

Tutorial for New Users of NASA's PILOT Data Search Service

- Welcome, you've found the **Planetary Image Locator Tool (PILOT)!**
(<https://pilot.wr.usgs.gov/>)
- **Start here for help getting going with your data search**
- **PILOT Snapshot**
 - PILOT is an image data portal designed for searching through the raw image archives of the Cartography and Imaging Sciences ("Imaging" or IMG) Node of NASA's Planetary Data System (PDS)
 - PILOT uses a catalog of spacecraft images acquired at visible, infrared and radar wavelengths of planetary bodies in our Solar System
 - The catalog differs from other PDS catalogs because it has been improved by characterizing image geometry in great detail
- **For information and additional data services, please visit the IMG home page:**
 - <https://pds-imaging.jpl.nasa.gov/>

Overview of PILOT

- PILOT is an online data portal used to search through the raw image archives of the Cartography and Imaging Sciences (“Imaging” or IMG) Node of NASA’s Planetary Data System (PDS). It accesses a large catalog of spacecraft images acquired at visible, infrared and radar wavelengths of planetary bodies in our Solar System.
- *PILOT supports data searches using the most accurate image and spacecraft geometry, planetary coordinates, and image positional information for PDS images.*
- PILOT relies on the Unified Planetary Coordinate (UPC) database developed at the USGS Astrogeology Science Center. The UPC database has detailed geometric and positional information about planetary image data calculated using a uniform coordinate system (Positive East Longitude, 0° to 360° E) and projected onto a 3D planetary surface shape.
- The UPC benefits from cartographic processing and map development at USGS using the Integrated Software for Imagers and Spectrometers (ISIS) software. ISIS is the primary tool for computing, maintaining, and continually improving the UPC database. The database is populated with up-to-date SPICE kernels, and improved pointing and location data are calculated for corners, edges, and for potentially every pixel in an image. The database is regularly updated with new and recalculated image data as improved location data are made available.
- An ISIS camera model for a given imaging instrument is required for ingestion of image data into the UPC. Thus PILOT presently supports ~85% of image data served by the PDS IMG node.
- **For the complete data catalog of the IMG node, please visit the home page:**
<https://pds-imaging.jpl.nasa.gov/>



Planetary Image Locator Tool explore NASA's largest raw spacecraft imagery archive

Mercury 287,132 images

Venus 7,254 images

Earth 17,674 images

Moon 3,224,044 images

Mars 2,487,489 images

Deimos 246 images
Phobos 444 images

Jupiter 85,491 images

Adrastea 23 images
Amalthea 227 images
Callisto 1,933 images
Europa 2,192 images
Ganymede 2,247 images
Himalia 393 images
Io 3,063 images
Metis 27 images
Thebe 46 images

Saturn 391,253 images

Atlas 1,401 images
Calypso 1,090 images
Daphnis 650 images
Dione 9,807 images
Enceladus 18,606 images
Epimetheus 1,853 images
Helene 2,062 images
Hyperion 4,956 images
Iapetus 9,754 images
Janus 2,640 images
Methone 1,003 images
Mimas 6,031 images
Pallene 1,052 images
Pan 1,394 images
Pandora 1,554 images
Phoebe 2,682 images
Polydeuces 738 images
Prometheus 3,855 images
Rhea 14,600 images
Telesto 1,093 images
Tethys 9,445 images
Titan 99,425 images
Ymir 66 images

Small Bodies

Ceres 35,866 images
Vesta 24,895 images

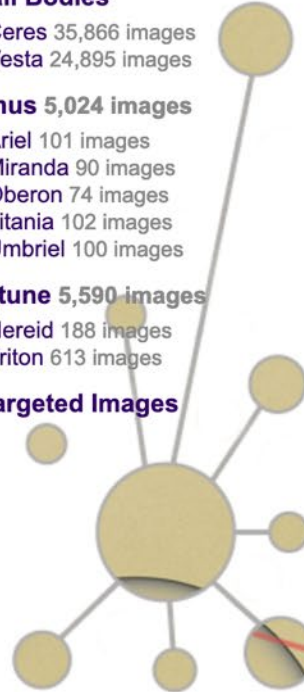
Uranus 5,024 images

Ariel 101 images
Miranda 90 images
Oberon 74 images
Titania 102 images
Umbriel 100 images

Neptune 5,590 images

Nereid 188 images
Triton 613 images

Untargeted Images



PILOT and UPC news is unavailable at this time.

