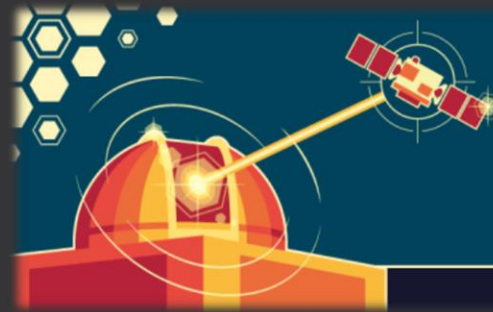




# DEGORAS PROJECT

A libre software and hardware for SLR stations



22<sup>ND</sup> INTERNATIONAL WORKSHOP  
ON LASER RANGING

7-11 November 2022  
Yebes, Spain

RECONNECTING THE ILRS COMMUNITY

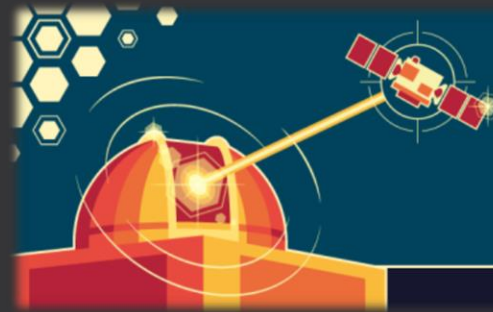


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# Issues in software and hardware

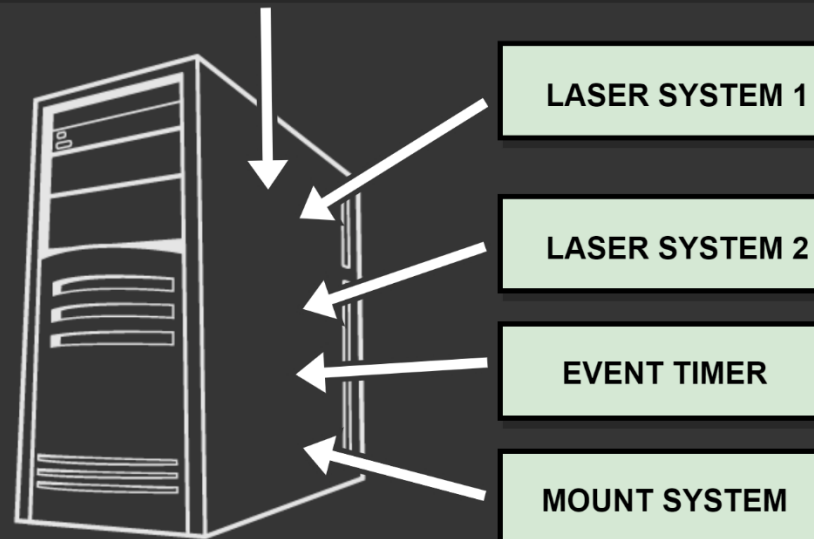
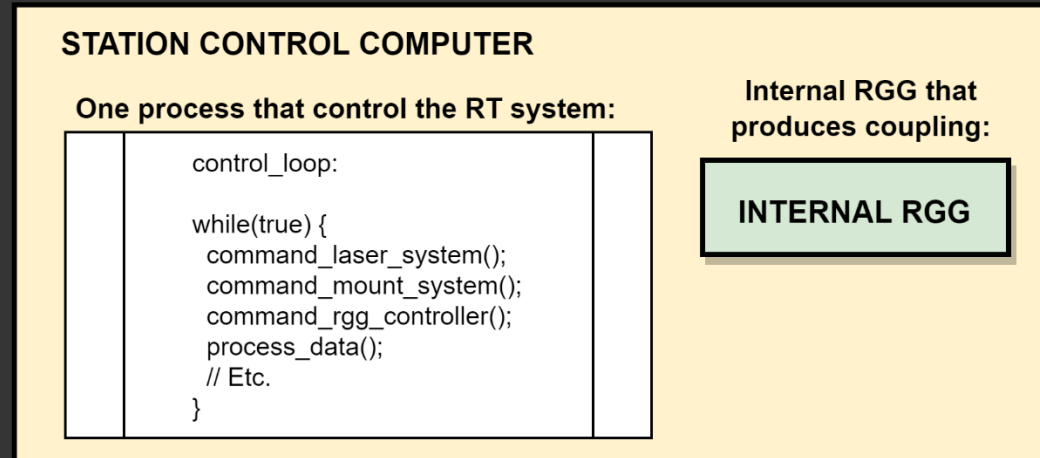
**Analysis of the state of the art related to the SLR software and hardware systems of several stations has revealed common problems.**

- Obsolete programming languages and technologies.
- Sequential programming of complex systems.
- All subsystems, including RT hardware, controlled by the same sequential software.
- High degree of interdependence (high coupling) among subsystems.

