UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Facultat d'Informàtica de Barcelona

FIB

Open Robotic Observatory Control System OpenROCS v2.0

Proyecto Final de Carrera
Ingeniería Técnica en Informática de Sistemas

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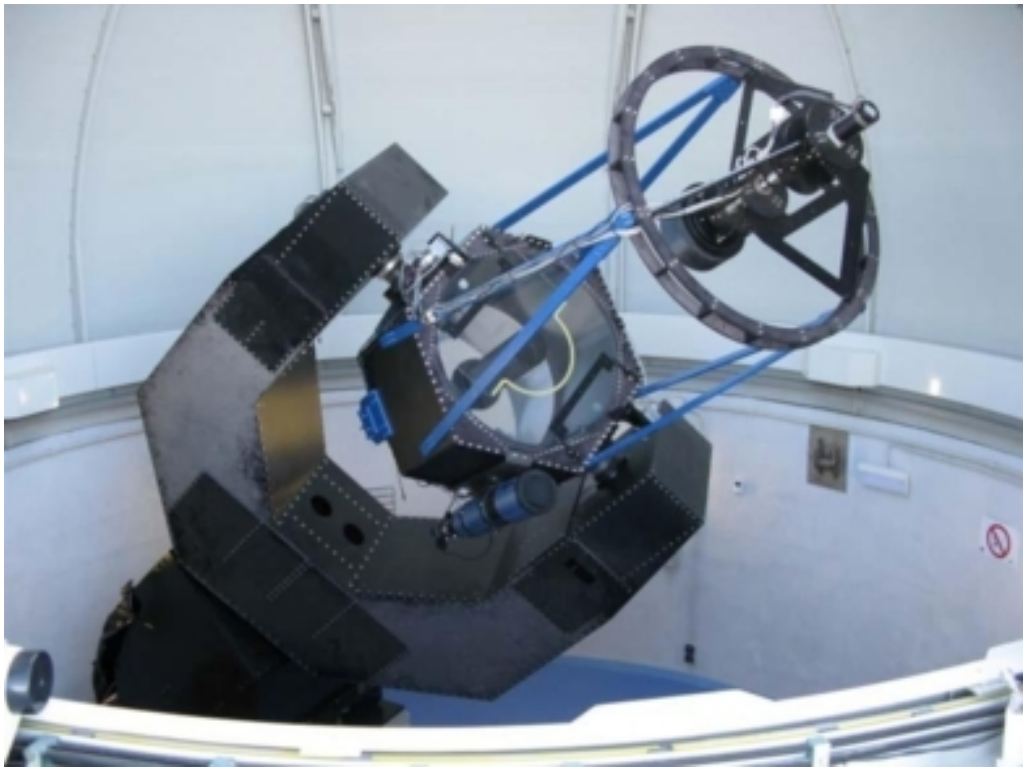
Mayo de 2015

OpenROCS: Índice

- Objetivos
- Introducción
- Sistema robótico
- Diseño global
- Requisitos
- Alternativas
- Diseño
- Tareas previas
- Implementación
- Resultados
- Planificación y costes
- Conclusiones

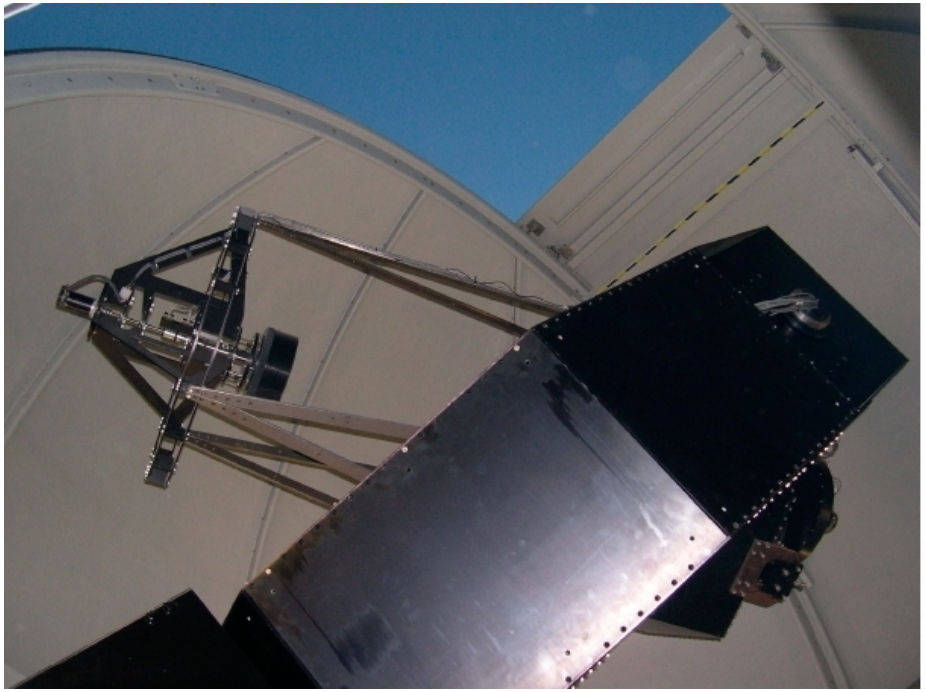
OpenROCS: Objetivos

El objetivo de este PFC es dar una solución a las necesidades de control robótico del Telescopio Joan Oró (TJO).



OpenROCS: Introducción

El TJO es un telescopio de 80cm fabricado por OMI



- Cúpula automática de 6m aprox. de diámetro
- Cámara de adquisición de imágenes (MEIA)

OpenROCS: Introducción

El Observatori Astronòmic del Montsec (OAdM)

- A 1570m. de altura en la sierra del Montsec.
- Denominación de “Reserva Starlight”

OpenROCS: Introducción

Telescopio Joan Oró

Telescopio Fabra-ROA-Montsec

Cámara all-sky del IEEC

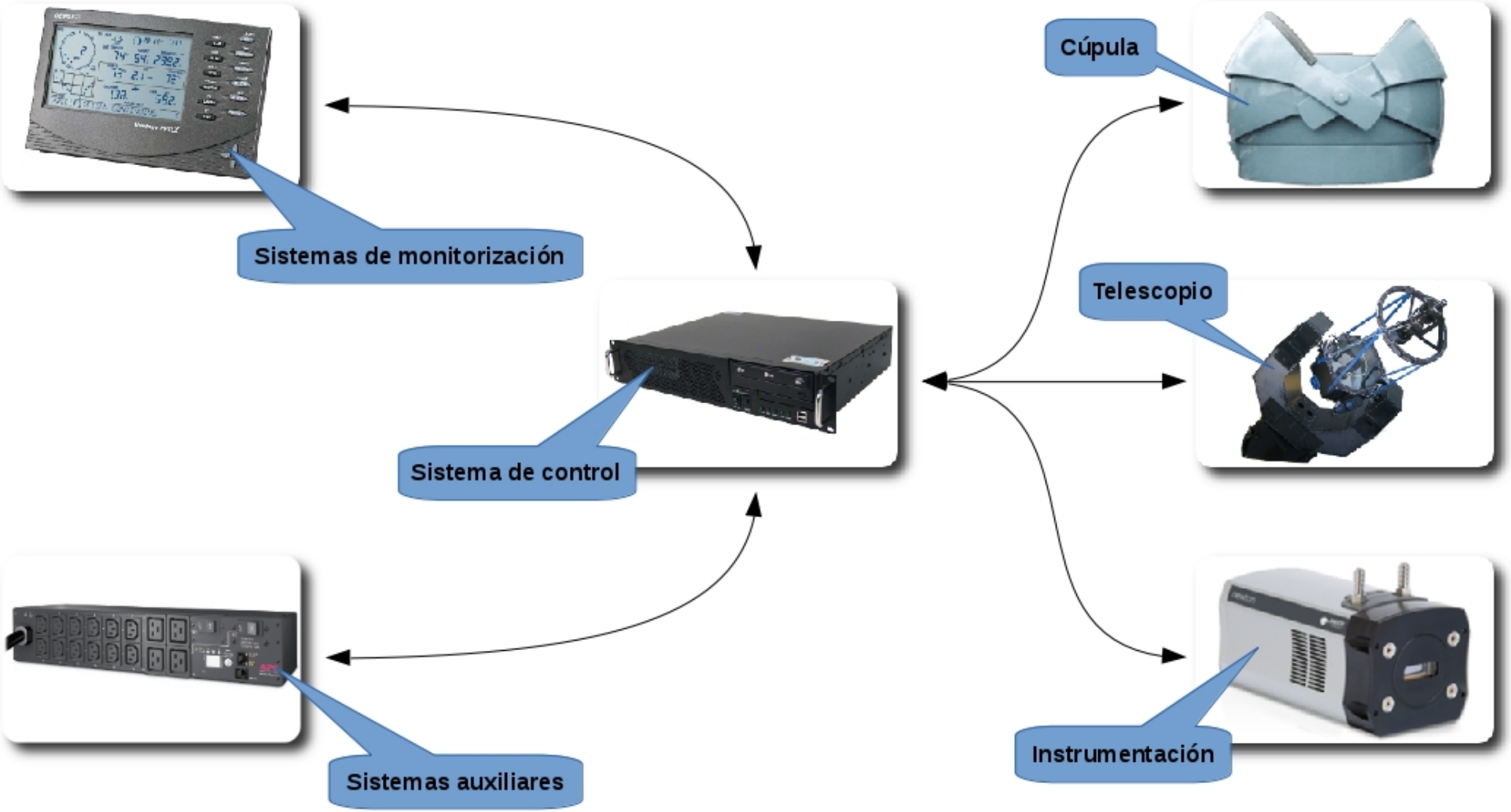
Unidad XO del STScI

Estación meteorológica del SMC

Estación XVPCA

OpenROCS: Sistema robótico

Elementos del sistema robótico:

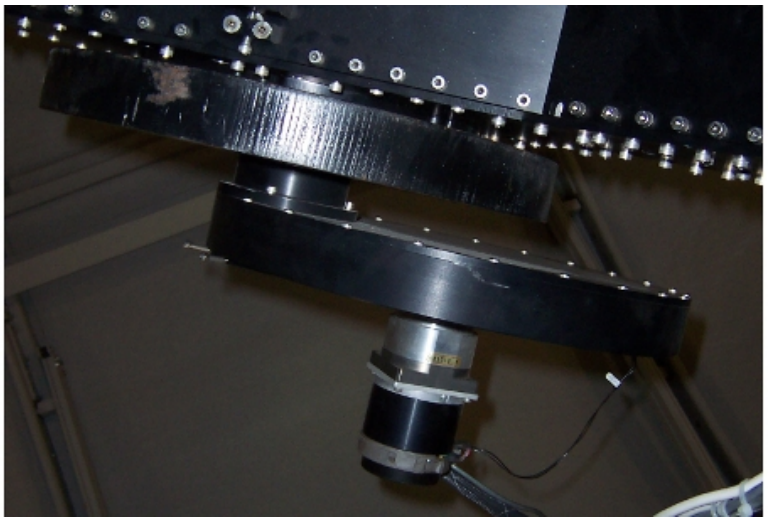


OpenROCS: Telescopio y cúpula

- Control por AVS y CSIMC
- Comunicación RS-232
- Software de control TALON

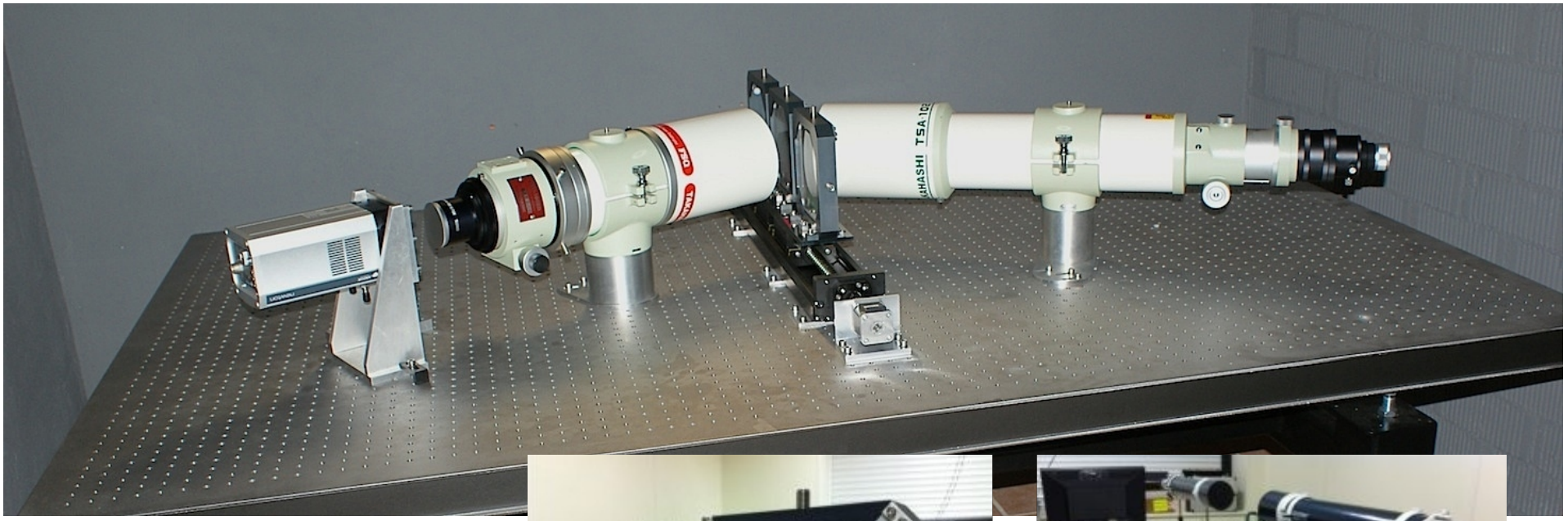
OpenROCS: Instrumentación

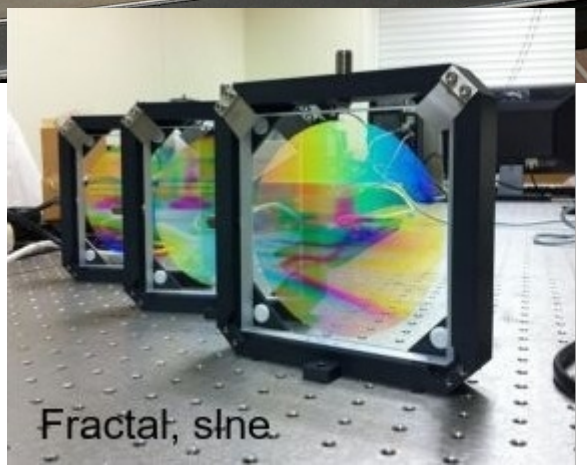
MEIA (instrumento principal)

