

STARLITE: the evolution of a miniaturized OGSE for testing attitude sensors

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ABSTRACT

Accurate attitude determination is a fundamental requirement for satellite missions, and star trackers represent the most precise sensors currently available for this purpose. By observing stellar patterns within their field of view and comparing them with onboard star catalogs, star trackers estimate spacecraft orientation and angular motion relative to the celestial sphere. As a result, they are considered critical subsystems for modern space platforms. To support the ground-based verification and validation of these sensors, the STARLITE (STAR Tracker LIght Test Equipment) project was developed within the PR FESR Toscana 2021–2027 program. STARLITE is a next-generation Optical Ground Support Equipment (OGSE) system designed to reach a Technology Readiness Level (TRL) of 7–8 and represents the evolution of the previous MINISTAR prototype. Building on the experience gained with MINISTAR, STARLITE adopts Commercial Off-The-Shelf (COTS) components to improve performance, reduce complexity, and facilitate future commercialization. The system generates realistic synthetic star fields in apparent motion, enabling the simultaneous testing of multiple star trackers and the assessment of their optical, electronic, and onboard processing functionalities. Particular attention has been devoted to minimizing the instrument’s size and mass, allowing its installation directly on assembled spacecraft configurations. In addition to stars, STARLITE can simulate extended celestial bodies such as the Sun, Earth, and Moon, as well as user-defined targets and environmental disturbances including stray light and cosmic-ray events. Laboratory activities have successfully validated the system from both geometric and radiometric perspectives. Compared with MINISTAR, STARLITE introduces significant improvements in simulation accuracy, optical performance, and radiometric fidelity. Key hardware upgrades include a high-resolution microdisplay and a commercial C-mount photographic lens used as a collimator, enabling flexible reconfiguration of the simulated field of view through simple lens replacement. This work presents the operating principles, architecture, and main technological advances that characterize the transition from MINISTAR to the STARLITE system.

Keywords: Star tracker; Optical Ground Support Equipment (OGSE); star field simulation; optical stimulator

1. INTRODUCTION

Accurate spacecraft attitude determination is a fundamental requirement for satellite navigation, pointing, and mission operations. Among the available attitude sensors, star trackers provide the highest accuracy, typically achieving arcsecond-level performance [1], [2]. These instruments estimate spacecraft orientation by observing the apparent motion of the stars on within their field of view (FOV) and comparing them with onboard star catalogs, using fixed stars as the primary inertial reference for attitude reconstruction. Given their critical role in space missions, star trackers undergo extensive verification and validation before launch. While Electronic Ground Support Equipments (EGSE) enable functional testing of individual subsystems, they are generally unable to detect issues arising from the integration of optical, electronic, and processing components, such as optical misalignments, detector positioning errors, or assembly defects. For this reason, Optical Ground Support Equipments (OGSE) are required to stimulate complete star tracker systems with realistic celestial scenes and evaluate their overall performance [3], [4], [5].

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Several commercial OGSE solutions are currently available, including Airbus STOS[6], Jena-Optronik OSI [7], and Terma Dynamic Optical Ground Support Equipment[3]. However, these systems are primarily intended for laboratory testing and are often not suitable for validation activities after integration of the star tracker onto the spacecraft platform. This limitation has motivated the development of compact and lightweight optical stimulators that can be directly mounted on the star tracker baffle, enabling end-to-end testing in representative operational configurations.