**Our old station system also had these problems, which drastically reduced its operational and evolutionary capacity.**

# Issues in software and hardware

## Bad practice: high coupling and low cohesion



# Issues in software and hardware

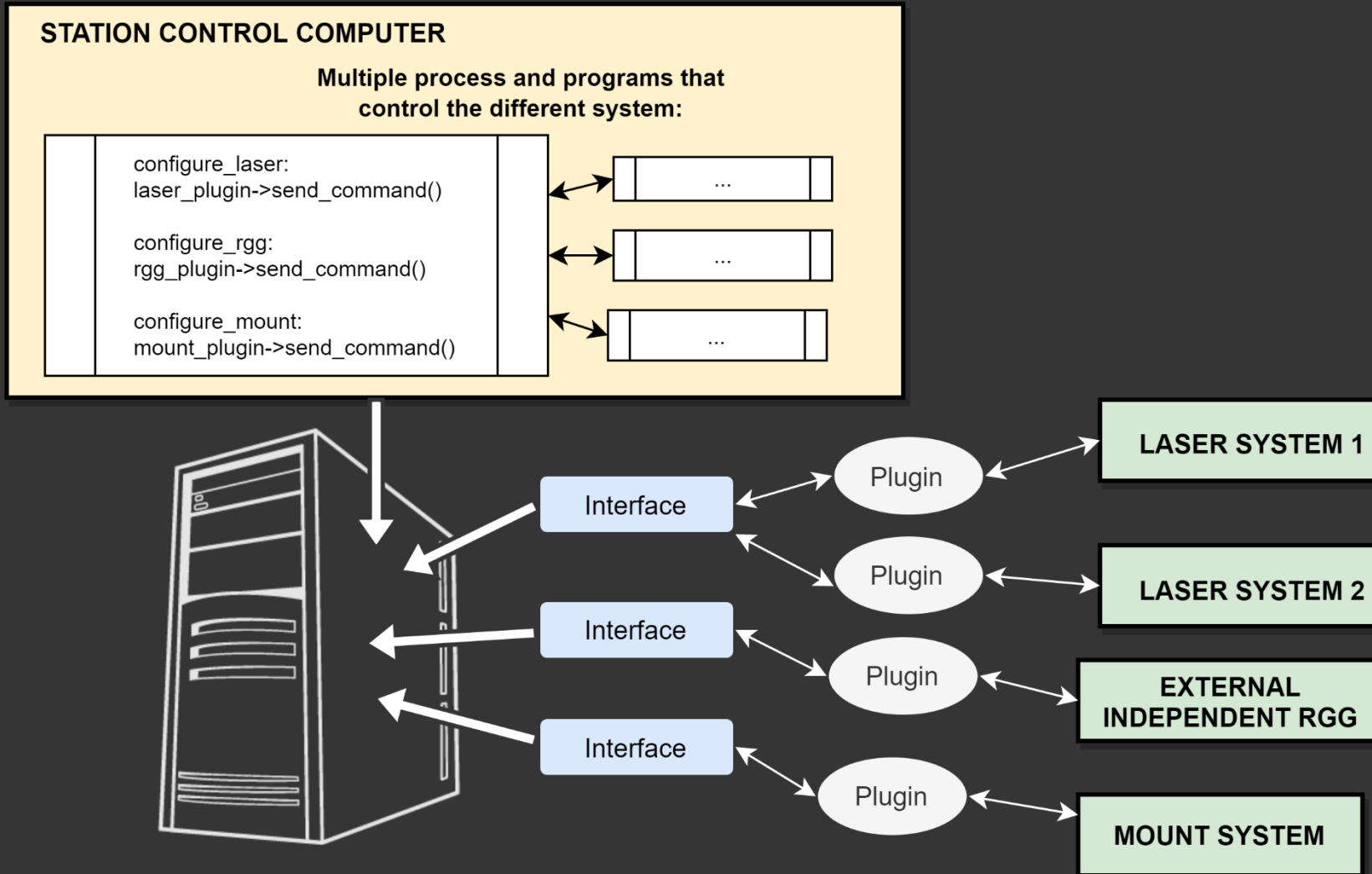
## Consequences and implications

- Hard maintenance of the whole SLR system.
- Difficult integration of new hardware components (lasers, optomechanics and other devices).
- Difficult integration of new software components (algorithms, debris compatibility, controllers, ...).
- Low computational performance that also affects RT systems.
- Complex operation for non-advanced users.

**The previous issues imply a series of consequences for SLR stations that should be solved to bring them to their maximum operational capacity.**

# Issues in software and hardware

Good practice: low coupling and high cohesion

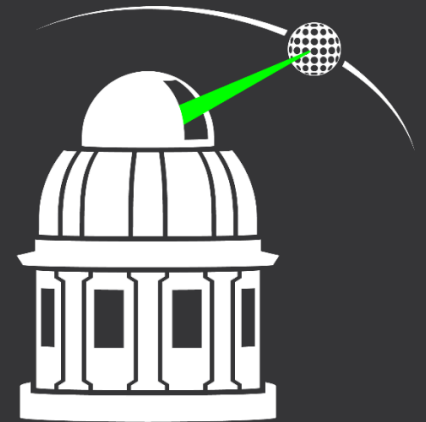


# Degoras Project

Degoras Project is a modern libre system designed to meet the main needs and tasks of any SLR station. Currently it is still under development.

The Project covers software and hardware development.

- Libre software and hardware (GNU GPLv3).
- User-friendly for operators, engineers and scientists.
- Adaptable and modular.
- Improved implementation of SLR algorithms.
- Prepared for ILRS and space debris tracking.



