

ScanCam Integrated Scanning Camera

Alexander Díaz^{*a}, Gaizka Murga^a, Tibor Agocs^b, Marta Escriche^a, Gorka Urrutia^a, Alberto Cobiella^a,
Mikel Landea^a

^aIDOM, Avenida Zarandoa 23, 48015 Bilbao, Spain

^b ESA – ESTEC, European Space Agency - Space Research and Technology Centre, Keplerlaan 1,
2201 AZ Noordwijk, The Netherlands

ABSTRACT

The ScanCam concept offers an innovative solution to a persistent structural and functional limitation in space optical systems: the need for separate mechanisms for field-of-view scanning and image derotation. While these duplicated mechanisms are functional, they introduce significant penalties in terms of system complexity, reliability, mass, volume, cost, and operational agility—factors that are especially critical in space missions, particularly in low Earth orbit (LEO) or very low Earth orbit (VLEO) platforms, where constraints on size and power consumption are stringent.

The operation principle, based on ESA patent ESA PAT 608, introduces a disruptive approach by integrating scanning and derotation into a single rotating mechanism. This ensures that the image formed at the detector's focal plane remains stable in orientation, as both the scanner and the image plane rotate together.

IDOM has developed for this concept a design implementation for an earth observation application featuring; a prime focus optical layout with a corrector lens with a GSD of 3.76m and a SWATH of 9.3km, baseline Scanning range of $\pm 15^\circ$, easily scalable to larger ranges, Frameless, ironless direct drive motor driven scanning mechanism, providing smooth, backlash-free motion while maintaining a compact and lightweight integration within the central mechanism, athermal optomechanical design, optimized to keep focus on a $\pm 10^\circ\text{C}$ range, easily scalable concept for a larger aperture, scanning range or FoV.

Keywords: Scanning Mechanism, Earth Observation, Pointing Agility

1. INTRODUCTION

Modern Earth Observation Systems seek to incorporate agility necessary to observe regions out of the track of the satellite or to increase the exposure time on a given region using forward motion compensation. Even though there is always the option to change the attitude of the satellite to achieve this agility, it is more efficient and accurate to change the pointing angle actuating on the system's optical elements, typically having a folding mirror mounted on a 1 or 2 Degrees of Freedom rotation mechanism. While these mechanisms offer a good solution for the application, they typically imply a limitation, the need to include an additional derotation mechanism for the detector. This introduces more complexity, mass, volume and thus cost and other implications such as reliability, very important considerations for space systems and specially for LEO/VLEO satellites.

The ScanCam concept offers a solution to these limitations by integrating the scanning and derotation functions into a single mechanism. This is based on ESA's patent PAT 608 (European Patent Application EP25181679.9), which describes a system featuring,

- A scanning mirror that redirects the optical beam into a telescope
- A detector mounted on the same rotating axis as the scanning mirror

* alexander.diaz@idom.com; phone +34 94 4797676; fax +34 94 4761804; www.idom.com/ada

This configuration eliminates thus the need for an additional mechanism to compensate for this rotation at the detector.

IDOM has developed in collaboration with ESA a design implementation aimed at an earth observation application that features,

- A prime focus optical layout with a corrector lens with a GSD of 3.76m and a SWATH of 9.3km
- Scanning range of $\pm 15^\circ$ at a rate of up to $10^\circ/\text{s}$
- Frameless direct drive motor driven scanning mechanism providing smooth, backlash-free motion while maintaining a compact and lightweight integration within the central mechanism
- Athermal optomechanical design, optimized to keep focus in a $\pm 10^\circ\text{C}$ range
- Easily scalable concept for a larger aperture, scanning range or FoV

The design will be described in detail hereafter.

2. OPTICAL DESIGN

The system proposed by IDOM consists of a prime focus telescope with a focus corrector which receives light from an actuated folding mirror, in perpendicular direction to the telescope optical axis. In this configuration, the folding mirror, corrector and detector are mounted in the scanning mechanism, rotating around the primary mirror's optical axis.

