



Observatoire
de la CÔTE d'AZUR

Early Satellite Laser Ranging for Geodesy at CNRS, CNES and ONERA in France; first geodetic junctions Europe-Africa. 1965-1975

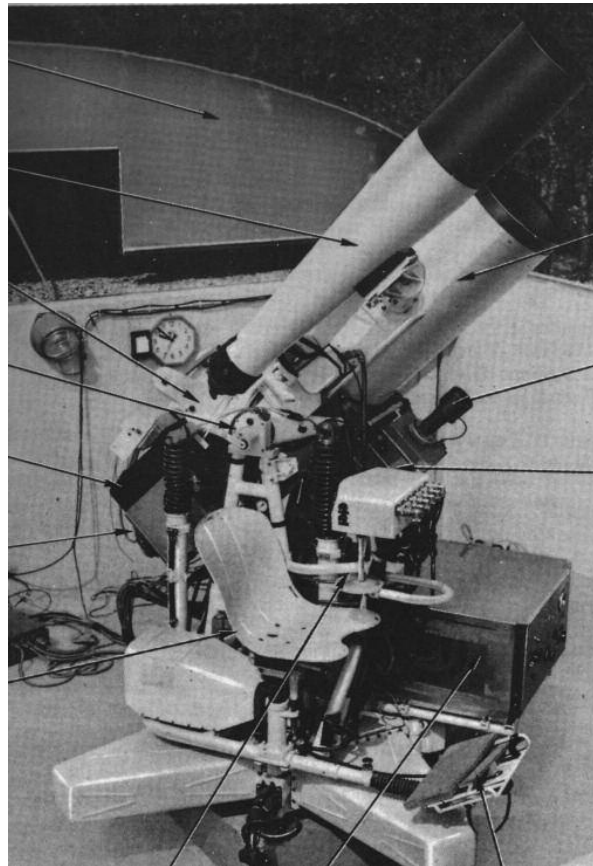
by François Barlier

Acknowledgment : the documents presented here are from the archives of the celebration of 40 years of **GRGS in 2011** and including especially presentations by Jean **Kovalevsky** , Michel **Lefebvre**, Georges **Balmino** Richard **Biancale** Pierre **Exertier** and many others. Thank you very much to everybody.





First CNES/CNRS LASER STATION in 1965



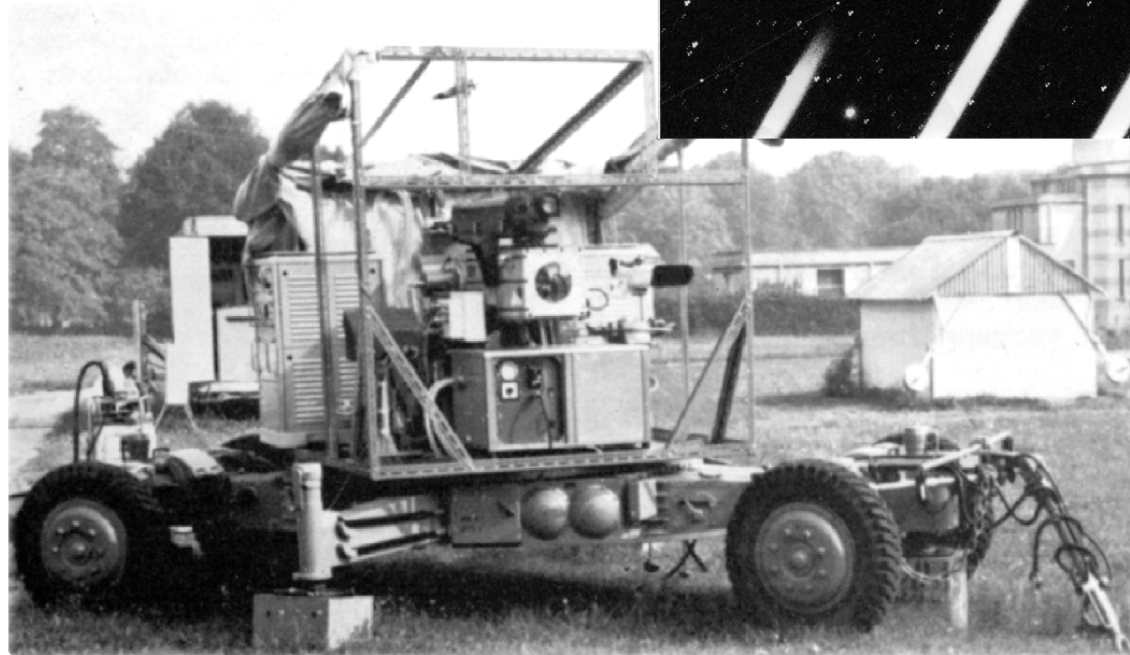


Some figures of the first CNES/CNRS laser station in 1965 First returns obtained in January 1965

