ESOcast Episode 15: Recoating a Giant VLT Mirror		
1. **[Visuals start]** **[Narrator] 00:05** Every night, all year round, the ESO Very Large Telescope, or VLT, opens its four giant eyes to scrutinise the beautiful southern skies. Each eye is a huge mirror, 8.2 metres in diameter that gathers the light of the night sky, and reflects it into optical systems that form ultra-sharp images of the Universe. But keeping the VLT´s eyes clear requires each mirror to be cleaned and recoated occasionally, a delicate and complex procedure.		Images: Salgado sequence VLT unit telescope with mirror Mirror in washing chamber
2. **ESOcast Intro 00:42** This is the ESOcast! Cutting-edge science and life behind the scenes of ESO, the European Southern Observatory. Exploring the ultimate frontier with our host Dr J, a.k.a. Dr Joe Liske.		ESOcast introduction
3. **[Dr J] 00:58** Hello and welcome to the ESOcast. In this episode, we're going to follow the recoating of one of the VLT's primary mirrors. Although this happens quite regularly, this is far from being a routine procedure. Under the open sky, dust collects on the surface of the mirror. And although this layer of dust is very thin, it nevertheless degrades the quality of the astronomical observations. And so the mirror must be cleaned regularly. In fact, it must not only be cleaned, it must be recoated, meaning that its thin layer of reflective aluminium must be replaced. The ESO technicians and engineers must work both quickly and carefully to complete this operation on the fragile 17-cm thick mirror in order to limit the telescope's downtime.		Dr J in virtual studio. VLT at sunset Mirror footage Salgado footage/ Layer of dust, close up VLT unit telescope with mirror

4. **[Narrator] 01:46** First, the telescope must be prepared so that the mirror and its cell can be taken out. The team is removing an instrument attached to the mirror cell. Outside, a custom-built carriage is moved into position. This carriage will support the mirror and the cell, cushioning the load during transport. A dedicated platform lifts the carriage to the mirror deck. When it reaches the deck, the carriage slides into the building on a stream of pressurised air, ending up just below the mirror and the cell. The carriage is raised to receive the cell and mirror.		Team disconnects VLT instrument Footage on carriage
5. **[Dr J] 02:23** Once the cell is safely on the carriage it can be disconnected from the rest of the telescope. All the bolts are released and the data and control cables are removed. Now this is always a pretty tense moment and the team is working very carefully to make sure that they don't damage the fragile mirror. After all, there is no spare at ESO, and making a new one would take years.		Dr J in virtual studio. Workers disconnect M1 cell from the telescope
6. **[Narrator] 02:45** The surface of the mirror is extremely vulnerable. It must be covered before it is taken out of the building. The cover not only protects the mirror but also prevents it from concentrating sunlight and burning anything in its path. Before the mirror can be covered completely, a smaller mirror must be dismounted. This mirror sends the light gathered by the main mirror to different instruments at the telescope. During the coming days, the optical engineers will inspect and clean this mirror as well. Eventually, the larger mirror is completely covered. The carriage slowly slides out of the telescope building, supporting the full weight of the mirror and the cell, a substantial 50 tons. Once again, the lifting platform is used, carefully lowering the carriage to ground level. A truck brings in the hydraulic trailer. The trailer is carefully positioned to take the precious load. The load is secured with chains to prevent it from sliding off the trailer in case of an earthquake or a sudden stop.		Images: Mirror being covered Removal of M3 mirror M1 is covered completely M1 and cell slide out the telescope building Trailer is positioned Worker chain the load
7. **[Dr J] 04:11** The team is now ready to start the trip down the mountain to the recoating plant. This journey is a		Dr J in virtual studio.

