# Introducing FRACTAL SLNE

# Services and Capabilities

## A Technological company for scientific projects

**Code:** **N/A**

**Issue:** 1.A

**Date:** 20 -November - 2022

**Pages:** 52

FRACTAL S.L.N.E.
www.fractal-es.com
info@fractal-es.com


## TABLE OF CONTENTS

## List of Acronyms and Abbreviations used

| | |
|---|---|
| AOR | Astronomical Observing Request |
| AT | Auxiliary Telescope |
| CFC | Continuous Flow Cryostat |
| CNIG | Centro Nacional de Información Geográfica (National Centre for Geographic Information) |
| CS | Control Software |
| CV | Curriculum Vitae |
| DDL | Differential Delay Line |
| ESA | European Space Agency |
| ESAC | European Space Astronomy Center |
| ESO | European Southern Observatory / European Organization for Astronomical Research in the Southern Hemisphere |
| ESOC | European Space Operations Center |
| GTC | Gran Telescopio CANARIAS |
| HIFI | Heterodyne Instrument for the Far Infrared |
| IA | Instituto de Astronomía |
| IAA | Instituto de Astrofísica de Andalucía |
| IAC | Instituto de Astrofísica de Canarias |
| ISO | Infrared Space Observatory |
| ISS | Interferometer Supervisor Software |
| ITA | Instituto Tecnológico de Aragón |
| IUE | Internacional Ultraviolet Explorer |
| JPL | Jet Propulsión Laboratory |
| OAN | Observatorio Astronómico Nacional (National Astronomical Observatory) |
| OPD | Optical Path Difference |
| PD | Preliminary Design |
| PDR | Preliminary Design Review |
| PPARC | Particle Physics and Astronomy Research Council |
| SOW | Statement Of Work |

| | |
|---|---|
| TCS | Telescope Control System |
| UAM | Universidad Autónoma de Madrid |
| UC | Universidad de Cantabria |
| UCM | Universidad Complutense de Madrid |
| ULL | Universidad de La Laguna |
| UNAM | Universidad Nacional Autónoma de México |
| US | Universidad de Salamanca |
| VLT | Very Large Telescope |
| VLTI | Very Large Telescope Interferometer |
| VO | Virtual Observatory |
| WBS | Work Breakdown Structure |
| WP | Work Package |


## 1. SUMMARY

This document presents an introduction of GARCIA VARGAS, MARIA LUISA 000852081X SLNE (hereafter FRACTAL S.L.N.E.), a technological company for engineering services, operations and development of scientific projects mainly specialized on professional Astrophysics. The document contains a summary of its services and capabilities as well as a list of the contracts already done for some of our customers.

## 2. INTRODUCTION

FRACTAL S.L.N.E. is a private technology company founded in August 2005, being now more than 17 years old. We provide consultancy services in different engineering areas, focusing our services mainly on Research and operation centers and universities, covering areas such as Management, System Engineering, Instrumentation Design and Development and Software for professional Astrophysics.

Most of FRACTAL's consultants worked at GRANTECAN Company, in charge of the development of the 10-m telescope, the GTC, being FRACTAL's General Manager the Head of the GTC Instrumentation Group for more than 9 years. FRACTAL people cover the following skills: Astronomical Instrumentation (including Optics, Mechanics, Electronics, Detectors, Cryogenics, etc.); Control and Software Development (Real Time Control, astronomical telescope software, active Optics loops, mechanisms control, Data bases and Data management and processing) and Management and System Engineering (including TRMAS analyses).

This specific expertise has allowed us to participate in the development of current major projects in global Astrophysics, such as the instrumentation for the 10m GTC telescope, the 6.5m San Pedro Mártir telescope in Mexico, the HEXA 6.5m telescope in CAHA, the MEGARA instruments for GTC, CARMENES for Calar Alto, and SCORPIO for the North and South Gemini observatories. Also, we can provide services to Space projects (at the level of instrumentation and software development, management, system engineering and quality control, being planning software for Euclid mission the most recent contribution).

### 2.1 Contractual Data and Company identification

The commercial name of the company is FRACTAL S.L.N.E. The "legal" name is: GARCIA VARGAS, MARIA LUISA 000852081X S.L.N.E., where S.L.N.E. is the acronym for Sociedad Limitada Nueva Empresa, New Company Limited Society, a legal form for small companies in Spain promoted by the Spanish Industry Ministry where the name comes from the surname of the main partner plus a combination of numbers and letters getting from the name and combined by an automatic algorithm. The company was registered in the *Registro Mercantil de Madrid, Tomo 53 Libro 0 Folio 46 Sección: SLNE Hoja: M.1250 Inscripción 3ª el 10/06/2009* (data from the Commercial Register in Madrid).

The identification code for the company is CIF (VAT): ESB38829107.

Formal / Legal Name: GARCIA VARGAS, MARIA LUISA 000852081X S.L.N.E.

Commercial Name: FRACTAL S.L.N.E.

Company address: C/ Tulipán nº 2, p.13, 1ºA. E-28231 Las Rozas de Madrid. Madrid (Spain)

Phone: +34 916379640 / +34 630737981 FAX: +34 917917113

Company Partners:

- Dr. María Luisa García Vargas (PhD in Astrophysics). Director (own: 70 %)
- Pedro Gómez-C. Álvarez (Msc. Physics). Head of the Software Area (own: 30 %)

We will provide the official document for the company constitution and the formal document with the CIF number or any other administrative document under request. The company pays regularly all the taxes to the Treasury Agency and to the Social Security. We can provide official and updated certificates from these institutions if required.

### 2.2 Technical capability

FRACTAL has an excellent team of highly qualified consultants, all with university education in scientific and engineering disciplines: Engineering, Mathematics, Physics, etc. We develop the projects with a multidisciplinary approach. Our professional career includes both private industry and universities and science operations centers. FRACTAL's value is the sum of the ability and imagination of FRACTAL people. We have been working together for many years and we do each project by combining our forces to produce the best results. We are a group of 16 people (some of us with more than 30 years of expertise) covering the following areas:

- Management
- System Engineering and RAMS analyses
- Software for Data Bases
- Control Software (Real Time, Distributed Systems, Mechanism control)
- Data Reduction Pipelines and Graphic User Interfaces
- Telescope Control Systems
- Optics (Optics, Opto-mechanics and Adaptive Optics)
- Mechanics
- Cryogenics, CCDs and Data Acquisition System
- Astronomy

The CVs of our partners and collaborators are available to our clients upon express request, respecting the current data protection legislation.

The following section includes a detailed list of the relevant contracts made as a company, including some reference persons who can endorse the technical capability of the company FRACTAL to undertake scientific and engineering services.


## 3. FRACTAL CONTRACTS

### 3.1 Management, System Engineering and Quality Assurance consultancy and services

[1] **Management, System Engineering and Quality Assurance services for CALEMOS, the Calibration Module of MOSAIC instrument for the ESO ELT and NIR spectrographs mechanisms.**

**Customer**: **UCM** (Universidad Complutense de Madrid)

**Description**: Management, System Engineering and Quality Assurance services for CALEMOS, the calibration module of MOSAIC instrument for the ESO ELT, and NIR spectrographs mechanisms. MOSAIC is the next optical/infrared spectrograph for ELT ESO giant telescope. FRACTAL consultants María Luisa García Vargas, Ana Pérez Calpena and María Peñataro have the roles of Project Manager, System Engineer and Quality Assurance manager, respectively. MOSAIC project is expected to be developed between 2022 and 2032 (+3).

**References**:

- Dr. Jesus Gallego Maestro (j.gallego@ucm.es), Member (representing Spain) in MOSAIC Consortium Board, Astronomy Department of the Universidad Complutense de Madrid.
- Dr Armando Gil de Paz, (agil@fis.ucm.es), MOSAIC Calibration Scientist, Astronomy Department of the Universidad Complutense de Madrid.

[2] **Maintenance plan for the LST/CTA subsystems: camera, bogies and Azimuth Locking System (ALS)**

**Customer: RAMEM-Arquimea**

**Description**: Development of a Maintenance Plan for the LST / CTA subsystems: camera, bogies and ALS. CTA project is the largest Cherenkov radiation telescope currently under construction.

**References**:

- Francisco Gutiérrez Macias (fgutierrez@ramem.com)
- Pablo Romero (p.romero@ramem.com)

[3] **Management and System Engineering services for TARSIS**

**Customer**: **CAHA (Calar Alto Observatory)**

**Description**: Management and System Engineering services for TARSIS instrument, spectrograph for the 3.5m telescope at CAHA Observatory.


**References**:

- Dr. Jesús Aceituno, CAHA Director, (aceitun@caha.es)
- Dr Armando Gil de Paz, (agil@fis.ucm.es), co-PI of TARSIS project, Astronomy Department of the Universidad Complutense de Madrid.
- Dr Jorge Iglesias, (jiglesia@iaa.es), co-PI of TARSIS project, IAA-CSIC.

TARSIS is in the Conceptual study phase. TARSIS has been selected as the next instrument for CAHA. The project will run between 2022 and 2026.

[4] **Management, System Engineering and Quality Assurance services for SCORPIO Optics, Mechanics and Cryogenics (from design to AIV phase)**

**Customer**: **SwRI (Southwest Research Institute)**

**Description**: Management and System Engineering services for SCORPIO (**S**pectrograph and **C**amera for the **O**bservation of **R**apid **P**henomena in the **I**nfrared and **O**ptical) is the next facility instrument for Gemini Observatory (two twin telescopes of 8.2m, one in north and one in the south). SCORPIO is a very complex instrument with both infrared (4) and visible (4) channels. FRACTAL is in charge of Optics, Opto-mechanics and Mechanics, Cryogenics and Integration. Management, System Engineering and Quality Control services cover all activities developed by FRACTAL.

**References**:

Dr. Pete W. Roming (pete.roming@swri.org) Director of Space Engineering Department; Space Science & Engineering Division, Southwest Research Institute

This contract is in place since 2017, being the instrument in the AIV stage in Madrid. End of AIV stage is planned end-2023 early 2024.

[5] **Management and System Engineering services for MEGARA**

**Customer**: **UCM** (Universidad Complutense de Madrid)

**Description**: Management and System Engineering services for MEGARA instrument (an IFU wide field instrument for the GTC 10-m telescope) in the whole instrument life-time [2010-2017], according to the customer requirements and constraints taken into account the interface constrains imposed by GTC and the scientific requirements and managerial constrains coming from the different scientific partners of the project: UCM, INAOE (Mexico), UPM and IAA. FRACTAL consultants María Luisa García Vargas and Ana Pérez Calpena have been the Project manager and the System Engineer of MEGARA project. MEGARA was commissioned in the summer of 2017 and it is currently in operation since July 2018.

**Reference**: Dr Armando Gil de Paz, (agil@fis.ucm.es), PI of MEGARA project, Astronomy Department of the Universidad Complutense de Madrid.

[6] **Management and System Engineering services for CARMENES project at CAHA**

**Customers**:

**LWS** (Landessternwarte Königstuhl-ZAH (Heidelberg, Germany)

**IAA** (Instituto de Astrofísica de Andalucía, Granada, Spain)

**CAHA Observatory**

**Description**: Management and System engineering services for CARMENES instrument, a new double arm echelle spectrograph for the 3.5m CAHA telescope in operation since 2016 and with almost 100 refereed scientific papers until now. FRACTAL consultants María Luisa García Vargas and Ana Pérez Calpena have been the Project manager and the System Engineer of CARMENES project.

**References**:

Dr. Andreas Quirrenbach (aquirren@lsw.uni-heidelberg.de)

Dr. Pedro J. Amado González, (pja@iaa.es), PI and co-PI of CARMENES project

Also, Dr. Jesús Aceituno (aceitun@caha.es) Director of CAHA and the two former directors Dr. David Barrado and Dr. José María Quintana.

[7] **Management and System Engineering Plan for the design and construction of San Pedro Mártir 6.5 Telescope (2015 – 2019)**

**Customer: IA-UNAM** (Institute of Astronomy. Universidad Nacional Autónoma de México)

**Description:** Management and System Engineering services for the 6.5m aperture telescope in San Pedro Mártir, being FRACTAL's consultants María Luisa García Vargas and Ana Pérez Calpena the Project Manager and Chief Engineer respectively and María Peñataro the Systems Engineer. The work implies communication with the different partners (IA-UNAM, University of Arizona (Steward Observatory, INAOE and Smithsonian Astronomical Observatory, Center for Astronomy, Harvard (SAO, CfA) and the participant companies (M3) and technological centers (CIDESI).

