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AN EFFICIENT DEPLOYMENT STRATEGY FOR THE ESA FLYEYE NEO SURVEY TELESCOPE PROTOTYPE

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ABSTRACT

The so-called “Flyeye” telescope is a new-generation wide-field high-sensitivity survey telescope which relies on an innovative optical design. The first prototype has been developed within the Planetary Defense segment of the ESA Space Safety (formerly SSA – Space Situational Awareness) programme and it is nearing completion at the OHB-I Turate premises (close to Milano, Italy). A network of at least three Flyeye telescope properly distributed across the globe is expected to provide a significant contribution to NEO discoveries. In order to address at best all the challenges involved in the Flyeye prototype deployment and operation, a two-step scenario is foreseen. The telescope will undergo an early temporary installation at the ASI Space Geodesy Centre (CGS – near the town of Matera, Italy) in order to carry out the commissioning and science verification phase in an ideal logistic and operational environment. Then it will be moved to the final site, on Monte Mufara (Sicily), which exhibits a sky quality fully compliant with the Flyeye technical characteristics and operational mode.

Introduction

The ESA Space Situational Awareness (SSA) Programme (now “Space Safety”) was started in 2009 with the aim to develop a European capability to protect ground- and space-based infrastructures from the hazards originating in space. The risk posed by NEOs (Near-Earth Objects), i.e. asteroids and comets with orbits approaching that of our planet, has been addressed by establishing the NEO Coordination Centre (NEOCC) and by developing the so-called “Flyeye” telescope. The NEOCC is located at ESA ESRIN (Frascati, Italy) and since 2013 carries out routine impact monitoring computations and follow-up observations [1]; in 2020 the Centre has undergone a

major upgrade in terms of orbit determination, impact monitoring and data dissemination functions.
The procurement of the first Flyeye telescope prototype was started in 2016 and it is being realized by a consortium led by OHB-I with the participation of companies from Luxemburg, Germany, Spain, UK, Czech Republic and Romania. The Flyeye telescope is an innovative sensor based on a modular architecture design [2]. It is equipped with 16 CCD cameras, collecting the light coming from a beam splitter located close to the focal point of a spherical primary mirror of approximately 1 m diameter (Fig.1). The CCD cameras recompose a continuous mosaic covering a total Field of View (FoV) of approximately 6.7° x 6.7°, with a resolution of 1.5"/pixel - in this respect the Flyeye can be considered as being equivalent to sixteen 1-meter class telescopes [2].
The Flyeye optical design aims to couple an extremely wide (45 square degrees) FoV with a high sensitivity (21.5 limiting magnitude) in order to scan the whole visible sky each night in automated mode.

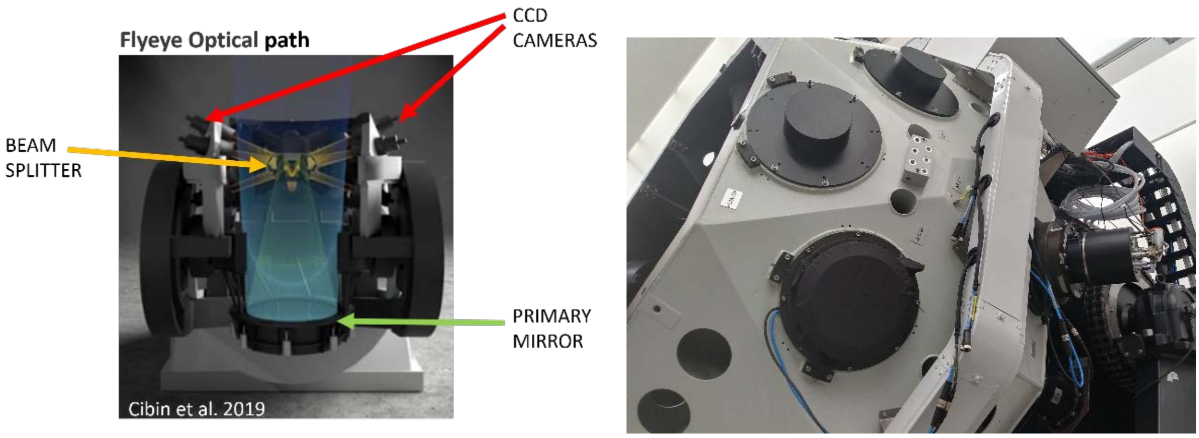

FIG 1 – The Flyeye optical Path (left) and the camera slots on the prototype (right). Courtesy OHB.