# DEGORAS PROJECT

# System implementation

## Some technologies and features

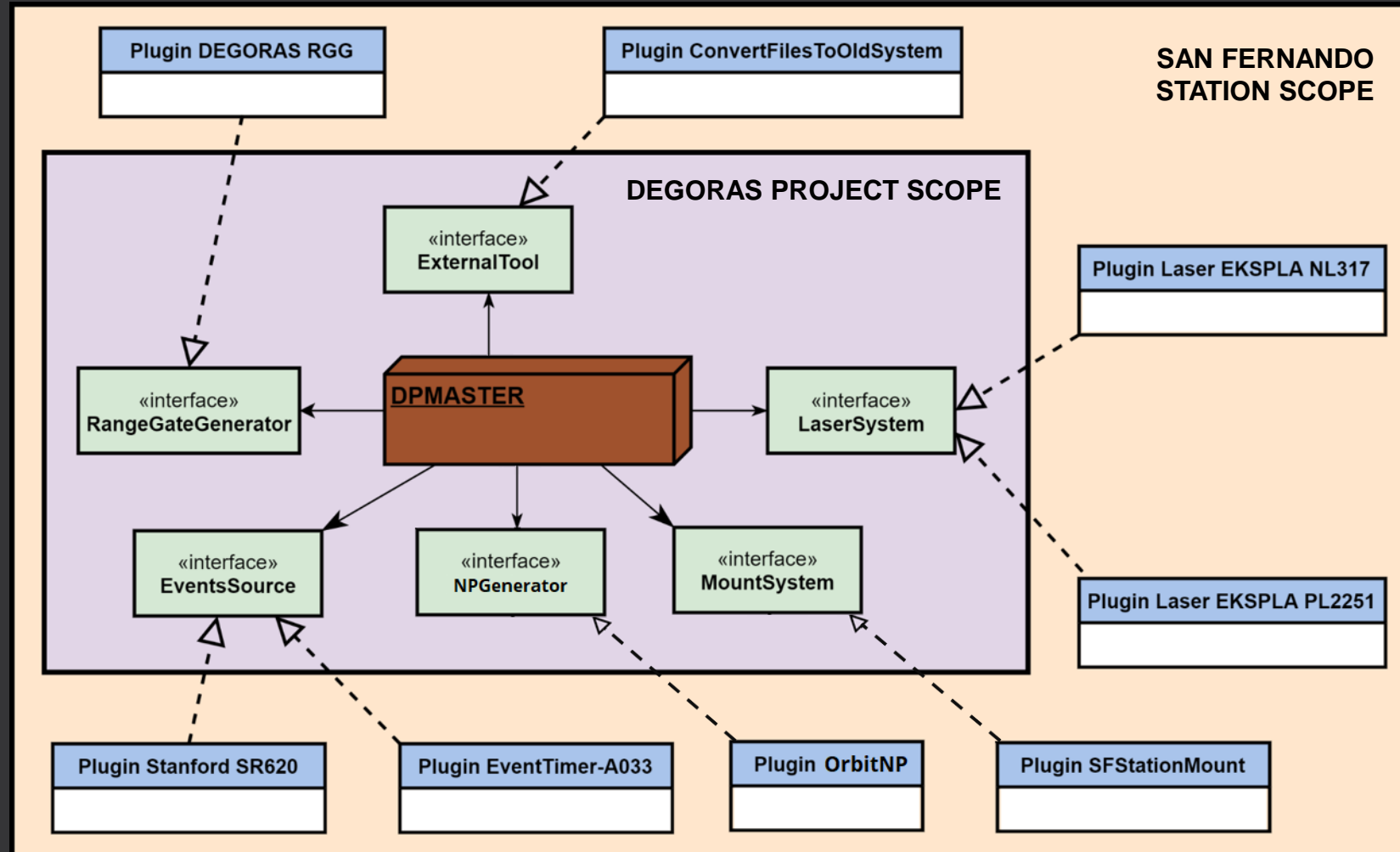
- Software development under Qt5 framework.
- C++17, Python 3 and VHDL as main programming languages.
- Hardware based in Intel Cyclone V SX SoC (FPGA + ARM).
- ZeroMQ for communications and MongoDB for databases.
- Model-view-controller (MVC) software design pattern.
- System of interfaces and plugins.