Within the POR FESR Toscana 2014–2020 program, the MINISTAR (MINIaturized STAR tracker tester) prototype was developed as a compact electro-optical OGSE capable of generating synthetic star fields in apparent motion. MINISTAR supported the simultaneous testing of up to three star trackers and enabled the evaluation of optical, electronic, and onboard software performance. The system was also capable of simulating extended celestial objects, such as the Sun, Earth, and Moon, as well as user-defined targets and environmental disturbances including stray light and cosmic-ray events. Laboratory testing demonstrated the feasibility of the concept through successful geometric and radiometric validation [8], [9]. Building upon the experience gained with MINISTAR, the PR FESR Toscana 2021–2027 program supported the development of STARLITE (STAR Tracker Light Test Equipment), a next-generation OGSE system aimed at achieving a higher Technology Readiness Level (TRL) and facilitating future commercialization. STARLITE addresses the growing need for compact, high-performance test equipment for pre-launch verification of attitude sensors through the extensive adoption of Commercial Off-The-Shelf (COTS) components. Compared with its predecessor, the system introduces significant improvements in simulation fidelity, optical performance, radiometric accuracy, manufacturability, and operational flexibility. The main hardware upgrades include the adoption of a high-resolution microdisplay and a commercial fixed-focal-length photographic objective equipped with a standard C-mount interface and used as a collimator. This modular architecture simplifies alignment procedures and enables straightforward adaptation of the simulated field of view through objective replacement. In parallel, the simulation software has been enhanced to improve the accuracy of celestial scene generation, including the representation of stars, extended objects, and disturbance sources.

This paper presents the operating principles, system architecture, and enabling technologies of STARLITE, highlighting the main technical developments achieved during the transition from the MINISTAR prototype to a higher-TRL, commercially oriented OGSE solution for star tracker validation.

2. SYSTEM REQUIREMENTS

The principal objective of the project is the realization of a compact optical stimulator capable of generating realistic stellar scenes in apparent motion. Such scenes must reproduce operational conditions encountered during spacecraft missions and enable validation of optical, electronic, and algorithmic functionalities of star trackers.

Several functional requirements drive system development:

- Real-time generation of dynamic star fields.
- Simulation of bright celestial bodies such as the Sun, Earth, and Moon.
- Generation of custom user-defined targets.
- Injection of disturbances including cosmic rays and stray light.
- Simultaneous stimulation of multiple star tracker heads.
- Compact size and low mass suitable for integrated spacecraft testing.
- High angular and radiometric fidelity.

To achieve realistic simulations, frame rates between 50 and 90 Hz are required [4], exceeding the minimum Nyquist requirement associated with typical star tracker acquisition frequencies. The system is also designed to support at least three independent optical channels operating simultaneously. The MINISTAR prototype supported the simultaneous stimulation of three star trackers and achieved a frame rate of 85 Hz with a 20° field of view. STARLITE is designed to extend these capabilities while maintaining a compact form factor (Figure 1).



Figure 1. STARLITE prototype, the image shows the actual compact form factor

3. MATHEMATICAL MODEL AND STAR FIELD SIMULATION

The STARLITE simulation framework generates synthetic celestial scenes from three principal inputs:

1. Stellar positions and magnitudes obtained from astronomical catalogs.
2. Spacecraft attitude information.
3. Relative orientation of the star tracker with respect to the spacecraft body frame.

3.1 Coordinate Systems and Attitude Representation

The celestial sphere serves as the inertial reference frame. Stellar positions are represented by right ascension (RA) and declination (DEC). Spacecraft attitude can be expressed either through Tait-Bryan angles (roll, pitch, yaw) or quaternions [10]. Both formulations are implemented within the simulation software, allowing flexible representation and conversion between attitude parameterizations.

The direction of view for each optical head is computed through a sequence of rotation matrices that combine:

- Spacecraft orientation in inertial coordinates.
- Fixed orientation of the optical head in spacecraft coordinates.

In this way it is possible the simulation of arbitrary spacecraft maneuvers while maintaining realistic star tracker positioning. Simulation relies on the HIPPARCOS catalog containing more than 118,000 stars. Direct processing of the entire catalog at every simulation frame would be computationally inefficient. To overcome this issue, the catalog is partitioned into partially overlapping spatial sub-catalogs covering different sky regions. Only the sub-catalog corresponding to the current viewing direction is processed.

Additional filtering based on stellar magnitude further reduces computational load. As only stars detectable within the dynamic range of the system are relevant, the number of processed sources is reduced from thousands to a few tens per frame, enabling real-time operation.