These unique characteristics pose unprecedented challenges for its installation and operation, having to deal with entirely new hardware and software components. Moreover, the massive equatorial mount needed to properly support and operate the telescope has been realized separately and the optics have never been integrated onto it. Therefore, the deployment strategy of the Flyeye prototype is expected to play a crucial role in allowing to reach its nominal performances, optimizing installation and operational procedures and providing technical feedback on the possible improvements, in both the design and the manufacturing of the subsequent Flyeye telescope units.
A two-step deployment strategy is foreseen to this end: upon completion of the secondary optics structure at the OHB premises, the Flyeye prototype will be transferred to and integrated at the ASI Space Geodesy Centre located in Matera (Italy) for carrying out a commissioning and science verification phase. The choice is motivated by the long-standing experience of the Centre in operating sophisticated ground systems such as a 20m Very Long Baseline Interferometry (VLBI) antenna and a Satellite/Lunar Laser Ranging station (SLR/LLR), thus offering the on-site support of skilled personnel and the availability of mechanical and optical labs, high-speed communication, and so forth. The lessons learned during this phase will be extremely helpful for easing the installation of the prototype at its final site, on the Mt. Mufara

(Sicily, Italy) and starting survey operations. In what follows, the main programmatic, technical and scientific challenges driving this deployment strategy are discussed.

Commissioning and Science Verification at Matera

ASI-CGS (Fig. 2) is a facility operated by the Italian Space Agency, with a long-standing expertise in optical observations and data analysis, focused on lunar and satellite laser ranging. Since 2016, the CGS is also involved in the EU Space Surveillance and Tracking (SST) support framework by routinely performing space debris optical observations. CGS brings together the advantages of providing full support in terms of logistics and personnel, granting the availability of warehouses storage, mechanical laboratories, GARR (high speed research data connection [3]), 24/7 surveillance, etc.

FIG 2 – ASI-CGS view: the dome hosts a 1.5m telescope used for providing satellite and lunar laser ranging operational services. Courtesy ASI.

The site is characterized by good sky quality, which is constantly monitored. This has allowed to carry out an exhaustive environmental evaluation (sky brightness, cloud coverage, seeing) relying on data covering slightly more than two years [4]. In particular the seeing data have been acquired by an in-situ Cyclope monitor pointing the North Star. The time period covered by the observational campaign spans from 8 August 2017 to 10 September 2019, for a total of 600 nights. By applying a quality check over the acquired data (i.e. excluding the nights with less than 30 measurements in order to avoid undersampling effects) a total of 466 nights and more than 96,000 seeing values were actually taken into consideration. The histogram in Fig. 3 has been obtained computing the mean seeing value for each night and displaying the data in bins of 0.5”. The results show that during most of the nights the seeing remained within the 1.5 - 2 arcsec range, with a significant fraction below 1.5”, in some cases even dropping to less than 1”. Overall, during some 45% of the time span analysed the mean seeing value was less than 2.0”, while for 70% of the time it remained below 2.5” arcsec.
These data show that CGS is by all means an astronomical site fully compliant with the 1.5” arcsec pixel scale characterizing the Flyeye optical design, thus allowing proper verification of its performances in terms of sensitivity. This, together with the low sky brightness (20.91 mag/arcsec^2) and high value of the annual clear sky

probability (64%) of the site [5], ensures that CGS will be extremely effective in testing the Flyeye prototype at both optical system and subsystem level, in performing meaningful NEO observations and in challenging the telescope tasking and data reduction SW.

