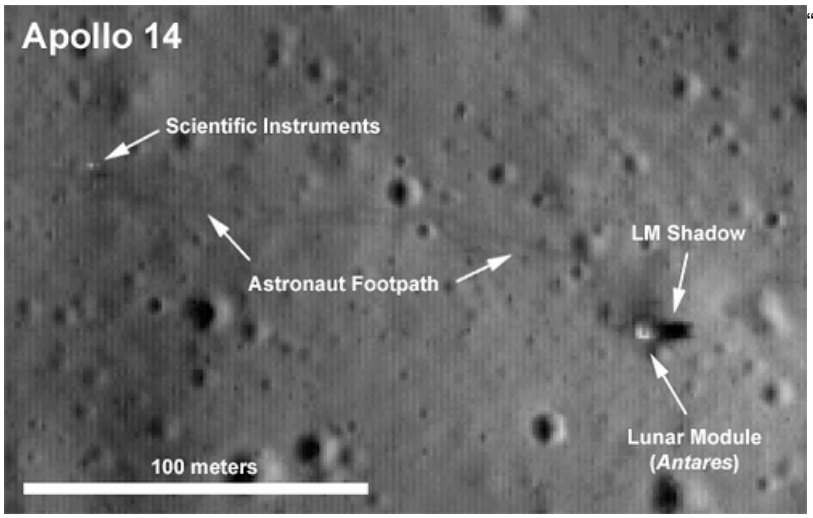
LATEST

NASA's LOR Images Apollo Landing Sites Using LROC! (http://www.astronutics.com/2009/07/nasa-images-apollo-landing-sites-with-lro/)

So by now, most everyone has heard that NASA's Lunar Reconnaissance Orbiter (LRO) imaged five of the six Apollo landing sites in unprecedented detail (the Apollo 12 landing site will be imaged in the coming weeks). More can be found on these amazing images **here (http://www.nasa.gov/mission_pages/LRO/multimedia/lroimages/apollosites.html)** and **here (http://blogs.discovermagazine.com/badastronomy/2009/07/17/apollo-landing-sites-imaged-by-lro/)**. Those little rectangular shadows amongst the sea of craters are being cast by the lower portion of the Lunar Exploration Modules (LEMs) that brought all 12 astronauts to the surface of our nearest satellite. Our astronauts left these parts of the LEM behind in order to reduce the mass of the portion of the LEM returning to the command module, thus reducing the amount of fuel each LEM needed to carry with it to the Lunar surface. It just so happens that they end up being and excellent marker for mapping these six locations where men actually walked/drove/**played golf (http://www.youtube.com/watch?v=1yNIMtagHck)** on the moon. In the Apollo 14 landing site image below you can even see tracks left behind in the lunar regolith from the astronauts and their moon buggy!



(http://www.flickr.com/photos/40545521@N08/3733590565/)

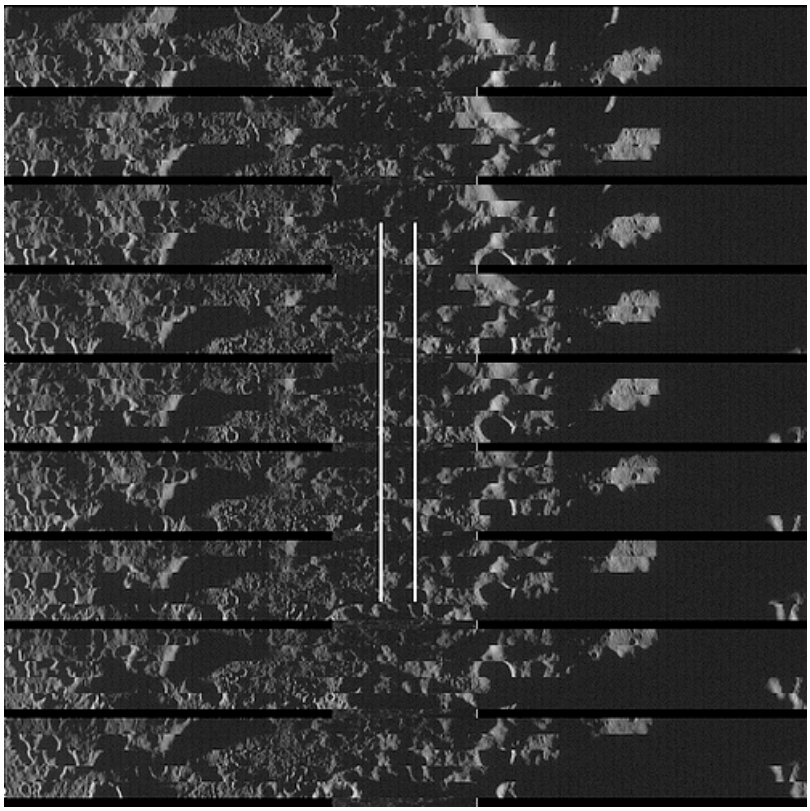
LRO Image of the Apollo 14 landing site: note the astronaut tracks! (NASA/GSFC/Arizona State University)

