

LEGACY *of* DISCOVERY  
— in —  
SPACE EXPLORATION

**The Crab Nebula is all that remains of a tremendous supernova located 6,500 light-years away in the constellation Taurus. This 2007 mosaic image, one of the largest ever taken by Hubble, spans 12 light-years.**

*credit: NASA / ESA / Jeff Hester (ASU)*

## The inner workings of **outer space**

ASU has been involved in space exploration since the early days of the Space Race. In 1961, the university opened the Center for Meteorite Studies (CMS), which is now the largest university-based meteorite collection in the world. It houses more than 30,000 pieces from 2,000 distinct meteorites. Researchers at ASU and around the world use the collection to learn about the origins of our planetary system.

In the 1970s, ASU began its long-standing relationship with NASA with the arrival of Ronald Greeley, one of the founders of planetary geology. Before coming to ASU, Greeley helped select landing sites for NASA's Apollo missions and assisted in geologic training for astronauts. He participated in numerous space missions to Venus, Mars, Jupiter, Saturn, Uranus and Neptune.

Another planetary geologist, Phil Christensen, launched ASU's foray into building space instruments. In the early 1980s, he began developing infrared imaging systems that help us to understand the physical makeup of the surface of Mars. These devices include the Thermal Emission Spectrometer (TES), Thermal Emission Imaging System (THEMIS), Mini-TES and OSIRIS-REx Thermal Emission Spectrometer (OTES).

In 1990, NASA launched the Hubble Space Telescope, which orbits outside of Earth's atmosphere, taking high-resolution images of deep space. ASU researchers have been involved in Hubble projects since its inception, producing images recognized around the world.

In 2009, NASA launched the Lunar Reconnaissance Orbiter (LRO), a robotic spacecraft now circling the moon. Mark Robinson, an ASU planetary geologist, leads the Lunar Reconnaissance Orbiter Camera (LROC), which captures high-resolution images of the lunar surface.

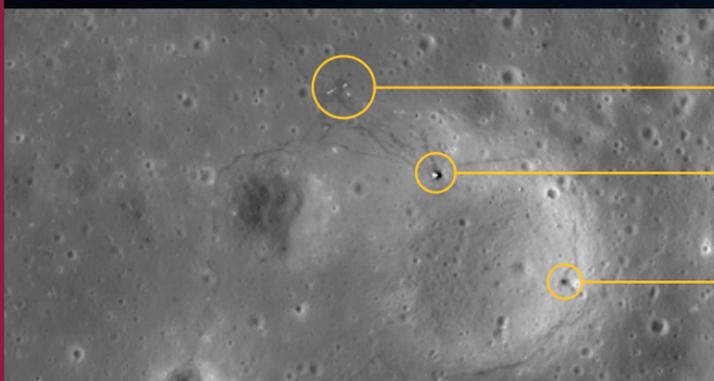


A life-sized replica of the Mars Curiosity Rover in ASU's Interdisciplinary Science and Technology Building 4



“This kind of big science can’t be done everywhere. It requires a commitment to working between traditional disciplines; a commitment of institutional support; a dedication to big questions and the long timelines big projects require; and a positive, team-oriented, collaborative culture. The combination of these things together is rare in academia. We have these things at ASU.”

Lindy Elkins-Tanton, director, School of Earth and Space Exploration



ALSEP equipment

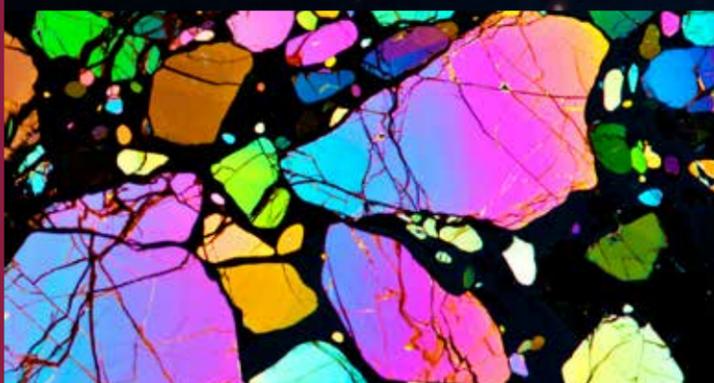
Intrepid descent stage

Surveyor 3

Apollo 12 landing site  
credit: NASA | GSFC | ASU



Carleton Moore, founding director of ASU's Center for Meteorite Studies.  
credit: University Archives Photographs, ASU Libraries



A thin slice of the Admire meteorite, magnified. Polarized light turns normally green peridot into a kaleidoscope of colors.  
credit: Laurence Garvie, Center for Meteorite Studies

### Infrastructure for exploration

ASU has built an ecosystem that enables the collaborative, creative approach needed to excel in space exploration. In 2006, ASU created the School of Earth and Space Exploration (SESE), bringing together planetary geologists, astronomers and engineers who work together to take missions from idea to instrument.

In 2012, the 300,000-square-foot Interdisciplinary Science and Technology Building 4 became a “home base” for space researchers to collaborate, innovate and communicate. The facility houses publicly viewable labs, clean rooms with vacuum chambers that simulate space, a 250-seat auditorium, a public gallery of space exploration and one of two mission operations centers on campus.

Looking forward, ASU recognizes that the traditional model for space research—massive, government-funded missions—may not be sustainable for the future. The NewSpace Initiative, launched in 2013, connects ASU researchers with private space companies to explore new ways to solve problems and answer questions.

