23 years of SLR in Santiago de Cuba, Cuba (1977-2000)

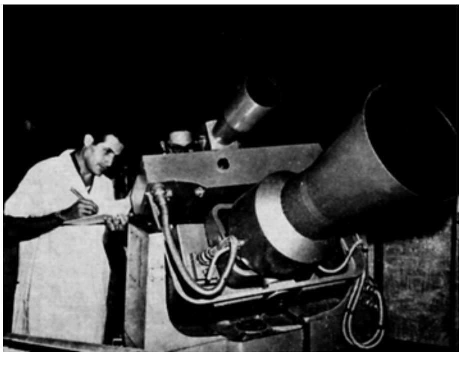
Station 1753, 24 years of photographical observations (1967-1991)

In 1966 several places in Cuba were explored by a USSR Academy of Sciences team in order to install several Satellite Photographical Stations as part of the Soviet Satellite tracking network. Two Stations were installed in Cuba, one near Havana (later closed due to bad sky conditions) and in a place on the outskirts of Santiago de Cuba, 5 km from the city center.

Early 1967:	Preliminary observations doing classical astronomical, visual tracking and photos with a 50 cm focal length camera in order to define preliminary coordinates and confirm favorable conditions for observations.
Early 1968:	Installation of the standard soviet satellite photographic camera AFU-75, the original exemplar operated until 1975 then exchanged with a newer exemplar.
1978:	First 1953 coordinates determination solution using 1974 observations (σ~25 m).
1977-1986:	Parallel operation with the SLR system 1853.
1985-1987:	Parallel operation with the SLR system 1953.
1987-1991:	Used only to monitor the Geostationary Band, during equinoctial periods.
Early 1991:	Ceases operation as part of the closing of the Soviet photographic Network.
1999:	AFU-75 camera shed disassembled.

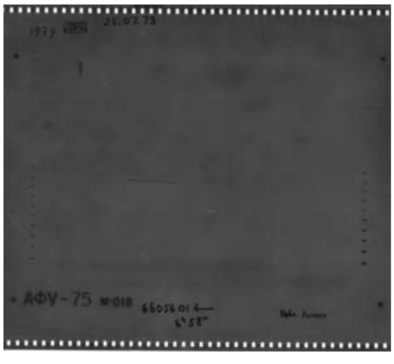
Technical information:

- The ephemeris were calculated in Moscow several months in advance and sent via normal post.
- Regular observation of all standard satellites including the Echo and Pageos balloon satellites.
- A monthly report of the photos taken, including satellite, epoch and photo quality sent to Moscow and requested negatives were sent several months later via post.
- Measurements and data reduction was carried out in the Soviet Union.
- The time service for the preliminary astronomical and visual observations was a maritime chronometer, manually synchronized to the WWW station signal in Boulder, Colorado at 20 MHz
- Time service for the AFU-75: quartz clock synchronized with the WWW station in Boulder, Colorado several times a day for drift compensation via short wave radio.
  Timing error less than 100 mS.



AFU-75 camera (1970)

Time Service Room



AFU-75 Negative

Station 1853, The First SLR system in Santiago de Cuba (1977-1985)

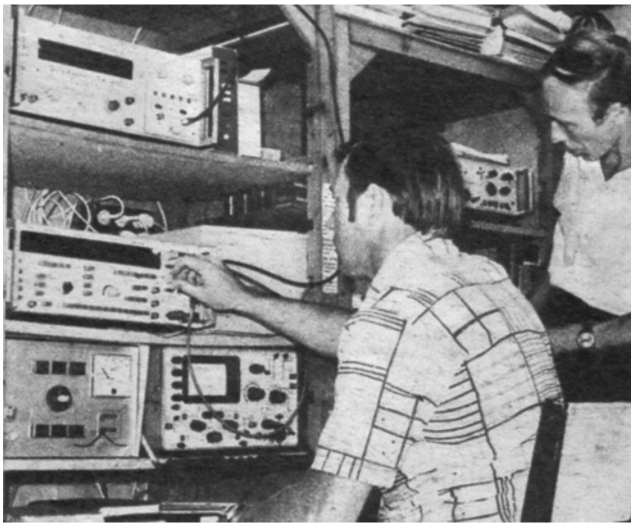
June 1975:	A survey team from the Prague Czech Technical University (Karel Hamal team leader), visit several places in Cuba, to select a place for the Interkosmos first generation SLR system.
October 1975:	The Satellite Photographical Stations 1753 is selected as the place.
Summer 1976:	The Cuban operators are trained in Prague.
Early 1977:	A dedicated housing is built on the Station Building roof
June 1977:	The SLR system is assembled in Cuba, operations starts few weeks later.
1983:	The system is modified with a bigger guidance telescope and laser collimator, following the idea of the Simeiz station. Lageos tracking by night in optimal condition is possible, a few passes done.
1985:	With the entrance in operation of the 1953 SLR, the system ceases operation. The ruby laser is donated to the Santiago de Cuba University Sciences Faculty.
mid 1990's	The SLR housing was used for hosting the first GPS receiver in Cuba, a GFZ-owned Trimble 4000 receiver
1999:	The housing dismantled in 1999.