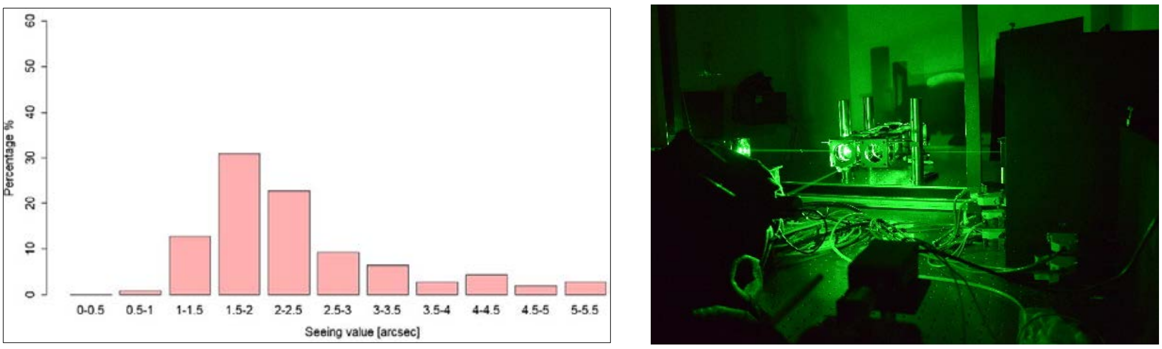

FIG 3 – The CGS seeing analysis (left) and the laser optical labs (right)

The commissioning and science verification activities to be undertaken can be described as follows:

- Optical system and equatorial mount:
  transport, installation and integration of the telescope main components; verification of the basic tasking and pointing functions.

- Telescope subsystems:
  pointing accuracy, thermal control system, mechanical/rotational speed, field stabilization in windy condition, camera alignment and focussing.

- Data quality and analysis:
  CCDs mosaic recomposition, FWHM characterisation, nominal S/N and magnitude limit verification, scientific results validation, software debugging, nominal astrometric accuracy, data products verification, etc.


FIG 4 – The Flyeye equatorial mount (left) and optical tube (right). Courtesy OHB

Moreover, the possibility of performing observations of the same object in coordination with the telescopes operated at CGS represents a powerful means to:

- compare the Flyeye performances with other optical systems under the same observing conditions;
- execute co-located NEO follow-up observations in order to test rapid response operational procedures.

In order to prepare the CGS site to host the Flyeye telescope, several activities have been started in order to:

- identify the best location for the telescope in terms of logistics and sky area coverage (maximum and minimum elevation, telescope N-S orientation, etc.);
- design the temporary infrastructure compliant with the telescope engineering requirements (telescope shelter, electrical power and network requirements, cooling system, computing facilities, etc.)
- continue monitoring the environmental conditions (seeing and weather conditions).

