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100 YEARS

Finding the Source of Dead Sea Sinkholes

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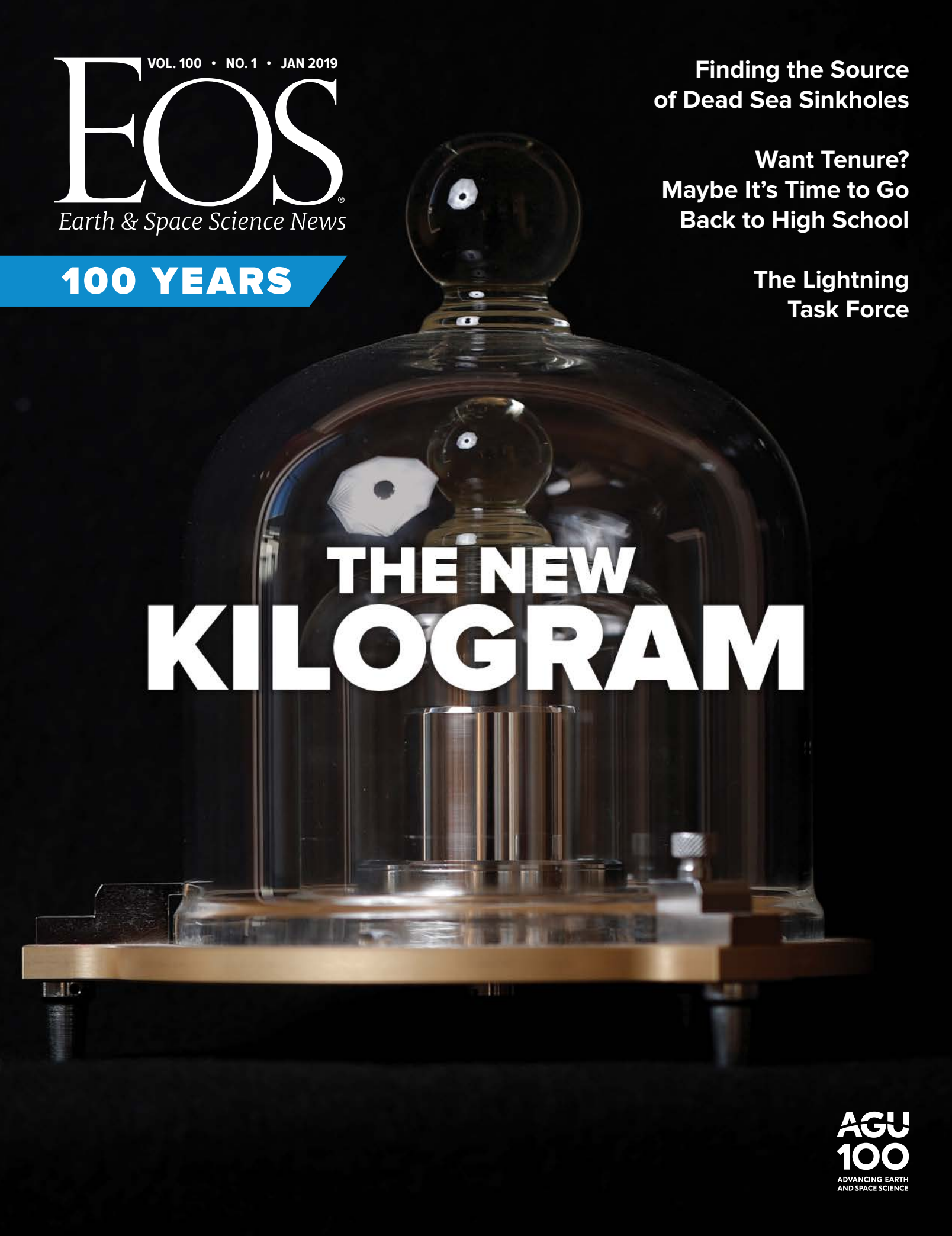
The Lightning Task Force

