Operations begin to de-ice Euclid's vision

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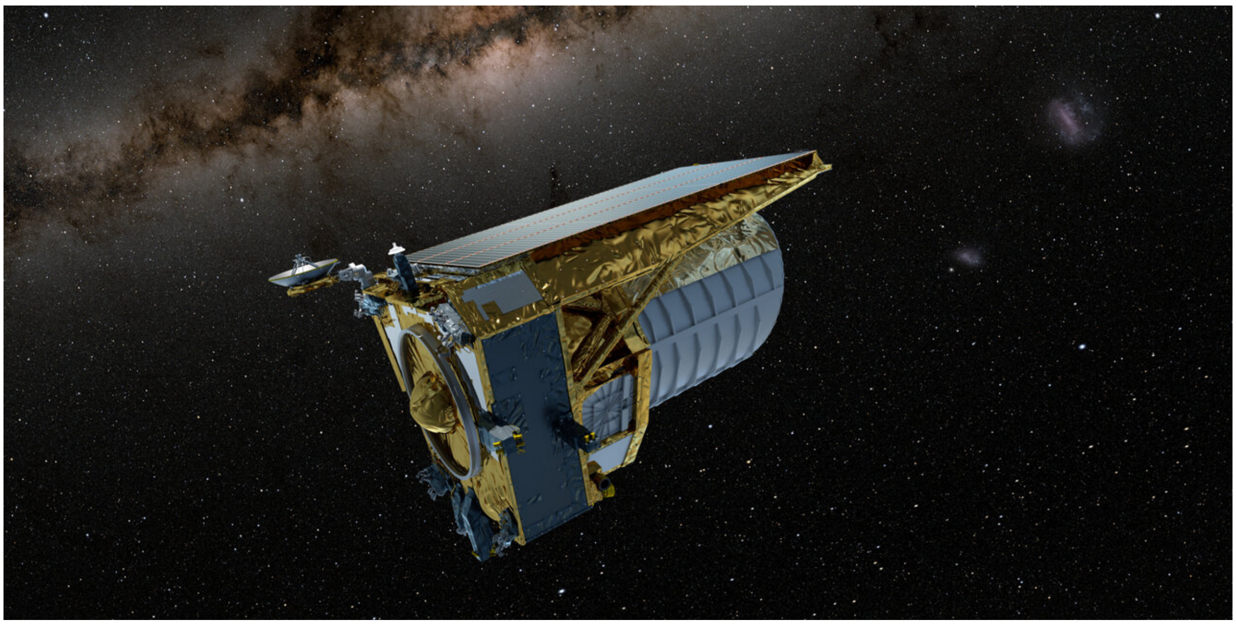

Euclid is designed to look far and wide to answer some of the most fundamental questions about our universe: What are dark matter and dark energy? What role did they play in formation of the cosmic web? The mission will catalogue billions of distant galaxies by scanning across the sky with its sensitive telescope. Credit: ESA

A few layers of water ice—the width of a strand of DNA—are starting to impact Euclid's vision; a common issue for spacecraft in the freezing cold of space, but a potential problem for this highly sensitive mission that requires remarkable precision to investigate the nature of the dark universe.

After months of research, Euclid teams across Europe are now testing a newly designed procedure to de-ice the mission's optics. If successful, the operations will validate the mission teams' plan to keep Euclid's optical system as ice-free as possible for the rest of its life in orbit.

Euclid's vision fogs as it steps 'outside'

In recent months, while fine-tuning and calibrating Euclid's instruments after launch and preparing for the start of the mission's first survey, science operations experts noticed a small but progressive decrease in the amount of light measured from stars observed repeatedly with the visible instrument (VIS).

Euclid is experiencing a common problem that spacecraft face once they get to space: water absorbed from the air during assembly on Earth is now gradually being released from certain components in the spacecraft, teased out by the vacuum of space.

In the freezing cold of Euclid's new environment, those released water molecules tend to stick to the first surface they land on—and when they land on this highly sensitive mission's optics, they can cause trouble.

"We compared the starlight coming in through the VIS instrument with the recorded brightness of the same stars at earlier times, seen by both Euclid and ESA's Gaia mission," explains Mischa Schirmer, calibration scientist for the Euclid consortium and one of the main designers of the new de-icing plan.

"Some stars in the universe vary in their luminosity, but the majority are stable for many millions of years. So, when our instruments detected a faint, gradual decline in photons coming in, we knew it wasn't them—it was us."