crucial stage in the whole process. Before the mirror is brought out, the weather is checked thoroughly: high winds must be avoided at all costs during the transit because any flapping of the lightweight mirror cover might scratch the mirror. Furthermore, the truck driver is supposed to never apply the brakes, because an abrupt halt might be dangerous for the mirror. And so the truck moves along at a leisurely 5 km/h. But even at this walking pace, it eventually arrives safely at the mirror maintenance building.		
8. **[Narrator] 04:51** The first task at the mirror maintenance building is to remove the mirror from the carriage and its cell. The carriage is positioned under a custom-made handling tool. Brackets connect the mirror and the cell. Engineers have to release each one manually. This may sound like a routine job, but, with the sensitive mirror surface only centimetres away, it requires the team's undivided attention. Forgetting to take off even one bracket could damage the mirror severely during the lifting operation. The team is only ready to lift the mirror off its cell after a triple check of every bracket. Hooks are lowered to bear against the back of the mirror and the handling tool lifts the mirror up and off the cell. Now the cell can be removed. Subsequently, the mirror is lowered again to allow some work to be carried out on its back surface.		Images: Mirror Removed and set up for cleaning
9. **[Narrator] 06:00** Before the optical engineers start work on recoating the optical side of the mirror they must clean its back surface by hand. This cleaning is essential as it removes oils, particles and other contaminants that could damage the mirror in the vacuum chamber. Afterwards the bottom half of the vacuum chamber is brought in and the mirror is carefully lowered into it. The mirror is next taken into a cleanroom.		Images: Back surface cleaning, Vacuum chamber Preparation
10. **[Dr J] 06:41** The first action in the cleanroom is to treat any badly polluted areas on the mirror manually. This requires a steady and skilful hand in order to avoid scratching the surface. The point of doing this is to remove any particles that might not easily be flushed away during the subsequent washing.		Dr J in virtual studio.

Afterwards, the vessel holding the mirror is positioned in the washing chamber where the old reflective coating of the mirror is washed off.		
11. **[Narrator] 07:09** The washing process begins and a giant, purpose-built sprayer arm rotates just above the surface of the mirror. Ultra-pure water and chemicals are used. Under the critical eye of the optical engineers the machinery does a flawless job and the operation proceeds smoothly. In the next stage, acid is used to remove the old aluminium coating. The real amber colour of the dish appears. The mirror is made of special ceramics that don't deform under temperature changes. Again, the mirror is rinsed intensively to provide as clean a surface as possible. Once done, all the liquid is pumped out and the mirror is ready for the vacuum chamber.		Images: Washing Process
12. **[Narrator] 07:57** The vacuum chamber lies next to the washing unit. The mirror is placed in the chamber immediately after cleaning to avoid contamination with new pollutants. The lower part of the vessel is lifted up and the chamber is closed. The air can now be pumped out to establish a nearly perfect vacuum, necessary for recoating.		Images: Vaccum Chamber pepared
13. **[Dr J] 08:25** Once the vacuum is established, the recoating can begin. The optical engineers use an electrically stimulated plasma, for a molecular cleaning of the optical surface of the rotating mirror. Then individual particles of aluminium are deposited on the mirror in a process known as sputtering deposition. This takes about half an hour. Only 12 grams of aluminium are used to create the new coating for the roughly 50 square metres of the primary mirror, and so the coating is only about 80 nanometres thick. It's really not a lot is it? Finally, the moment of truth has come: Will the quality of the new coating meet the high standards of the VLT?		Dr J in virtual studio. Sheet of foil to show amount of aluminium

14. **[Narrator] 09:10** Recoating a mirror is always a tricky business: if the mirror isn't thoroughly clean or if the vacuum chamber is contaminated then the coating will be flawed. Tension is high as the chamber opens and the mirror is brought out. A first visual inspection suggests that the recoating has succeeded. But what really matters is how reflective the mirror is, so the percentage of light the mirror reflects and scatters is measured. The result confirms the high reflectivity of the mirror and the experts are fully satisfied.		Images: Mirror is checked
15. **[Dr J] 09:46** The recoating was successful and the mirror is all shiny and new again. Our team is now ready to take the mirror back up the mountain and reinstall it at the telescope. The VLT will be back in full operation exactly on schedule to provide astronomers with a superb view of our Universe. This is Dr J signing off for the ESOcast. Join me again next time for another cosmic adventure.		Dr J in virtual studio.
16. **[Outro] 10:15**		ESOcast is produced by ESO, the European Southern Observatory. *ESO, the European Southern Observatory, is the pre-eminent intergovernmental science and technology organisation in astronomy designing, constructing and operating the world's most advanced ground-based telescopes.*

END