

Integration and test of the Ariel space telescope: status of the structural and engineering models

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ABSTRACT

The Atmospheric Remote-Sensing Infrared Exoplanet Large Survey (Ariel) is ESA’s M4 mission of the “Cosmic Vision” program, with the purpose of surveying the atmospheres of a large sample of known exoplanets through transit spectroscopy. Launch is scheduled for 2031.

Ariel is based on a 1 m class telescope, an off-axis unobscured Cassegrain whose mirrors and supporting structures are realized entirely in the aerospace-grade aluminum alloy 6061. The choice brings athermal behavior and ease of manufacturing, at the price of a structure that is comparatively compliant and that contracts substantially on cooling. The telescope must therefore be assembled and aligned on ground, at room temperature

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and under gravity, in a configuration appreciably different from the one in which it will operate: below 60 K and in weightlessness.

What can be measured on ground is dominated by effects that will not be present in flight, and the telescope must be aligned towards a configuration that cannot be directly observed. The response adopted for Ariel is to make the integration sequence itself the instrument of verification: rather than verifying the telescope only once it is complete, its optical state is characterized at successive stages of the build, in configurations chosen to separate the effect of gravity from the intrinsic contributions, and correlated at each step with the structural models that must ultimately predict the in-flight performance.

A previous paper presented this plan. Here we report its execution and the status reached by the structural and engineering models of the telescope. We discuss where practice has departed from the plan, the steps that remain towards the end-to-end cryo-optical test, and the outlook towards the Critical Design Review and the proto-flight model.

Keywords: space telescope, Ariel mission, aluminum mirrors, assembly integration and test (AIT), optical alignment, gravity release, cryo-optical testing

1. INTRODUCTION

Ariel (Atmospheric Remote-sensing Infrared Exoplanet Large-survey) is the fourth medium-class mission of ESA's *Cosmic Vision* program, devoted to surveying the atmospheres of about one thousand known exoplanets by transit spectroscopy.¹ The spacecraft is scheduled for launch in 2031 into an orbit around the L2 Lagrange point of the Sun–Earth system, where the payload is kept permanently shaded by the service module, allowing the telescope to cool passively to below 60 K.²

The payload is built around a 1 m class telescope: an off-axis, unobscured Cassegrain followed by a re-colimating parabolic tertiary and a flat folding mirror, which delivers a collimated beam to the optical bench.³ There the beam is shared between the Fine Guidance System, providing photometry in three visible channels and low-resolution spectroscopy up to 1.95 μm , and the Ariel InfraRed Spectrometer (AIRS), covering 1.95 μm to 7.8 μm .⁴ The secondary mirror is mounted on a mechanism (M2M) that allows tip, tilt and focus to be used for in-flight adjustments and fine alignment on ground. The telescope is required to be diffraction limited at 3 μm , which by the Maréchal criterion corresponds to a total wavefront error (WFE) of 214 nm RMS.⁵ The mechanical layout of the Telescope Assembly (TA) is shown in Figure 1.

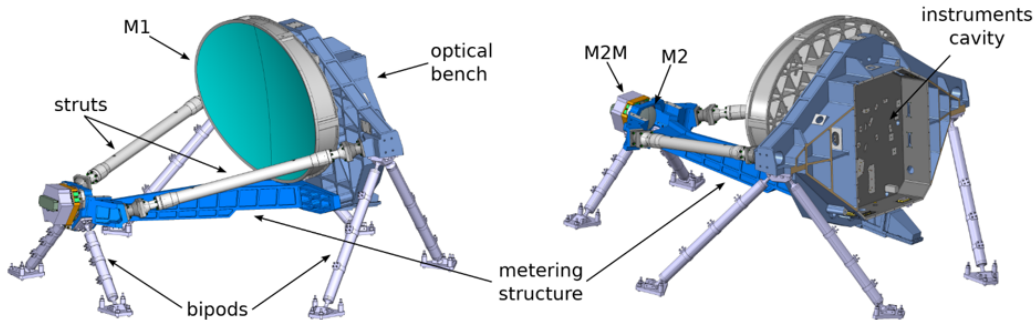


Figure 1. Mechanical design of the Ariel Telescope Assembly.

The mirrors and all the supporting structures are manufactured in the aerospace-grade aluminum alloy 6061-T6, selected during the assessment phase for its athermal behavior, availability, cost and machinability.⁶ Two consequences of that choice have shaped the assembly and verification of the telescope from the outset: the first is that aluminum is considerably less stiff than the glass ceramics and silicon carbide normally used for mirrors of this size. Under gravity the wavefront error introduced by telescope deformation is far larger than the alignment procedure's own target: against some tens of nanometers RMS for the alignment, the structural–thermal–optical (STOP) analysis predicts about 620 nm RMS from gravity alone, the contribution of M1 by itself being about 720 nm RMS (Figure 2).⁷ Any optical measurement performed on the ground is therefore dominated by a

contribution that will disappear in flight, and the telescope must be aligned towards a configuration that cannot be observed directly.

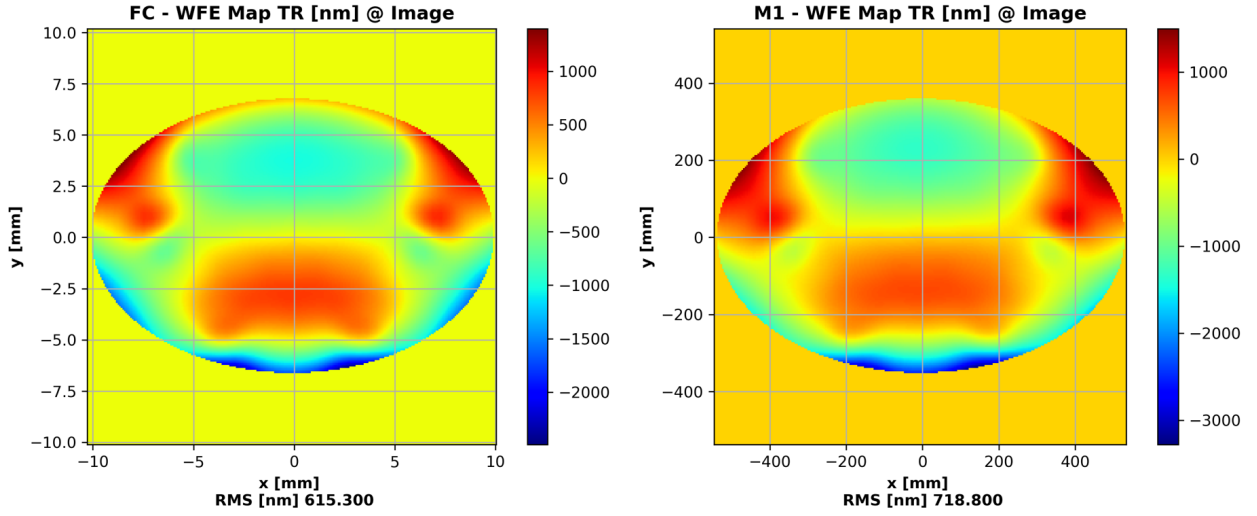


Figure 2. Wavefront error of the Telescope Assembly predicted on the ground by the STOP analysis, dominated by the gravity term (left) and corresponding WFE of the M1 mirror alone (right). Piston, tip and tilt terms are removed from the maps.

