

Recent Experience in Operating the First Quantum and Optical System of Satellite Laser Ranging Installed in Brazil

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UnB

OJC - RPC - PSI,
Moscow - Russia



UN/Russian Federation Workshop on Applications of GNSS

IEBC, Krasnoyarsk, Russia

May 18th – 22nd, 2015

Timeline Overview

- 2006 Brazilian and Russian governments signed an agreement to install GLONASS reference and monitoring stations in Brazilian territory;
- 2012 Brazilian Space Agency elected University of Brasilia to receive the first station;
- 2013 GLONASS Differential Correction Station start operation;
- 2014** GLONASS Quantum Optical Station start operation.



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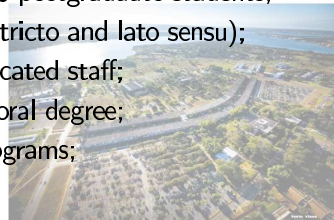
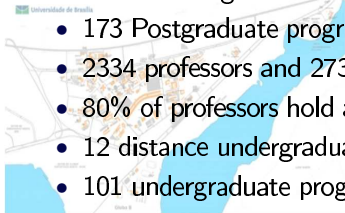
Brasília city



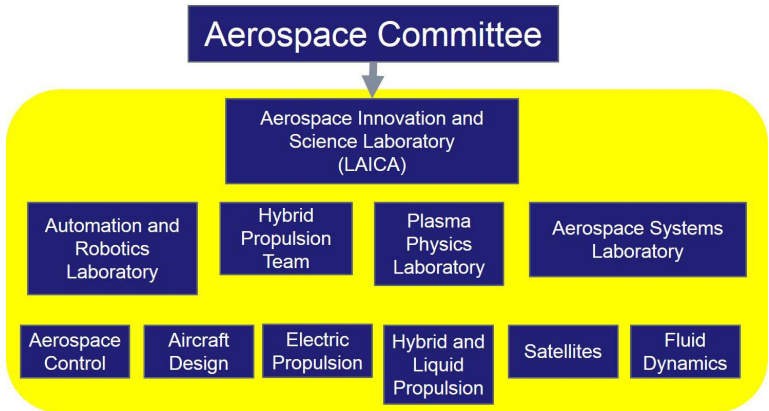
UnB in numbers

- 45152 undergraduate and 8019 postgraduate students;
- 173 Postgraduate programs (stricto and lato sensu);
- 2334 professors and 2738 dedicated staff;
- 80% of professors hold a doctoral degree;
- 12 distance undergraduate programs;
- 101 undergraduate programs;
- 20 Research centers;
- 26 Faculties;
- 4 Campuses;

⇒ 238 agreements with universities from 50 countries and International Organizations.



Aerospace Administrative Structure



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Compact Laser-Optical System for SLR, Angular Measurements and Photometry

Mount Parameters

Mount type Az-El, with two flanges for equipment mounting

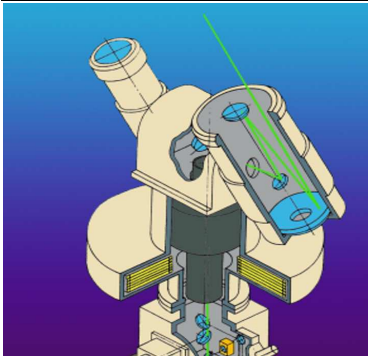
Digitally controlled torque motor drive

Equipment weight on each mount flange $\leq 20\text{kg}$

Angular elevation rotation range from 0 to 90 deg

Angular azimuth rotation range from -270 to 270 deg

Maximum angular speed and acceleration are 30deg/s and 5deg/s^2



Compact Laser-Optical System Parameters

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- **SLR of SC with retroreflectors:**

Parameter Description	Feature
SC orbit height range	400 to 36000 <i>km</i>
Orbit height for SC daytime measurements	400 to 6000 <i>km</i>
NP RMS error (averaging interval 60s)	0.5 to 2 <i>cm</i>
Elevation range	20 to 85 <i>deg.</i>

