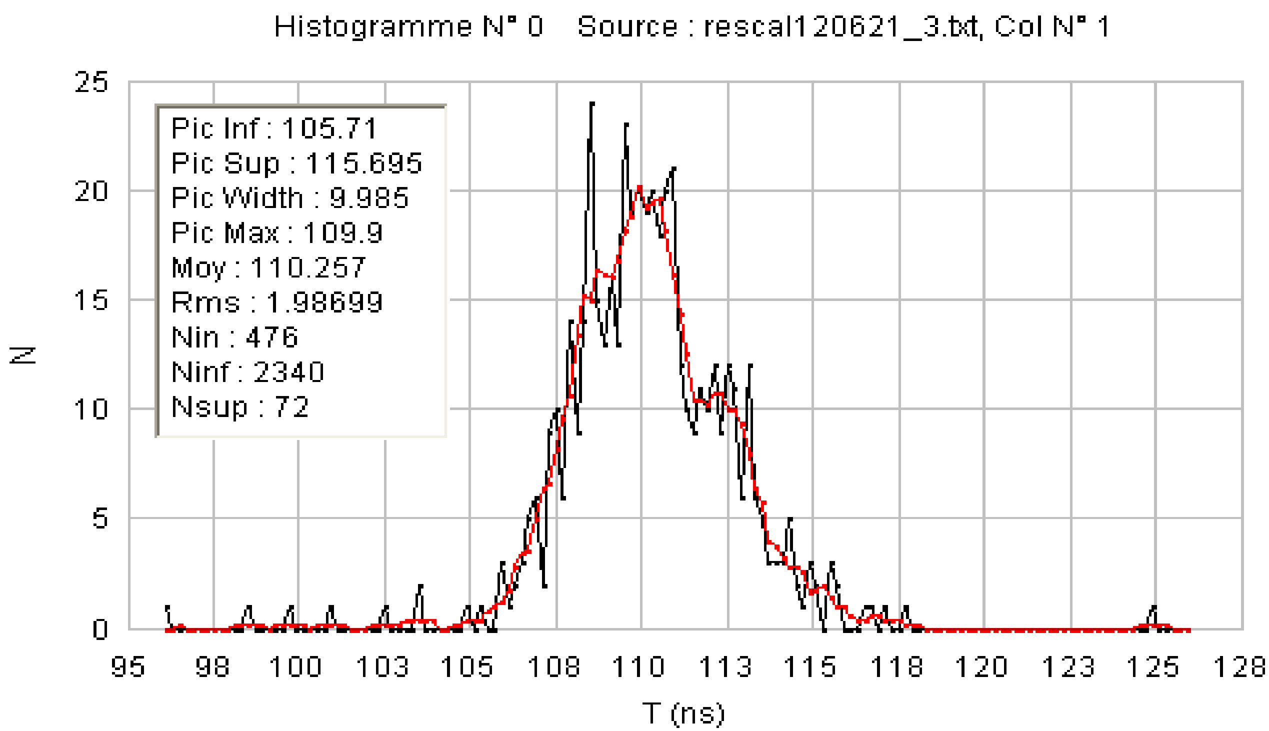


Noise and temporal resolution measurement

Distance calibration : repeatability error

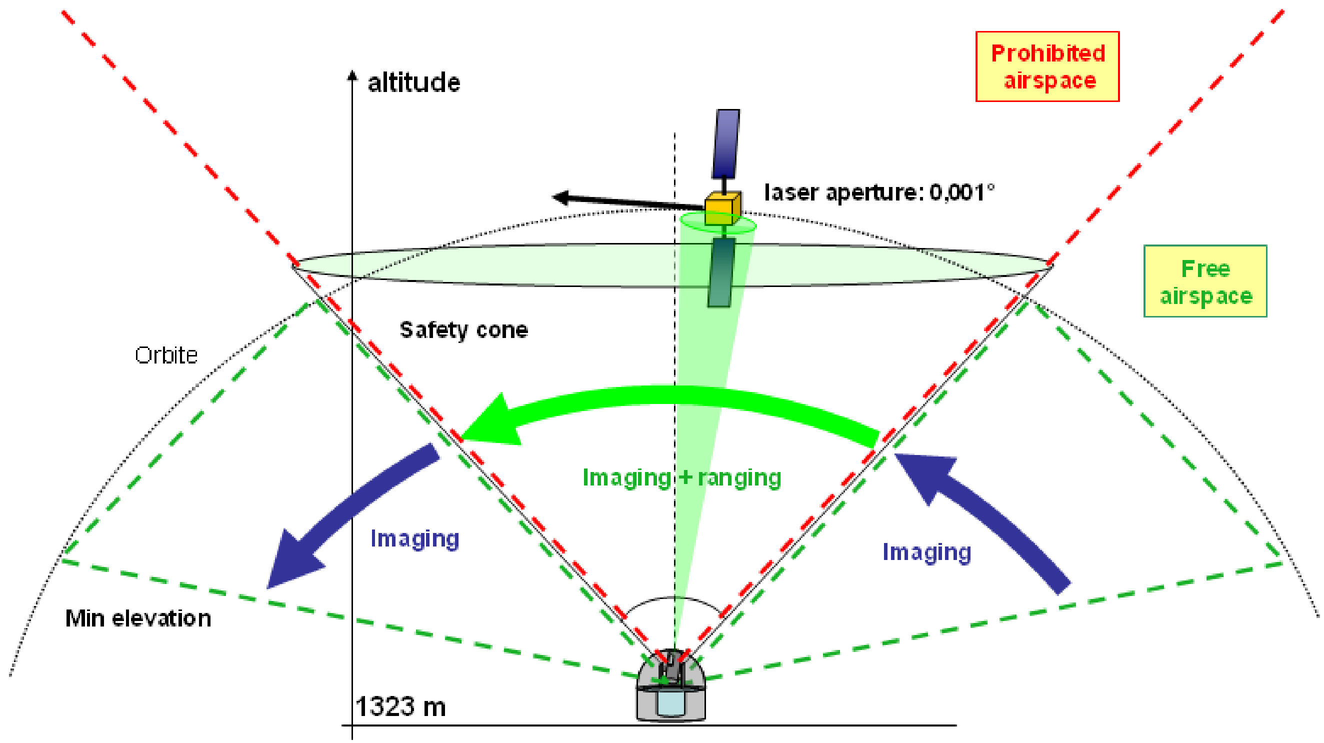
- **Calibration** is performed through a telemetry made on an internal corner cube - The final telemetry is deduced from the difference between the time of flight obtained on that corner cube and the target

- The **repeatability error** of the whole system is **2 ns**: In accordance with the FWHM of the laser pulse and the photo detection noise

