

18 | MOONSHOT AT 50: APOLLO ANNIVERSARY

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Mapping the moon

Arizona scientists played major role in locating lunar landing sites

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In 1961, when President John F. Kennedy announced the United States would land a man on the moon by the end of the decade, modern lunar and planetary science was still in its infancy.

Is its birthplace? The University of Arizona in Tucson. The story of the Apollo 11 moon landing, which occurred nearly 50 years ago, wouldn't be complete without the endeavors of a team led by Gerard Kuiper, who became the director of the UA Lunar and Planetary Laboratory.

Lunar atlases

Even before the Space Race began with the launch of Soviet satellite Sputnik in 1957, Holland-born Kuiper, director of the University of Chicago's Yerkes Observatory in southern Wisconsin, was working on compiling the best images of the moon at the time to create a photographic lunar atlas.

Until that time, maps of the moon were drawn by hand and the names of the moon's features were not agreed upon, said Timothy Swindle, the UA lab's current director.

At an astronomical conference in Dublin, Ireland, in 1955, Kuiper asked anyone interested in assisting him in his endeavor to create a moon atlas to reach out to him.

Even Whitaker, then the director of the lunar section of the British Astronomical Association, was the only one to respond. Kuiper asked Whitaker to join him at Yerkes Observatory for a monthlong project.

Whitaker left for the United States the day after Sputnik took to the skies. Then, Kuiper secured funding from the Air Force to complete the lunar atlas and Whitaker never returned to the United Kingdom, according to the 2016 documentary "Desert Moon," by science writer Jason Davis, which details the UA's role in helping the United States reach the moon.

While at Yerkes, Kuiper and his team published the first photographic lunar atlas. It was the most comprehensive photographic record of a planetary body ever published.

Kuiper moves to the desert

The moist air and cloudy skies of southern Wisconsin, as well as tension among colleagues agitated by Kuiper's abrasive personality, were not ideal for observing the moon, according to those who worked closely with him.

Kuiper was drawn to Tucson for the dry and clear night skies, the newly built Kitt Peak National Observatory located about 50 miles southwest of the city, and the surrounding Santa Catalina Mountains, which were well-suited for observatories because of their high elevation.

Kuiper's mind was set. He and his team moved to Tucson.

They started out in a wing of the UA's Physics, Mathematics and Meteorology Building — now the Physics and Atmospheric Sciences building. Years later, and after much growth in the program, NASA funded the construction of what is now called the Kuiper Space Sciences Building.

Kuiper and his team arrived in 1960, the same year their first and second lunar atlases were published. But the team's work was just beginning.

"Going to the moon became a national priority in the spring of 1961. Until that point, no one else was looking at the moon and he and his group were suddenly in demand," Swindle said.

Mapping the moon

If the astronauts were going to land on the moon, they would need maps to land them there and navigate. Kuiper set out to create a Rectified Lunar Atlas. It was published in 1963.

To accomplish this, William Hartmann, one of the laboratory's first graduate students, projected the best images of the moon onto a white globe, then took pictures of the globe from the side. This technique allowed him to see what the moon's surface would look like as seen from directly above at every angle, without the distortion experienced in viewing the moon from Earth, Hartmann said.

This technique not only led to new theories about the moon's history, but also to the creation of mineral and navigational maps of our celestial companion.

Hartmann, one of the founders of the Planetary Science Institute in Tucson, is now also an acclaimed science artist and writer.

Navigating the moon

In 1967, Kuiper and his team published another version of his lunar atlas called the Consolidated Lunar Atlas.

"This atlas was a collection of very high quality, loose-leaf photographic prints of all of the best images taken from Earth-based telescopes ... (it was distributed to members of the space community to support the upcoming



From left, Ewen Whitaker, Gerard Kuiper and Ray Heacock stand in front of a lunar hemisphere and model of a Ranger spacecraft. Kuiper and his team worked at the University of Arizona and published in 1967 the Consolidated Lunar Atlas, which included a collection of photographs of the Moon taken from Earth-based telescopes.

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The surface of the moon

With too sparse an atmosphere to impede impacts, a steady rain of asteroids, meteors and comets strikes the surface of the moon, leaving numerous craters behind. During the course of billions of years, these impacts have ground up the surface of the moon into fragments ranging from huge boulders to powder. Nearly the entire moon is covered by a rubble pile of charcoal-gray, powdery dust and rocky debris called the lunar regolith. Beneath is a region of fractured bedrock referred to as the megaregolith.