**References:**

Dr. William Lee wlee@astro.unam.mx Coordinator of Scientific Research-UNAM and TSPM project Director

Dr. J. Jesús González jesus@astro.unam.mx Director IA-UNAM

[8] **Management and System Engineering Plan for the design and construction of San Pedro Mártir 6.5 Telescope (2014 – 2015)**

**Customer**: **IA-UNAM** (Institute of Astronomy. Universidad Nacional Autónoma de México)

**Description:** Management and System Engineering Plans for the design and construction of a new 6,5m aperture telescope in San Pedro Mártir. Our services included also the production of requirements, specifications and interface control documents.

**References:**

Beatriz Sánchez y Sánchez beatriz@astro.unam.mx

Dr. William Lee wlee@astro.unam.mx
Coordinator of Scientific Research-UNAM and TSPM project Director

Dr. J. Jesús González jesus@astro.unam.mx Director IA-UNAM

[9] **Management Plan for the design and construction of San Pedro Mártir 6.5m Twin Telescopes (early project 2007)**

**Customer**: **IA-UNAM** (Institute of Astronomy. Universidad Nacional Autónoma de México)

**Description**: Management Plan according to the customer requirements and constraints and in order to produce a fair distribution, industrial return and task responsibility for the partners. We produced the WP definition and distribution, described the Project Organization issues, established the schedule and milestones, gave estimations of cost and related cash flow, and discussed the industrial return and other partnership-related issues.

We have had several contracts since the beginning of the proposal. The references for the Management contracts have been:

**References**:

Dr. José Franco, (pepe@astroscu.unam.mx). Ex - Head of the Astronomy Department of the Universidad Nacional Autónoma de México.

Dr. William Lee (wlee@astro.unam.mx). Coordinator of Scientific Research-UNAM

Dr. J. Jesús González (jesus@astro.unam.mx ). Director IA-UNAM

[10] **Consultancy for the market study of VIA-SKA**

**Customer**: **IAA**

**Description**: Consultancy services for studying the feasibility of the Spanish Industrial Participation in the Square Kilometer Array (SKA). This work is part of the actions carried out by the VIA-SKA project, which has been funded by the Ministerio de Ciencia e Innovación (MICINN) and includes researchers and engineers from the Instituto Geográfico Nacional, Universidad de Granada, Universidad de Barcelona, Universidad Carlos III, Instituto de Física de Cantabria / Universidad de Cantabria, Universidad de Valencia, Centro de Astrobiología and Instituto Astrofísico de Canarias

**Reference**: Dr. Lourdes Verdes-Montenegro (lourdes@iaa.es ), IAA Researcher

[11] **Safety and maintenance plan for the LST of the CTA project**

**Customer: UCM** (High Energy Department)

**Description**: Development of a Safety and Maintenance Plan for the LST of the CTA project, the largest Cherenkov radiation telescope currently under construction.

**Reference**: Dr. José Miguel Miranda miranda@fis.ucm.es

We have been collaborating in some internal meeting and workshops.

[12] **Management and System Engineering Plan for HEXA 6.5m telescope at CAHA**

**Customer: CAHA**

**Description:** Management and System engineering services for developing the HEXA 6.5m telescope and its instrumentation for CAHA Observatory.

**Reference:** Dr. David Barrado, (barrado@caha.es ), Ex-CAHA Director

[13] **Management services for The PDR Documentation Package. Two Towers Project**

**Customer: INTA** (Instituto Nacional de Técnica Aeroespacial)

**Description:** Management support services to INTA in the framework of the Preliminary Design Documentation package preparation of the Two Towers project for SEOSAT Ingenio.

**Reference:** Dr. Héctor Guerrero Padrón, (guerreroph@inta.es). Instrumentation Department. Opto-electronics laboratory. Spatial Programs and Spatial Science, INTA

### 3.2 Software services at customer

[14] **Software Development of the Euclid mission planning software system.**

**Customer: Telespazio for ESA (European Space Agency)**
*Service Contract No. TVUK/AG/17/02052 (01Jul2017 – 31Dic2024)*

**Reference:** Anna Corlyon (Anna.Corlyon@telespazio.com )

**Description:** A consultant worked at customer's offices and remotely in ESAC (Madrid) to develop the Euclid-ESA Mission Planning software system.

FRACTAL is participating in the ESA Frame Contract for Software and Scientific Services as a sub-contractor of Telespazio company,

[15] **Software Development for the pipelines of VLT instruments**.

**Customer: European Southern Observatory, ESO**

*Service Contract No. 20147/ESO/08/18366/GWIE*

**Reference**: Gerd Wieland (gwieland@eso.org) and Pascal Ballester (pballest@eso.org)

Head of Contract procurement department and Head of Pipelines Department

**Description:** A consultant worked at customer's offices in Garching (Munich) during 2 years (April 2008 – April 2010) to develop customized software for reduction and analysis of data taken with the instruments of the VLT telescopes (4 telescopes of 8m diameter placed at Cerro Paranal in Chile). Among his tasks, he has contributed to the development of the pipeline for instrument HAWK-I and for SINFONI.

[16] **Preparation of data reduction procedures for the ESO VLT pipelines, and the implementation of these parts in ANSI-C with the ESO-CPL library**

**Customer: European Southern Observatory, ESO**

*Service Contract No. 32518/ESO/10/32982/YWE*

**Reference:** Pascal Ballester (pballest@eso.org), Head of Pipelines Department

**Description:** A consultant worked at customer's offices in Garching (Munich) during 2 years (April 2010 – April 2012) to develop customized software for ESO VLT pipelines.

[17] **Software consultancy for the development of an astronomical database to store and handle the data from the HIFI/Herschel mission (ESA)**

**Customer: Centro Nacional de Información Geográfica, CNIG**

**Reference**: Dr. Pere Planesas (p.planesas@oan.es), CNIG researcher and contract responsible.

**Description:** A consultant was working at customer during 1.5 years to develop customized applications to manage a database of final products resulting from scientific astronomical observations. The database (on MySQL) is managed by a Java application local-based. Users (with different profiles) can connect to this database through Internet. From Internet, a user can interact with the database according to their permissions and with a basic tool for quick look and analysis of the calibrated images and spectra. The main functionalities are the management of:

- Herschel/HIFI (spectra) Data - Radiosources Catalogue (from SIMBAD)
- Spectral Lines Catalogue (from JPL Molecular Spectroscopy).
- Users and Groups Management
- Permissions according to the data property policy

Through Internet it shall be possible to:

- Make queries to the database
- Many search criteria available
- Visualize and/or Download the spectra (with the adequate permissions)
- Applet for the Calibrated Spectra allows smoothing, unit change, zoom etc.

[18] **Software consultancy (part-time) for the development and maintenance of an astronomical database and other software facilities for the HIFI/Herschel (ESA)**

**Customer: Instituto Geográfico Nacional / National Astronomical Observatory**. OAN

**Reference**: Dr. Valentín Bujarrabal (v.bujarrabal@oan.es)

OAN researcher and contract responsible

**Description**: A consultant worked at customer during 2 years (July 2008 –June 2010) to develop customized applications to manage a database of final products resulting from scientific astronomical observations and other software developments and facilities related to HIFI/Herschel project.

### 3.3 Scientific Support and Operations services at customer

[19] **Astronomical support for the Spanish National Observatory (Radioastronomy) in the development of a user support platform for the HIFI instrument (Herschel mission, ESA).**

**Customer:** **Centro Nacional de Información Geográfica, CNIG**

**Reference:** Dr. Pere Planesas (p.planesas@oan.es), CNIG researcher and contract responsible.

[20] **Pre-launch Operational support for the Spanish National Observatory (Radioastronomy) for the HIFI instrument (Herschel mission, ESA).**

**Customer:** **Centro Nacional de Información Geográfica, CNIG**

**Reference**: Dr. Pere Planesas (p.planesas@oan.es), CNIG researcher and contract responsible.

**Description:** The two former contracts for scientific operations implied that two people were working at customer's offices to develop the agreed contract scope. In particular they had the following associated tasks for the support to the users granted with OAN Guaranteed Time Key Program for HIFI

Scientific tasks

- Simulations
- Data reduction
- Millimetric observations proposal submission from the Ground

Support tasks

- Installation and updates of HSPOT ESA software
- Support to OAN astronomers in the HSPOT use
- Meetings with ESA HIFI/HSPOT responsible
- Preparation of the AOR, Astronomical Observing
- Request for the OAN Key-Program
- Meetings and talks at OAN
- HIFI/OAN User Support Web Page. Documentation
- Twiki, Distribution Lists, internal and outreaching (public) web pages

### 3.4 Astronomical Instrumentation Development

[21] **TARSIS Feasibility Study, spectrograph for the 3.5m telescope at CAHA**

**Customer: CAHA (Calar Alto Observatory)**

**Description**: TARSIS instrument design, spectrograph for the 3.5m telescope at CAHA Observatory. TARSIS is in the Conceptual study phase. TARSIS has been selected as the next instrument for CAHA. The project will run between 2022 and 2026.

**References**:

- Dr. Jesús Aceituno, CAHA Director, (aceitun@caha.es)
- Dr Armando Gil de Paz, (agil@fis.ucm.es), co-PI of TARSIS project, Astronomy Department of the Universidad Complutense de Madrid.
- Dr Jorge Iglesias, (jiglesia@iaa.es), co-PI of TARSIS project, IAA-CSIC.

[22] **Completion of four ESO standard Continuous Flow Cryostats for the following ESO projects:**

- IRLOS: Detector system
- HARMONI: Visible Focal Plane Test Cryostat
- Infrared Detector Laboratory: Saphira Detectors Test Cryostat
- Cryogenic Laboratory: Cryogenic Systems Test Bench for ELT

**Customer**: **European Southern Observatory (ESO)**

**Reference:** Matteo Accardo (maccardo@eso.org)

**Description:** Manufacturing, integration and tests of 4 CFCs for ESO

Contract: Delivered

[23] **Final contract for the Optics, Mechanics and Cryogenics elements of SCORPIO imager and spectrograph for Gemini (South and North)**

**Customer: South West Research Institute, SwRI (San Antonio, Texas, USA)**

**Reference:** Pete Roming (proming@swri.edu), SCORPIO Project Manager.

**Description:** Optics, Mechanics and Thermal packages: full design (from Preliminary to detailed), manufacturing tracking, integration and test of the SCORPIO instrument for Gemini, the 8-channel mid-resolution spectrograph for Gemini Observatory. The project is currently facing the AIV stage.

Contract: In progress, **2017 - 2023**

[24] **Optics, Mechanics and Cryogenics Conceptual Design for OCTOCAM (Gemini)**

**Customer: IAA**

**Reference:** Antonio de Ugarte Postigo (adeugartepostigo@gmail.com)

**Description**: Conceptual design of the optics, mechanics and cryogenics of the 8-channel mid-resolution spectrograph for Gemini Observatory.

The project has been selected by Gemini.

[25] **MEGARA, a mid-resolution intermediate spectrograph for the GTC**

**Customer**: **Universidad Complutense de Madrid**

**Reference:** Dr. Armando Gil de Paz (agil@fis.ucm.es)

Professor/ UCM Researcher and contract responsible

**Description:** Services and products to design and develop MEGARA: a spectrograph for the GTC. These services have been agreed for the whole project duration [2010-2017] and include: Optical Fiber Bundles design and integration; Optics, Mechanics and Detector design of the spectrograph, final integration and tests as well as the Management and System Engineering WP. Also, FRACTAL is in charge of specifying and procuring the whole set of VPH-based elements and of the MEGARA Control System architecture.

**Contract:** closed. Instrument commissioning finished August 31st 2017.

[26] **Conceptual Design for MEGARA, a mid-resolution intermediate spectrograph for the GTC**

**Customer: Universidad Complutense de Madrid**

**Reference:** Dr. Armando Gil de Paz (agil@fis.ucm.es)
Professor/ UCM Researcher and contract responsible

**Description:** Conceptual design of MEGARA for the GTC. FRACTAL was in charge of Management, System Engineering, Optics, Mechanics and Detector of the spectrograph.

