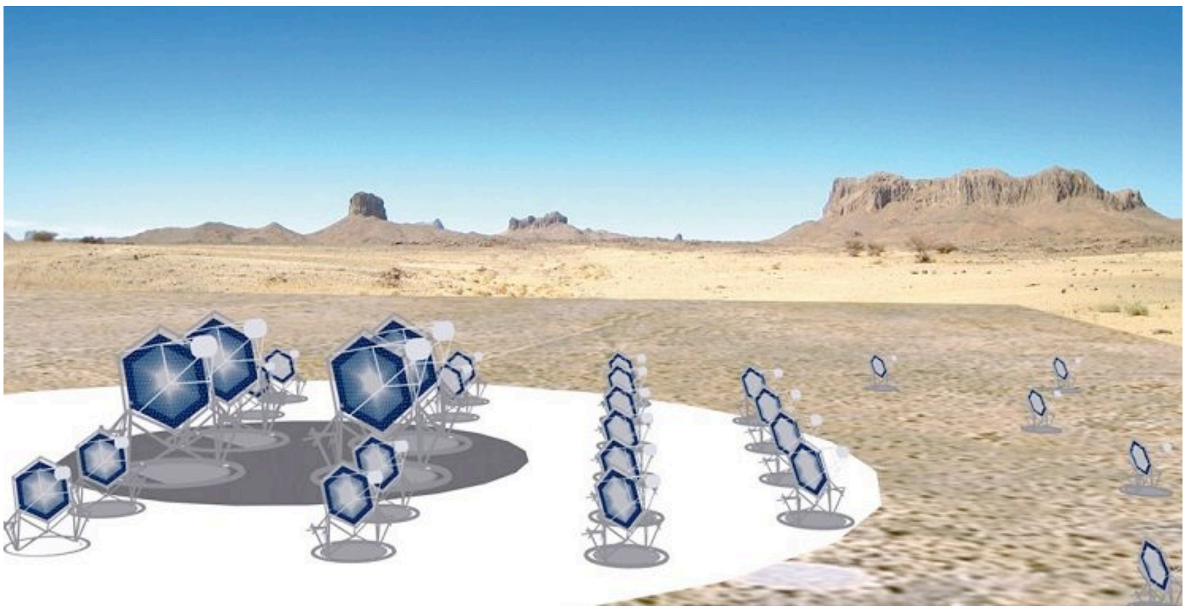
Statement of the Work for the engineering designs of mechanical subsystems for a dual-mirror Cherenkov telescope prototype for the ASTRI project:

the Small Size Telescope of the CTA observatory



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LIST OF ACRONYMS

ASTRI	Astrofisica con Specchi a Tecnologia Replicante Italiana
CTA	Cherenkov Telescope Array
DC	Davies-Cotton
INAF	Istituto Nazionale di AstroFisica
LST	Large Size Telescope
MAPMT	Multi Anode Photon Multiplier Tube
MST	Medium Size Telescope
OAB	Osservatorio Astronomico di Brera
OAPd	Osservatorio Astronomico di Padova
PMT	Photon Multiplier Tube
SC	Schwarzschild-Couder
SiPM	Silicon Photon Multiplier
SOW	Statement Of the Work
SST	Small Size Telescope
TBC	To Be Confirmed
TBD	To Be Defined
TR	Technical Report

APPLICABLE DOCUMENTS

[AD1] The CTA Consortium, *“Design Concepts for the Cherenkov Telescope Array”*, May 2010, http://arxiv.org/abs/1008.3703

REFERENCE DOCUMENTS

[RD1]

Change log

ACTION	
First release and distribution	31 May 2011

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.

In particular, the SST array is devoted to the observations of the very high-energy domain. Multi-TeV events (up to few hundreds of TeV) are very rare, but when they occur then produce an abundant amount of secondary particles emitting Cherenkov light in a very broad light-pool. From these considerations pop up easily the basic requirements for the SST array: it should be composed by an elevated number of relatively small telescopes:

- "small telescopes" since the amount of light generated during these events is much and easy to collect against the night-sky background;
- "elevated number", where "elevated" means as much as affordable within the cost envelop of the project, is required to better define the angular position of those events.

The implementation of this kind of array is at the present stage still debated and controversial. There are two main philosophies under investigation:

to use a number of classical Davies-Cotton (SST-DC) layout 7 meters aperture telescopes equipped with single PMTs cameras;

to use innovative Schwarzschild-Couder (SST-SC) layout 4 meters aperture telescopes equipped with multi-anode PMTs (MAPMTs) or Silicon PM (SiPM) cameras.