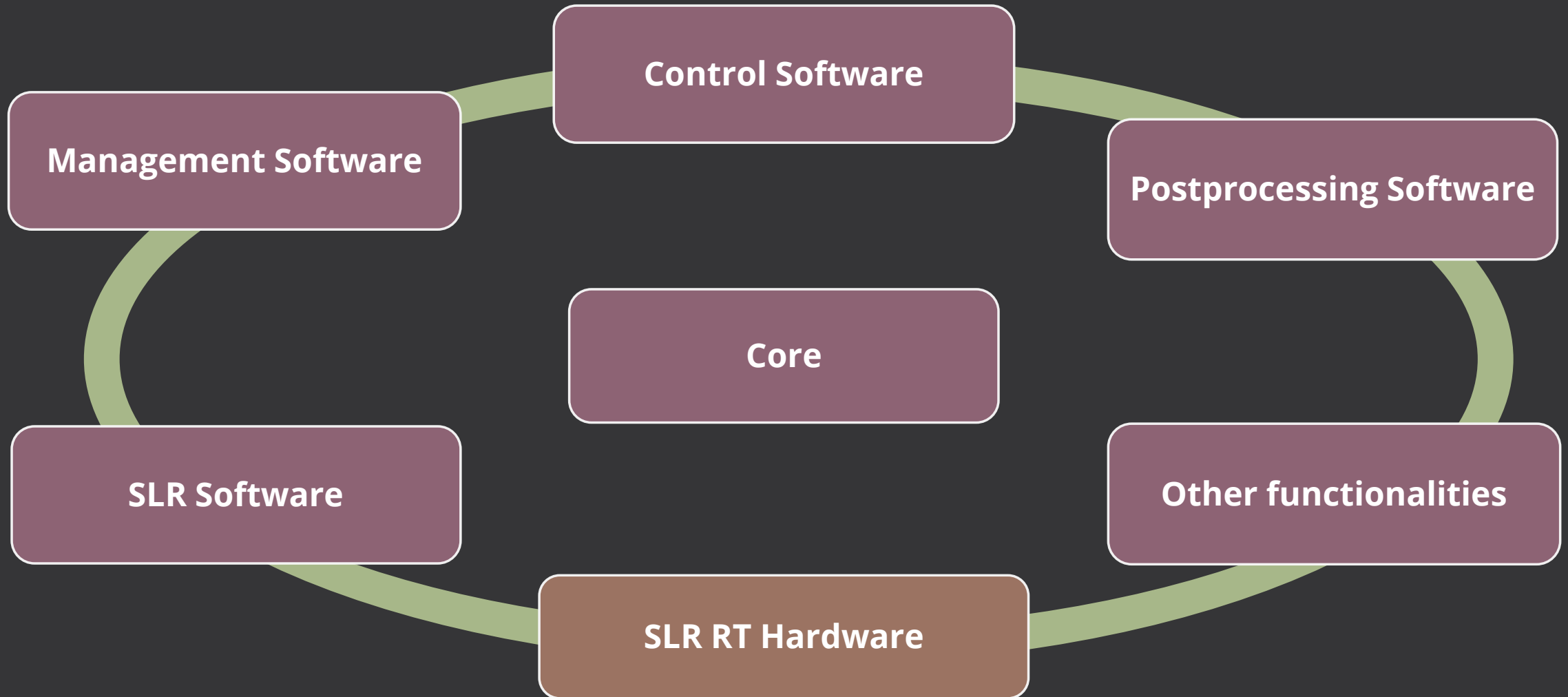


# System implementation

## Interfaces and plugins: adaptability scenario



# Functionalities within the scope



# Software under development

## Desktop GUI applications

SPACE OBJECTS MANAGER



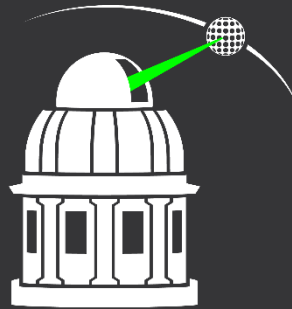
CPF FILES MANAGER



PREDICTIONS GENERATOR



Management software



# DEGORAS PROJECT

Control software

STATION CONTROL



TRACKING SYSTEM



SLR software

RANGE GATE GENERATOR MANAGER



ENVIRONMENTAL MONITOR



Other functionalities

# Software under development

## Desktop GUI applications

SPACE OBJECTS MANAGER



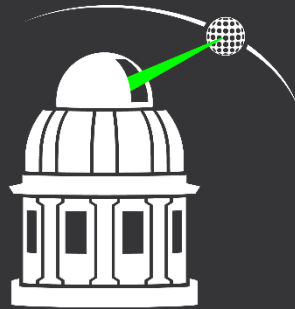
CPF FILES MANAGER



PREDICTIONS GENERATOR



Management software



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Control software

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SLR software

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ENVIRONMENTAL MONITOR



Other functionalities



Space Objects Data Table

EN. POLICY	NORAD	NAME	ILRS NAME	COSPAR	ILRS ID	SIC	CLASSIFICATION	LRR	DEBRIS	TRACK POLICY	PRIOR	CPF	ALTITUDE	RCS	NPI	BS	
Disabled	40129	GALILEO6	GALILEO202	2014-050B	1405002	7202	Galileo	Yes	No	Always	0	All	21605	9	300	5	
Disabled	40128	GALILEO5	GALILEO201	2014-050A	1405001	7201	Galileo	Yes	No	Always	0	All	21605	9	300	5	
Disabled	38858	GALILEOFM4	GALILEO104	2012-055B	1205502	7104	Galileo	Yes	No	Always	0	All	23220	13.22	9	300	5
Disabled	38857	GALILEOFM3	GALILEO103	2012-055A	1205501	7103	Galileo	Yes	No	Always	0	All	23220	10.355	9	300	5
Disabled	37847	GALILEOFM2	GALILEO102	2011-060B	1106002	7102	Galileo	Yes	No	Always	0	All	23220	48.772	9	300	5
Disabled	37846	GALILEOPFM	GALILEO101	2011-060A	1106001	7101	Galileo	Yes	No	Always	0	All	23220	51.378	9	300	5
Disabled	29656	ETS8	ETS8	2006-059A	0605901	1579	Geostationary	Yes	Yes	Always	0	All	36000	11	9	300	6
Disabled	20026	COSMOS2024	ETALON2	1989-039C	8903903	4146	Glonass Constellation	Yes	No	Always	0	All	19135	1.259	9	300	6
Disabled	19751	COSMOS1989	ETALON1	1989-001C	8900103	0525	Glonass Constellation	Yes	No	Always	0	All	19105	1.084	9	300	6
Enabled	23560	ERS2	ERS2	1995-021A	9502101	6178	Earth Resources, Brightest	Yes	Yes	Always	0	All	800	9.231	3	15	9
Enabled	21574	ERS1	ERS1	1991-050A	9105001	6177	Earth Resources, Brightest	Yes	Yes	Always	0	All	780	11.009	3	15	9
Enabled	27386	ENVISAT	ENVISAT	2002-009A	0200901	6179	Earth Resources, Brightest	Yes	Yes	Always	0	All	772	19.497	3	15	9
Enabled	2680	DIADEME2	DIADEME1D	1967-014A	6701401	6704	Space & Earth Science	Yes	Yes	Always	0	All	585	0.637	3	15	3
Enabled	2674	DIADEME1	DIADEME1C	1967-011A	6701101	6703	Space & Earth Science	Yes	Yes	Always	0	All	545	0.527	3	15	3
Disabled	36508	CRYOSAT2	CRYOSAT2	2010-013A	1001301	8006	Space & Earth Science	Yes	No	Always	0	All	725	2.97	3	15	9
Disabled	41315	BEIDOU21	COMPASSM3	2016-006A	1600601	2011	Beidou Navigation System	Yes	Yes	Always	0	All	21500	9	300	5	
Disabled	38250	BEIDOU12	COMPASSM3	2012-018A	1201801	2004	Beidou Navigation System	Yes	No	Always	0	All	21528	5.623	9	300	5
Disabled	31115	BEIDOU1	COMPASSM1	2007-011A	0701101	2001	Experimental, ...igation System	Yes	Yes	Always	0	All	21500	5.461	9	300	5
Disabled	40549	BEIDOU17	COMPASSI1	2015-019A	1501901	2006	Beidou Navigation System	Yes	Yes	Always	0	All	35786	9	300	5	
Disabled	41434	BEIDOU22	COMPASSI6B	2016-021A	1602101	2012	Beidou Naviga...Geostationary	Yes	No	Always	0	All	35677	9	300	5	
Disabled	37948	BEIDOU10	COMPASSI5	2011-073A	1107301	2005	Beidou Navigation System	Yes	No	Always	0	All	35786	7.943	9	300	5
Disabled	37763	BEIDOU9	COMPASSI4	2011-038A	1103801	2009	Geostationary...gation System	Yes	Yes	Always	0	All	42161	7.943	9	300	5
Disabled	37384	BEIDOU8	COMPASSI3	2011-013A	1101301	2003	Geostationary...gation System	Yes	No	Always	0	All	35786	25.119	9	300	5



**Sets Tools**

System Set: **DEBRIS ILRS + ROCKETS**  
 Loaded Set: **DEBRIS ILRS + ROCKETS**

Selected Set: **DEBRIS ILRS + ROCKETS**

Buttons: Set as System Set and load, New Set, Delete Selected, Load Selected, Save Selected