Contract finished: **2009 - 2010**

[27] **Preliminary Optical Design of Telescopio San Pedro Mártir**

**Customer**: **IA-UNAM**

**Description:** Preliminary Design of the Telescopio San Pedro Mártir

**References:**

Dr. Michael Richer richer@astro.unam.mx Director OSPM

Dr. Jesús González jesus@astroscu.unam.mx Director IA-UNAM

[28] **Optical Design and Filter specifications for the PAU camera for the 4.2m WHT**

**Customer**: **Instituto de Estudios Espaciales de Cataluña (IEEC)**

**Reference:** Ricard Casas (casas@ieec.uab.es )

IEEC Researcher and contract responsible

**Description:** Optical design and filter specification for the PAU camera, a wide FOV imager for the 4.2m William Herschel Telescope at La Palma

[29] **Design and development of ARES spectrograph and Fiber Link**

**Customer: Instituto de Estudios Espaciales de Cataluña (IEEC)**

**Reference:** Dr. Ignasi Ribas (iribas@ice.csic.es)

IEEC Researcher and contract responsible

**Description:** Design and development of the fiber-fed spectrograph, ARES for the IEEC at R=12000. The project started at the level of requirements and finished with the installation at the telescope.

[30] **Design and development of LICA laboratory for Universidad Complutense**

**Customer: Grupo GUAIX, Departamento de Astrofísica, UCM**

**Reference:** Dr. Jaime Zamorano (jzamorano@fis.ucm.es)

Professor/ UCM Researcher and contract responsible

**Description:** We have developed the design of the for Laboratory for Scientific Advanced Instrumentation of GUAIX group at UCM (Astrophysics department)

[31] **Diagnostics of TROBAR camera for ARAS de los Olmos Observatory**

**Customer**: **Universidad de Valencia**

**Reference**: Dra. Julia Suso (julia.suso@uv.es )

Professor/ UV Researcher and contract responsible

**Description:** We performed a diagnosis of the CCD camera of the TROBAR telescope at the Aras de los Olmos Observatory (belonging to University of Valencia – Spain)

[32] **Wasatch Photonics Volume Phase Holographic Gratings**

**Partner: Wasatch Photonics**

**Customer:** Several customers / only authorized distributors for whole Europe

We specify and provide VPH holographic gratings to different customers to be used in their applications for ground-based and space instrumentation projects. In particular these gratings have been also produced for large ground-based observatories (like the ones for MEGARA for the GTC 10m telescope and ARES for Observatory of Montsec) and for Space in the framework of Exo-Mars RAMAN spectrograph (INTA).

[33] **Holographic Gratings for the RAMAN spectrograph on board of the Rover of the ExoMars mission**

**Customer: INTA**

**Reference**: María Colombo Bueno (colombobm@inta.es)

Spectrograph Project Manager (INTA)

**Description**: Design and provision of 37 VPH gratings to be qualified and finally fly in the ExoMars mission.

[34] **Acam Conceptual Design (future instrument for the 4.2 WHT at ORM)**

**Customer: PPARC / Isaac Newton Group of telescopes, ING**

**Reference**: Dr. René Rutten (rgmr@ing.iac.es), currently at GTC Project Office

Director of Isaac Newton Group of telescopes

**Description**: We carried out the feasibility study and the optical conceptual design of a new camera and spectrograph for the 4.2m William Herschel Telescope.


[35] **OASIS enlarger Preliminary Design (existing instrument at 4.2 WHT)**

**Customer**: **PPARC / ING**

**Reference:** Olivier Martin (olivier@ing.iac.es)

Instrumentation engineer at ING and contract responsible

**Description:** We developed an upgrade of the entrance Optics of the OASIS instrument in order to enlarge the FOV. Also, the study will include a detailed analysis about stray light to improve the instrument performance.

[36] **Specification and manufacturing tracking of z-filters for Elmer (GTC)**

**Customer: IAC**

**Reference**: Dr. José Alfonso López Aguerri (jalfonso@iac.es)

IAC Researcher and contract responsible

**Description:** We made final manufacturing specifications for a set of narrow band filters for the instrument Elmer from the high-level user requirements (pure scientific requirements)

[37] **Design, and manufacturing tracking of filter mounts and masks for Elmer**

**Customer**: **Instituto de Astrofísica de Canarias, IAC**

**Reference**: Dr. José Alfonso López Aguerri (jalfonso@iac.es)

IAC Researcher and contract responsible

**Description:** We made final the design (including manufacturing drawings, manufacturing tracking, integration and tests of the mounts for the new set of narrow band filters for the instrument Elmer (previous contract)

[38] **Design and development of ESTRANGIS Fiber Link**

**Customer**: **Instituto de Astrofísica de Canarias (IAC)**

**Reference:** Dr. Enric Pallé (epalle@iac.es)

IAC Researcher and contract responsible

**Description:** Design and development of the two-arms fiber link spectrograph, ESTRANGIS for solar observations.

[39] **ALBIREO refurbishment for the Observatorio de Sierra Nevada**

**Customer**: **IAA**

**References**:

José Manuel Vílchez (jmv@iaa.es) Director IAA

Olga Muñoz (olga@iaa.es ) Sub-Director (IAA)

**Description:** Complete refurbishing of the spectrograph ALBIREO for the Observatory of Sierra Nevada (Granada, Spain) under contract with the IAA. The project includes design, manufacturing, new gratings and observing modes and a new module of A&G and calibration as well as several software developments.

[40] **Optical conceptual design of a new telescope for CAHA**

**Customer: CAHA**

**Description:** Conceptual design of a new telescope for CAHA Observatory.

**Reference:** Dr. David Barrado, (barrado@caha.es ), CAHA Director

[41] **Conceptual design of HECATE: a Fiber-Fed spectrograph for HEXA telescope**

**Customer: CAHA**

**Description:** Conceptual design of a high spectral resolution spectrograph for HEXA telescope, the next 6.5m telescope at CAHA Observatory.

**Reference:** Dr. David Barrado, (barrado@caha.es ), CAHA Director

[42] **IACAT Preliminary Design: Telescope and Atmosphere simulator for Adaptive Optics systems**

**Customer**: **Instituto de Astrofísica de Canarias, IAC**

**Reference:** D. Luis Fernando Rodríguez (lrr@iac.es)

Head of the IAC Electronics Department

**Description:** We made the optical, mechanical and control preliminary design of the IACAT system: an atmosphere and telescope simulator to test instruments for AO system at the laboratory. Three telescopes were simulated: OGS, WHT and GTC. Ths system included a wavefront sensor and a complete star simulator system able to provide a single star, double stars and a star cluster.

[43] **Mechanical Conceptual Design for the instrument NAHUAL for the GTC**

**Customer**: **Instituto de Astrofísica de Canarias, IAC**

**Reference**: Dr. Eduardo Martín (ege@iac.es)

IAC Researcher and contract responsible

**Description**: We carried out the conceptual mechanical design of NAHUAL instrument: an echelle spectrograph (R = 130.000) in the near IR (1 to 2.5 microns) for the GTC.

[44] **Conceptual Design for NIRINTS, a high-resolution intermediate spectrograph for the GTC**

**Customer: Centro de Astrobiología**

**Reference**: Dr. Eduardo Martín (ege@iac.es)

Professor/ IAC Researcher and contract responsible

**Description:** We have carried out the conceptual design of NIRINTS: a near-IR spectrograph for the GTC. FRACTAL was in charge of the Optical Design.

[45] **Optical Conceptual Design for ACTUEL, a 2.5m telescope at OAJ**

**Customer: ITA (Instituto Tecnológico de Aragón)**

**Reference**: Emilio Esco (eesco@aragon.es)

**Description**: We carried out the conceptual optical design of a 2.5m telescope with a FOV of 10 squared degrees optimized for survey programs.

[46] **Mechanical Conceptual Design for ACTUEL, a 2.5m telescope at OAJ**

**Customer**: **ITA**

**Reference:** Emilio Esco (eesco@aragon.es)

**Description:** We carried out the conceptual mechanical design of a 2.5m telescope with a FOV of 10 squared degrees optimized for survey programs.

[47] **Coronagraph for CAHA**

**Customer: Universidad de Cantabria**

**Reference**: Dr. Manuel Pérez Cagigal (perezcm@unican.es)
Professor/ Researcher and contract responsible

**Description**: We carried out the whole system design, specification, manufacturing tracking, system integration and tests of a visible coronagraph.

[48] **Infrared Spectrograph and camera for the Antarctic (new instruments)**

**Customer**: **Universidad Autónoma de Madrid, UAM**

**Reference:** Dr. Carlos Eiroa de San Francisco (carlos.eiroa@uam.es)

Professor/ Researcher and contract responsible

**Description**: We carried out the conceptual optical design of two IR instruments: a near IR spectrograph and camera (1.0µm to 2.5µm), PNIRC, and a mid-IR spectrograph and camera in the extended range 8µm to 40µm, PMIRC. Both instruments are being designed for the 2.5m telescope, PILOT, to be in operation at Dome C, Antarctic.

[49] **Design of a high-resolution grating for the Instrument Elmer**

**Customer: Instituto de Astrofísica de Canarias, IAC**

**Reference**: Dra. Casiana Muñoz Tuñón (cmt@iac.es)

IAC Researcher and contract responsible

**Description:** We carried out the complete and detailed design of a novel VPH grating able to produce relatively high resolution (10.000 to 15.000) with high throughput and in Littrow configuration. The element will be a prototype manufactured for the instrument Elmer.

[50] **Tunable Filter Unit (to be used in an existing instrument, upgrade)**

**Customer: Universidad Complutense de Madrid, UCM**

**Reference:** Dr. Jesús Gallego Maestro (j.gallego@fis.ucm.es)

Professor/ UCM Researcher and contract responsible

**Description:** We carried out a design of a Tunable filter in the near-IR (in particular in the K band) to be installed at CIRCE and/or EMIR instruments at the GTC 10m telescope.

[51] **Feasibility study for the spectrograph MSIX for the 3.5m telescope at CAHA**

**Customer: Universidad Complutense de Madrid, UCM**

**Reference:** Dr. Jesús Gallego Maestro (j.gallego@fis.ucm.es) / Armando Gil de Paz

Professor/ UCM Researcher and contract responsible

**Description**: Feasibility study of the instrument MSIX, a grid of 6 - 9 spectrographs fed by an Integral Field Unit design in the visible range for the CAHA 3.5m telescope.

[52] **Feasibility study for the echelle high resolution spectrograph XHAIRS for the 3.5m telescope at CAHA**

**Customer**: **Instituto de Estudios Espaciales de Cataluña, IEEC-CSIC, Barcelona**

**Reference**: Dr. Ignasi Ribas (iribas@aliga.ieec.uab.es )

IEEC Researcher and contract responsible

**Description**: Feasibility study of the instrument X-HAIRS, an echelle very high-resolution spectrograph in the near-infrared range for the CAHA 3.5m telescope.

[53] **Cryostats for very low temperatures experiments**

**Customer**: **Universidad de Salamanca**

**Reference:** Dr. Enrique Díez (enrisa@usal.es )

University of Salamanca Researcher and contract responsible

**Description**: We carried out the detailed design and the corresponding manufacturing specification and tracking of two cryostats optimized for very low temperature experiments.

[54] **Digital Ophthalmoscope Prototype**

**Customer**: **R+D project**

**Description**: Development of a functional prototype of a digital ophthalmoscope for glaucoma early diagnosis.

### 3.5 Software development

[55] **PyPopStar database and GUI**

**Customer**: **CIEMAT**

**Reference:**

Dra. Mercedes Mollá-Lorente (CIEMAT, mercedes.molla@hotmail.es)

**Description**: **HR-pyPopStar** model provides a complete set of high resolution (HR) Spectral Energy Distributions (SEDs) of Single Stellar Populations. The model uses the most recent high wavelength-resolution theoretical atmosphere libraries for main sequence, post-AGB/planetary nebulae and Wolf-Rayet stars. The SEDs are given for more than a hundred ages ranging from 0.1 Myr to 13.8 Gyr, four different values of the metallicity (Z = 0.004, 0.008, 0.02 and 0.05), and four different IMFs. We developed a public web-based software tools and a database to manage HR-pyPopStar models and to make this available to the user's community: https://www.fractalslne.es/PopStar/

[56] **MEGASTAR database and GUI**

**Customer**: **CIEMAT, INAOE**

**Reference:**

Dra. Mercedes Mollá-Lorente (CIEMAT, mercedes.molla@hotmail.es)

Dra. Esperanza Carrasco Licea (INAOE, bec@inaoep.mx)

**Description**: **MEGASTAR** is a stellar spectral atlas for MEGARA (Multi Espectrógrafo en GTC de Alta Resolución para Astronomía). MEGARA is an optical (3650 – 9750 Å), fiber-fed, medium-high spectral resolution (R = 6000, 12000, 20000) instrument in operation on the GTC 10.4m telescope. The scientific exploitation of MEGARA demanded a stellar-spectra library to interpret galaxy data and to estimate the contribution of the stellar populations. MEGASTAR atlas is focused on the highest resolution setups, HR-R and HR-I, and already has almost 1000 stars (twice spectra) thanks to the filler-type OpenTime. We developed a web-based tool and a database that allow handling the observations and making the products available to the community:

https://www.fractal-es.com/megaragtc-stellarlibrary/private/home (user: public; password: Q50ybAZm).