- **Angular measurements:**

Parameter Description	Feature
Visual star magnitude	$\leq 14^m$
RMS error for SC angular velocity up to 40 arcsec	2"

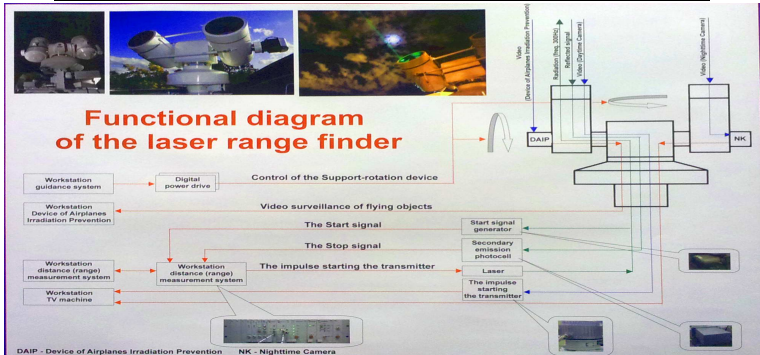
- **Photometry:**

Parameter Description	Feature
Visual star magnitude	$\leq 12^m$
Brightness determination error	0.2 ^m

Compact Laser-Optical System Parameters

- Laser ranging system parameters:

Parameter Description	Feature
Operation wavelength	532nm
Pulse repetition rate	300Hz
Laser pulse duration	150ps
Minimum laser pulse energy	2mJ
Output beam divergence	5arcsec
Receive telescope diameter	25cm
Laser fire epochs accuracy	200ns



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- **One Way Station and IRLS:**

- ↪ L_1 and L_2 radio signals receivers for GPS and GLONASS;
- ↪ IRLS Site Code BRAL, Station #7407, DOMES# 48081S001, 15.7731 S, 132.1347 W.



Activities in this first year:

- Technical team training;
- Software and hardware update.



Activities in this first year:

- GLONASS system and the UnB QOS presentations;
- Authorities visits.



Operation of the QOS for SLR

Pointing/tracking control virtual panel.

The screenshot displays the QOS for SLR software interface. At the top, it shows the date (2015/05/15), time (00:53:36), and various system parameters. The main window is divided into several sections:

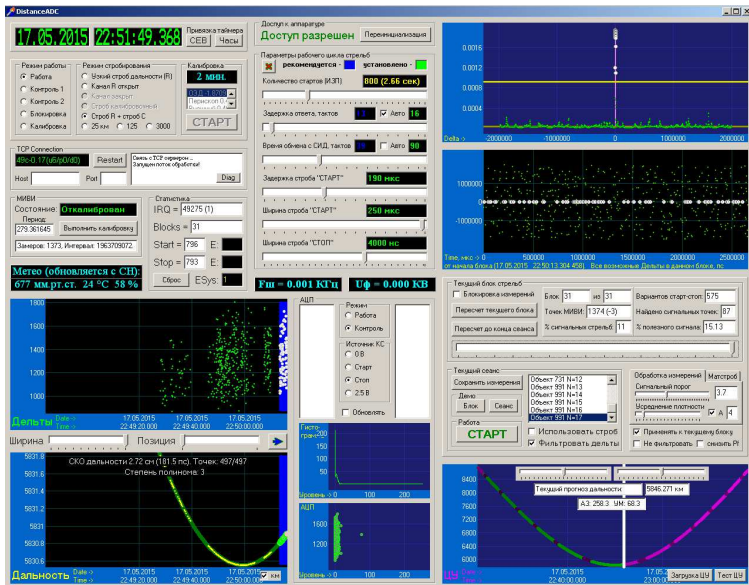
- Left Panel:** Contains control fields for Azimuth and Elevation, including 'Axis of sight', 'Program', 'True', 'Correction', 'Error', 'Bearing', 'Progr Vel', 'Actual Vel', 'Sun', 'Moon', and 'Binding'. Each field has a numerical value and a small display.
- Top Center:** A 'Camera' control panel with options for 'D' or 'N', 'Discard', and a list of time intervals (1s, 5s, 15s) and distances (1m, 2m, 5m).
- Center:** A large circular star field with a grid of azimuth and elevation. A yellow arrow points to a specific star, indicating the tracking target.
- Right Panel:** A 'Trajectory YES' section with a 'Position' graph showing a grid from -100 to 100 on both axes. Below it are 'Clear', 'Algorithm' (set to Mstar=3), and range selection buttons for 'Day', 'AC and Photometry', and 'Night'. A 'Start' button is also present.
- Bottom Left:** A 'Speed' control panel with 'D', 'M', 'S' fractions and 'S' fractions, and an 'INPUT' field. Below it are 'Step ms' and 'Tuning correction' controls.
- Bottom Center:** A 'Date' and 'RD of star duration' section with various numerical inputs and a 'To Pnt' button.
- Bottom Right:** A 'Point Coordinates' panel with 'AZIMUTH' and 'ELEVATION' fields, and a 'Driving ON/OFF' section with 'ON' and 'OFF' buttons. A language dropdown is set to 'English'.