Starting at the [PILOT home page](https://pilot.wr.usgs.gov/) (<https://pilot.wr.usgs.gov/>), first select the planetary body for which you want to find an image. In this example, we will choose Earth's Moon.

Moon
Missions
Map
Advanced
Stereo

Select one or more image sets...

Cassini (1999)			
ISSNA	<input type="checkbox"/> 12 unmapped		
ISSWA	<input type="checkbox"/> 44 unmapped		
Chandrayaan-1 Orbiter (2008 - 2009)			
CH1-M3	<input type="checkbox"/> 1,762 mapped	<input type="checkbox"/> 38 unmapped	
Clementine (1994)			
HIRES	<input type="checkbox"/> 574,471 mapped	<input type="checkbox"/> 2,143 unmapped	
LWIR		<input type="checkbox"/> 287,707 unmapped	
NIR	<input type="checkbox"/> 359,751 mapped	<input type="checkbox"/> 4,075 unmapped	
UVVIS	<input type="checkbox"/> 564,930 mapped	<input type="checkbox"/> 7,924 unmapped	
Galileo Orbiter (1990 - 1992)			
SSI		<input type="checkbox"/> 2,026 unmapped	
Lunar Reconnaissance Orbiter (2009 - 2017)			
LROC-NACL	<input checked="" type="checkbox"/> 705,382 mapped	<input type="checkbox"/> 4,421 unmapped	
LROC-NACR	<input checked="" type="checkbox"/> 704,462 mapped	<input type="checkbox"/> 4,420 unmapped	
Mariner 10 (1974)			
VID A		<input type="checkbox"/> 159 unmapped	
VID B		<input type="checkbox"/> 190 unmapped	
Mars Reconnaissance Orbiter (2005)			
CTX		<input type="checkbox"/> 5 unmapped	
HiRISE		<input type="checkbox"/> 40 unmapped	
Messenger (2005)			
MDIS-NAC	<input type="checkbox"/> 16 mapped		
MDIS-WAC	<input type="checkbox"/> 65 mapped	<input type="checkbox"/> 1 unmapped	

Total 1409844
Order Date (ASC)
Select

HOW TO SEARCH FOR IMAGES

- Select one or more image sets (on the **Missions** tab)
- The **Total** will show up above. Search results will show up here unless your **Total** is greater than 20000 images. **Restrict your search by using the steps below:**
- Restrict by area:** select **Map** tab and create a bounding box using one of the following methods:
 - Click button, draw a polygon on the map, double click to complete bounding box
 - Enter max and min latitudes and longitudes
 - Use **feature finder** to set the bounds to a geologic feature
- Restrict by metadata:** select **Advanced** tab and set ranges for mission dates and/or photometric keywords

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PILOT was developed by the USGS Astrogeology Science Center / NASA PDS Cartography and Imaging Science Node

In the default **Missions tab**, choose the mission you want to browse for images. In this example, choose the Lunar Reconnaissance Orbiter Narrow Angle Camera image sets. Check both the left (LROC-NACL) and right (LROC-NACR) cameras, as shown.

Next, click on the **Map tab** at the top. This will take you to a map view of the Moon with tools for finding images. The upper left side button functions (top down) are as follows:

- Zoom in
- Zoom out
- Enable navigation by cursor
- Home (reset)
- Select footprint (only works when you have several footprints showing on the map)
- Draw **Bounding Box** tool
- Download map

USGS science for a changing world

PILOT

PDS Planetary Data System

NASA

Moon Missions **Map** Advanced Stereo

Left-hand side tools:

1000 km

Set Bounding Box

Lat Lon:

Positive East
0° to 360°
Planetocentric
Map Settings

Set bounding box below...

Max Lat
Min Lon Max Lon
Min Lat

Feature Finder
Select Type

Clear Bounding Box

Select a Feature

Total 1409844

Order Date (ASC)

Select

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- **Restrict by area:** select **Map** tab and create a bounding box using one of the following methods:
 - Click **Bounding Box** button, draw a polygon on the map, double click to complete bounding box
 - Enter max and min latitudes and longitudes
 - Use **feature finder** to set the bounds to a geologic feature
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To draw a **bounding box**, select the Bounding Box tool (second from bottom at left) and click once on the map to start, then move the cursor to surround your feature and click once for each corner. Double-click to complete the box.

In the lower left corner, below the scale bar, there are tools that allow you to change the map projection, choose how the latitude and longitude are displayed, and show the latitude and longitude of the cursor.