- The guide telescope: 20 cm in diameter, field of view : 2.5°
- Event timer: a resolution of 10 ns
- The chronograph : a resolution of 0,1 ms
- The receiving Cassegrain telescope : 36 cm of diameter
- The laser: a ruby laser (6943 Å): triggered by a rotating prism (48 000 revs per mn)
- The energy of a single pulse: 1 joule- 25 to 30 ns width- divergence 2. to 0.5 mrad
- the detector : a photomultiplier tube cooled to - 30 °
- The turret : a military cine theodolite
- Expected Precision of a measurement : 1.2 – 1.5 m
- **A second laser station will be built up.**
- **Technical aspects**
Team in charge of technical aspects : R. and M. **Bivas**, then J.**Gaignebet** and his team (J.L **Hatat**, P. **Caumette** M. **Laplanche**.....)
- First orbit determination based on laser data ; COSPAR 1965-Mar del Plata : The precision of laser data is confirmed

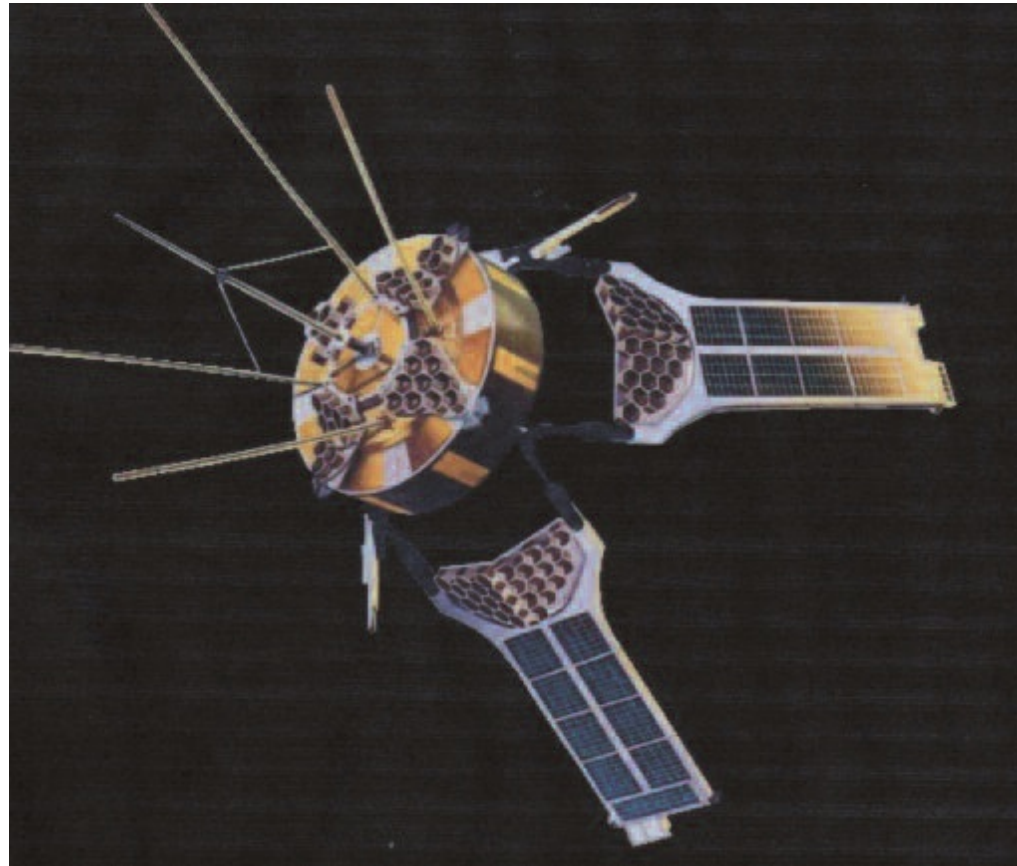
Laser returns on photographic plates of a schmidt telescope located near the laser station ONERA (Obs. de Meudon)

1967- Système Onera d'éclairage des satellites





DIADEME Satellites : D1C – D1D launched in 1967
Tracking by (LASER + DOPPLER) techniques onboard
+ B.N. (SAO)