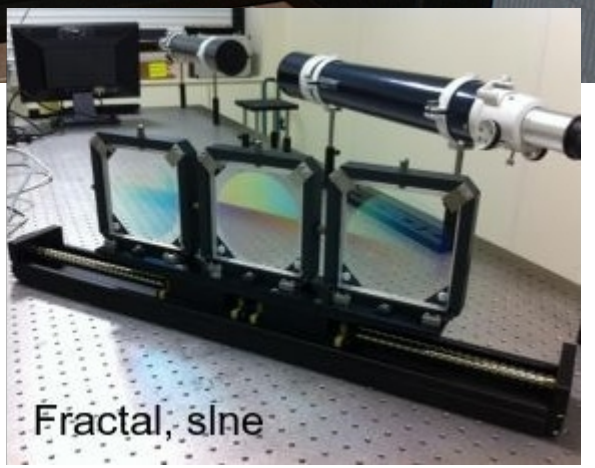


OpenROCS: Instrumentación

ARES (Espectrógrafo alimentado por fibra)

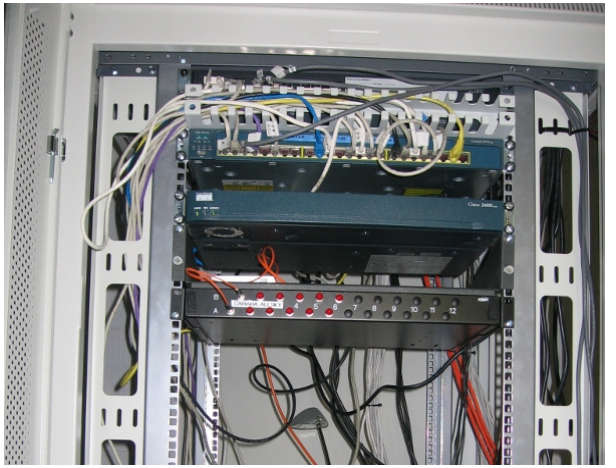






OpenROCS: Monitorización

OpenROCS: Sistemas auxiliares



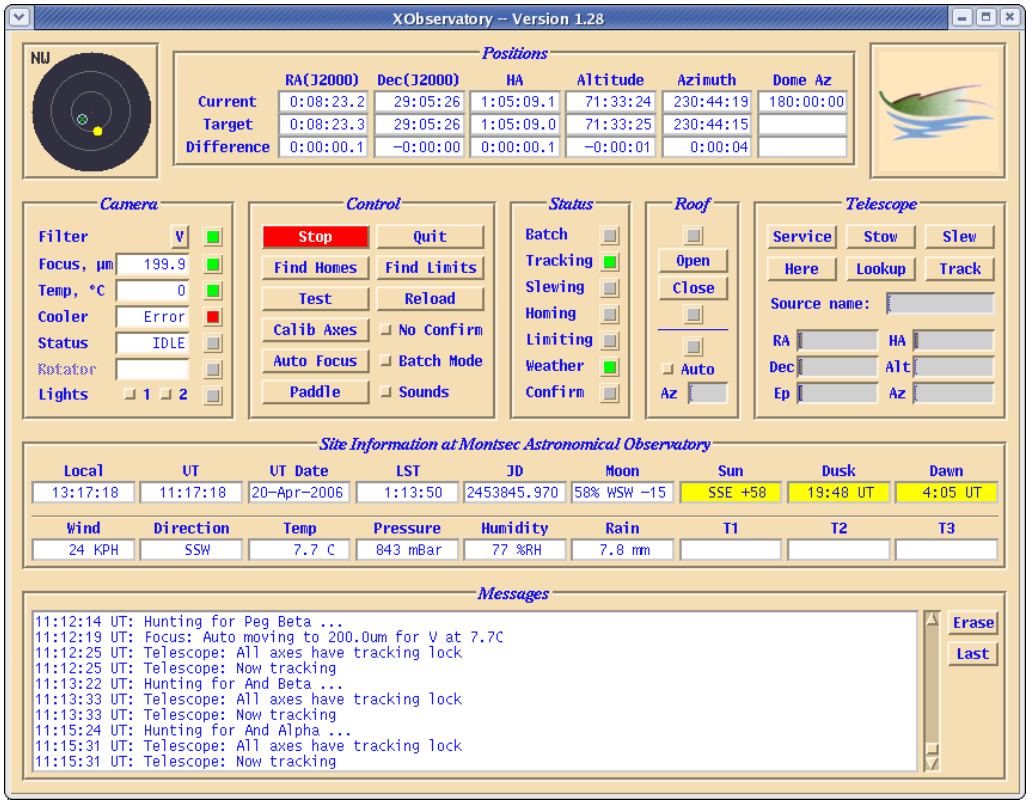
OpenROCS: Sistema de control

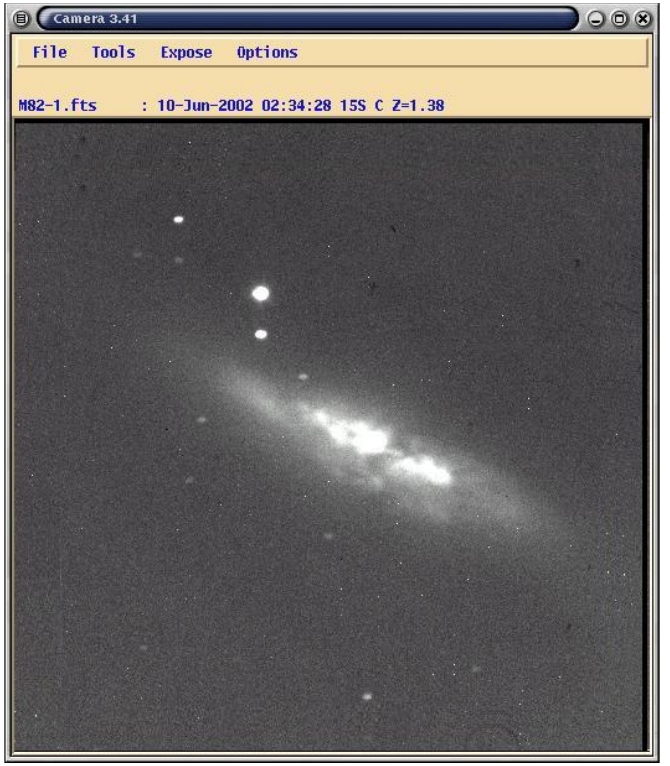
Se empezó a desarrollar un software de control llamado OpenROCS v1.0 que realizaba las siguientes tareas:

- Monitorizar la estación meteorológica
- Monitorizar el sensor de lluvia
- Iniciar el software TALON

OpenROCS: Sistema de control

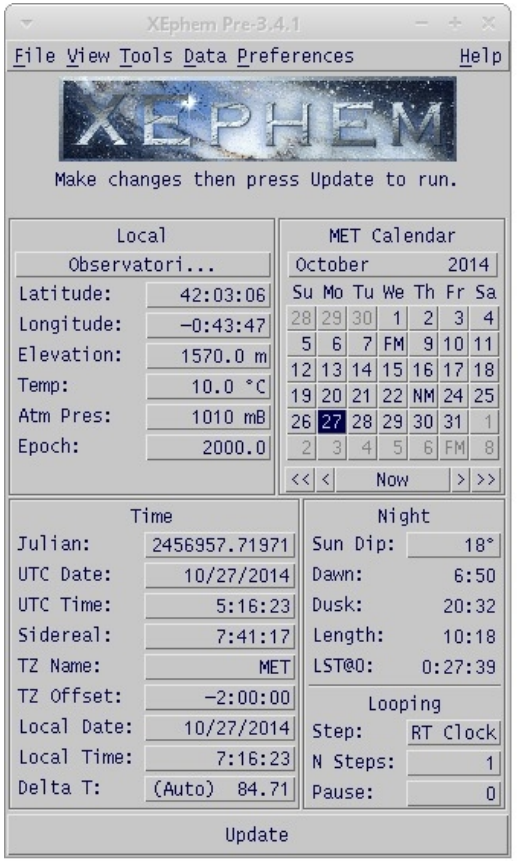
El software de control proporcionado por el fabricante fue TALON

