Aluminum based large telescopes: the ARIEL Mission case

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INTRODUCTION

The Telescope Assembly (TA) of the ARIEL space mission passed the Preliminary Design Review (PDR) in 2023. Due to the high degree of innovation and risk of the implementation (see [1] and [2]), the Design Authority remained with the team headed by INAF both for the structural model (SM) and for the engineering one (EM) which are under construction in the recent months. At the same time, it continues the Research & Development activity on some critical parts of the telescope, mainly the Primary Mirror M1 with its mechanical support and the M2-M4 mirrors. Here below is shown the TA structure, highlighting the main components (see [3]).

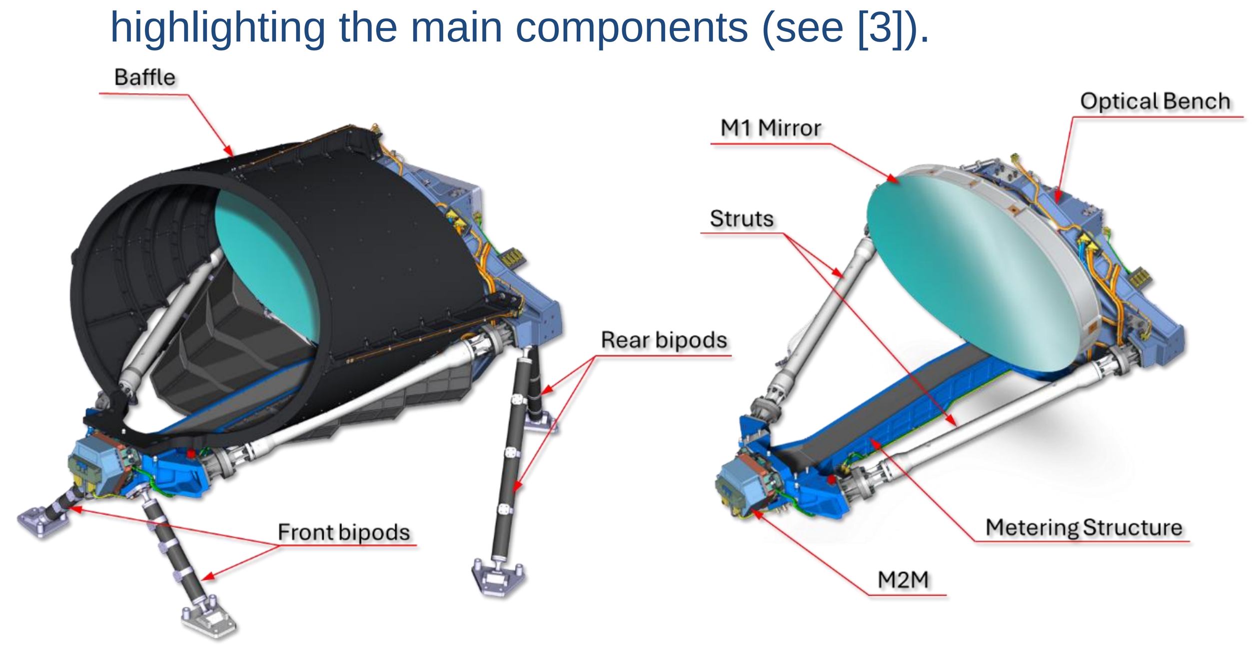


Fig. 1 ARIEL TA components.

Currently, the telescope mirrors, which are the most critical components of the telescope, are under the manufacturing phase of the EM models. Each mirror will be subjected to the following processes, in chronological order:

- Row machining
- Diamond turning
- Polishing
- Coating deposition

The primary mirror EM completed all the manufacturing phases with success, complying with the SFE requirements (see Fig. 2-4). M2 to M4 completed the diamond turning process and will go through the polishing and coating phases in the next months. However, with respect to M1, the manufacturing of these mirrors is considered less critical.