At bottom center, you can set a min and max latitude and longitude, instead of drawing a bounding box. You can also zoom in to a particular feature (at lower right), if you know its type and name.

USGS science for a changing world

PILOT

PDS Planetary Data System

NASA

Moon Missions **Map** Advanced Stereo

Total 1409844 Order Date (ASC) Select

HOW TO SEARCH FOR IMAGES

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Here I have chosen feature type as Mare using the Feature Finder and the specific feature Mare Crisium. Once selected, all of the images at least partially covering Mare Crisium are displayed at right as browse or thumbnail images.

Moon
 Missions
 Map
 Advanced
 Stereo

Lat Lon:

Positive East

0° to 360°

Planetocentric

Set bounding box below. . .

Max Lat

Min Lon 24.53
 Max Lon

 Min Lat 9.69

Clear Bounding Box

Feature Finder

Mare, maria
 Mare Crisium

Total 4449

Order Date (ASC)

Select

22 2009-08-05

23 2009-08-05

24 2009-08-05

25 2009-08-06

26 2009-08-06

27 2009-08-06

28 2009-08-06

29 2009-08-06

30 2009-08-06

31 2009-08-06

32 2009-08-06

33 2009-09-01

To view a specific image, click on its **thumbnail** at right. The **footprint** of the image will appear on the map to the left. The full image itself will appear in the middle. You can use this feature to see if the image covers the right area or has adequate resolution for your needs.⁸



Moon
 Missions
 Map
 Advanced
 Stereo

Overlays

☒ Footprint Images

☐ Moon 2.5M Quad Charts

☐ Moon 1M Quad Charts

☐ Show Feature Names

Base maps

☐ Kaguya TC Ortho Mosaic (Kaguya)

☐ LROC LOLA Steel Color Shade (LOLA)

☒ LROC WAC (LOLA)

☐ LROC LOLA Color Shade (LOLA)

☐ Lunar Orbiter (ULCN 2005)

☐ LROC LOLA Grayscale Shade (LOLA)

☐ Clementine/UV Lunar Orbiter (ULCN 2005)

☐ Clementine - UV/VIS warp (ULCN 2005)

☐ Clementine - UV/VIS v2 (ULCN 2005)

Lat Lon: **19.81, 55.94**

☐ Positive East
☒ 0° to 360°
☐ Planetocentric

Set bounding box below...
 Min Lon: 49.51, Max Lon: 24.53, Min Lat: 9.69, Max Lat: 68.53
 Clear Bounding Box

Feature Finder
 Mare, maria
 Mare Crisium

Total 4449

Order Date (ASC)

Select

1 2009-08-04	2 2009-08-04	3 2009-08-05	4 2009-08-05
5 2009-08-05	6 2009-08-05	7 2009-08-05	8 2009-08-05
9 2009-08-05	10 2009-08-05	11 2009-08-05	12 2009-08-05
13 2009-08-05	14 2009-08-05	15 2009-08-05	16 2009-08-05

At upper right in the map view, you can choose different **layers** to overlay on the map view to help you find the right place on the planetary body for which you need images.

The screenshot displays the USGS PILOT (Planetary Image Library Online Tool) interface. At the top, logos for USGS, PILOT, PDS (Planetary Data System), and NASA are visible. The main navigation bar includes tabs for Moon, Missions, Map, Advanced, and Stereo. The 'Map' tab is active, showing a grayscale image of the Moon's surface with a red rectangular bounding box drawn over a specific area. A scale bar in the bottom left of the map indicates 50 km. On the left side of the map, a vertical toolbar contains various icons, with the 'Draw Bounding Box' icon (a rectangle) circled in red. Below the map, there are input fields for 'Lat Lon' (Positive East, 0° to 360°, Planetocentric) and a 'Set bounding box below...' section with fields for Min Lon (50.83), Max Lon (19.78), Min Lat (16.26), and Max Lat (53.96). A 'Feature Finder' section shows 'Mare, maria' selected. A 'Clear Bounding Box' button is circled in red. On the right side, a grid of 16 image thumbnails is displayed, each with a date (e.g., 2009-08-06, 2009-09-02, 2009-10-13). The top right of the interface shows 'Total 323' images, an 'Order' dropdown set to 'Date (ASC)', and a 'Select' button.