At the very bottom, there is a table of data points:

Date	2015/05/15	Alpha=07 46 14.975	Delta=r27 59 12.120	M = 1.30
TStart =	000:52:00	TFinish =	001:02:00	DT = 000:10:00
Number of Points =	601			
SeGr=	3.496228906			
000:52:00	154:20:03	-000:00:12	034:17:01	-000:00:09
000:52:01	154:19:52	-000:00:12	034:16:52	-000:00:09
000:52:02	154:19:40	-000:00:12	034:16:43	-000:00:09
000:52:03	154:19:28	-000:00:12	034:16:34	-000:00:09
000:52:04	154:19:16	-000:00:12	034:16:24	-000:00:09

Operation of the QOS for SLR

Laser ranging control virtual panel (Lageos satellite 991).



Operation of the QOS for SLR

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Night camera virtual panel (Glonass satellite 747).

Число введенных кадров = 7875



DB:17:05:15 E:31:15 ZB:19:09:21 A:000:00:00:0 D:000:00:00:0 R:205430
AZ:125:31:51.6 W:040:59:38.5 AZюн 125:31:51.6 Wиюн 040:59:38.5
Фок:173 Wгн:78 Ркость:200 Контраст:181 СредРкость:160
Ф:0:0:0 F:000:0:0:0.7 Ф:18:0 F:000:0:0:0.3 Wм:1
W: -000:00:25.6 W: -000:00:10.9 W: -000:00:32.2 W: Wм: 162:00:30.0
Коды Объекта: X=000:00 Y=000:00 J=000
ИндСтрел ФанО ЯвляюО КонтрФ СбРкость О Зар:7875
Масштабированно 0 Контраст Label5

00747 00000000

Видк:Нис Залк Показать:30 Чиселк:Бескон

Размер Стрелы

Показать стрелу	<input type="checkbox"/>	ФН стрелы
Показать крест	<input type="checkbox"/>	Ремон:УИ и Ф
Спробовать	<input type="checkbox"/>	Ремон:ОШ
Отмена отправки	<input type="checkbox"/>	Ремон:Ф
	<input type="checkbox"/>	Ремон:УИ

Колесико: 1, 2, 4, 8, 16, 32, 64, 128

Выделенная: ДА:АВ:1

Имя: English Russian

Колесико: Переключено на 12х АВП

Контраст: [120]

Увеличить разрешение: 1, 2, 4, 8, 16, 32, 64, 128

Уменьшить разрешение: 1, 10

Состояние Программы: СбРФ Обр:Н:сбн Обр:ОШ Ремон:ОШ Ремон:Ф Ремон:УИ Стрел:ИЭИ Стрел:ОИ

СбРФ СбРФ:К:А СбРФ:В:К:А Виз:Панель КН:В:К:Л О:О:В:К:А К:В:Панель ST:Count Label2 Label0

Operation of the QOS for SLR

Some statistics.