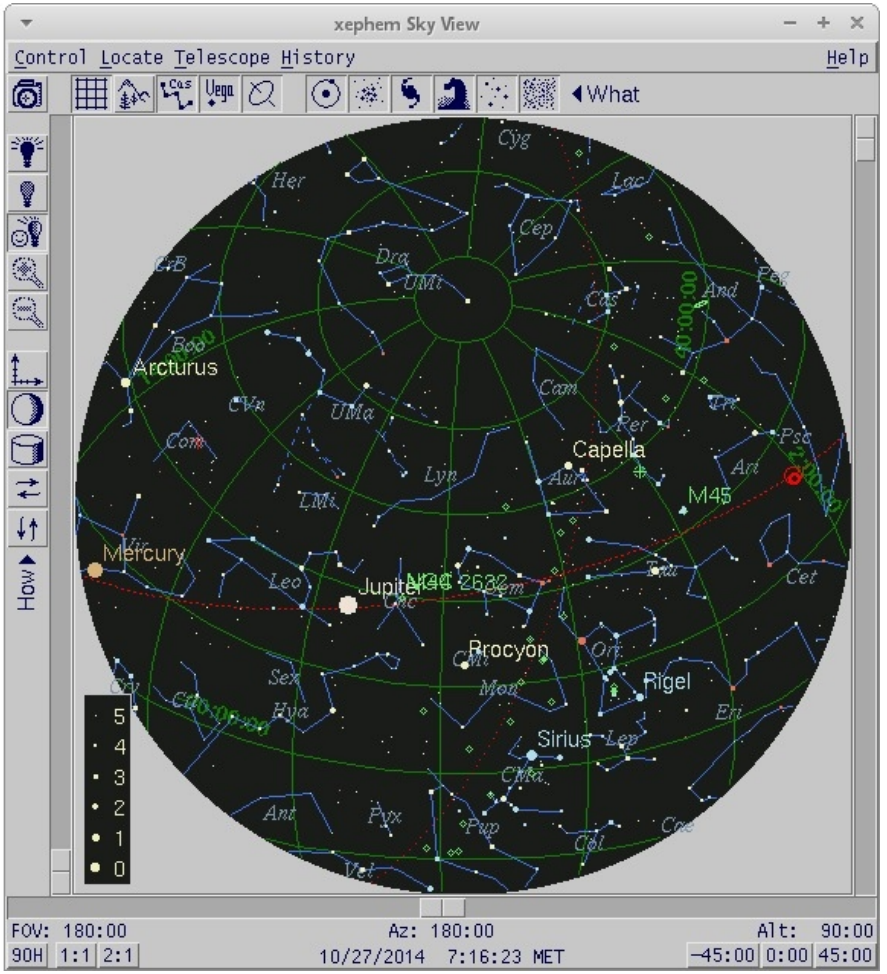




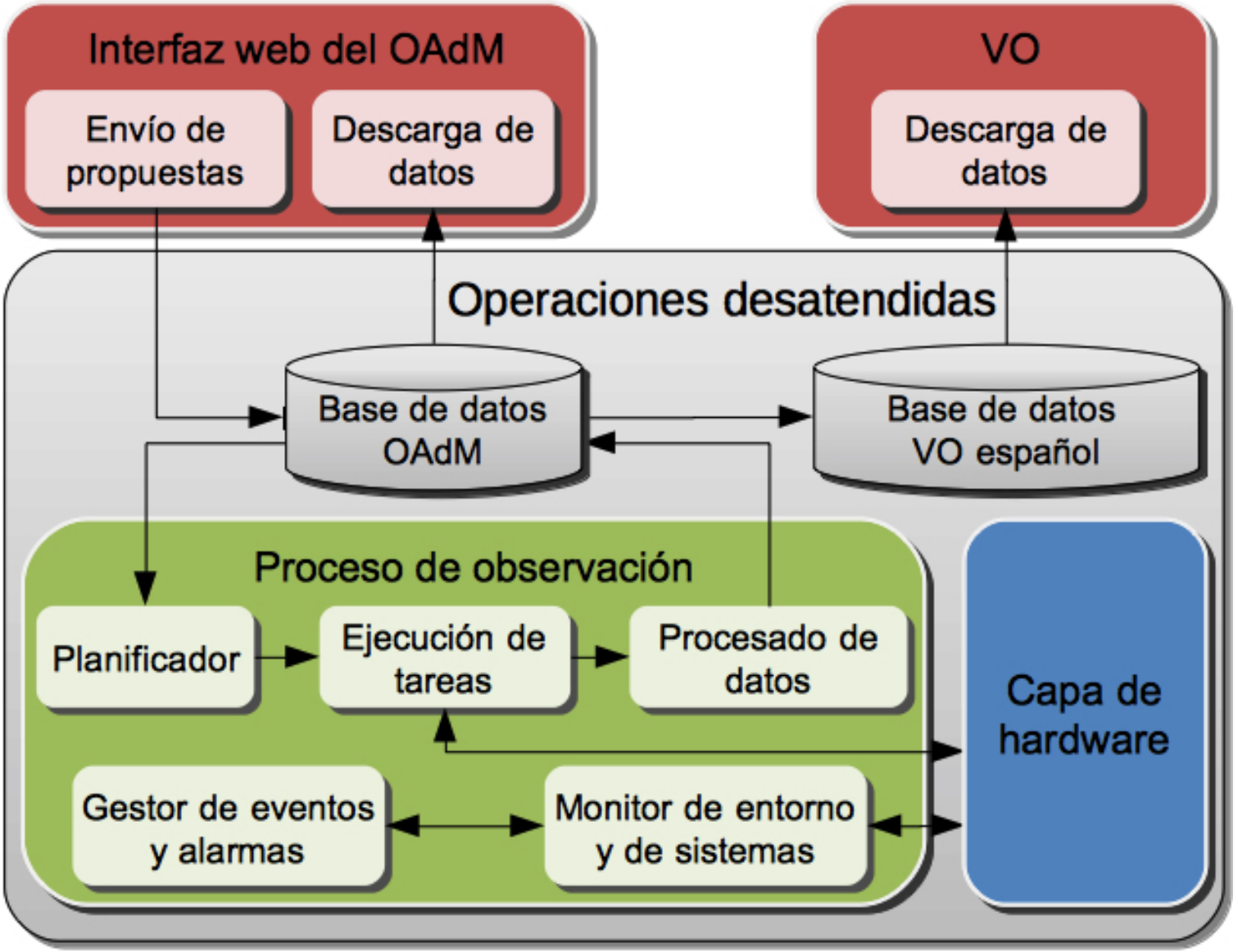
OpenROCS: Sistema de control

Interfaz XEphem





OpenROCS: Funcionamiento



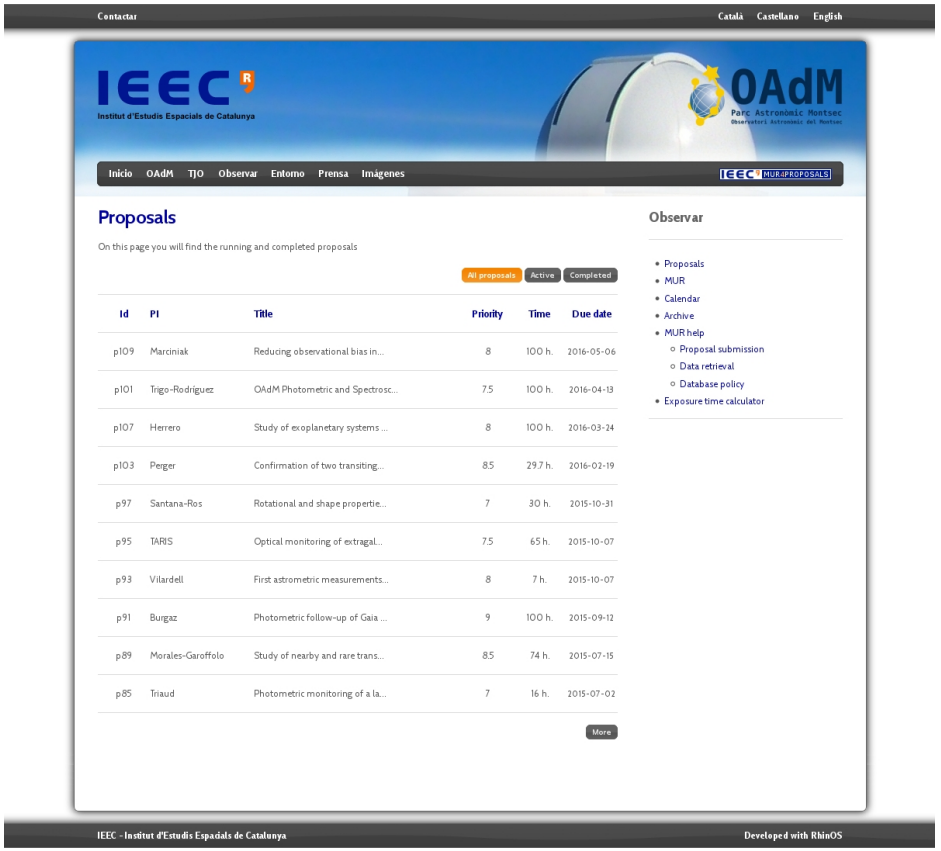
OpenROCS: Web OAdM

Página Web

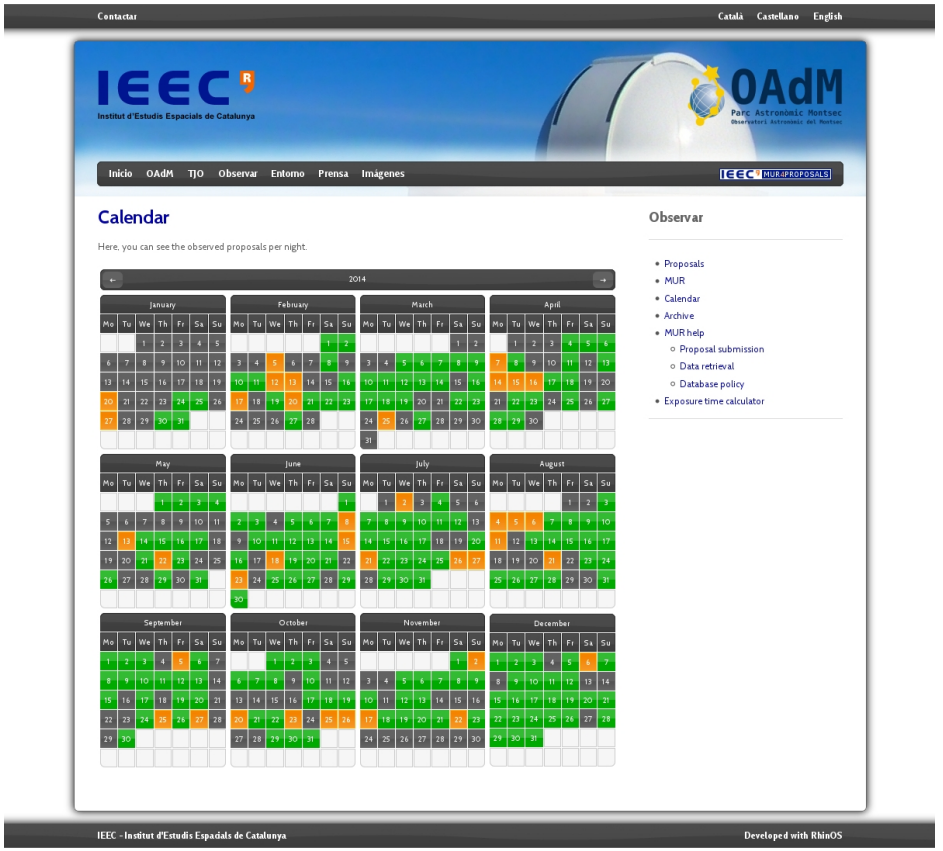
Meteorología

OpenROCS: MUR

Propuestas



Calendario



OpenROCS: MUR

Archivo

Acceso usuarios

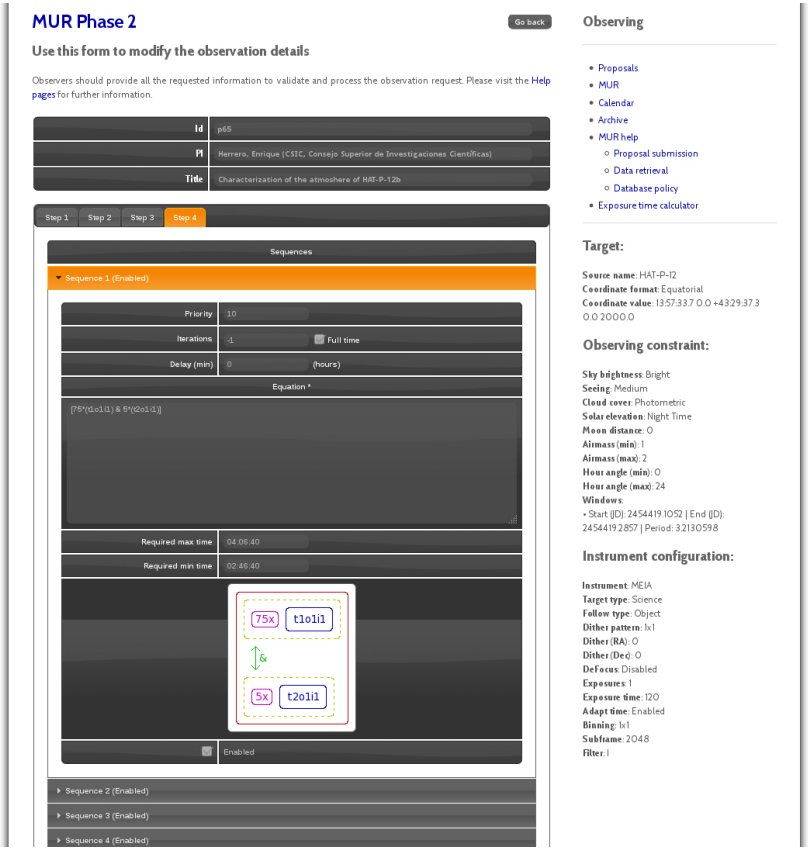
OpenROCS: MUR

Panel principal

Fase 1

OpenROCS: MUR

Fase 2



Fase 3

OpenROCS: Requisitos

Es necesario un sistema que realice las siguientes **tareas**:

- Monitorizar las variables de entorno
- Tomar decisiones
- Comunicarse con los diferentes dispositivos
- Intercambiar información con otros equipos

Pero además, debe cumplir las siguientes **restricciones**:

- Debe permitir evolutivos de forma fácil, rápida y fiable.
- Debe ser flexible para adaptarse a cambios de hardware.
- Debe ser automático para ejecutarse de forma desatendida.
- Mecanismos para comunicarse con otros programas existentes.

OpenROCS: Alternativas

Estudio de mercado

Remote Telescope System - 2nd version

ASCOM Standards for Astronomy

INDI Library

Astronomical Instrumentation
Automation & Control

Talon - Observatory Control Software: Project Web Hosting - Open Source Software

Talon - Observatory Control Software

The Orocos Project

Smarter control in robotics & automation!