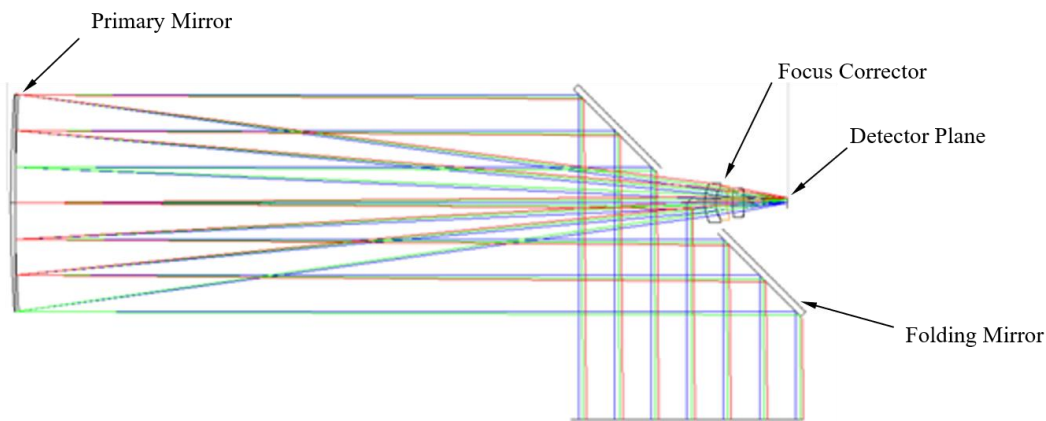


Figure 1. Optical layout of the implementation proposed by IDOM

The design features a hyperbolic primary mirror and a focus corrector that reduces the complete length of the system for the same effective focal length. Additionally, this corrector is composed of two lenses to correct chromatic dispersion effects.

The folding mirror would be the first element in the optical train and responsible for the scanning motion. This is an elliptical flat mirror with a central hole, allowing for the returning light from M1 to reach the camera focus corrector and detector. This central hole introduces an obscuration of 22%.

In this implementation the optical system has an aperture of 130mm and an effective focal length of 364 mm ($f/2.8$). The Sony IMX568 has been selected as the detector, providing a 2472×2064 px resolution with a pixel size of $2.74 \mu\text{m}$. This, in combination with the optical parameters, results in an angular resolution of 1.55 arcsec/px with a FoV of 1.37° for the detector diagonal, implying thus a GSD of 3.76 m assuming a LEO satellite at 500 km.

3. MECHANICAL DESIGN

From the mechanical point of view, the design proposed by IDOM has been developed with the objective of achieving compact, lightweight, and thermally stable mechanical architecture. the system is divided in three main sections,

- Static Structure, that would be fixed to the satellite platform. It hosts the Primary Mirror

- Scanning Mechanism, which contains the actuator, bearings and encoder
- Rotating Structure, which rotates around the optical axis creating the scanning movement. It hosts the Scanning Mirror, Corrector Lenses and the Detector