It was always expected that water could gradually build up and contaminate Euclid's vision, as it is very difficult to build and launch a spacecraft from Earth without some of the water in our planet's atmosphere creeping into it.

For this reason, there was an "outgassing campaign" shortly after launch where the telescope was warmed up by onboard heaters and also partially exposed to the sun, sublimating most of the water molecules present at launch on or very near Euclid's surfaces. A considerable fraction, however, has survived, by being absorbed in the multi-layer insulation, and is now being slowly released in the vacuum of space.

After a huge amount of research—including lab studies into how minuscule layers of ice on mirror surfaces scatter and reflect light—and months of calibrations in space, the team determined that several layers of water molecules are likely frozen onto mirrors in Euclid's optics. Likely just a few to few tens of nanometers thick—equivalent to the width of a strand of DNA—it's a remarkable testament to the mission's sensitivity that it is detecting such tiny amounts of ice.

While Euclid's observations and science continue, teams have come up with a plan to understand where the ice is in the optical system and mitigate its impact now and in the future, if it continues to accumulate.

Brand-new plan to decontaminate Euclid from 1.5 million km away

"A complex mission requires a united response from teams across Europe, and I'm incredibly thankful for the effort and skill that so many have poured into this," says Ralf Kohley, Euclid Instrument Operations Scientist who coordinated the response.

"It took work from teams at ESA's ESTEC technical heart in the Netherlands, the ESAC science operations center in Madrid and the

Flight Control Team at ESOC mission control in Darmstadt—but we couldn't have done it without the Euclid consortium and the critical inputs we got from spacecraft prime contractor Thales Alenia Space and its industrial partner Airbus Space."

The easiest option would be to use the decontamination procedure developed well before launch and heat the entire spacecraft. Teams at mission control would send the commands to turn on every onboard heater for several days, slowly increasing temperatures from about –140 °C to, in some parts of the spacecraft, a "balmy" –3°C.

Doing this would clean the optics but would also heat the entire mechanical structure of the spacecraft. As most materials heat, they expand and don't necessarily return to precisely the same state after a week-long cool-down, meaning a potentially subtle difference in Euclid's optical alignment. This won't do for such a sensitive mission where effects can be noticed on the optics from a temperature change of just a fraction of a degree, requiring at least several weeks of fine recalibration.

"Most other space missions don't have such demanding requirements on 'thermo-optical stability' as Euclid," explains Andreas Rudolph, Euclid Flight Director at ESA's mission control.

"To fulfill Euclid's scientific goals of making a 3D map of the universe by observing billions of galaxies out to 10 billion light-years, across more than a third of the sky, means we have to keep the mission incredibly stable—and that includes its temperature. Switching on the heaters in the payload module therefore needs to be done with extreme care."

To limit thermal changes, the team will begin by individually heating low-risk optical parts of the spacecraft, located in areas where water released is unlikely to contaminate other instruments or optics. They will start with two of Euclid's mirrors that can be warmed up independently. If the loss in light persists and starts to have an impact on science, they will continue to warm up other groups of Euclid's mirrors, checking each time what percentage of photons they get back.

Small amounts of water will continue to be released within Euclid over the life of the mission, so a long-term solution is needed to regularly de-ice its optics without taking up too much precious mission time—Euclid has six years to complete its survey.

"VIS will be measuring weak gravitational lensing—how matter in the universe has bunched together under the influence of gravity as the universe expands—and to understand this, the more galaxies we observe, the better," explains Reiko Nakajima, VIS instrument scientist.

"De-icing should restore and preserve Euclid's ability to collect light from these ancient galaxies, but it's the first time we're doing this procedure. We have very good guesses about which surface the ice is sticking to, but we won't be sure until we do it."

Mischa concludes, "Once we have isolated the affected area, the hope is that we can then simply warm up this isolated part of the spacecraft in the future as needed. What we are doing is very complex and fine-grained, so that we can save valuable time in the future—I'm extremely excited to find out just where this water ice is accumulating, and how well our plan will work."

Despite how common this contamination issue is for spacecraft operating in cold conditions, there is surprisingly little published research about precisely how ice forms on optical mirrors and its impact on observations. Not only could Euclid reveal the nature of dark matter, but it could also shed light on an issue that has long plagued our roving eyes in space, peering down at Earth and out across the universe.

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