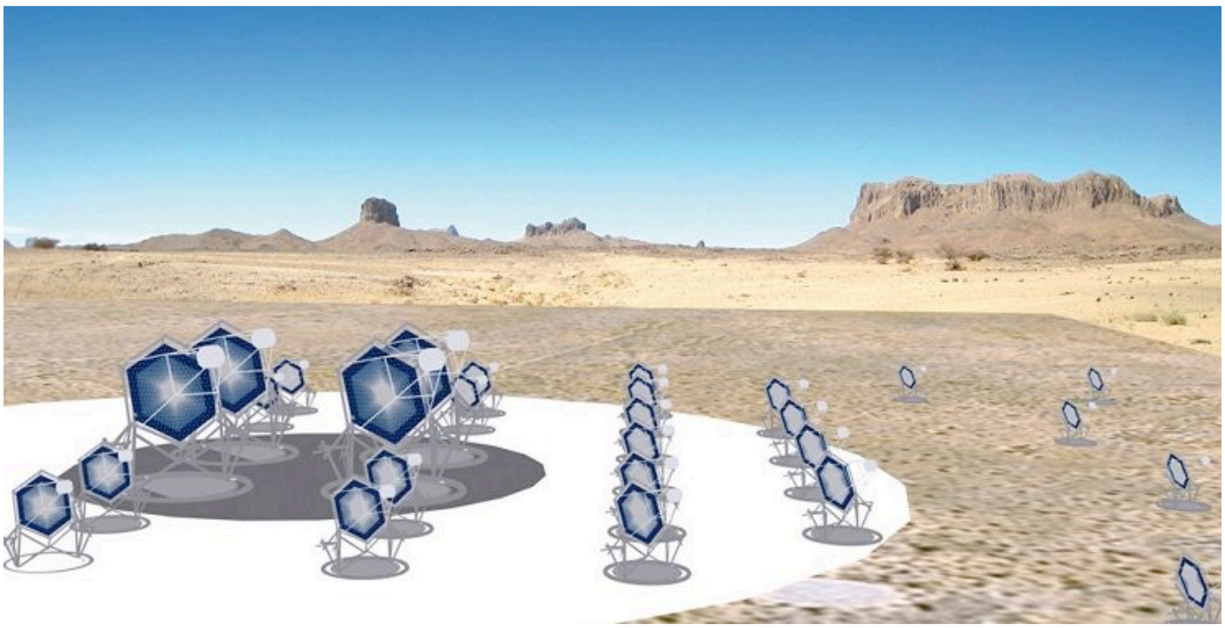
# Specifications for the mirror facets for the Medium Size Telescope of the CTA observatory project



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## Change log

ACTION

First release and distribution

## List of acronyms

| | |
|---|---|
| CTA | Cherenkov Telescope Array |
| INAF | Istituto Nazionale di AstroFisica |
| LST | Large Size Telescope |
| MST | Medium Size Telescope |
| OAB | Osservatorio Astronomico di Brera |
| SST | Small Size Telescope |
| TBC | To Be Confirmed |
| TBD | To Be Defined |

# 1. Scientific introduction

The Cherenkov Telescope Array is a scientific project studied by a worldwide collaboration. CTA is composed by an elevated number of Cherenkov telescopes of different sizes and working together in a stereoscopic configuration. This working mode will enhance significantly the performances of the observatory with respect to the single instruments and the present days experiments (H.E.S.S., MAGIC I and II, VERITAS, CANGAROO).

The Cherenkov telescopes are used to image light traces generated by cosmic-ray particles in the atmosphere onto an array of photon detectors. The light traces are similar to trails left by shooting stars. The light collected by the telescope covers a wavelength range from 300 nm to 600 nm with the highest intensity being around 400 nm.

At the present stage of the design, CTA is composed by three different classes of Cherenkov telescopes namely the Large Size Telescope (LST), the Medium Size Telescope (MST) and the Small Size Telescope (SST) for a total number of about 80 units.