3.2 Stellar Magnitude Simulation and sub-pixel accuracy

The simulator reproduces stellar brightness by mapping apparent magnitude values into display luminance levels. The conversion follows the standard logarithmic astronomical magnitude scale. Because display dynamic range is limited, the achievable magnitude interval is approximately 4.5 magnitudes, which is comparable to existing state-of-the-art systems. To account for differences between display emission spectra and star tracker detector sensitivity, a calibration procedure based on visual magnitude and B–V color index is implemented. Polynomial corrections compensate for spectral mismatches between simulated and real stellar sources.

Achieving high angular precision is a major challenge because individual display pixels correspond to finite angular increments. The adopted solution represents stars using multi-pixel intensity distributions rather than single pixels. The star position is determined from the barycenter of a $N \times N$ pixel matrix, allowing sub-pixel positioning. In the following, we consider, without loss of generality, the case with $N=2$. Using a large N can improve sub-pixel resolution further, but it also increases the star's apparent angular size. Small matrices are preferred to minimize the risk of resolving the star image into a non-point-like object. Allocating a portion of the display's dynamic range to enable finer sub-pixel positioning and mitigate the effects of coarse angular resolution for faint stars reduces the maximum theoretical dynamic range available for star luminance adjustment. (Figure 2).

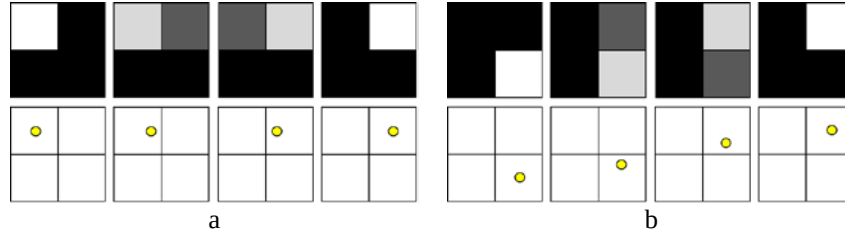


Figure 2 . An example of a 2×2 pixels matrix used for representing the position of a star (yellow dot) with sub-pixel precision, for x axis, varying left to right (a) and for y axis, varying bottom to top (b). The gray level of each pixel represents its luminance value 0 (black) to 255 (white).

The adopted approach significantly improves angular accuracy while maintaining the star image within the point spread function (PSF) typically observed by star trackers. The achieved angular positioning accuracy is $1/255$ of a pixel for a star having maximum luminosity (255) and decreases with the increase of magnitude.

4. HARDWARE ARCHITECTURE

The STARLITE project represents a technological evolution of MINISTAR aimed at achieving commercial maturity and improved performance. Several major upgrades have been introduced, in particular: enhanced display, commercial optical components and improved calibration.

The STARLITE architecture consists of:

- Simulation workstation.
- Display subsystem.
- Optical collimator.
- Monitoring and control software.

The overall system architecture is shown in Figure 3, which also illustrates closed-loop and open-loop testing configurations.

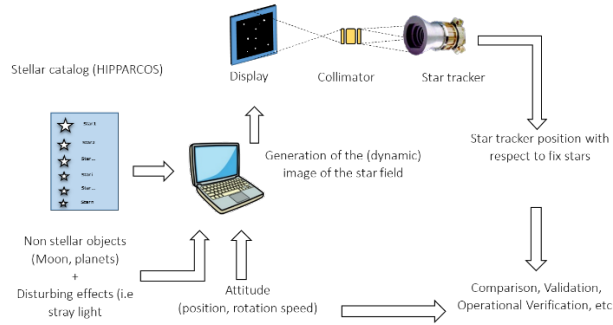


Figure 3. STARLITE validation system architecture. Input data are processed by a PC, providing the dynamic, real-time rendering of the scene on the instrument's display and projected after collimation into the star tracker optical head under test. Star tracker output data can be analyzed, allowing checks in both open and closed-loop configurations

4.1 Display Evolution

MINISTAR employed a WUXGA OLED display manufactured by eMagin with:

- Resolution: 1920×1200 .
- Pixel pitch: $9.6 \mu\text{m}$.
- Refresh rate: 85 Hz.