Technical information:

- 4-axis hand controlled mount, along-track following control done via potentiometer on motor, cross track following done manually.
- Analogue range gate generator on the mount, setting one using 3 values for 3 along-track positions.
- Czech-built, multimode Ruby Q switched (using a rotating mirror) laser, 25 nS, shooting on demand by the operator, (later at a fixed 0.5-Hertz rate). Two operators crew
- Observations only possible by night, with satellite illuminated.
- Initial time service shared with the AFU-75 system, later a Cuban built Loran-C steered quartz receiver is used, Timing error ~10 µS, signal propagation delay measured using a HP cesium clock from the Czech Technical University.
- **No computer capability available in all Santiago de Cuba!**
- **No real time communication available.**
- The ephemeris were calculated in Moscow several months in advance and sent via normal post.
- Measurements (TOF/epoch) printed on a 16-character paper tape printer.
- Local data analysis: A TOF/time plot done manually!
  Measurements falling into the predicted parabola, hand transcribed to programming formulary and sent via post to Moscow.
  Practically no feedback if passes were successful or not.
- Simultaneous Photo/SLR observations were carried out, in particular with the visually bright satellite Bulgaria-1300 (Interkosmos 22) during 1981-1982.

June1977 SLR assembly
(SLR housing, the white one with red star on door)

June 1977, SLR Assembly



SLR control room circa 1890

1985 SLR housing, (right, Loran-C antenna)

1977 Mount configuration

1984 Mount configuration

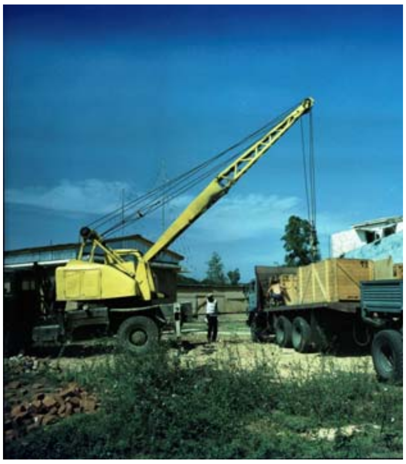
Station 1953, A Fully operational SLR -The Ruby Years- (1985-1993)