[57] **FMAT (Fiber MOS Assignment Tool) for MEGARA**

**Customer**: **IAA**

**Reference**: Dr. Jorge Iglesias (jiglesia@iaa.es)

Researcher at IAA and representative of IAA in the MEGARA Consortium

**Description:** Development of an S/W Tool for allow the astronomers to prepare and optimize the Multi-Object mode observations with MEGARA instrument for the GTC.

[58] **Quick Look and Cube viewer for MEGARA**

**Customer**: **UCM**

**Reference:** Dr. Armando Gil de Paz ((agil@fis.ucm.es)

Researcher at UCM and PI in the MEGARA Consortium

**Description**: Development of an S/W Tool for Quick Look of MEGARA products and MEGARA spectra-cube viewer.

[59] **MEGARA-GTC Library Database and GUI**

**Customer**: **CIEMAT & INAOE**

**Reference:** Dra. Mercedes Mollá

Dra. Esperanza Carrasco

**Description:** Development of a database and the corresponding web services for user support to manage the MEGARA-GTC Library Observations.

[60] **Web interface for CALIFA database observations**

**Customer: CAHA Observatory**

**Reference:** Dr. Sebastián Sánchez (sanchez@caha.es)

Ramón & Cajal Researcher at IAA/CAHA

**Description**: we developed a complete a web interface for the CALIFA project database.

http://www.caha.es/CALIFA/public_html/

[61] **Database for GTC 10m telescope observations**

**Customer**: **Instituto de Astrofísica de Canarias, IAC**

**Reference:** Dra. Casiana Muñoz Tuñón (cmt@iac.es)

IAC Researcher and contract responsible

**Description**: we developed the database and the corresponding web services for user support to manage the GTC observations of the "Starburst" project of the IAC.

[62] **Hosting FRACTAL Suite services**

**Customers and users**: **UCM, IAA, UPM, CSIC, CNRS, LSW, MPIA, IAG, HS, TLS, INAOE, IA-UNAM**

**Description**: We provide our S/W tools (GECO, DOCMA, MANATEE, SUMO, LLAMA) in hosting mode in our servers to different customers.

[63] **Web Services for the Project "Estallidos"**

**Customer: Instituto de Astrofísica de Canarias, IAC**

**Reference**: Dra. Casiana Muñoz Tuñón (cmt@iac.es)

IAC Researcher and contract responsible

**Description**: we developed a complete web services kit for a scientific project

[64] **Web services for IScAI and GTC-Consolider projects and market study for IScAI**

**Customer**: **Instituto de Astrofísica de Canarias, IAC**

**Reference:** Dr. Rafael Guzmán (guzman@astro.ufl.edu)

Professor at University of Florida, and contract responsible

**Description**: we developed web services (internal and external) of the International School of Advanced Instrumentation, IScAI, as well as a market study of education services through Internet. IScAI is an initiative of the IAC, the University of Florida, the University Complutense of Madrid and UNAM at Mexico.

[65] **Study of the requirements for the definition of the data reduction systems (pipelines) for the E-ELT (ESO)**

**Customer: Universidad Complutense de Madrid**

**Reference:** Dr. Jesús Gallego (j.gallego@fis.ucm.es)

Professor at University Complutense de Madrid, and contract responsible

**Description**: we have carried out a study of the requirements for the definition of the data reduction systems (pipelines) of the E-ELT (ESO) instruments.

[66] **Study of the requirements for the implementation of the data from E-ELT (ESO) instruments in the Virtual Observatory**

**Customer: LAEFF / Centro de Astrobiología (CAB)**

**Reference:** Dr. Miguel Mas-Hesse (mm@cab.inta-csic.es)

Researcher at LAEFF/CAB and contract responsible

**Description:** we have carried out a study of the requirements needed for the implementation of the E-ELT data coming from the instruments in the Virtual Observatory.

[67] **Web services for MEGARA**

**Customer: Universidad Complutense de Madrid**

**Reference**: Dr. Armando Gil de Paz (agil@fis.ucm.es)

Professor/ UCM Researcher and contract responsible

**Description**: we developed web services (internal and external) of the MEGARA project, see webpage by FRACTAL http://guaix.fis.ucm.es/megara

[68] **Web services for SECPhO**

**Customer: SECPhO Cluster in Optics and Photonics**

**Reference**: Sergio Sáez (sergio.saez@secpho.org)

Cluster Manager

**Description:** we developed web services (internal and external) of the SECPhO, Southern Cluster in Photonics and Optics, see webpage by FRACTAL http://www.secpho.org/.

[69] **Web services for VIA-SKA**

**Customer**: **IAA**

**Reference:** Dr. Lourdes Verdes-Montenegro (lourdes@iaa.es)

Cluster Manager

**Description**: we developed web services (internal and external) of the VIA-SKA project, see webpage by FRACTAL http://www.via-ska.es/.

## 3.6 Technology Transfer

### Anti-Vibration Mount. ESO (2018)

**Partner: ESO**

**Description:** FRACTAL signed with ESO an agreement to license the Anti-Vibration Mount (from ESO to FRACTAL) for Closed Cycle Cooler Cold Heads.

The Antivibration mounts are used to reduce vibrations of the Leybold helium cold heads (in particular, Leybold 10-MD) to the levels demanded in order to achieve an optimum performance of the instrument.

### Continuous Flow cryostat Technology. ESO (2015)

**Partner: ESO**

**Description**: FRACTAL signed with ESO an agreement to license the cooling system technology (from ESO to FRACTAL). Continuous flow cooling systems were first developed at ESO for the cooling of instruments and detectors for the Very Large Telescope (VLT). The photo (Credit: ESO) shows The MUSE instrument on the VLT equipped with 24 continuous flow cooling systems.

Continuous flow systems are more compact than traditional systems that use a bath of very cold liquid, but share the advantage of being vibration free. The continuous flow system allows the temperature within an instrument to be changed from room temperature to –193 degrees Celsius and is not affected by the loss of electrical power. As a result, the instrument can be kept very close to its operating temperature and the vacuum within the instrument can be retained.

This agreement includes the licensing of the well-proven cryostats (which regulate the low temperatures) that are used to cool individual detectors from room temperature down to –193 degrees Celsius and the more sophisticated version that is used for the cooling of the ultra-stable detectors used in more sensitive measurements.


### 3.7 Collaboration in Research + Development Projects (only funded projects listed here)

**Estudio de viabilidad para el diseño y caracterización de redes de alta resolución (Feasibility study for the design and characterization of high-resolution gratings).**

**Leader**: FRACTAL SLNE, with the partnership of University Complutense of Madrid

Program: Ayudas para el sector aeroespacial de la Comunidad de Madrid (2009)

**Reference** 04-AEC-0913-000022/2009

Budget: 60% by CAM + 40% by Fractal

**Estudio de viabilidad de sistemas de pupila novedosos para su incorporación en la nueva generación de instrumentos de los grandes telescopios, VIENTOS, IDC-20101106 (Feasibility study of innovative pupil systems to be implemented in the new generation instruments for large telescopes)**

**Leader:** FRACTAL SLNE, with the partnership of University Complutense of Madrid

Program: Industria de la Ciencia (2010-2012)

**Reference** *IDC-20101106*

Funded: 85% by CDTI (119.936,40 euros) + 15% by FRACTAL/UCM

**AstroMadrid, Astrofísica y desarrollos tecnológicos en la Comunidad de Madrid**

**Leader:** Consejo Superior de Investigaciones Científicas, CSIC

**Reference:** Dr José Miguel Mas-Hesse (mm@cab.inta-csic.es). Principal Investigator.

**ASTRID, "Project for development and exploitation of astronomical instrumentation", supported by Madrid Government.**

**Leader**: Universidad Complutense de Madrid, UCM

**Reference:** Dr Jesús Gallego (j.gallego@fis.ucm.es). Principal Investigator.

**Consolider Ingenio 2010 "First Light with the GTC telescope", funded by the Spanish Ministry for Science and Education.**

**Leader**: Instituto de Astrofísica de Canarias, IAC

**Reference:** Dr. José Miguel Rodríguez Espinosa.(jre@iac.es). Principal Investigator

**Project for the detection of telluric exoplanets with very high spectral resolution instruments in very large aperture telescopes, funded by the Spanish Ministry for Science and Education.**

**Leader:** Instituto de Astrofísica de Canarias, IAC

**Reference:** Dr. Eduardo Martín (ege@iac.es). Principal Investigator

**"Herschel: Contribution to the Science and Instrument Control Centres of SPIRE and PACS " funded by the Spanish Ministry for Science and Education.**


**Leader**: Instituto de Astrofísica de Canarias

**Reference**: Dr. Ismael Pérez Fournón (ipf@iac.es). Principal Investigator.

**"Star Formation Bursts"**

**Leader:** Instituto de Astrofísica de Canarias

**Reference:** Dr. Casiana Muñoz-Tuñón (casiana@iac.es). Principal Investigator

**"Design and development of a coronagraph"**

**Leader:** Universidad de Cantabria

**Reference**: Dr. Manuel Pérez Cagigal (perezcm@unican.es). Principal Investigator

We also have participated in infrastructure projects with U. Complutense and U. Salamanca

# 4. FRACTAL SERVICES

## 4.1 Strategic goals

FRACTAL SLNE is a private technological company for the execution of scientific-oriented projects whose main goals are:

- To keep updated as a company specialized in engineering and managing services for scientific projects, particularly for professional Astrophysics.
- To focus our services mainly to the research centers and universities, who define and lead the scientific projects.
- To collaborate with other companies, universities and research centers in Research + Development + Innovation Projects for scientific applications.
- To contribute to the consolidation of Instrumentation and Software groups for professional Astrophysics, participating in the international consortia and projects.

## 4.2 FRACTAL Services

The services we provide to our customers are:

- Management, and Development of multidisciplinary scientific projects
- Engineering and Scientific Support services at customer's site
- Consultancy in Management, Optics, Detectors, Data Acquisition Systems, Software and Systems Engineering.
- Volume Phase holographic gratings and related projects
- System Engineering
- Software Development for scientific applications
- Software Tools for Systems Engineering and Project Management
- Professional Training
- Web services and hosting for scientific projects
- "Astrojobs" web service for job positions search/promotion in Astronomy

The products we offer are:

- Software Tools for Project Management and Systems Engineering: GECO, DOCMA, MANATEE, SUMO, LLAMA.
- Continuous Flow Cryostats (CfC´s) under ESO licensed technology.
- Anti-vibration mounts for cryogenic cold heads under ESO licensed technology.
- Holographic gratings under collaboration with Wasatch Photonics

- Stand-alone software control tool based on Beckhoff control systems for real-time control of Continuous Flow Cryostats.

### 4.2.1 Management and Development of multidisciplinary scientific projects

The FRACTAL team is specialized in managing and developing multidisciplinary projects with scientific goals. Starting from the basic scientific requirements of our customers, FRACTAL can do feasibility studies, design studies (at different levels) or even the whole project, including the manufacturing and test phases, with the help in some areas of other companies (mainly for manufacturing) with which FRACTAL has previously worked. In FRACTAL we offer an ad-hoc management service to complement the academic and scientific capital in hands of the universities and research centers, with our professional and highly qualified engineering team. This will lead to a science-driven project, well managed and executed by people with many years of professional experience developing and participating in scientific projects.

We offer a solution focused on our customer's needs. We can help them to review their scientific requirements and to find a feasible solution executable in a competitive schedule. We specifically offer Project Management and System Engineering services (including RAMS and Quality Assurance services) for scientific projects that developed by International Consortia. Under the Principal Investigator, we provide project management of the project and coordinate the effort of the different institutions. We also provide all kind of engineering services and organization-related software and tools (web services; documentation, management and configuration database, through Fractal Suite etc.).