Only the central 1200×1200 region could be effectively used due to optical constraints.

STARLITE adopts a SeeYA SY103WAM01 micro-OLED featuring:

- Resolution: 2560×2560 .
- Pixel pitch: $7.2 \mu\text{m}$.
- Luminance: 1800 cd/m^2 .
- Refresh rate: 60–90 Hz.

This change substantially improves angular sampling, brightness, and field-of-view utilization.

4.2 Optical Design Evolution

One of the most significant advancements achieved in the transition from MINISTAR to STARLITE concerns the optical subsystem. The basic operating principle remained unchanged, i.e. the projection of a synthetic celestial scene at optical infinity through a collimating system. On the other hand, the optical architecture underwent a substantial redesign aimed at improving performance, manufacturability, flexibility, and commercial viability.

The MINISTAR prototype employed a fully custom-designed optical system specifically optimized for the project requirements. The design process included complete control of lens geometry, aberration correction, mechanical mounting, and alignment strategies. Although this approach allowed the development team to achieve the desired optical performance, it introduced several practical limitations.

First, the custom optical assembly required precision mechanical manufacturing and highly accurate alignment procedures. Small positioning errors during assembly could significantly affect image quality, angular accuracy, and distortion performance. Consequently, manufacturing costs were relatively high and the system was difficult to replicate on an industrial scale.

Second, the optical design was optimized for a specific field of view (20°) and display configuration. Modifying the optical characteristics to accommodate different star tracker models would have required a substantial redesign of both optics and mechanics. This reduced system versatility and limited the possibility of adapting the simulator to the growing diversity of commercial star trackers.

Finally, the overall integration procedure was time-consuming due to the need for dedicated alignment fixtures and optical verification activities during assembly. These limitations highlighted the need for a more modular and commercially sustainable solution.

STARLITE addresses these limitations through the adoption of Commercial Off-The-Shelf (COTS) optical components. Instead of designing a dedicated optical assembly from scratch, the development team evaluated a range of commercially available aspheric lenses, achromatic doublets, and high-performance photographic objectives using Zemax OpticStudio simulations.

The analysis considered several candidate lenses with focal lengths around 40 mm, selected to maintain a field of view comparable to or larger than that of MINISTAR. Performance evaluation focused on:

- RMS spot radius;
- chromatic aberration;
- field curvature;
- distortion;
- angular resolution;
- mechanical integration complexity.

Zemax simulation results demonstrated that many off-the-shelf lenses were unable to fully exploit the theoretical angular resolution provided by the new high-resolution display, as residual optical aberrations became the dominant limiting factor. Finally, a professional photographic objective, the Kowa LM35XC 35 mm lens, allowing the best compromise between optical quality, compactness, cost, and ease of integration was selected. In particular, Kowa lens provides:

- improved optical quality;
- reduced complexity;
- lower manufacturing costs;
- standard C-mount compatibility;
- easy FOV adaptation by lens replacement. .

4.2.1 Improved Angular Resolution

The optical redesign was performed simultaneously with the replacement of the display subsystem.

MINISTAR utilized a 1920×1200 OLED display, of which only a 1200×1200 region could be effectively exploited for star field generation. STARLITE instead employs a 2560×2560 square-format micro-OLED display with a smaller pixel pitch ($7.2 \mu\text{m}$ versus $9.6 \mu\text{m}$).

The combined effect of increased display resolution, reduced pixel pitch, and optimized focal length results in significantly finer angular sampling.

For a 35–40 mm focal length collimator, the theoretical angular sampling approaches approximately 0.01° per pixel. This improvement directly contributes to more accurate representation of stellar positions and enhances the effectiveness of the sub-pixel centroiding algorithm used for star generation. Furthermore, the larger display area allows STARLITE to support wider fields of view while maintaining angular precision comparable to or better than that achieved by MINISTAR.