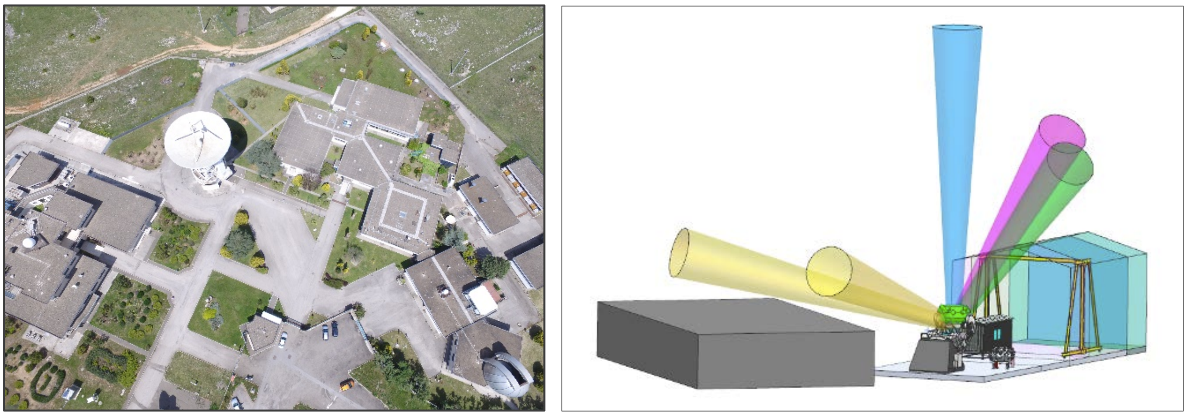

FIG 5 – (left) Aerial View of CGS: the large VLBI dish on center left and the dome for satellite laser ranging in the lower right corner are clearly recognizable; (right) simulating the telescope pointing constraints.

The Mt. Mufara site

In November 2018 an agreement between ESA and ASI has been signed in order to convene the final destination of the Flyeye prototype on top of Mt. Mufara, within the area of "Parco delle Madonie" in Sicily. The choice was supported by a trade-off study among the best Italian sites for performing an all-sky survey [5] and eventually motivated by two concurring factors: the excellent sky quality and the synergies with the nearby Gal Hassin International Astronomical Centre [6], established in 2010, which has recently completed the installation of a state-of-the-art 1m telescope on top of Mt. Mufara as well.
Monte Mufara is located in northern Sicily at Long=14.0166 °E and Lat=37.9375 °N, reaching up 1865 m altitude and it is characterized by two distinct hill-shaped mountain tops (Fig. 6). On one of them (marked by a red circle in Fig. 6) the Gal Hassin "Wide-field Mufara Telescope" (WMT) is located, whose technical characteristics (1m aperture, a remarkable 6 square deg. FoV, telescope equipped with multicolor filters) are well suited for operating in coordination with the Flyeye telescope for NEO either

astrometric or physical characterization follow-up observations. Sharing support infrastructures and routine maintenance represents also cost-effective opportunities during operations.
In Fig. 6 the location of the Flyeye telescope is marked by a blue circle: the site area is owned by different townships, whom have agreed to make it available to ESA through a 30-year free loan; a suspended chairlift and a mountain road guarantee access to the site, as indicated by the white arrows in Fig. 6).

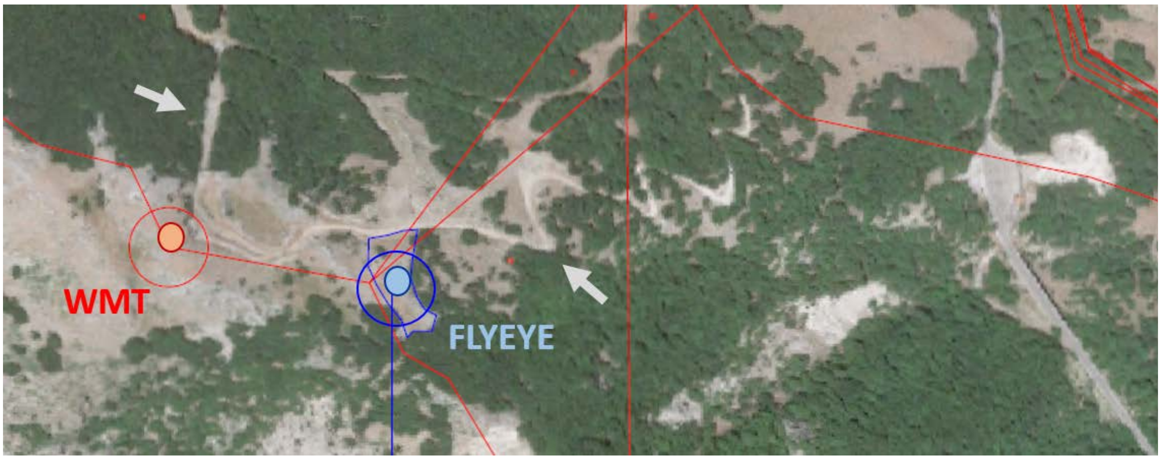

FIG 6 – Satellite view of the Mt. Mufara with, superposed, the land property borderings (red lines) and the location of the two telescopes; white arrows point to the chairlift (upper left corner) and to the access road (center image).