### 4.2.2 Engineering and Scientific Support Services at customer's site

FRACTAL S.L.N.E. can send highly qualified staff (PhD. in Science, Degree in Science and Engineers) to the customer offices to develop projects in-situ. This gives our customers the opportunity of counting on excellent engineers and scientists but only for the required time and without the problems and time-consuming efforts of finding, contracting and training new staff. This service can give the projects the needed dynamism to make them highly competitive.

FRACTAL staff is especially trained on the operation and exploitation of scientific facilities, and in particular, astrophysical observatories at both, Ground and Space.

### 4.2.3 Consultancy

Consultancy service is nowadays one of the most efficient tools used in the Industry for the quality control of its own work. FRACTAL offers consultancy services for bid revisions, project planning, technical specifications, design, acceptance and test plans, etc. in the areas of Management, System Engineering, RAMS analyses, Optics, Mechanics, Software and Control systems.

We offer different consultancy solutions according to our customer's needs:

- By e-mail: Sending the report with the revision provided by the customer.
- In person: at customer's offices for design reviews or technical meetings.
- Organization and management of Project Design Reviews: FRACTAL can select and manage the professional services of a panel of experts (Fractal's consultants or external consultants) for Design Reviews at customer's offices.

In particular we can provide all kind of Optics services. We provide design, specification, manufacturing and tests of optical systems. We can carry out the design and/or development of any optical system. Starting from the basic scientific requirements, we can produce feasibility studies, designs (at different levels) or even the development of the whole project, including the manufacturing, which we would subcontract to companies or centers with which FRACTAL has been worked for years. In particular we do specification, design, acquisition and tests of collimators, cameras, mirrors, beam-splitters, filters, prisms, grisms, and Volume holographic gratings (VPHs), especially for astronomical instruments and telescopes.

### 4.2.4 Volume Phase holographic gratings and related projects

We are distributor in Europe for Wasatch Photonics. This American company is specialized in high performance Volume Phase Holographic Gratings (VPHGs) and Volume Phase Holographic Optical Elements (VHOEs). https://wasatchphotonics.com/. We have provided VPHs to different Astronomy projects in Spain (UCM, IAA, INTA, CAB).

### 4.2.5 System Engineering

Systems Engineering is essential for the success of projects, especially the more complex ones, which include different professional disciplines and whose partners and working groups are often geographically distributed. In addition, Systems Engineering also includes the Operation and Maintenance plans for the facilities, once the project construction is finished. A good Operation and Maintenance Plan guarantees the expected return, optimizes the human and economic resources and eases, thanks to the use of specific software tools, the facility management. FRACTAL team has been working in SE for frontline scientific projects. The services in Systems Engineering we can provide to our customers are:

#### *4.2.5.1 Systems Engineering Consultancy*

- Systems Engineering Plan Definition
- RAMS Plan
    - Reliability and Availability Plan
    - Operation and Maintenance Plan
    - Safety Program Plan

#### *4.2.5.2 Systems Engineering Plan Definition*

The success of every project in terms of both, the performance specifications and the schedule and budget fulfillment, strongly depends on a good organization. One of the bases of this organization is the definition and the implementation of a Systems Engineering Plan. The Systems Engineering is the interdisciplinary effort that governs the global technical effort done in the project framework to transform the initial requirements into a final system. A Systems Engineering Plan has to describe the approach, techniques, tools, organization and plan of the technical effort needed to reach the project goals. The Systems Engineering Plan functions include:

- To assure the integration of the different project disciplines.
- To implement the requirements engineering, whose goals are: to assure that the user needs are being correctly traduced; to generate, control and keep a coherent set of specifications at the different system levels; and to assure the traceability between the system requirements and the subsystems specifications.
- To develop the analysis, needed to solve the conflicts among requirements, to study the different design alternatives and to study the project risks and their effects on the cost and the schedule.
- To define the configuration: System Product Tree.
- To probe the System functionality and performance, by producing the verification matrix and by designing and carrying out the test plans.

#### *4.2.5.3 RAMS Plan*

The Reliability, Availability, Maintenance and Safety Plan, RAMS, includes all the considerations to take into account in the different project phases, to fulfill the requirements of Reliability, Availability, Maintenance and Safety.

**Reliability and Availability Plan**

The ILS (Integrated Logistic Support) is an important plan of the Systems Engineering Plan. The ILS has to assure that the reliability and availability requirements of the systems are taken into account in the design. This plan includes the distribution of these requirements among the different subsystems; the definition and development of the analysis to evaluate the requirements fulfillment and the execution of the actions to assure the reliability and availability requirements (e.g. component selections, redundancy decisions, etc.). These analyses include:

- Feasibility Analysis to study the failure probability of a subsystem and its parts. This includes the determination of the MTBF (Mean Time Between Failures) and the MTTRs (Mean Time to Repair) of the different components.

- FMECA (Failure Modes Effect and Criticality Analysis) identifies and offers solutions to potential failures. The FMECA identifies the hazardous event, the cause, the method of control, and the corrective action. The failure probability analysis, its severity, the possible solutions, detection methods and prevention should be done for each of the critical system components.

**Operation and Maintenance Plan**

In parallel to the Systems Engineering Plan, a project has to define from the beginning the basis of the Operation and Maintenance Plan, which has to include the following aspects:

- Goal definition and Operation and Maintenance Policy.
- Operation tasks definition and operation restrictions.
- Maintenance tasks definition and maintenance restrictions including both predictive and corrective maintenance.
- Definition of the resources (personnel, workshops, tools, spares, supplies, external services and documentation) to carry out the operation and maintenance tasks.

From this Plan, the Systems Engineering will distribute requirements and restrictions to each subsystem that will have to be taken into account during the design and

**Safety Program Plan**

The project has to include a Safety Program and to track its fulfillment through all the project phases. This plan has to control the risks associated to both, the design and the final use of the system. This safety plan will include the safety policy and the risk levels definitions. The plan will also include the necessary analysis to study the safety of people, the facility and the equipment. The results of these analyses will provide an input for the design and for the final use.

### 4.2.6 Scientific Software Development

The technological challenge of the different scientific and engineering subjects has evolved from the need of improving the detection instruments (to produce better CCDs in Astronomy, better sequencing methods in Biotechnology, better particle detectors in High Energy Physics, etc.) to the current status, in which the most critical issue is the management of the large amount of data produced by the faster, more powerful and more capable instruments. The current development status of scientific instrumentation reached the past 20 years has been possible thanks to the technological advances in Optics, Electronics and Material Physics. However, this progress has produced a new need: the development of powerful software tools able to process, reduce, visualize, analyze, archive and distribute the huge amount of data produced by the instruments. This evolution has led to the growth of the intrinsic complexity of the scientific facilities,

transferring the complexity of the parts to the System Control. This implies the use of the most advanced techniques in Software Engineering.

The FRACTAL team has experience in the Development and Operation of Complex Control Software Systems for Data Reduction and Analysis of scientific projects and also in the Definition and Implementation of Distributed Control Systems.

As examples of the software which our company can develop for scientific applications:

- Reduction and Visualization of data
- User interfaces (GUIs)
- Distributed Control systems
- Mechanism Control
- Real Time Control
- Telescope control systems: FRACTAL is currently developing a SW application for integral control of a ground telescope in Linux.

#### *4.2.6.1 Software for a stand-alone Beckhoff-based control of CFCs*

FRACTAL has developed a stand-alone Beckhoff-based control system for CFC (Continuous Flow Cryostat, ESO technology). This tool allows the authorized users to control the CFC system in real time (start/stop the system, start/stop subsystems, modify different parameters, etc.).

### 4.2.7 System Engineering Software Tools

We provide customized development of software tools for System Configuration Management and for the Management of the tasks and activities carried out during the Operation Phase of a given facility. Both tools contain a Database and a user interface adapted to the requirements of each customer. The Database is implemented in MySQL and the user interface is developed in JAVA, in order to offer a Platform-independent product based on free distribution software.

**GECO: System Configuration Management Tool**

GECO is a customized software tool for System Configuration Management. This tool would be an essential part of the System Engineering Plan in order to control and to maintain the requirements, specifications and interfaces of a System.

To illustrate the advantages of this tool, we list here its main utilities:

- Configuration data repository: product tree elements and parts archiving. The product tree provides a representation of the entire system and breaks it down into the subsystem

levels that will be designed and acquired independently. A Part is the lowest level that can be reached in the system breakdown.

- Configuration data repository: documentation archiving. GECO provides the means to organize, classify and access all the documents generated within the organization.
- Configuration data repository: interface and requirements archiving. An interface is defined as the boundary between two subsystems (hardware or software). It is especially important that the interfaces between subsystems that are under the responsibility of different work groups are controlled. A requirement is defined as the capacity or condition that a system, subsystem or component must meet to satisfy the specification or contract that has been formally imposed on this system, subsystem or component.
- System Traceability Tool and Analysis Traceability Tool: All requirements must be justified by a source or by one or several main requirements. Therefore, any change in a requirement may affect many other requirements. GECO provides the tool to analyze which requirements may be affected by a configuration change of a main requirement.
- Verification / Compliance Matrix Control Tool: The verification matrix collects all the information that will be generated during the requirements verification process, including information such as the planning of the verification tests and the result of these activities. The compliance matrix provides the state of the system, and the user can easily verify which requirements have been met and which could compromise the objectives of the system.
- Configuration Changes (CC) Control Tool: GECO allows to manage and archive configuration changes (referring to changes on some element of the product tree, interface, requirement or plan). All relevant information generated during the life cycle of a CC can be entered and maintained in the application. GECO will also help in the coordination and distribution of information about the configuration changes by sending emails in the most important life cycle transitions of the configuration change.
- Non-conformities control tool: A non-conformity or non-conformance is defined as the breach of a specific requirement. All relevant information generated during the life cycle of a non-conformance can be entered and maintained in the application. GECO will also help in the coordination and distribution of information about non-conformance by sending emails in the most important life cycle transitions of non-conformance.
- Anomalies control tool: An anomaly is any abnormal behavior of the system that must be recorded and investigated. All relevant information generated during the life cycle of an anomaly can be entered and maintained in the application. GECO will also assist in the coordination and distribution of information about the anomaly by sending emails in the most important life cycle transitions of the anomaly.
- RAMS module for GECO: RAMS module for GECO: This tool allows managing reliability/availability analyses and reliability/availability budgets for astronomical telescopes and instruments. The authorized users can create components, introduce its

reliability/availability parameters (such a MTTF, MTBF and MTTR) and the tools supports the calculation of system reliability, downtime and downtime rate (i.e. reliability/availability analyses).

**DOCMA: Document Management Tool**

DOCMA is a customized software tool for tracking and managing the documentation generated within any organization during the whole document life-cycle. Access to the documents is granted through different user – permissions and roles (authors, reviewers, approvers, etc.).

DOCMA uses an open-source code relational database and provides a graphical user interface based on web forms. The tool allows to consult the database and to interact with the system from any PC with access to the Internet and an account in the system with the suitable permissions.

To illustrate the advantages of this tool, we list here its main utilities:

- Documentation archive:
  - Documents are arranged and organized into projects.
  - Documents searching based on several criteria: by project, authors, title, code, keywords, etc. Searches can be exported to PDF or Excel.
  - Controlled user access to projects and documents through permissions.
  - External access and distribution (i.e. by e-mail) to authorized users.
- Documentation life-cycle management:
  - New documents can be created and their properties assigned (e.g., project, access level, authors, reviewers, approvers, authorized users, etc.).
  - Control of the status and transitions of the documents during their lifecycle
  - The properties of the existing documents can be modified.
  - Involved users are informed (by e-mail and internal notifications) of the status and all relevant changes of documents and projects.
- System administration:
  - Project administration: Define new projects, modify their properties or manage its life-cycle.
  - User administration: Create new users, modify user properties, unsubscribe users, import documents from an external database.
  - Database administration: Data backups (database, documents and web application) and Data restores (users, databases, documents and web applications).

**MANATEE: MANAgement Tool for Effective Engineering**


MANATEE is our customized software tool for Project Management. It is designed to facilitate the global management of all the projects within an organization by controlling each project most relevant parameters (scope, schedule and budget) while maintaining the project quality and keeping all users informed of the relevant actions taken.