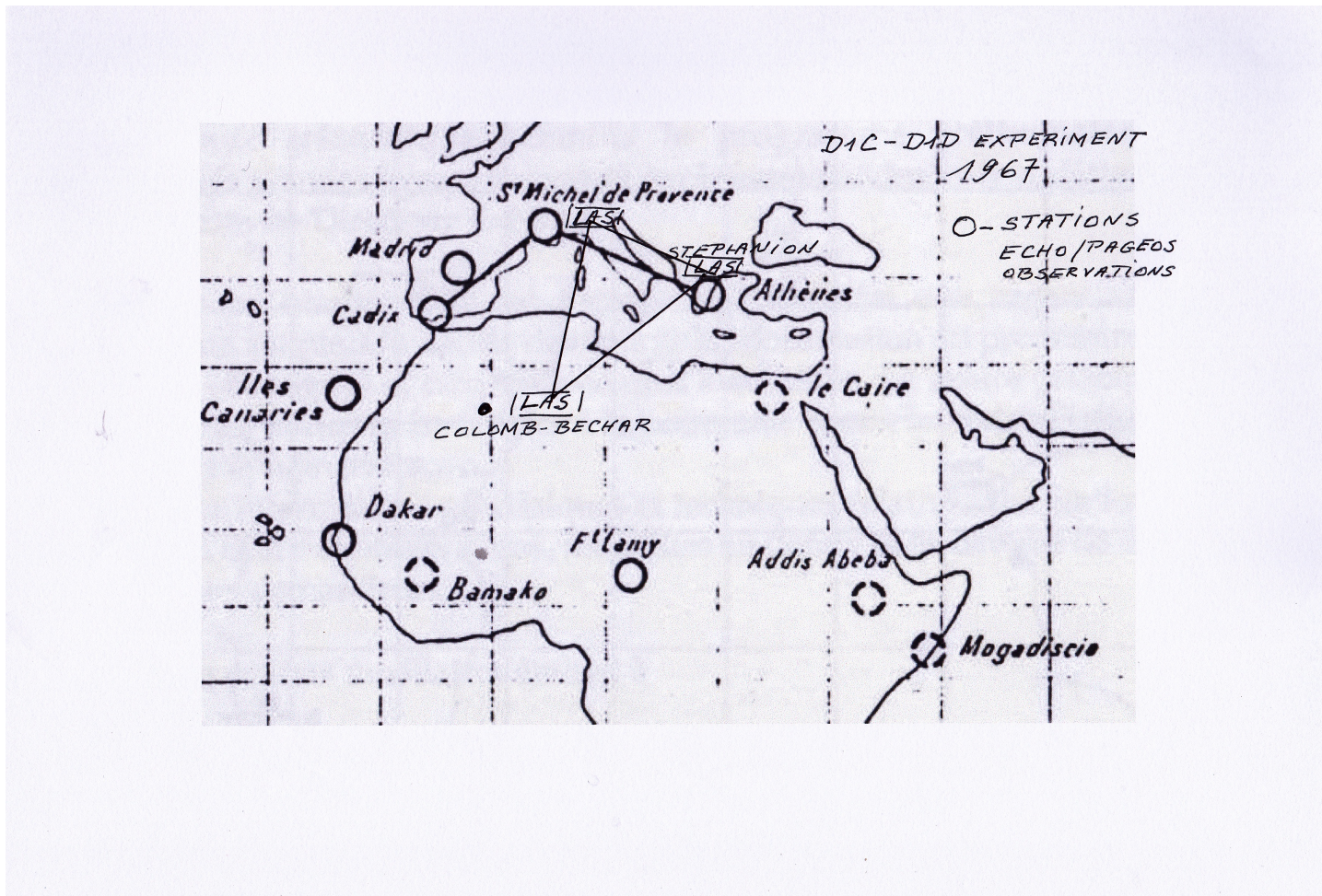
-- First Diademe (D1C- D1D) satellites campaign :

in 1967 . Satellite tracking by 3 French Laser stations (CNES/ONERA) :

CBL- HPL- STL

+(Las. Greenbelt GSFC + Las. Organ Pass SAO)

+ B.N.SAO network



Statistic : Diademe Campaign 1967

5 satellites BEB-BEC-GEOS 1- D1C- D1D : (about 80 000 echos)

