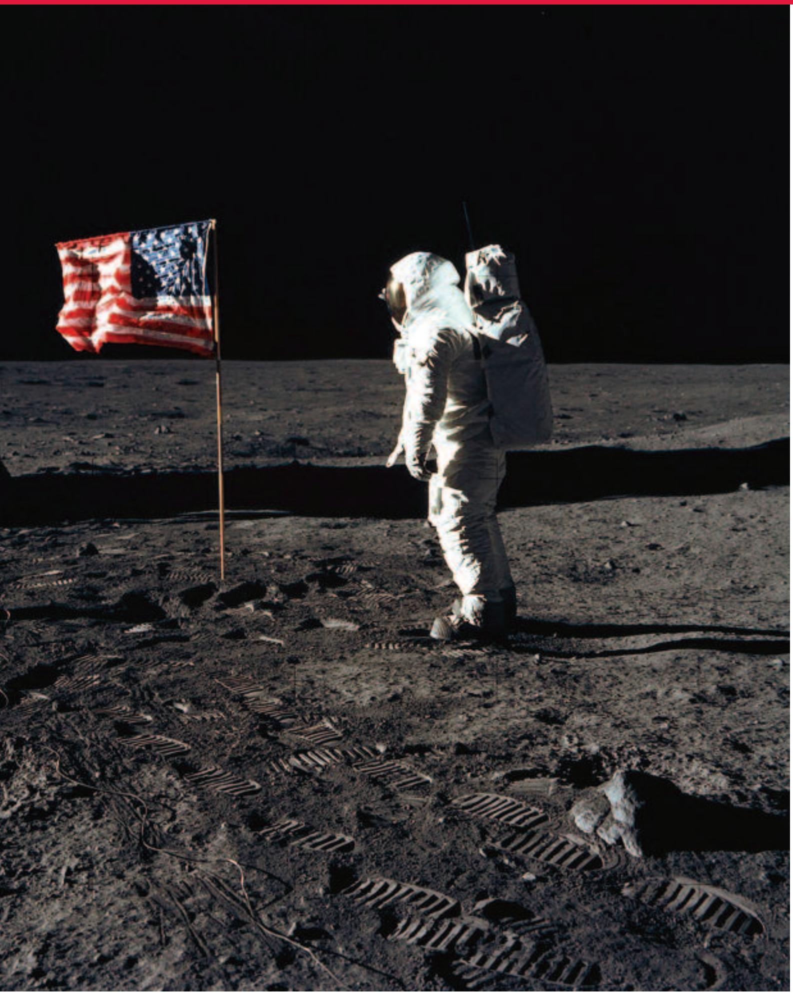


A Sticky Lunar Problem

BY BRIAN O'BRIEN

A dusty problem for the Apollo astronauts has taken on new significance with US plans to return to the Moon by 2020.

A set of original NASA data tapes from Moon landings in the 1960s may hold the keys to overcoming problems associated with the effects of lunar dust on future missions to the Moon. The 177 data tapes, now held in Western Australia, are most likely the only tapes of their kind in the world, and contain the results of experiments using dust detectors on the surface of the Moon by Apollo 11, 12 and 14 astronauts. They have been recently supplemented by secondary data from Apollo 12, 14 and 15 missions.

Dust tormented the Apollo astronauts. Apollo 12 astronauts landed blind because of clouds of dust stirred up by rocket exhausts. Astronauts readily kicked up dust during moonwalks. It clung to anything and everything, from Apollo hardware, optics and deployed experiments to spacesuits.

In the decades since the Apollo missions there has been a massive change in cultural attitudes to lunar dust. Before Apollo, science fiction writer Isaac Asimov popularised a view that spacecraft landing on the Moon would sink majestically out of sight in deep lunar dust. The lunar surface, unprotected by an atmosphere such as Earth's, has been pulverised for four billion years by large and small meteors travelling at 25,000 km/h.

In 1966, soft-landing Russian *Luna* and American *Surveyor* missions showed that these fears were indeed science fiction. Once Apollo engineers were free of that great risk, they largely treated dust as a housekeeping problem for astronauts to manage personally using brushes and a vacuum system. Yet astronauts on Apollo 17, the last mission, were very dusty indeed.

The adhesive strength of moon dust increases as the Sun becomes stronger throughout the 710-hour lunar day. This means that future astronauts working on the Moon's surface in the middle of the day are likely to be covered with much more dust than those working in the morning, which is when Apollo astronauts ventured outside.

This finding was one of a suite of discoveries reported in *Geophysical Research Letters* last May – 40 years after the Apollo missions. The measurements were made by the matchbox-sized Dust Detector Experiments (DDEs) that I invented before dinner on a flight from Los Angeles to Houston on 12 January 1966. A DDE was put on the Moon by Apollo 11, 12, 14 and 15 astronauts, and its measurements were transmitted every 54 seconds to Earth.