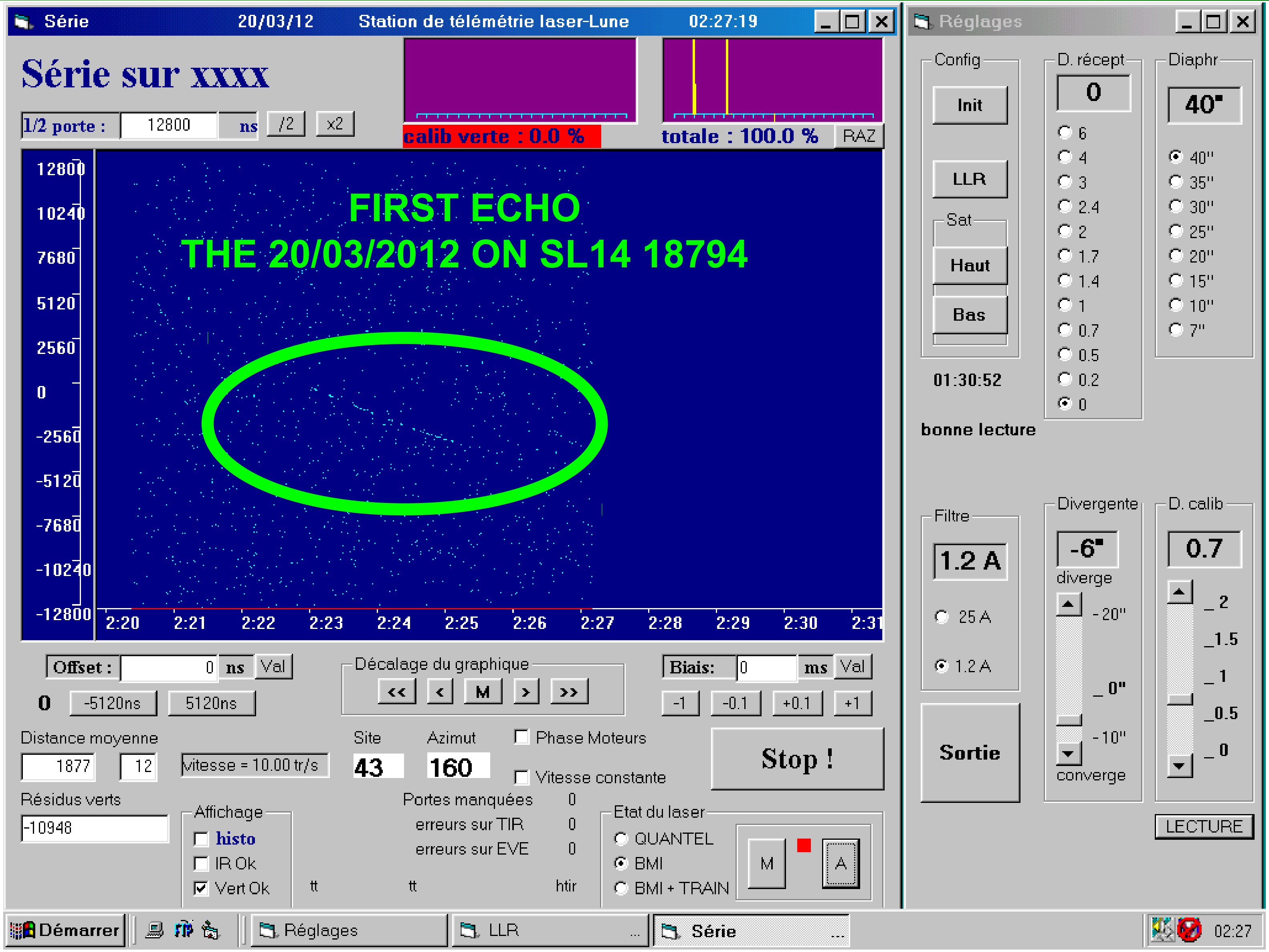


✗ Constraint : **precision of the TLE predictions** : ± 10 km → angular error = ± 0.5°
2 aligned telescopes → automatic or manual tracking
- Skywatcher, FoV = 2,33°, Φ 12 cm, FLI camera
- MéO, FoV = 3 ', Φ 152 cm, ANDOR EMCCD camera

✗ Requiring attention : observation scheme – **airspace safety** (collaboration with French Civil aviation)

