Large Size Telescope Report

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Abstract. The Cherenkov Telescope Array (CTA) observatory will be deployed over two sites in the two hemispheres. Both sites will be equipped with four Large Size Telescopes (LSTs), which are crucial to achieve the science goals of CTA in the 20-200 GeV energy range. Each LST is equipped with a primary tessellated mirror dish of 23 m diameter, supported by a structure made mainly of carbon fibre reinforced plastic tubes and aluminum joints. This solution guarantees light weight (around 100 tons), essential for fast repositioning to any position in the sky in <20 seconds. The camera is composed of 1855 photomultiplier tubes and embeds the control, readout and trigger electronics. The detailed design is now complete and production of the first LST, which will serve as a prototype for the remaining seven, is ongoing. The installation of the first LST at the Roque de los Muchachos Observatory on the Canary island of La Palma (Spain) started in July 2016. In this paper we will outline the technical solutions adopted to fulfill the design requirements, present results of element prototyping and describe the installation and operation plans.

INTRODUCTION

The Large Size Telescopes (LSTs) of CTA are designed to cover the energy range from 20 GeV to several TeV. There will be 4 LSTs in CTA-South and CTA-North, each, dominating the performance of the array between 20 GeV and 200 GeV. The LST design targets the low energy threshold and the fast rotation speed in order to a) provide good energy overlap with the currently existing space based instrument of Fermi-LAT; b) open up observable volume with Cherenkov telescopes from currently less than $z=1$ to more than $z=2$ (see Figure 1, left plot); and c) study fast variability and transient phenomena such as flares of galactic and extragalactic sources as well as observing GRBs (see response to transient sources in Figure 1, right plot, based on [1]).

In March 2015, the LST team and the IAC (Canary Islands) signed an agreement to build the first LST (the prototype telescope that should become the first LST once successfully commissioned) at the Observatorio del Roque de los Muchachos. Since La Palma is the prime candidate to become CTA-North site\textsuperscript{1}, it is a very convenient location, meaning that the first LST will be built on its final site.

OVERVIEW OF THE TECHNICAL DESIGN

The reader is referred to the Technical Design Report (TDR) of the LST for a detailed description of the telescope and its component parts [2]. A short description of the main assemblies of LST can be found at [3]. Here we only provide a general overview of the design as illustrated in Figure 2. The LSTs main parameters are summarized in tabular form in Figure 3.

\textsuperscript{1}On 19 September 2016, the Council of the Cherenkov Telescope Array Observatory (CTAO) concluded negotiations with the Instituto de Astrofísica de Canarias (IAC) to host CTAs northern hemisphere array at the Roque de los Muchachos Observatory in La Palma, Spain.
FIGURE 1. The strengths of the LSTs within CTA: increase of the accessible volume in the universe (left plot, the axes are in redshift units centered at the position of the Earth, in blue are the known TeV gamma-ray sources, in red recently discovered ones), and the time domain for transients and rapid variability phenomena (right).

FIGURE 2. The 3D model of the LST.

STATUS OF THE PRODUCTION

The LST prototype is in the production phase. Most elements are produced at companies, some assembly and elements are produced by participating institutes. In the following we give a short status of the production.

Telescope structure

The Lower Structure of the LST is made of steel tubes; the Dish Structure is from carbon fiber reinforced plastic (CFRP), steel and aluminium tubes. The Lower Structure and the Dish are being produced by the company MERO-TSK. The delivery is planned for Autumn 2016 in La Palma.

The Lower Structure of the LST rests on six Bogies equally spaced in a hexagonal arrangement, running on a circular Rail. Two of those Bogies are located under the Elevation Bearings, withstanding the higher percentage of the

http://www.mero.de/index.php/en/
FIGURE 3. The relevant technical parameters of the LST.

FIGURE 4. Some produced parts of the LST structure. Left: Rail segment. Middle: one of the six Bogies. Right: part of the Camera Support Structure.

Telescopes weight. The Bogies run on a circular flat Rail of 23.9 m diameter and 500 mm width, which is fixed to the Foundation through the pedestals. One can see a segment of the Rail produced by MBM Company in Germany[^3] in Figure 4, left picture. The six Bogies (see one of them in Figure 4, middle picture) are produced in the LST member institutes, namely by CIAMAT and IFAE (Spain), INFN Padova (Italy), University of Hamburg and MPI for physics (Germany). IFAE in Barcelona coordinates the production and is responsible for the Bogie assembly on site.

The baseline design of the Camera Support Structure is based on an almost parabolic arch geometry, reinforced along its orthogonal projection by two symmetric sets of stabilizing fixed headstays. Most of its elements make use

[^3]: [http://www.maschinenbau-muehldorf.de/en.html](http://www.maschinenbau-muehldorf.de/en.html)
of CFRP, which is well known to provide a very high performance to mass ratio. The procurement is shared between LAPP in France and INFN in Italy. See a segment (1 out of 6) of CSS in Figure 4, right picture.

**Optical system**

![Image of mirror and AMC system of LST](image)

**FIGURE 5.** Mirror and AMC system of LST. Left: Picture of a mirror. Middle: Measured radii from 60 mirrors delivered to ICRR from two different molds. Right: AMC performance to align a mirror from a random position to within the required green circle.

The Optical System of the LST is an active optics system that includes a large parabolic reflector equipped with an Active Mirror Control system (find more details in [4]) and a flat focal surface. The optical reflector is composed of 198 hexagonal mirrors each with an area of 2m². The Mirrors are manufactured using the cold slump technique with a sandwich structure consisting of a soda-lime glass sheet, an aluminum honeycomb box and another glass sheet. The mirror box is made of stainless-steel. The production of mirrors is ongoing in Japan by a company Sanko, 60 are already produced, and 400 more will be produced in the next 12 months. One can see one of them in Figure 5, left plot. The middle panel shows the measured mirrors radii made in two different moulds (marked with different colors, accordingly). Due to the parabolic dish shape of LST we require three different moulds for the mirror production.