MIRRORS MANUFACTURING

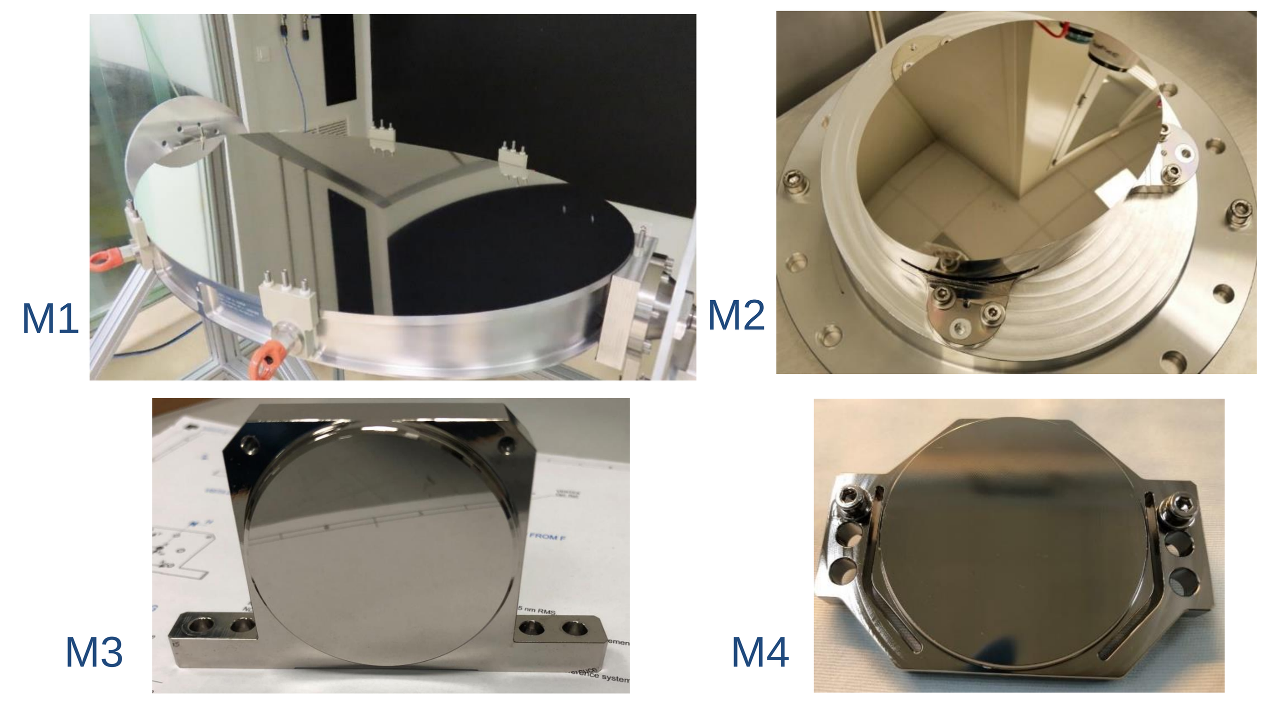
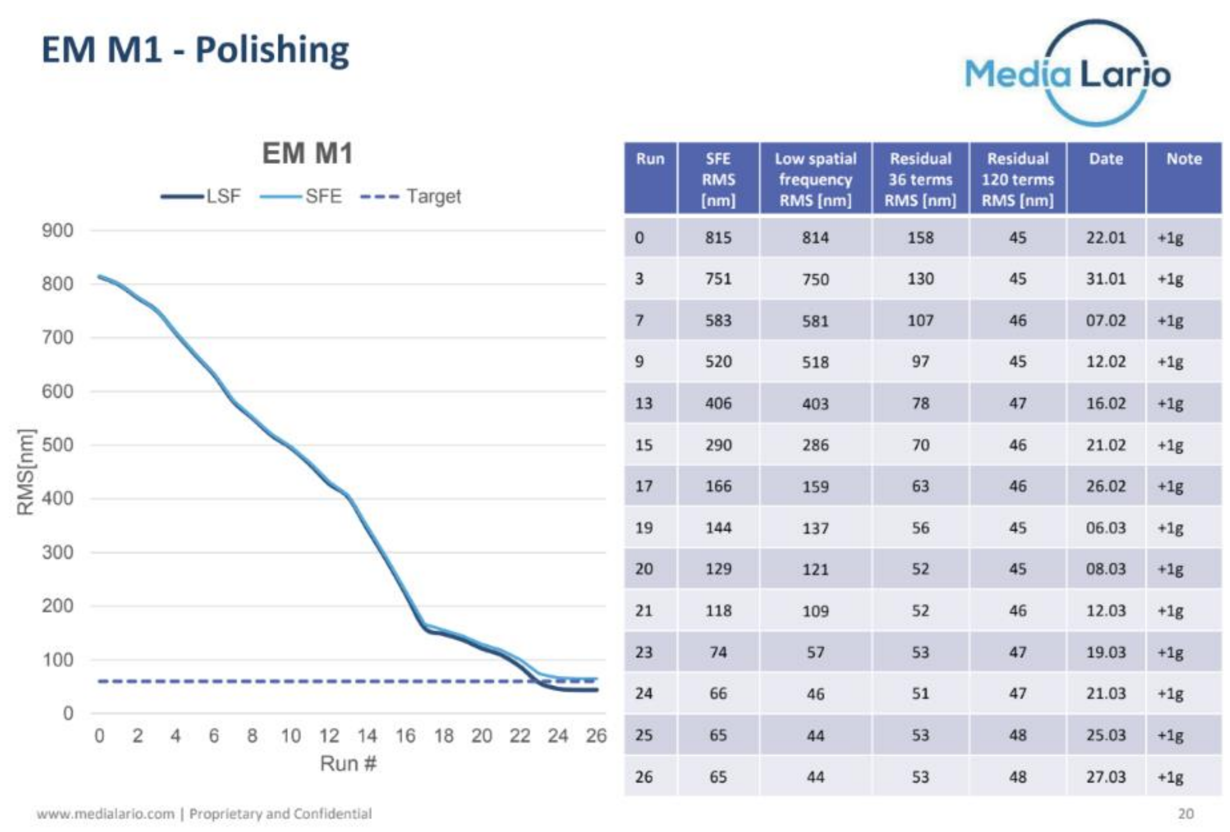