The DDE was a delightfully minimalist experiment. Three solar cells gave output voltages that could be predicted due to the reliability of the Sun as a light source, with output decreasing by 10% if about 0.5 mg/cm^2 of lunar dust covered the solar cells.

The dust detectors were attached to equipment on the lunar surface outside the Apollo craft, and are especially important because they provide the only direct measurements of spacecraft lift-off conditions and dust clouds caused by rocket exhausts. This can be crucial in determining how close astronauts can leave scientific equipment on the Moon without it being adversely affected by dust when spacecraft depart.

During the Apollo 12 mission, Alan Bean deployed the mission's scientific package 130 metres from the lunar module. The photo on page 43 shows lunar dust on the DDE from his spacesuit. As the Apollo 12 astronauts left the Moon, rocket exhausts then cleansed the horizontal and vertically arranged solar cells of the DDE differently, providing new insights into the stickiness of lunar dust.

Interest in lunar dust has grown since 2004, when US President George W. Bush announced plans for human missions to the Moon by 2020. While hypotheses and computer modelling of lunar dust are now better funded, for the next few years the only hard data about surface dust will come mainly from DDEs and hard-learned anecdotal lessons from Apollo.

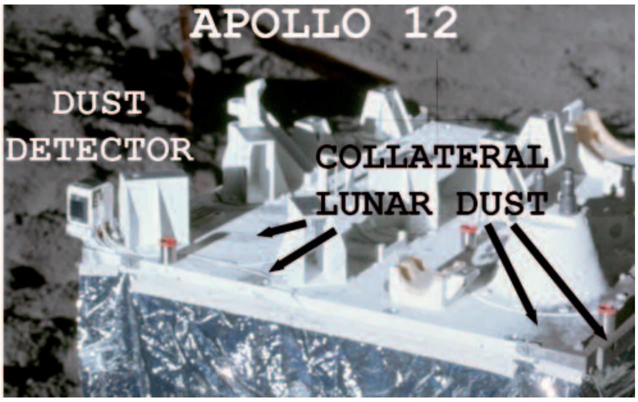
However, NASA revealed on its website in 2006 that the original tapes containing the DDE data had been misplaced before they could be archived. Fortunately my original principal investigator records were safely stored in Perth, including 100 paper charts, calibrations and 177 digital tapes with six million measurements. Prof John de Laeter and laboratory manager Glen Lawson of Curtin University's Department of Applied Physics had kindly saved the 10-inch computer tapes for me. They are now stored with Perth-based company SpectrumData.

The tapes are of international significance, especially since Russia, China, Japan, India and the European Union are also undertaking lunar projects. It is likely to be a decade or more before such countries could carry out experiments into the effects of lunar dust on human and robotic activities on the dust-covered lunar surface.

It is now accepted that dust is the number-one environmental problem on the Moon. Dust adhesion encountered by future astronauts in the middle of lunar days may be much greater than with Apollo astronauts, who walked there only during early lunar mornings. Concerns include fine dust clogging up instruments and possible problems if it comes off astronauts' space suits in their space capsule.

There are also implications for the astronauts' health. Once they leave lunar gravity and enter zero gravity in a capsule, the dust floats everywhere and inhalation issues can be very important. Lunar dust has an average particle size of about 70 µm, or about the thickness of a human hair, but many particles can be only a few microns, and grains tend be sharp and angular. If inhaled they would be a health hazard.

A new field of science is now emerging with the Moon being recognised as a unique and ever-changing laboratory of "dusty plasmas". With its atmosphere and magnetic field only about 10^{-15} and 10^{-3} as strong as the Earth, respectively, during each lunar day the Moon is bombarded by the solar wind, with proton densities about 10/cm^3 travelling at 300 km/s. By day the Moon is also bathed in a dense sea of photoelectrons knocked out of dust particles by energetic ultraviolet and X-rays in raw sunlight, leaving the dust charged a few volts positive.



Sticky lunar dust accumulated on instruments deployed during the Apollo missions.

The long magnetospheric tail of the Earth, fluttering comet-like in the solar wind, brings other plasmas to the Moon. These are richer in the more energetic electrons and protons that cause the divine auroras in polar regions on Earth. Cosmic and solar nuclei with even greater energies have unlimited access. At sunrise and sunset, electrically charged dust may even levitate.

We now know a few of the ways that lunar dust is richly mysterious. But as yet we have few facts.

So scientific justifications for exploring the Moon in the 21st century are increasingly energised by dusty-plasma physicists, just as they were in the 20th century by geologists asking Apollo astronauts to bring back special rocks.

Truly we live in interesting times.

Brian O'Brien is an Adjunct Professor of Physics at the University of Western Australia. He is a former Director and Chair of the Environmental Protection Authority of WA and in 1973 was the first Australian to be awarded the NASA Medal for Exceptional Scientific Achievement. He was elected Fellow of the Australian Academy of Technological Sciences and Engineering in 1993. This article is adapted from the October 2009 issue (158) of ATSE *Focus*.