ROS

OpenROCS: Diseño

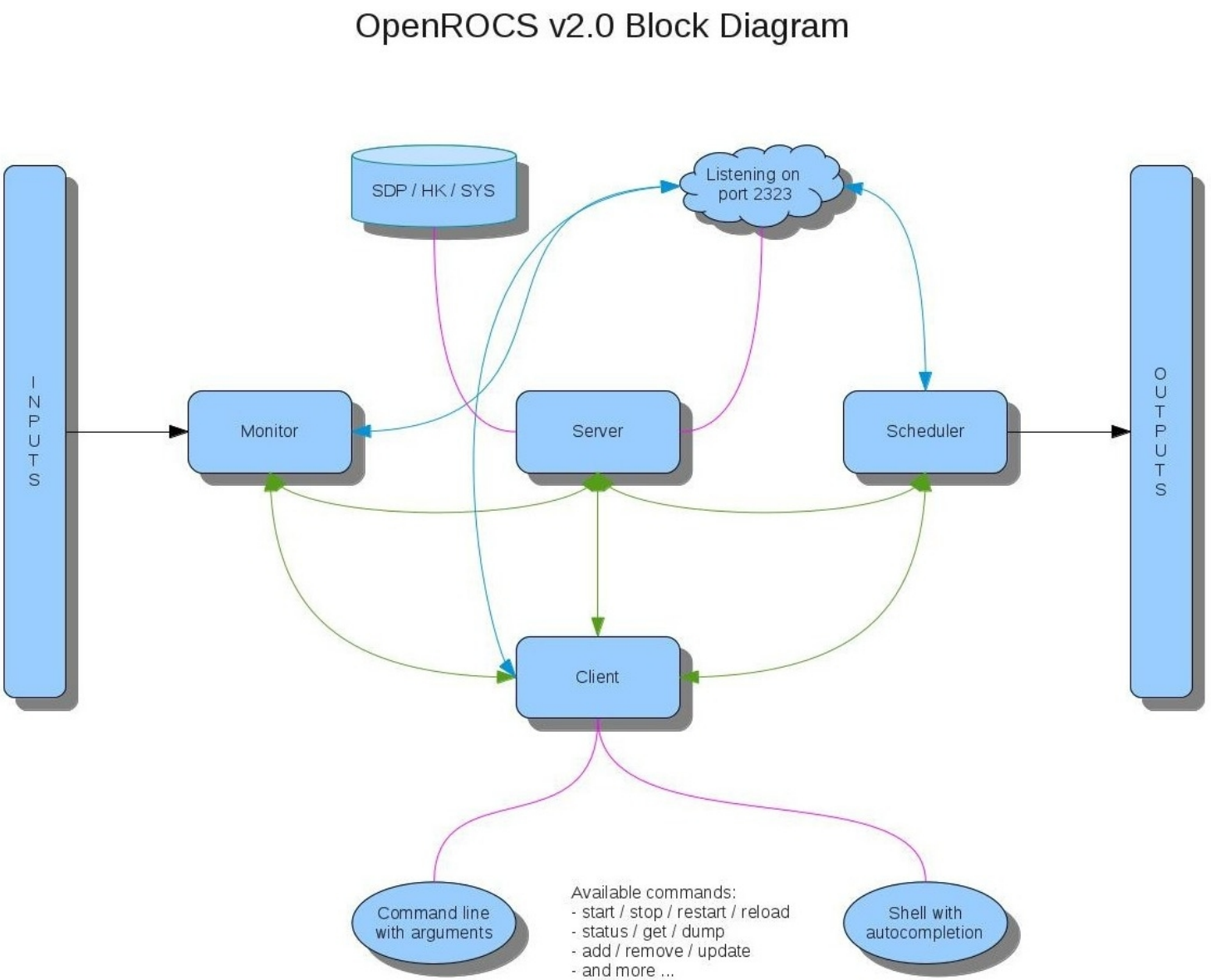
Es un programa para:

- Leer entradas
  - Estaciones meteorológicas, controladores de motor, ...
- Actuar sobre las salidas:
  - Interruptores electrónicos, controladores de motor, …

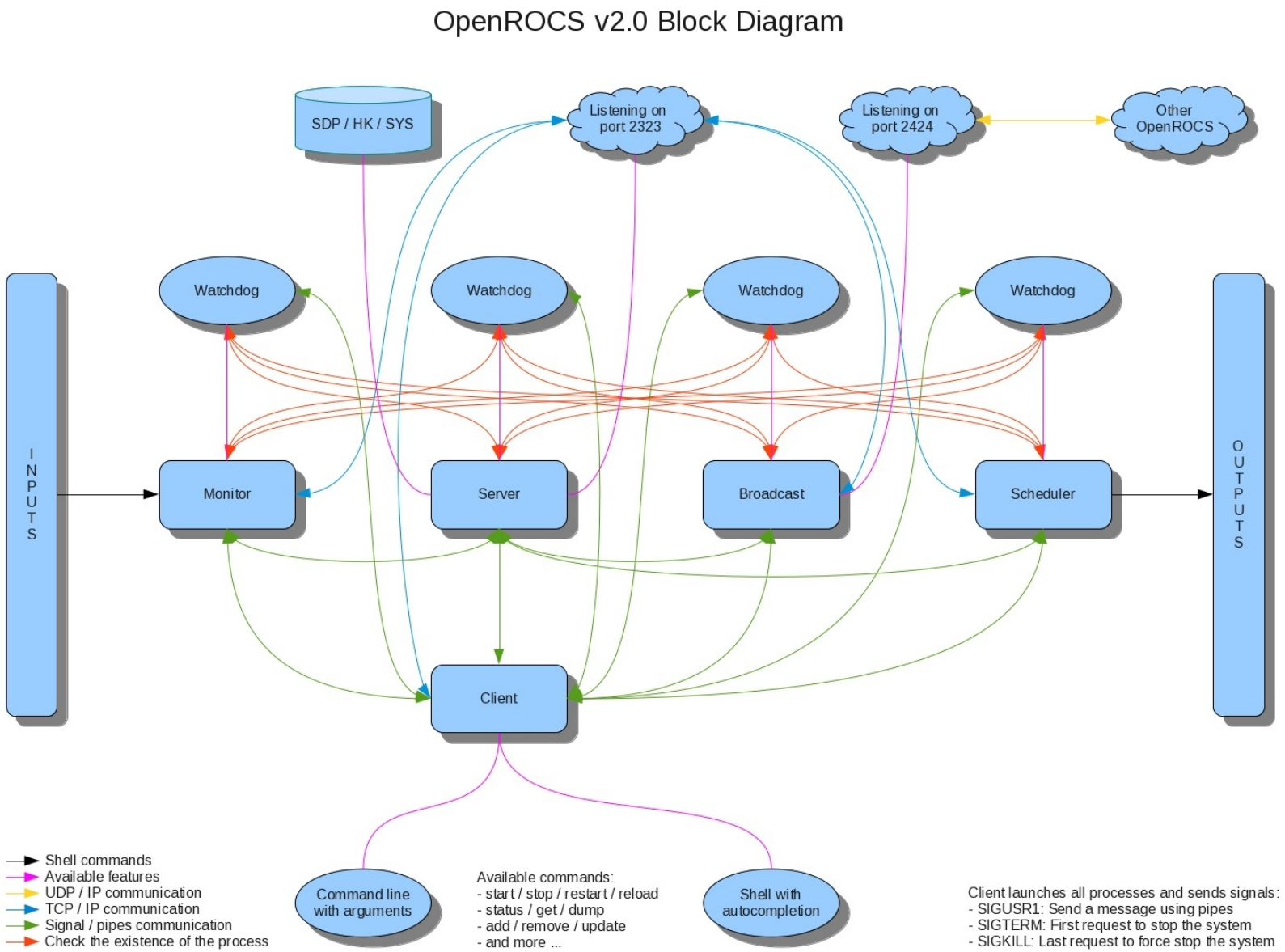
Objetivos tecnológicos:

- Usar archivos XML para la configuración: fácil y estructurado
- Disponer de herramientas como:
  - Un cliente de línea de comandos para interaccionar con el software
  - Ficheros de registro personalizados especificados por el usuario