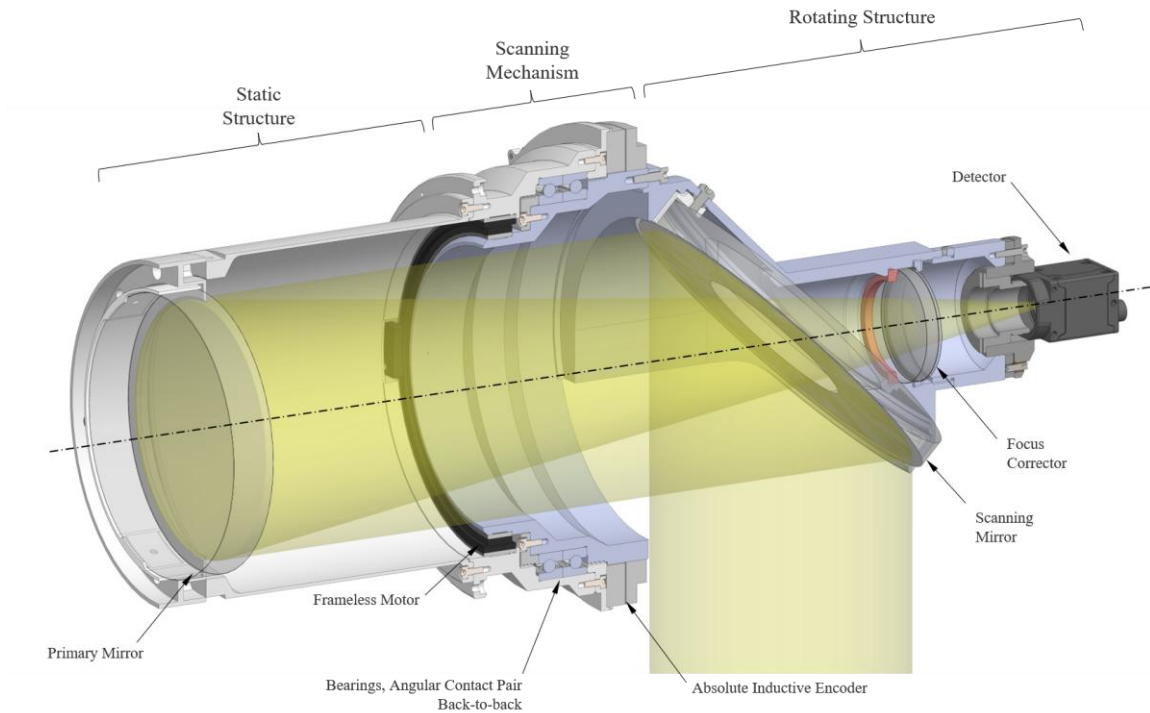


Figure 2. ScanCam design overview

3.1 Static Structure

The main function of the static structure is to support the Primary Mirror and to provide the camera's external mechanical interface.

To securely support the Primary Mirror, a simple and robust technique to isostatically support the mirror is implemented by means of a dedicated cell-ring. This establishes contact with the mirror at six discrete points, 3 axial seats and 3 radial centring points. This ring is flexible in radial direction, making the support isostatic, which allows the mirror to be adequately restrained while avoiding the introduction of unwanted stresses or deformations that could degrade its optical performance. To prevent mirror displacement and ensure long-term mechanical stability, the mirror is secured to the cell using a silicone elastomer adhesive, specifically RTV 566. This elastomer is selected due to its low outgassing characteristics and its extensive heritage in space applications.

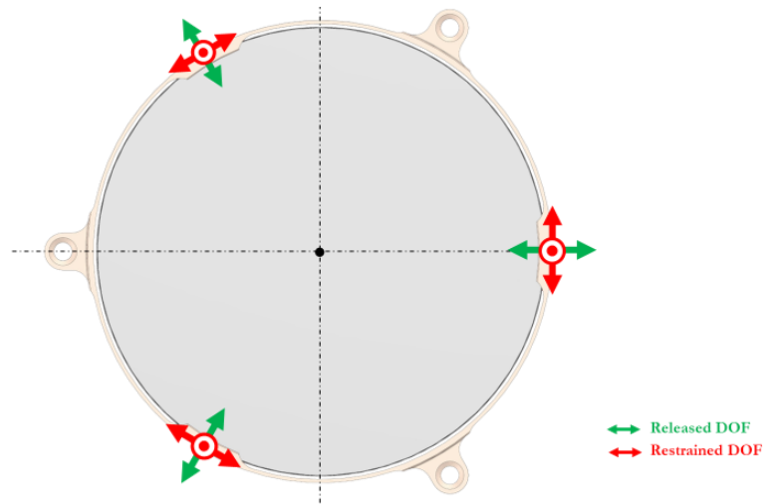


Figure 3. Primary Mirror supporting strategy

This cell is attached, via a coupling support to the tube structure that conforms the static structure. Additionally, this is done in such a way that its tip-tilt and centring with respect to the rest of the structure can be modified. This will be key for ensuring proper alignment of the mirror's optical axis and the rotation axis, a necessary condition to obtain a stable image even when the scanning mechanism is in motion.