Set En. Policy: Disabled

**Database Tools**

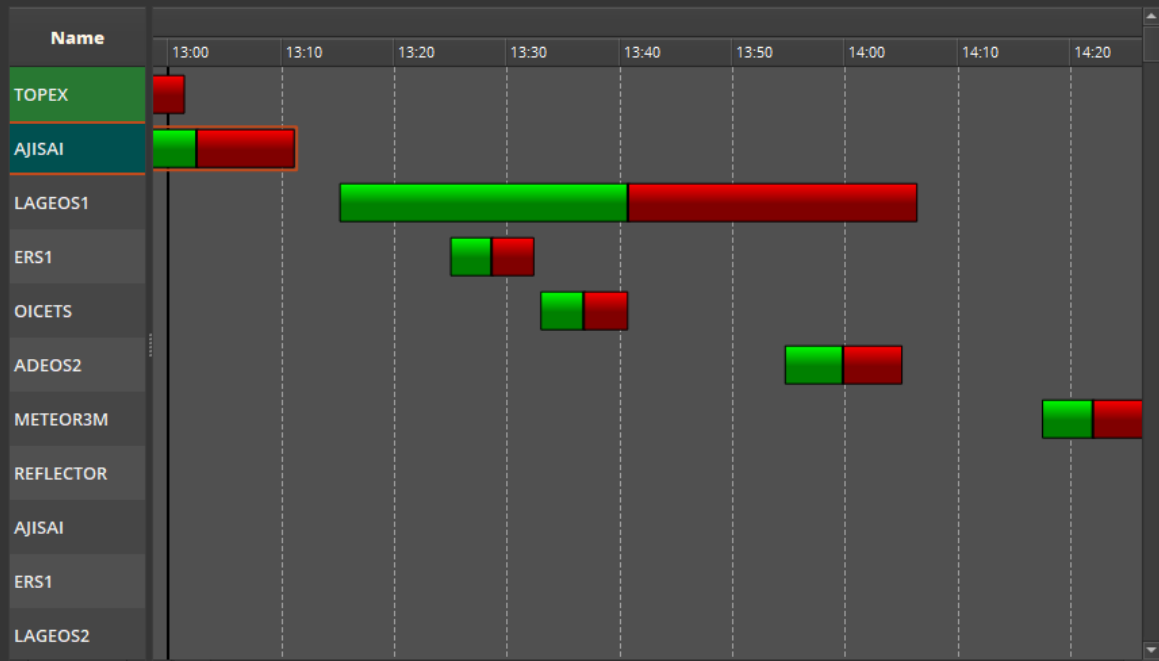
Buttons: Add Space Object, Edit Selected, Delete Selected, Load Database, Save Database

Enablement Policy:  All  Enabled  Disabled |
 Laser Retro Reflector:  All  With  Without |
 Debris:  All  Is  Is not |
 ILRS:  All  Is  Is Not |
 Search:

Database | Name: **ROASLR\_Database\_v2** | Date: **2020-08-31 12:29:13 UTC** |
 Objects | Enabled: **28** | Loaded: **505** | Displayed: **505** |



### Planning



Go to Current Time  Real Time  Pass Notices

WEEKDAY	DATE	NAME	NORAD	LRR	DEBRIS	START TIME	MAX. ALT.	END TIME	PASS	AZIMUTHS
Monday	28-09-2020	TOPEX	22076	Yes	Yes	12:48h	24 - 12:54h	13:01h	SO/NE	262 315 10
Monday	28-09-2020	AJISAI	16908	Yes	No	12:53h	40 - 13:02h	13:11h	NO/NE	307 17 86
Monday	28-09-2020	LAGEOS1	8820	Yes	No	13:15h	35 - 13:40h	14:06h	SO/NO	194 257 324
Monday	28-09-2020	ERS1	21574	Yes	Yes	13:24h	21 - 13:28h	13:32h	SE/NE	115 65 15
Monday	28-09-2020	OICETS	28809	Yes	Yes	13:32h	47 - 13:36h	13:41h	NE/SE	24 99 175
Monday	28-09-2020	ADEOS2	27597	Yes	Yes	13:54h	87 - 13:59h	14:05h	SE/NO	166 271 346
Monday	28-09-2020	METEOR3M	27001	Yes	Yes	14:17h	20 - 14:22h	14:26h	NE/SE	45 93 142
Monday	28-09-2020	REFLECTOR	27005	Yes	Yes	14:27h	40 - 14:32h	14:40h	NE/SE	20 08 160

### Control Cameras



### Laser System State

**Connections**

Laser Device: Yes Calibration Flipper: Yes  
 Filter Wheel: Yes Motorized Stage: Yes

**Configuration and State**

Laser State: Fire On Laser Mode: Max  
 Laser Warm: Warmed Up Laser Amplification: 1%  
 Sync Mode: External Calibration Filter: No  
 Cooling 1: 24.79°C Filter Wheel Positio: No. 1  
 Cooling 2: 24.88°C Stagel Position: 0/-108

### Working Mode

**STOP**

**SYSTEM WARM**

**WAIT**

**CALIBRATION**

**TRACKING**

**MINIMUM ENERGY** **MAXIMUM ENERGY**

**MANUAL CONTROL** **ADJUSTMENT**

### Station State

Controller State: Connected Laser State: CONNECTED

### Laser System Plugins

Control: FOAHLST (ns) Connect Disconnect

### Laser Fire

**Tiro Permitido** More Info...

Start Firing Stop Firing

### Range Gate Config

500 ns Send Upper Offset

-500 ns Send Lower Offset

0 ns Send Time Bias

0 ns Send Custom Delay



## Last Calibration

Date: 03-11-2022 10:25:31 UTC  
 Mean: 142468 ps  
 RMS: 51 ps (15 mm)

## Current Tracking Data

NORAD: 16908 Start Time: 03-11-2022 17:58:29 UTC  
 Name: AJISAI End Time: 03-11-2022 18:16:29 UTC  
 Source: SGF Duration: 00h 18' 00"

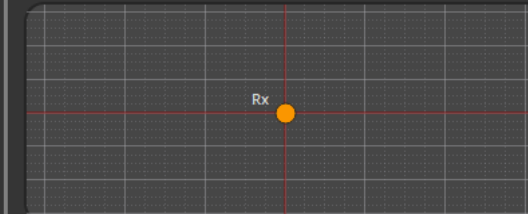
## Mount System

State: **Stop** Advanced  
 Connected Go Home Go Calibration  
 Manual Adjust **Tracking**