The light areas of the moon are known as the highlands. The dark features, called maria (Latin for seas), are impact basins that were filled with lava between 4.2 and 1.2 billion years ago. These light and dark areas represent rocks of different composition and ages, which provide evidence for how the early crust may have crystallized from a lunar magma ocean. The craters themselves, which have been preserved for billions of years, provide an impact history for the moon and other bodies in the inner solar system.

— NASA

Apollo missions to the moon," according to the Lunar and Planetary Institute in Houston.

NASA wasn't sure what the Apollo 11 astronauts would find when they got to the moon. Some scientists feared the dust might be so thick on the moon that the astronauts would sink deep into it. So Kuiper was tasked with participating in a series of robotic missions to the moon that would take up-close photos of the surface years before the astronauts made an attempt to land.

At the same time, he had his graduate students explore places such as Mexico to understand the geology of landscapes shaped by volcanoes and molten rock, Hartmann said. They also studied geology under Spencer Titley, professor emeritus in geoscience.

Kuiper saw the importance of people getting trained to look at the moon as a place rather than just an object in a telescope, Swindle said.

When the first robotic spacecraft, Surveyor 1, landed on the lunar surface on June 2, 1966, and scientists announced its landing site, Whitaker did his own analysis of its location. By examining the horizon and other geographic features, he correctly determined a more accurate location where Surveyor 1 had positioned itself, according to "Desert Moon" documentary.

Because of his success in locating Surveyor 1 landing spot, Whitaker was asked to locate Surveyor 3 after it landed on the moon, an important event for the astronauts just two years later.

When Apollo 11 reached the moon on July 20, 1969, the astronauts were deterred from the original landing site

by an unexpectedly rocky surface. The astronauts had to travel 4 miles away to land safely.

"With Apollo 12, NASA wanted to demonstrate a precision landing," Swindle said about the second moon landing, "but the problem is, how do you do a precision landing site when you don't know where anything is? This is before GPS or anything like that."

The location of Surveyor 3, accurately found by Whitaker years earlier, was their lunar lighthouse, guiding the Apollo 12 astronauts to their pinpoint landing.

On the horizon

Kuiper was director of the LPL until his death in 1973. Whitaker died in October 2016.

The Kuiper Belt, the region of the solar system beyond Neptune containing small, icy, astronomical bodies, was named in his honor.

To this day, LPL is still a world leader in lunar and planetary science. Currently, the university leads the OSIRIS-REx mission to the asteroid Bennu to learn more about the origins of life and the solar system.

"But the moon isn't done. The Apollo program is done," but the samples returned from those missions are still being studied to this day, Swindle said. And as humans again ramp up efforts to revisit the moon (and possibly Mars), the laboratory is paying attention to the needs of those explorers.

When it comes to exploration, he said "there are different parts to the problem. When it comes to the scientific problems, we hope to be players."

Significant dates in lunar history

1609: Thomas Harriot becomes the first person to use a telescope aimed at the sky and later made the first maps of the moon.

1610: Galileo Galilei publishes scientific observations of the moon in *Sidereus Nuncius* (Starry Messenger).

1959-1976: The U.S.S.R.'s Luna program of 17 robotic missions achieves many "firsts" — including the first glimpse of the far side of the moon — and three sample returns.

1961-1968: The U.S. Ranger, Lunar Orbiter, and Surveyor robotic missions pave the way for Apollo human lunar landings.

1969: Astronaut Neil Armstrong is the first human to walk on the moon's surface.

1994-1999: Clementine and Lunar Prospector data suggest that water ice may exist at the lunar poles.

2003: The European Space Agency's SMART-1 lunar orbiter inventories key chemical elements.

2007-2008: Japan's second lunar spacecraft, Kaguya, and China's first lunar spacecraft, Chang'e 1, both begin one-year missions orbiting the moon; India's Chandrayaan-3 soon follows in lunar orbit.

2008: The NASA Lunar Science Institute is formed to help lead NASA's research activities related to lunar exploration goals.

2009: NASA's Lunar Reconnaissance Orbiter and LCROSS launch together, beginning the U.S. return to lunar exploration. In October, LCROSS was directed to impact a permanently shadowed region near the lunar south pole, resulting in the discovery of water ice. LRO is still exploring the moon from orbit.

2011: Twin GRAIL spacecraft launch to map the interior of the moon from crust to core, and NASA begins the ARTEMIS mission to study the moon's interior and surface composition. After the successful mission, the twin GRAIL spacecraft were directed to impact the moon in 2012.

2013: NASA launches LADEE to gather detailed information about the structure and composition of the thin lunar atmosphere. The successful mission ended in April 2014.

Dec. 14, 2013: China becomes the third nation to safely land a robotic spacecraft on the moon with the touchdown and deployment of Chang'e 3's Yutu rover.

— NASA