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

Historical perspectives, session 02, 3108

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Abstract. *Following the work of Alfred Kastler (Nobel Prize for Physics, 1966) on the "optical pumping" in the 1950s, new work began in France in the early 60s to develop lasers invented by Thomas Maiman in the USA (1960). In 1963, H.H. Plotkin announced the upcoming launch of the BEB satellite with laser retroreflectors on board, inviting organizations interested in participating to this experiment. The first echoes were obtained in January 1965. In 1967, CNES (the French Space Agency) launched two satellites called Diademe D1C and D1D with laser retro reflectors and radio tracking on board. NASA also launched several American satellites. International campaigns were then organized to track all theses satellites and to establish a global terrestrial reference system and to determine the Earth gravity field. We review these historical aspects and we briefly describe the increasing amount of contributions of the laser technique to applications of space geodesy for Earth sciences.*

Introduction

Following the work of Alfred Kastler (Nobel Prize for Physics, 1966) on the "optical pumping" in the 1950s, new work began in France in the early 60s to develop lasers invented by Thomas Maiman in the USA (1960). In 1963, at the Third International Quantum Electronics conference held in Paris, H.H. Plotkin announced the upcoming launch of the BEB satellite with laser retroreflectors on board, inviting organizations interested in participating to this experiment. This proposal was extremely well received in France by the Service Aéronomy headed by J.E Blamont. The implementation and development of a telemetry station was entrusted to R.Bivas. The first echoes were obtained in January 1965.

In 1967, CNES launched two satellites called Diademe, D1C and D1D with laser retro reflectors and radio system tracking on board. NASA also launched several American satellites. International campaigns were then organized to track all theses satellites and to establish a global terrestrial reference system and to determine the Earth gravity field. The French teams actively participated to these campaigns. They started to develop specifically a geodetic junction Europe-Africa based on Diademe satellites observations. Then in 1968 SAO sponsored a campaign around the new GEOS 2 satellite. Another satellite was launched by CNES (Peole) in 1970 at a very low inclination. In this context French teams promoted specifically an international campaign based on the tracking of satellites by the laser technique, ISAGEX (1971). This campaign will be followed by the EPSOC campaign sponsored by SAO. Finally a spherical dedicated geodetic satellite, Starlette, covered with retro reflectors will be launched by CNES in 1975.

A group of research was established in 1971 in France to exploit from a scientific point of view all these data (Groupe de Recherche de Géodésie Spatiale, GRGS) and to develop European cooperation in particular with the Munich University (DGFI). Visits at SAO and Goddard Space Flight Center were extremely fruitful to develop cooperation in the laser and radio tracking techniques. Being invited for attending the Willamstown workshop in 1969 (J.Rosenberg

NASA), it was very beneficial for contributing later to the application of space geodesy to geosciences including altimetry for oceanography.
A specific geodetic and geodynamic observatory was created near Grasse in France in the early 70s (CERGA) including the development of SLR and LLR stations. Very good cooperation in this field was also established in Europe with regular seminars in Luxembourg.
A French team participated also to the Lunar Laser Ranging experiment at Pic du Midi in 1970. First returns were obtained by A. Orsag and O. Calame on the Lunokhod 1 panel on December 6, 1970 (made in France and launched by the USSR). Lunokhod 1was lost then retrieved thanks to the American LRO experiment in 2010 and new returns were obtained at Calern (LLR/Méo station) in 2013, 43 years later by J-M. Torre, D. Féraudy.

Operations

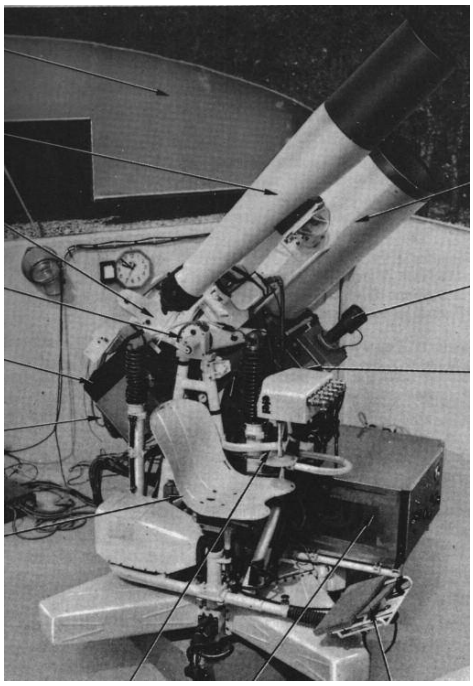

Figure 1. First CNES-CNRS laser station.