## System Log

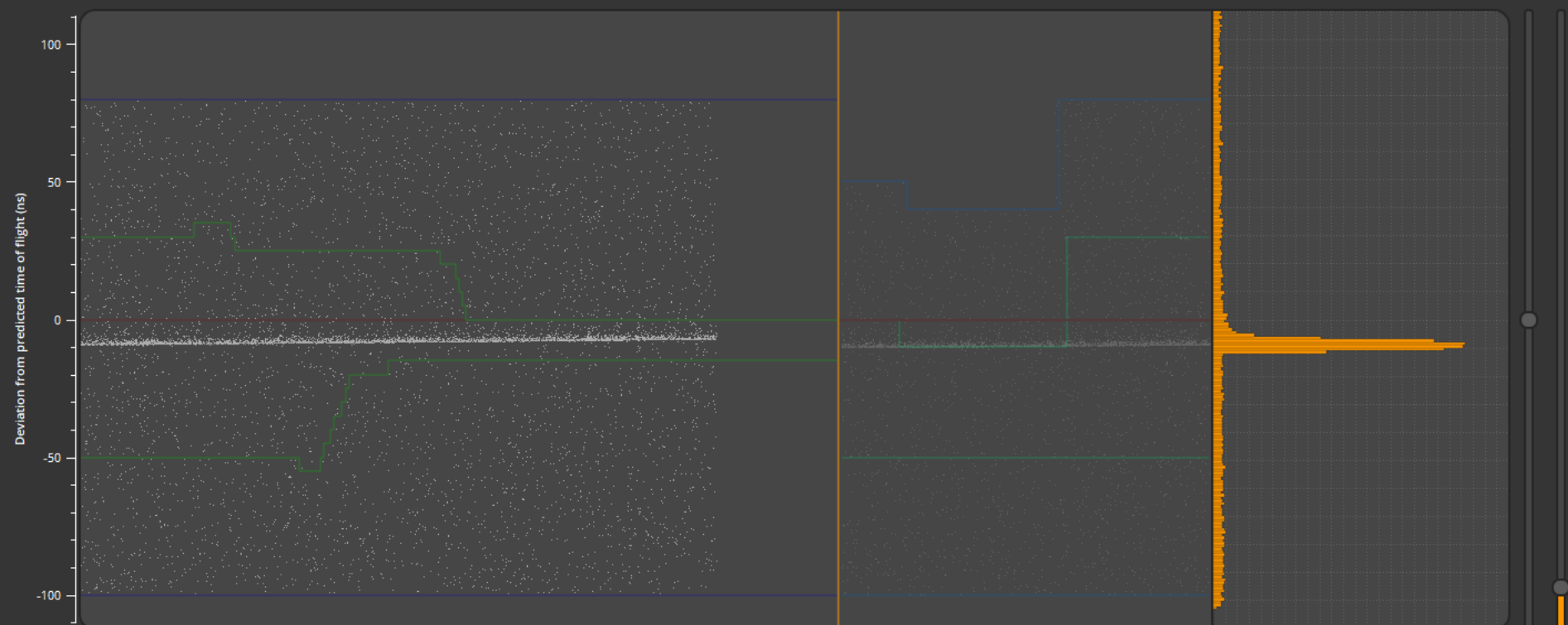
Mount system connection successful.  
 Mount system enters Tracking mode.

## Telescopes Offsets



	Az.	$\Delta$ Az.	El.	$\Delta$ El.
Tx:	0"	1"	0"	1"
Rx:	0"	1"	0"	1"
Dr:	0"	1"	0"	1"

## Real Time Residuals Plot



Current State:

Gate Lower: -100 ns Prefilter Lower: -15 ns Time Bias: 0 ms Accum. RoR: 0%

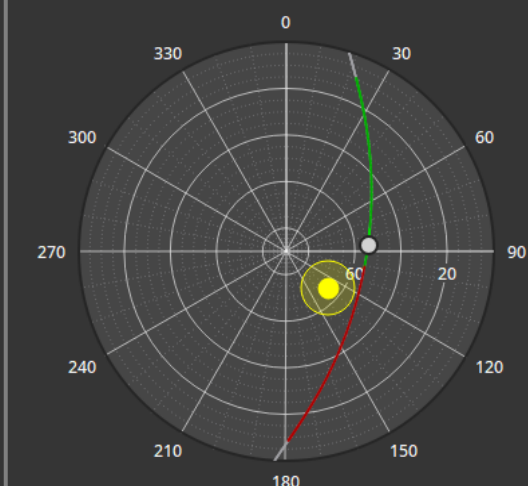
Mode: Continuous

TRACKING  
SIMULATION

Gate Upper: 80 ns Prefilter Upper: 0 ns Range Bias: 0 ns RT RoR: 0%

Bin: 1 ns

## Tracking Polar Plot



	Azim.	Elev.	Azim.	Elev.
Obj:	85.200	54.160	Tx:	—
Sun:	129.992	66.055	Rx:	—

# RT Hardware under development

## Degoras Range Gate Generator (DRGG)

- Libre hardware (like all the Project).
- Gating accuracy of  $<10$  ns in kHz systems.
- Fully configurable and modular.
- Communications over TCP/IP.
- GUI app plus an API for easy integration.
- It will be encapsulated in an external standard NIM module.

Example of a standard NIM module.