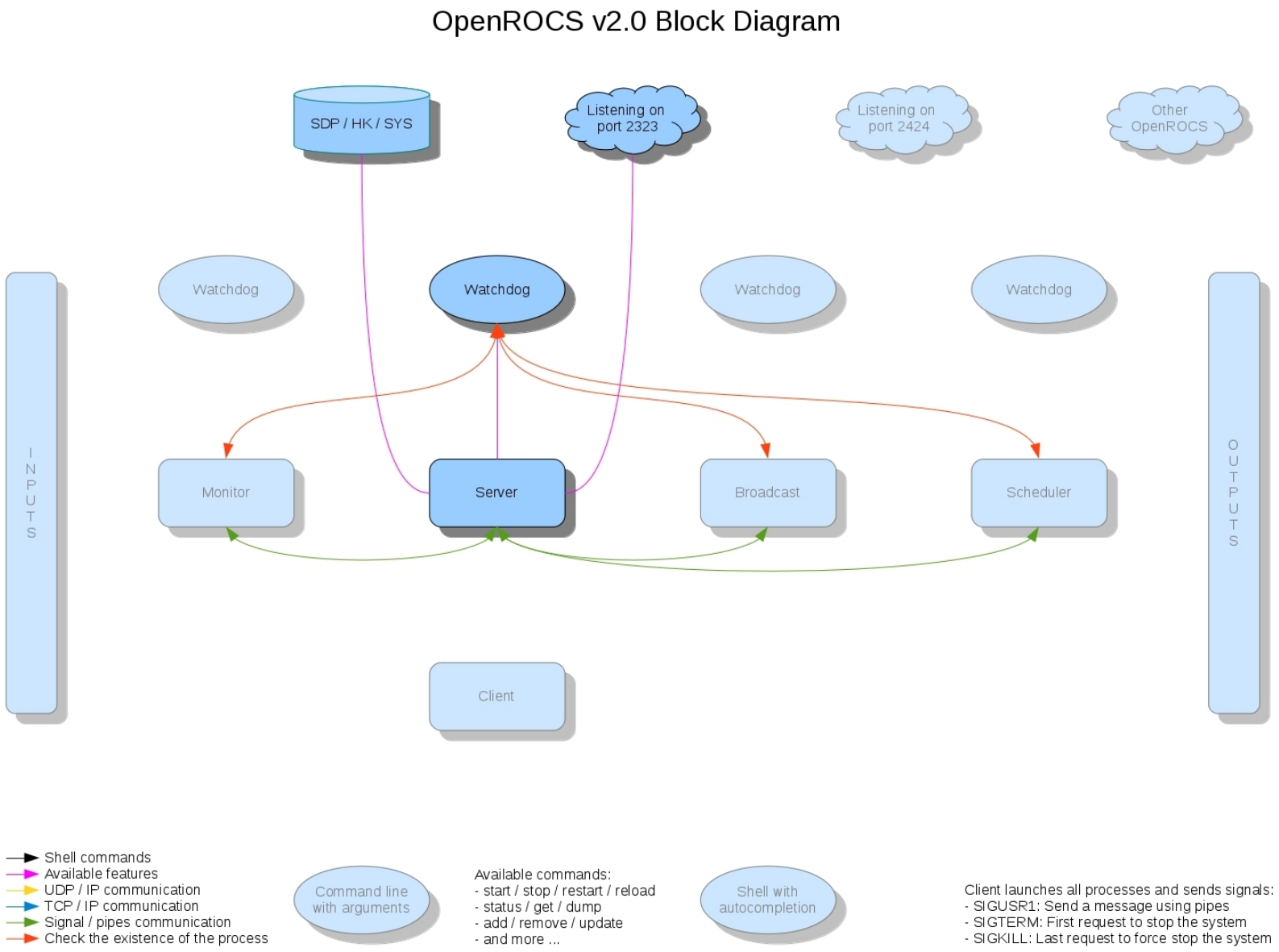
OpenROCS: Diagrama básico



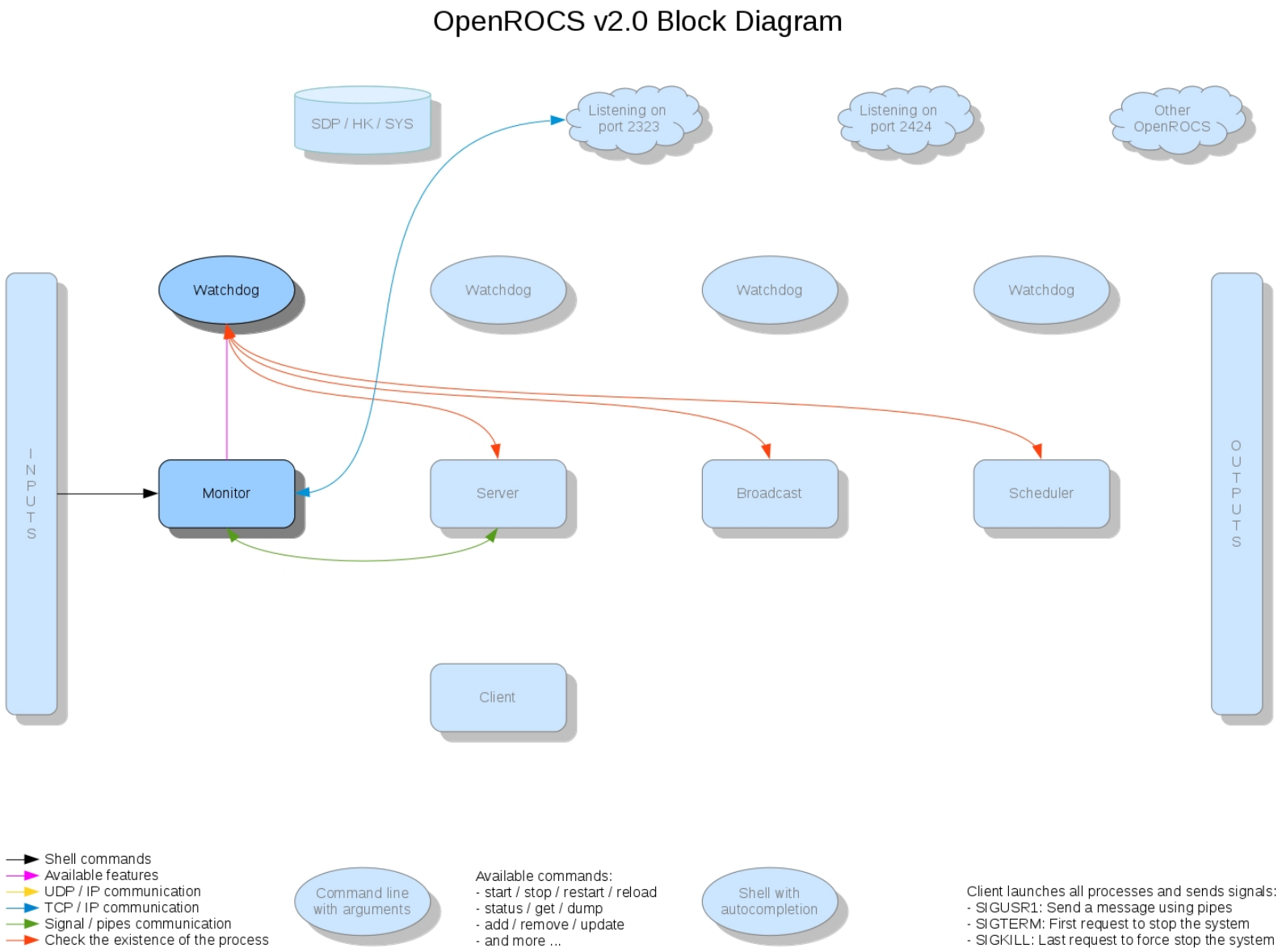
OpenROCS: Diagrama completo



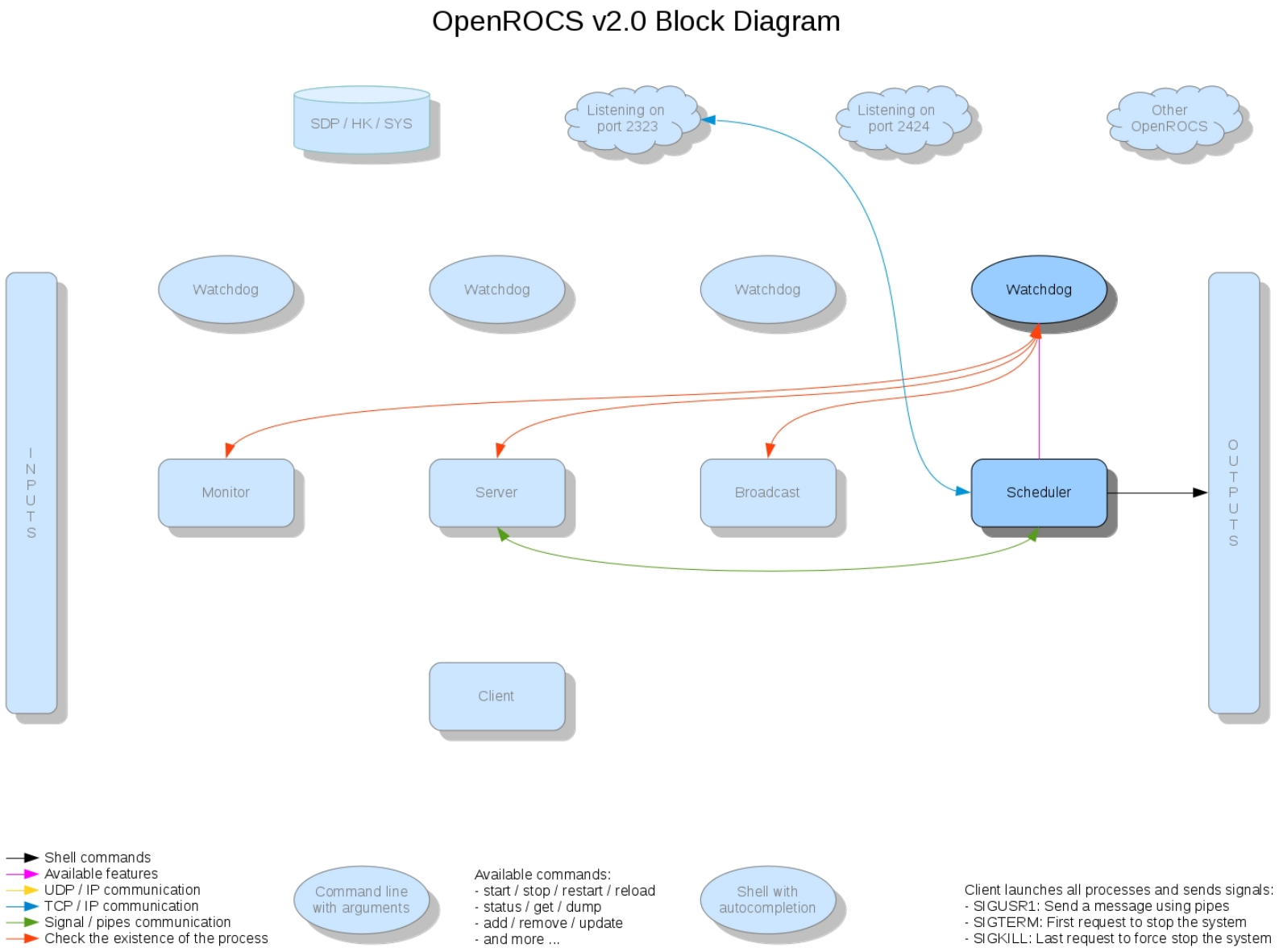
OpenROCS: El servidor



OpenROCS: El monitor

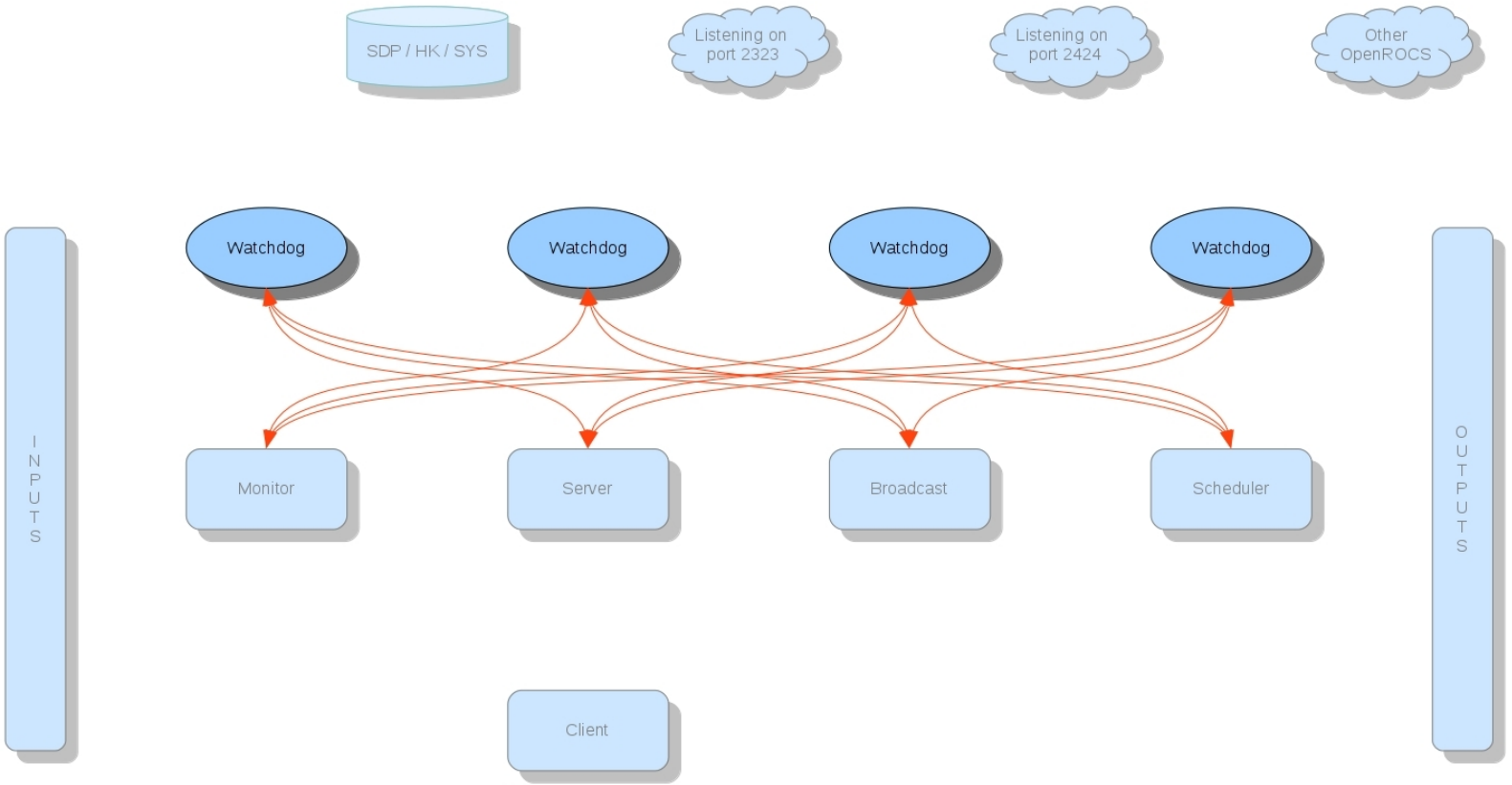


OpenROCS: El scheduler



OpenROCS: El watchdog

OpenROCS v2.0 Block Diagram



Shell commands
Available features
UDP / IP communication
TCP / IP communication
Signal / pipes communication
Check the existence of the process

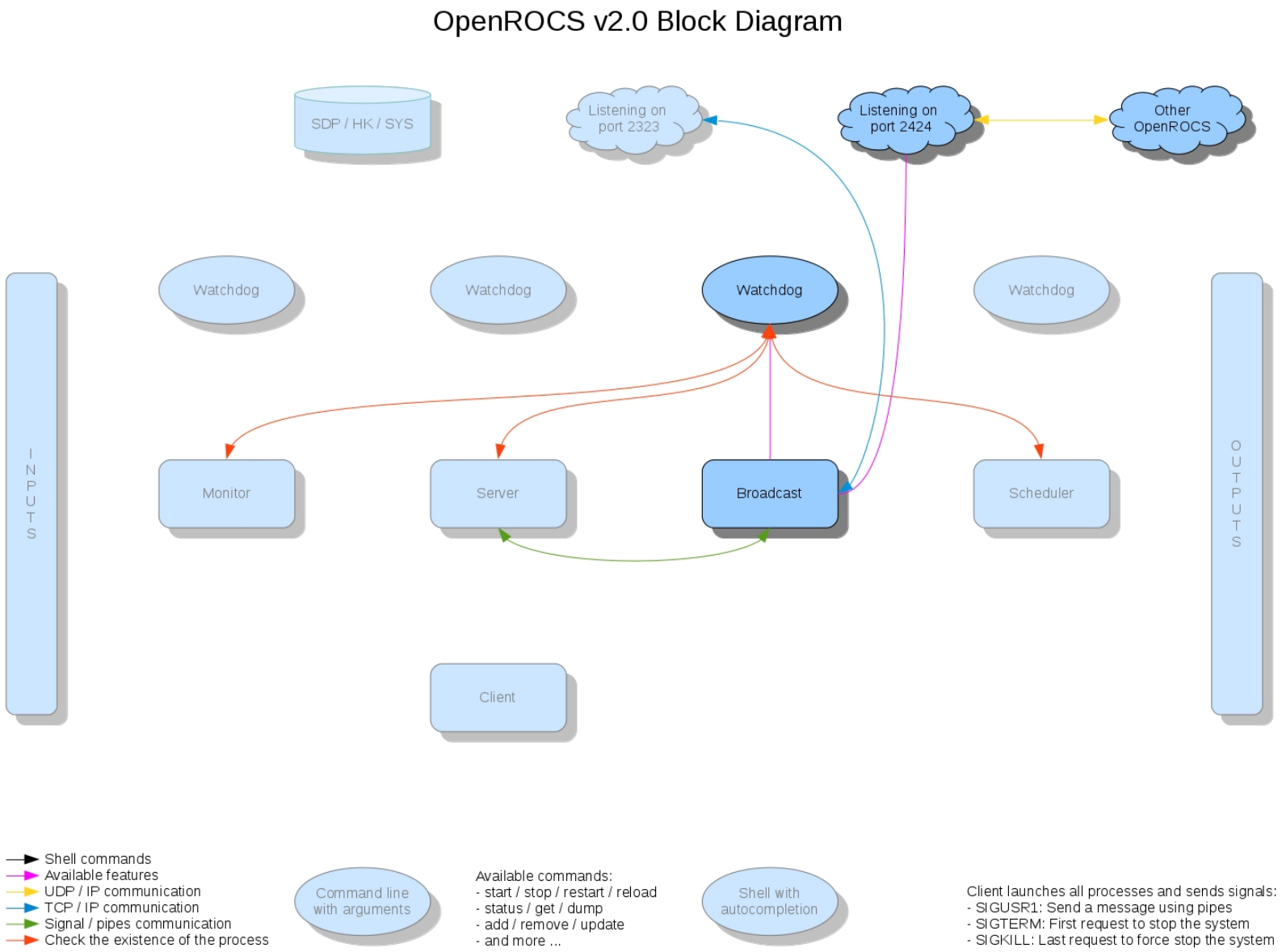
Command line with arguments

Available commands:
- start / stop / restart / reload
- status / get / dump
- add / remove / update
- and more ...