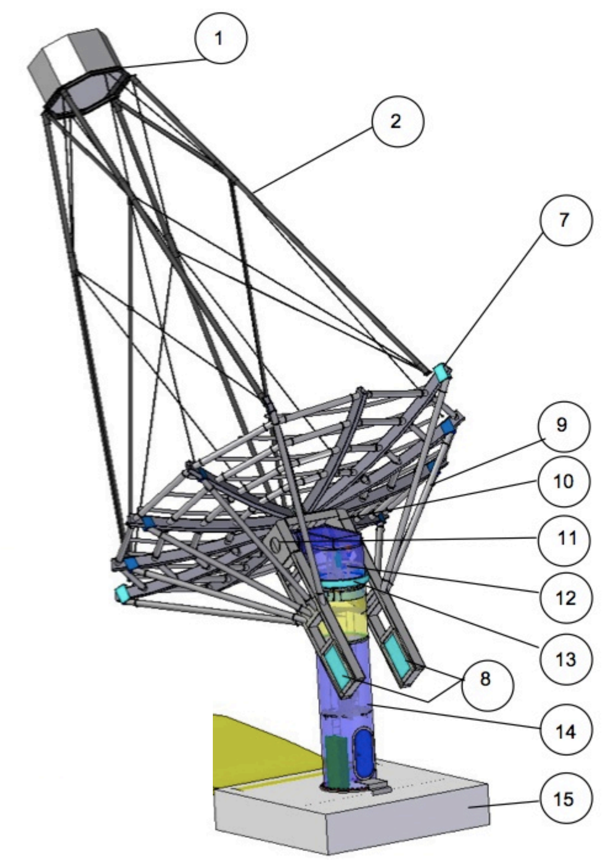


*Figure 1: Schematic drawing of the MST.*

In particular, the MST is a 12 m aperture Cherenkov telescope (see Figure 1) that adopts the classical Davies-Cotton optical layout. This optical layout consists of a number of <u>identical</u> mirror facets having a spherical profile. The mirrors are placed on a mechanical structure, called dish, having a radius of curvature equal to the focal length of the mirrors. In the case of MST the focal length of the telescope will be of 16 meters and the dish will be filled with about 90 mirror facets of hexagonal shape to cover a total area of 110 $m^2$.

This provides sufficiently good imaging, since requirements on the optical quality of the images are reduced compared to astronomical optical telescopes.

The topics treated in this document refer to the mirrors for the CTA project with particular respect to the mechanical characteristics of the mirror facets that will equip the MST.

## Technical introduction

The specifications for the mirror facets are given below. The mirrors will be measured individually and mirrors failing specifications will be rejected. In case certain specifications are exceedingly difficult to meet and result in significantly higher costs, it may be possible to relax some specifications slightly; where and to which extent this is possible needs to be negotiated individually.
The facets construction will be the cold glass slumping approach, developed and consolidated in the past years in the context of the collaboration between Media Lario Technologies and INAF with particular respect to the MAGIC 2 mirrors production. The mirrors have to be coated with an Aluminum reflective layer and with a protective surface treatment of Quartz optimized to get a maximum efficiency in the blue part of the visible spectrum.
Apart from the interfacing pads (see details in the following), INAF will offer to the supplier the possibility to use one master for the replica of the mirrors. The master shows the following characteristics:

- radius of curvature 32.0 +/- 0.1 m, TBC;
- P/V profile error better than 40 mm, TBC;
- RMS profile error better than 10 mm, TBC.

The equipment provided by INAF will remain property of INAF and it will be returned back to INAF after the delivery of the mirrors.
A total of 25 mirrors are required. The nominal curvature radius of the 25 panels to be produced is 32 m. To be accepted, the encircled energy on the focal spot at a level of 80% at the nominal focal length of each single panel has to be better or equal to 1 mrad.