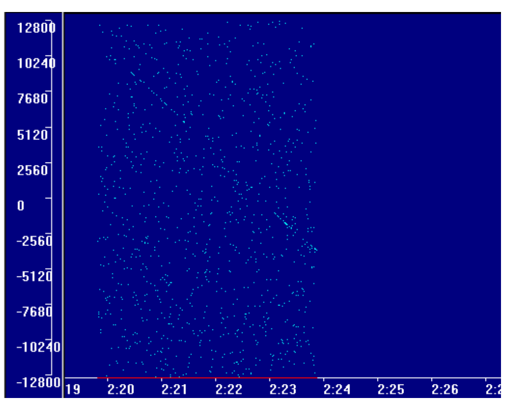


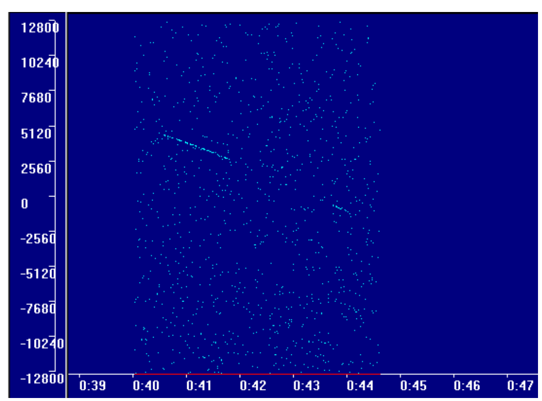
First echoes

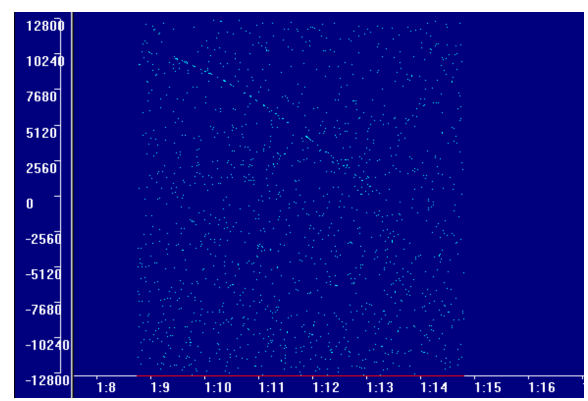


→ 10 non cooperative objects detected

Date	Name	# NORAD	Tracking start	Tracking stop	Distance min (km)
28 march	SL14	20197	2h22'12	2h35'52	1500
29 march	SL14	20238	0h20'05	0h27'48	1475
	SL14	16594	0h32'05	0h43'02	1800
	SL19	37155	1h15'07	1h24'25	1480
	SL8	14085	2h18'03	2h25'32	1170
	Ariane 40	22830	2h26'51	2h32'21	847
	SL14	19196	2h40'33	2h53'32	1520
30 march	SL14	14522	1h05'07	1h18'20	1580
	SL8	07443	2h02'36	2h16'13	1670
	SL14	16144	2h15'49	2h27'45	1700