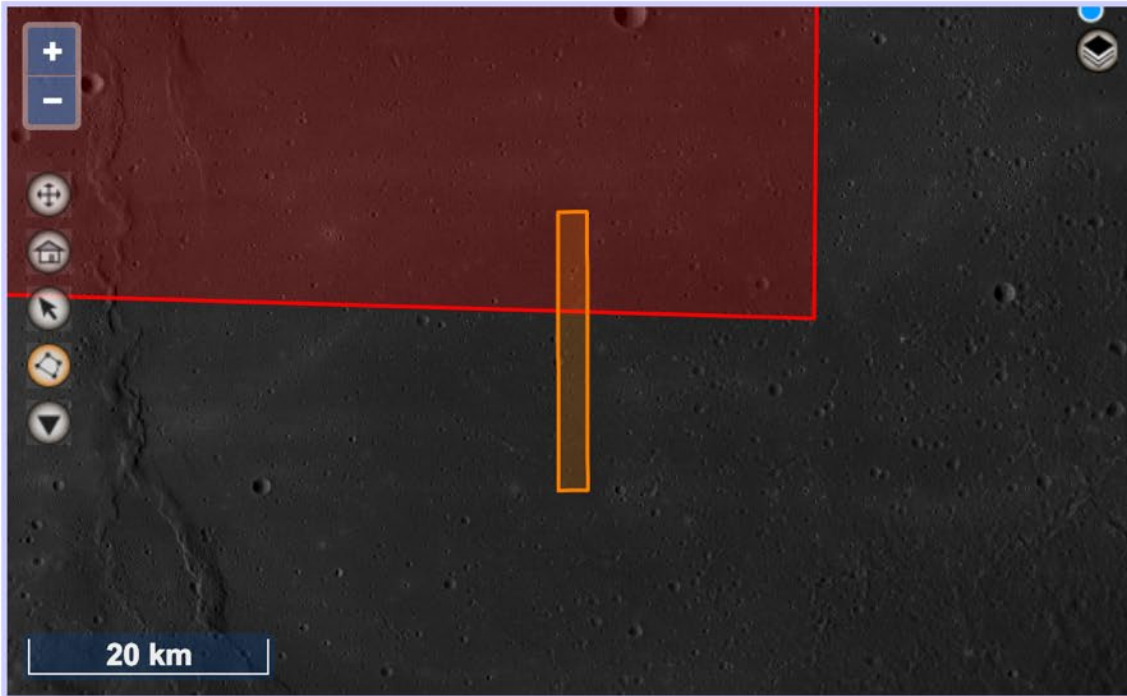
In the previous view of Mare Crisium, 4449 images covered the selected area. PILOT cannot display more than 500 image footprints at once on the map, so to see all of them we need to select a smaller area. To do this, zoom in to the desired area and click "Clear Bounding Box." Now draw a new box over a smaller area, using the "Draw Bounding Box" tool in the map menu at left, as shown.

The screenshot displays the USGS PILOT web interface. At the top, the USGS logo and 'PILOT' title are visible, along with NASA and PDS (Planetary Data System) logos. The main interface is divided into two panels. The left panel shows a map of the Moon with a yellow bounding box overlaid on a cratered region. Below the map, there are controls for map interaction, including a '50 km' scale bar, a 'Lat Lon' input field, and a 'Set bounding box below...' section with fields for 'Min Lon', 'Max Lon', 'Min Lat', and 'Max Lat'. The right panel shows a list of 16 image thumbnails, each with a date and a small globe icon. The 'Total' count of 323 images is displayed at the top of the right panel. The globe icon next to the 'Total' count is circled in red, indicating it is the icon to click to view all footprints at once.

Now we can see how many images are covering the area of the new bounding box we have made: 323. This is fewer than 500, so we can view all the footprints at once and see how complete the coverage is of the area we have chosen. To do this, click on the orange **globe icon** to the right of the Total box at the top of the list of images on the right. To remove all footprints from the map, click the gray globe icon. If we wanted to choose specific images for an area, we could view the footprints one at a time by clicking on the globe icon beneath each thumbnail individually.



Moon Missions Map Advanced Stereo



Lat Lon:

☐ Positive East
☐ 0° to 360°
☐ Planetocentric

Set bounding box below...