MONTH	WORKING DAYS	TOTAL MEASUREMENTS	SUCCESS	FAILURE	AVG. SUCCESS/DAY	% SUCCESS
Aug/2014	12	245	212	33	17.67	86.53
Sep/2014	16	414	296	118	18.50	71.50
Oct/2014	10	206	104	102	10.40	50.49
Nov/2014	9	78	8	70	0.89	10.26
Dec/2014	13	231	53	178	4.08	22.94
TOTAL	60	1174	673	501	11.22	57.33

Sample of the work done on 01/19/2015 - 27 success out of 53 tries.

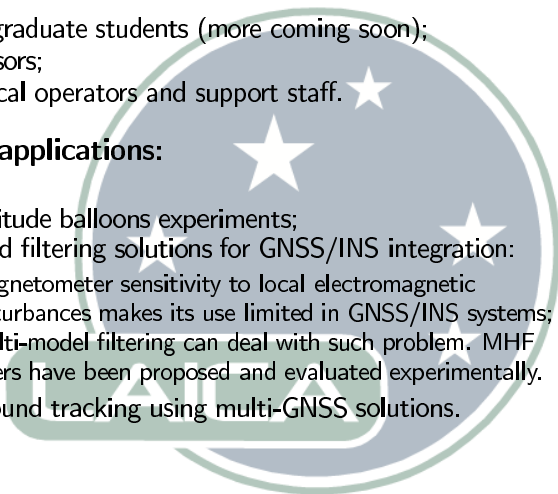
Satellite number	Start time	Stop time	Reflected signal	Amount reflected	RMS sm	Calibration (%)	Trajectory		
							Rising	Zenith	Downward
701	00:40	00:55		-	-	13%			
745	01:05	01:13		691	3.77	13%			
733	01:26	01:42		-	-	13%			
745	01:50	01:57		1037	2.97	13%			
701	02:12	02:19		214	4.36	13%			
733	02:26	02:40		-	-	13%			
755	02:46	02:51		1359	2.86	14%			
755	03:25	03:31		900	2.9	14%			
731	03:45	03:53		443	2.91	14%			

Current team at LAICA in the field of GNSS:

- 4 undergraduate students (more coming soon);
- 5 professors;
- 7 technical operators and support staff.

Immediate applications:

- High-altitude balloons experiments;
- Advanced filtering solutions for GNSS/INS integration:
 - ↪ Magnetometer sensitivity to local electromagnetic disturbances makes its use limited in GNSS/INS systems;
 - ↪ Multi-model filtering can deal with such problem. MHF filters have been proposed and evaluated experimentally.
- UAV ground tracking using multi-GNSS solutions.

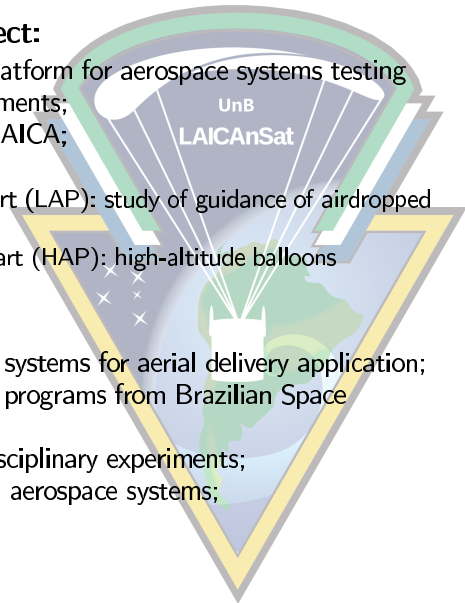


The LAICAnSat project:

- Development of a platform for aerospace systems testing and scientific experiments;
- Started in 2013 at LAICA;
- Divided in:
 - ~ Low Altitude Part (LAP): study of guidance of airdropped systems;
 - ~ High Altitude Part (HAP): high-altitude balloons experiments.

Motivation:

- Study of airdropped systems for aerial delivery application;
- Cansats educational programs from Brazilian Space Agency (AEB);
- Platform for multidisciplinary experiments;
- Students training on aerospace systems;
- Low budget.