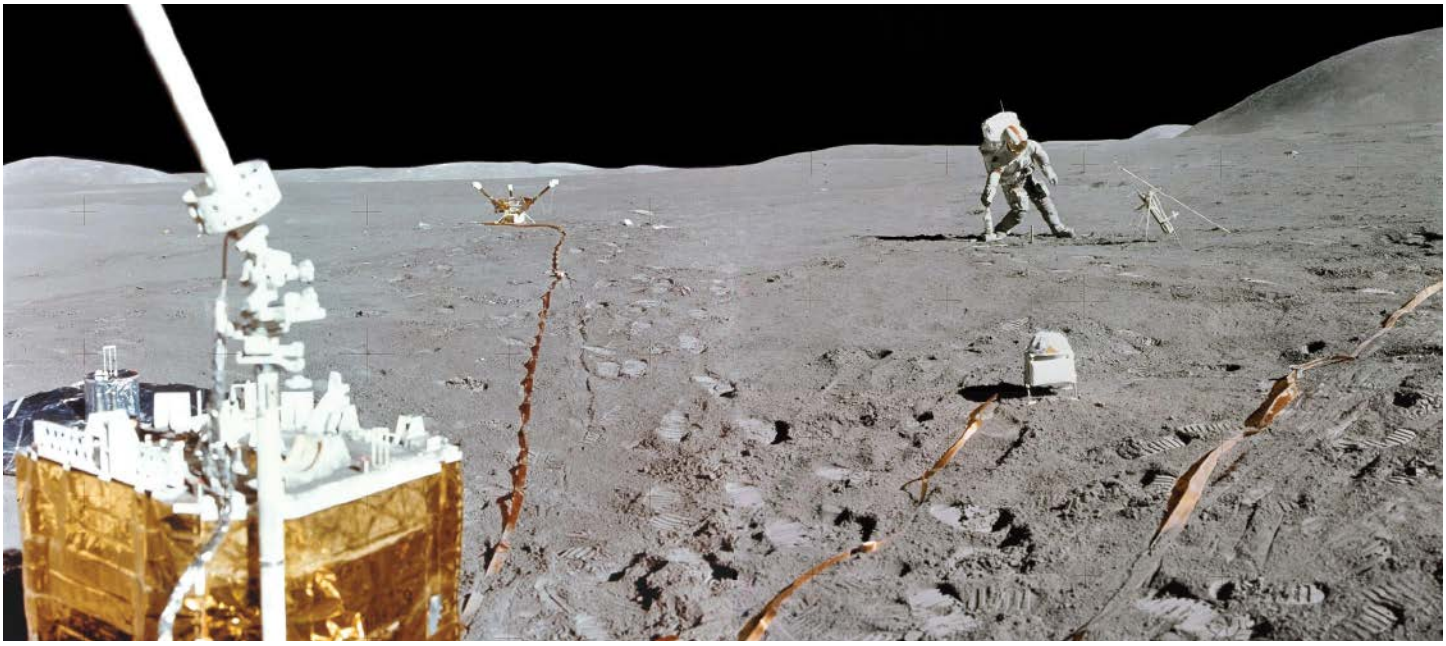


THE NEW KILOGRAM

AGU 100

ADVANCING EARTH AND SPACE SCIENCE

The Case of the Missing Lunar Heat Flow Data Is Finally Solved



Astronaut David Scott installs a heat flow probe in the lunar surface during the Apollo 15 mission. At lower left is the central station for the Apollo Lunar Surface Experiment Package, which the heat flow probes were part of. The seismometer, covered by a silver Sun shield, is behind the central station. Credit: NASA

During the Apollo 15 and 17 missions, astronauts installed four temperature-sensing probes in shallow, 1.0- to 2.4-meter-deep holes drilled into the Moon. They aimed to measure how much of the Moon's heat was lost to space, which could provide insights into the origin and the differentiation history of the Moon.

The Apollo Heat Flow Experiment ran from 1971 to 1977, but the original researchers analyzed and archived only the data collected between 1971 and December 1974. The rest of the records were lost. *Nagihara et al.* have now recovered, restored, and evaluated major portions of the missing data, finding that a warming trend observed from 1971 to 1974 continued through 1977.

To track down the missing data, the authors retraced the original data-recording process. Raw data from Apollo lunar surface experiments were captured on open-reel magnetic tapes at NASA's Johnson Space Center, but for unknown reasons, many were never sent to NASA's archives at the National Space Science Data Center. After the Apollo program ended, the tapes disappeared.

In 2011, the researchers reported that they had found about 10% of the missing tapes at the Washington National Records Center in Maryland. The tapes were somewhat degraded, but with the help of data recovery experts and old documents outlining how the data were organized, the researchers were able to restore much of the data, including measurements from the Heat Flow Experiment. They also found that some of the data were also recorded in the weekly performance logs kept at the Johnson Space Center.

To analyze the recovered heat flow data, the scientists needed just one more missing piece: calibration records for the temperature sensor probes. They found this information in old reports and memos from companies hired to help develop the instruments. With enough missing information recovered, the researchers were finally able to analyze the heat flow data.

They found that from 1974 until the Heat Flow Experiment concluded in 1977, the lunar subsurface warmed up, with greater warming occurring at shallower depths. This continued the warming trend observed by the original researchers in data collected between 1971 and December 1974. The measurements indicate that the observed warming began near the surface and spread downward.

The researchers then evaluated several previously proposed explanations for the warming, which have been debated in recent years. These include slow cyclical changes in the Moon's orbital axis, radiation from Earth, solar radiation into the drilled holes, and increased solar heat absorption by the surface after astronauts disturbed it with their activities.

Calculations from heat conduction models suggest that the timing and amount of warming seen at different depths are best explained by a rapid increase in surface temperature at the time of probe installation. This finding supports the hypothesis that disturbance of the lunar surface by astronauts' footprints and other activities increased its roughness, reducing the amount of solar radiation reflected back to space. Thus, increased absorption of solar heat caused the observed warming.

These findings suggest that to accurately measure heat flow in a planetary body, future experiments should aim either to minimize or to better account for surface disturbances. (*Journal of Geophysical Research: Planets,* https://doi.org/10.1029/2018JE005579, 2018) **—Sarah Stanley, Freelance Writer**