The second is the relatively high coefficient of thermal expansion of aluminum. Alignment is necessarily performed at room temperature, so the telescope reaches its operating configuration only by contracting isomorphically as it is cooled. Verifying that it does so is the purpose of the end-to-end cryo-optical test performed at the end of the TA Engineering Model assembly, integration and test (AIT) sequence.

The Telescope Assembly is developed through a sequence of models. The Structural Model (SM), with mass dummies in place of the mirrors and the M2M, verifies the mechanical architecture and rehearses the integration procedures. The Engineering Model (EM) is the first model on which the optical performance of the telescope is verified. Finally, lessons learned from the EM campaign feed the design of the proto-flight model (PFM), which will be approved at the Critical Design Review (CDR).

M1 is going to be the largest aluminum mirror to fly in a space mission. Its development required advances in the manufacturing technologies, especially for the diamond turning, polishing and mounting. Given its size and the low stiffness of aluminum, M1 is the largest expected contributor to gravity-induced and mounting deformations. A series of gravity release measurements are therefore crucial to assess the deformation through assembly and integration, allowing the development of a carefully designed mounting procedure to keep that deformation small.

The technological development started before the Preliminary Design Review (PDR) with a full-size demonstrator (PTM) and two breadboards (BB1 and BB2) that were used to develop the lightweighting and polishing processes and to make an initial assessment of thermomechanical stability.⁸ The structural model campaign was provisioned to take this further with the manufacturing of two M1 models: the non-optical dummy M1 integrated on the TA SM and an optically measurable M1 with diamond turned surface available for standalone testing (Section 3). Measuring that unit in opposite orientations with respect to gravity resolved its gravity-induced deformation and allowed it to be correlated with the finite element model (FEM), while the residuals confirmed the expected magnitude of the contribution of the interfaces through which the mirror is held.⁹

Cryogenic tests of the same model are now ongoing at the INAF Osservatorio Astronomico di Palermo (INAF-OAPA)¹⁰ to derisk the development ahead of the final cryo-optical test of the TA EM. On this basis the single gravity-release measurement originally foreseen in the plan has grown into the sequence of measurements described in Section 4. An M1 EM was then manufactured and integrated on the TA EM, which is now being

aligned and will be tested in the cryo-optical test at the Centre Spatial de Liège (CSL). An Elegant Bread Board (EBB) M1 has also been manufactured and is slated to become the candidate flight mirror (Section 6).

The models, and the activities carried out on each of them, are summarized in Figure 3.

In a previous paper we described the plan devised for the AIT of the Ariel telescope: the integration sequence, optical alignment procedure, the strategy adopted to estimate gravity release on the entire TA, the shimming strategy to fix the position of the secondary mirror on ground and in flight, and the test campaign.⁵ This paper reports on the execution of that plan, with the status of the structural and engineering models as of September 2026 as outlined in the following sections.

Section 2 recalls the AIT plan and describes the two significant changes it has undergone. Section 3 reports on the structural model, and Section 4 on the integration of the engineering model and the characterization performed along the build sequence. Section 5 outlines the test campaign ahead, and Section 6 the road towards the CDR and the proto-flight model.

Ariel Telescope Assembly — development models and the activities carried out on them

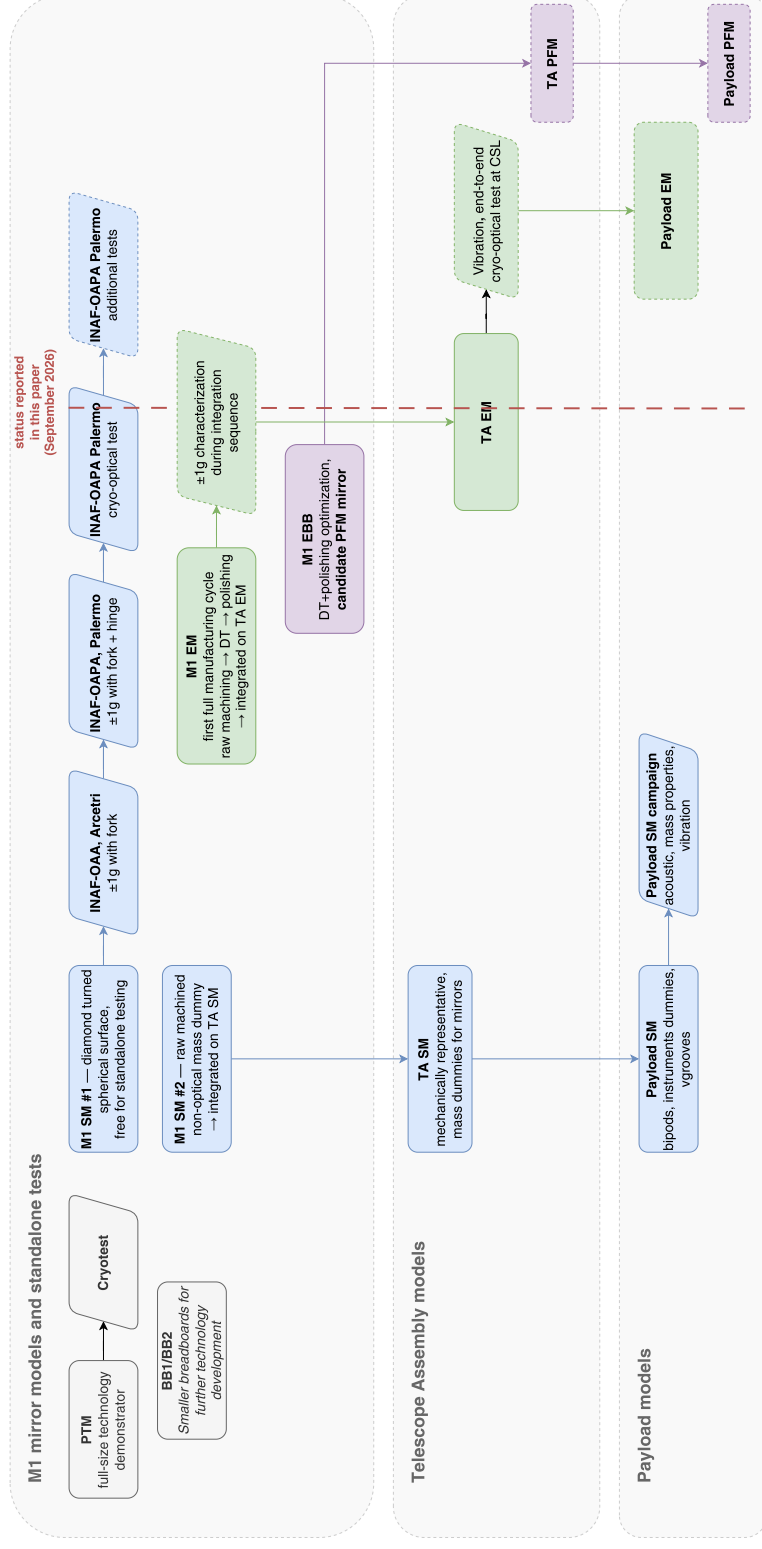


Figure 3. Overview of the development models and activities of the Ariel Telescope Assembly described in this paper.