Fig. 2 ARIEL M1-M4 EM mirrors.



Run	SFE RMS [nm]	Low spatial frequency RMS [nm]	Residual 36 terms RMS [nm]	Residual 120 terms RMS [nm]	Date	Note
0	815	814	158	45	22.01	+1g
3	751	750	130	45	31.01	+1g
7	583	581	107	46	07.02	+1g
9	520	518	97	45	12.02	+1g
13	406	403	78	47	16.02	+1g
15	290	286	70	46	21.02	+1g
17	166	159	63	46	26.02	+1g
19	144	137	56	45	06.03	+1g
20	129	121	52	45	08.03	+1g
21	118	109	52	46	12.03	+1g
23	74	57	53	47	19.03	+1g
24	66	46	51	47	21.03	+1g
25	65	44	53	48	25.03	+1g
26	65	44	53	48	27.03	+1g

Fig. 3 ARIEL M1 EM polishing campaign.

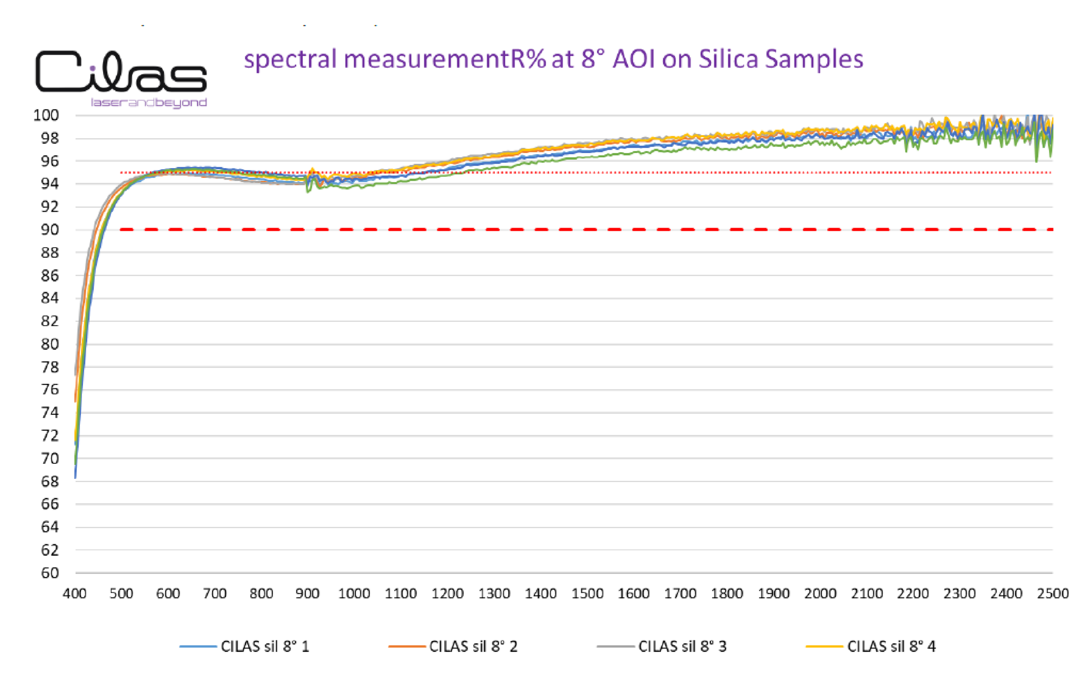


Fig. 4 M1 EM coating curve.

