Building the Coolest X-ray Satellite
Chapter 3 Script

Chapter 3: Building the X-ray Spectrometer and the X-ray Telescopes

Chapter 3, part 1: The X-ray Spectrometer

Video

ANIMATION OF ASTRO-E2 IN SPACE
PHOTO OF NASA GSFC SIGN
PHOTO OF X-RAY TELESCOPE ASSEMBLY
CLIPS OF XRS IN CRIF

Audio

MUSIC CHANGE
KEVIN: Here at Goddard we are building the 5 x-ray telescopes or XRTs. And we are also building the XRS, which is one of the instruments that looks at the x-rays coming through these telescopes.

Video

CURTIS OC
CLIPS OF MIRROR FOIL MANUFACTURING

Audio

CURTIS: That is the work is simultaneous, but it's not linked together by schedule, we just all have to be at the spacecraft at the same time.

Video

CLIP OF WORK IN THE CLEAN TENT
TEXT: BUILDING THE XRS: X-RAY SPECTROMETER
TEXT: CRIF: CRYOGENICS RESEARCH & INTEGRATION FACILITY, BUILDING 7, NASA GSFC

Audio

NARRATIVE: Most assembly and testing of the XRS instrument is done here in the Cryogenic Integration Facility or CRIF for short.

Video

TEXT: THE XRS CALORIMETER
CAROLINE OC
TEXT: CAROLINE KILBOURNE INFO

Audio

CAROLINE: At the very heart of the XRS is the microcalorimeter array. This is a very small detector, but it has unique and powerful capabilities. The final steps of its assembly are done in this laboratory right here. So let's go and see what all the fuss is about.

Video

CLIP OF CAROLINE IN BUNNY SUIT IN LAB SHOWING THE XRS DETECTOR ARRAY
ANIMATION OF PHOTONS HITTING THE ARRAY.

Audio

CAROLINE: This is the XRS micorcalorimeter array. Essentially it's an array of very tiny thermometers designed to measure the temperature increase when an individual x-ray photon is absorbed.

Chapter 3, part 2: Getting the XRS Cold

Video

CLIPS OF THE XRS DEWAR WITH FROST

Audio

NARRATIVE: To detect the minuscule amount of heat given off by a single x-ray, engineers must employ Cryogenics – the science of the super cold.

Video

TEXT: WHY SO COLD ???
CLIP OF CAROLINE IN BUNNY SUIT

Audio

CAROLINE: Now, in order to make a good spectrometer, the detector needs to be very cold.

Video

KEVIN OC

Audio

KEVIN: An ordinary object does not change much when an x-ray hits it; so making it cold helps in 2 ways. One: it means that the temperature change is a larger fraction of the temperature that it's sitting at and 2, the heat capacity of almost everything goes down very rapidly as you get close to absolute zero. So a little bit of energy causes the temperature to rise a lot. So we have to keep it very, very cold.

Video

CLIP OF CAROLINE IN BUNNY SUIT
TEXT: 0.060 KELVIN
ANIMATION SHOWING THE XRS PLACEMENT IN THE ASTRO-E2 SPACECRAFT

Audio

CAROLINE: We have to operate this detector at 60 millidegrees above absolute zero. So that's what the rest of the XRS instrument does – it makes this tiny detector cold.

Video

GRAPHIC**:** ABSOLUTE ZERO DEFINITION

0 KELVIN OR –273 CELSIUS OR –459 FAHRENHEIT

Audio

KEVIN: When you try to keep something that cold, you usually have to have a multi-stage system. We do that as well.

Video

CLIP SHOWING NEON DEWAR
TEXT: SOLID NEON IS: 17 KELVIN OR –256 CELSIUS

Audio

KEVIN: There's an outer layer of solid neon, that's 17 Kelvin. That's pretty cold for you and me, but that's still blazingly hot for our detectors.