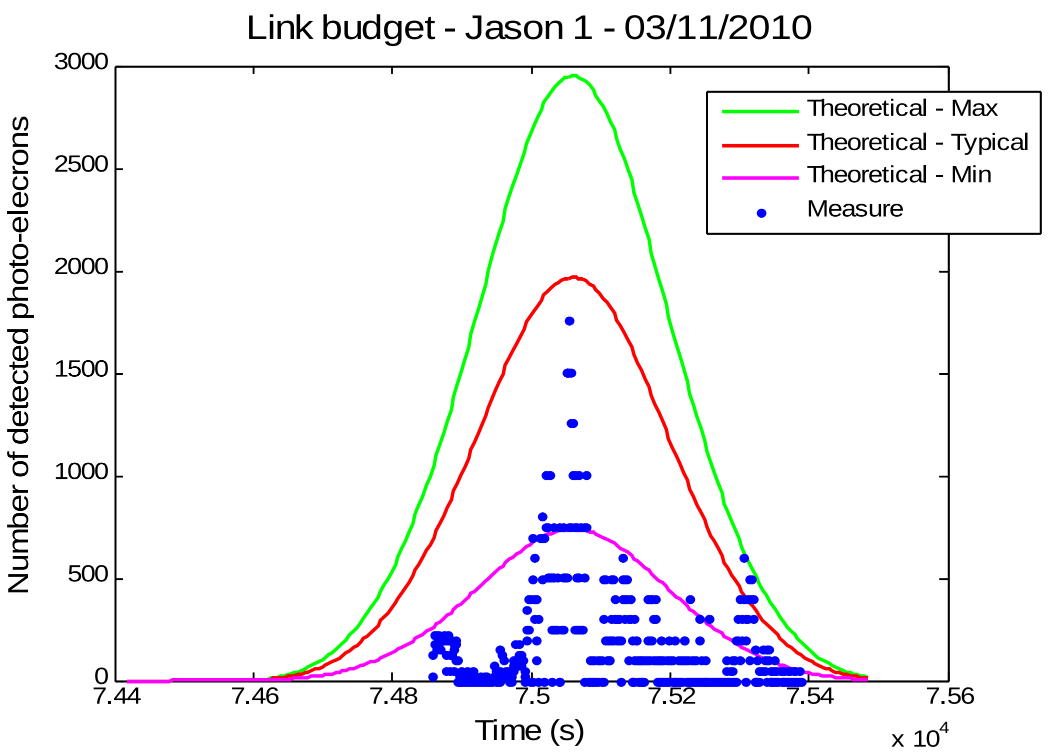






Link budget (1/3) : Validation on cooperative objects

- Measurement with the Continuum laser at **low energy** (30 mJ/pulse)
- Tracking from CPF[1] orbital data
- The OCS[2] of the cooperative objects are well known
- ⇨ **Good correspondence with the theoretical model** (radar link equation)



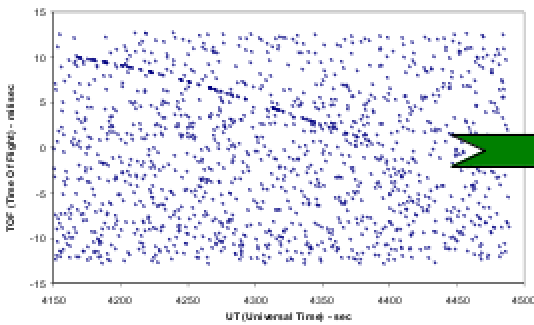
[1] *Consolidated Prediction Format provided to each SLR station by IRLS*

[2] *Optical Cross Section*

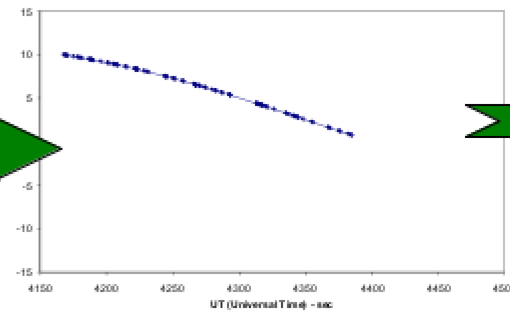
Link budget (2/3) : Validation on non cooperative objects

- From laser ranging measurements
- By photometric extraction (light curves)

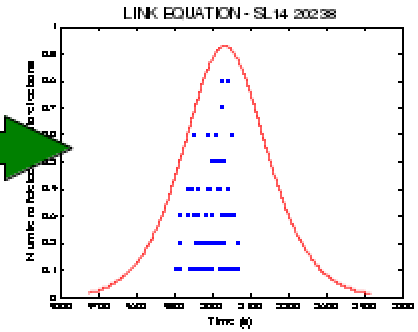
⇨ **Good correspondence between laser ranging and photometric measurements**