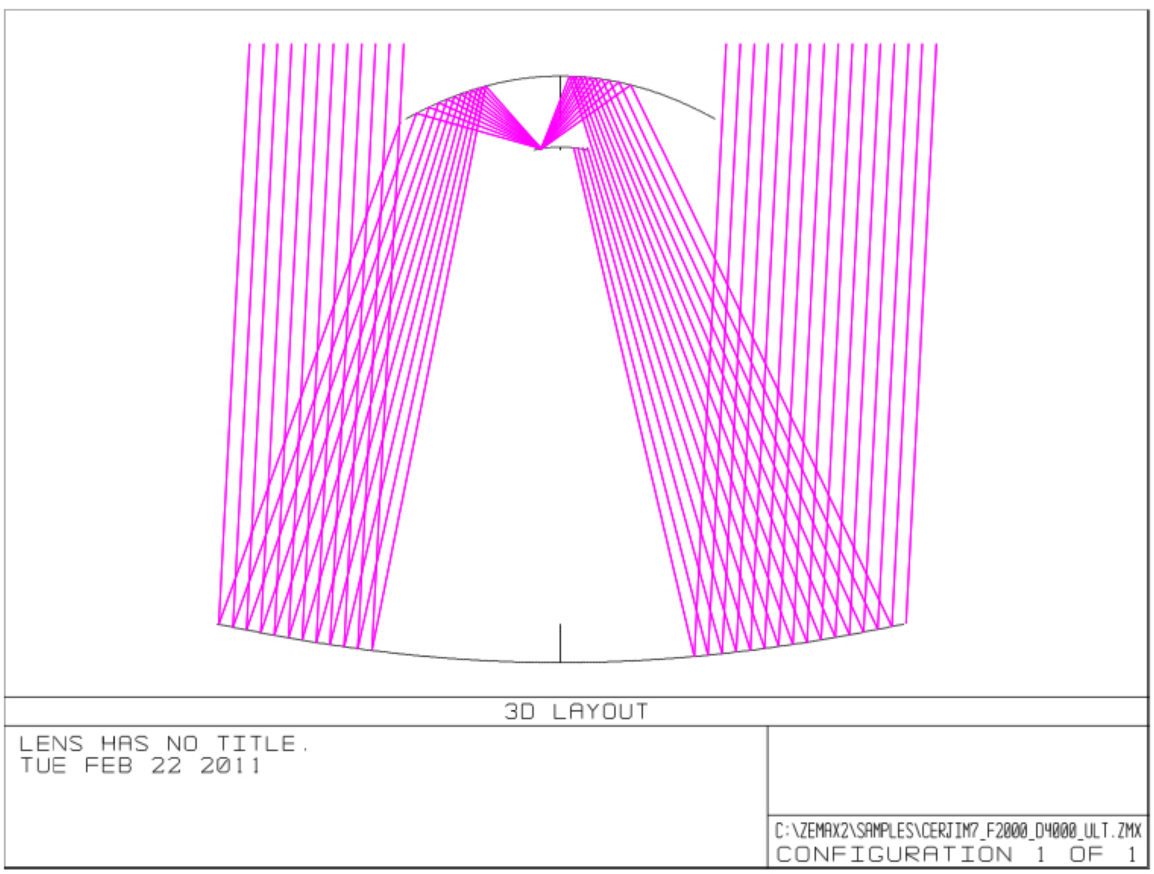
While the first approach relies on about twenty years of experience and knowledge by the scientific community, it could pose severe limitations on the performances achievable by the telescopes. First of all, the maximum number of units implementable is most probably cost-limited by the single-PMTs cameras. Moreover, those cameras are very large and heavyweight, and needs to be positioned several meters away from the mirror surface in order to achieve the desired optical performances over the large field angle.

On the other hand, with the second approach the cameras become very compact and lightweight, and possibly much cheaper. This is at the expense of a more complicated mechanical structure because of the double reflection of the Schwarzschild-Couder optical layout; more complex mirrors profiles since they are strongly curved and aspherical. A dedicated effort in technological developments needs to be addressed in order to implement such an innovative instrument.

The topics treated in this document refer to the SST of the CTA project with particular respect to its mechanical structure implementation.