Intel Cyclone SoC V TSoM

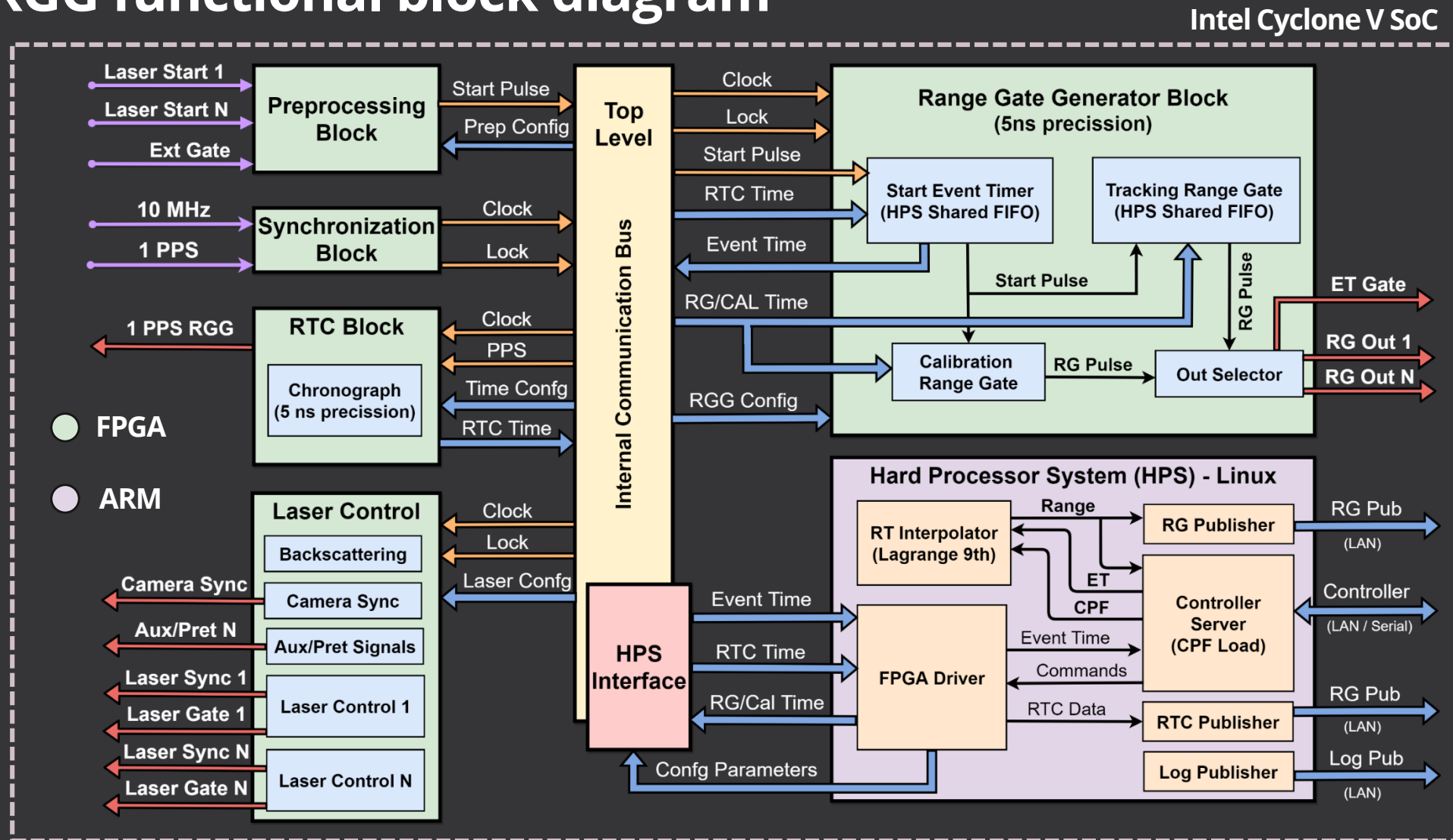


**It uses CPF files internally to work and can operate as an independent subsystem without the need for complex integration or dedicated computer.**



# RT Hardware under development

## DRGG functional block diagram



# Aims of the project

## Short-term

- Continue working in the development of Degoras Project .
- Make the DRGG fully compatible with kHz systems and industrialize it.

## Mid-term

- Include an automatic remote operation mode to the system.
- Test the software and hardware at other stations.

## Long-term

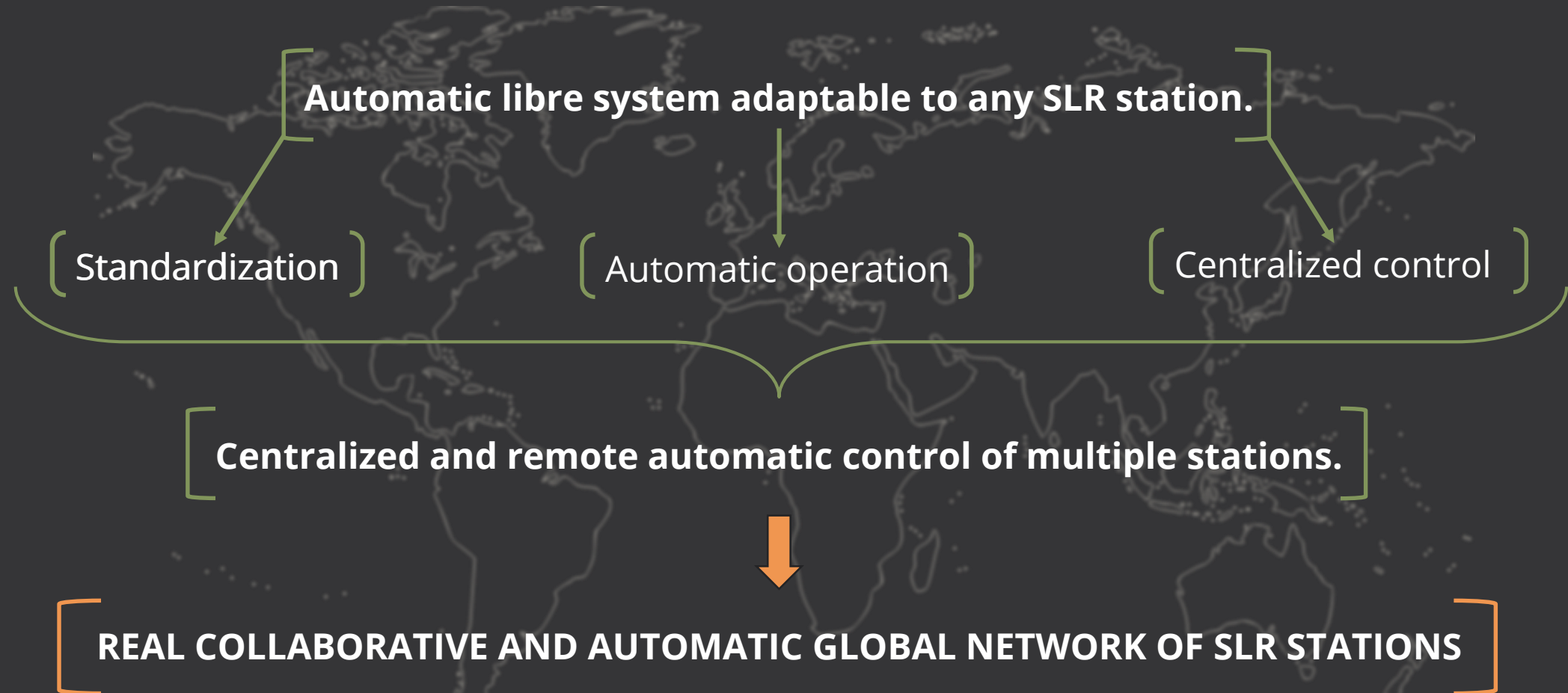
- Multistatic mode for the RGG.
- **Automatic real-time global control of multiple SLR stations.**