Min Lon	50.83	Max Lat	19.78	Max Lon	
		Min Lat	53.96		
			16.26		

Feature Finder

Total 323 Order Date (ASC) Select

Product ID: M115964000RE

Instrument: LROC-NACR

EDR Source:
http://pdsimage.wr.usgs.gov/Missions/Lunar_Record/

ISIS ID: LRO/1/283017533:32688/NACR

Target: MOON

Band Filter Used For Statistics: BroadBand

Bands In Geometry: 1

CK Kernel Type: Reconstructed

Center Emission Angle: 1.1420949120826

Center Incidence Angle: 80.384685971258

Center Latitude: 16.16510557453

Center Line Resolution: 0.48699463520339

Center Longitude: 53.231832494719

Center Phase Angle: 79.253777461433

Center Pixel Resolution: 0.73049195280509

Center Radius: 1733693.9217796

Center Sample Resolution: 0.97398927040678

Center Wavelength Of Band Used For Statistics: 600

Centroid Line: 9221.4063455858

Centroid Radius: 1733693.9473469

Centroid Sample: 1267.6335476714

Compress Flag: 1

Data Set Identifier: LRO-L-LROC-2-EDR-V1.0

Declination: -12.399320997894

Dnmaximum: 1095.5

Dnmean: 95.536255118511

Dnminimum: 33.5

Dnstandarddeviation: 30.962733227819

Error In Processing: f

Filters: BroadBand

Frame ID: RIGHT

Global Coverage: 0.000159

Has Longitude Boundary: f

Has North Pole: f

Has South Pole: f

Image Center Line: 9216

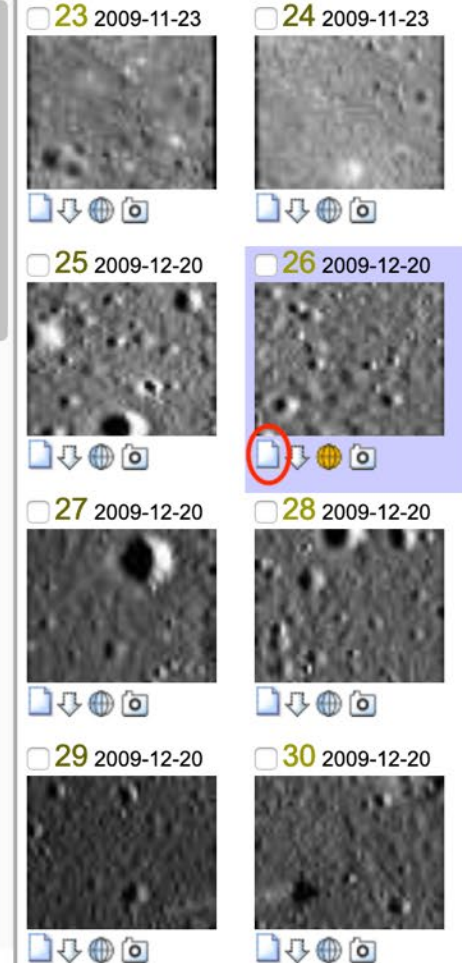
Image Center Sample: 1266

Instrument Pointing Quality: Reconstructed

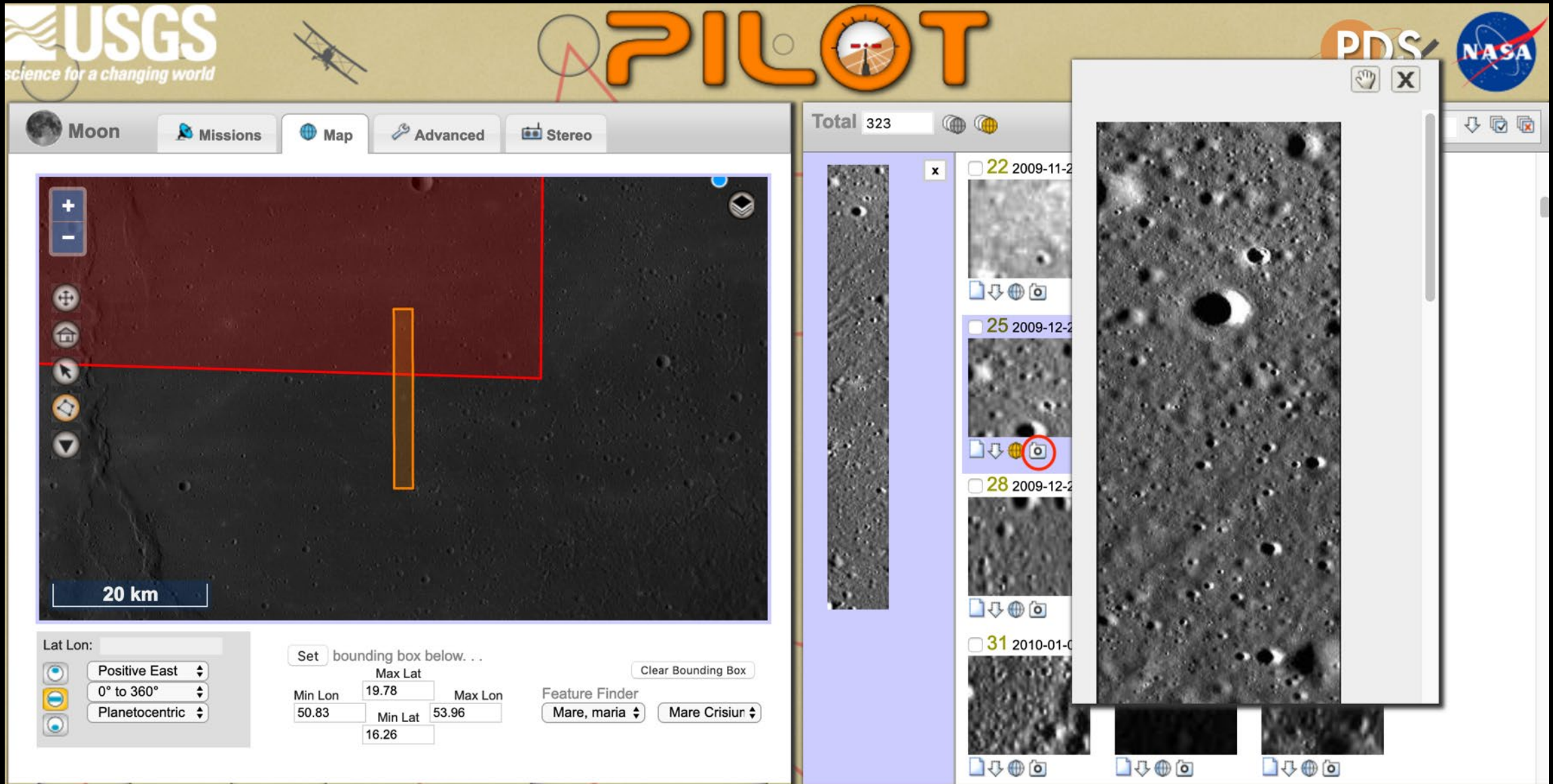
Instrument Position Quality: Reconstructed

Isis Version: 3.4.5.5677 stable | 2014-01-14

Line Exposure Duration: 0.815467