Video

CLIP CONTINUES, WITH A HAND PULLING THE HELIUM DEWAR OUT OF THE NEON DEWAR
TEXT: LIQUID HELIUM GOES HERE
TEXT: LIQUID HELIUM IS: 1.3 KELVIN OR –271.9 CELSIUS
GRAPHIC OVERLAY SHOWING THE "INSIDE" OF THE HELIUM DEWAR AND THE PLACEMENT OF THE ADIABATIC DEMAGNETIZATION REFRIGERATOR
TEXT: ADIABATIC DEMAGNETIZATION REFRIGERATOR
TEXT: 0.060 KELVIN

Audio

KEVIN: So inside that, there's a layer of liquid helium. And that's helium, like helium in your helium balloons and that's at about 1.3 Kelvin. And then inside that there's what we call an adiabatic demagnetization refrigerator, which uses magnetic spins inside actual atoms and aligns them and de-aligns them in such a way to get us down to 60 millikelvin.

Video

CLIP OF WORK IN THE CLEAN ROOM
KEVIN OC
ANIMATION SHOWING A CUT-AWAY OF THE DEWAR WITH TWO WALLS AND OUTSIDE HEAT STOPPED BY THE OUTER WALL
TEXT: INVENTED BY SIR JAMES DEWAR IN 1892

Audio

KEVIN: The XRS detectors are placed inside a Dewar. A Dewar is like a thermos bottle. If you have a real glass thermos bottle to keep your coffee in, that's a Dewar. And it's 2 walls, and between the walls is vacuum, so the heat can't get through from one side to the other by conduction or convection. It can only go through by radiation and that' why it's – if you look inside your thermos bottle it's silver and that reflects the radiation.

Video

KEVIN OC

CLIP OF THE XRS AND ITS HOUSING

Audio

KEVIN: We have just a tiny amount of power and if there's a lot of heat – even if there is just a little bit of heat getting into the system, we won't be able to keep it cold. So you have to be very careful to isolate the inner structures that are very cold with the outer structures that are not so cold.

Chapter 3, part 3: Working in a Clean Room

Video

CLIP OF A CLEAN TENT

Audio

NARRATOR: Certain portions of the XRS instrument require work in a clean tent.

Video

CLIP OF WORK IN A CLEAN TENT WITH PEOPLE IN BUNNY SUITS
KEVIN OC

Audio

KEVIN: One of the parts of this experiment is a bunch of filters, very, very thin filters to let the x-rays through but keep out visible light, infra red – that sort of thing. These filters are very, very thin. And even just one tiny particle, too small to see, could penetrate them during launch when it's being shaken around. So we had to keep everything scrupulously clean, which means doing everything that has to do with inside of the detector assembly in a clean room

Video

ANIMATION SHOWING HOW A CLEAN ROOM WORKS WITH AIR PULLED IN THE TOP, PUSHING AIR OUT THE BOTTOM

Audio

NARRATOR: A clean tent works by pulling the air in at the top, passing it though special filters to remove dust particles. This raises the air pressure inside the tent, which keeps outside air from coming in.

Video

CLIP OF PEOPLE IN BUNNY SUITS WORKING IN THE CLEAN TENT

Audio

NARRATOR: Keeping the clean tent environment virtually dust free requires the use of special clothing commonly referred to as bunny suits. It also requires cleaning all items entering the tent and the use of special materials.

Video

CLIP OF CAROL CLEANING PAPER
TEXT: CAROL JONES INFO

Audio

CAROL: This is clean room paper, but when you run it through the printer you get a lot of toner on it, you have to wipe it off before you take it in to the clean room. Tedious, but it does come up pretty black. Yah, why am I wiping paper off, yah, well.

Chapter 3, part 4: Building the XRTs

Video

CLIP OF THE EXTERIOR OF BUILDING 2
TEXT: MEANWHILE IN BUILDING 2
CLIP OF A BUILDING 2 HALLWAY

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.