	D1-D		D1-C		BEB		BEC		GEOS		TOTAL	
	<u>NE</u>	<u>OBS</u>	<u>NE</u>	<u>OBS</u>	<u>NE</u>	<u>OBS</u>	<u>NE</u>	<u>OBS</u>	<u>NE</u>	<u>OBS</u>	<u>NE</u>	<u>OBS</u>
HPL	5025	107	6871	113	2305	54	3975	50	6207	118	2483	<u>442</u> (55)
STL	10933	147	11453	138	2336	53	5685	67	7407	90	37814	<u>495</u> (76)
BCL	7785 (127)	61	4141 (92)	45	882 (62)	13	689 (57)	12	3092 (163)	19	15589	<u>150</u> (110)
TOTAL	23743 (75)	315	22465 (76)	296	5523 (46)	120	10349 (80)	129	16706 (74)	227	78785	<u>1087</u> (72)

RESULTATS DE LA CAMPAGNE DIADEME

(nombre d'échos obtenus, nombre de passages observés et moyennes par passage)



Diademe Campaign : 5 satellites (1967)
 BEB – BEC - GEOS 1- D1C -D1D
 some results

- Geodetic vectors between laser stations located in **Europe** and **Africa** (Haute Provence- HPL- Bechar -BCL, Stephanion-STL-)
- Differences in (X, Y, Z), and distance, precision : 5 to 10 meters

HPL-BCL	HPL-STL	BCL-STL
847 974 ± 5,4	75 979,5 ± 7	- 771 994,6 ± 7
- 647 267,4 ± 3,6	1 501 220 ± 5	2 188 487,5 ± 7
- 1 068 559 ± 7,5	- 518 759 ± 11	549 790 ± 12,5
1 527 486,5 ± 6,5	1 590 143,5 ± 6,3	2 384 894,6 ± 8



Origin of the Ellipsoid European Datum - ED 50 /Center of mass of the Earth
 DIADEME Campaign (1967)

Some results- comparison with **SE-I** (Standard Earth Model presented at
 COSPAR, in Vienna 1966)

Gaposchkin, E.M. (1966). Orbit determination. In: **C. Lundquist** and **G. Veis** (eds.), Geodetic Parameters for a 1966 Smithsonian Institution Standard Earth. Smithsonian Astrophys. Obs. Spec. Rep, 200, 1

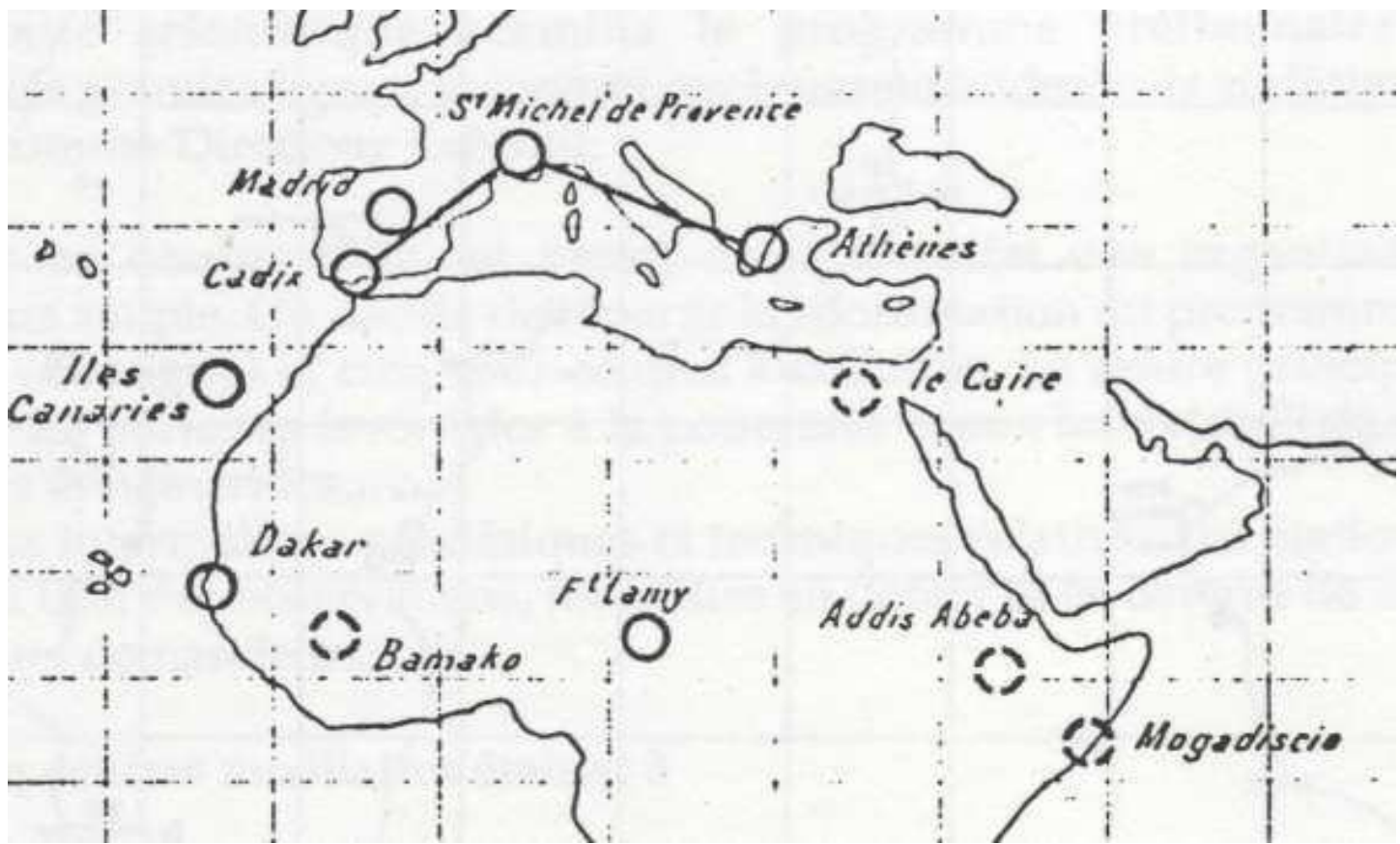
Composantes du vecteur centre de masse-centre de l'ellipsoïde Europe 50							
	Semi-dyn. Doppler	Semi-dyn. Mélange	Semi-dyn. Chassaing	Veis	Dynamique	Levallois Dufour	Levallois (1978)
ΔX	- 75	- 76	- 67	- 90	- 68	- 30	- 67
ΔY	- 131	- 131	- 128	- 133	- 126	- 100	- 114
ΔZ	- 102	- 131	- 135	- 140	- 124	- 150	- 130



