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Robotic operation of the Observatorio Astrofísico de Javalambre

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Abstract

The Observatorio Astrofísico de Javalambre (OAJ) is a new astronomical facility located at the Sierra de Javalambre (Teruel, Spain) whose primary role will be to conduct all-sky astronomical surveys with two unprecedented telescopes of unusually large fields of view: the JST/T250, a 2.55 m telescope of 3 deg field of view, and the JAST/T80, an 83 cm telescope of 2 deg field of view. CEFCA engineering team has been designing the OAJ control system as a global concept to manage, monitor, control and maintain all the observatory systems including not only astronomical subsystems but also infrastructure and other facilities. Three main factors have been considered in the design of a global control system for the robotic OAJ: quality, reliability and efficiency. We propose CIA (Control Integrated Architecture) design and OEE (Overall Equipment Effectiveness) as a key performance indicator in order to improve operation processes, minimizing resources and obtain high cost reduction maintaining quality requirements. Here we present the OAJ robotic control strategy to achieve maximum quality efficiency for the observatory surveys, processes and operations, giving practical examples of our approach.

1 Introduction

The OAJ [2, 3] is a new astronomical facility at the Pico del Buitre, in Teruel, Spain, promoted by the Centro de Estudios de Física del Cosmos de Aragón (CEFCA; `http://www.cefca.es`) to carry out large sky surveys with two dedicated telescopes of very large FoV. These are the Javalambre Survey Telescope (JST/T250), a 2.55 m telescope with 3 deg FoV, and the

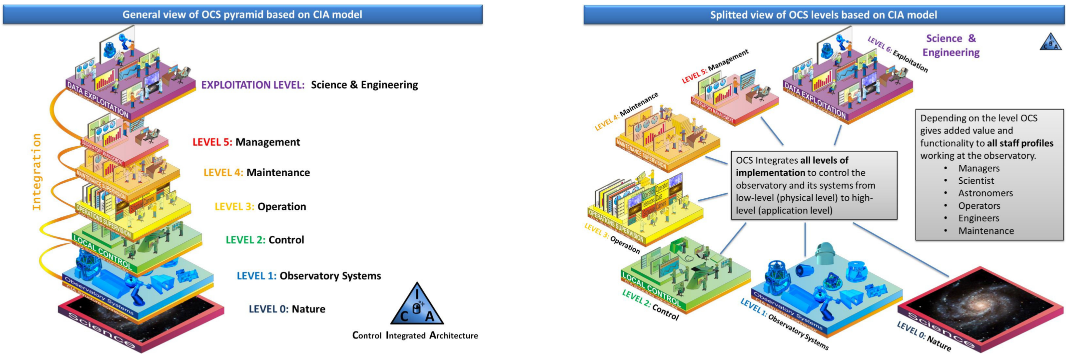
Javalambre Auxiliary Survey Telescope (JAST/T80), an 83 cm telescope with a FoV diameter of 2 deg. The most immediate scientific goals of JST/T250 and JAST/T80 are two large sky multi-filter surveys, the Javalambre-PAU Astrophysical Survey [1, 6] (J-PAS; `http://j-pas.org`) and the Javalambre Photometric Local Universe Survey [11, 6, 4] (J-PLUS; `http://www.j-plus.es`), to be performed respectively with their first light panoramic cameras, namely JPCam and T80Cam.

Times of deep reflection about operational effectiveness at astrophysical observatories are becoming more important in this competitive world. In this context, there are many valuable tools to improve processes and operations, which could be very helpful for applying at the observatory operational model. For instance the McKinsey 7S model [10] could be very useful. This model shows many ways to obtain information about your process using Key Performance Indicators, also known as KPI [12, 10], which provides a feedback of actions and processes to maintain high performance throughout the entire life cycle of the observatory and subsystems. Therefore, it seems very reasonable implementing these kind of tools at the Observatory Control System (OCS) as part of the whole functionality.

Taking into account the economic aspects of performing operations at the observatory, not only night operation for astronomy, but also day operation for engineering and maintenance, cost reduction has been the main point of our OCS design due to the relevant importance in achieving scientific targets, maintaining quality requirements but also minimizing resources, material and human resources. In order to achieve these targets, the OCS has been designed from scratch taking into account two key points: Overall Equipment Efficiency (OEE) [12] and Control Integrated Architecture (CIA) [12, 7, 13]. On the one hand, OEE is a well-known tool, developed by Seiichi Nakajima [8] in 1960's for the automation manufacturing industry. On the one hand, OEE is directly related to study downtimes and other wasting time analysis, so it can be used in manufacturing industry and also in observatories. On the other hand, from our point of view CIA summarizes the set of minimum requirements to fulfill the design of the OCS in order to add and obtain high performance in the observatorys functionality. It extends the functionality of classical OCS to achieve the main goals by adding the following requirement criteria. In CIA concept all systems at the observatory must be included as a global idea, not only those related directly with astronomy are important, but also those related with infrastructure. This is our main premise because all systems are interrelated and as a matter of fact they have a real dependency in the deployment of the operational model of the observatory. CIA also includes the goal of giving added value and functionality to all staff profiles working at the observatory and covering at the same time these functionalities: Operation, Management, KPI, Maintenance, Engineering, and Exploitation.