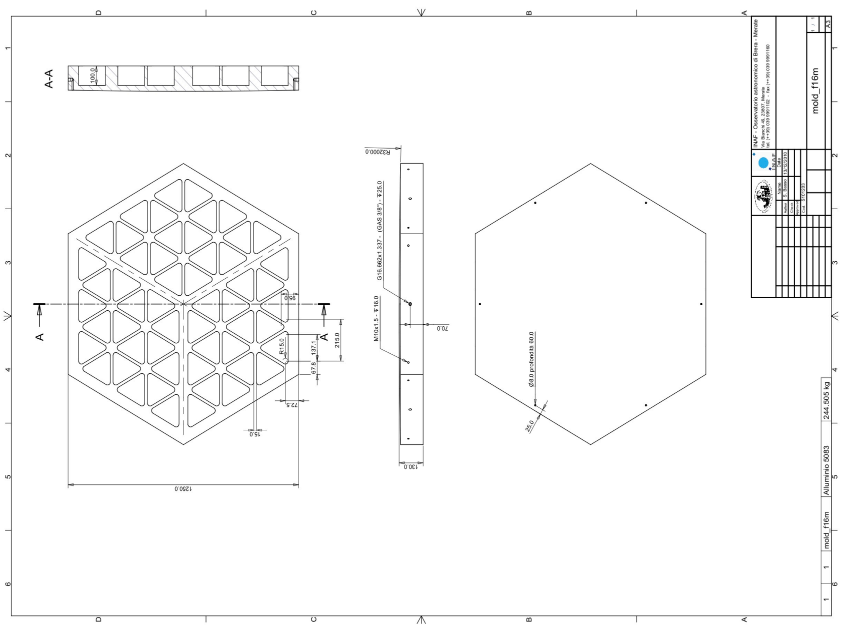

*Figure 2: Mould design.*

### Mechanical characteristics

**Geometrical shape:** regular hexagon 1.2 m width (face-to-face dimension) in agreement with Figure 3. In case, it is acceptable the cut of two corners to meet the needs of the coating facility. Possibly, will be anyway required the cut of one corner to allocate the laser holder, TBC.

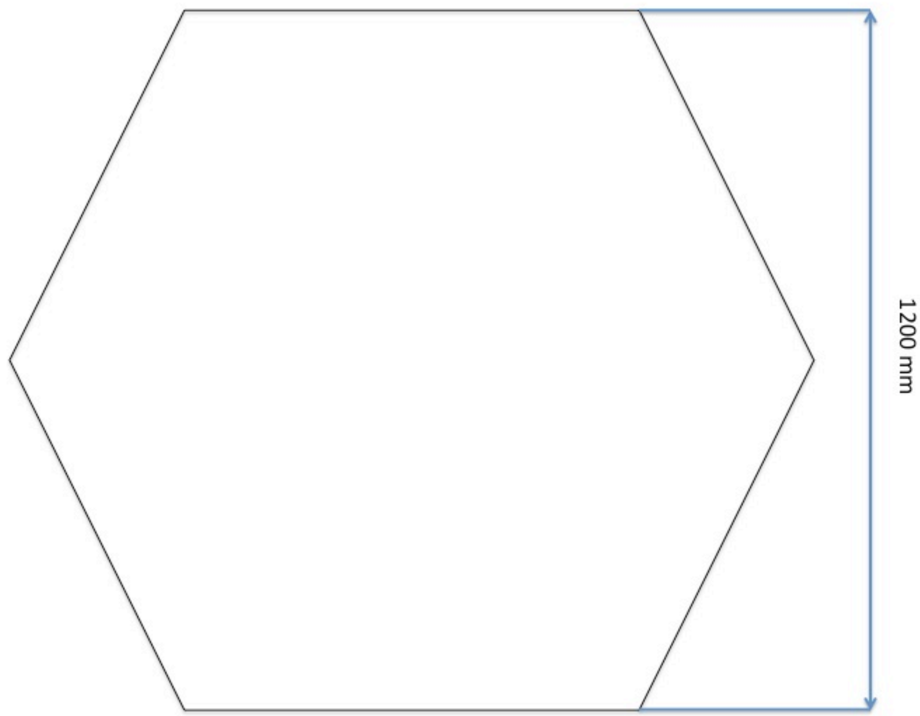


*Figure 3: mirror facet geometrical shape.*

**Front surface:** the front surface of the mirror shall have a concave spherical profile with 32.0 +0.15/-0.0 meters radius of curvature.

**Rear surface:** the rear surface should provide the proper interface to the actuators or to the attaching points of the telescope. The interface consists of three steel pads to be provided by INAF-OAB. The pads have to be fixed to the rear using a flexible silicone layer. The position of the pads will be communicated to the supplier later on and anyway before any production activity.

Moreover, the rear of the panel should be coated with a white reflecting film (e.g. a paint or a permanent adhesive foil, white colored and water-proof) in order to avoid problems of thermal excess due to sunlight exposition during the daytime.

**Thickness:** The thickness of the mirrors is not specified explicitly. The mirrors shall fulfill the requirements on optical quality, mechanical stability, mirror deformation, etc. while meeting the weight restrictions.

**Weight:** equal or less than 15 kg

**Mirror deformation**: The orientation of the telescope and therefore the mirrors changes between horizontal and vertical. The mirror deformation under gravity must be small enough to maintain the specifications for the reflectivity and for the resolution for all orientations. During daytime, mirrors face downwards, with the mirror surfaces having angles up to 90° to the vertical (depending on the facet position).

## 2. Operation conditions

**Temperature range**: -10°C to +60°C. Temperature variations of 20°C between daytime and nighttime are not uncommon. The mirrors shall not suffer any damage or irreversible change of optical properties from temperature variations within this range.

**Operating temperature range**: -5°C to 25°C. The optical specifications shall be maintained within this range.

**Wind range:** 0 km/h to 180 km/h. The mirrors shall not suffer any damage or irreversible change of optical properties from winds within this range.