Tab. 1: ARIEL Mirrors specifications

Mirror	Mirror type	Clear aperture shape	Clear aperture dimensions at 50 K (mm)	SFE at 293 K (nm)
M1	Concave parabolic mirror	Elliptical	1100 x 746.8	65[1]
M2	Convex hyperbolic mirror	Elliptical	110 x 80	40[2]
M3	Concave parabolic mirror	Elliptical	28 x 20	18[2]
M4	Plane mirror	Circular	24	12[2]

1: The indicated SFE is measured.
2: The indicated SFE is as per specification and not still measured, since the mirror manufacturing shall still to be completed.

NiP Treatment

To improve the quality of aluminum mirrors, a NiP treatment is applied. Being harder than Aluminium, can lead to better quality surface during polishing activities: it permits more control and precision in removing higher aberration orders, leading to improved encircled energy and less scattered light. In the ARIEL mission, this treatment was planned for each mirror; however, since the polishing on NiP is applied at ambient temperature and the telescope will work at cryogenic temperatures (50 K), it could, in principle, cause deformations on the surface of M1, introducing aberrations that could be a limitation for the optical performances of the telescope. The reason of this is that NiP and Aluminum have different Coefficients of Thermal Expansion (CTE) and Young Moduli (YM), see [4] for data on NiP.

FEA simulations have been performed on M1: the overall deformation has been derived and characterized in function of different parameters of the deposition, such as: NiP thickness, NiP Young modulus and NiP CTE, since no unique values are present.

It can be seen that with a 2 µm thickness NiP a total deformation of 408 nm is found, reduced to just 36 nm RMS once the first four Zernike terms (i.e., Piston, Tip, Tilt and Power) are removed. The NiP coating is still under investigation, as there are numerous uncertainties regarding its mechanical characteristics, which vary significantly depending on Phosphorus content and temperature. In addition, it is necessary to establish the feasibility of depositing a very thin layer with uniform thickness. The situation is under study and a probable substitute of NiP will be an additional polishing run using a new, proprietary technique that is focused on the removal of the medium and high frequencies, without affecting the surface form of the surface (low aberrations).

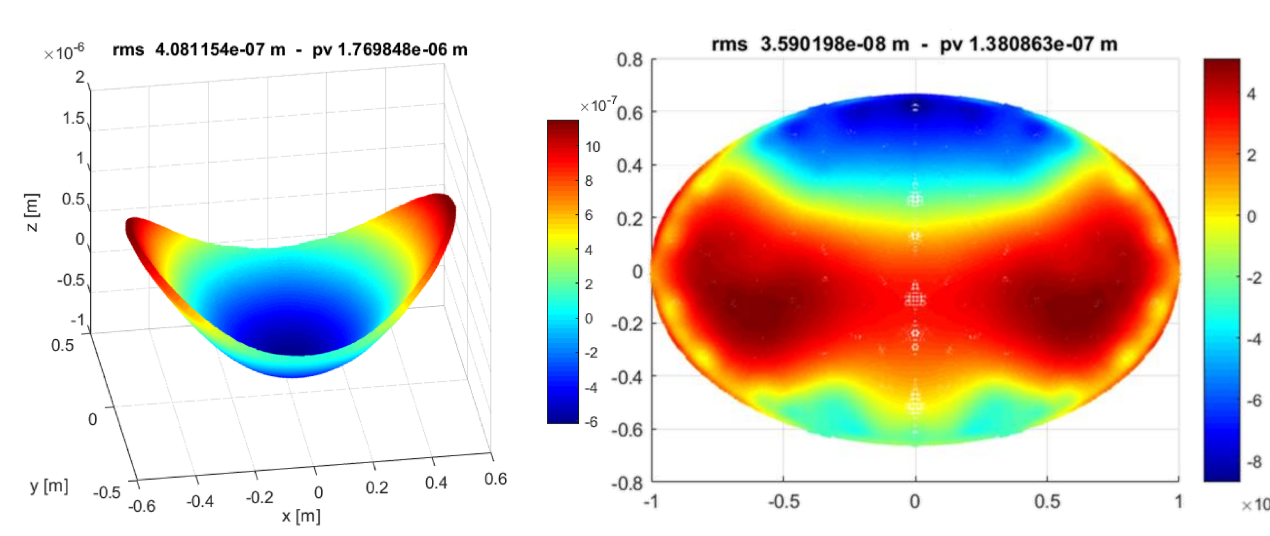


Fig. 5 Total deformation due to NiP treatment (left image), deformation due to NiP treatment without the first 4 Zernike terms (Piston, Tip, Tilt and Power, right image).

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