2. AIT PLAN EVOLUTION

2.1 The original plan in brief

The initial AIT plan of the TA, developed for the Preliminary Design Review milestone, was presented at SPIE 2024.⁵ We present here its main points, and the findings and optimizations that followed the completion of the TA SM program and of the further M1 development models.

Integration sequence. The telescope is built from the optical bench outward. The first step is to mount the three flexure hinges on M1 and then M1 is mounted on the Telescope Optical Bench (TOB) through the three flexure hinges shown in Figure 4; the M2M and its supporting structure, the recollimating tertiary and the folding flat, the struts and the harness follow (Figure 5).

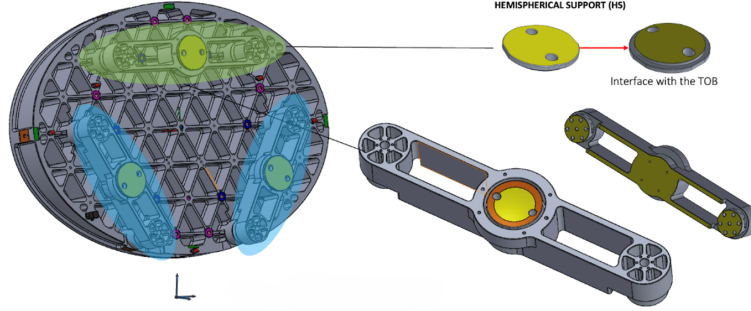


Figure 4. M1 with the three flexure hinges used to mount it on the Telescope Optical Bench.

Three-step optical alignment. The initial optical alignment plan consisted in three steps guided by interferometric measurements in double pass (see Figure 6 for reference). In the first, M2 is aligned against M1 with the interferometer at the intermediate Cassegrain focus and a large auto-collimation (AC) flat in front of M1, M2 and the AC flat acting as the compensators; in the second, the tertiary and the folding flat are aligned illuminating them from the intermediate Cassegrain with a small auto-collimation flat at the telescope exit pupil. The last step consisted in an end-to-end measurement at the telescope exit pupil in double pass, with the AC flat.

Gravity release. The telescope wavefront error measured at the exit pupil on the ground is dominated by gravity (Section 1). The expected zero-gravity wavefront error is therefore derived by correlating FEM simulations with a gravity release measurement: the telescope is measured in two opposite orientations with respect to gravity and the two results averaged, their difference being the gravity term. The 2024 plan foresaw one such $\pm 1g$ measurement at Telescope-Assembly level, obtained by rotating the telescope on its bipods (Figure 7), feeding the correlation of the STOP models.

Ground and flight shims. The position of M2 on the telescope after alignment is set by a shim at the interface between the M2M and the TMS. Two shims are foreseen: a *ground* shim, used during alignment and testing of the TA on the ground until payload integration, and a *flight* shim, which places M2 in the calculated position that optimizes the telescope alignment in the absence of gravity and at the cryogenic operating temperature (Figure 8). The flight shim is derived from the gravity-release and STOP results.

Test campaign. The TA EM is subjected to a set of environmental tests: a vibration test followed by a cryo-optical test, in which the telescope is cooled to its operating temperature and the wavefront error measured, to verify that the aligned telescope reaches its optical configuration on cooldown.

The plan was developed jointly with Leonardo S.p.A.^{*}, who translated it into the detailed assembly and alignment procedures and carry out all integration activities.

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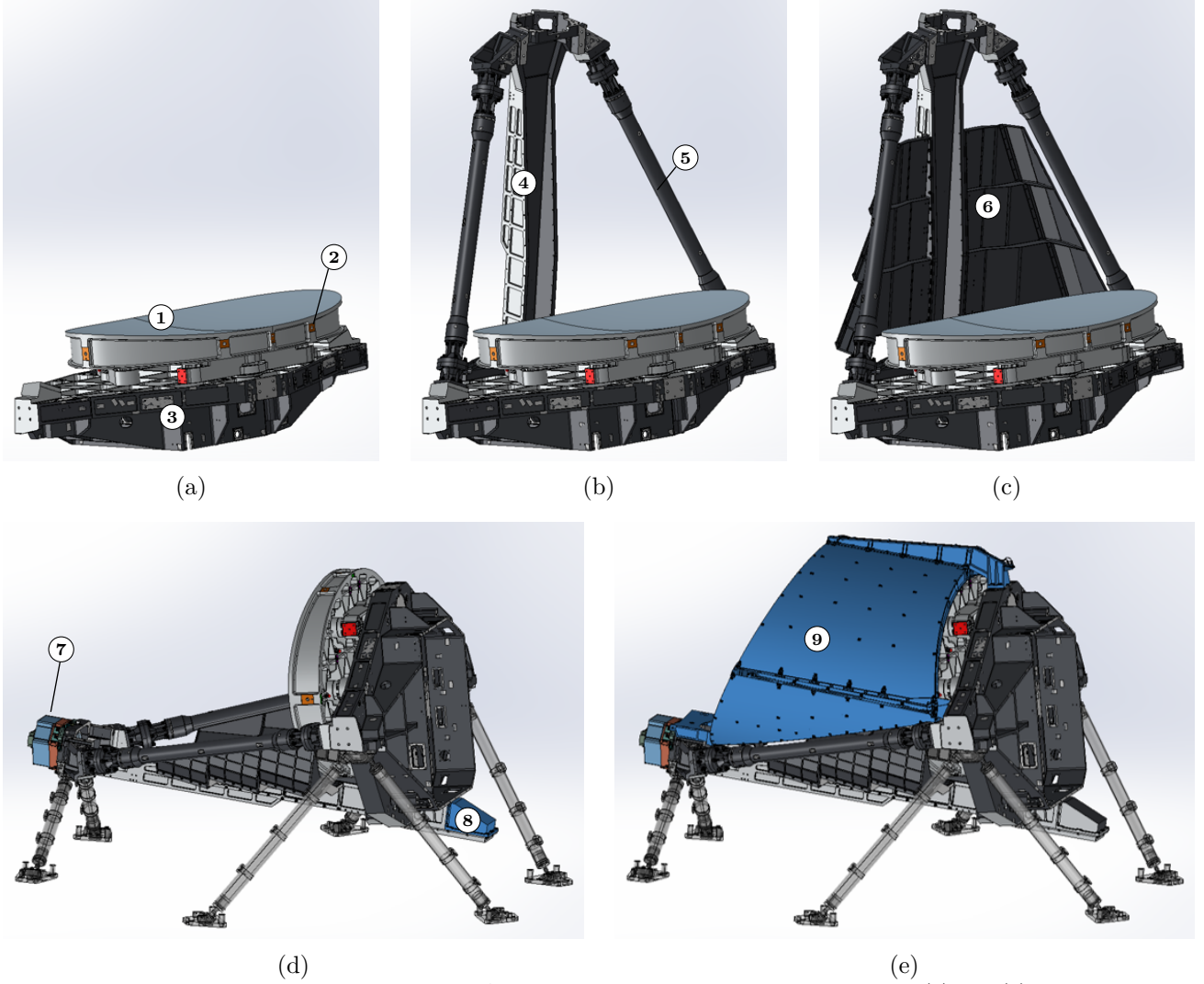


Figure 5. Integration sequence of the Telescope Assembly, from the optical bench outward. (a) M1 (1) is mounted first on the TOB (3) through the three flexure hinges (2); (b) the telescope metering structure (TMS, 4) and the struts (5) follow; (c) then the contamination shield (6); (d) the M2M with M2 (7) and the M3/M4 box (8); (e) finally the baffle (9). The bipods visible in (d) and (e) support the assembly on the ground and are not part of the Telescope Assembly. The engineering model in the configuration of panel (c) is shown in Figure 15.