2 Development

The CIA concept is a CEFCA own design specifically adequate for astrophysical observatories. The idea of functionality and technology are easily exportable to other observatories. In the following sections we are going to explain the three important points in the development: goals, resources and planning. It is clear that the main target of the OCS is to give



OCS Integrates **all levels of implementation** to control the observatory and its systems from low-level (physical level) to high-level (application level)

Depending on the level OCS gives added value and functionality to **all staff profiles** working at the observatory.

- Managers
- Scientist
- Astronomers
- Operators
- Engineers
- Maintenance

Figure 1: OCS functional levels of implementation based on the CIA model.

functional capability to the observatory in order to operate the telescopes and their instrumentation. In the OAJ particular case the immediate goal is perform the J-PAS and J-PLUS surveys, but having considered that astronomical operation was the minimum requirement for the OCS, then we focused our developments on adding more value providing effectiveness feedback tools as it was mentioned at the introduction. In other words, our big goal is perform quality operations, minimizing errors, resources, time and costs. This point of view has been the key to design the functional structure of the OCS. Efficient operations enable better performance of observatory goals and quality standards, reducing material and human resources. Automation gives a great capability to reduce resources performing observatory operations in a robotic way. The more the observatories operates in robotic mode, the more the observatories has these resources available to do other alternative tasks, obtaining indirectly global unexpected quality because staff could be distributed to other different tasks saving time at once. In our particular case, the number of people foreseen for the project was restricted initially. Because of this it was mandatory to take matters into our own hands, designing an OCS adapted to this restriction as much as possible from the beginning. In our OCS design, other way to reduce time is alarming and enabling corrective actions before problems or deviations occur, getting the right information to the right person. The ability to access relevant observatory data increases long term performance by analyzing root causes and making recommendations to improve decision making.

3 Architecture

Architecture is a key concept in the CIA modeling and it is related to building a tool which can give functionality in all areas covering the wide range of staff profiles requirements at the observatory. In Fig.1 is represented a general architecture view including the OCS levels of implementation based on the CIA model.

The OCS gives added value and functionality to all staff profiles working at the observatory: managers, scientist, astronomers, operators, engineers, and maintenance technicians.

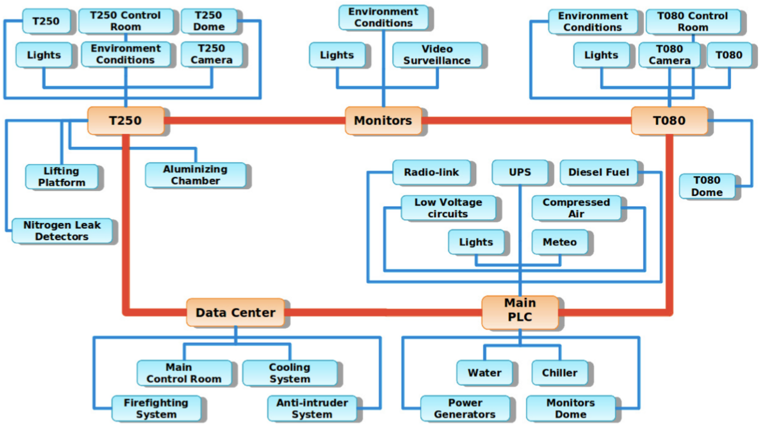


Figure 2: General node distribution diagram of the OAJ

It covers a full range of areas of functionality to give added value to all profiles: management –global administration of all systems at the observatory; operations –actions and processes performed at the observatory by a certain group of systems such as astronomical systems, in this case called astronomical operations; engineering –analysis, design, development and implementation of all systems at the observatory; maintenance –supporting tasks to keep all systems at the observatory in good condition; KPI –Key Performance Indicators provide immediate information about performance and efficiency at observatory operations; exploitation –extract useful data in real-time, giving a reported feedback for re-engineering tasks in order to improve accuracy and reliability of observatory processes (science and engineering; Fig. 1).

4 Distributed hardware real-time control system with Beckhoff

The EtherCAT (Ethernet for Control Automation Technology; `http://ethercat.org/`) protocol is an Ethernet-based field-bus for industrial communications integrated on the IEC (International Electrotechnical Commission). It is a high performance and open Network.