Autumn 1980:	Proposed, in the frame of the Interkosmos program, to build a duplicate of the Potsdam SBG camera-based Station 1181 in Santiago de Cuba. Project partners were ZIPE (GDR), Astrosoviet (USSR) and IGA (Cuba). Team Leader will be Dr. R. Neubert (ZIPE).
1981-1982:	Preliminary design and procurement work.
1983:	Modification of the SBG camera to be sent to Cuba is carried out at Carl-Zeiss Jena, GDR. The ruby laser system, (5 nS running at 1/6 Hz) and main electronics are built in Potsdam, The software set running on the 8 kb EMG/666B programmable calculator is written in Potsdam/Cuba. All components checked for operation in Cuba's 110 V/60 Hz.
1984:	System assembly and component testing in Jena and Potsdam.
January-June 1985:	SLR Building completed in Cuba, System disassembled and sent to Cuba by cargo ship.
June-November 1985:	System fully assembled, and tested.
December 1985:	First observations carried out including a first Lageos-1 pass.
December 1985-Early 1986:	First tracking campaign, more than 42 Lageos passes. First 1953 coordinates determination using SLR data carried at ZIPE, Potsdam GDR.
Late 1986-1987:	Second tracking campaign. The EMG/666B programmable calculator is upgraded with and 16 kb external RAM. Additional software for blind tracking is written. On the first version, the star identification for the mount modeling is done against a printed catalogue and keyed in manually!
1987-1992:	Start of regular tracking. Collocation experiment with a Doppler Magnavox Receiver as part of the Interkosmos IKDOK campaign.
1987-1990:	First experimental night blind tracking passes. First Etalon-1 tracking (3 passes in 1989)
1990-1992:	Partial hardware Upgrade: A new time service using a single frequency GPS Austron clock. A 286 DOS PC (16 MHz CPU, 32 kb ram, 40 Mb HD) with an IEEE-488 card replaces the programmable EMG/666B calculator. The tracking software is re-written using PowerBasic 3.0. Full night blind-tracking capability, limited to about 6-7 passes per night, a full mount model determination needed for each pass. A few test daylight passes (only one per day) carried out. Participation on the preparatory tracking of Mir Station for the ERS-1 campaign. Regular Tracking of ERS-1
1992:	The INTERKOSMOS association disappears. A cooperation agreement on the operation of the 1953 SLR station is signed between the newly founded centers GFZ (Germany) and CENAIS (Cuba). 1953 start participating in Eurolas
April-May 1993:	The Ruby configuration ceases operation. Full upgrade to a 10 Hz NdYag laser based configuration

Technical information:

- The SBG 4-axis computer controlled mount, 3rd and 4th axis moves using digital stepper motors and encoders connected to the controller.
  1st and 2nd axes setting done manually, fine setting of the 2nd and 4th axis using a theodolite level.
- Single mode Ruby laser, dye Q-switched, 5 nS, operating at 1/6 Hz rate, firing moment computer controlled. The laser designed and built by Dr. L, Grunwaldt at ZIPE, Potsdam.
- Manual laser beam divergence setting at the laser collimator for each satellite pass.
- Polish Time Interval Counter PS-500, resolution better than 100 pS.
- Start PD on the laser head, and PMT mounted on the backside of the main mirror.
- Visual guiding possible using the guiding telescope or at the main mirror, a pass-band filter permits sharing the between the PMT channel and the visual one.
- Initial observations only possible by night, with satellite illuminated. Single operator operation possible.
- 1985-1991 time service: A Cuban built Loran-C steered quartz clock,
  Timing error ~1 µS,
  The Loran-C signal propagation delay measured several times during the period 1985-1990 using flying Rb, Cs and H-maser clocks from the Cuban and Soviet Time services.
  An experimental time service using the TV signal tested between the Cuban Time service in Havana and the SLR station.
- 1991-2000 time service: An Austron GPS single-frequency steered quartz controlled clock.
- 1985-1991: a Hungarian programmable calculator EMG-666B used as controller, a similar model was used at the SLR station 1181 Potsdam
  Main parameters:
  Main Memory (sharing software and data): 8 kb. 16 kb of hard wired subroutines in EPROMS
  Mass storage using audiotape. Serial parallel interface similar to IEEE-488
  Hard output: 5-hole paper tape puncher and reader, a 16-character wide paper printer, a telex machine was used as a secondary printer.
- From 1991: a 286 PC
  PC parameters:
  CPU at 16 MHz, 32 kb Ram, 40 Mb HD with an IEEE-488 card.
  Running under DOS, PowerBasic 3.0 using as programming software.
  A 24-pin printer and 5-hole telex tape reader/puncher as data I/O interface.
- International communication using telex (situated on the city at about 3 km from the 1953 building). Normal points sent every Monday at about 13 UTC, orbital elements (SAO format) received during the same communication season. Data transfer using 5 hole paper telex tape.
- No phone connection at the observatory!
- For the first time local data filtering, time bias analysis and NP generation, fast feedback of the tracking results is now possible, increasing the efficiency.

Testing the Electronics in Potsdam (1985)



Summer 1985, arrival of the SLR boxes

Assembly of the SBG system

SBG mount with ruby laser

Control Room circa 1985

The Ruby Laser

External View

Control Room circa 1991

Part of the tracking crew

Station 1953, Upgrading the SLR -The NdYAG Years- (1993-2000)

In order to support the ERS-1 tracking; the GFZ-sponsored DARA project **50 ee 9219 "ERS-Lasertracking Santiago de Cuba"** was approved and carried out during 1993-1996.