3.2 Scanning Mechanism

The Scanning Mechanism is composed of a compact rotational assembly designed to steer the instrument's optical path by rotating the Scanning Mirror, the Corrector Lenses, and the Detector as a single aligned unit. The mechanism enables controlled angular motion around the Primary Mirror optical axis, providing the required pointing agility for the camera concept while maintaining structural stiffness and optical stability throughout the full operational range.

A frameless direct drive motor has been selected as the actuator for the movement, which provides not only a compact and lightweight solution, but also offers smooth, backlash-free motion. The direct-drive architecture eliminates the need for gearboxes or mechanical transmissions, ensuring a stiff and continuous torque path between the stator and the rotating elements.

To guide the rotating movement, a pair of thin-section angular-contact ball bearings is integrated at the core of the mechanism. These are assembled in a back-to-back configuration, effectively restraining radial and axial displacements while also providing the required tip-tilt stiffness. The opposing contact angles of the bearing pair ensure stable preload and structural rigidity along the rotation axis, supporting the alignment of the optical assembly during operation.

Finally, the position feedback is given by an inductive absolute encoder. This operates using a non-contact inductive principle, where the stator containing all electronic measures the absolute angular position of a passive rotor without requiring any mechanical coupling. This architecture inherently eliminates wear, ensures long-term stability, and allows operation in harsh environments where optical or capacitive encoders may fail.

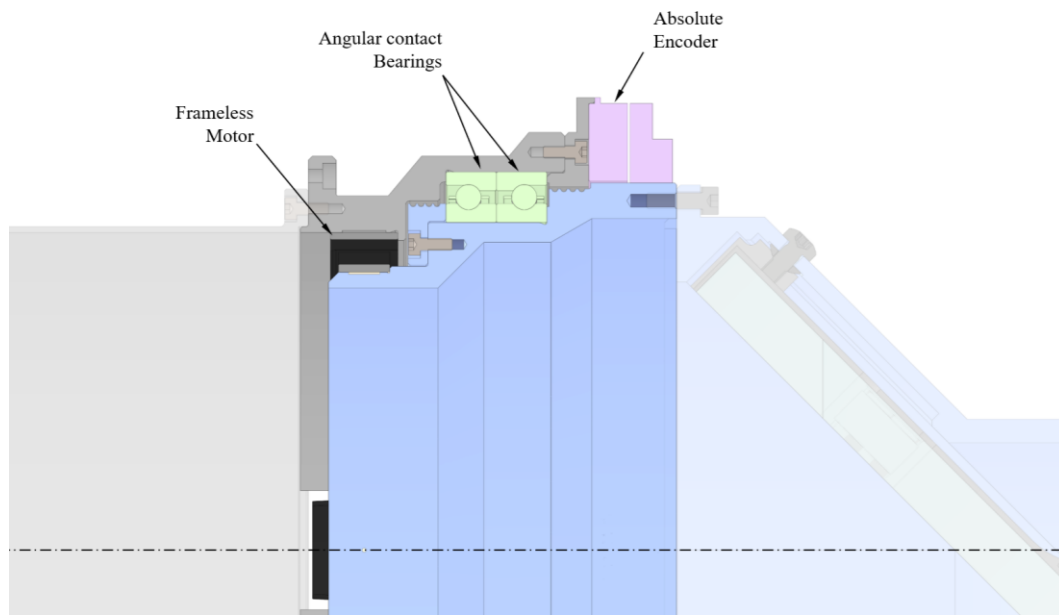


Figure 4. Scanning Mechanism cross-section view

It has to be noted that, even though a rotation range of $\pm 15^\circ$ is foreseen for the LEO earth observation application, none of the elements in the mechanism impose a limit on this. Thus, the same concept could be easily scalable to larger ranges that could be required for other use cases.

