



Higher Education Lunar Consortium

Resources

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Lunar Science

The Center for Lunar Science and Exploration (CLSE)

<http://www.lpi.usra.edu/nlsi/index.shtml>

One of seven NASA Lunar Science Institute teams, the CLSE Team will re-examine Apollo samples with new technology – coupled with lunar geologic and geophysical data - to assess the bombardment history of the Moon. This, in turn, will build our understanding of the history of the inner solar system. This investigative theme carries us from the earliest moments of the Moon's origin through the immensely important basin-forming epoch to new analyses of impact contributions to the lunar regolith.

NASA Lunar Science Institute

<http://lunarscience.arc.nasa.gov/>

NLSI is comprised of a central office at NASA Ames Research Center and distributed, collaborative national and international teams, all of which are investigating aspects of lunar science, including the Moon's formation and geologic evolution, the lunar environment, potential for exploration, and the science that can be undertaken on the Moon. The site, as well as the CLSE site, offers links to the other NLSI teams.

Lunar Science and Exploration Portal

<http://www.lpi.usra.edu/lunar/>

One-stop-shop for lunar science and exploration information, including mission summaries, Apollo era documents, images, maps, sample and meteorite information, surface studies, lunar science and exploration documentation, computational tools, course resources, and student opportunities.

Astromaterials Research and Exploration Science (ARES)

<http://ares.jsc.nasa.gov/>

NASA's ARES group performs the physical science research at Johnson Space Center, including research on astromaterials, curates all NASA-held extraterrestrial samples, and provides support to the human and robotic spaceflight programs with expertise in orbital debris modeling, analysis of micrometeoroid/orbital debris risks to spacecraft, image analysis and earth observations.

Lunar Sample Compendium

<http://www.lpi.usra.edu/lunar/samples/>

Detailed comprehensive presentation of the results of petrographic, mineralogic, radiogenic, and isotopic, studies of numerous individual Apollo samples.

Lunar Sample Atlas

<http://www.lpi.usra.edu/lunar/samples/atlas/>

This library of images provides pictures of the Apollo samples taken in the Lunar Sample Laboratory, full-color views of the samples in microscopic thin-sections, cutting views and diagrams that illustrate how the samples were subdivided for scientific analyses, and in situ views of the samples on the lunar surface. The atlas contains information about the type of sample (e.g., rock, soil), the lithology (e.g., basalt, norite), and a description of the sample.

Scientific Context for Exploration of the Moon

http://www.nap.edu/catalog.php?record_id=11954

The Committee on the Scientific Context for Exploration of the Moon (National Research Council) authored this final report on the current understanding of the early earth and Moon; the identification of key science concepts and goals for Moon exploration; an assessment of implementation options; and a set of prioritized lunar science concepts, goals, and recommendations.

Lunar Source Book

http://www.lpi.usra.edu/lunar_sourcebook/

The *Lunar Sourcebook*, a concisely presented collection of data gathered during the American and Soviet missions, is an accessible and complete one-volume reference encyclopedia of scientific and technical information about the Moon. A digital version of the *Lunar Sourcebook* is now available for limited distribution. This book provides a thorough introduction to lunar studies and a summary of information about the nature of the lunar environment. It explores the formation and evolution of the Moon's surface, the chemical and mineralogical nature of lunar rocks and soils, and scientific knowledge about the nature, origin, and history of the Moon. *Lunar Sourcebook* is intended for the post-Apollo generation of scientists, engineers, teachers, and students. It has two purposes. First, it summarizes what we know about the Moon as a result of U.S. and U.S.S.R. lunar missions and the continuing analysis of lunar samples and data here on Earth. Second, it provides a convenient, accessible sourcebook for planning the future study of the Moon and the eventual use of the Moon by space faring humans.

Course Materials and Resources

Lunar Exploration Summer Intern Program

http://www.lpi.usra.edu/lunar_intern/

During this 10-week intensive program, ten interns work closely with LPI/JSC NLSI science staff and other collaborators to evaluate the best landing sites for robotic and human exploration missions to address the NRC's science priorities. This will be a unique team activity that should foster extensive discussions among students and senior science team members. Student applications are due in January; the program runs from June into August.