### Pillars of Creation 1995

ASU astronomers Jeff Hester and Paul Scowen image a portion of the Eagle Nebula using the Hubble Space Telescope. The iconic “Pillars of Creation” image shows three columns of cold gas bathed in the scorching UV light from a cluster of young, massive stars. (see p. ii)

### Mars Odyssey 2001

NASA's Odyssey orbiter launches, carrying Christensen's THEMIS instrument, which will help determine the distribution of minerals on the Martian surface—particularly those that form in the presence of water.

### Revisiting the moon landing 2009

The ASU-led LROC photographs the Apollo 12 landing site, which clearly shows the Surveyor 3 spacecraft; lunar module descent stage, Intrepid; and Apollo Lunar Surface Experiment Package (ALSEP). It also shows tracks made in 1969 by astronauts Pete Conrad and Alan Bean.

### Mars Global Surveyor 1996

NASA launches the Mars Global Surveyor, which carries a Thermal Emission Spectrometer (TES) designed by ASU planetary geologist Phil Christensen. MGS is the first successful U.S. mission to Mars since the Viking mission in 1976.

### Roving Mars 2004

ASU-designed Mini-TES instruments touch down on Mars aboard each of the Mars Exploration Rovers, Spirit and Opportunity (launched in 2003). The rovers search for signs of past water activity on Mars.

### Curiosity rover 2011

Three SESE researchers are members of the instrument science teams for the Mars Science Laboratory Curiosity rover: Jim Bell (Mastcam, MAHLI, MARDI cameras), Jack Farmer (CheMin instrument) and Meenakshi Wadhwa (SAM instrument).

Only **30** institutions in the U.S. can build spacecraft.  
 Only **7** institutions can build interplanetary spacecraft.  
**Arizona State University** is one of them.

## On the launchpad...

### Galactic discovery 2012

ASU astronomers discover a faraway galaxy that is ranked among the 10 most distant objects currently known in space—13 billion light-years away. The research team, led by James Rhoads, Sangeeta Malhotra and Pascale Hibon, identifies the remote galaxy using the Magellan Telescopes at the Carnegie Institution's Las Campanas Observatory in Chile.

### The moon's north pole 2014

By combining 10,581 narrow angle camera images collected over four years, the LROC team produces a complete picture of the moon's northern polar region in stunning detail.

### OTES send-off 2015

ASU scientists and engineers, led by Christensen, complete the first space instrument built entirely on the ASU campus. The OSIRIS-REx Thermal Emission Spectrometer will travel aboard a 2016 NASA mission to collect a sample from an asteroid and return it to Earth.

### Meteorite molecules 2013

Scientists led by ASU chemist Sandra Pizzarello find that the Sutter's Mill meteorite, which exploded in a blazing fireball over California in 2012, contains organic molecules not previously found in any meteorites. This suggests a greater availability of extraterrestrial organic molecules than previously thought.

### Martian mineral map 2014

ASU's THEMIS instrument on board the Mars Odyssey orbiter provides data to create the most detailed map yet made of Martian surface properties. The map was developed by the U.S. Geological Survey in collaboration with ASU.

### ASU leads CubeSat mission 2015

The first completely ASU-led space mission, the Lunar Polar Hydrogen Mapper (LunaH-Map), is awarded to postdoctoral scholar Craig Hardgrove. This shoebox-sized CubeSat will create a map of water-ice on the moon. Lunar resources such as hydrogen could enable astronauts to manufacture fuel and other provisions for a journey to Mars, reducing the amount of fuel (and weight) needed to leave Earth.

### AOSAT 1 CubeSat (Earth orbit) 2017

**Science lead:**  
Erik Asphaug  
**Engineering lead:**  
Jekan Thanga

### Emirates Mars Mission 2020

(first space mission from the United Arab Emirates)  
**Emirates Mars Infrared Spectrometer:**  
Phil Christensen

### NASA Europa mission 2022

**E-THEMIS instrument:**  
Phil Christensen

### Lunar Polar Hydrogen Mapper (moon) 2018

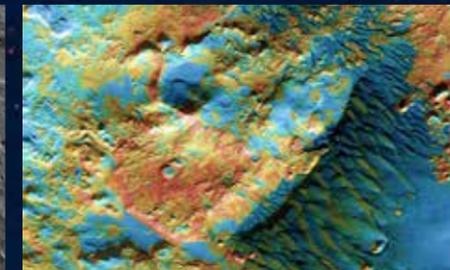
**Mission lead:**  
Craig Hardgrove

### Mars 2020 rover 2020

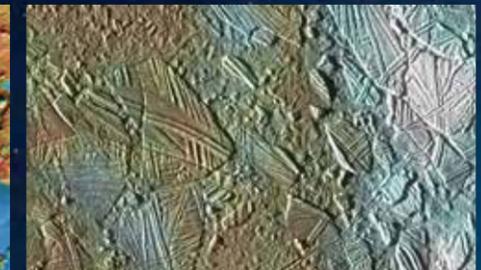
**Mastcam-Z cameras:**  
Jim Bell



A map of the moon's northern polar region, comprised of 10,581 LROC images.  
 credit: NASA | GSFC | ASU



This false-color THEMIS image shows sand dunes inside a crater in Arabia Terra on Mars.  
 credit: NASA | JPL | ASU



The surface of Jupiter's moon Europa, shot from NASA's Galileo mission. ASU geologist Ronald Greeley was part of Galileo's camera team.  
 credit: NASA | JPL-Caltech