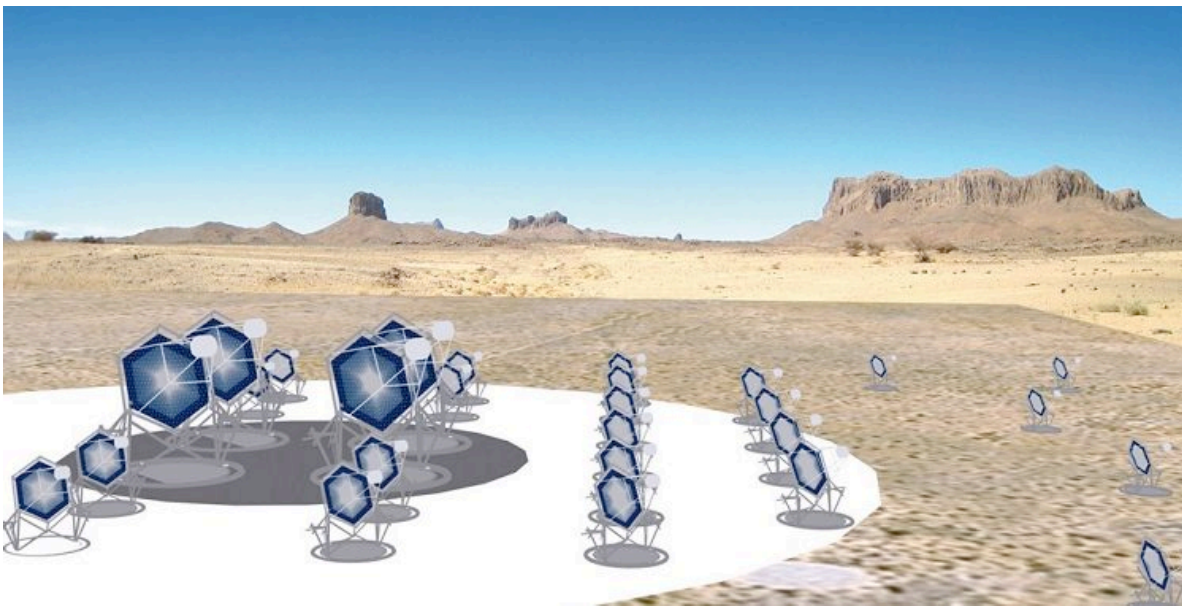
Statement of the Work for the engineering structural design of a dual-mirror Cherenkov telescope prototype for the ASTRI project:
the Small Size Telescope of the CTA observatory



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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	DATE
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.