MANATEE provides the following functionalities:

- Project Definition and Management: All the information required to track project execution can be defined and maintained in MANATEE by filling in the application forms. Project details such as planned and real dates, manpower, hardware and software resources, deliveries, objectives, etc. are added to WP, WBS, Milestones and Cash Milestones in order to ease the low-level project control. During the project development, data will be periodically reviewed and completed. MANATEE facilitates the generation of the WBS reports, where the project status and the deviations from the planned project parameters (scope, budget and schedule) can be identified.
- Human resources administration: MANATEE allows the Human Resources Manager to define the hourly cost of each user. The organization staff can fill in the weekly PTR (Personnel Time Reports).
- Analysis and visualization tools: MANATEE use the project and human resources information described in the previous points to generate different reports and graphs, which help to visualize how each project is being developed and, in general, to manage the organization resources. Those analyses provide an overview of project and organization budgets, external expenses, cash-flow, manpower distribution among the different projects, project Gantt charts, people occupation, etc.
- Project Quality Control: The application also helps to maintain the quality of the projects by managing risks, non-conformities, preventive / corrective actions, etc.
- System administration:
    - User administration: Create new users, modify user properties, unsubscribe users.
    - Tools: Import WP, WBS, milestones and actions from an external database.
    - Database administration: Data backups (database, documents and web application) and Data restores (users, databases, documents and web applications).

Each role (Project Manager, WP manager, WBS responsible) has its own permissions; access rights can be defined by users and by projects. MANATEE uses an open-source code relational database and provides a graphical user interface based on web forms. There is no need for any specific software installed on your client computers, just a web browser and access to the Internet is required. MANATEE is running alone or in combination with DOCMA.

**SUMO: System User Management Tool**


SUMO, our Operation and Maintenance Management Tool, is a web-based tool intended to manage the operation and maintenance tasks, as well as all type of resources required for the exploitation of a complex facility during the Operation and Maintenance phase. This tool also includes the inventory of system elements and their spares, as well as the support elements for the task execution. The tool allows the person in charge of running the facility, to schedule and prioritize the tasks and to organize the work for the Maintenance and Operation team.

To illustrate the advantages of this tool, the main utilities are listed below:

- Operation and Maintenance tasks register.
- Facility Inventory.
- Spares and supplies management tool.
- Operation and Maintenance tasks scheduler tool.
- Executed tasks register.
- Failures register and anomalies control.

SUMO automatically schedules periodical tasks and facilitates the search and programming of non-periodical tasks. Tasks planning can be visualized in different formats and edited dynamically. This allows to adjust the available resources, take care of anomalies, already allocated dates and other constrains that may occur during daily operation. It provides warnings to the users, notifying potential conflicts such as “the required personal is not available” or “the stock has run out of the spares needed for carrying out the scheduled tasks”.

SUMO uses an open-source code relational database and provides a graphical user interface based on web forms. There is no need for any specific software installed on your client computers, just a web browser and access to the Internet is required.

**LLAMA: Laboratory MANAgement Tool**

LLAMA, our Laboratory Management Tool, is a web-based tool intended for managing all items that are kept in a laboratory (inventory, material, personnel, documentation, etc.).

LLAMA allows to store, classify and manage all the documents, capital equipment and consumables in the laboratory of an organization. It allows also to create and manage users and projects. Access rights can be assigned for the different users to define the actions that can be performed and the elements that can be visualized by each user.

To illustrate the advantages of this tool, the main utilities are listed below:

- Asset management:
    - Identify capital equipment and consumables.
    - Add and manage elements information (price, supplier, etc.)
    - Facilitate access to the elements in the tool and to locate them at the laboratory

- Control using (input/output) of consumables in the laboratory.

- Documentation archive: Documents related to the elements registered in the application, such as manuals or datasheets, can be also kept in LLAMA. LLAMA facilitates the remote access to these documents and allows to have an electronic copy of them.

- Management of organizations, projects and user rights: The capital equipment and consumables, as well as their associated documents, are always registered in LLAMA associated to an organization and to the implied projects. LLAMA allows registering and managing new organizations and projects. In particular, the application allows to define what users can access to the different elements and documents and the actions that can perform on them (create new elements, modify the information, add inputs/outputs of consumables or just visualize the information).

LLAMA uses an open-source code relational database and provides a graphical user interface based on web forms. Anyone with access to the Internet and an account in the system with the suitable permissions may access the project's documentation.

### 4.2.8 Professional Training

Our training courses in Management, Engineering and Software are offered as:

- General courses: conducted in Madrid, currently in Spanish and English. The courses last 8, 15 or 18 hours and are given over 1, 2 or 3 days.

- Ad-hoc courses for our customers at different levels, oriented to each particular need. These courses can be imparted at customer's offices or via zoom.

- As part of Master programs in Physics or Engineering. Examples of these are:

    - The course on Management and Opto-mechanics at the International SChool of Advanced Instrumentation (an initiative of the Instituto de Astrofísica de Canarias, Universidad Complutense de Madrid, Universidad Nacional Autónoma de México and University of Florida. Courses 2008, 2009, 2010, 2011, 2012.

    - The courses on Optics, Opto-mechanics, Adaptive Optics and Management for the master in Spatial Instrumentation and Technologies at the University of País Vasco (Bilbao, Spain) that we have been imparting yearly from 2010 up to present (2021-2022).

    - The course on opto-mechanics for instrumentation developers for SPIE org.

The courses cover Project Management, System Engineering, Optics, Mechanics and Software. The current available courses are:

- Three views on Project Management
- System Engineering: Application and Development
- Introduction to RAMS analyses for Telescopes and Astronomical Instruments
- Optical principles and Instrumentation
- Opto-mechanical Systems Projects
- Introduction to Mechanical Design for Infrared Instrumentation
- Advance opto-mechanics
- Adaptive Optics
- Optical fibers in Astronomy
- Software Projects Engineering with Object-Oriented Techniques
- C++ Object-Oriented Software
- CAN/CANOpen Field Bus Integration

The calendar for the courses can be found in our course schedule: https://www.fractalslne.es/en/calendar.jsp

### 4.2.9 Web services and hosting for scientific projects

We provide different type of web services for our customers: web pages, web applications with public and private parts for the scientific projects, web services for astronomical data handling, also with a VO layer (astronomical databases on line, spectra and images visualization).

We also offer hosting for those web applications in case of our customer prefer that we also do the maintenance and update of the servers and the applications, providing also ftp facilities, documentation database, etc. for their projects.

### 4.2.10 "Astrojobs" web service for search and promotion of Astronomy positions

AstroJobs (https://www.fractalastrojobs.com/) is an initiative developed by FRACTAL for offering a web service to publish and promote all our clients job positions related with Astronomy, Engineering and Research. The aim is:

- To attract the talent to professional Astrophysics jobs
- To announce our customers job positions

- To promote the job positions offered by our customers
- To be a reference job source for potential candidates that are or want to be involved in Astronomy
- To give visibility to our customers job positions

## 5. APPENDIX: LICA FACILITIES AT UCM USED FOR FRACTAL PROJECTS

LICA, Spanish acronym for Laboratory for Scientific Advanced Instrumentation, is property of Universidad Complutense de Madrid (UCM), the largest public university in Spain. LICA is being used for GUAIX Extragalactic Research Group of the Astrophysics Department of UCM. FRACTAL has been collaborating in the lab design since its conception in 2010, mounting the lab together with the UCM team and contributing with part of its equipment and different set-ups with both perishable and non-inventory material. Major equipment belongs to UCM.

FRACTAL has open access[1] (24/7 since all FRACTAL staff has special authorizations for that) and total availability for using the LICA facility either for performing common projects shared with the UCM as for its own particular projects, taking advantage of the support and security offered by the institution in the building. Projects in which UCM group is not involved need a special agreement and contract signed between FRACTAL and UCM for the use. In the case of SCORPIO instrument for Gemini, the contract is fully signed to use LICA facilities for the instrument Integration and Tests. At the same time that LICA is being used for a given project, FRACTAL can request, through the UCM group access to other facilities at the university, like clean rooms, workshops etc.

At LICA, FRACTAL has assembled, integrated and carried out verification tests of instruments for different institutions and research centers as: the whole instrument *MEGARA* a fiber-fed visible spectrograph for the 10m telescope (GTC, Canary Islands) for the Complutense University (UCM, Spain); the VIS detector system for *CARMENES*, a visible and near infrared fiber-fed exoplanet finder (high resolution spectrograph) for the Spanish Calar Alto Observatory (CAHA, Spain), where the CCD was characterized and assembled by FRACTAL; spectrograph and fibers link of ARES, a visible fiber-fed spectrograph for the Institute of Space Studies of Catalonia (IEEC-CSIC, Spain); ALBIREO, a refurbished spectrograph for the Sierra Nevada Observatory of the Institute of Astronomy of Andalucía (IAA, Spain), and our R+D developments as HRSPG, High Resolution Sliced Pupil Grating a novel grating designed by FRACTAL, among others.

The LICA is provided with 2 optical benches: 1) 1000mm × 2000mm × 200mm and 2) 1500mm x 2500mm x 200mm equipped with vibration isolator table supports for high precision assemblies. A clean room is also available, as well as a clean bench (ISO 5 vertical laminar flow clean air cabinet).

[1] Currently access is regulated with a specific COVID-19 protocol

FRACTAL has at its disposal a variety of qualified material and ad-hoc set-ups and test benches for carrying out the assembly, integration, verification and tests for specific subsystems as:

i. Detectors
ii. Optical systems and gratings
iii. Optical fibers
iv. Electronic wiring design
v. Spectroscopy calibration
vi. Software prototyping and development

**Detectors Test Bench (CCDs and CMOS)**

The set-up for detector characterization is provided with an illumination system (equipped with different interchangeable halogen lamps) followed by two filter wheels (one with neutral density filters and other with order-sorting filters). After the previous line, the light beam feeds an Oriel Cornerstone 260 monochromator with a resolution of 0.1 nm, and after that it comes into an 8″ integrated sphere that illuminates the detector. The system makes use of a photodiode (S2281, previously calibrated by the National Physical Laboratory, UK) and a blue LED of GaN for the characterization of flats.

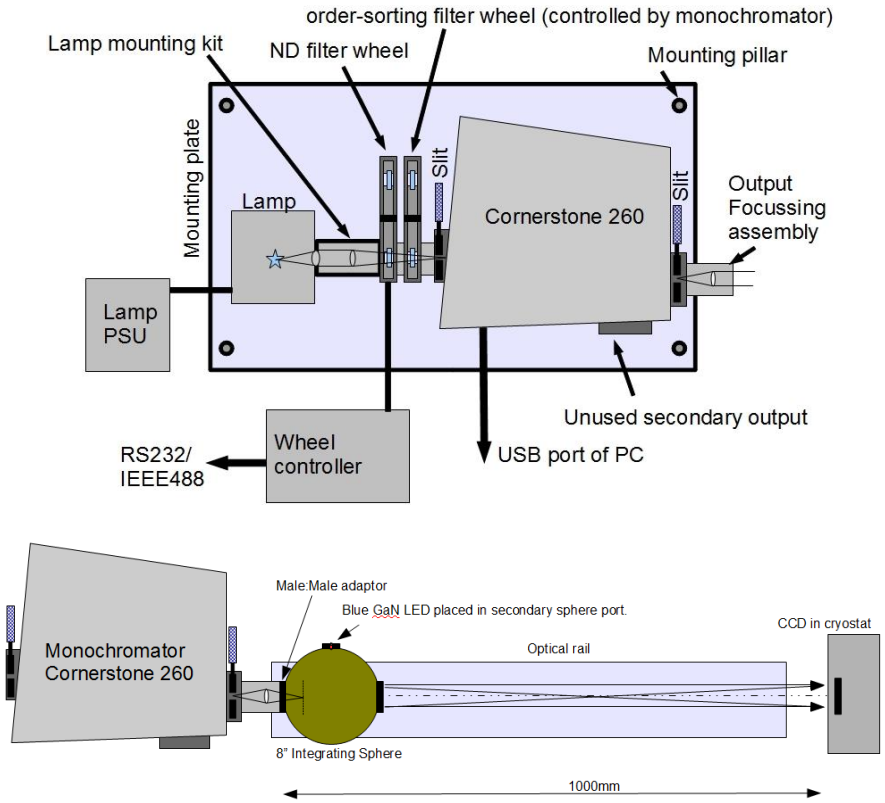


***Figure 1:*** *Set-up of the detector characterization test bench*


***Figure 2:*** *Cryocooler, vacuum unit, PKR251 Vacuum Gauge and Lakeshore 325 available at LICA*

This arrangement is supplemented with a cryogenic system (InfraRed Cryotiger), a vacuum unit (Pfeiffer Hi Cube Classic) and a temperature controller (Lakeshore 325) assembled to a Pt100 sensor. The aim of this set us is to characterize the quantum efficiency, the linearity regime of detectors, as well as blooming, flats and crosstalk.