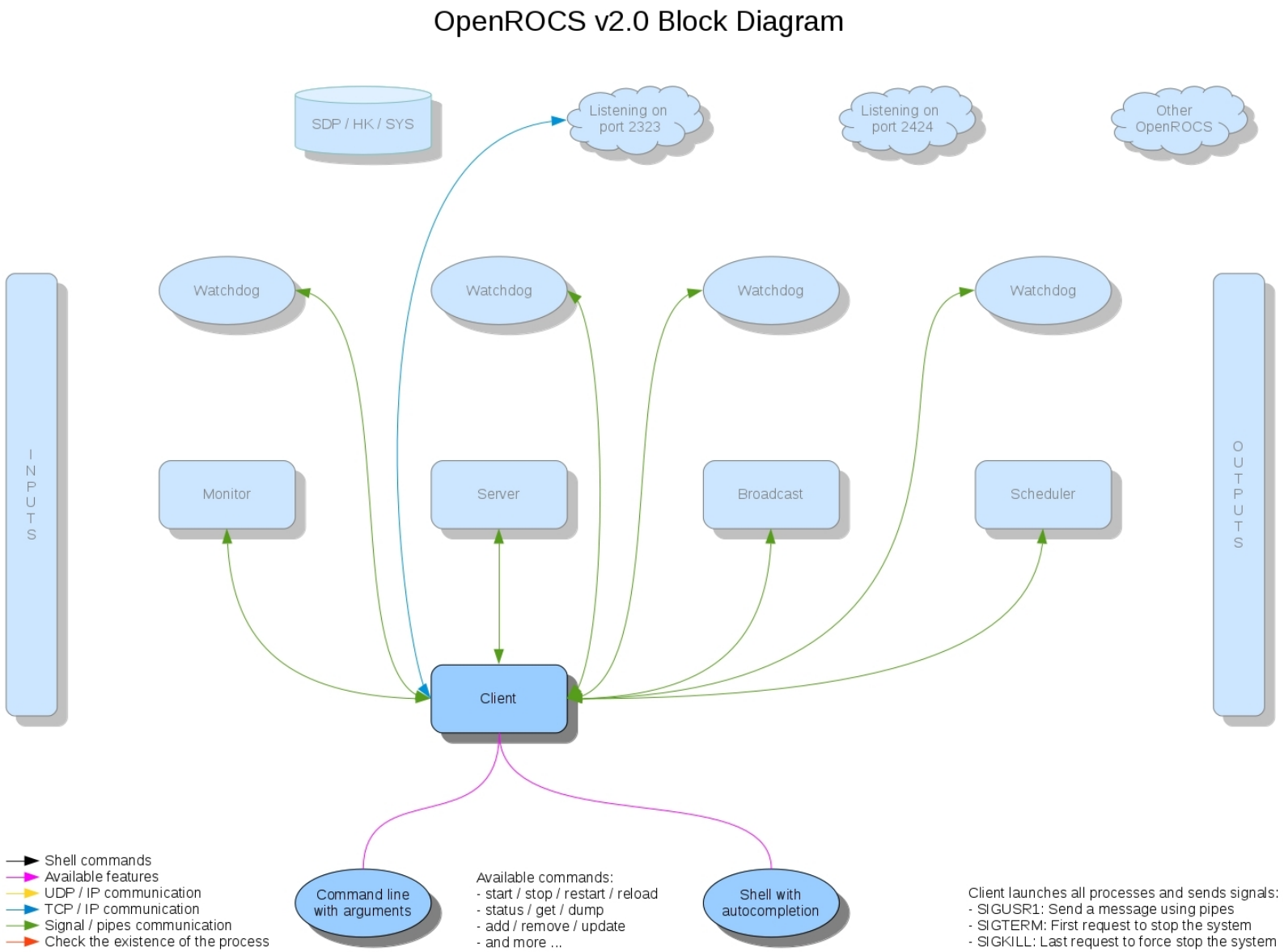
Shell with autocompletion

Client launches all processes and sends signals:
- SIGUSR1: Send a message using pipes
- SIGTERM: First request to stop the system
- SIGKILL: Last request to force stop the system

OpenROCS: El broadcast



OpenROCS: El cliente



OpenROCS: Interfaces

Tuberías y señales.

- Comunicación entre procesos

TCP/IP

- Comunicación con el servidor

UDP/IP

- Comunicación entre broadcasts

Shell command

- Interacción con programas externos

OpenROCS: Comandos shell

La shell es importante:

- OpenROCS no incluyen código para acceder a dispositivos.
- Cada tarea debe poder ejecutarse desde la línea de comandos.
- Feedback usando el stdout o stderr.
- Permite reciclar una gran cantidad de programas existentes
- Independencia del lenguaje de programación

OpenROCS: Configuración

El fichero config.xml

- Servidor (IP, puerto, nombre, stacks)
- Broadcast (enabled, puerto, discovery, sync)
- Debug (permite obtener trazas internas)
- Shell (define comportamiento del cliente)
- Timeouts / Pollings / Retries
- ini_set / putenv (variables de PHP)

OpenROCS: Configuración

Ejemplo de fichero variables.xml

```
<variables>
    <IP>
        <SERVER>192.168.0.10</SERVER>
        <SENSORS>192.168.0.11</SENSORS>
        <TELESCOPE>192.168.0.12</TELESCOPE>
        <DOME>192.168.0.13</DOME>
        <CAMERA>192.168.0.14</CAMERA>
        <POWER>192.168.0.15</POWER>
    </IP>
    <INTERVAL>10</INTERVAL>
    <PDU>
        <OID>.1.3.6.1.4.1.318.1.1.12.3.3.1.1.4</OID>
        <ON>1</ON>
        <OFF>2</OFF>
    </PDU>
</variables>
```

OpenROCS: Configuración

Ejemplo de fichero monitor.xml

```
<monitor>
    <name>mymonitor1</name>
    <task>
        <interval>10</interval>
        *****   Process nodes   *****
    </task>
    <task>
        <frequency>10</frequency>
        *****   Process nodes   *****
    </task>
</monitor>
<monitor>
        *****   Task nodes   *****
</monitor>
```

OpenROCS: Configuración

Ejemplo de fichero scheduler.xml

```
<scheduler>
    <name>myscheduler1</name>
    <hash>
        <variable>myvariable1</variable>
        <variable>myvariable2</variable>
        <variable>myvariable3</variable>
    </hash>
    *****   Process nodes   *****
</scheduler>
<scheduler>
     *****   scheduler nodes   *****
</scheduler>
```

OpenROCS: Configuración

Lenguaje de configuración de OpenROCS

- <action>
- <shell>, <timeout>, <ontimeout>
- <php>
- <choose>, <when>, <eval>, <fromiter>, <everyiter>, <untiliter>, <fromsec>, <everysec>, <untilsec>, <otherwise>
- <send>
- <log>

OpenROCS: Tareas previas

Sistema de control del telescopio y cúpula

- TALON: talon_fifo y talon_alias

Sistemas de meteorología

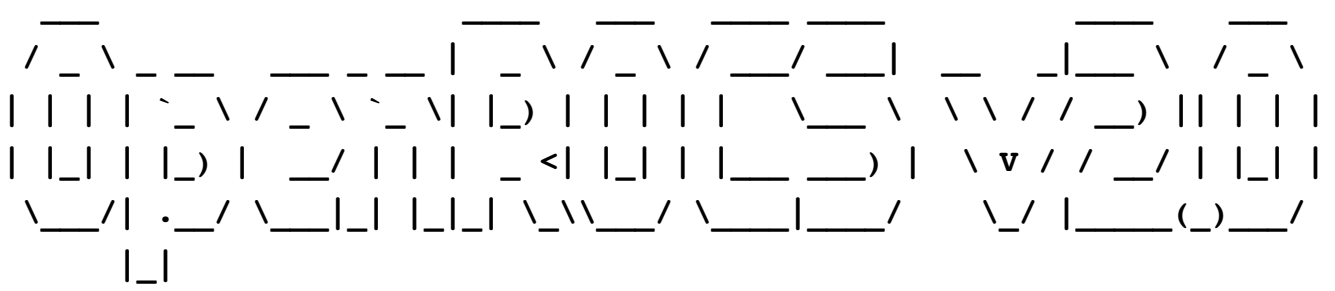
- Previstorm: previstorm.c
- EM-Davis: davis.c
- EM-SMC: PBCdlComm, emsmc.php y EMSMC.xml
- EM-TFRM: vaisala.php
- Sensor de lluvia: raindetect.c
- Sensor de nubes: cloudsensor.c

OpenROCS: Lenguaje PHP

OpenROCS esta escrito en PHP:

- Similar a Python o Perl
- Sintaxis muy parecida al lenguaje C
- pcntl_fork y pcntl_signal
- register_tick_function y unregister_tick_function
- socket_create, socket_bind, socket_listen, socket_select y socket_accept
- register_shutdown_function
- set_error_handler y set_exception_handler