January-May 1993:	Software upgrade for the operation at 10 Hz of the PowerBasic/DOS tracking suite. Procurement of the new hardware.
May-June 1993:	Hardware upgrade carried out in Santiago de Cuba New laser system (3-5 nS pockels cell Q-switched, 10 Hz NdYAG laser from Spektrum gmbh, Berlin.) New event timer Stanford 620. Installed the upgraded software.
1993-1999:	Participation on all international tracking campaigns, in particular ERS-1 & -2, GFZ-1 and Topex-Poseidon. Record observation number in one year, over 600 passes in 1996. Telex service stopped in 1994. A new automatic meteorological station from Timetech, Germany.
1995-2000:	Parallel operation with a GFZ-owned GPS Trimble receiver, after 1998, the receiver exchanged for an Ashtech ZXII.
1990-2000:	Because of technical obsolescence, High RMS, impossibility of laser upgrading due of the lack of a coudé focus on the SBG system, low possible maximum yearly amount of passes and the impossibility of regular daylight tracking, the station 1953 stops operating,

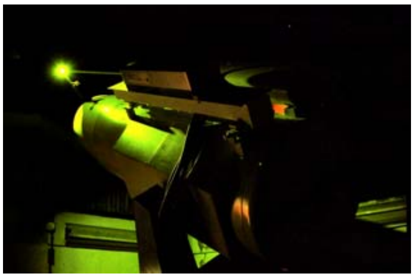
Technical information:

- The SBG 4-axis computer controlled mount, 3rd and 4th axis using digital stepper motors and encoders. 1st and 2nd axis setting done manually.
  The use of a pass-by-pass mount model using star observations simplifies the 2nd and 4th axis setting, no fine setting using the theodolite level needed.
- Visual guiding possible but rarely used. Guide and Main Mirror oculars used only for the single pass mount model determinations.
- Single mode 3-5 nS pockel cell Q-switched, 10 Hz NdYAG laser from Spektrum gmbh, Berlin.
- Remote controlled divergence setting from the laser control unit for each satellite pass.
- Stanford Research 620 time Interval Counter, external frequency from the Time Service.
- Austron GPS single frequency, quartz controlled clock as Time Service.
  An EFRATOM external 10 MHz Rb frequency standard can be used as external 10 MHz source.
- Pentium PC running at 50 MHz, 128 kb Ram, 400 Mb HD with and IEEE-488 card.
  Programming using PowerBasic 3.5 on DOS 5 OS.
- CD burner and external 100 Mb ZIP driver as external mass memory.
- Email connection (or direct point to point connection with GFZ-Potsdam via international phone at up to 14400 bps) available at Santiago de Cuba city.
  Data transfer between the observatory and the city connection point by floppy disk.
- Time bias calculated at the station and shared with station 7836 Potsdam via email, by using the same algorithm, a time bias prediction formula it's software implemented in both stations increasing the pointing efficiency.
- Phone connection installed in the final months of 1999.

10 Hz system in operation

Control room circa 1994

Sprektrum NdYAG laser



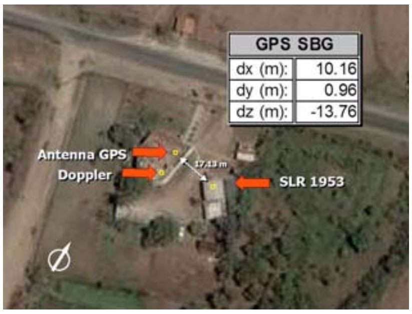
Target Calibration

Alignment Test using a target at about 1.5 km.

The European Space Agency
presents
on the occasion of the first two years of successful operation of ERS-1
this
ERS-1 Laser Tracking Award
to the
SLR Station Santiago de Cuba
operated by
CENAIS, Cuba and GFZ, Germany
For significant contributions to the laser tracking of the first European Remote Sensing Satellite ERS-1, in support of high precision orbit determination of the spacecraft and optimal use of the Radar Altimeter for the ERS-1 Oceanographic Mission.
esa
ESA Director General

ERS-1 tracking

A view of the station with the systems locations



Google Earth view

1953 from the GPS pillar