2.2 Plan evolution overview

As mentioned in the introduction, to characterize the evolution of mounting effects on the surface of M1 during the various TA integration steps, the integration plan now foresees a sequence of gravity release measurements at four successive build states: M1 alone; M1 with the three flexure hinges installed; M1 mounted on the TOB; and M1 on the fully assembled TA. The contribution of the mounting is thereby separated from that of gravity and attributed as the telescope is assembled. The M1 mounting procedure was also further optimized with the goals of minimizing stress induced on the mirror that would reflect on its surface error and improving repeatability. This is the subject of Section 4.

The alignment plan was subsequently optimized to a two-step procedure. Both steps are performed with the telescope on its bipods and are double-pass measurements closed on an AC flat large enough to cover the M1 aperture, and they differ only in where the interferometer is placed: at the intermediate focus to align M2 against M1, and at the telescope exit pupil to align the tertiary and the folding flat and verify the telescope end

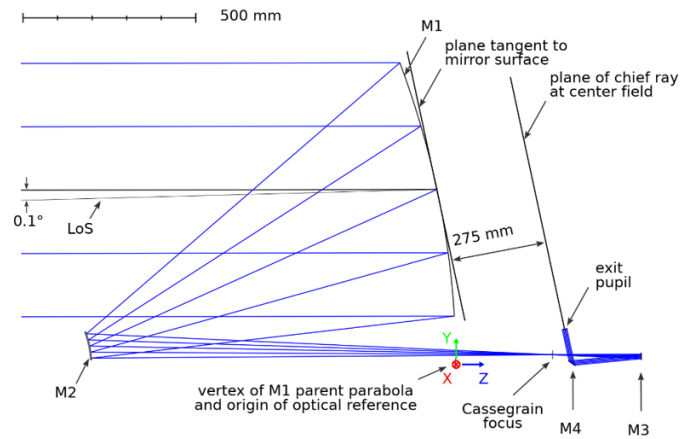


Figure 6. Optical design of the Ariel Telescope.

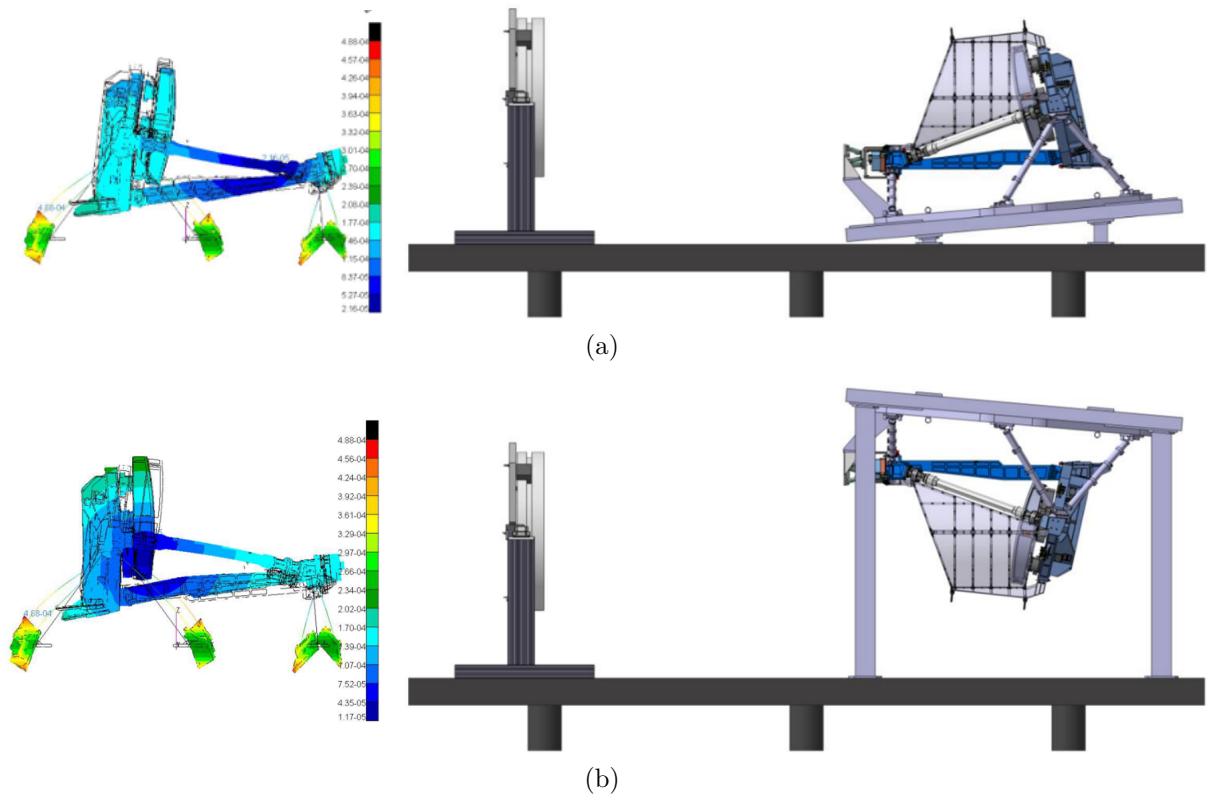


Figure 7. Gravity release at Telescope-Assembly level. The telescope is measured in its nominal orientation (a) and rotated by 180° on its bipods (b). The AC flat sits on the optical bench to the left of the telescope in both cases. For each orientation the predicted deformation is shown on the left and the corresponding alignment configuration on the right; the average of the two measurements gives the intrinsic wavefront error and their difference the gravity term.