First returns were obtained in January 1965. See on Figure 1 the first CNES/CNRS laser station, equipped with :

- a guide telescope: 20 cm in diameter, field of view : 2.5°;
- an event timer: a resolution of 10 ns;
- a chronograph : a resolution of 0,1 ms;
- a receiving Cassegrain telescope, 36 cm of diameter;
- a laser: a ruby laser (6943 A): triggered by a rotating prism (48 000 revs per mn).
- The energy of a single pulse: 1 joule - 25 to 30 ns width- divergence of 2 to 0.5 mrad ,
- the detector a photomultiplier tube cooled to – 30°.
- the turret : a military cine-theodolite.
- Expected Precision of measurement : 1.2 -1.5 m.

A second laser station will be built up a little later.
Team in charge of technical aspects was: 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 of 1.2 m was confirmed.

First Diademe (D1C- D1D) satellites were launched in 1967 and geodetic campaign started in 1967. Satellite tracking was performed by 3 French laser stations (CNES/ONERA): CBL (Algeria) – HPL (France) – STL (Greece) + 1 Laser at Greenbelt (GSFC) + 1 Laser at Organ Pass (SAO) + the Baker Nun SAO network + the Antares camera Nice in France. A purpose was to realize a geodetic Europe-Africa junction.
During the Diademe campaign in 1967 5

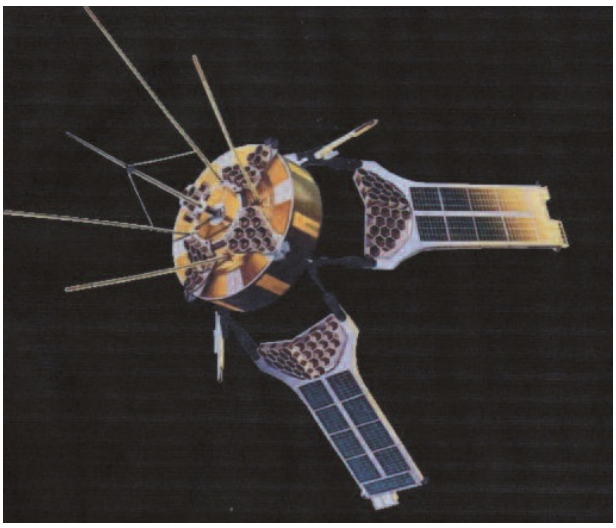

Figure 2. Diademe geodetic satellite D1C and D1D.

satellites BEB-BEC-GEOS 1 (with optical flashes observed thanks to a Schmidt telescope)- D1C- D1D were observed: (about 80 000 echoes).

Cooperation Phase

In 1968 visit at SAO: Meeting with M. Gaposchkin, C. Lundquist, J. Rolff , C. Lehr... , for discussions on scientific applications and exchange of laser data. On this occasion many thanks for the very efficient support of the SAO BN network. Strong encouragement for cooperation was given by F. Wipple (SAO Director).

In 1968 after SAO visit at GSFC by M. Lefebvre, G. Balmino, F. Barlier. Meeting with H. Plotkin (laser-optical division) and F. Von BUN. Exchange of D1 C and D1 D laser data (1967 Diademe campaign) was made.

In 1969 Visit at GSFC by M. Lefebvre and G. Brachet. Visit of the Mt Hopkins station (Laser +Baker Nunn.) was organized by C. Lundquist with discussion of a possible international laser campaig. Invitation at a symposium organized by NASA in July 1969 at Williamstown was made. On this occasion also contacts were made with APL, NWL with discussions with D. Anderle, D. Cohen on doppler data with Transit satellite and on new results on Polar motion, LOD, Earth gravity field obtained with these satellites.

Some results from Diademe campaigns

Geodetic vectors between laser stations located in Europe and Africa (Haute Provence- HPL- Bechar -BCL, Stephanion-STL-) were computed. Differences in (X, Y, Z) and distance were obtained with a precision of 5 to 10 meters. Origin of the Ellipsoid European Datum-ED 50 /Center of mass of the Earth was determined with the same precision.

Comparison with SE-I results (Standard Earth Model presented at COSPAR, in Vienna 1966 by Gaposchkin, E.M. (1966) was made. SE-I results can be found in: C. Lundquist and G. Veis (eds.), Geodetic Parameters for a "1966 Smithsonian Institution Standard Earth"; Smithsonian Astrophys. Obs. Spec. Rep, 200, 1.

The cooperation with NASA, SAO, APL

We attend the NASA Workshop in July 1969 dedicated to Earth and Ocean Application Physics.

NASA Workshop in 1969:

"Earth and Ocean Application Physics"

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

the SAO NEWS

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!