**Operating wind range:** 0 km/h to 50 km/h. The optical specifications shall be maintained within this range.

**Optical properties**

**Surface roughness:** The surface roughness is not specified directly but it is constrained by the requirements on reflectivity (for short-scale roughness) and resolution (for long-scale roughness).

**Reflectivity**: The effective reflectivity (as defined below) shall exceed 80% for wavelengths in the range from 300 nm to 600 nm, ideally close to 90%. The range of short wavelengths (300 nm to 450 nm) contains most intensity of the light observed in the experiment and in case the optimization of coatings prefers certain wavelength regions, reflectivity should be optimized for this range. The required minimum of 80% of the incident light to be reflected shall be contained within a circle of 1 mrad diameter. Facets with worse performance will be rejected.

**Resolution:** Obtaining an image of a point source fully illuminating the mirror at twice the focal distance the diameter containing the 80% of the reflected light is estimated. This value must not exceed 1 mrad. Facets with worse performance will be rejected.

**Diffuse reflection:** A diffuse reflected component is uncritical as long as it is spread out over a large solid angle. A diffuse component of 10% of the incident light concentrated over an area of 1 degree diameter, on the other hand, would add a halo to images and would deteriorate the performance of the instrument. Limits on a diffuse component depend on the angular distribution of the diffuse reflection and need to be addressed individually for manufacturing techniques which result in significant amounts of diffuse reflected light.

**Scratches, digs, and surface imperfections**: Scratches and surface imperfections are uncritical to the extent that they do not (a) reduce the reflectivity and the resolution below specifications, (b) do not generate a significant diffuse component of reflected light and (c) do not impact the long-term stability of the mirrors, for example, by acting as a starting point for corrosion processes. Nevertheless, there shall be no scratches wider than 2 mm, and the summed length of scratches and digs between 0.3 mm and 2 mm shall not exceed 30 cm. No stains or discolorations are allowed which are readily visible to the unaided eye.

# 3. Environmental durability characteristics

**Long-term stability:** The mirrors will be used only for testing activities on a prototype telescope of the MST class. Nevertheless, these mirrors will serve as benchmark for the technology of the mirrors to be used within CTA. For this reason it is highly recommended that the mirrors are capable to last for a period of at least 10 years (and possibly beyond). The mirror material shall not exhibit flow or relaxation processes that change the resolution significantly (i.e. beyond specifications) over this time. Most critical is the long-term stability of the reflectivity under the given environmental conditions. We aim for a reflectivity loss of not more than 3% per year, in line with results obtained with earlier instruments under similar conditions. The given mirror and coating production technique shall have demonstrated long-term durability proven in field tests or field usage, or equivalent applications or tests.

**Adhesion of coating**: The coating shall show no damage under usual adhesion tests, where a 3M Scotch Brand No. 600 tape (or equivalent) is pressed firmly against the front mirror surface (the coated surface) and removed quickly.

**Abrasion**: The coating shall not show damage under moderate abrasion tests, after a standard 200-rub test with a cheesecloth pad. The bearing force shall be nominally one pound.

**Accelerated aging**: Short-term tests of durability include humidity and temperature cycling and a salt fog test. The coating and the optical characteristics shall show no deterioration after exposure to a 10-day humidity test where humidity is cycled between 0% and 100% and temperature between 0°C and 50°C. The coating and optical characteristics shall show no deterioration after exposure to a standard 24 hour salt fog test.

**Mechanical impact:** The mirrors may occasionally be subject to mechanical impact, such as birds flying into the mirrors, birds picking on the mirrors, or possibly hail. Mechanical impact is simulated by dropping a steel sphere with a diameter of 10 mm from a height of 3 m onto the mirror. Under the impact the mirror shall not shatter, develop cracks, or change its global optical properties as specified above. Local loss of reflectivity or deformation over an area not significantly exceeding the size of the sphere is acceptable.

# 4. Logistic

**Delivery:** the full set of 25 mirrors shall be ready for shipping to the site before the end of August 2011.

**Packaging:** the supplier shall provide a stable packaging for the mirrors. The standard packaging would be wooden boxes for single mirrors with additional protective material inside. Larger boxes for several mirrors may be acceptable upon request if handling of mirrors and boxes is manageable.

**Transport:** TBD.

**Payment terms:**
50% at the kick-off meeting, TBC
50% upon delivery ex-works of the full set of 25 mirror facets, TBC

**Project management:** The management of the project and the acceptance tests for INAF-OAB will be performed by:
Prof. Giovanni Pareschi – INAF-OAB