4.2.2 Increased Field-of-View Capability

A major design objective of STARLITE was compatibility with modern star trackers, many of which feature fields of view between 20° and 25° .

While MINISTAR provided a nominal field of view of approximately 20° , STARLITE targets fields of view between 25° and 30° , depending on the installed objective. This increase enables the simulator to reproduce larger portions of the celestial sphere and therefore more closely replicate operational conditions encountered by current-generation attitude sensors.

The use of interchangeable objectives offers an additional advantage. Different focal lengths can be installed through a standard C-mount interface, allowing rapid adaptation of the simulator to the optical characteristics of a specific star tracker without redesigning the entire system. This capability significantly enhances operational flexibility and broadens the range of compatible sensors.

4.2.3 Reduction of Chromatic Aberration

An important consideration in optical star simulators is the minimization of chromatic aberration. Because stars are represented by extremely small image features, any wavelength-dependent focus shift can introduce positioning errors and unwanted image spreading.

To mitigate this effect, both MINISTAR and STARLITE primarily operate using a single display color channel, typically the red channel. However, the improved optical quality of the STARLITE lens system further reduces chromatic effects and allows better preservation of stellar point-like characteristics across the entire field.

The higher optical performance contributes to improved centroid estimation and therefore to more accurate attitude-sensor testing.

4.2.4 Enhanced Mechanical Integration

One of the less obvious but highly important improvements concerns the relationship between optics and mechanics.

The custom MINISTAR optical system required dedicated mounts and relatively complex alignment procedures. STARLITE introduces a simpler mechanical architecture based on commercially standardized optical interfaces. The use of C-mount objectives significantly reduces assembly complexity while improving maintainability and repeatability.

Additionally, the optical head interface has been redesigned to facilitate installation directly into the star tracker baffle. This approach minimizes the distance between the simulator exit pupil and the entrance pupil of the tested instrument, reducing optical losses and mitigating vignetting effects.

4.3 Calibration improvements

For STARLITE prototype, a new two-step geometric calibration procedure was adopted. Unlike MINISTAR, STARLITE explicitly calibrates the reference camera itself before characterizing STARLITE distortion, thus reducing systematic uncertainty and improving positioning accuracy.

For the measurement setup, a panchromatic Teledyne MOMENT camera with a resolution of 3200×2200 pixels (W $\times$ H) was used. The distortion of the STARLITE optical system was estimated by mounting the same 35mm Kowa LM35XT lens on the MOMENT camera.

A target consisting of vertical reference structures was used for the distortion measurement. Verticality, resolved at the pixel level in the acquired images, was achieved using a set of thin plumb lines (Figure 4).

The camera was subsequently rotated by 90° to acquire the same scene with the image orientation rotated accordingly. This configuration facilitates the estimation of TV distortion along both image axes. The position of each plumb line was measured at multiple locations across the image along both the horizontal and vertical directions.

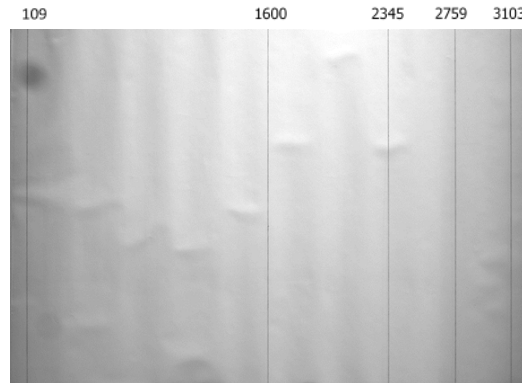


Figure 4. Set of thin plumb lines arranged along the image columns. The column indices corresponding to the plumb lines are indicated in the figure.