The OCSN [13] has a main node on each building. At the same time each node has several systems and many subsystems connected as well. Main nodes and systems at the OAJ are detailed in Fig. 2.

5 Deployment

As it was illustrated in Fig. 2, the OCS is a global tool which has the responsibility of controlling, monitoring and managing all systems installed at the observatory. In this section we will explain how the OCS modules and infrastructure are split and physically located around CEFCA facilities and infrastructures in order to control all these elements and devices. These

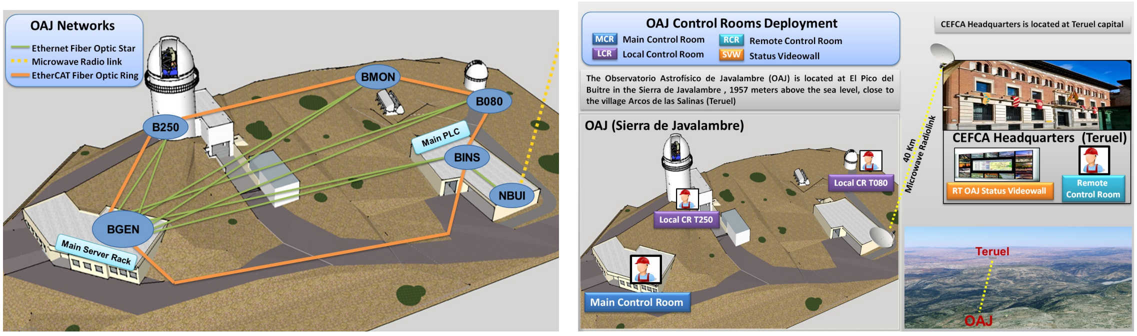


Figure 3: *Left:* general view of OAJ networks. *Right:* location of the OAJ control rooms.

systems are split into groups depending on its localization inside the OAJ. This is the reason why there exists five mains Control-Nodes (CN): Service Building (BSER), T080 Building (B080), Monitors Building (BMON), T250 Building (B250) and General Building (BGEN). All these nodes are linked thanks to an EtherCAT Ring topology network and Ethernet Star topology network illustrated in Fig. 3. This strategy gives a stronger redundancy and error identification thank to bi-directional communication channel. These communications are implemented by multi-mode fiber optics, using a protocol and technologies from EtherCAT and Ethernet. In both cases there are different control branches that are implemented by copper cable spreading out from each node. The fibers, from each node, are centralized on the Main Server Rack inside the General Building. The total distance that the fiber goes through the network is about 350 m. The network topology is configured on the Main Server Rack. The Central PLC based on Beckhoff (`http://www.beckhoff.com/`) platform is located at the General Service Building. All systems, including acquisition and actuator devices are controlled using different EtherCAT Bus extensions through each node.

The right panel of Fig. 3 shows the control rooms deployment at CEFCA facilities. The Main Control Room is located at the general services building to perform global control over all systems included in the observatory. Although both telescope controls are available at Main Control Room, there are also local control rooms for the JAST/T80 and JST/T250 telescopes, in order to perform specific tasks on the telescopes requiring physical proximity to avoid long displacement to the telescope. For instance, during instruments and telescopes commissioning, maintenance, engineering tasks, etc. In CEFCA Headquarters there is a Remote Control Room to manage, control and perform observatory operations remotely from Teruel city, as well as a videowall with the OAJ real time status.

6 Conclusions

This paper presents a quick overview of the OCS for the OAJ trying to cover all important parts of the architecture and development. The OCS has been designed following the CIA rules and recommendations in order to improve uptime, quality and yields; gain real-time visibility to performance parameters and access directly to quality details for observatory process control, fulfilling scientific and technical standards compliance. The main idea at this point is that to reach our goals, we really need to improve our system, minimizing errors, resources, time and costs. Therefore the first thing we have done is preparing infrastructures to measure acquiring key information, taking into account the condensed phrase: "If you cannot measure it you cannot improve it", which comes from "If you cannot measure it you cannot control it" [5], and "If you cannot measure it, then it is not science" [9]. A dedicated effort has been made to set up the basic infrastructure of the OCS and develop the observatory systems. Currently most of them are installed at OAJ infrastructures and they are prepared to be controlled locally and autonomously. The development team is prepared to continue with the following steps in order to set up integration and management functionality. First results related to low level infrastructure and local control systems deployed at OAJ have already demonstrated its great potential. More work is still needed, but we are confident that the OAJ will be operated efficiently in a near future. More effort is required on optimizing the performance of sub-system controls and the experience obtained by the team in the following steps is crucial to reach that objective.

Acknowledgments

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