NASA was able to capture these high resolution images of the Apollo LEMs using the Lunar Reconnaissance Orbiter Camera, or LROC, one of the seven main science instruments being flown on LRO. I suspect most every image the public will see from LRO will have originated from LROC. So what is LROC and what does it do for the LRO mission?

The main science objectives for LROC include providing us with a high resolution images of the lunar surface suitable future landing site selection as well as characterizing the illumination of craters in the polar regions through an entire year. Past missions as well as earth-based spectrometers have detected the presence of water ice in the permanently shadowed regions of some polar craters. Detailed and correlated measurements of where these shadowed regions are and how their illumination changes throughout the year will provide NASA with information on lunar resources that may be key for future manned missions, such as water and methane trapped in the shadowy permafrost on the floors of these craters.

A quick look through the various documents available on the LRO mission web site tells us that LROC is really two separate instruments; a Wide Angle Camera (WAC) and two identical Narrow Angle Cameras (NAC). The WAC instrument is based off of the **Mars Reconnaissance Orbiter's Mars Color Imager instrument (MARCI) (http://www.flickr.com/photos/40545521@N08/3734413804/)** which provides global image data in 5 visible and 2 UV wavelengths and helps provide a context for the rest of the LRO imaging systems with it's ~100m/pixel resolution. Two objective lenses are used on the WAC, one for the near IR-visible spectrum and the other for the two UV wavelengths, and they all point to the same Kodak KAI-1001 1000×1000 pixel CCD. Each wavelength exposes a wide horizontal image across a section of the CCD resulting in a sort of odd image where each of the seven wavelengths end up stacked one on top of the other. Post processing is done on the ground to combine the seven different image segments into a false-color composite which geologists and other scientists can use to determining things like the geologic composition of the lunar regolith in addition to providing wide area context images for the NAC cameras. It's also interesting to note that the acquisition control software and electronics behind the WAC have been sent to Mars on no less than four different missions

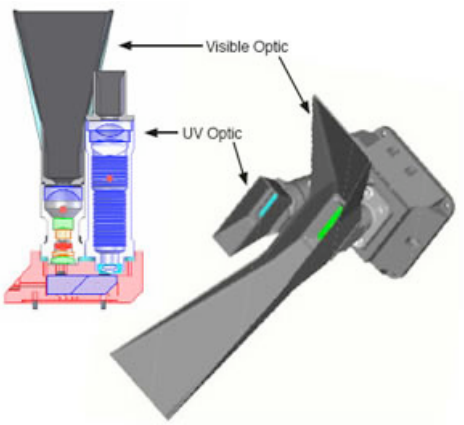
including MRO, Mars Climate Orbiter and the Mars Phoenix Lander!



(http://www.flickr.com/photos/40545521@N08/3734468798/)

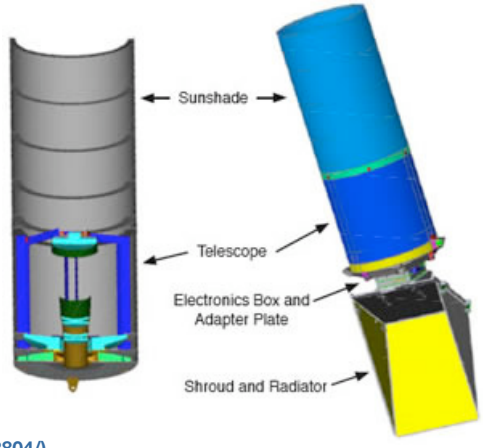
Image showing color segments from the WAC array with two lines demarcating the FoV of the NAC
{NASA/GSFC/Arizona State University}