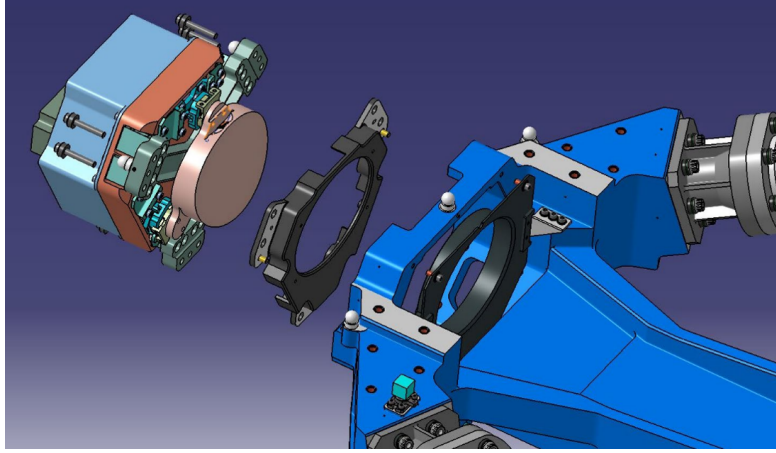


Figure 8. The shim used to adjust the position of M2 after telescope alignment is seen in the middle of this picture between the M2M+M2 block on the left and the telescope structure on the right. Note the retroreflective reference spheres on the M2M and on the telescope structure, used to measure the relative position of M2 with a laser tracker. The shim is designed to be replaced with a flight shim after the TA cryo-optical test.

to end. Dropping the separate configuration that the 2024 plan used for M3 and M4 removes one interferometric set-up and the error sources that came with it. The procedure as executed on the engineering model is described in Section 4.

3. THE STRUCTURAL MODEL

The Structural Model of the Telescope Assembly reproduces the flight design in dimensions, mass, interfaces and mass properties, moments of inertia and center of gravity included, with mass dummies in place of the mirrors and the instruments. Its integration was concluded at the end of 2025 and the model was shipped for integration into the payload module⁹ (Figure 9).

Its purpose was not only to verify the mechanical architecture but to rehearse the integration procedures in view of the EM, and above all the mounting of M1 on the TOB through the three flexure hinges, the operation the 2024 plan had identified as the most delicate of the sequence.

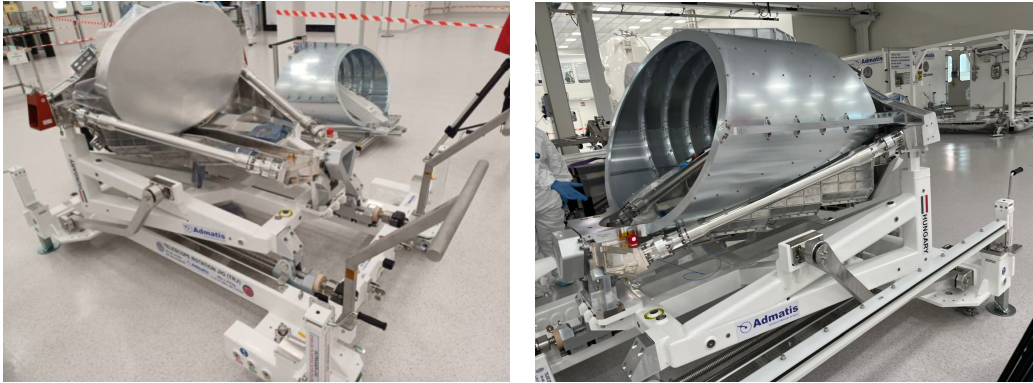


Figure 9. The TA Structural Model. Left: in the final integration stage, with the raw-machined M1 dummy mounted on the TOB and the M1 baffle, still to be integrated, visible behind.⁹ Right: fully assembled and ready to be shipped to RAL Space for integration on the bipods and installation of the dummy instruments, the instrument radiator cover and the V-grooves. In both photographs the model is mounted on a transport and rotation ground support equipment (GSE) from Admatis. Image credit: Leonardo S.p.A.

Handling of the assembly relies on a dedicated transport and rotation GSE supplied by Admatis[†], which also

[†]Admatis Ltd., 5 Kandó Kálmán Str., 3534 Miskolc, Hungary

carries the model through the payload-level campaign.

Two M1 SM units were manufactured to the same mechanical design.⁹ One was left raw-machined and is the mass dummy integrated on the TA SM; the other was additionally taken through diamond turning, so that it could be measured interferometrically. Its optical surface is spherical rather than the off-axis parabola of the flight mirror, which makes the measurement far easier, while dimensions, mass properties and mechanical interfaces stay representative; after diamond turning its surface form error is 1360 nm RMS, smooth enough for reliable interferometry.

The diamond-turned M1 underwent a first series of room temperature measurements at the INAF Osservatorio Astrofisico di Arcetri (INAF-OAA) in Florence (Figure 10), mounted on a fork support specifically designed for gravity release measurements (similar to the one visible in Figure 11a). It yielded a gravity-induced deformation of 255 nm RMS⁹ agreeing with the FEM prediction to better than 15 nm RMS.

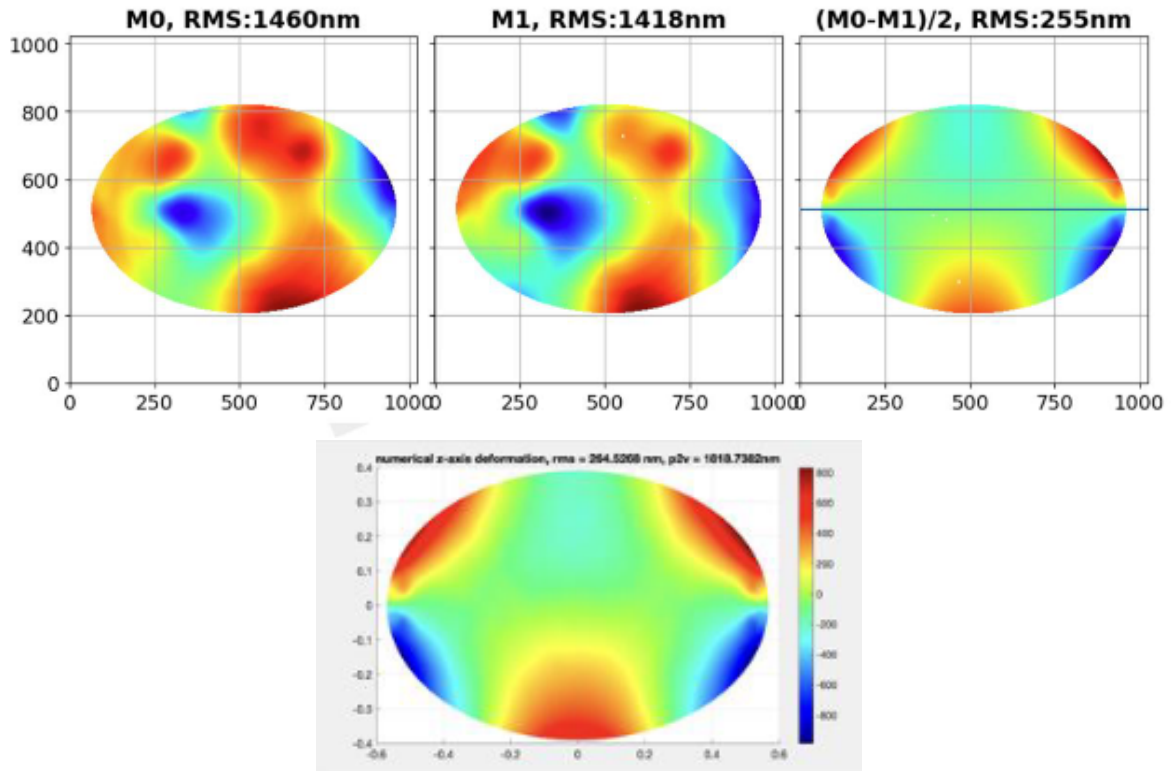


Figure 10. Comparison of the measured (top) and FEM predicted (bottom) gravity-induced deformation of the M1 SM mirror. The top row shows the +1g (indicated as $M0$) and -1g ($M1$) measurements and the difference between the two, amounting to the gravity effect. Measurement and prediction agree to better than 15 nm RMS.⁹