GEOS-2 (With Flashes) Campaign in 1968 - SAO -

Laser SF + Laser OHP + Laser Mt Hoptkins + Laser Maui
+ Laser Greenbelt) + B.N. SAO network

Extension of a geodetic junction “**Europe –Africa**” with Pageos: Dakar- Ft Lamy
(Recherche Coopérative sur programme RCP133 J.J Levallois)



In 1968 visit at SAO

Meeting with **M.Gaposchkin**, **C.Lundquist**, **J. Rolff** ,
C.Lehr... , Scientific applications and exchange of laser data
 - Thank for the very efficient support of the SAO BN network
 Strong encouragment for cooperation of **F. Wipple**, Director



Jan. 1968

French Scientists Analyze Laser Data Here

Three French scientists associated with their country's space program visited the Observatory last month to compare observational data obtained by Baker-Nunn cameras and French-operated lasers.

Dr. Francois Barlier and M. Georges Balmino of the Meudon station of the Paris Observatory and M. Michel

Lefebvre of the Centre National d'Etudes Spatiales worked with Mike Gaposchkin and Carlton Lehr of the SAO staff.

The combined optical-laser observations were made a year ago, with lasers in France, Greece and North Africa using SAO's satellite predictions. The joint program was coordinated by Dr. J. Kovalevsky of the French Bureau de Longitudes and SAO's Jan Rolff.

Dr. Barlier and M. Lefebvre have returned to France, but M. Balmino will remain here until Spring* to continue analysis of the refine orbits.



From Left: Mike Gaposchkin, Dr. Francois Barlier, Michel LeFebvre, Georges Balmino, and Carlton Lehr.

* He actually staid the whole year
 ... and got married there!



Visit at GSFC



Goddard Space Flight Center

- In 1968 after SAO visit at GSFC by M. Lefebvre, G. Balmino, F. Barlier
Meeting with **H. Plotkin** and (laser –optical division) and **F. Von BUN**.
Exchange of D1 C and D1 D laser data- 1967 (Diademe campaign)
- In 1969 Visit at GSFC by M. Lefebvre and G. Brachet
 - Visit of the Mt Hopkins station (Laser +B.N.) organized by C.Lundquist
 - Discussion of a possible international laser campaign
 - Invitation at a symposium organized by NASA in July 1969 at Williamstown
- On this occasion ,also contacts with APL, NWL, discussions with D. Anderle, D. Cohen...,
on doppler data with **Transit satellite**, on new results on **Polar motion, LOD, Earth gravity field**,