( Final idea )



# Aims of the project

## Our final idea

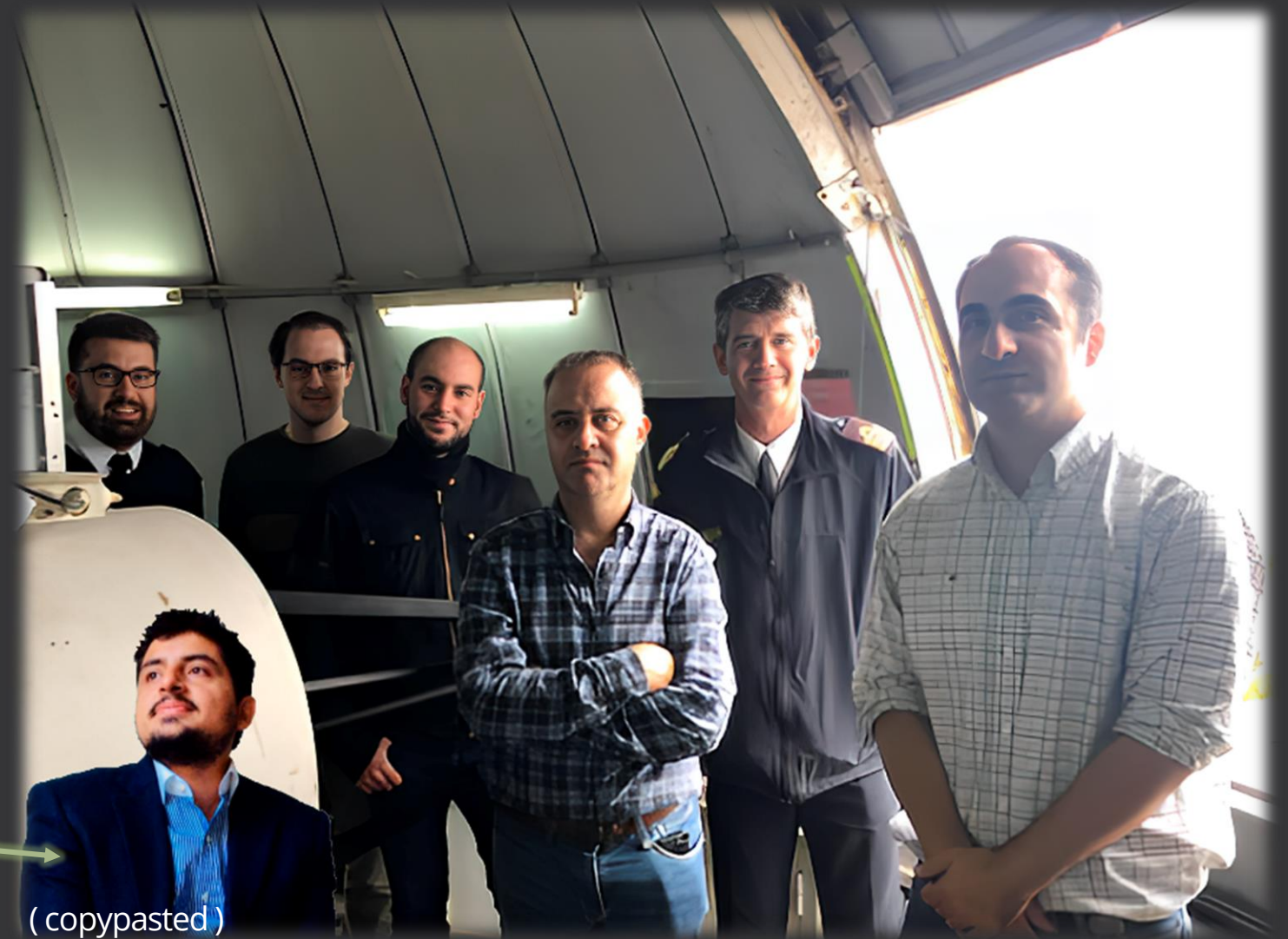


# Let's get in touch!

Ángel Vera Herrera

( on behalf of the Degoras Team )

[avera@roa.es](mailto:avera@roa.es)



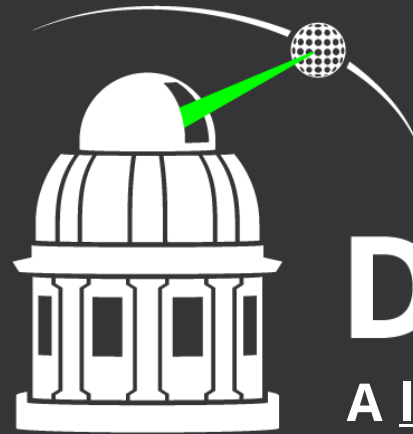
Currently collaborating with:

- Julian Rodriguez from Zimmerwald  
Signal detection and new algorithms

(copypasted)

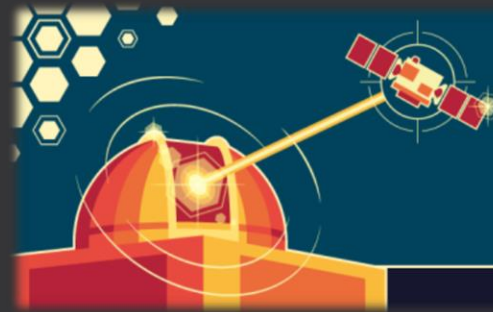
We are looking forward to collaborate with more stations !!





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