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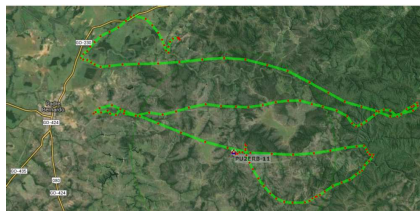


LAICAnSat-1, May 2,
2014.

LAICAnSat Launches



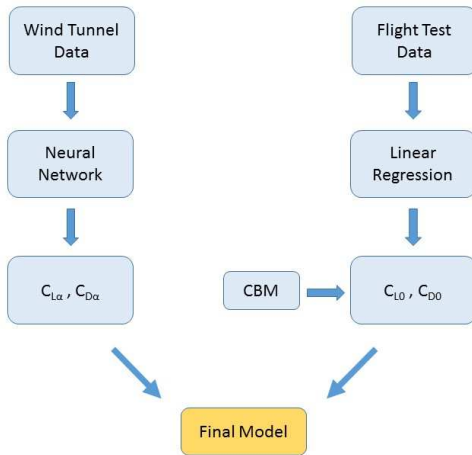
LAICAnSat-2, May 24, 2014.



LAICAnSat-1 trajectory.

Aerodynamic Coefficients Estimation Using GNSS

Aerodynamic model identification procedure.¹



¹A. V. S. Silva et al. System identification of a square parachute and payload for the LAICAnSat. In Proc. of the 36th IEEE Aerospace Conference, Montana, USA, March 2015.

Aerodynamic Coefficients Estimation Using GNSS

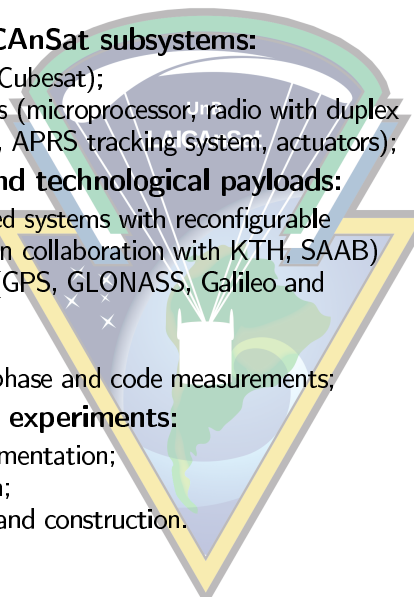
- Flight tests under different weather conditions (humidity, wind, temperature);
- Analysis of straight segments of trajectory;
- Constant control deflection;
- Constant forward airspeed V_0 and wind vector \vec{V}_W assumption;
- V_0 and \vec{V}_W to be estimated based on GPS positions;
- Aerodynamic and gravity are the only considered forces.



Complete test trajectory.



Selected data.

- **Standardization of LAICAnSat subsystems:**
 - ~> Payload structure (3U Cubesat);
 - ~> Electronics and avionics (microprocessor, radio with duplex communication system, APRS tracking system, actuators);
 - **Boarding of scientific and technological payloads:**
 - ~> Fault-tolerant embedded systems with reconfigurable self-healing hardware (in collaboration with KTH, SAAB)
 - ~> Multi-GNSS solutions (GPS, GLONASS, Galileo and BeiDou);
 - ~> Differential GLONASS;
 - ~> PNT based on carrier phase and code measurements;
 - **Unifying HAP and LAP experiments:**
 - ~> Guidance system implementation;
 - ~> Impact point prediction;
 - ~> Ground station design and construction.
- 

- The GLONASS SLR and OW station represents an **excellent opportunity for the advancement of research on GNSS in Brazil**, especially at UnB, and also **improve the accuracy of PNT in the South America**;
- This first year operating the SLR station was important for **technical team training, adjustment of the station equipment, and providing a better understanding of the weather condition** in our region and its impact on the operation of the station;
- Future perspectives include:
 - ~> study and evaluation of atmospheric error models in our region;
 - ~> GLONASS precise position;
 - ~> study of SBAS typical architecture and implementations;
 - ~> **practical applications on HASP (LAICAnSat) and multipurpose autonomous rovers travelling (UE H2020).**

Thank You!

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AEB
Brazilian Space Agency



ROSCOSMOS
Russian Space Agency