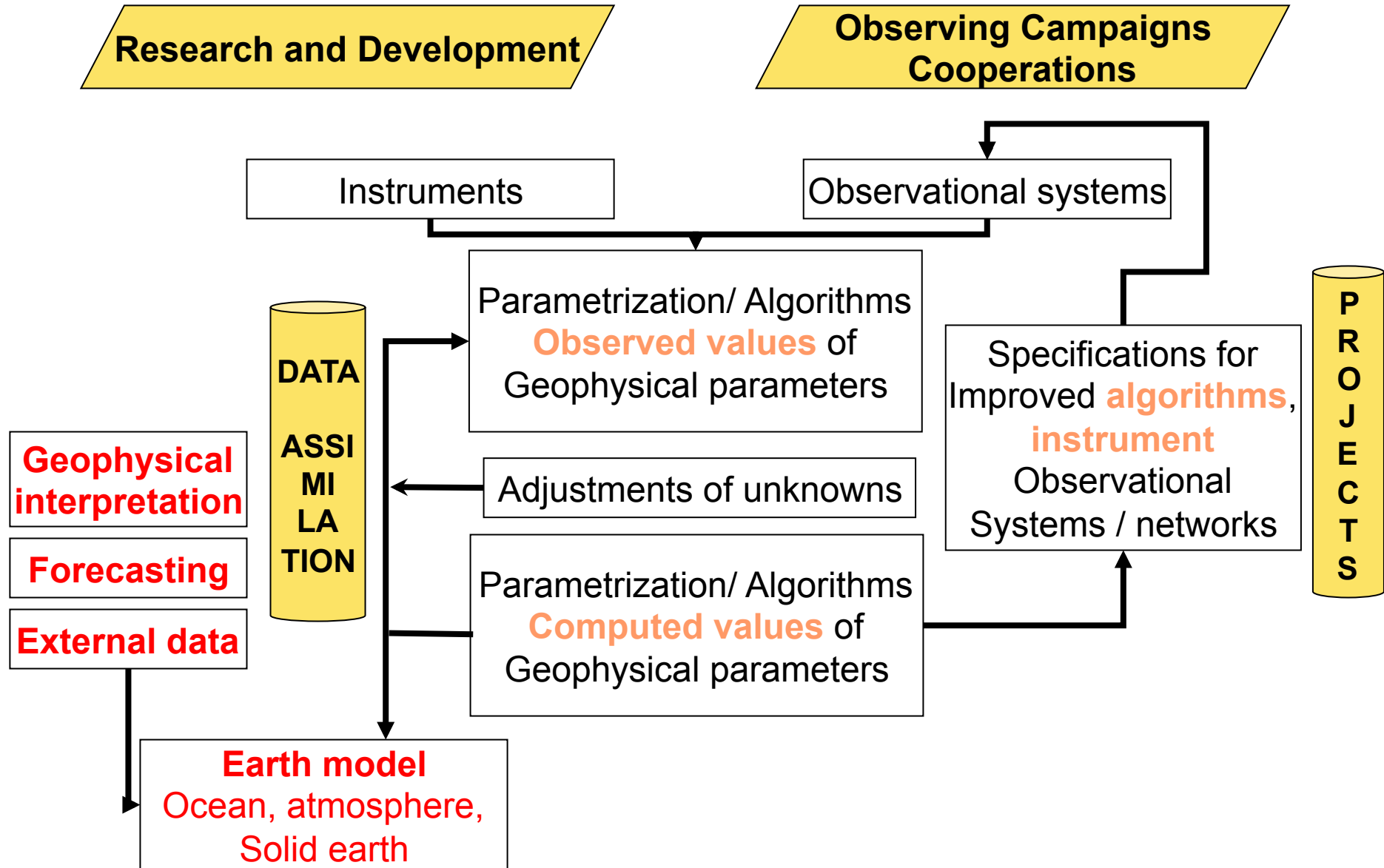
NASA Workshop in 1969 :

“Earth and Ocean Application Physics” EOPAP

- The expertise being acquired, it was time to have some perspective.
 - New projects
 - New technologies
- Chaired by W. Kaula
- Organized by C. Lundquist



Lundquist's chart
(from NASA document, 1969)





International SATellite Geodetic EXperiment ISAGEX 1971

- Projet supported by COSPAR XIII (General Assembly in Leningrad, June 1970)
- Managed by G.Brachet

- 15 countries participating :RDA, RFA, Australia, USA, Finland, France, Greece, Japan, NL, Poland, UK, Sweden, CH, Czechoslovakia, URSS,
- A main operational center : CNES Bretigny =
- 5 operational centers
Cambridge (USA –Mass) SAO (the new full SAO laser network was included)
Greenbelt (USA Maryland) GSFC
Moscow (Astr. Council)
Ondrejov (CZ East Europe)
Bretigny (France)