CLSE Classroom Illustrations and Slide Sets

<http://www.lpi.usra.edu/nlsi/training/>

Illustrations with extensive captions for educational use, including:

- Lunar Polar Shadowed Crater Temperatures
- Terrestrial Planetary Cores
- Oriente Basin: A Texas-sized Impact Site
- Oriente Basin Cross-Section and Clementine Location Map
- South Pole-Aitken Basin Cross-Section and Clementine Location Map
- Lunar Impact Basins
- Early Earth Impact Crater Lakes and Hydrothermal Systems
- Early Earth Impact-generated Hydrothermal Systems
- Simple Crater Formation
- Complex Crater Formation
- Asteroid with a Layered Interior
- Asteroid with a Rubble Interior
- Basaltic Volcanism
- Upper Lunar Crust
- Shackleton Crater Compared to the Grand Canyon

Slide sets at this location include Clementine Explores the Moon and the Apollo Landing Sites.

Lunar Lecture Series for Non-Specialists (videos)

<http://www.lpi.usra.edu/lunar/moon101/>

- Introduction to the Moon, *Dr. Paul Spudis*
- The Lunar Environment, *Dr. Wendell Mendell*
- Physiography and Geology of the Moon, *Dr. Paul Spudis*
- The Lunar Surface, *Dr. Jeff Plescia*
- The Lunar Crust, *Dr. Gary Lofgren*
- The Lunar Interior, *Dr. Jeff Plescia*
- The Lunar Polar Environment, *Dr. Ben Bussey*
- A Brief, Selective History of the Apollo Program, *Dr. Dean Eppler*
- Future Scientific Exploration of the Moon, *Dr. Paul Spudis*
- Lunar Meteorites, *Dr. Kevin Righter*

Slide-only versions at: <http://www.spudislunarresources.com/moon101.htm>

NASA's Astromaterials Research and Exploration Science team offers on loan to educators:

Lunar Sample Educational Disk Program

<http://curator.jsc.nasa.gov/lunar/sampreq/disks.cfm>

To be discussed during the Consortium Meeting

The disks contain six samples of lunar material (three soils and three rocks) and are accompanied by descriptions of each sample and educator resources. Educators (primarily K-12 and informal) must be trained in the use and security of the disks prior to receiving the loan.

Lunar Petrographic Educational Thin Section Set

<http://curator.jsc.nasa.gov/lunar/sampreq/lptsp.cfm>

<http://www-curator.jsc.nasa.gov/lunar/letss/contents.cfm>

To be discussed during the Consortium Meeting

Thin sections intended for use in upper-level petrography classrooms; students are encouraged to examine the thin sections and write petrographic descriptions. A potentially useful site for the undergraduate classroom using the samples:

http://minerva.union.edu/hollochk/c_petrology/moon_rocks/background.htm

Note that sites, contact information, and accessibility information are being updated

Computational Tools

Online or downloadable computer programs that assist with past and future exploration of the Moon.

LPI Clementine Mapping Project

<http://www.lpi.usra.edu/lunar/tools/clementine/>

The LPI Clementine Mapping Project is an on-line tool for users wanting to generate maps of the lunar surface and its composition using data from the Clementine mission. The Clementine mission (1994) was a technology demonstration mission that produced nearly 1 million ultraviolet to visible wavelength (UVVIS) images, over 600,000 high-resolution CCD images, over 300,000 near-infrared images, and additional topographic details of the lunar surface. This tool seamlessly combines the data so that users can generate their own image mosaics, chemical maps, and topographic maps of any region on the lunar surface.

Lunar Impact Cratering

<http://www.lpi.usra.edu/lunar/tools/lunarcratercalc/>

This tool allows users to calculate the sizes of impact craters produced on the lunar surface as a function of several independent impact parameters. This is an excellent resource created by Prof. Keith A. Holsapple at the University of Washington. For those who want to explore impact cratering into other types of planetary surfaces, another good tool is Crater Sizes from Explosions or Impacts (<http://keith.aa.washington.edu/craterdata/scaling/index.htm>) at the University of Washington.

Lunar Distance Calculator

<http://www.lpi.usra.edu/lunar/tools/lunardistancecalc/>

This tool allows users to calculate the distance between two points on the lunar surface. For example, it can be used to calculate the distance between two lunar landing sites or the distance between a landing site and another location on a geologic traverse.

Lunar Images and Maps

Digitized photographic images of the Moon taken from Earth with telescopes, from spacecraft orbiting the Moon, from astronauts and their equipment on the lunar surface, and by spacecraft flying by the Moon, plus digital images taken by spacecraft exploring the Moon.