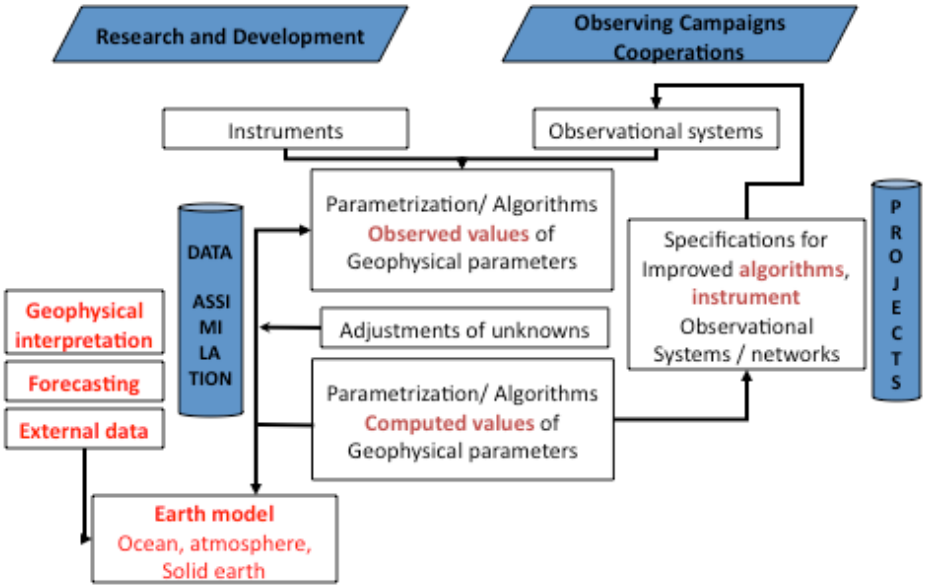

Figure 3. Lundquist's chart, from NASA document, 1969.

ISAGEX EXPERIMENT : International Satellite Geodetic Experiment

A new project supported by COSPAR XIII (General Assembly in Leningrad, June 1970) and managed by G.Brachet was developed including 8 SLR stations for the first time.

Around 15 countries were participating: RDA, RFA, Australia, USA, Finland, France, Greece, Japan, NL, Poland, UK, Sweden, CH, Czechoslovakia, URSS. There were 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 was launched by CNES (inclination 15°). 2 CNES laser stations in Dakar and in San Fernando thanks to a very good cooperation with Spain +1Onera Laser station at Haute Provence were participating as well as 4 SAO laser stations and 1 GSFC laser station.

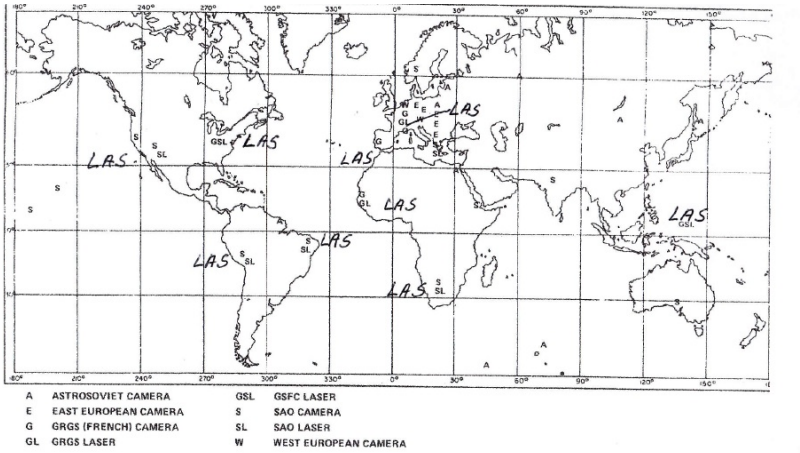

Figure 4. Locations of Stations which collected Data during the ISAGEX campaign.

Extension of ISAGEX: ARCANT Campaign. A geodetic Junction Arctic-Antarctic in 1972 was managed by USSR. A French laser station was installed at Oujgorod.

A Earth Physics Satellite observation Campaign (EPSOC) 1972-1975 was managed by SAO including with its own network, 1 CNES laser station (at Nouakchott in 1973 then at San Fernando in 1975 in an excellent cooperation with our Spanish Colleagues) and 1 CNES laser station at Debre-Zeit /Addis-Abeba in 1972. This campaign was extended in 1975 to the observation of the American GEOS-3 satellite with an altimeter for oceanography and of the CNES D5 B satellite (CASTOR satellite with a very precise micro-accelerometer CACTUS on board, the beginning of a series used for gravity field determination); for that a B.N. station was installed in Ouagadougou managed by R. Futaully.

New results and improvements

New models were developed by several institutions, SE models, GEM Goddard model, GRIM model (German SFB78-DGFI Institute and CNES/GRGS) and NWL model. A new generation of SLR stations was prepared with a decimeter precision; in France it was at CERGA.

Acknowledgment

The document and figures presented here are from the archives of the celebration of 40 years of GRGS in 2011 and including especially presentations by J. Kovalevsky, M. Lefebvre, G. Balmino, R. Biancale, P. Exertier who also thanks to his support makes this presentation at the 19th workshop possible and many others. Thank you very much to everybody. Success of this first period is linked to a very good cooperation especially with SAO and GSFC and also in Europe. Thank very much to Mike Pearlman for having organized these historical perspectives.

References

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