- On this context in December 1970 : Peole launched by CNES (inclination 15°)

- 2 CNES laser stations Dakar– San Fernando + 1 ONERA Laser station at Haute Provence

ISAGEX campaign 1971

8 laser stations + many Cameras

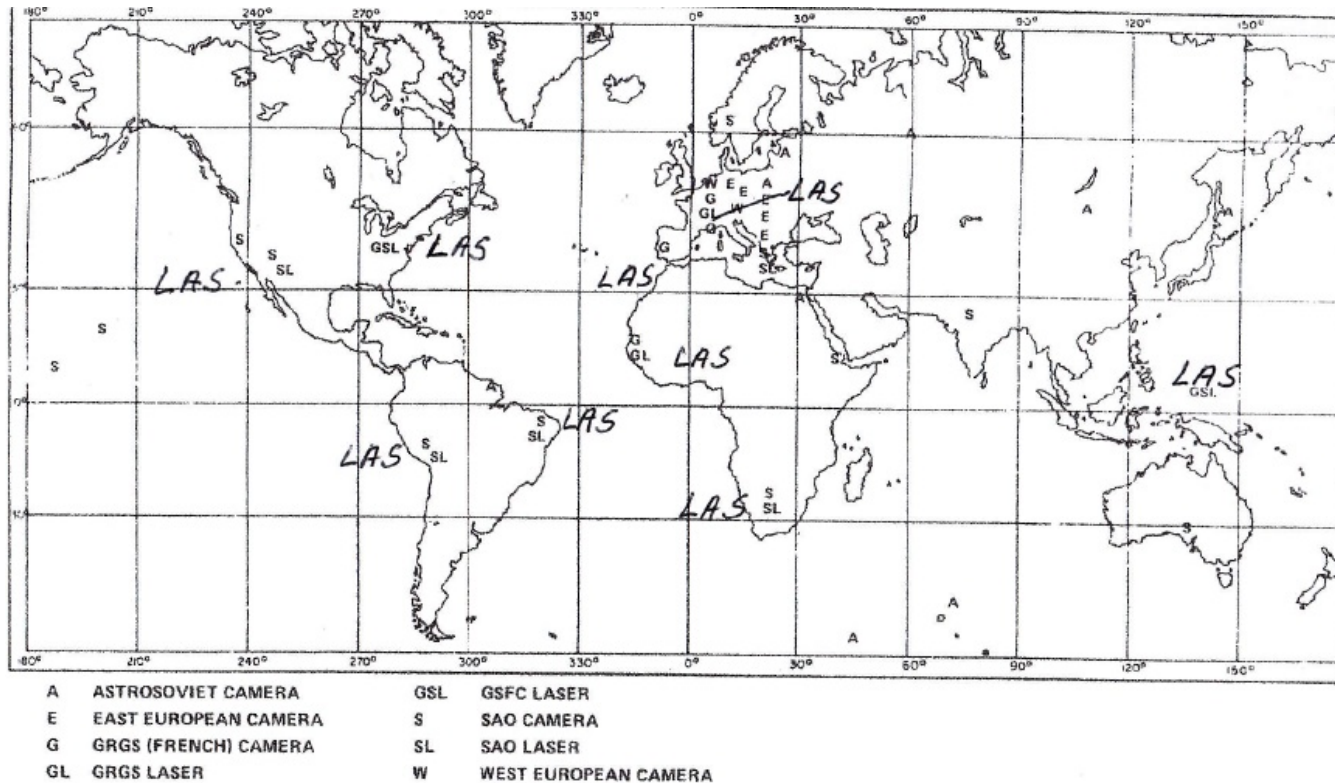


Fig. 111 Locations of Stations Which Collected Data During the International Satellite Geodesy Experiment



Extension of ISAGEX : ARCANT Campaign Geodetic Junction Arctique-Antactique in 1972 (USSR)



Earth Physics Satellite observation Campaign (EPSOC) 1972-1975

- managed by SAO –
including in 1975 (D5 B, GEOS-3)

