Higher Education Lunar Consortium

LPI and CLSE Resources

Lunar Science Course Materials and Resources Exploration and Missions

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 (http://lunarscience.arc.nasa.gov/) 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.

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.

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.

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.

Apollo Thin-Section Atlas
http://www.lpi.usra.edu/lunar/samples/atlas/thin_sections/
The Apollo Thin Sections catalog is a subset of the Lunar Sample Atlas and includes those samples for which thin-section views are available.

Virtual Microscope
http://www.lpi.usra.edu/lunar/samples/atlas/virtual_microscopes/

The Virtual Microscope catalog is a subset of the Lunar Sample Atlas, and provides interactive views of selected thin sections as they would be seen through a microscope.

Lunar-related Textbooks

http://www.lpi.usra.edu/publications/books.shtml

Planetary Science: A Lunar Perspective
http://www.lpi.usra.edu/publications/books/planetary_science/
Lunar Source Book: A User's Guide to the Moon
http://www.lpi.usra.edu/lunar_sourcebook/
Guidebook to the Geology of Barringer Meteorite Crater, Arizona (aka Meteor Crater)
http://www.lpi.usra.edu/publications/books/barringer_crater_guidebook/
Traces of Catastrophe
http://www.lpi.usra.edu/publications/books/CB-954/CB-954.intro.html
Lunar Stratigraphy & Sedimentology
http://www.lpi.usra.edu/publications/books/lunar_stratigraphy/
Lunar Bases & Space Activities of the 21st Century
http://www.lpi.usra.edu/publications/books/lunar_bases/
To a Rocky Moon: A Geological History of Lunar Exploration
http://www.lpi.usra.edu/publications/books/lunar_bases/
Moon Trip: A Personal Account of the Apollo Program and its Science
http://www.lpi.usra.edu/publications/books/moonTrip/index.shtml
The Geology of the Terrestrial Planets
http://www.lpi.usra.edu/publications/books/geologyTerraPlanets/
Guide to Lunar Orbiter Photographs
http://www.lpi.usra.edu/resources/lunar_orbiter/photoGuide/

Course Materials and Resources

CLSE Classroom Illustrations

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

Illustrations with extensive captions for educational use, including:

Bombardment of Planetary Surfaces http://www.lpi.usra.edu/nlsi/training/illustrations/bombardment/
Impact Crater Formation http://www.lpi.usra.edu/nlsi/training/illustrations/craterFormation/
Impact Crater Morphology http://www.lpi.usra.edu/nlsi/training/illustrations/craterMorphology/
Impact Cratering Mechanics http://www.lpi.usra.edu/nlsi/training/illustrations/craterMechanics/
Impact Ejecta http://www.lpi.usra.edu/nlsi/training/illustrations/impactEjecta/
Shock Metamorphism & Impact Lithologies
http://www.lpi.usra.edu/nlsi/training/illustrations/shockMetamorphism/
Impact Melt Production http://www.lpi.usra.edu/nlsi/training/illustrations/meltProduction/
Asteroids & Comets http://www.lpi.usra.edu/nlsi/training/illustrations/asteroidsComets/
Lunar Surface Geology http://www.lpi.usra.edu/nlsi/training/illustrations/lunarGeology/
Planetary Interiors http://www.lpi.usra.edu/nlsi/training/illustrations/planetaryInteriors/
Lunar Surface Environment http://www.lpi.usra.edu/nlsi/training/illustrations/surfaceEnviron/
Lunar Exploration http://www.lpi.usra.edu/nlsi/training/illustrations/lunarExploration/

Powerpoint Presentations and PDF Briefing Packages

Determining Impact Ages with K-Ar and Ar-Ar Methods (PPT)
http://www.lpi.usra.edu/nlsi/training/presentations/IntroAr_ArGeochronology.ppt
Determining Impact Ages with K-Ar and Ar-Ar methods (PDF)
http://www.lpi.usra.edu/nlsi/training/presentations/IntroAr_ArGeochronology.pdf
Simulation (with Movie) of Ries Crater Impact (PPT)
http://www.lpi.usra.edu/nlsi/training/presentations/SimulationMovieRiesCraterImpact.ppt
Simulation of Ries Crater Impact (PDF)
http://www.lpi.usra.edu/nlsi/training/presentations/SimulationMovieRiesCraterImpact.pdf

Briefing Topics (PDF)

Lunar Electric Rover (LER) and Crew Activities, Black Point Lava Flow
http://www.lpi.usra.edu/nlsi/training/LERBriefingforStudentsII.pdf
Parameters of Lunar Soils
http://www.lpi.usra.edu/science/kring/lunar_exploration/briefings/lunar_soil_physical_properties.pdf
Lunar Crater Slopes and Roughness
http://www.lpi.usra.edu/science/kring/lunar_exploration/briefings/lunar_craterslopes_roughness.pdf
Lunar Mobility Review
http://www.lpi.usra.edu/science/kring/lunar_exploration/briefings/lunar_mobility_review.pdf
Cinder Lakes Crater Field, Arizona Lunar Analogue Test Site
http://www.lpi.usra.edu/science/kring/lunar_exploration/CinderLakesCraterField.pdf
Geologic Tools for the Moon: Review of Apollo
http://www.lpi.usra.edu/science/kring/lunar_exploration/geologicTools.pdf
Lunar Ionizing Radiation
http://www.lpi.usra.edu/science/kring/lunar_exploration/briefings/lunar_ionizing_radiation.pdf
Field and Sample Guidebook to Apollo Impact Melt Breccias
http://www.lpi.usra.edu/science/kring/lunar_exploration/apolloImpactBreccias.pdf

