Science Fact

The Science Behind "The Power of Apollo (16)"

Marianne J. Dyson

Apollo astronauts left a lot more than footprints on the Moon. Scattered near the six landing sites are items as small as golf balls all the way up to the 10-foot (3-meter) tall descent modules. For my story, "The Power of Apollo (16)," I asked myself the question, "Would any of these Apollo leftovers be useful to a crew stranded on the Moon?"

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Radioactive Apollo Science

Considering that lunar night lasts two weeks, modern spacecraft use solar panels (that recharge batteries), and that survival depends on power to run life support systems . . . stranded explorers could certainly use a nuclear-powered generator. Luckily for them, the Apollo 12 through 17 experiment packages were powered by radioisotope thermonuclear generators (RTGs) that are still actively producing power!

I chose Apollo 16's RTG to salvage because it is furthest south and one of the "youngest," having been deployed in 1972. But while preparing this article, I discovered that my choice was good for another reason: at its last check before telemetry was shut down in 1977, the Apollo 16 RTG was producing more power than any of the others.[1]

RTGs use the radioactive decay of plutonium-238 (PU-238) to produce heat that is converted to electricity. There are no moving parts to break down. The SNAP-27 (Systems for Nuclear Auxiliary Power) Apollo reactors each contained about eight pounds (3.6 kg) of PU-238 with a half-life of 87.7 years. This PU-238 came from the Savannah River Site's nuclear weapons facility in South Carolina. After the Cold War, countries ceased making PU-238, and the US obtained supplies from Russia for spacecraft such as the Mars Curiosity rover. With stockpiles depleting, the US restarted production of PU-238 at Oak Ridge National Laboratory in 2015.[2]

Manufactured by General Electric, the hardy Apollo RTGs are about 18 inches (45 cm) tall and 16 inches (40 cm) in diameter, including the heat radiating fins (that are actual "space" heaters!). The portable containers are made of beryllium and weigh about 28 pounds (13 kg) unfueled.

An astronaut salvaging an RTG won't have to worry about radiation. Alpha particles released by the plutonium won't penetrate human skin. Plutonium is only toxic if inhaled or swallowed, which isn't going to happen while it is encased in a graphite fuel cask. This cask was designed to contain the plutonium in case of an accident such as what happened on Apollo 13. That cask survived reentry through the atmosphere and remained intact after plunging more than three miles into the Pacific Ocean.[3]

The initial power output of the Apollo 16 RTG was around 72 watts and dropped to around 35 watts at the termination of operations.[1] That should be sufficient to light and heat (via radiated heat from the fins) a small greenhouse to provide food (and produce oxygen and absorb carbon dioxide). But even if it is much less, as my character notes, "We need every watt we can get."

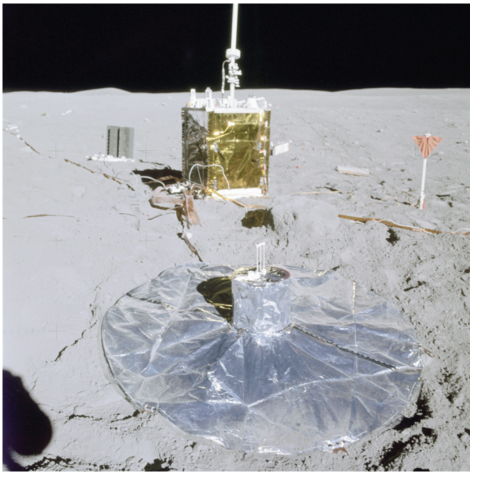

Photo A

In this photo taken during Apollo 16's first EVA, the passive seismic experiment is in the foreground under a Mylar shroud to protect it from thermal expansion and contraction. In the background is the Apollo Lunar Science Experiment Package Central Station with the RTG to the left. One of the anchor flags for the Active Seismic Experiment is on the right. Credit: NASA. AS16-113-1837, April 21, 1972.