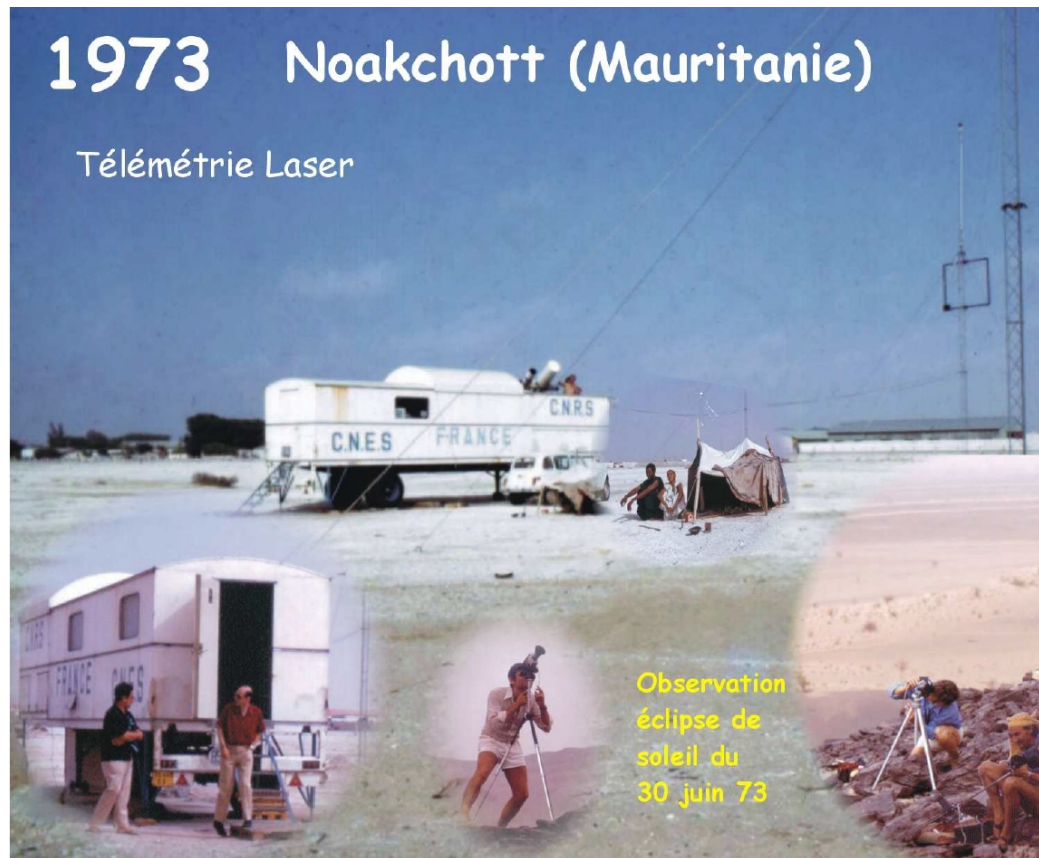
Laser station CNES (Nouakschott in 1973 then San Fernando in 1975 –Debre Zeit /
Addis Abeba in 1972) .

B.N.SAO at Ouaguadougou (1972-1975) (R.Futaully)



EPSOC Campaign 1972 -1975 (SAO)
2 CNES laser stations (Addis abebba in 1972, Nouakchott in 1973
then San Fernando in 1975)
SAO - B.N. Ouaguadougou in 1972 -1975

R. Futaully



Some results as a first conclusion

First Earth gravity field models : SE (SAO) I;II, III; GEM; GRIM models

Gaposchkin, E. M. (editor). *1973 Smithsonian Standard Earth (III)*, Smithsonian Institution, Astrophysical Observatory, Cambridge MA, Special Report 353, 1973

Pearlman, M. R., Lehr, C. G., Lanham, N. W., Wohn, J., "*The Smithsonian Satellite Ranging System*", Proceedings of the Second International Workshop on Laser Ranging Instrumentation, Prague, Czechoslovakia August 11-16, 1975 (available at the ILRS Central Bureau).

GEM : Goddard Earth Models,

GRIM : GRGS and SF878/DGFI models (European)

SAO : Smithsonian Astrophysical Observatory

models

NWL : Naval Weapon Laboratory models.

Starlette Satellite launched by CNES in 1975





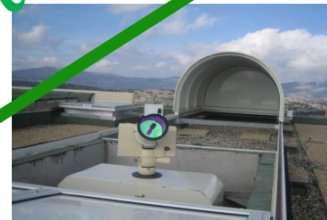
Lunar Laser Ranging in 1970 at Pic du Midi

- **First echoes on Lunokhod 1 on 5-6 December 1970**
- Lunokhod 1 lost but retrieved thanks to LRO experiment in 2010
- New returns at Calern (LLR Méo station) in 2013, **43 years** later by J-M. Torre, D.Féraudy

(See next presentation by J. Faller,)

Success of this first period linked to very good cooperations especially with SAO and GSFC

Thank you, Mike Pearlmann, for having organized this historic session



L'Observatoire géodésique de Tahiti



Station mobile sur le site d' Ajaccio

Merci de votre attention