1.1 The Schwarzschild-Couder layout

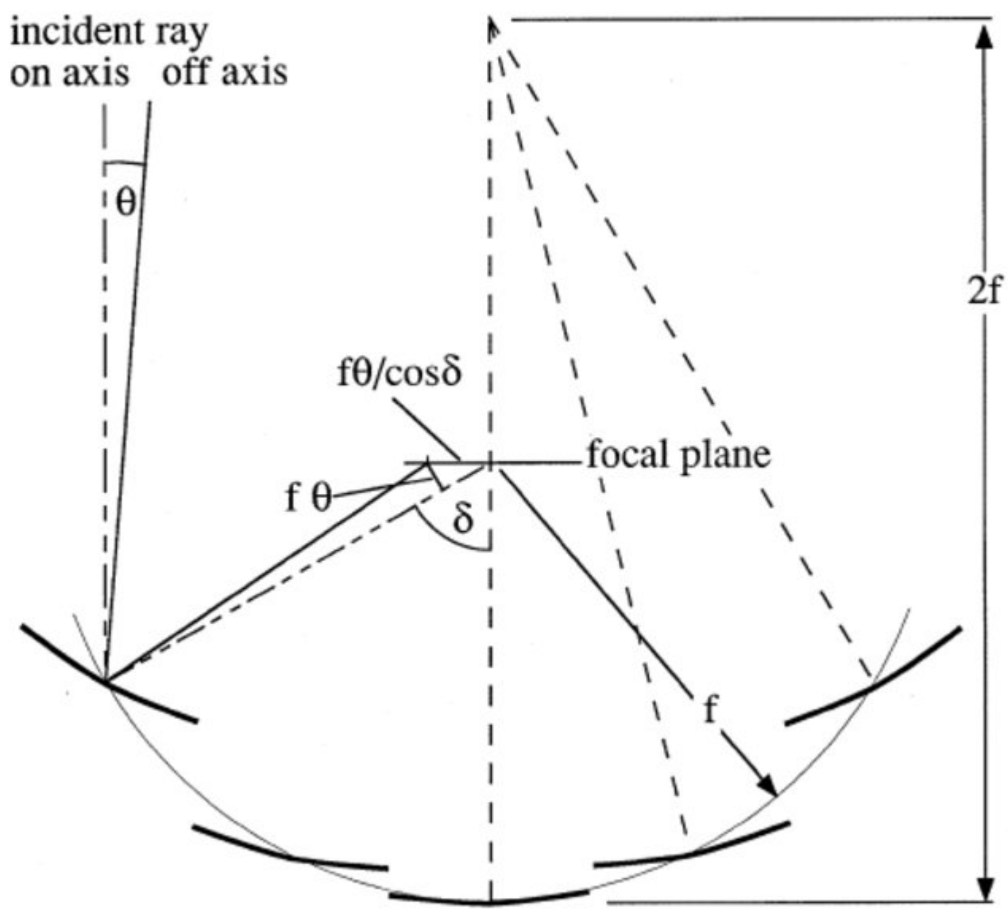
The SC layout is a de-magnifying aplanatic two-mirror design that allows shrinking the telescope PSF down to few millimeters. This opens the possibility to use novel detectors such as MAPMTs or SiPM. A picture showing the geometry of a SC system can be found below: both the surfaces of the primary and secondary mirrors are concave, while the focal plane is trapped with them.



1.2 The Davies-Cotton layout

Typical use in Cherenkov telescopes is the so called Davies-Cotton optical layout, derived from solar concentrator applications. All the mirror facets have a spherical profile with a focal length f, identical to that of the telescope as a whole. The facets are supported by a mechanical structure called “dish”, with a spherical profile and radius of curvature f. A picture describing this layout can be found here below.

In the following sections are reported a set of reference design specifications specifically tailored for the DC option. The design is derived from the outcomes of the CTA Design Study phase. In particular, it is driven by the “hardware sharing philosophy” adopted so far.



2. Statement of the Work

In the contest of the CTA worldwide project, INAF is carrying on a parallel project called ASTRI. ASTRI is a technological program funded by the Ministry of Education, University and Research aiming at developing breadboards, prototypes and proof of concepts by performing specific studies, designs and prototypes relative to CTA components. All the outcomes (breadboards, prototypes and proof of concepts) generated within ASTRI shall be compliant with the CTA scientific and technical requirements.

