Telescope controlled by PC Control surveys the skies

Observatorio Astrofísico de Javalambre (OAJ), which went into operation in 2015 in the southern Aragón region of Spain, is regarded as an incredibly unique astronomical research facility. The observatory is operated by the CEFCA foundation, whose main research goal is to photometrically survey several thousand square degrees of sky. Two Javalambre telescopes with an unusually wide field of view will make it possible for the first time to record the positions of hundreds of millions of galaxies and their development in order to supply the first full 3D map of the universe. To ensure high quality and efficiency, the telescopes operate with robotic assistance, based on an industrial PC control platform.

The Centro de Estudios de Física del Cosmos de Aragón, or CEFCA for short, is a state institute concerned with research into the development of galaxies and cosmology. Its headquarters are located in Teruel, Spain – some 40 km from the OAJ site which was constructed on the "Pico del Buitre" at an altitude of 1,957 meters above sea level. The observatory is equipped with two telescopes: the JST/T250, a telescope with a mirror diameter of 2.55 m and a 3-degree field of view, and the smaller JAST/T80, with a mirror diameter of 83 cm and a 2-degree field of view. All data from the sky surveys carried out at the OAJ are sent to the main server in Teruel via wireless communication.

EtherCAT network connects all systems and subsystems

The observatory's control system is based on a C6640 Industrial PC (IPC) as the master control platform and various CX5000 series Embedded PCs that provide decentralized control. The PC platform ensures the reliable control, monitoring and management of all systems and subsystems installed in the observatory. These systems are divided into five groups according to their location within the observatory: the operations building (Main PLC), the T080 telescope (B080), the monitoring room (BMON), the T250 telescope (B250) and the main operations building (Main Server Rack) (see fig. 1). The main control room is located in the main operations building and is used for the general control of all systems, including the observatory. Even though both telescopes can be controlled from the main control room, local control rooms are available for carrying out specific tasks, such as commissioning, maintenance or other technical work.

All control nodes are linked via EtherCAT in a ring topology, as well as via an Ethernet network with a star topology. The latter links the control units of the C250 camera with the observatory's EtherCAT network over the EtherCAT Automation Protocol (EAP). Communication takes place via a fiber-optic cable using EtherCAT or Ethernet protocols. The high bandwidth of EtherCAT enables the transmission of status information with each cycle. A remote control center is installed at the CEFCA headquarters in Teruel, from which the observatory can be managed, controlled and operated. The status of the OAJ is displayed in real-time on a video wall.

Embedded PC facilitates complex control of telescopes

The smaller of the two telescopes, the T80, performs some sky surveys referred to as JAST, beginning with the planned J-PLUS, a photometric multiband survey of the entire sky with expected completion in around two to three years' time. The results will be used to support the calibration of the astrophysical J-PAS survey, which is to be carried out with the JST/T250 telescope. In the next five years the T250 telescope will have surveyed 800 square degrees, or one fifth of the entire sky.

The Observatorio Astrofísico de Javalambre, erected on the El Pico del Buitre at an altitude of 1,957 meters above sea level, is an astronomical facility designed to survey the sky using two telescopes with unusually wide fields of view.

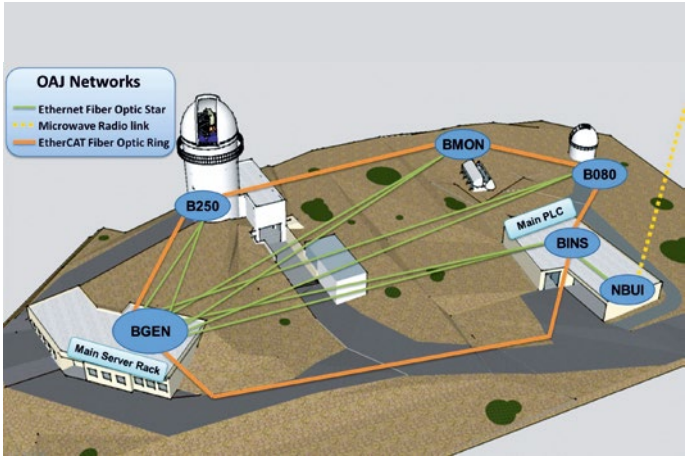


Fig. 1: The PC-based platform is used for complex monitoring and management of all systems and subsystems installed in the observatory, which are divided into five groups according to their location within the observatory. All control nodes – the operations building (Main PLC), the T080 telescope (B080), the monitoring room (BMON), the T250 telescope (B250) and the main operations building (Main Server Rack) – are linked via EtherCAT in a ring topology, as well as via an Ethernet network with a star topology.