The mirrors are attached to the Dish of the LST structure using two actuators and a fixed point. The actuators have accurate step motors (5 µm step size), which are controlled by the Active Mirror Control (AMC) program to achieve the required optical performance at any moment of time. Each mirror facet has a small CMOS camera attached that observes a fixed-point (generated by a laser) on the Camera plane, and the position of the fixed-point is used as a reference to correct any misalignment of the mirrors. The actuators are produced by the University of Zurich. In Figure 5, right plot, one can see the accuracy of actual alignment of a single mirrors using a reference spot and a CMOS camera.

**Camera**

The Camera of the LST shares many elements with the NectarCam [5] proposed for use in the cameras on the Medium Size Telescopes of CTA. With a weight of less than 2 tonnes the camera is comprised of 265 PMT modules that are easy to access and maintain. Each module has 7 channels, providing the camera with a total of 1855 channels. Hamamatsu photomultiplier tubes (PMTs) with a peak quantum efficiency of 42% (R11920-100) are used as photosensors converting the light to electrical signals that can be processed by dedicated electronics. Each module incorporates a slow control board to steer and monitor the PMTs, a trigger electronics (2 level) mounted on a mezzanine, a readout using DRS4 chips as well as an analog backplane for trigger and clock propagation. A Mini-Camera with 19 modules is setup at ICRR, Japan to test and characterize all modules functionalities. The schematic view of the Mini-Camera is shown on Figure 6, a picture of the assembled Mini-Camera is shown in the central panel. The Mini-Camera tests were successful and the production and quality control of the modules continues and should be finished by February 2017.

The camera mechanical structure is being produced at CIEMAT, Spain. The tubular structure is ready (see Figure 6, right panel), and until end of 2016 all mechanical parts are expected to be finished and tested. Then the camera
mechanics and the modules will be shipped to IFAE in Barcelona for final integration and testing campaign before shipping the camera to La Palma.

**Auxiliary Systems**

The Auxiliary Systems refer to all instruments and devices on the LST excluding the Camera. The main functions of these devices include driving the telescope, correcting the telescope pointing or focus and calibrating the Camera. The devices used for Structure Condition Monitoring as well as Lightning Protection are also considered to be Auxiliary Systems.

The fast and precise movement of the LST is achieved by using electric servomotors on both the elevation and azimuth axis. Four synchronized motors are used for the azimuth axis and two for the elevation one. Synchronization of the motors is managed directly by the Drive controller. The procurement of the drive motors and electronics is about to start.

The central facet position of the LSTs mirror is kept vacant to accommodate several devices. These include: a) a Calibration Light Source box used to calibrate the gain of the cameras photosensors; two boxes are designed by Indian and Italian groups and will be tested and compared until end of 2016; b) an Optical Axis Reference Laser used by the AMC to define the optical axis of the telescope (already purchased by MPI, Munich); c) an Inclinometer used to measure the pointing elevation (already purchased by MPI, Munich); d) a star guider camera to relate the pointing of the telescope with respect to the sky field (purchased and tested by the Swedish group); e) a Camera Displacement Monitor used to monitor any sagging of the Camera (designed and already partly purchased by a Croatian group); and f) Distance Meters used to measure any displacement or rotation of the Camera along the optical axis with respect to the Dish centre (already procured). This relatively sophisticated pointing setup is necessary to meet the strict requirements defined for the LSTs pointing (1 arcsec, post-calibration) and lightweight structure.

**STATUS ON SITE AND PLANS**

The prototype LST is being built in La Palma. Necessary permissions to start LST constructions in La Palma were obtained by May 2016 and the foundation works started in July 2016. One can see detailed foundation and assembly area drawings in Figure 7. The first LST will be positioned close to the existing MAGIC telescopes [6], which allows one to cross-calibrate the new instrument with the existing ones.

The current planning foresees end of the foundation works by October 2016. The Rail and the Bogies will be assembled then. After that, the Lower Structure will be assembled on top of the Bogies. In parallel to the Lower Structure Assembly, the Dish Structure will be erected next to that. Once ready (estimated time is 6 weeks), the Dish will be united with the lower structure. Then the back part of the arch can be then mounted, safety access prepared and motors connected and cabled. The telescope will be then moved to a parking position for easy access to the dish and mirrors as well as the AMC system mounted. This should take about 1.5 months. After that the Telescope will be placed in vertical position\(^4\) and CSS (previously assembled on site) mounted on the dish. In the meanwhile the camera

\(^4\)mirrors will be covered during CSS assembly
access tower must be ready. Then the telescope will be brought back to the parking position and the camera will be
inserted from the camera access tower. We plan to finish the installation by Summer 2017 and have the first light in
October 2017.

The LST2-4 will be built in the CTA-North. The funding for them is basically secured, mainly through the
Japanese and Spanish funding agencies with smaller contributions from France, Italy, Germany, India, Brazil, Swe-
den, and Croatia. The three telescopes can be built on La Palma in 2017-2019. The procurement for CTA-South
telescopes is expected to start in 2018. It can go in parallel with the CTA-North telescopes.

CONCLUSION

The LST project as a part of CTA Consortium is progressing very well and construction of the first LST is ongoing.
The civil works for LST-1 started in La Palma in July 2016. All telescope parts have been designed and are now
in production and verification phases. The construction of the first LST is expected to be finished by Summer 2017
and the construction of the LST2-4 in La Palma by 2019. The 4 LSTs for CTA-South can be built and installed in
2018-2021, according to the CTA plans.

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http://www.cta-observatory.org/.

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