To view the metadata for an image, click on the **icon** at the bottom left of its thumbnail.



To view a zoomed-in version of the selected full image, click on the **camera** icon at the bottom right of the thumbnail.

Another way to get a smaller and more relevant set of images is to filter by metadata. To do this, click on the Advanced tab at the top of the screen and move the sliders or manually input a specific range for each criteria you want to filter by. This will return only the images within the bounding box you set that match these criteria.

The screenshot displays the USGS P10L Moon image search interface. At the top, the USGS logo and tagline "science for a changing world" are visible, along with a small airplane icon and the P10L logo. Below the header, a navigation bar includes tabs for "Moon", "Missions", "Map", "Advanced", and "Stereo". The "Advanced" tab is currently selected. Underneath, there are two sub-tabs: "LROC-NACL" and "LROC-NACR", with "LROC-NACR" being the active filter. The main content area contains several filter criteria, each with a text input field, a range selector, and a histogram icon:

- Start Time: 2009-06-30 to 2017-03-15
- Solar Longitude: 0 to 360
- Mean Ground Resolution (mpp): 0 to 8
- Minimum Phase Angle: 0 to 179
- Maximum Phase Angle: 1 to 180
- Minimum Incidence Angle: 0 to 180
- Maximum Incidence Angle: 0 to 180
- Minimum Emission Angle: 0 to 90

Each filter has a corresponding slider bar below the input fields, and a small histogram icon to the right of the range selector.