In this respect, INAF intends to reserve a particular care to the investigation of all the SST sub-systems (such as telescope structure and mechanics, mirrors, focal plane instrumentations, software). The type of the activities requested and the depth of their investigation should both bring the project up to an executive level, within a well defined timeframe.

The activities requested in the present SOW are, hence, engineering designs and studies of the mechanisms of the SST in the Schwarzschild-Couder (SST-SC) and Davies-Cotton (SST-DC) configuration presented in the previous section. INAF requires to developt the solutions:

- SST-SC at the executive level;
- SST-DC at the general design level, but taking as reference the solutions of the Schwarzschild-Couder Telescope, unless the performances will require different solutions.

The Company identified by INAF shall conduct the activities listed in the following sub-section plus those ones not explicitly listed here below but fundamental for the good development of the project.

<u>The Company shall work adopting a results-sharing philosophy and in synergy with INAF personnel. Moreover, the same approach is also requested respect to other Companies involved by INAF in the project, with particular respect to those involved in the design of the main mechanical structure that will guide the overall design.</u>

2.1 Main mechanical design activities

The telescopes mechanics have to be completely designed. All the components shall be drawn at level of constructive design review. Mandatory components to be studied are mechanisms, drive and electrical and safety systems, controls, actuators. Other parts not explicitly mentioned here but essential for the design must be considered.

The mechanical designs shall be conducted in close collaboration and under the indications of the Company(ies), selected by INAF, taking care of the overall structural design.

At least the following items shall be faced during the activities with a depth compliant to the requested designing level concerning the SST-SC configuration and at the level of general design for the SST-DC configuration:

1. design of the mechanisms for the two principal movements requested to the telescope, i.e. the azimuth and the elevation;
2. design, calculation and tests of the engines and position-measuring devices used for the telescope pointing/tracking, evaluation of the power consumption including peaks;
3. design of the safety systems in case of motor failures and/or power cuts (Dampers and stow pins of the two axes, Emergency manual driving systems.);
4. design of the whole telescope assembling/disassembling procedures and related safety aspects;
5. design and tests of the actuators and position-measuring devices for the mirrors alignment and their interface with the mirror supports.
6. Design and study of solutions to minimize operations during mounting/dismounting of mirror panels and their actuators.
7. Support and control systems of the secondary mirror of the telescope.
8. Detail design and manufacturing of a prototype of the support and control systems of one segment of the primary mirror of SST-SC. Furthermore, the related test bench for the simulation of the operational conditions, the dummy, the handling device for integration and substitution, and the testing procedure are to be developed. The segment prototype including the control system shall be also tests at the minimum operational temperature. This item will have the same dimensions of the segments of the SST-DC, all the developments and the results shall be shared/shareable with the single mirror solution.
9. General Design of the mechanism of the two axis of the Davies-Cotton telescope taking as reference the solutions of the Schwarzschild-Couder Telescope, unless the performances will require different solutions.

The design of the critical mechanical components shall also be supported by analyses made by Finite Element approach in order to demonstrate the compliance of the systems under the strong survival conditions requested by the project.

INAF does not require any optical post-processing analysis to the Company, but it requires supplying the data relevant to the deformed shape of the structures and mirrors at least under operative loads in order to be able to check the compliance of the designs with the specifications of the CTA project.

In addition, the activities should also include the production of reliable cost and manufacturing time estimates for the entire telescope systems (mirrors, focal plane instruments and software excluded).

Concluding, main purpose of the activities is to support the telescope structural design providing all the needed information, cooperation, ideas and help in order to achieve a complete design of the SST-SC option and general design for the SST-DC, respecting the requirements given by INAF. In performing the design activities the Contractor should also look for a reduction of costs (used materials and manufacturing processes), on-site assembling complexity and shipping. All the activities shall be considered complementary to other contractual activities specifically devoted to the structural design.

3. Main system parameters and specifications

In the following is listed a set of parameters to be used as general reference numbers. Some of the parameters value shall not to be considered as definitive, they will be confirmed before the beginning of the contractual activities or anyway at any time when needed by the different design steps. Hence, the values are here presented with the only intent to introduce the project problematics and the reference framework.

3.1 Schwarzschild-Couder layout

Telescope aperture (M1): 4.3 m

Secondary mirror aperture (M2): 1.8 m

M1/M2 separation: 3 m

Telescope equivalent focal length: 2.2 m

Focal plane instrument mass: 100 kg

Focal plane instrument size (CAM): 0.4 m

M2/CAM separation: 0.5 m

First eigenfrequency: >2.5 Hz

Azimuth movement range: ±270°

Elevation movement range: -5°÷95°

Azimuth/elevation speed/acceleration: capability to reach any point of the sky, within the allowed movement range requested, in less than 1 (one) minute.

