

Specification for the COS NCM1 Mirror Substrate

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ABBREVIATIONS & ACRONYMS

Å	Angstroms
ATP	Acceptance Test Procedure
CASA	Center for Astrophysics and Space Astronomy
COS	Cosmic Origins Spectrograph
CU	University of Colorado
HST	Hubble Space Telescope
N/A	Not Applicable
NCM1	NUV Correcting Mirror 1
NUV	Near Ultraviolet
rms	Root Mean Sum
TBD	To Be Determined
TBS	To Be Specified

1. PURPOSE

This specification defines the requirements for manufacture, performance, and verification testing of the NUV channel correcting mirror (NCM1) substrate for the Hubble Space Telescope's (HST) Cosmic Origins Spectrograph (COS). This specification only refers to the mirror substrate and not the optical coatings which will be applied at a later date.

2. APPLICABLE DOCUMENTS & DRAWINGS

2.1 APPLICABLE DRAWINGS

CASA-COS-1005 Substrate, NCM1 Correcting Mirror

3. REQUIREMENTS

3.1 ITEM DESCRIPTION & DEFINITION

The mirror substrates are made of fused silica and incorporate a concave, anamorphic aspherical optical surface, mounting surfaces, and mirrored surfaces for use during installation and alignment of the mirror into the COS instrument. The mirror blank dimensions, clear aperture, material, and fiducial marks are presented in drawings CASA-COS-1005.

3.2 OPTICAL REQUIREMENTS

3.2.1 Optical Surface Specifications

3.2.1.1 Aspheric Prescription

The concave anamorphic aspheric substrate shall be described by the aspheric equation shown below, where the sag Z is in millimeters. The signs have been set to give the sag as a positive value to match the output of the Code V Sag function.

$$Z = \frac{CUX \cdot X^2 + CUY \cdot Y^2}{1 + \sqrt{1 - (1 + KX) \cdot CUX^2 \cdot X^2 - (1 + KY) \cdot CUY^2 \cdot Y^2}} +$$

$$AR \cdot \{(1 - AP) \cdot X^2 + (1 + AP) \cdot Y^2\}^2 +$$

$$BR \cdot \{(1 - BP) \cdot X^2 + (1 + BP) \cdot Y^2\}^3$$

Coefficient	Value	Tolerance
CUY	6.384053 X 10 ⁻⁴	±0.1%
CUX	6.529823 X 10 ⁻⁴	N/A
CUX _{as built} -CUX _{as built}	1.4577 X 10 ⁻⁵	±1%
AR	0.158937 X 10 ⁻⁸	N/A
BR	0.782585 X 10 ⁻¹³	N/A
AP	-1.17315 X 10 ⁻²	N/A
BP	-1.32681 X 10 ⁻²	N/A
KX	0	N/A
KY	0	N/A

3.2.2 Clear Aperture

3.2.2.1 Aspherically Figured Clear Aperture

The figured clear aperture shall be as specified in drawing CASA-COS-1005.

3.2.3 Substrate Surface & Finish

3.2.3.1 Surface Figure

The fused silica mirror substrate shall have a surface figure of ≤ λ/100 rms over the entire clear aperture measured at 6328 Å. This specification shall be met over the following spatial frequencies:

Surface Error Bandwidths	
Surface Errors	Spatial Frequencies
Surface Figure	> 1 mm
Surface roughness	< 0.5 mm

3.2.3.2 Surface Roughness

The clear aperture of each mirror substrate must have a surface roughness < 10 Å rms.

3.2.3.3 Scratch and Dig

The polished clear aperture shall meet or exceed a Scratch & Dig specification of 20-10 per MIL-O-13830H.

3.2.4 Wedge, Offsets, and Substrate Thickness

3.2.4.1 Wedge

The wedge shall be <30 arc sec with knowledge to 3 arcsec. For the aspheres, wedge is defined as the complement of the angle between the plane defined by the fiducial surface on the back of the substrate and the normal to the sphere vertex.

3.2.4.2 Offsets

The aspheric optical axis shall be within ± 0.1 mm of the geometric center of datum D.

3.2.4.3 Back Side Surface Quality

The entire back side, defined as the side directly opposite the anamorphic surface, must be figured to $\lambda/10$ P-V at 6328 Å over the circular 79mm diameter clear aperture. The surface roughness of the figured areas must be <10 Å rms.

3.2.4.4 Unspecified Surfaces

All unspecified surfaces shall be polished to allow for visible inspection of the interior of the substrate. Bevel surfaces are excluded from this requirement.

3.3 MECHANICAL

3.3.1 Substrate Material

The mirror blanks shall be fabricated from fused silica, Corning 7980, inclusion class 2 or better.

3.3.2 Dimensions

Physical dimensions of the mirror substrates shall be per Drawings CASA-COS-1005.

3.3.2.1 Dimensional Knowledge

Optics diameters shall be measured and recorded to a precision of 0.0025 mm. Center thickness shall be measured and recorded to a precision of 0.025mm.

3.3.3 Fiducials

Fiducials on the substrates shall be provided in the locations shown on drawings CASA-COS-1005. Fiducials may be scribed, lithographically applied, or implemented through another technology with prior approval from CU/CASA. Fiducials shall be 0.002" to 0.004" wide.

3.3.4 Serialization & Marking

The mirror substrates shall be identified by a serial number to retain identification. The serial number shall be sand blasted on the side of the finished element in the location shown on drawings CASA-COS-1005. Since the mirror substrates will be subjected to a vacuum environment, the marking method shall not outgas in this environment. Marking method shall be approved by CU prior to application. Witness samples are to be scribed on the backside with the letters CW followed by a simple number, i.e. CW 23.

