Manufacturing the Astro-E2 X-ray Telescopes Script
Clip from *Building the Coolest X-ray Satellite*

Video

CLIP OF A MIRROR SEGMENT
TEXT: BUILDING THE XRTS: ASTRO-E2'S X-RAY TELESCOPES

Audio

NARRATIVE: Meanwhile, just across the center, another team is building the 5 x-ray telescopes.

Video

CURTIS OC
TEXT: CURTIS ODELL INFO

Audio

CURTIS: X-ray telescope development is a lot like any other instrument developed for space flight. We make small components, like reflectors and we test them, we make assemblies including many reflectors and we test that assembly. We make the full-up telescope assembly from those and we test it. And we test and we test. Because you have to know it's going to work on the ground, cause you can't fix it in space.

Video

ANIMATION OF ASTRO-E2 IN SPACE
TEXT: ASTRO-E2 INSTRUMENTS: XRS: X-RAY SPECTROMETER WITH 1 TELESCOPE; XIS: X-RAY IMAGING SPECTROMETERS WITH 4 TELESCOPES; HXD: HARD X-RAY DETECTOR

Audio

CURTIS: We're making the 5 telescopes for the XIS and the XRS instrument that will be on board the ASTRO E2 spacecraft.

Video

CLIPS OF MIRROR MANUFACTURING PROCESS
TEXT: MIRROR MANUFACTURING

Audio

NARRATIVE: The telescope mirror manufacturing process begins with some raw materials like the metal foil.

Video

CLIPS SHOWING FOIL CUTTING

Audio

CURTIS: The earliest operation is foil cutting and forming. We have to produce upwards of 10,000 foils for the one mission in order to get the 6800 foils that we need to fill up 5 telescopes.

Video

CLIP OF FOIL GOING THROUGH A ROLLER

Audio

NARRATIVE: The technician puts the foils through a special roller.
CURTIS: This is going to impart the gross curvature that we need and the slight bit of conical shape that we want.

Video

CLIP SHOWING A FORMING MANDREL WITH A "WINDOW" WHERE FOILS WILL BE PLACED
TEXT: FORMING MANDREL MADE OF QUARTZ
CURTIS OC

Audio

CURTIS: Then we'll put that stack inside this little window here. This forming mandrel has a cone shape that is the proper prescription for it's place in the mirror. While it's still under vacuum and so the atmospheric pressure is pressing them against the mandrel, it takes on the exact shape of that mandrel.

Video

ANIMATION OF ASTRO-E2 IN SPACE

Audio

NARRATIVE: The X-rays that Astro-E2 will observe get absorbed in many materials including glass and ordinary mirrors. So ASTRO-E2 and other x-ray telescopes require a unique strategy to focus x-rays on to a detector.

Video

CURTIS OC
ANIMATION SHOWING THE PATH OF LIGHT THROUGH A GRAZING INCIDENCE TELESCOPE
ANIMATION SHOWING THE PATH OF LIGHT THROUGH THE XRT TO THE XRS IN RELATION TO THE SPACECRAFT

Audio

CURTIS: We use an x-ray telescope, which depends on a grazing incidence reflection, in which the reflectors are nearly edge on to the X-ray source. The x-ray beam hits the primary reflector, then hits the secondary reflector and then moves on to the detector about 4 and a half meters away. We add a pre-collimator, before the primary reflection, to block off axis x-rays.

Video

CLIPS OF THE REPLICATION LAB
TEXT: REPLICATION LAB; BUILDING 2, NASA GSFC

Audio

CURTIS: So, now they have the proper figure is what we say… they're curved just right and they're smooth enough on that surface – but they're still not shinny enough. So then they go down to the replication lab.

Video

CLIPS OF A GOLD-COATED MANDREL

TEXT: GOLD IS DEPOSITED ON GLASS REPLICATION MANDRELS

Audio

CURTIS: They've been busy cleaning up the glass mandrels and then they're put into a gold deposition system and gold is deposited on the outer surface of that glass tube mandrel.

Video

CLIPS OF SPRAYING EPOXY ON THE FOILS

Audio

CURTIS: We spray thinned-out epoxy on the foils.

Video

CLIPS OF PLACING THE MANDRELS ON THE FOILS AND PLACING THEM IN THE OVEN

Audio

CURTIS: And once it's in vacuum that round mandrel is lowered and it just sits on top of the foil. And then we put that mandrel inside an oven and bake it over night. Now, it's not a real bake – it's just 40 degrees C.