Digital Movies and Video Resources

From the Earth to the Moon: An inspirational video and soundtrack about lunar exploration
http://www.lpi.usra.edu/nlsi/moonVideo/
Meteor Crater Flyover
http://www.lpi.usra.edu/publications/books/barringer_crater_guidebook/flyover/
3D 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.
Impact Cratering Simulations
http://www.lpi.usra.edu/nlsi/training/presentations/ImpactCratering%20Simulations.pptx
Mare Exemplum: A film showing the impact cratered evolution of the lunar surface
http://www.lpi.usra.edu/lunar/lunar_flyovers/mareExemplum/
Lunar Rover Vodcast
http://www.nasa.gov/mp4/415275main_nasa360-0214.mp4

Moon 101 Lecture Series for non-specialists (videos)
http://www.lpi.usra.edu/lunar/moon101/
Slide-only versions at: http://www.spudislunarresources.com/moon101.htm

3D Models of Future Lunar Landing Sites
http://www.lpi.usra.edu/nlsi/training/3dModels/
Linné Crater (simple crater) http://www.lpi.usra.edu/nlsi/training/3dModels/index.shtml#Linne
Tycho Crater (complex central peak crater)
http://www.lpi.usra.edu/nlsi/training/3dModels/index.shtml#tycho
Schrödinger Basin (complex peak ring basin)
http://www.lpi.usra.edu/nlsi/training/3dModels/index.shtml#Schrodinger

Laboratory Exercises
Impact Cratering Mechanics and Crater Morphology
http://www.lpi.usra.edu/nlsi/education/hsResearch/crateringLab/lab/part1/background/
Features and Motion of Crater Ejecta
http://www.lpi.usra.edu/nlsi/education/hsResearch/crateringLab/lab/part2/background/

Consortium Laboratory Exercises
Google Mars: Wind Processes (Hurtado – GEOL 5308)
http://www.geo.utep.edu/pub/hurtado/public/hurtado_planetary_science_exercises/exercise3.pdf
Planetary Surface Analysis (Hurtado – GEOL 5308)
http://www.geo.utep.edu/pub/hurtado/public/hurtado_planetary_science_exercises/exercise4.pdf
Planetary Exploration: K10 and Desert RATS Analysis Team Projects (Hurtado – GEOL 4315/5315/6315)
http://www.geo.utep.edu/pub/hurtado/public/hurtado_planetary_science_exercises/lab1.pdf
Lab 1: GigaPan Imagery from K10
http://www.geo.utep.edu/pub/hurtado/public/hurtado_planetary_science_exercises/lab1b.pdf
Lab 2: GigaPan Imagery from Desert RATS
http://www.geo.utep.edu/pub/hurtado/public/hurtado_planetary_science_exercises/lab2.pdf
Impact Cratering: Analog Experiments and Computational Modeling (Hurtado)
http://www.geo.utep.edu/pub/hurtado/public/hurtado_planetary_science_exercises/lab4.pdf
Impact Cratering and Crater Counting (Hurtado)
http://www.geo.utep.edu/pub/hurtado/public/hurtado_planetary_science_exercises/lab5.pdf
Lunar Samples (Hurtado)
http://www.geo.utep.edu/pub/hurtado/public/hurtado_planetary_science_exercises/lab8_lunarsamples.zip

Lunar Analogue Site Data Sites
Barringer Meteorite Crater (aka Meteor Crater)
http://www.lpi.usra.edu/publications/books/barringer_crater_guidebook/
Black Point Lava Flow, Arizona
http://www.lpi.usra.edu/lunar/analogs/blackpoint/

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 Image Atlases

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.

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.

Additional Educational Resources

Lunar Sample Disk
http://ares.jsc.nasa.gov/ares/lmdp/index.cfm (short term loan from JSC)

Lunar Petrographic Thin Section Package
http://curator.jsc.nasa.gov/Education/LPETSS/index.cfm (short term loan from JSC)

Lunar Regolith Simulant
http://www.orbitec.com/store/simulant.html (commercially available)

Lunar Globe
http://www.shopatsky.com/product/moon-globe/new-arrivals (commercially available)

Moon Posters
http://www.lpi.usra.edu/education/moon_poster.shtml
These three posters examine what — and how —we know about how the Moon formed and has changed through time, how scientists and engineers investigate the surface with spectroscopy, and how in-situ resources may be used to support future human exploration of the Moon.

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.

Exploration and Missions

Lunar Exploration Summer Intern Program
http://www.lpi.usra.edu/lunar_intern/
During this 10-week intensive program, 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.

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.lpi.usra.edu/lunar/missions/apollo/