Installed on the T250 is a JPCam wide-field camera, specially designed for the photometric surveillance of the northern sky. It consists of a mechanical filter shutter unit and camera system. The latter consists of the cooling and vacuum systems, the CCD detector field, an optically controlled entrance window and electronics. Filter inserts, the shutter and the interface with the telescope form the mechanical basis for the unit. A total of four CX5020 Embedded PCs are used to control the optical lenses, the camera and the hexapod on which the camera is mounted (see fig. 2). The control of the temperature-regulating glycol water for the camera is also performed with an embedded controller, EtherCAT slave module and inline EtherCAT terminals. The cooling system ensures that all heat is removed from the system, including the electronics and the shutter, so that the camera remains at a constant temperature. This prevents irregularities in the imaging due to the expansion or contraction of camera components caused by heat.

Control of the dome – an entire world of automation

The dome that covers the T250 telescope is almost 13 m in height and weighs 17 tons. It is controlled by a CX5020 Embedded PC with TwinCAT 2 NC PTP software. The compact PC-based controller controls the azimuth movement, which reaches a speed of 27 m/min, the opening and closing of the windshield and the observation window, as well as the rotary movement of the dome. The entire system is driven by Beckhoff AX5xx Servo Drives with integrated safety option card and servo motors. Safety I/Os are also integrated seamlessly into the control system via TwinSAFE terminals. The CX5020 is connected with a slip-ring system over PROFIBUS to a further CX5020, which is mounted in the lower, immobile part of the dome.

Mirror maintenance necessitates high-precision transport

The mirror of the T250 telescope has a diameter of 2.55 m – a precision instrument whose surface must be polished with extremely high accuracy to ensure that the deviation of the reflected beams is as small as possible. Such a mirror is valued around several hundred million euros, which means that maintenance work, such as the renewal of the aluminum layer, requires the utmost care. The OAJ has a special aluminizing room for this, in which the characteristic values of the mirror surface are meticulously maintained, remaining as close as possible to the state in which it was delivered from the factory. In view of the size and weight of the mirror, its transport to the maintenance room some 16.5 meters away represents a remarkable challenge. The lifting system that moves the mirror up and down is controlled with the highest precision by an Embedded PC and a servo drive with integrated safety functionality. The speed is only 15 cm per minute – a movement that is barely perceptible by the human eye. However, each minute acceleration or deceleration could cause tiny scratches on the glass, which would result in sky observation errors.

Integrated safety technology with TwinSAFE

Many of the safety circuits in the OAJ were designed on the basis of the TwinSAFE system. "With the aid of the EL6900 TwinSAFE logic terminal, we are able to add functional groups that control the various inputs and outputs, enabling us to implement important tasks such as emergency stop, AND and OR logical function blocks, as well as power-on and power-off delays with T_{ON} and T_{OFF}, among others," explains Axel Yanes, head of engineering at the OAJ. "The OAJ control system is conceived as a global system in which all components are interconnected and the devices constantly exchange information. They interact in a synchronous manner, so our entire safety system must be able to do the same." The safety information is transmitted via the FailSafe over EtherCAT (FSoE)