Moon
 Missions
 Map
 Advanced
 Stereo

Convergence Angle: 0 to 180

Base Height Ratio: 0 to 1

Incidence Angles: 0 to 90

Incidence Angle Difference Maximum: 90

Intersect Area (km²): 0 to 445

Resolution Difference Maximum (multiplier): 5

Shadow Tip Difference Maximum: 10

Solar Azimuth Difference Maximum: 90

The PILOT Stereo Matcher

- Matching is restricted to search results under 200 images.
- The panel to the lower right represents overlapping images and possible stereo matches.
- Use the sliders and input boxes to the left to cull the result set.
- One slider may limit another slider (e.g. base height ratio is a function of the convergence angle, emission angle is used to compute convergence angle, etc.)
- Derived values (convergence angle, shadow tip difference, etc.) are taken from the center of the pair of images and may not reflect the exact values of the intersect. If more exact information is necessary, please

Total 91

Order Date (ASC)

Select

1 2009-08-06

2 2009-09-02

3 2009-09-29

4 2009-09-29

5 2009-11-23

6 2009-11-23

7 2009-12-20

8 2009-12-20

Stereo Matches 824

Order Area

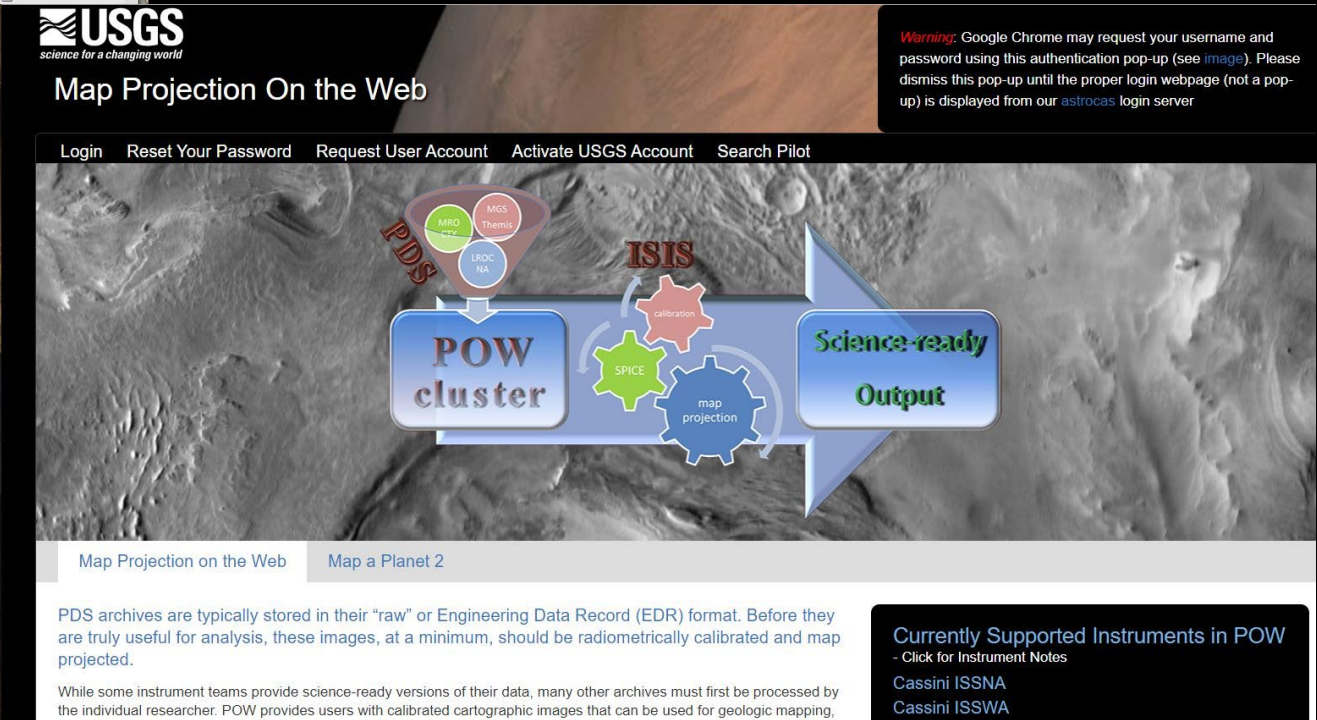
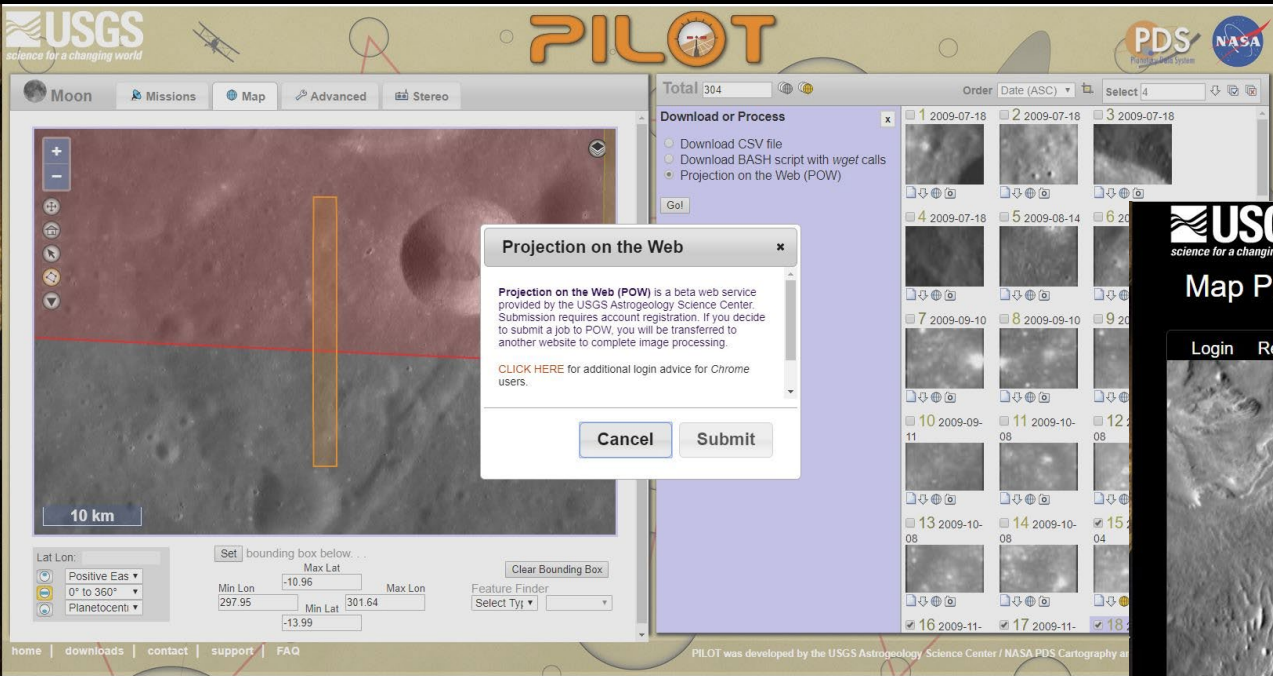
1	LROC-NACL: M104175766LE 532.30 km ² 1.42 mpp LROC-NACL: M1096150773LE 485.47 km ² 1.36 mpp	444.97 km ² convergence ctr 0.0°
2	LROC-NACL: M106532957LE 585.96 km ² 1.51 mpp LROC-NACL: M1184490714LE 358.18 km ² 1.18 mpp	345.33 km ² convergence ctr 3.5°
3	LROC-NACL: M106532957LE 585.96 km ² 1.51 mpp LROC-NACL: M1153880746LE 396.98 km ² 1.24 mpp	341.23 km ² convergence ctr 3.6°