Apollo Surface Panoramas

<http://www.lpi.usra.edu/resources/apollopanoramas/>

Apollo Surface Panoramas is a digital library of photographic panoramas that the Apollo astronauts took while exploring the Moon's surface. These images provide a spectacular boots-on-the-ground view

of the lunar landscape. The panoramas are stitched together from individual 70mm Hasselblad frames, each of which is also accessible through this new atlas. Lunar surface features captured in the panoramas can be studied using zoom and pan tools. An annotated version of each panorama is also available to assist users with the identification of major geographic features around each Apollo landing site.

Lunar Surface Flyovers

http://www.lpi.usra.edu/lunar/lunar_flyovers/

This atlas of Lunar Surface Flyovers provides a series of digital movies that allow viewers to fly over the dramatic terrain of the lunar surface. The spectacular landscapes revealed in this atlas provide scientists with another tool to study the geology of the lunar surface. They also provide mission planners with another tool to select landing sites and design robotic and crew traverses. This is a "living" atlas. As new spacecraft missions generate additional flyovers, those digital movies will be added to the collection.

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Lunar Atlases

The Lunar Orbiter Photo Gallery

<http://www.lpi.usra.edu/resources/lunarorbiter/>

The gallery offers an extensive collection of over 2,600 high- and moderate-resolution photographs produced by all five of the Lunar Orbiter missions. These photographs were taken in 1966–1967 to survey possible lunar landing sites and provide baseline imagery for geologic analysis of the lunar surface. The images were used to select the Apollo landing sites and to produce many of our existing lunar geologic maps (<http://www.lpi.usra.edu/resources/mapcatalog/>). This photo gallery is the web's most comprehensive collection of Lunar Orbiter photographs and supporting mission documents.

Digital Lunar Orbiter Photographic Atlas of the Moon

http://www.lpi.usra.edu/resources/lunar_orbiter/

The atlas by Bowker and Hughes (NASA SP-206) is considered the definitive reference manual to the global photographic coverage of the Moon. The images contained within the atlas are excellent for studying lunar morphology because they were obtained at low to moderate Sun angles. The digital Lunar Orbiter Atlas of the Moon is a reproduction of the 675 plates contained in Bowker and Hughes. The digital archive, however, offers many improvements upon its original hardbound predecessor. Multiple search capabilities were added to the database to expedite locating images and features of interest. For accuracy and usability, surface feature information has been updated and improved. Finally, to aid in feature identification, a companion image containing feature annotation has been included. The symbols on the annotated overlays, however, should only be used as locators and not for

precise measurements. More detailed information about the digital archive process can be read in abstracts presented at the 30th and 31st Lunar and Planetary Science Conferences.

The Consolidated Lunar Atlas

<http://www.lpi.usra.edu/resources/cla/>

Gerald P. Kuiper, Ewen A. Whitaker, Robert G. Strom, John W. Fountain, and Stephen M. Larson compiled this collection of the best photographic images of the Moon. These digital renditions were created and edited by Eric J. Douglass.

The Apollo Image Atlas

<http://www.lpi.usra.edu/resources/apollo/>

This comprehensive collection of Apollo-Saturn mission photography includes almost 25,000 lunar images, both from orbit and from the Moon's surface, as well as photographs of the Earth, astronauts, and mission hardware.

The Lunar Map Catalog

<http://www.lpi.usra.edu/resources/mapcatalog/>

This collection contains topographic, geologic, and shaded relief maps and charts of the Moon in a variety of scales. The collection includes the USGS Geologic Atlas of the Moon, Lunar Chart (LAC) Series, Lunar Earthside, Farside and Polar Chart (LMP) Series, Apollo Intermediate Charts (AIC), Lunar Photomaps Traverse Charts, and the more recent Lunar Topographic Orthophotomap (LTO) Series.

Ranger Photographs of the Moon

<http://www.lpi.usra.edu/resources/ranger/>

This site offers the online version of the NASA documents on the 1964–1965 NASA Lunar Ranger Program. It contains selected Ranger 7, Ranger 8, and Ranger 9 mission images and documentation from the photographic edition of the following Ranger publications.

Planetary Science Research Discoveries

<http://www.psr.d.hawaii.edu/Archive/Archive-Moon.html>

Archive of articles about formation and evolution of the Moon and the lunar environment.