3.4 ENVIRONMENTAL REQUIREMENTS

During the fabrication of the mirror substrates defined in this document no process or materials shall be employed which would preclude the substrate from meeting or exceeding the operational specifications under the environmental conditions presented in Section 3.4.1. The environmental conditions under which the substrate performance must be verified are outlined in Section 4, Acceptance & Verification Testing, of this document.

3.4.1 Operating:

Temperature	15° C to 25° C
Relative humidity	0% to 50 %
Pressure	8×10^2 Torr to $<1 \times 10^{-5}$ Torr

3.4.2 Solvents

The mirror substrate may not come into contact with any solvent or substance which could damage the optic in any way prior to the application of the optical coating. Such a substance would be hydrofluoric acid.

3.4.3 Silicones

The exposure of the mirror substrate to silicones during any activity during its fabrication process shall be minimized. The presence of silicones in an epoxy bond can drastically reduce the strength of the bonded interface. The COS NCM1 mirrors, when complete, will be bonded into mounts prior to final alignment. Since removal of silicones is extremely difficult the exposure of the mirror substrates to silicones must be minimized where practical. Should the mirror substrates knowingly be exposed to silicones during the fabrication process, the manufacturer shall notify CU/CASA in writing.

3.5 SHIPPING & HANDLING

3.5.1 Handling

During all phases of substrate fabrication suitable precautions must be employed during handling of the optic to insure that it is not damaged in any way which would preclude use of the substrate as a correcting mirror in the COS instrument.

3.5.2 Shipping

At the time of delivery the substrate must meet or exceed class 1000 cleanroom specifications. The clean substrate will be shipped in a shipping container that also meets or exceeds class 1000 cleanroom specifications during installation of the substrate into the shipping container.

3.5.3 Shipping/Handling Environmental Restrictions

The completed blank must be maintained within the following environmental limits:

Temperature	-50 to 100°C
Humidity	≤ 95% relative humidity
Pressure	< 800 Torr.

4. ACCEPTANCE & VERIFICATION TESTING

4.1 ACCEPTANCE TEST PROCEDURE

The supplier shall prepare an acceptance test procedure (ATP) including the following as minimum.

- a) Test to be performed and description of accomplishment method.
- b) Sequence of tests.
- c) Article being tested (i.e., flight article or witness sample).
- d) Equipment to be used.
- e) Accuracy of measurement.
- f) Calibration techniques (as appropriate).
- g) Data sheets.

The tests shall be adequate to verify that the mirror satisfies the requirements of this specification per the specification verification matrix shown in Section 6.0 of this document. The ATP shall be submitted to CU for approval at least four weeks prior to acceptance testing.

4.2 ACCEPTANCE TEST

The supplier shall perform an acceptance test of each flight optic. Data packages must be available for review at the acceptance test but may be submitted to CU at a later date. Interferometric and radius of curvature tests must be witnessed. Other parameters may be verified by data review of previously performed tests and review of as built mechanical data or in process logs. The supplier shall notify CU at least 1 week in advance of each acceptance test. Multiple optics may be tested during the same acceptance test.

A redundant verification test of the optical prescription within the clear aperture is also required (sections 3.2.1.1, 3.2.1.2, 3.2.1.3)

CU retains the right for any responsible CU optical engineer, QA representative associated with the HST/COS project, or US government representative to witness any and all acceptance tests; however, it is anticipated that this will occur on a limited basis to accept and approve the ATP.

4.3 ACCEPTANCE TEST ENVIRONMENTAL CONDITIONS

Acceptance testing of the NCM1 substrates may be conducted under normal laboratory operating conditions provided they fall within the environmental limitations presented in Sections 3.4.1 and 3.5.3. It is anticipated that the mirror substrates will be tested at $22.5^{\circ}\text{C} \pm 2^{\circ}\text{C}$.

4.4 SPECIFICATION VERIFICATION MATRIX

Section	Description of Requirement	Method of Verification	Verification of Deliverable
3.2.1.1	Aspheric Prescription		
3.2.2.1	Aspherically Figured Clear Aperture		
3.2.3.1	Surface Figure		
3.2.3.2	Surface Roughness		
3.2.3.3	Scratch & Dig		
3.2.4.1	Wedge		
3.2.4.2	Offsets		
3.2.4.3	Back Side Surface Quality		
3.2.4.4	Unspecified Surfaces		
3.3.1	Material		
3.3.2	Dimensions		
3.3.2.1	Dimensional Knowledge		
3.3.3	Fiducials		
3.3.4	Serialization & Marking		
3.4.1	Operating Environments		
3.4.2	Solvents		
3.4.3	Silicones		

5. WITNESS SAMPLES

The supplier shall provide a minimum of five witness samples per deliverable flight optic. Each witness sample shall be made from the same material (lot) as the specified substrate. The witness samples shall have their coated surface polished flat in a similar manner as the optical element specified herein. These witness samples shall be delivered along with the mirrors to CU. The witness samples shall have the following dimensions:

Diameter	25.4 mm \pm 0.25 mm
Thickness	3.18 mm \pm 0.25 mm
Clear Aperture Diameter	20.32 mm minimum
Bevel	45 deg edge bevel
Surface figure	\leq 1 λ PV
Surface finish	Best commercial polish (\leq 30 Å rms goal)