This measurement configuration enables the distortion along the x-axis (variation in the measured vertical position) and the y-axis (variation in the measured horizontal position) to be determined with respect to the corresponding values at the image center. The diagonal distortion was then estimated as the root-sum-square (RSS) of the distortion values measured along the two axes.

This process is expected to significantly improve the angular accuracy of the STARLITE system compared to its predecessor, MINISTAR, enabling more precise mapping between display coordinates and viewing directions by removing the camera intrinsic distortion.

Table 1. Camera MOMENT specifications.

SPECIFICATIONS	Camera Performance
Sensor	Sony IMX420 CMOS sensor
Active Array Size	3200 x 2200 (7.1 Megapixel)
Pixel Area	4.5 x 4.5 μm (20.25 μm^2)
Sensor Area	14.4 mm x 10 mm (17.6 mm diagonal)
Peak QE%	> 73%
Readout Modes	Global shutter
Digital Binning	2 x 1 charge domain (on chip) binning up to 4 x 4 digital binning
Linearity	> 99%
Cooling Options	Uncooled
Digital Interfaces	USB 10 Gbps (3.2 Gen 2)
Lens Interfaces	C-mount
Camera Weight	0.096 kg, 0.21 lbs

The measured results were acquired using the Teledyne MOMENT camera, whose characteristics are summarized in Table 1, equipped with the same 35 mm lens used as the collimator for STARLITE. The diagonal distortion results obtained from the images acquired with the MOMENT camera were then extrapolated assuming the same Kowa 35 mm objective coupled with the STARLITE sensor (2560 × 2560 pixels). The resulting values are reported in Table 2.

The cumulative distortion along the image diagonal is limited to 0.07° over the nominal diagonal half field of view (FOV/2). Considering the diagonal dimension of the sensor in pixels, the corresponding error per pixel is on the order of 10^{-5} . At present, no angular distortion correction is planned. However, the implemented system supports a geometric calibration procedure for distortion correction should a lens with a larger field of view be adopted.

It should also be noted that the nominal field of view is larger than the effective field of view due to the vignetting effects described in the following section.

Table 2. Teledyne MOMENT camera and STARLITE sensor parameters. The distortion values were estimated from images acquired with the MOMENT camera, assuming the same 35 mm focal length configuration.

SPECIFICATIONS	Camera Performance
Moment camera sensor width (mm)	14.4
Moment camera sensor height (mm)	10.0
Lens focal length (mm)	35.0
Moment camera FOV/2 along width (deg)	11.62
Moment camera FOV/2 along height (deg)	8.13
Moment camera FOV/2 along diagonal (deg)	14.06
STARLITE sensor width (mm)	18.43
STARLITE sensor height (mm)	18.43
STARLITE nominal FOV/2 along width (deg)	14.75
STARLITE nominal FOV/2 along height (deg)	14.75
STARLITE nominal FOV/2 along diagonal (deg)	20.42
STARLITE Diagonal distortion	-3.55E-03
STARLITE Diagonal distortion (deg)	-0.07
STARLITE angle error on single pixel (deg)	-4.01E-05

5. STARLITE PRELIMINARY RESULTS AND FUTURE DEVELOPMENTS

The ability of STARLITE output in simulating stellar magnitudes was evaluated starting from the specification of STARLITE display. Conversion between photometric and radiometric quantities depends on the source spectrum, for this reason a first evaluation of the luminous output of a single pixel at the device's maximum luminance ($1800 \text{ cd}\cdot\text{m}^{-2}$ for the display used for STARLITE) was performed assuming that, at 555 nm 1 W is equal to 683 lm.

The display luminance (in cd m^{-2}) was converted into radiance ($\text{W m}^{-2} \text{sr}^{-1}$) and integrated over the solid angle subtended by an individual pixel. Given the focal length of the collimator, the instantaneous field of view (IFOV), or solid angle subtended by a pixel with pitch p , is given by $IFOV = p^2/f^2$.

Using the apparent bolometric magnitude m_{ref} of the star Vega as zero-point, the maximum apparent magnitude m emitted by a single pixel, observed through a 35 mm collimator, is estimated to be approximately $m \approx -1.6$.