Fourmilab Switzerland

<http://www.fourmilab.ch/earthview/vplanet.html>

An interactive site created by John Walker that allows you to view the Moon from Earth, our Sun and the night side. It also gives descriptions and details of lunar formations. This site is suitable for all ages.

Google Moon

<http://www.google.com/moon/>

Moon in Google Earth

<http://earth.google.com/moon/>

Impact Crater Posters

<http://www.lpl.arizona.edu/SIC/education.php>

The Geological Effects of Impact Cratering poster illustrates the effects such as crater formation, shock quartz, transition crater diameter, breccia and shattercones (downloadable).

The Environmental Effects of Impact Cratering shows the local, regional and global effects of impact cratering, such as atmospheric heating, tsunamis, shock waves, and global wildfires (downloadable).

MyMoon

<http://www.lpi.usra.edu/mymoon/>

A site designed to engage and educate 18 to 35 year olds about lunar science and exploration through science, art, and social media.

Connect to the Moon

<http://www.lpi.usra.edu/education/lprp/>

Paths for inquisitive adults, students, and formal and informal educators to find online resources, information, and opportunities for involvement in lunar science and exploration.

ALTA II Hand-Held Reflectance Spectrometer for the Classroom

<http://www.vernier.com/labequipment/altaspectrometer.html>

The ALTA is a rugged, simple classroom instrument designed to help students in grades 5 to undergraduate learn about light, color, and spectroscopy. Using the spectrometer, students can collect data reflected from rocks, minerals, and other materials in specific wavelengths of the visible to infrared electromagnetic spectrum. Lesson plans are included. ALTA's can be borrowed from the Lunar and Planetary Institute (<http://www.lpi.usra.edu/education/products/spectrometer/> and <http://www.lpi.usra.edu/education/products/spectrometer/loan.shtml>).

Moon Mineralogy Mapper Education Web site

<http://m3.cofc.edu>

A suite of hands-on inquiry based activities engage middle-school students in understanding and interpreting reflectance spectra from Earth and Moon rocks. These activities are part of a suite of educational resources that investigate the geologic history of our Moon, the Chandrayaan-1 Mission, spectrometry, and future lunar exploration.

Moon Globes

Sky and Telescope (customerservice@SkyandTelescope.com) -

<http://www.shopatsky.com/index.asp?PageAction=VIEWCATS&Category=37>

Astronomical Society of the Pacific (1-800-335-2624) - [http://www.astrosociety.org/cgi-](http://www.astrosociety.org/cgi-local/SoftCart.exe/online-store/scstore/p-OA196.html?L+scstore+lfmp4394ff710c71+1148894817)

[local/SoftCart.exe/online-store/scstore/p-OA196.html?L+scstore+lfmp4394ff710c71+1148894817](http://www.astrosociety.org/cgi-local/SoftCart.exe/online-store/scstore/p-OA196.html?L+scstore+lfmp4394ff710c71+1148894817)

Lunar Soil Simulant can be ordered from <http://www.orbitec.com/store/simulant.html>

Exploration and Missions

NASA Exploration System Mission Directorate

<http://www.nasa.gov/exploration/home/index.html>

The exploration arm of NASA, from designing the hardware to astronaut health to strategies for exploration. The "Getting to the Moon" pages (<http://www.nasa.gov/exploration/home/programs.html>) present the NASA programs, missions, and research involved in lunar exploration. Potentially useful videos/images for the classroom can be found at: <http://www.nasa.gov/exploration/multimedia/index.html>.

Vision for Space Exploration

http://www.nasa.gov/pdf/55583main_vision_space_exploration2.pdf

Plan for the Nation's exploration of the solar system, with an integrated lunar exploration program.

Constellation

http://www.nasa.gov/mission_pages/constellation/main/index.html

Updates and information on all the latest in hardware that will get us to the Moon, Mars, and beyond. Constellation hardware overview, with links to fact sheets can be found at:

<http://www.lpi.usra.edu/lunar/constellation/>

Ares I Crew Launch Vehicle

http://www.nasa.gov/mission_pages/constellation/ares/aresI/index.html

Overview: Ares V Cargo Launch Vehicle

http://www.nasa.gov/mission_pages/constellation/ares/aresV/index.html

Orion Crew Exploration Vehicle

http://www.nasa.gov/mission_pages/constellation/orion/

Exploring the Moon at LPI

<http://www.lpi.usra.edu/expmoon/>

Exploring the Moon offers extensive imagery and information associated with every lunar mission — manned and remote. Discussion of the history of Moon exploration and future missions, as well as products, materials, and links to other lunar Web sites, complements this rich resource.