OpenROCS: GPL-3.0



```
OpenROCS: Open Robotic Observatory Control System
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More information in http://www.ieec.cat or ieec@ieec.cat

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```

OpenROCS: Resultados

Actualmente, el TJO dispone de un sistema de control que ha aportado mejoras en varios aspectos:

- Estabilidad
- Recuperación ante errores
- Escalabilidad
- Adaptabilidad
  - TJO
  - SuperWASP Qatar Telescope

OpenROCS: Resultados

Algunas imágenes obtenidas con el TJO:

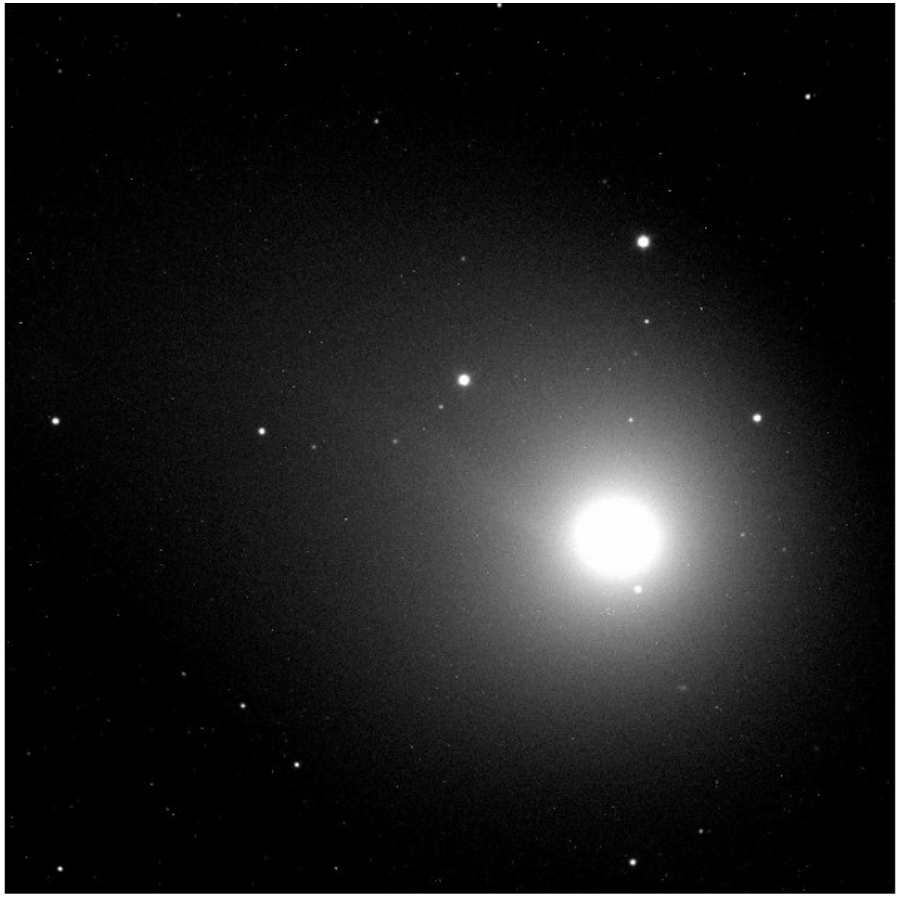
M82 y SN2014
Galaxia M82 con la supernova SN2014J indicada con líneas amarillasJ

Arp316
Galaxias en interacción

OpenROCS: Resultados

Algunas imágenes obtenidas con el TJO:

M1
Nebulosa del Cangrejo



Cometa Lulin C/2007 N3
Coma del cometa Lulin

OpenROCS: Resultados

Algunas imágenes obtenidas con el TJO:

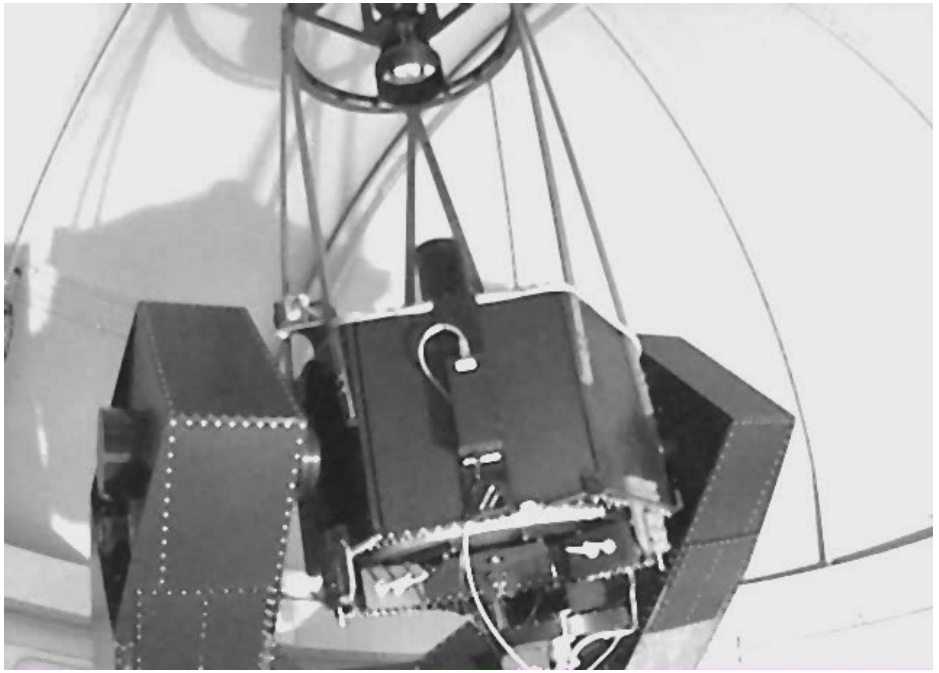
NGC7331
Galaxia espiral, en la constelación de Pegasus.

M13
Gran cúmulo globular de Hércules

OpenROCS: Resultados

Cámara exterior

Cámara interior



OpenROCS: Resultados

Primeras observaciones científicas

OpenROCS: Resultados

OpenROCS: Resultados

Desde el IEEC-CSIC, se ha solicitado un acta de depósito notarial para OpenROCS

- Número de Protocolo: 1392/2012
- Fecha de depósito: 16 de noviembre de 2012

Este deposito notarial:

- Aporta un aumento de protección de la propiedad intelectual
- Facilita la transferencia con la industria

OpenROCS: Resultados

Spectroscopic confirmation and additional photometry of the M31 nova candidate PNV J00423972+4120117 (2014-10-24)
G. Sala, P. Rodriguez-Gil, M. Henze, et al.
Astronomer's Telegram, #6616

Spectroscopy and photometry of the novae M31N 2014-09a and M31N 2014-09b (2014-09-25)
E. A. Barsukova, S. Fabrika, A. F. Valeev, et al.
Astronomer's Telegram, #6498

SN 2013df, a double-peaked IIb supernova from a compact progenitor and an extended H envelope (2014-09-17)
A. Morales-Garoffolo, N. Elias-Rosa, S. Benetti, et al.
Monthly Notices of the Royal Astronomical Society, Volume 445, Issue 2, p.1647-1662

New optical nova candidate in the M 31 disk (2014-07-10)
M. Henze, G. Sala, J. Jose, et al.
Astronomer's Telegram, #6305

Optical and near-infrared observations of SN 2011dh - The first 100 days (2013-05-08)
M. Ergon, J. Sollerman, M. Fraser, et al.
Astronomy & Astrophysics, Volume 562, id.A17, 35 pp.

The 2011 October Draconids outburst. I. Orbital elements, meteoroid fluxes and 21P/Giacobini-Zinner delivered mass to Earth (2013-04-29)
J. M. Trigo-Rodríguez, J. M. Madiedo, I. P. Williams, et al.
Monthly Notices of the Royal Astronomical Society, Volume 433, Issue 1, p.560-570

OpenROCS: Resultados

Observing with the Telescopi Joan Oró

2013, may

Vilardell, F., Colomé, J., Sanz, J., Gil, P., Ribas, I.

Highlights of Spanish Astrophysics VII, pp. 958-958

OpenROCS: a software tool to control robotic observatories

2012-09-30

J. Colomé, J. Sanz, F. Vilardell, I. Ribas, P. Gil

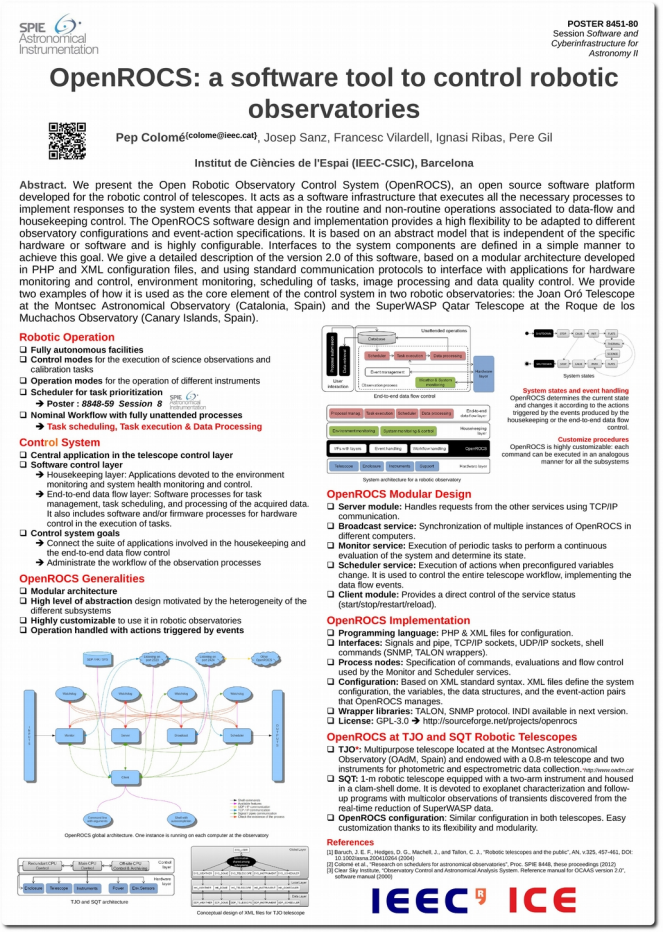
Proceedings SPIE, Amsterdam (2012)

The Open Robotic Observatory Control System (OpenROCS)

2012

Colomé, J., Ribas, I., Sanz, J., Vilardell, F.

CSIC-IEEC, RPT, ICE_OpenROCS_RPT-001



SPIE Astronomical Instrumentation

POSTER 8451-80
Session Software and Cyberinfrastructure for Astronomy II

OpenROCS: a software tool to control robotic observatories

Pep Colomé{colome@ieec.cat}, Josep Sanz, Francesc Vilardell, Ignasi Ribas, Pere Gil

Institut de Ciències de l'Espai (IEEC-CSIC), Barcelona

Abstract. We present the Open Robotic Observatory Control System (OpenROCS), an open source software platform developed for the robotic control of telescopes. It acts as a software infrastructure that executes all the necessary processes to implement responses to the system events that appear in the routine and non-routine operations associated to data-flow and housekeeping control. The OpenROCS software design and implementation provides a high flexibility to be adapted to different observatory configurations and event-action specifications. It is based on an abstract model that is independent of the specific hardware or software and is highly configurable. Interfaces to the system components are defined in a simple manner to achieve this goal. We give a detailed description of the version 2.0 of this software, based on a modular architecture developed in PHP and XML configuration files, and using standard communication protocols to interface with applications for hardware monitoring and control, environment monitoring, scheduling of tasks, image processing and data quality control. We provide two examples of how it is used as the core element of the control system in two robotic observatories: the Joan Oró Telescope at the Montsec Astronomical Observatory (Catalonia, Spain) and the SuperWASP Qatar Telescope at the Roque de los Muchachos Observatory (Canary Islands, Spain).

Robotic Operation

- ❑ **Fully autonomous facilities**
- ❑ **Control modes** for the execution of science observations and calibration tasks
- ❑ **Operation modes** for the operation of different instruments
- ❑ **Scheduler for task prioritization**
  - ➔ **Poster : *8848-59 Session 8***
- ❑ **Nominal Workflow with fully unattended processes**
  - ➔ **Task scheduling, Task execution & Data Processing**

Control System

- ❑ **Central application in the telescope control layer**
- ❑ **Software control layer**
  - ➔ Housekeeping layer: Applications devoted to the environment monitoring and system health monitoring and control.
  - ➔ End-to-end data flow layer: Software processes for task management, task scheduling, and processing of the acquired data. It also includes software and/or firmware processes for hardware control in the execution of tasks.
- ❑ **Control system goals**