***Figure 3:*** *Images at LICA and clean room obtained from characterization and assembly of different detectors.*

For detector handling in cleanliness condition, a new clean bench (ISO 5 vertical laminar flow clean air cabinet) as shown in the next figure has been acquired (Scanlaf Fortuna from Labogene):

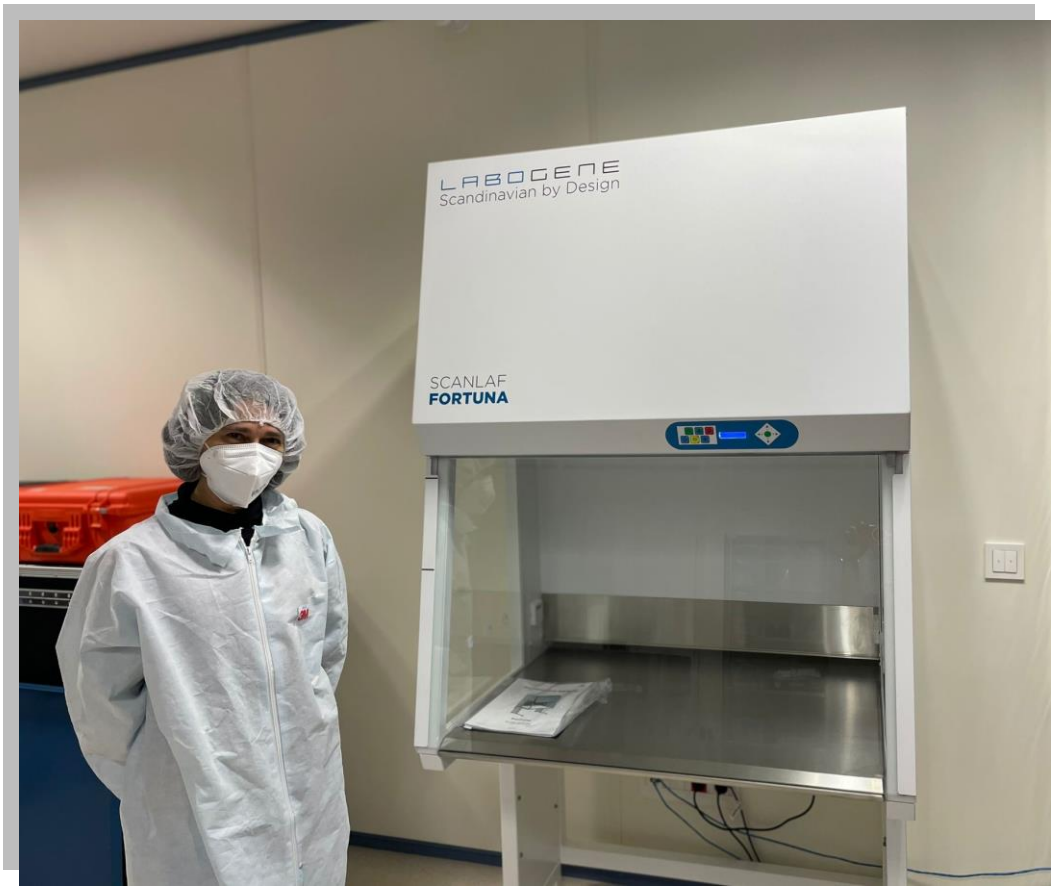


***Figure 4:*** *Clean bench for detectors handling (among other applications).*

**Optical Systems**

FRACTAL performs the assembly, integration and verification of several optical systems, carrying out different tests to characterize them, obtaining the transmission curve of filters, lenses, dimensional properties of any optical component, making use of the monochromator and the calibrated diode. We measure the surface quality and wave front error with the aid of a Fizeau Interferometer and a reference λ/20 optical flat. In addition, we perform high precision measurement of prisms angles and wedge errors, study of aberrations, obtaining the line per mm of gratings, transmission wave front errors of PSF degradation, etc. In addition to the equipment described previously, for these purposes, a laser (512nm), a set of pinholes with different sizes, lenses, detectors with different formats and pixel sizes and two Celestron refractor telescopes (D=102 cm, F#=8.8) are available.

For assembly, integration and high alignment precision, a digital calliper, a depth micrometer for CCDs alignment, indicators, alignment targets, a set of linear translators (X, XY, and XYZ) and goniometers with different precisions, an autocollimator telescope (Trioptics ACM F500-57) with a precision of 50 microns, and an alignment telescope (Möller-Wedel Optical, FAKR 300/40/14.7) with a precision of 10 microns, are available for FRACTAL´s use.

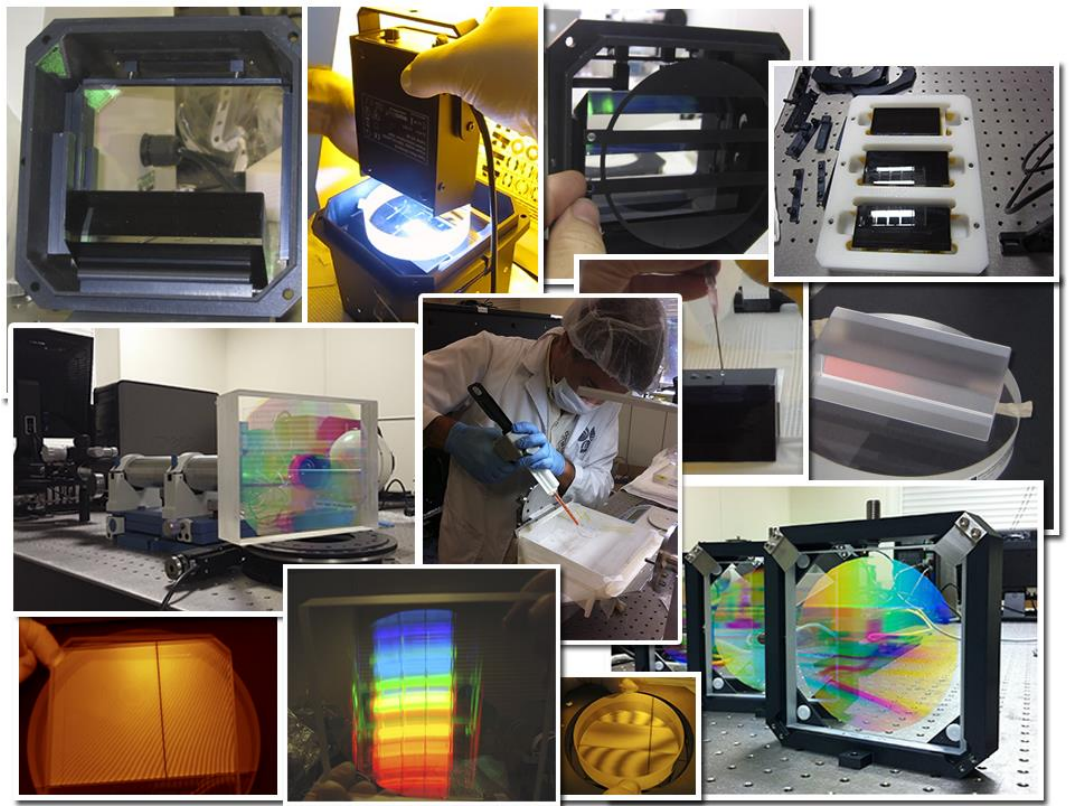

***Figure 5:*** *Images obtained at LICA during the characterization and assembly of several volume phase hologram gratings and prisms for different projects.*

***Figure 6:*** *Optical tests carried out at LICA*

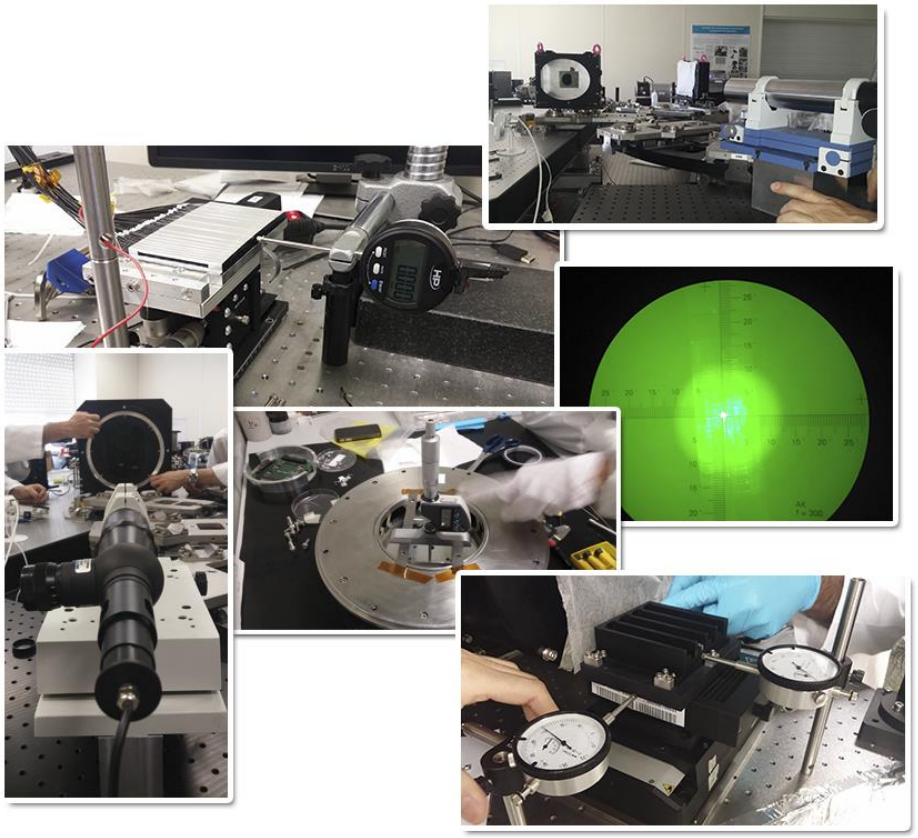

***Figure 7:*** *Alignment instruments used at LICA facility*

**Fiber optics test bench**

In FRACTAL, we have designed and developed several set-ups focused on the characterization of optical fibers. These set-ups allow us to determine the final transmission of a fiber bundle in a determined wavelength range and the impact of the focal ratio degradation thanks to our far field and near field unit. For instance, we have acquired experience in the gluing process of fiber bundles to optical related systems, such as microlenses arrays, used to decrease the F-number and minimize the flux loses, a very important issue for most fiber-fed astronomical instruments.

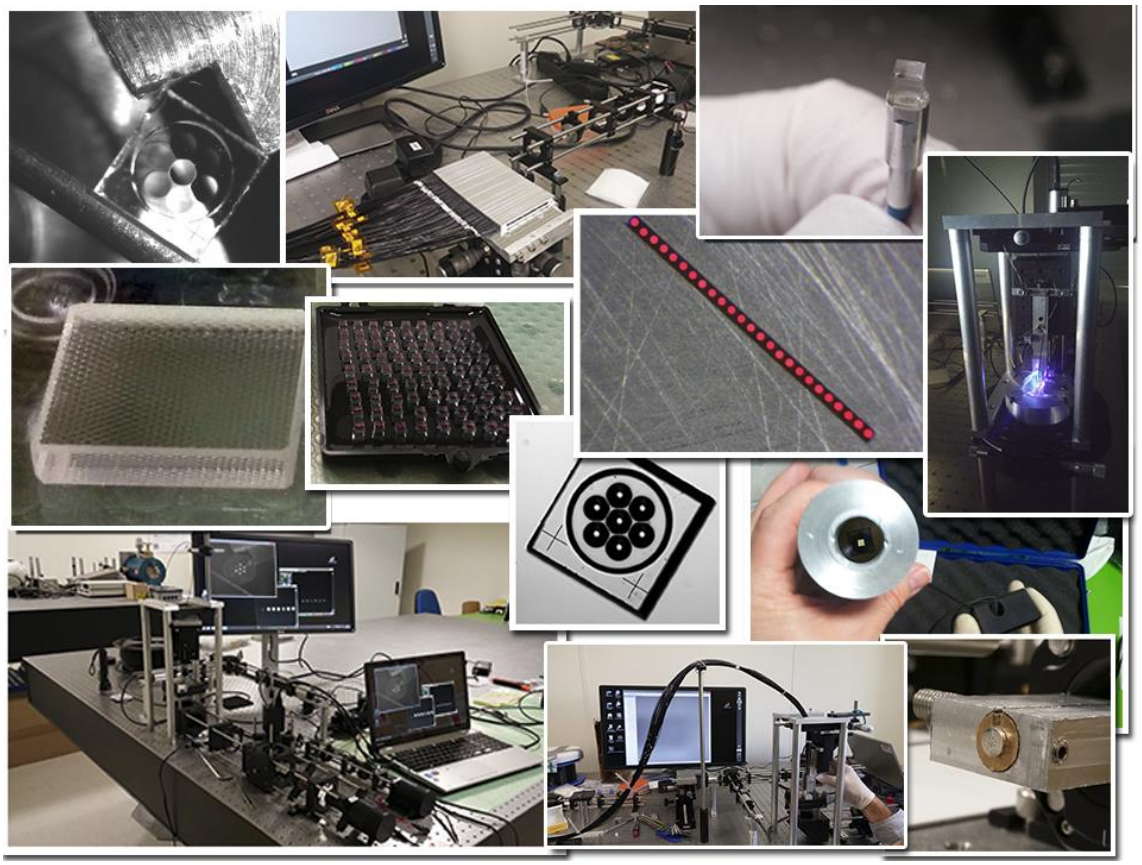

***Figure 8:*** *Optical fibers characterization set-ups and different microlenses arrays after gluing process obtained at LICA*

**Electronic wiring design**

FRACTAL has access to highly qualified consultants with skills in designing and integrating electric components (for detectors) applying high precision welding procedures that allow to perform and control the way and the velocity in which the electrons are read in the detectors, minimizing the readout noise.