3.3 Rotating Structure

The rotating structure comprises all the moving elements, including the scanning mirror, corrector lenses, detector, and the structure that supports these. This section is based on a single part, the rotating frame, that serves as the interface with the rest of the system and supports all the elements that rotate with it.

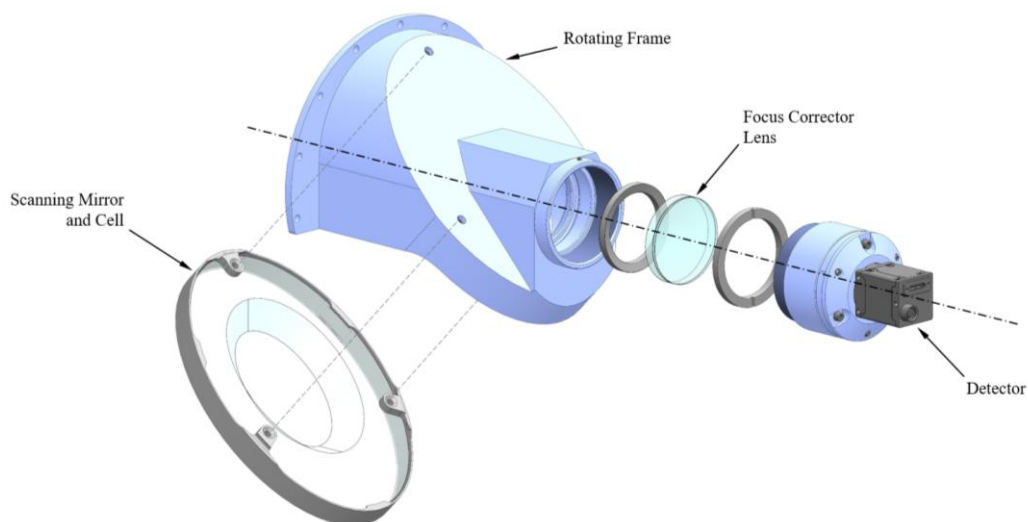


Figure 5. Rotating Structure exploded view

The elliptical scanning mirror is supported radially, in a similar way to primary mirror, via a separate cell that is then attached to the rotating frame.

The corrector lenses are directly integrated into the structure. The design of the contact surface between lens convex face and its respective cell have been conceived as a tangential seat. This design is generally regarded as the nearly ideal interface for convex surfaces. This tangential seat tends to produce smaller contact stress in the lens than other alternatives, such as sharp corner interfaces

The tangential seat for the corrective doublet is implemented on a dedicated support ring, which simultaneously serves as the axial positioning interface for the lens during the alignment process. If axial adjustment of the lens position is required, specialized shims can be inserted directly beneath this ring and cell's seat, enabling precise Z-direction tuning while preserving the centring of the optic. The lens remains accurately centred thanks to the machined centring feature integrated into the surrounding tube, which ensures that the shimming operation does not compromise lateral alignment.

The doublet position is secured using a threaded retaining ring. This ring applies a controlled preload onto the opposite face of the lens through a compliant elastomeric O-ring, which provides sufficient holding force to withstand launch and operational, while avoiding inducing undesirable stresses that could degrade the optical performance. After tightening, the retaining ring is locked in place using small dabs of a space-compatible epoxy adhesive, preventing any loosening of the threaded joint throughout lifetime.

Finally, the detector is attached to the back of the rotating frame through a low thermal conductivity ceramic part. This prevents the heat generated by it to be directly transmitted to the rest of the structure, which would induce thermal gradients leading to optical performance degradation. Additionally, for the assembly and alignment process it has been foreseen the possibility to adjust the axial position of the detector by shimming the coupling between the structure and the ceramic support part.