  - ➔ Connect the suite of applications involved in the housekeeping and the end-to-end data flow control
  - ➔ Administrate the workflow of the observation processes

OpenROCS Generalities

- ❑ **Modular architecture**
- ❑ **High level of abstraction** design motivated by the heterogeneity of the different subsystems
- ❑ **Highly customizable** to use it in robotic observatories
- ❑ **Operation handled with actions triggered by events**

OpenROCS global architecture. One instance is running on each computer at the observatory

TJO and SQT architecture

Conceptual design of XML files for TJO telescope

System architecture for a robotic observatory

System states

System states and event handling
OpenROCS determines the current state and changes it according to the actions triggered by the events produced by the housekeeping or the end-to-end data flow control.

Customize procedures
OpenROCS is highly customizable: each command can be executed in an analogous manner for all the subsystems

OpenROCS Modular Design

- ❑ **Server module:** Handles requests from the other services using TCP/IP communication.
- ❑ **Broadcast service:** Synchronization of multiple instances of OpenROCS in different computers.
- ❑ **Monitor service:** Execution of periodic tasks to perform a continuous evaluation of the system and determine its state.
- ❑ **Scheduler service:** Execution of actions when preconfigured variables change. It is used to control the entire telescope workflow, implementing the data flow events.
- ❑ **Client module:** Provides a direct control of the service status (start/stop/restart/reload).

OpenROCS Implementation

- ❑ **Programming language:** PHP & XML files for configuration.
- ❑ **Interfaces:** Signals and pipe, TCP/IP sockets, UDP/IP sockets, shell commands (SNMP, TALON wrappers).
- ❑ **Process nodes:** Specification of commands, evaluations and flow control used by the Monitor and Scheduler services.
- ❑ **Configuration:** Based on XML standard syntax. XML files define the system configuration, the variables, the data structures, and the event-action pairs that OpenROCS manages.
- ❑ **Wrapper libraries:** TALON, SNMP protocol. INDI available in next version.
- ❑ **License:** GPL-3.0 ➔ http://sourceforge.net/projects/openrocs

OpenROCS at TJO and SQT Robotic Telescopes

- ❑ **TJO*:** Multipurpose telescope located at the Montsec Astronomical Observatory (OAdM, Spain) and endowed with a 0.8-m telescope and two instruments for photometric and espectrometric data collection. http://www.oadm.cat
- ❑ **SQT:** 1-m robotic telescope equipped with a two-arm instrument and housed in a clam-shell dome. It is devoted to exoplanet characterization and follow-up programs with multicolor observations of transients discovered from the real-time reduction of SuperWASP data.
- ❑ **OpenROCS configuration:** Similar configuration in both telescopes. Easy customization thanks to its flexibility and modularity.

References

[1] Baruch, J. E. F., Hodgers, D. G., Machell, J., and Tallon, C. J., "Robotic telescopes and the public", AN, v.325, 457-461, DOI: 10.1002/asna.200410304 (2004)
[2] Colomé et al., "Research on schedulers for astronomical observatories", Proc. SPIE 8448, these proceedings (2012)
[3] Clear Sky Institute, "Observatory Control and Astronomical Analysis System. Reference manual for OCAAS version 3.0", software manual (2006)

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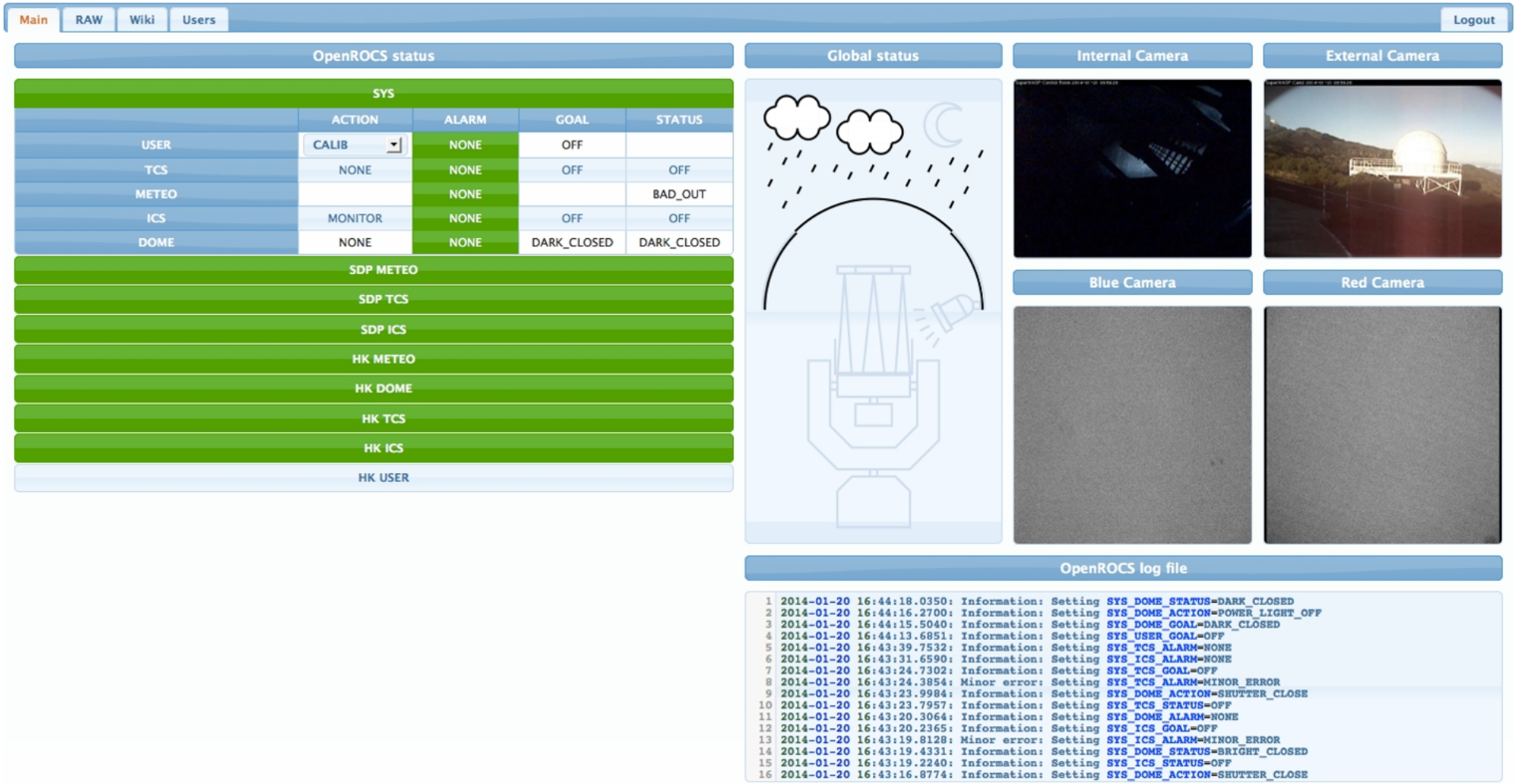
OpenROCS: Resultados

SuperWASP Qatar Telescope (SQT)

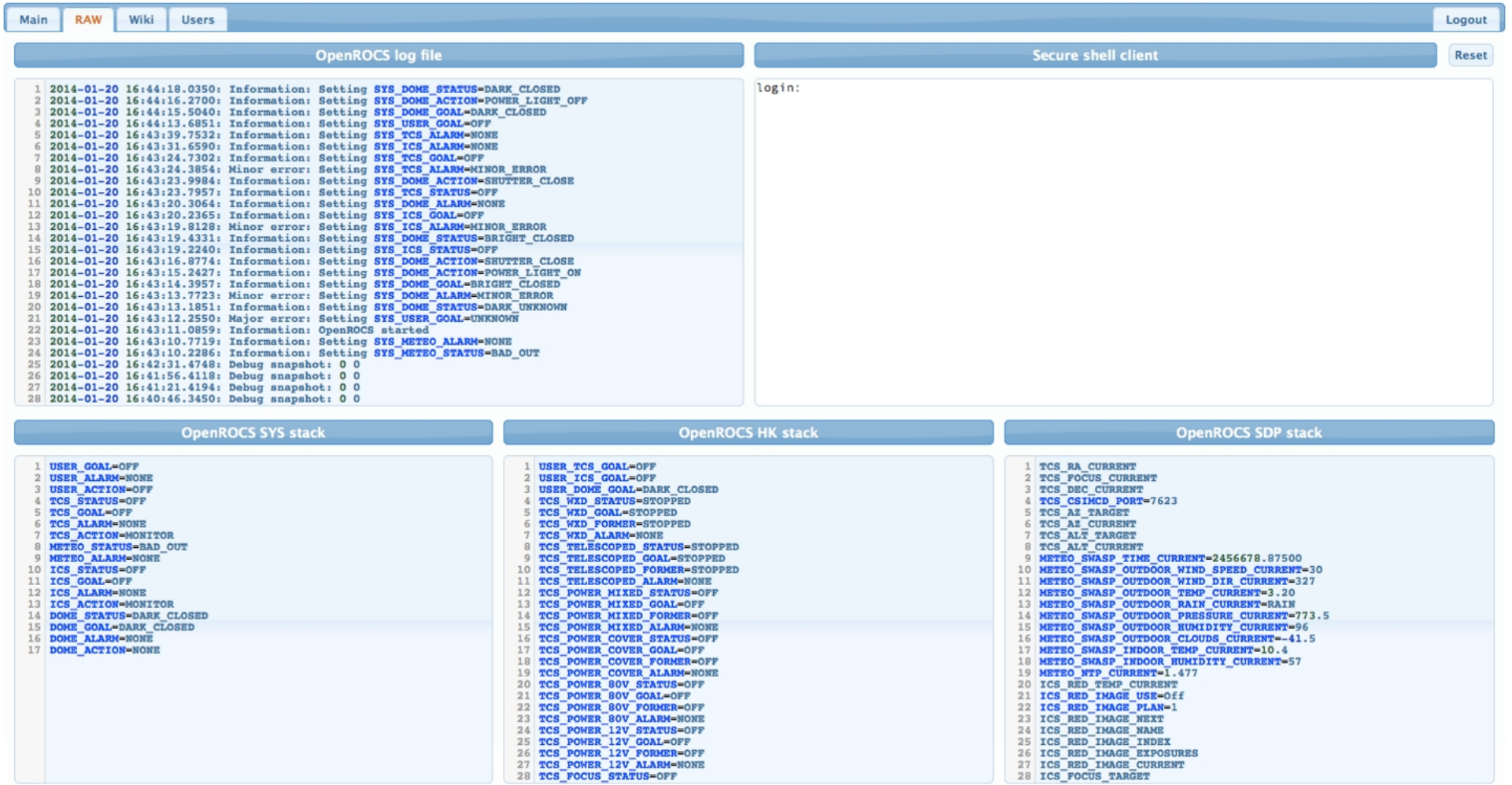
- Ubicado en el Roque de los Muchachos Observatory (Islas Canarias, España)
- Telescopio del fabricante OMI de 1m de diámetro
- Proporcionará fotometría de alta precisión de exoplanetas en tránsito

OpenROCS: Resultados

OpenROCS: Resultados



OpenROCS: Resultados



OpenROCS: OAdM+TJO

Inversión en la construcción y equipamiento

Descripción	**%**
Obra civil (año 2003, fase A)	18 %
Obra civil (año 2007)	22 %
Telescopio OMI 80cm en configuración Ritchey-Chrétien	45 %
Instrumentación (MEIA/ARES/Equipos informáticos)	15 %
Total	**100 %**

- Supuso un coste inversión de **1.328.000,00€**

Descripción	**Precio**	**%**
Inversión	1.328.000,00€	60 %
Mantenimento del OAdM en el periodo 2004-2013	887.000,00€	40 %
Total	**2.215.000,00€**	**100 %**

- Supuso un coste total de **2.215.000,00€**

OpenROCS: Planificación

Distribución de la dedicación por tareas

Diagrama de Gantt con la planificación

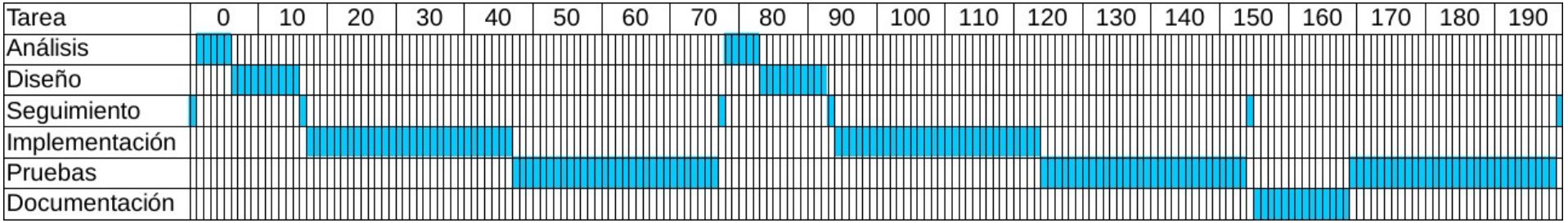
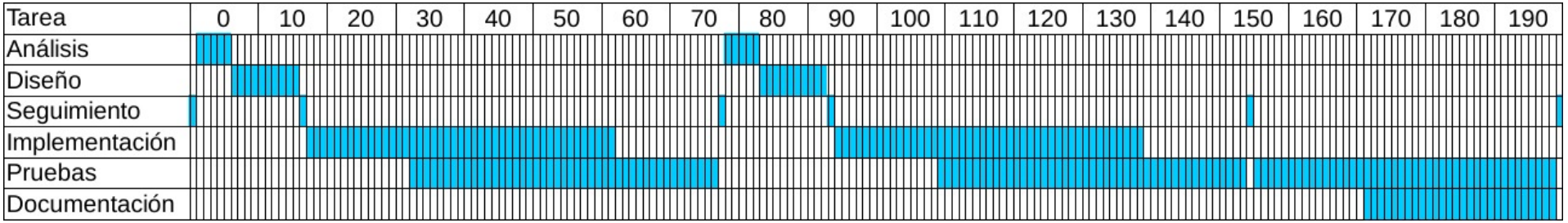


Diagrama de Gantt con la ejecución real



OpenROCS: Costes

Coste de ejecución de este proyecto

Tarea	%	Días	Horas	Personas	Precio hora	Total
Análisis	5 %	10	75h	1	30,00€/h	2.250,00€
Diseño	10 %	20	150h	1	30,00€/h	4.500,00€
Seguimiento	3 %	6	45h	1	30,00€/h	1.350,00€
Implementación	30 %	60	450h	1	30,00€/h	13.500,00€
Pruebas	45 %	90	675h	2	30,00€/h	40.500,00€
Documentación	7 %	14	105h	1	30,00€/h	3.150,00€
Total	**100 %**	**200**	**1500h**			**65.250,00€**

- **4.91%** respecto a la inversión del OAdM y TJO.
- **7,36%** respecto a la partida destinada al mantenimiento.
- **2.95%** respecto al total de todo el proyecto.

OpenROCS: Conclusiones

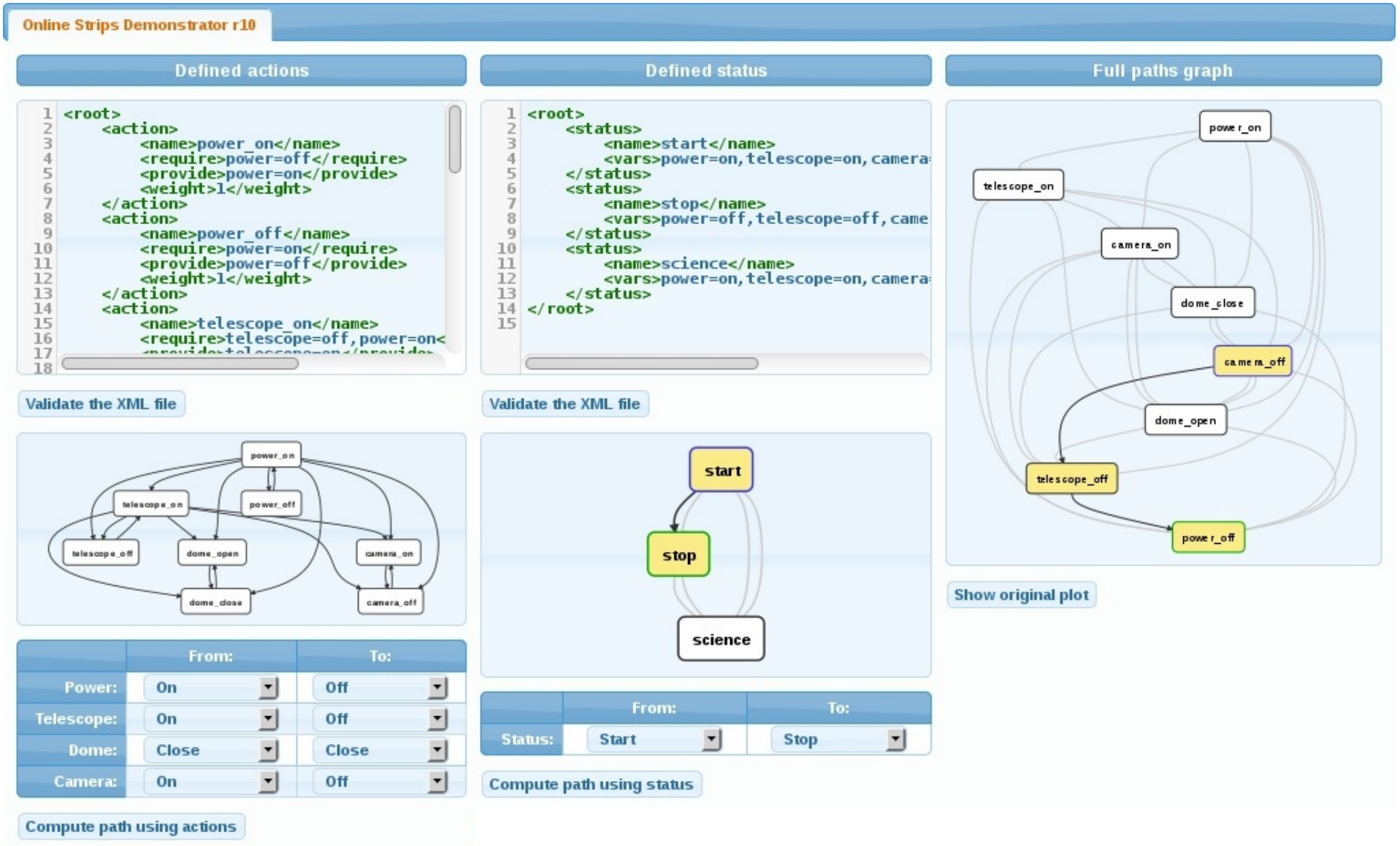
Actualmente, estamos controlando 2 telescopios:

- TJO en el Observatorio Astronómico del Montsec (OAdM).
- SQT en el Observatorio del Roque de los Muchachos en La Palma.

Hemos planteado de hacer mejoras para:

- Mejorar la especificación del lenguaje de configuración (XML) para simplificarlo.
- Buscar reemplazos para el interprete de PHP que proporcionen mejoras de rendimiento
- Añadir un algoritmo de Inteligencia artificial para tomar decisiones de forma automática mediante el uso del algoritmo STRIPS

OpenROCS: Conclusiones



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