Pointing accuracy: <10 arcsec. The pointing accuracy requested could be reached also with off-line correction methods. On the contrary, it is more important to have a good knowledge of the telescope position.

Tracking accuracy: <6 arcmin. A precise tracking is not requested to this kind of instruments.

Allowed deformations: <1 mrad. The deformations introduced on the telescope by the different loads shall not contribute more than the mentioned value to the optical properties of the design.

Expected lifetime: 30 years. This is referred to the complete telescope system (excluding mirrors, actuators and focal plane instruments)

Telescope target cost: 100 k€. This is referred to a series production of about 60 units to be completed in about 5 years (excluding mirrors, actuators and focal plane instruments).

3.2 Davies-Cotton layout

Telescope aperture: 7 m

Telescope focal length: 11.2 m

Focal plane instrument mass: 1.6 t

Focal plane instrument size: 1.6 m

First eigenfrequency: >2.5 Hz

Azimuth movement range: ±270°

Elevation movement range: -5°÷95°

Azimuth/elevation speed/acceleration: capability to reach any point of the sky, within the allowed movement range requested, in less than 1 (one) minute.

Pointing accuracy: <10 arcsec. The pointing accuracy requested could be reached also with off-line correction methods. On the contrary, it is more important to have a good knowledge of the telescope position.

Tracking accuracy: <6 arcmin. A precise tracking is not requested to this kind of instruments.

Allowed deformations: <1 mrad. The deformations introduced on the telescope by the different loads shall not contribute more than the mentioned value to the optical properties of the design.

Expected lifetime: 30 years. This is referred to the complete telescope system (excluding mirrors, actuators and focal plane instruments)

Telescope target cost: 200 k€. This is referred to a series production of about 30 units to be completed in about 5 years (excluding mirrors, actuators and focal plane instruments).

3.3 Operative conditions

In this situation the telescope as a whole shall guarantee the full set of requested performances, including optical stability.

Temperature range: 0°C to +30°C. Variations of 20°C between daytime and nighttime are not uncommon. The telescope shall guarantee all the requested performances, including optical stability.

Wind speed range: 0 km/h to 50 km/h. The telescope shall guarantee all the requested performances, including optical stability.

Humidity range: 0% to 70%.

Precipitations (rain, snow, hail): absent.

Seismic: n.a.

Pointing/tracking speed, acceleration and accuracy: full.

3.4 Survival conditions

In this situation the telescope as a whole shall not suffer any damage or irreversible change of all its components (structural, mechanical, electrical, optical) from parameters variations within the reported ranges. The telescopes shall also guarantee some reduced performances in terms of movements.

Temperature range: -15°C to +60°C. The telescope as a whole shall not suffer any damage or irreversible change of all its components (structural, mechanical, electrical, optical) from temperature variations within this range.

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

Humidity range: 0% to 100%.

Precipitations (rain, snow, hail): possible.

Seismic: n.a.

Pointing/tracking speed, acceleration and accuracy: no pointing/tracking acceleration and accuracy required. Speed limited to 10% up to winds at 100 km/h to allow driving the telescope to its parking position.

4. Logistic

Meetings: regular meetings will be organized in order to check the status of the work, report the results, supply further inputs if requested by the Company. The meetings will be held at the Merate or Milan sites of INAF-OAB with a biweekly rate, TBC.

Milestones and deliverables: INAF expects to conclude this designing phase within nine (9) months from the kick-off meeting, TBC. Monthly Technical Reports (TRs) shall be produced by the Company and discussed during the meetings. These documents can be presented either as paper work or transparencies; they are intended to show the results and the work done.
In addition to these TRs, also two (2) detailed documents shall be produced in according to the following scheme:

NAME	TIME
Kick-off	T
Preliminary Design Review	T+3
Final Design Review	T+9

Payment terms: 30% at the kick-off meeting, TBC**.**
The remaining to be agreed according to the progress of the activities.

Project management: the management of the project for INAF will be performed by:
Technical aspects: Dr. Rodolfo Canestrari – INAF-OAB (SST-SC responsible)
Dr. Enrico Giro – INAF-OAPd (SST-DC responsible)
Legal aspects: Prof. Giovanni Pareschi – INAF-OAB