Given the system configuration the detector is attached to the rotating structure, thus requiring guiding of its cabling to the static part. This is done routing the cable through the rotating structure to the interface with the static part. There the cable is folded to a static cable guide ensuring that the flex cable follows a repeatable and constrained motion path throughout the full rotation range.

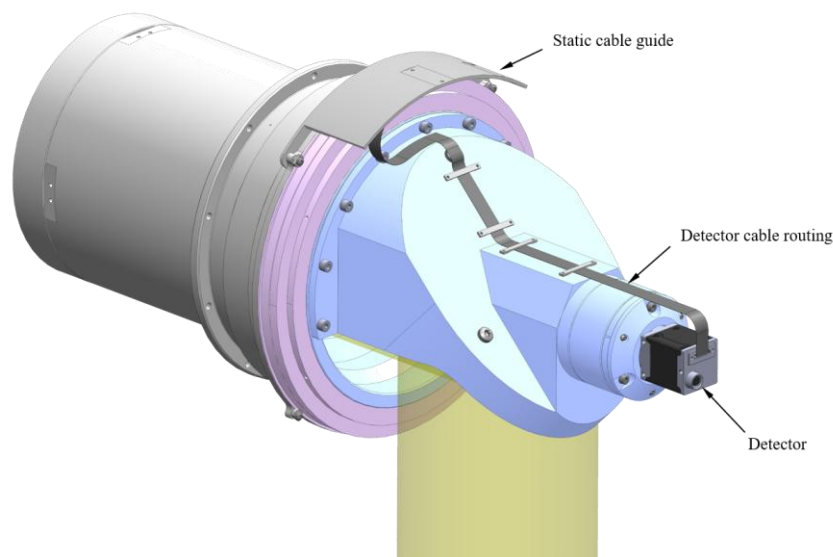


Figure 6. Detector Cable routing

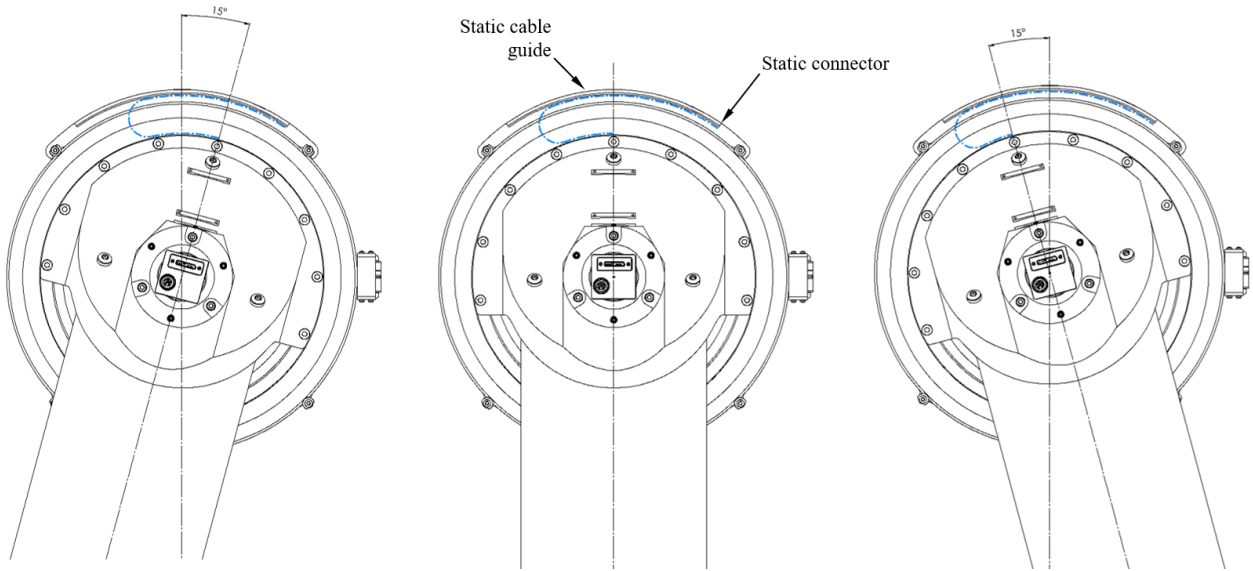


Figure 7. Detector Cable Wrap over rotation range

3.4 Thermal Performance Analysis

The optomechanical design has been conceived so that the camera can passively keep focus on a range of $\pm 10^\circ\text{C}$, this has, in this case, been achieved with a structure mainly based on INVAR parts keeping a short aluminium section at the end of the optical train, just in the coupling the detector, to compensate for the focal length changes with temperature, due to geometrical and optical elements refractive index changes. Zemax has been used to optimize the length of this aluminium section

Finally, the system has been verified not to introduce any significant degradation of the camera PSF.

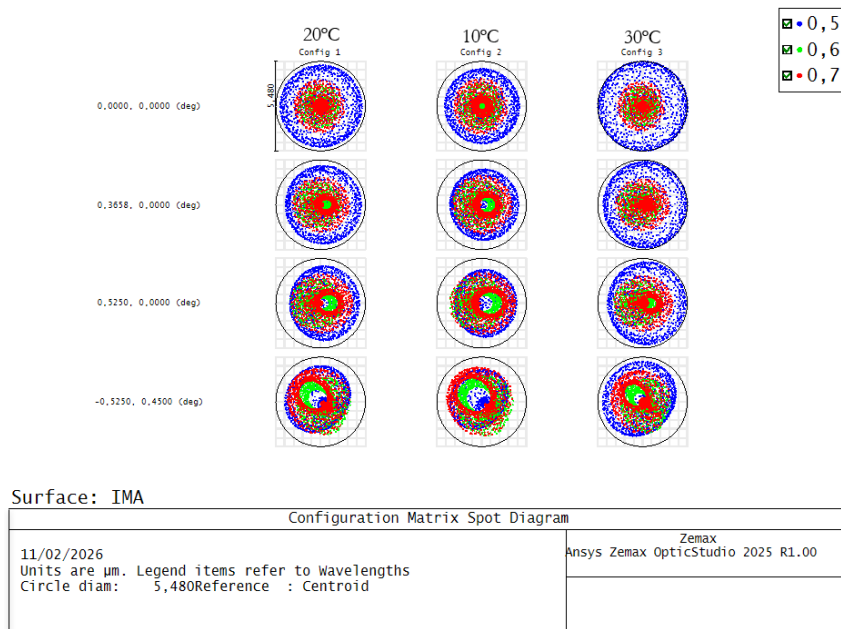


Figure 8. Thermal performance analysis results $\Delta T \pm 10^\circ\text{C}$ from an assumed initial condition of $T = 20^\circ\text{C}$

4. CONCLUSIONS AND NEXT STEPS

An implementation of the ScanCam concept has been developed for an Earth Observation application. The design features a compact prime focus telescope with a focus corrector with the lenses and detector mounted on the scanning mechanism together with a folding mirror that rotates around the primary mirror optical axis. The proposed design has been conceived to rotate $\pm 15^\circ$ but is easily scalable to higher ranges. The optomechanical design has been designed to be athermal being able to keep focus on a $\pm 10^\circ\text{C}$ range.

As of writing this paper, a fully functional breadboard is being produced and will be integrated and tested during the last quarter of 2026, reaching a TRL4.

REFERENCES

- [1] “An Optical System and Method for Scanning of Incident Light”, European Space Agency, European patent application EP 25 181 679.9, 2025, unpublished
- [2] Yoder P.R., “Opto-Mechanical Systems Design”, 3rd Edition CEC Press, Boca Raton, FL, USA
- [3] Yoder P.R., “Mounting Optics in Optical Instruments”, 2nd Edition, SPIE Press, Bellingham, WA, USA.