The mirror then continued its tests at the cryogenic facility of INAF-OAPA. The campaign consists of room-temperature interferometric measurements of M1 alone on an improved gravity-release fork, and then of M1 with one flexure hinge mounted, to evaluate the effect of the mounting on the surface error. The mirror was then positioned inside a cryostat, where measurements at ambient temperature and pressure were followed by two cooldown cycles; correlation of the difference between the room-temperature and cryogenic measurements with the models is under way. One early giveaway from the test is the confirmation that the mirror, due to the high thermal expansion coefficient of aluminum, is very sensitive to temperature gradients on its surface, as expected. The facility is shown in Figure 11.

In parallel to the M1 SM cryo-optical tests, the structural testing of the TA SM was performed on the fully integrated Payload SM: instrument dummies, bipod supports and V-groove radiators. The payload structural model was integrated during 2025 and taken through acoustic, mass-properties and vibration testing at the UK



(a)



(b)

Figure 11. The M1 SM test facility at INAF-OAPA in Palermo. (a) The interferometric set-up used for the room-temperature measurements; (b) the cryogenic chamber, with the gas-handling system on the left, in which the mirror is measured through an optical window during the cooldown cycles.¹⁰ Image credit: INAF-OAPA.

National Satellite Test Facility in the first quarter of 2026.² Pre- and post-test modal surveys showed no change in structural response and the post-test inspection found no damage; the relative orientation of the optical alignment cubes, measured with theodolites before and after the campaign, was stable to the accuracy of the measurement itself, approximately 6".

4. INTEGRATION OF THE ENGINEERING MODEL

The Engineering Model is form, fit and functional with respect to the flight design, built from components that are not space qualified, and it will go through the whole performance verification campaign at both Telescope-Assembly and payload level.⁹

Manufacturing of the EM parts was completed during 2025. The parts were painted black for thermal reasons and then baked out for decontamination, and integration was authorized at the Integration Readiness Review and started at Leonardo in December 2025. The TOB, which carries M1 and hosts the instruments in its bay, was machined from a single aluminum block 1.5 m on a side, so that the coefficient of thermal expansion is as homogeneous as possible and the thermo-elastic deformation transmitted to M1 correspondingly small; its critical interfaces are finished to micrometer precision by fly-cutting or diamond turning. The TMS connects the TOB to the M2M and M2. Both are shown in Figure 12.

The mounting sequence of M1 on the TOB, as anticipated in Section 2, is the most complex and delicate since the mirror has proven to be very sensitive to induced stresses that deform measurably the optical surface.



Figure 12. TOB (left) and TMS (right) of the Engineering Model after painting and bakeout, ready for integration. The TOB carries M1 and hosts the instruments in its bay; the TMS connects it to the M2M and M2. The areas left unpainted are the machined interfaces, kept bare for the components mounted on the structure — temperature sensors, accelerometers and, in the instrument bay, the instruments themselves. Image credit: Leonardo S.p.A.

This is the reason why the M1 mirror was measured after each step, at the four build states listed in Section 2, so in case of anomalies the source could be identified and corrected before proceeding to the next step.

After measuring the M1 EM mirror alone in $+1g$ and $-1g$ configurations on the fork designed by INAF-OAA (Figure 13a), and comparing the result with the outgoing measurement at the manufacturer (MediaLario S.r.l.[‡]), the flexure hinges were mounted and the mirror was measured again to assess the effect of the mounting.

Then the critical step of mounting M1 on the TOB and adjusting its position in the x-y plane, parallel to the back surface of the mirror, and clocking, was performed. The step was further optimized with respect to the initial version, rehearsed on the SM. The procedure was made iterative, with the mirror lifted and lowered several times to check the repeatability of the operation and to verify that the mirror was not stressed by the mounting. The position of M1 was measured with a laser tracker through reference spheres on its back face and on the TOB, and adjusted until it was within the required tolerances. The final position was verified with a second measurement, and the mirror was then locked in place.

After this step, the mirror on the TOB was measured again using a new fork capable of supporting the heavier TOB+M1 configuration. The measurement procedure was repeated in $+1g$ and $-1g$ configurations (Figure 13b).

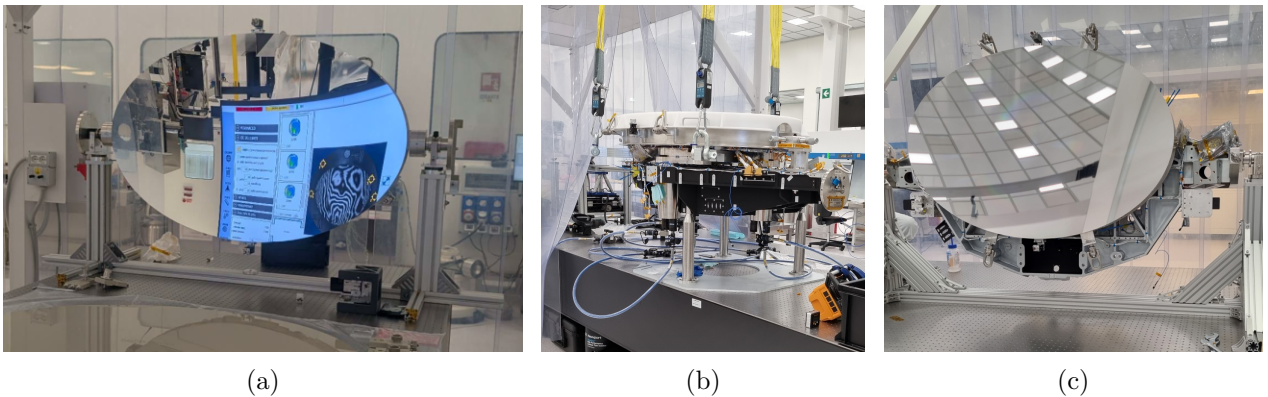


Figure 13. Gravity-release measurements along the build sequence of the Engineering Model. (a) M1 alone on the fork support; (b) M1, under its protective cover, being lowered onto the TOB, the step whose repeatability the sequence is meant to check; (c) M1 mounted on the TOB, on the larger fork built to carry the two together. Each configuration is measured in $+1g$ and $-1g$, the average giving the intrinsic shape and the difference the gravity term. Image credit: Leonardo S.p.A.