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The Impact of Science

The Apollo 16 active seismic experiment was designed to acquire data on the physical properties of the lunar surface. Both natural and artificially produced seismic waves were monitored by the passive seismic experiment. The artificial waves were produced by shotgun-like charges fired by the astronauts (John Young for Apollo 16) using a "thumper" device, and by firing explosive grenades from a mortar box assembly. Yes, you read that right: grenades!

The seismic waves caused by the explosions were measured by a network of geophones deployed by the crew using their rover and marked with anchor flags. The geophones were electromagnetic listening devices that were cable-connected to the central station where their signals were amplified, digitized, and transmitted to Earth.

The crew set the mortar box on a pallet to provide stability during the firings and aid them in aligning the experiment. The pallet was supposed to be held in place with four stakes, but one stake got bent and jammed so that the crew could not pull it out.

The mortar box assembly contained four grenades. Each grenade was to be launched a different distance from the box with the ranges being 150, 300, 900, and 1,500 meters (492, 984, 2953, and 4921 feet) via command from Earth after the crew had lifted off the surface.[4] The first three launched as planned. But after the third launch, the pitch-angle sensor went off-scale high. Although tests on Earth indicated that three stakes should be sufficient to hold the device stable, it is possible that the lack of a fourth stake caused the assembly to tip over (from recoil) after the third shot. Another explanation is that the sensor simply failed.[5]

However, the concern was that the fourth grenade might go straight up or sideways and impact one of the other experiments. So the fourth grenade was not launched. But in 1977, when the decision was made to terminate experiment operations, the scientists decided to try launching this last grenade. They sent a series of commands to set off the explosion. "An arming command was transmitted but arming capacitors would not charge."[1]

So, the grenade is still sitting there in the launch tube, waiting for that capacitor to send it a pulse! Would the explosive still be viable like old WW2 unexploded bombs that have become unstable over time? How might my character set it off?

I called the Lunar and Planetary Science Institute in Houston and was fortunate to talk with an astrogeologist who worked Apollo. First, I asked his opinion of whether or not the explosive would still be capable of detonation. He noted the dry lunar environment and said he didn't see why not. Then I asked how to set off the explosion. He said all it would take is an electrical pulse, perhaps a static discharge?

Objects on the lunar surface are known to build up an electric charge.[6] My character uses an electric drill to cut the live wire attached to the RTG that is still providing power to the launcher. While this might be an improbable way to detonate a grenade, the proposed scenario does not violate any laws of physics, and Murphy's Law (what can go wrong will go wrong) gives it a definite go!

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The First Telescope on the Moon

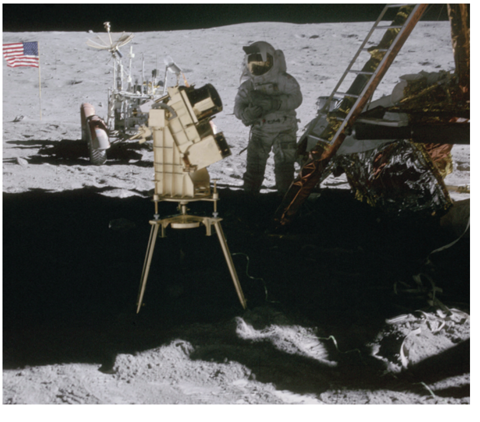

Photo B

Astronaut John Young deployed the Carruthers Far UV camera in the shadow of the Apollo 16 Lunar Module to block the sun while looking at Earth and other objects. The LM landed on a slope so that the shadow was shorter than planned. With the ascent module gone, the shadow is now half as tall. When the sun is farther west, at least part of the telescope is in sunlight and would be extremely bright. NASA photo AS-16-114-18439, April 22, 1972.

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I couldn't resist having my character pick up a few souvenirs. Each of the Apollo landing sites contains some unique items, but none more unique than the gold-plated telescope that sits beside the Apollo 16 lander. I hope readers will be as fascinated as I was to learn not only of its beauty, but the inspiring story of its creator, a brilliant astronomer named Dr. George Carruthers (1939-2020).