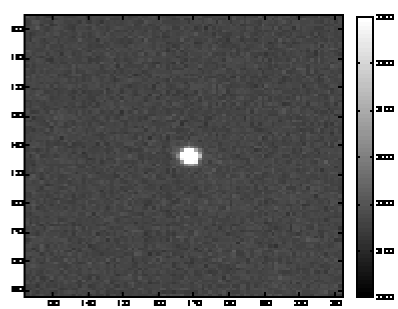
Active tracking



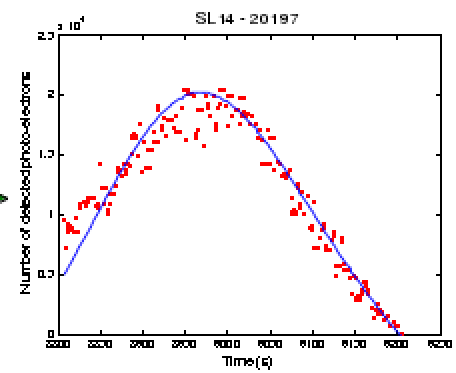
Noise extraction



Link budget



Passive tracking

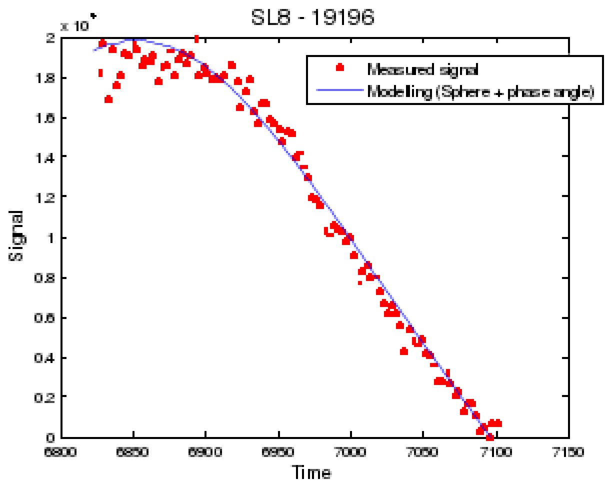


Light curve

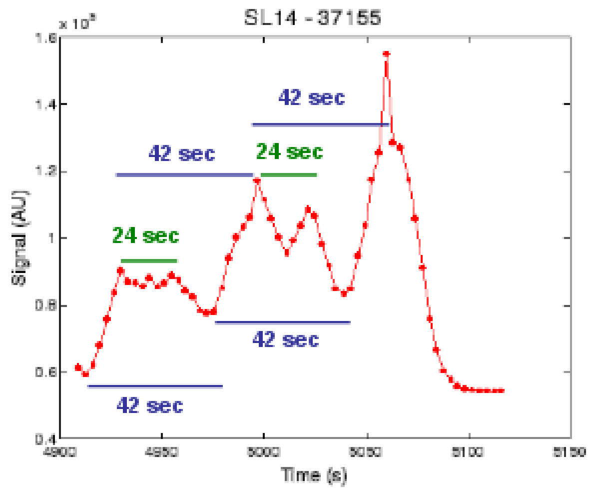
Link budget (3/3) : Conclusion

3 types of objects:

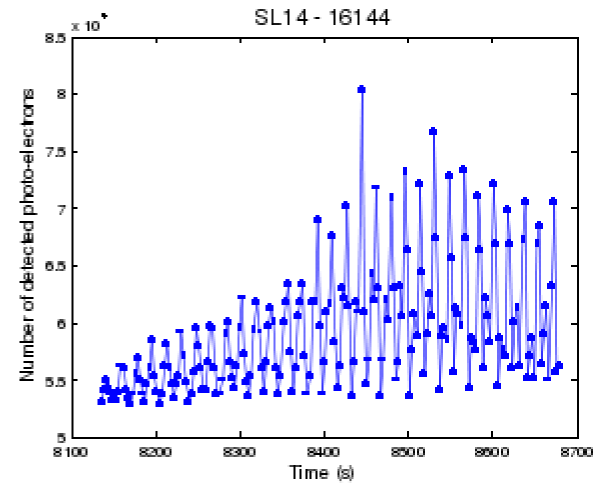
- ✓ 6 **spherical**-like objects
- ✓ 3 **cylindrical**-like objects, with 2 rotation periods
- ✓ 1 purely **spinning** object



Spherical-like behavior



Cylindrical-like behavior



Spinning object
(period = 7.2 s)

Conclusions and Next steps

- ✔ *First observations on **non-cooperatives satellites** with simultaneaous **laser ranging** technique and **optical** observations: campaigns very **successful**, good **achievements.***

- ✔ ***Issues overcomed** : energy densities manipulated, optical strength, telemetry calibration accuracy, low noise photodetection, target choice ...*

- ✔ *System can be quickly **operational** and perennial. SLR stations spread around the world => an alternative/complementary for collision avoidance.*

- ➔ ***Astrometric** measurements obtained ~2 arcsec*
- ➔ *Final **laser ranging** measurement by the end of the summer*
  - ***=> orbit computation prediction improved better than 60 % compared to passive technique***

- ➔ *Test of the robustness of the system : ranging of smaller debris*

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