[‡]MediaLario S.r.l., Bosisio Parini (LC), Italy

The build then followed the planned sequence. The TMS, the struts, the contamination shield were integrated on the TOB and the Telescope Assembly is waiting to be mounted on its bipods, in the configuration in which it will be aligned, after a last gravity release measurement using the same TA support GSE of Figure 7; optical alignment is due to begin in October 2026.

Optical alignment. The two-step procedure outlined in Section 2 is executed as follows; the two configurations are shown in Figure 14. Before the optical set-up is assembled, M1 is positioned metrologically on the TOB in decenter and clocking, and its vertex located with a laser tracker through reference spheres on its back face and on the bench: this is part of the M1 mounting procedure described before. The AC flat is then set with a theodolite with respect to the telescope nominal line of sight, sighting on the M1 reference cube through a dedicated aperture in the TOB. Referring it to the mirror establish the telescope line of sight that will be kept fixed for the remainder of the alignment procedure.

Step 1 — double pass at the intermediate focus. M2, carried on a hexapod, is placed with respect to the M1 vertex; the interferometer, fitted with a transmission sphere, has its beam focused at the intermediate focus, materialized with a pinhole. From here M2 is the only compensator, and the five degrees of freedom of the hexapod are adjusted iteratively until the low-order aberrations are minimized, each of them driven by a defined M2 degree of freedom. The axial position of M2 is by far the most sensitive parameter of the procedure, a micrometer-scale displacement producing a readily measurable amount of power.

Step 2 — double pass at the exit pupil. M3 and M4 are then mounted at their nominal positions with respect to the TOB to metrological precision and the interferometer is moved to the telescope exit pupil. The intermediate focus is first recentered using the M3 and M4 tilts, which brings the light back into the interferometer; then the output wavefront error is iteratively minimized while keeping the exit beam at the exit pupil aligned in centration and tilt.

The flow has been verified by Monte Carlo analysis in the optical design model, with and without gravity. It converges, although gravity effects are significant as anticipated in the introduction. The simulation covers the optical procedure alone: mirror figure errors, mounting errors, and the finite resolution of the hexapod carrying M2 and of the ground support equipment are not yet included, and their allocation is among the items being closed towards the CDR.

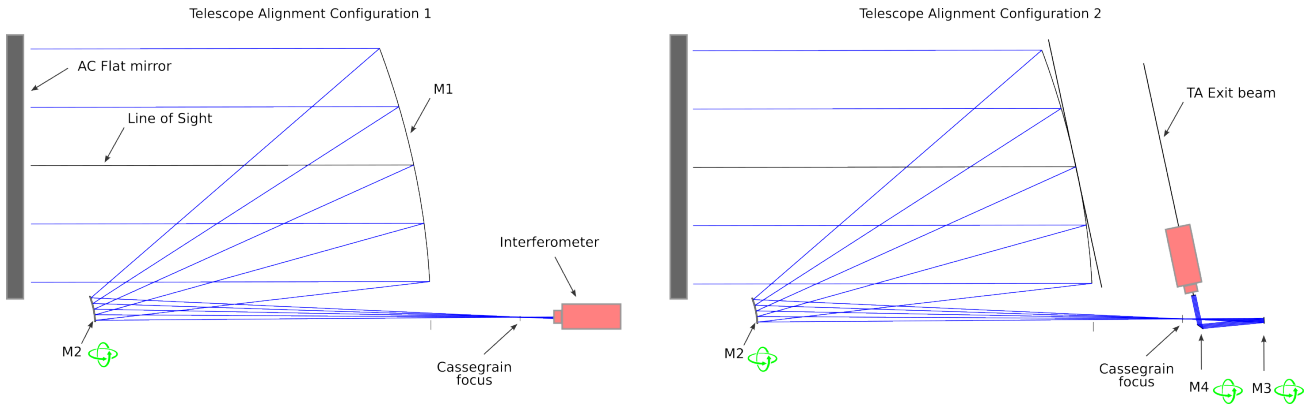


Figure 14. The two optical alignment configurations, after M1 is installed and aligned on the TOB and the AC flat is aligned with respect to the nominal line of sight. Both are double-pass measurements closed on the auto-collimation flat placed in front of M1. In configuration 1 the interferometer sits at the Cassegrain focus and M2 is the compensator, M3 and M4 not yet being on the bench; in configuration 2 they are mounted and the interferometer is moved to the telescope exit pupil, where the telescope is aligned and verified end to end. The green symbols mark the elements adjusted in each configuration.

Meanwhile, before integration on the TA, the M2M was tested with dedicated electrical ground support equipment (EGSE) developed by INAF-OAA to confirm that the mechanism is functional and can be operated correctly.

The state reached at the time of writing is shown in Figure 15.

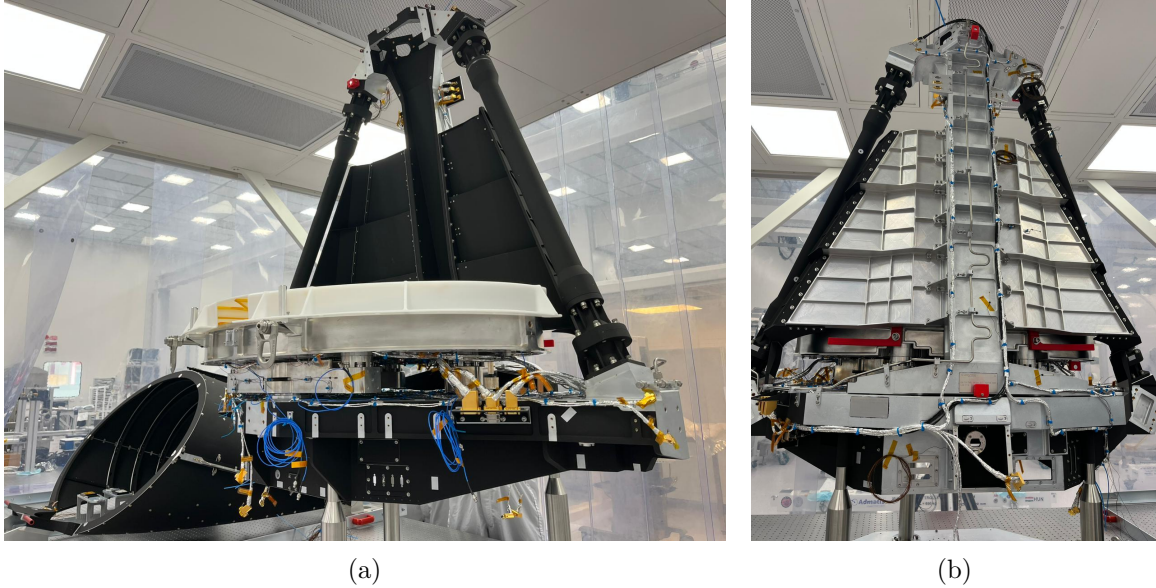


Figure 15. The Telescope Assembly Engineering Model as integrated at Leonardo, in the build configuration of Figure 5(c). (a) Front view, with M1 under its protective cover; the M1 baffle stands on the floor to the left; (b) rear view, showing the lightweighted back of the TMS and the M2M purge pipe routed along it. Image credit: Leonardo S.p.A.