In addition to the wide-field view we get from the WAC instrument on LROC we also have the two NAC instruments consisting of a 700mm F3.6 Ritchey-Chretien telescope and a **Kodak KLI-5001G (http://www.kodak.com/global/plugins/acrobat/en/business/ISS/datasheet/linear/KLI-5001LongSpec.pdf)** 5000×1 pixel linear CCD array. These cameras are the true imaging workhorses of LRO and are the instruments NASA used to snap those awesome pictures of the Apollo landing sites. The NAC produces long, continuously sampled images covering an area up to 2.5 x 26km using a Honeywell ADC9225 12-bit CCD image processor and an Actel rad-hardened RT54SX32-S FPGA. Each NAC images adjacent 2.5 x 26 km areas by sequentially sampling the 1×5000 pixel array of their respective KLI-5001G CCDs and then stitching the individual pixel rows together in a ~520MP composite image with a 50cm/pixel X-Y resolution! The fine detail images produced by the NAC instruments will do for NASA and the moon what **Hubble's WFPC II (http://en.wikipedia.org/wiki/Wide_Field_and_Planetary_Camera_2)** accomplished for raising awareness of the space program in general.



(http://www.flickr.com/photos/40545521@N08/3734413804/)

Diagram of the WAC imager from LROC



(http://www.flickr.com/photos/40545521@N08/3734413800/in/photostream/)

Computer model of the NAC telescope and CCD

Both the two NAC instruments and the WAC connect to the LRO's main spacecraft data systems through the Sequence and Compressor System (SCS). The SCS provides an interface between the imaging systems acquisition hardware and the **SpaceWire (http://en.wikipedia.org/wiki/SpaceWire)** bus connecting all of the LRO instrumentation, communication, and control subsystems. Pretty much all I know about the SCS hardware is that it runs off of a Xilinx XQR2V3000 FPGA running canned software developed by Malin Space Science System for the MRO mission.

Seeing pictures from a spacecraft orbiting the moon some 380000 km away from us seems a bit more real to me after understanding the basics of the LROC imagers. There is nothing too terribly exotic about the instrument, and in fact it is based off of some well understood, widely used, and space proven designs. Yet, at the same time it will provide us with amazing detail of the lunar surface and help us answer many of the open questions we desperately need answers to before establishing a sustainable presence on the moon. At the same time these images of the Apollo landing sites prove what humanity is capable of when we have a clear goal in mind an a motivated population. Let's hope LRO is able to rekindle an appreciation for the technological feats that landed us on the moon four decades ago as well as instill another generation of explorers with awe and wonder.

Resources:

[1] **http://lroc.sese.asu.edu/EPO/LROC/lroc.php?pg=specifications (http://lroc.sese.asu.edu/EPO/LROC/lroc.php?pg=specifications)**
[2] **http://lro.gsfc.nasa.gov/library/LRO_Space_Science_Paper.pdf (http://lro.gsfc.nasa.gov/library/LRO_Space_Science_Paper.pdf)**
[3] **http://lro.gsfc.nasa.gov/library/keller51906.pdf (http://lro.gsfc.nasa.gov/library/keller51906.pdf)**
[4] **http://lro.gsfc.nasa.gov/library/IAC-07-C1_7_06.pdf (http://lro.gsfc.nasa.gov/library/IAC-07-C1_7_06.pdf)**

Jul 19, 2009 | Categories: **Electronics (http://www.astronutics.com/category/electronics/)** , **Instrumentation (http://www.astronutics.com/category/space/instrumentation/)** , **News (http://www.astronutics.com/category/news/)** , **Space (http://www.astronutics.com/category/space/)** | Tags: **LRO (http://www.astronutics.com/tag/lro/)** , **LROC (http://www.astronutics.com/tag/lroc/)** , **Moon (http://www.astronutics.com/tag/moon/)** , **NASA (http://www.astronutics.com/tag/nasa/)** | **Leave A Comment » (http://www.astronutics.com/2009/07/nasa-images-apollo-landing-sites-with-lro/#respond)**

Apollo 11 40th Anniversary (http://www.astronutics.com/2009/07/apollo-11-40th-anniversary/)

(http://www.astronutics.com/2009/07/apollo-11-40th-anniversary/)

It looks like this is my inaugural post on AstroNutics.com and it only seems fitting to raise awareness of this big anniversary for our species: the day we sent off three of our own into the darkness of space to set foot on a new frontier. Four days after the launch of Apollo 11 on [...]

Jul 16, 2009 | Categories: **News (http://www.astronutics.com/category/news/)** , **Space (http://www.astronutics.com/category/space/)** | **1 Comment » (http://www.astronutics.com/2009/07/apollo-11-40th-anniversary/#comments)**

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