FRACTAL is able to produce electronic wiring that allow a better efficiency reducing the current noise between the detector controller and the CCD, with the aim, once again, of

attenuating the read-out noise. For characterizing and controlling the electronic noise, FRACTAL makes use of a WaveSurfer 44MXs-B oscilloscope (with 4 channels).

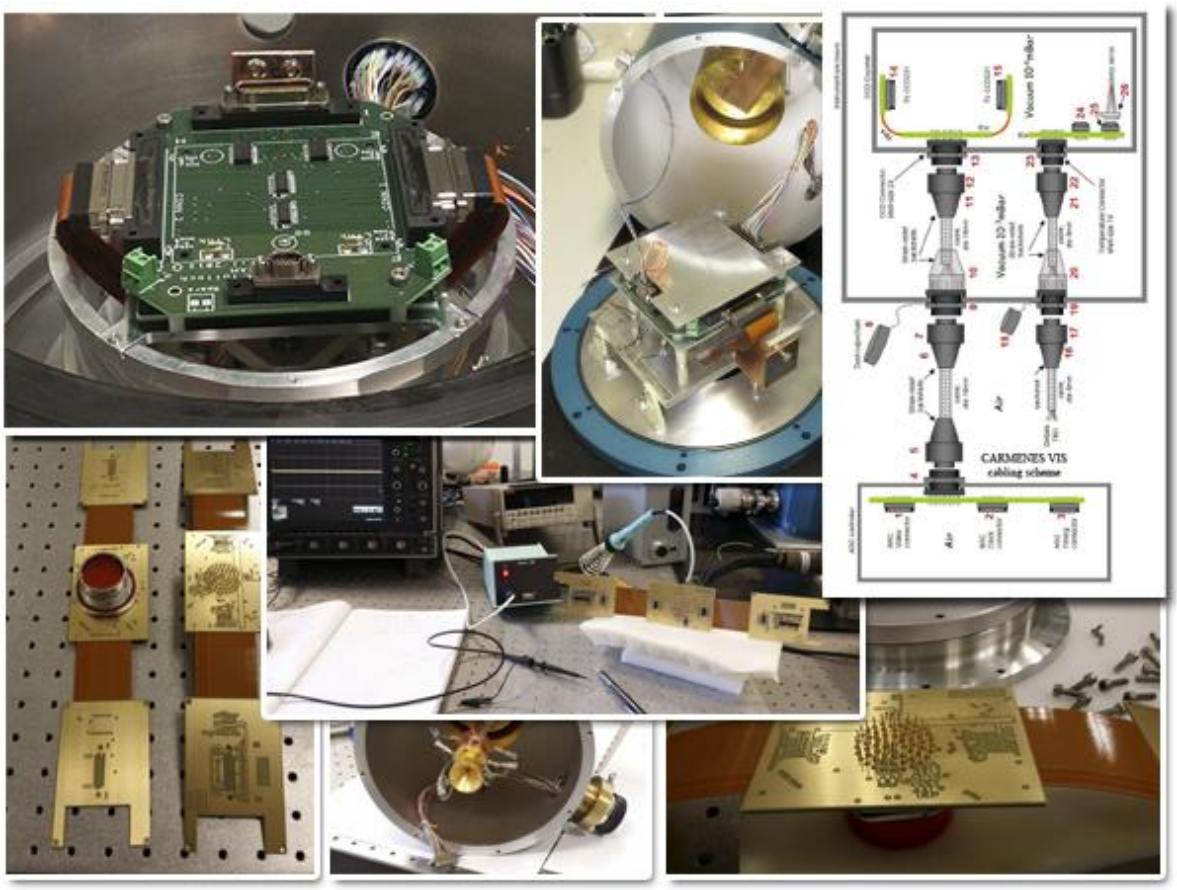


***Figure 9:*** *Electronic circuits designed by FRACTAL and tested at LICA*

**Spectroscopy Calibration**

FRACTAL carries out the spectroscopy calibration for astronomical spectrographs with the aid of several pencil style lamps (Na, Xe) and hollow cathode lamps (ThNe, ThAr) as well as with several integrating spheres with different apertures (up to 230 mm), providing the fitting parameters of the calibration curves for being implemented in the customer software pipelines, together with a set of emission line maps.

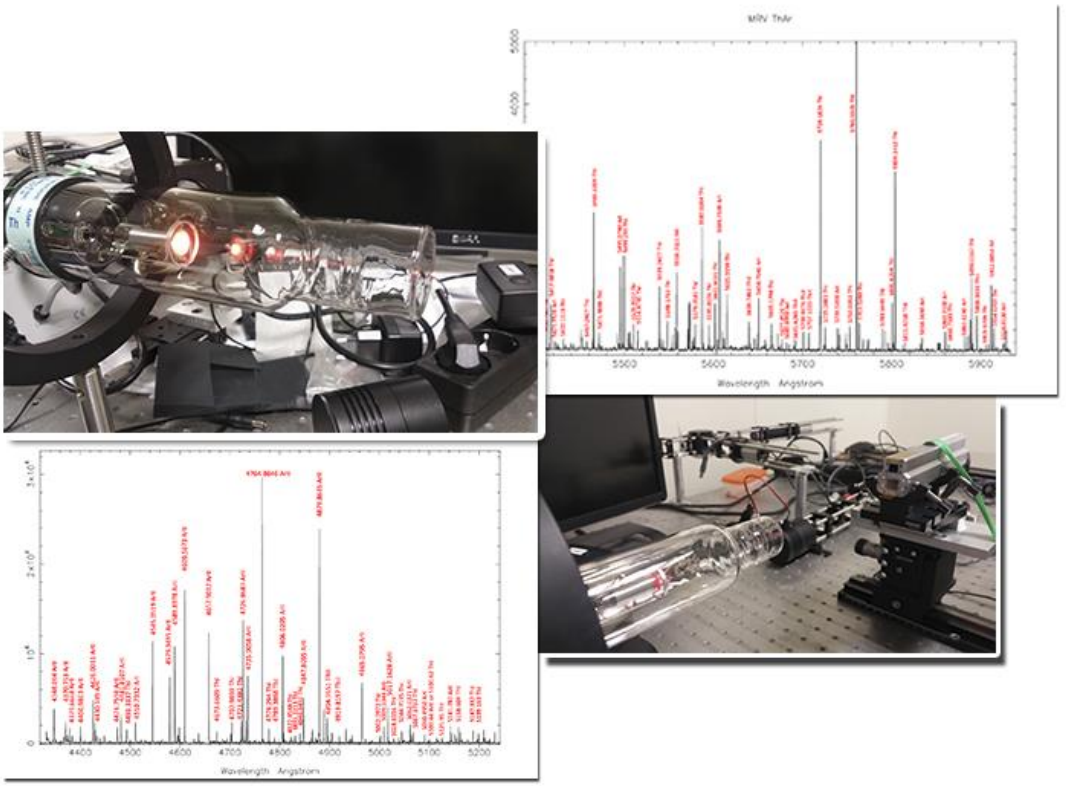

***Figure 10:*** *HCL calibration lamps and line emission maps produced by FRACTAL*

**Software prototyping and development**

FRACTAL and UCM were responsible for the Control System (hardware and software) design and development of MEGARA instrument. During this process we mounted several prototypes and have a GTC-software simulator and many hardware components, spares of the real elements working at MEGARA.

FRACTAL developed the complete Control System (hardware and software) of the instrument ALBIREO, what was done based on Phidget (motor controller, single board computer, interface kits etc.) and we have a full-software simulator based on this hardware/software.

At present, FRACTAL has mounted a new prototype based on Beckhoff PLC hardware. FRACTAL will use this software as the basis for the Continuous Flow Cryostats, whose technology was transferred from ESO in 2015. Also, this technology is the one adopted for ESO in the new generation of instruments for the ELT.

On top of these H/W prototypes, FRACTAL has developed many user-oriented software tools (control of optical fibers, preparation of Multi-Object Spectrograph Observations), Exposure Time Calculators, Quick Look Visualization Tools, Date Bases, GUI for different purposes.

Further information can be found here:

https://www.fractalslne.es/files/FRACTAL-Services-Instrumentation-and-software-general.pdf

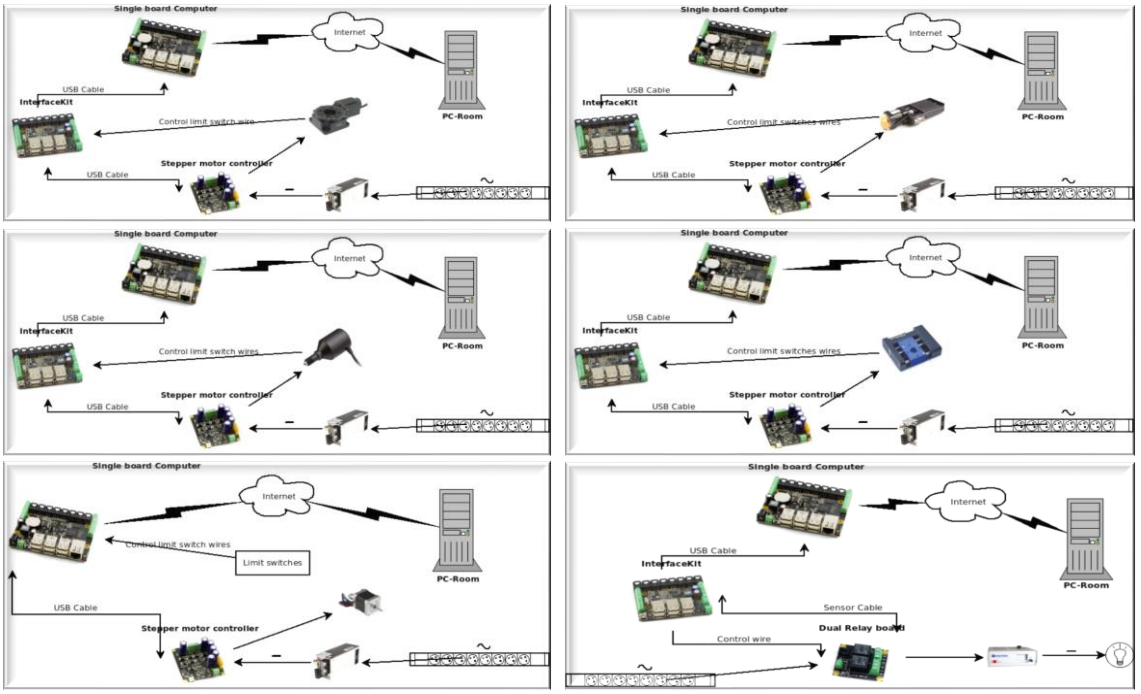


***Figure 11:*** *Architecture produced by FRACTAL for Phidget-based instrument control system*