Apollo Program

<http://www.hq.nasa.gov/office/pao/History/SP-350/toc.html>

<http://www.lpi.usra.edu/lunar/missions/apollo/>

<http://www.nasm.si.edu/collections/imagery/apollo/apollo.htm>

Clementine

<http://nssdc.gsfc.nasa.gov/planetary/clementine.html>

In 1994 Clementine, a joint venture between the Department of Defense and NASA, tested instruments in a long-term space environment and acquired a global multispectral map of the Moon's surface.

Lunar Prospector

<http://lunar.arc.nasa.gov/>

Lunar Prospector orbited the Moon from January 1998 to July 1999, acquiring a global map of lunar resources, gravity, and magnetic fields.

Chang'e-1

<http://www.clep.org.cn/>

Chang'e-1, part of the first phase of the Chinese Lunar Exploration Program, orbited the Moon from November 2007 to March 2009, acquiring imagery and data about the lunar surface composition and environment.

Smart-1 (Small Missions for Advanced Research in Technology 1)

<http://nssdc.gsfc.nasa.gov/nmc/masterCatalog.do?sc=2003-043C>

Smart-1 tested a solar-powered ion drive, in addition to collecting data to investigate the geology, morphology, topography, mineralogy, geochemistry, and exospheric environment of the Moon. The mission orbited the Moon for approximately three years from 2003 to 2006.

Kaguya

http://www.kaguya.jaxa.jp/index_e.htm

The Japan Aerospace Exploration Agency's (JAXA) Kaguya mission orbited the Moon from September 2007 to June 2009. The mission undertook global mapping of the lunar surface and gathered magnetic and gravity field measurements.

Chandrayaan-1

<http://www.chandrayaan-1.com/index.htm>

The Indian Space Research Organization's spacecraft currently is in a polar orbit around the Moon at a height of 100 km from the lunar surface. Its 11 instruments are undertaking chemical, mineralogical and photo-geologic mapping of the Moon.

The Lunar Reconnaissance Orbiter Site – LRO

<http://lunar.gsfc.nasa.gov/>

LRO currently is in low polar orbit (50 km) for a 1-year mission under NASA's Exploration Systems Mission Directorate. LRO will return global data, such as day-night temperature maps, a global geodetic grid, high resolution color imaging and the moon's UV albedo. There is particular emphasis on the polar regions of the moon where continuous access to solar illumination may be possible and the prospect of water in the permanently shadowed regions at the poles may exist. Objectives of LRO include finding safe landing sites, locating potential resources, and characterizing the radiation environment. Multimedia link offers potentially useful images and video for the classroom.

The Lunar Crater Observation and Sensing Satellite – LCROSS

<http://lcross.arc.nasa.gov/>

The LCROSS mission will send an impactor into a permanently shadowed crater in the south pole region of the lunar surface, creating a debris plume that will be analyzed by the LCROSS spacecraft, LRO, and Earth-based telescopes. The mission will analyze the plume for the presence of hydrated minerals; if water is present in the plume, LCROSS will help confirm the presence of water ice on the lunar surface. Multimedia link offers potentially useful images and video for the classroom. Impact Date: 9 October 2009. Potentially viewable with backyard telescopes.

Gravity Recovery and Interior Laboratory - GRAIL

<http://moon.mit.edu/>

GRAIL, scheduled to launch in 2011, will fly twin spacecraft in tandem orbits around the Moon for several months to measure its gravity field in unprecedented detail. The mission will provide scientists a better understanding of how Earth and other rocky planets in the solar system formed.

Lunar Atmosphere and Dust Environment Explorer – LADEE

<http://nasascience.nasa.gov/missions/ladee>

LADEE will orbit the Moon to characterize the atmosphere and lunar dust environment.

International Lunar Network – ILN

<http://nasascience.nasa.gov/missions/iln>

ILN will provide an organizing theme for all landed science missions in the 2010s by involving each landed station as a node in a geophysical network. Ultimately, this network could be comprised of 8-10 or more nodes, some located on the lunar far side. Each node would have core capabilities, such as seismic, heat flow, or laser retro-reflectors.

LPRP