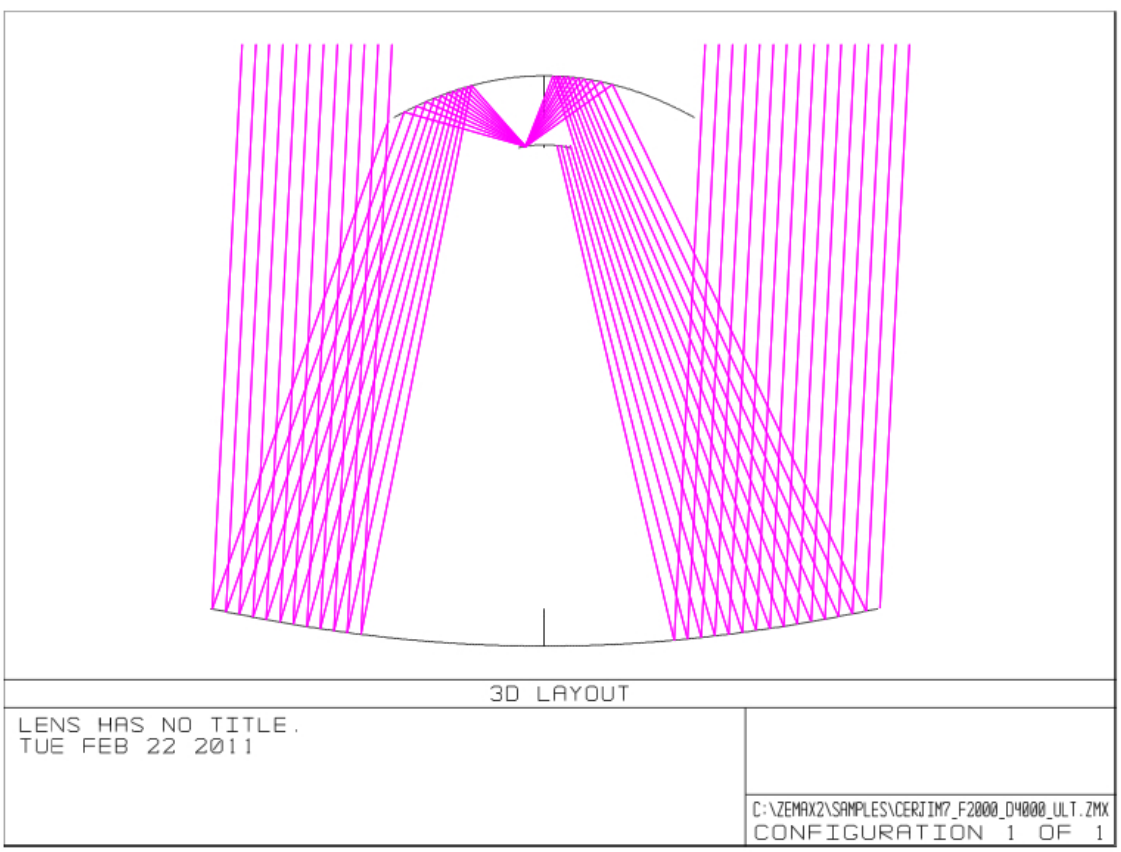
While the first approach relies on about twenty years of experience and knowledge by the scientific community, it could pose severe limitations on the performances achievable by the telescopes. First of all, the maximum number of units implementable is most probably cost-limited by the single-PMTs cameras. 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.



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 and designs related 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 for a prototype structure of the SST in the Schwarzschild-Couder configuration (SST-SC) presented in the previous section.

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.

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 mechanical parts.

1.2 Main structural design activities

The telescope structure has to be completely designed. All the structural components shall be drawn at level of detailed design. Shop drawings are not required in the present SOW. Mandatory components to be studied are foundation, telescope, pillar and counterweights, mirrors cells and mirror segments supports, mast and camera interfaces. Other parts not explicitly mentioned here but essential for the structural design must be considered.

Structural design shall be supported by structural analyses made by Finite Element approach of the telescope structure and of the mirror segments supports. At least the following items shall be faced in the structural analysis with a depth compliant to the requested designing level:

1. deformations of the structures and of the mirrors supports related to gravity load, to operative winds, to operative temperatures and to other eventual loads worth to be investigated;

2. stress of the main structures due to gravity load, to survival winds, to survival temperatures, seismic loads and to other eventual loads worth to be investigated;
3. evaluation of the eigenfrequencies in different configurations, such as different pointing orientation, different stow/parking positions.

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

Concluding, main purpose of the activities is to deliver one complete design for a prototype structure of the SST-SC option, 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 design activities relevant to mechanical components as for instance drives, servos, kinematic joints, bearings, actuators and so on are not included in the present SOW. The Contractor of the present SOW shall coordinate its activity with the Company charged by INAF-OAB for the design of the mechanical components, for the necessary data exchange and for the definition of the interfaces between telescope structures and mechanical components.

Likewise the Contractor shall collaborate with the designers of other on board systems and components (primary and secondary mirrors, electric system and so on) charged by OAB-INAF, for the definition of interfaces with telescope structures.

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.

1.3 Schwarzschild-Couder layout

Telescope aperture (M1): 4.3 m

Secondary mirror aperture (M2): 1.8 m

M1/M2 separation: 3.1 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).

1.4 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.

1.5 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 monthly rate, TBC. No meetings out of INAF-OAB premises are required.

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