The wider field of view targeted by STARLITE introduces a new challenge associated with vignetting. STARLITE generates an image at optical infinity, thus the collimated light bundle diverges geometrically after leaving the exit pupil. If the distance between STARLITE and the star tracker becomes excessive, part of the optical beam may fall outside the acceptance aperture of the tracker optics, causing a progressive reduction of brightness toward the field edges. Theoretical analysis, supported by preliminary experimental results, highlighted the importance of minimizing the distance between the STARLITE prototype and the star tracker's entrance pupil.

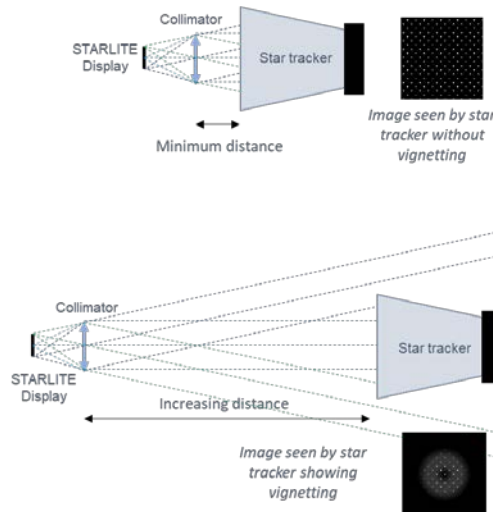


Figure 5. Vignetting effect between STARLITE and star tracker

Figure 5 illustrates this phenomenon by showing the progressive increase in vignetting with increasing separation between the collimator projecting the synthetic scene and the star tracker under test.

STARLITE calibration activities aim at quantifying vignetting for different commercial star trackers. In this way STARLITE can preserve the large field-of-view capability while maintaining uniform radiometric performance across the image. In Figure 6 the experimental set up for measuring the vignetting effect and determine the effective FOV is reported.

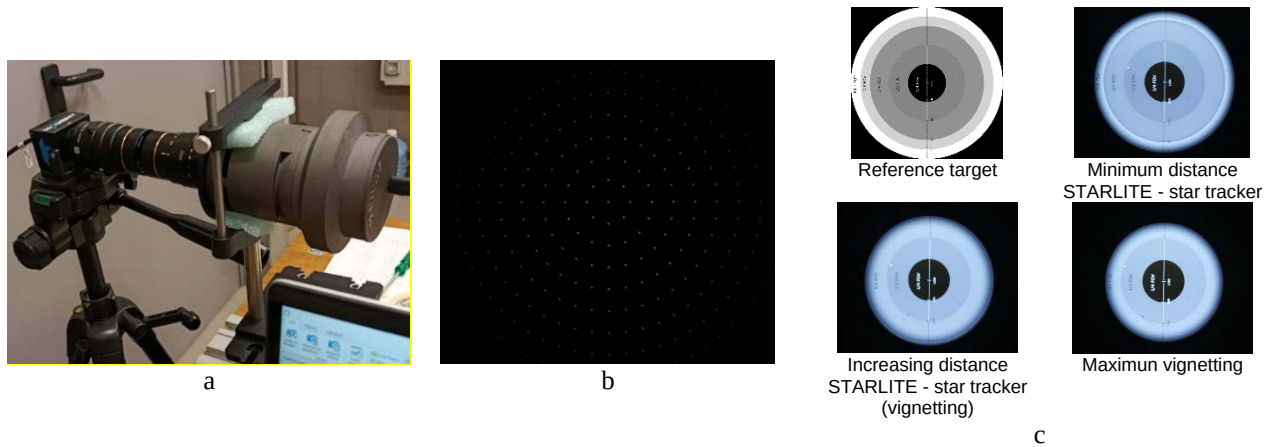


Figure 6. Experimental set up reference calibrated camera (a) used to characterize STARLITE (i.e. actual FOV, alignment and star positioning accuracy). Image of a calibration pattern (apparent magnitude 1.2 at 1.31° angular step, along a FOV of $\pm 10.48^\circ$) generated by STARLITE and observed with a 25mm objective (b). Target image shown by STARLITE display at increasing distance, showing the vignetting effect.