Born in Cincinnati, Ohio, Carruthers built his first telescope at age ten. In an oral history[7], he said his parents and classmates considered his interest in space and science fiction to be "strange." Undaunted, he read everything he could find about space at the library. After his father's death, twelve-year-old Carruthers moved to Chicago. There, he was one of only a handful of African-American students to compete in high school science fairs where he won first prize for a telescope he designed and built. Overcoming a lack of prerequisite courses not offered at his mostly black high school, Carruthers earned a degree in physics in 1961, a Masters in nuclear engineering in 1962, and a PhD in aeronautical and astronautical engineering in 1964 from the University of Illinois.

Wanting to do astronomical research, he took a job with the U.S. Naval Research Laboratory. His design of an imaging device that converted photons to electrons and recorded the signal on film earned him a patent in 1969. During a rocket flight in 1970, his image converter proved the existence of interstellar molecular hydrogen. This device was the heart of the Apollo 16 Far UV Camera/Spectrograph for which he was the Principal Investigator. The film brought back in 1972 captured the first ever images of the Earth's atmosphere in ultraviolet as well as images of stars, nebulae, and galaxies. A backup unit flew on Skylab 4 and was used to study comet Kohutek. A replica is on display at the Smithsonian National Air and Space Museum.[8]

Photo C

Project Engineer William Conway (left) and Principal Investigator Dr. George Carruthers (right) with the Apollo 16 Far Ultraviolet Camera/Spectrograph instrument invented by Carruthers. The telescope was coated with gold (like the James Webb telescope) to increase reflectivity in infrared light and thus limit thermal expansion and contraction of the instrument. Credit: NRL, courtesy AIP Emilio Segrè Visual Archives, Ronald E. Mickens Collection.

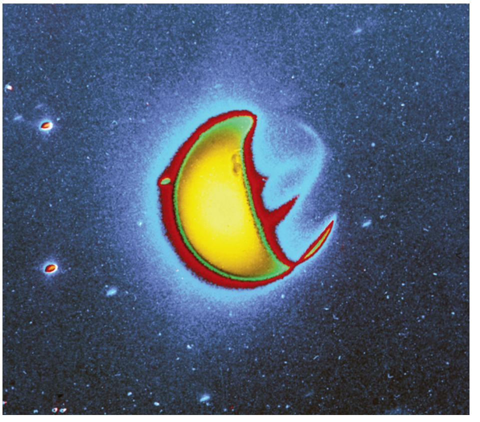

Photo D

This is an exposure of Earth taken by the Carruthers' 3-inch (7.5-cm) aperture Far UV Camera/Spectrograph during Apollo 16. A filter blocked atomic hydrogen, revealing the glow caused by atomic oxygen and molecular nitrogen. The part of the Earth facing the Sun (bright) reflects much of the UV light. Bands of UV emission seen on the night side are aurora caused by charged particles from the Sun. Credit: NASA S72-40821, enhanced version of AS16-123-19657, April 21, 1972. https://images.nasa.gov/details-S72-40821

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Carruthers was awarded NASA's Exceptional Scientific Achievement Medal for this work. In 2003, he was inducted in the National Inventor's Hall of Fame. In his later years, he served as a role model for Black youth and taught Earth and space science at Howard University.[9]

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In the story, the character suggests using 3-D printing to make a film cartridge or other adapter so that students can use this telescope. I bet there is some enterprising young person out there, maybe reading this article, who will figure it out and perhaps win their high school science fair!

Apollo astronauts left way more than footprints on the Moon. Even if we decide not to revisit the landing sites and repurpose any Apollo "leftovers," the legacy the crews and science teams left behind, and especially their can-do attitude, will ensure the survival of future space explorers and continue to inspire young people to dream big and reach for the Moon.

As one of NASA's first female flight controllers, Marianne Dyson had the privilege of working with many Apollo veterans, including John Young and T.K. Mattingly. A member of the Manned Spaceflight Operations Organization and the NASA Alumni League, Dyson works to preserve the history of Mission Control and inspire the next generation of space explorers. Her latest books are Shuttle Mission Control: Flight Controller Stories and Photos, 1981-1992; *and for kids,* Welcome to the Moon, *and* Up in Space: we built a Station. *Visit her at https://www.mariannedyson.com.*

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