5. THE TEST CAMPAIGN AHEAD

Once alignment is complete the engineering model enters its environmental campaign: vibration testing and end-to-end cryo-optical test at CSL.

The vibration test of the TA, consisting of quasi-static and sine test will be crucial to determine the effects of the mechanical loads on the optical performance of the telescope. While the vibration test on the Payload SM did not highlight any significant metrological change, the test on the TA EM will be followed by an optical end-to-end alignment test to verify that the telescope is still aligned and that the optical performance is within the requirements. The test will be performed in the exact same configuration as the alignment, with the telescope on its bipods and the interferometer at the exit pupil.

The cryo-optical test verifies the telescope at its operating temperature below 60 K. The set-up (Figure 16), designed and built at CSL, measures the end-to-end wavefront error in double pass on the same auto-collimation flat used for the room-temperature alignment (Section 2). The telescope, on its bipods, is mounted on a hexapod inside a large vacuum chamber and cooled by a copper thermal tent circulated with gaseous helium at 20 K; a thermal tunnel with a remotely operated shutter isolates it from the flat and limits the chamber heat load. Relay optics carry the beam from the interferometer outside the chamber to the telescope exit pupil, part of them on a second hexapod for adjustment during the test.

A first measurement is taken at room temperature, once the two hexapods and the flat are aligned, then repeated after cooldown and again after the telescope returns to room temperature. Thermal contraction is expected to spoil alignment and pointing on cooldown, so the two hexapods are operated to restore it before the cryogenic wavefront is measured. The difference between the wavefront errors at room and cryogenic temperature is expected to be small and consistent with the thermoelastic effects predicted by simulation; the two room-temperature measurements, before and after the cycle, should agree and confirm that the configuration has not changed. As in the alignment, the measurement is complicated by the large gravity-induced WFE of M1 and the structure, so all sources of measurement error have to be carefully estimated beforehand.

The cryogenic tests of the M1 SM at INAF-OAPA showed the mirror to respond measurably to small gradients across it as mentioned in Section 3, which places gradient control among the driving requirements on the set-up. Measurements of the thermal conductance of the M1 mounting interfaces have since returned values above those

assumed in the early thermal models,⁹ so the gradients the assembly actually sustains are expected to be smaller than once predicted. The requirement is nonetheless set by the sensitivity of the mirror.

One additional test planned for the TA EM is the characterization of the M2M, planned as a follow-on of the alignment: the mechanism was calibrated in terms of linear movement of the three actuators and angular movement of a representative dummy mirror at ambient and cryogenic temperatures. Once mounted on the TA, the effects of M2M movements will be characterized by commanding a pre-defined set of positions and acquiring the resulting WFE at the exit pupil of the telescope.

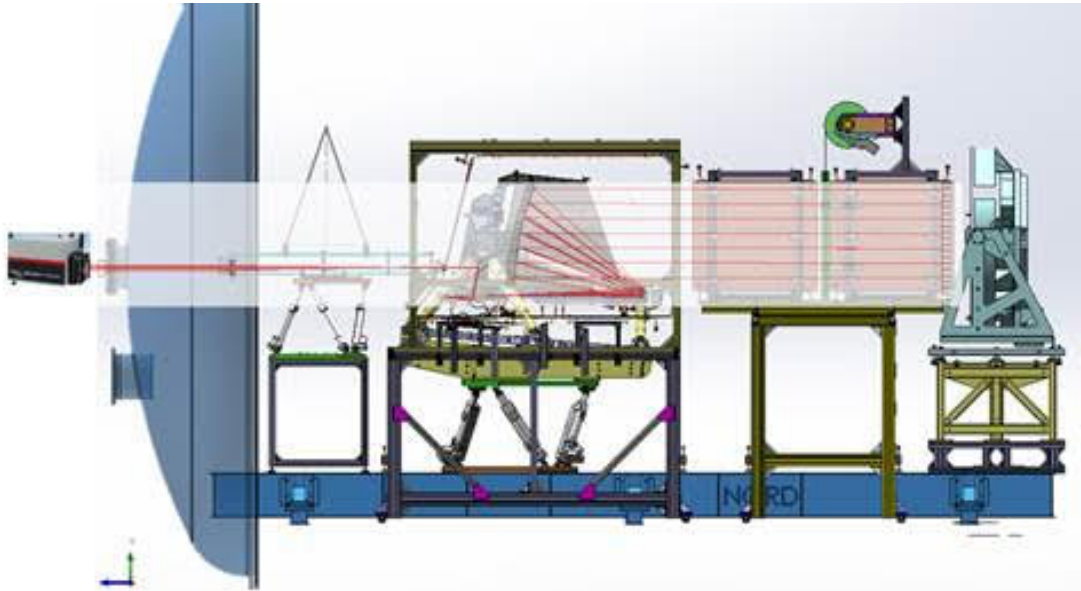


Figure 16. Schematic representation of the cryo-optical test setup for the Ariel Telescope Assembly at CSL, with the optical path of the interferometric measurement superimposed.

6. TOWARDS THE PROTO-FLIGHT MODEL

Manufacturing of M1 has continued in parallel on a further model. The EBB was introduced to refine the process by which the mirror is made. The diamond turning that precedes polishing was reworked around a redesigned adapter plate and a mounting procedure repeatable enough to allow toolpath compensation, and an additional pitch-polishing step was added to the polishing sequence.¹¹ The gain is concentrated in the medium spatial frequencies, which polishing can only partially recover once they are present and which act directly on the throughput of the telescope. The EBB is the candidate proto-flight mirror.

Leonardo is now in charge of the design of the proto-flight Telescope Assembly, which the Critical Design Review will examine. Preparation for the review is already under way, and it draws on everything described in this paper: the structural model that rehearsed the integration, the engineering model that is now executing it, the gravity-release sequence and the correlated models that come out of it. That is, in one sentence, what the EM campaign is for. The proto-flight design itself cannot be described publicly before the review.

7. CONCLUSIONS

Two years after the AIT plan for the Ariel telescope was published, it has met the hardware.

The structural model verified the mechanical architecture and rehearsed the integration procedures, above all the mounting of M1 on the optical bench, and passed through the payload-level environmental campaign with its interfaces stable to the accuracy of the measurement. A second M1 SM unit, kept optically measurable and free of the assembly, established the gravity-release measurement and correlated it with the finite element model to

better than 15 nm RMS. The engineering model has been integrated up to its bipods, and M1 is being measured at each build state as the assembly proceeds.

Two things have changed with respect to the plan, and both follow from the same recognition: that the way M1 is mounted deserves characterization in its own right. The single gravity-release measurement became a sequence of four, one at each build state, and the alignment flow was simplified. Neither is a correction of the plan. Both are what two years of hardware taught about where the effort belongs.

What remains open is the part that matters most. The telescope has not yet been aligned, and the cryo-optical test intended to show that an aluminum telescope aligned warm and under gravity arrives at its configuration cold and weightless is still ahead of it. Those results, and the correlated models that will come with them, are what the Critical Design Review and the proto-flight design will be built on.

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