To address this issue, STARLITE incorporates: a dedicated insertion flange and an optimized mechanical coupling in order to reduce separation between optical systems.

Beyond pure optical performance, the redesign has a strong impact on system maturity. The transition from a laboratory-oriented custom optical design to a modular architecture based on COTS components substantially lower manufacturing costs and assembly effort. Optical modules become easier to replace, calibrate, and maintain, while overall system reliability increases.

Consequently, the optical redesign is one of the main factors enabling STARLITE to progress from the MINISTAR TRL-5 prototype toward a $TRL \geq 7$ instrument suitable for industrial production and commercial deployment within the space sector.

Key optical improvements can be summarized as follows:

- Transition from custom optics to high-performance COTS objectives.
- Increase in display resolution from 1200×1200 effective pixels to 2560×2560 pixels.
- Expansion of field of view from 20° to more than 25° .
- Frame rates up to 90 Hz.
- Magnitude range of approximately 4.5 magnitudes.
- Mass below 1 kg.
- Improved angular sampling and star-position accuracy (Alignment accuracy better than 0.001° , Star positioning accuracy better than 0.005°).
- Reduced chromatic aberration effects.
- Simplified mechanical integration through standard C-mount interfaces.
- Better compatibility with different star tracker models.
- Reduced fabrication and alignment costs.
- Improved resistance to vignetting through optimized optical coupling.
- Increased Technology Readiness Level and commercial potential.

Finally, Table 3 compares STARLITE with commercial systems such as Airbus STOS and Jena-Optronik OSI. The comparison highlights STARLITE's competitive performance, especially in terms of display resolution, flexibility, custom catalog support, and multi-head simulation capability.

Table 3. Comparison of STARLITE main features with STOS (Airbus Space Equipment) and OSI (Jena Optronik) systems

	STARLITE	STOS	OSI
Close loop stimulation	Yes	Yes	Yes
Display dimensions	2560x2560 pixels	1280x1024 pixels	-
FOV	$\geq 25^\circ$ ($\pm 12.5^\circ$)	configuration dependent	$> 20^\circ$
Frame rate for dynamic scene	Up to 90 Hz	255 Hz monochrome	≥ 60 Hz
Device dimensions	175 mm ($\varnothing$) $\times$ 150 mm	200 mm ($\varnothing$) $\times$ 350 mm	77 mm ($\varnothing$) $\times$ 180 mm
Alignment error	0.001°	0.001°	-
Attachment	star tracker baffle	star tracker baffle	star tracker baffle
Single star accuracy	0.005°	0.005°	0.0075°
Star catalog	Hipparcos/custom	Hipparcos	Hipparcos
Star magnitude range	4.5	4.5	4.5
Star diameter	$< 0.05^\circ$	$< 0.13^\circ$	$< 0.1^\circ$
Large objects	Yes	Yes	Yes
Protons simulation	Yes	Yes	Yes
Stray light simulation	Yes	Yes	Yes

6. CONCLUSIONS

STARLITE represents a significant evolution of the MINISTAR concept, transforming a laboratory prototype into a compact and commercially oriented OGSE platform for star tracker validation. The system combines advanced simulation software, high-resolution displays, flexible optical architectures, and rigorous calibration methodologies to provide realistic and accurate testing of attitude sensors. Experimental validation of MINISTAR has demonstrated the feasibility of the approach, while STARLITE introduces substantial improvements in optical quality, geometric accuracy, radiometric fidelity, and ease of integration. Through the adoption of COTS components and enhanced calibration procedures, the project aims to achieve TRL 7–8 and establish STARLITE as a competitive solution for next-generation spacecraft attitude-sensor verification.

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