Video

CLIP OF REMOVING GOLD-COATED FOILS FROM THE MANDRELS

Audio

CURTIS: Gold won't stick to glass very well. Through a process that is more magic than anything else, we lift the foil off the mandrel and gold that had been on the mandrel now is stuck to that thin film of epoxy. The front surface of this foil sandwich with gold on the front has the surface quality of the glass mandrel.

Video

CLIP OF THE EXTERIOR OF BUILDING 2
TEXT: METROLOGY LAB: MIRROR INSPECTION; BUILDING 2, NASA GSFC

Audio

NARRATOR: As the XRS team prepares to tackle the helium leak and hopefully beat the clock – the x-ray telescope manufacturing process enters another phase – testing.

Video

CLIPS OF THE MIRROR FOILS

Audio

CURTIS: We now have foils that have the front surface we want and it goes into the Metrology lab where the foil is inspected.

Video

CLIPS OF THE MIRROR FOIL IN A PROFILOMETER
TEXT: VOICE OF DR. JOHN LEHAN, XRT SCIENTIST

CLIPS SHOWING A MAP OF THE SURFACE OF A MIRROR FOIL ON A COMPUTER SCREEN

Audio

JOHN LEHAN: A Wiko Profilometer measures using light so it's a non-contact method. It uses visible light to actually measure the roughness of the surface. As far as x-rays go these are pretty close to mountains, but these are very short mountains being only about 1/1000th the height of a human hair. So we would like to have them a small a difference between the maximum and minimum as practical.

Video

CLIPS OF MIRROR FOILS IN THE LAB

Audio

CURTIS: So then they are graded. Some are rejected, some are what we call flight and some are put in a small class of "usable if you have to get yourself out of a jam."
NARRATOR: All the parts are ready

Video

CURTIS OC
CLIPS OF MIRROR HOUSE WITH ONE FOIL

Audio

CURTIS: So we are going to start building up a telescope, and we do this one quadrant at a time. After you've put the bars in, you put one foil in the middle of the housing somewhere, and you put it on an alignment fixture

Video

CLIPS OF MIRROR HOUSE WITH ONE FOIL
CURTIS OC
CLIPS OF THE TELESCOPE HOUSING FULL OF FOILS

Audio

CURTIS: The alignment bars are the ones that create the angle and perfectly position the foils in the housing and make it so that we can stick one housing on top of another and have 175 concentric nesting line up perfectly with 175 below.

Video

CLIP OF EXTERIOR OF BUILDING 2
CURTIS OC
CLIPS OF THE MIRROR HOUSING ASSEMBLY

Audio

CURTIS: The mirror team had its share of problems too. Early on we had some structural problems. In a couple of cases mirror assemblies did not past vibration testing, which simulates the rigors of launch. We went in and made repairs to the assemblies and retested successfully.

Video

Video

CLIP OF XRT MIRROR QUADRANT

Audio

NARRATOR:. The x-ray telescope quadrants are ready for more testing and final assemblies.

Video

CLIP OF CURTIS HOLDING AN XRT MIRROR QUADRANT

Audio

CURTIS: You're seeing the edges of the foils in many, many arcs like that. That's the 175 nestings.

Video

CLIPS OF THE XRT MIRROR QUADRANT IN THE TESING EQUIPMENT

Audio

CURTIS: So then you've got a quadrant, now we're going to do some optical testing with that, then we start doing x-ray testing.

Video

CLIP OF X-RAY TEST CHAMBER
CLIP OF COMPUTER SCREEN SHOWING X-RAY TESTS

Audio

CURTIS: So what we are looking for is to contain the photons in as small a circle as possible

Video

CLIP OF COMPUTER SCREEN SHOWING X-RAY TESTS

Audio

NARRATOR: The better the focus, the more photons will arrive onto the XRS.

Video

CLIPS OF THE XRT MIRRORS IN THE TESING EQUIPMENT

Audio

CURTIS: So the process is done again in optical – in white light - by putting the 4 quadrants on the ring and then looking at where each quadrant projects it's image – and adjusting these until they all project to the same spot.

Video

CLIPS OF PACKING THE MIRRORS

Audio

NARRATIVE: With the assemblies complete, the telescopes can be packed and sent to Japan for further testing and final assembly onto the spacecraft.