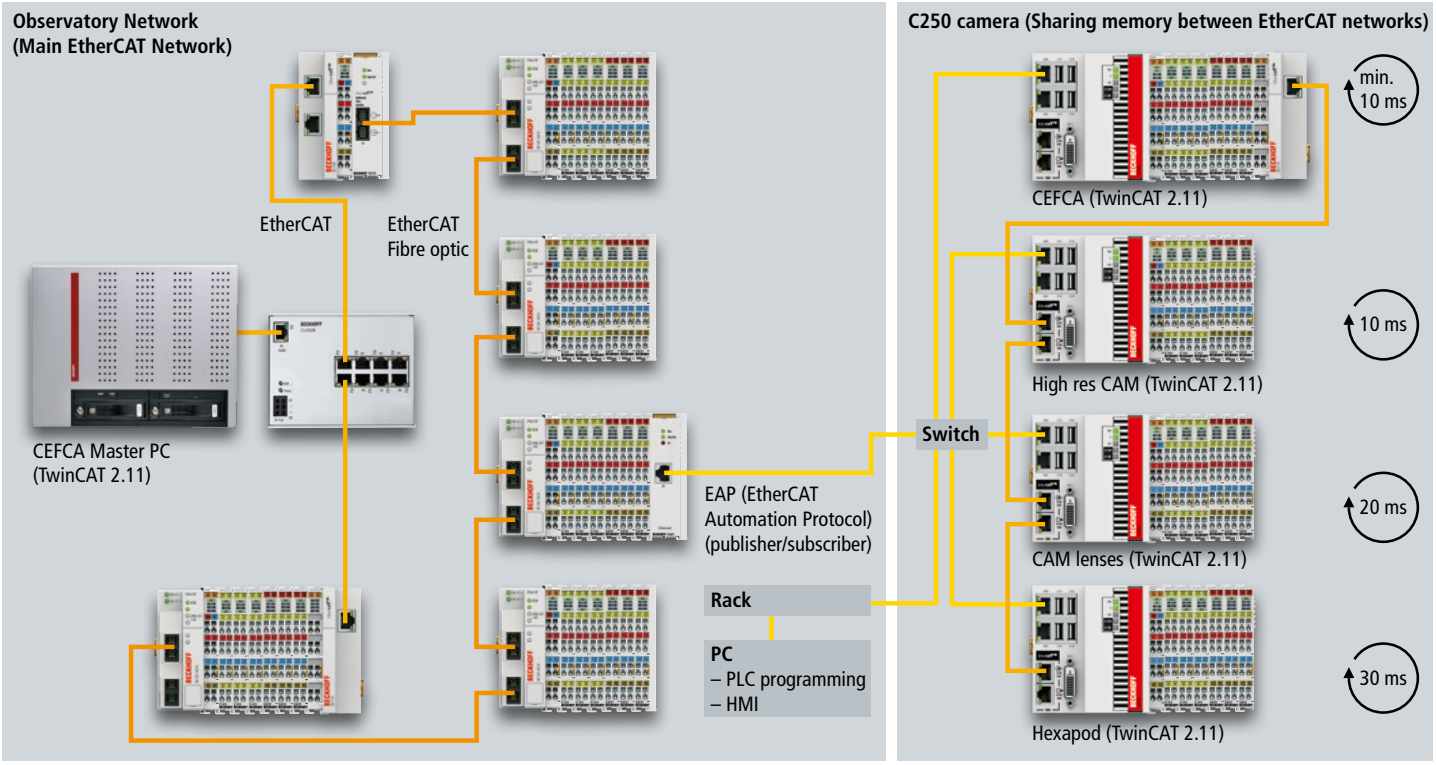
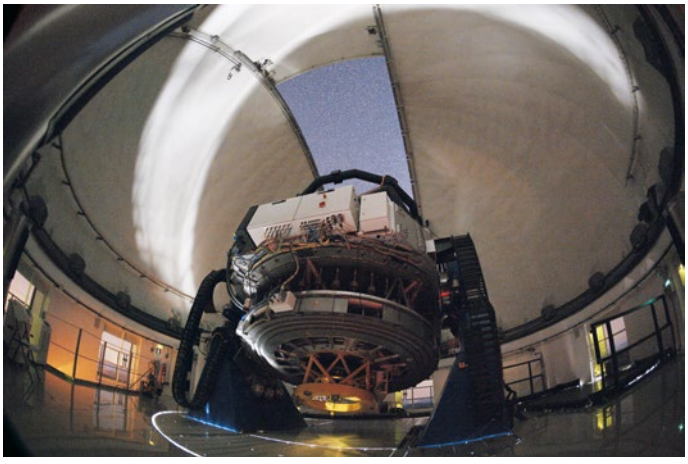


Fig. 2: The control architecture of the observatory network with connection of the camera control over Ethernet. Some subsystems are not shown here, such as the control of the camera cooling water, the aluminizing room for the T250 mirror and the HVAC control for the cleanrooms.

protocol. With this protocol, the PLCs form a bidirectional publisher-subscriber relationship, enabling each PLC to publish a variable (publisher) and subscribe to another (subscriber). These variables must be linked within the safety logic terminal (EL6900), which treats them as safety inputs or outputs. If the EL6900 detects an error, it can publish a warning signal that is received by another CPU within the EtherCAT network, which then places its own system into a safe state.

Extensions already planned

Axel Yanes is already devising plans for the future: "We will put some more interesting devices into operation at the OAJ. We have been able to integrate some functions in the observatory control system that hadn't been planned until now, such as BACnet/IP, condition monitoring and much more. We are very pleased to have Beckhoff as a technology partner. They have fulfilled our requirements with regard to a high-quality, reliable and, at the same time, flexible and easy to maintain system. The global support, which we have made use of for the coordination of the project in a total of 10 countries, was also extremely valuable for us."



The JST/T250 is a telescope with a diameter of 2.55 m and a 3-degree field of view. It will make it possible to record the positions of hundreds of millions of galaxies and their development for the first time, and ultimately to supply the first full 3D map of the universe.

Further information:

http://oajweb.cefca.es/

www.beckhoff.es