Designing the Flyeye Observatory has been a challenging exercise, carried out by EIE, an Italian company specialized in the realization of astronomical observatories. Major drivers were the massive equatorial mount, the demanding survey strategy, and the compliancy with the constraints deriving from Parco delle Madonie being a natural reserve protected area. Eventually, a 13 meter diameter high-speed rotating dome has been designed, which integrates into a low profile building structure that nicely follows the topography of the surroundings (Fig. 7)

FIG 7 – Artistic view of the Flyeye observing station: on the right the WMT dome is also drawn. Courtesy EIE.

The astronomical quality of the Mt. Mufara site has been thoroughly investigated. The behaviour of the astronomical seeing has been monitored along the year and the background luminosity has been checked by ad-hoc processing Earth observation data [5]. The results, summarized in Fig.8, have confirmed that the site ensures the necessary conditions for carrying out a successful NEO survey.

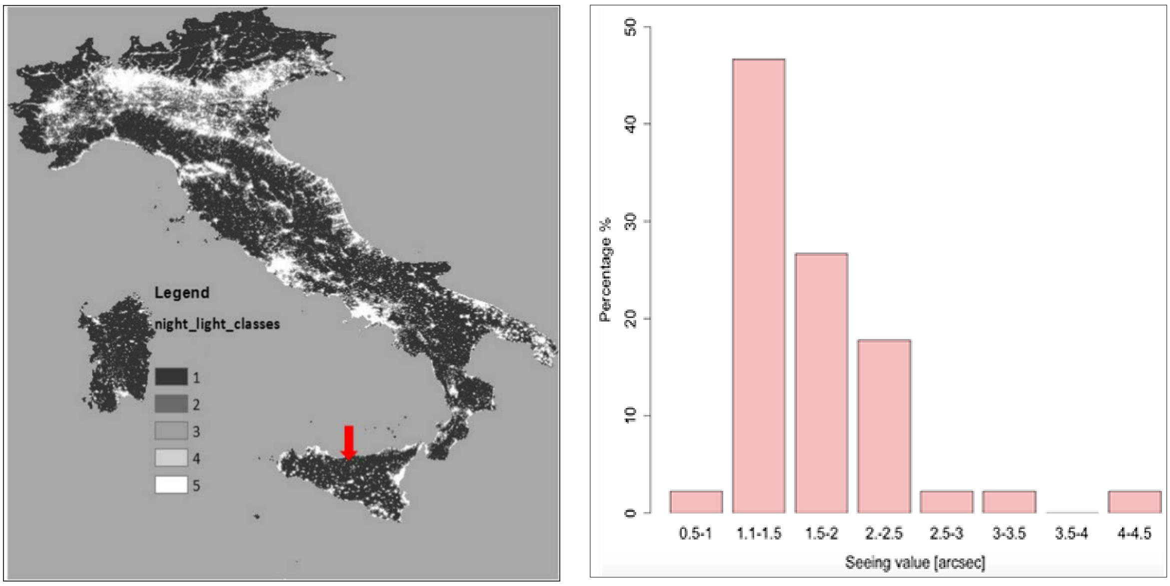

FIG. 8 – Italy cloudless map; the red arrow points the inland direction where Mt. Mufara is located (left). Mt. Mufara seeing analysis (right). Data are from ref. [5]

Conclusions

The Flyeye is an innovative telescope with an entirely new optical design covering an extremely wide field of view which will be devoted to perform a challenging NEO survey never attempted in Europe before. The many "firsts" involved in the realisation and installation of the prototype deserve a demanding commissioning and science verification phase which can be best executed at the ASI Space Geodesy Centre. This will allow to speed up assembling the telescope and starting nominal operations at the final site.

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