4	LROC-NACR: M1138567841RE 426.56 km ² 1.27 mpp LROC-NACL: M1202140613LE 340.37 km ² 1.11 mpp	334.93 km ² convergence ctr 3.0°
5	LROC-NACL: M1123256632LE 379.37 km ² 1.25 mpp LROC-NACL: M1153880746LE 396.98 km ² 1.24 mpp	330.28 km ² convergence ctr 0.0°

To search for stereo pair images for making Digital Elevation Models (DEMs), click on the **Stereo** tab at top right of the left panel. This tool is limited to 250 images or less, so I have drawn an even smaller bounding box. The Stereo tab allows you to filter images within your bounding box even further by choosing only those images that fall within your selected criteria. The identified stereo pairs are listed on the bottom right of the screen. View each one on the map by clicking on the globe icon to the right of the names of the images.

The screenshot shows the USGS PILOT (Planetary Image Location and Orientation Tool) web interface. The top header includes the USGS logo, the PILOT logo, and the PDS (Planetary Data System) and NASA logos. The main interface is divided into several sections:

- Map Section:** On the left, there is a map of the Moon with a red rectangular bounding box. Below the map are controls for latitude and longitude, including a "Set bounding box below..." section with input fields for Min Lon, Max Lon, Min Lat, and Max Lat. There are also buttons for "Feature Finder" and "Clear Bounding Box".
- Download or Process Section:** On the right, there is a section titled "Download or Process" with a list of image thumbnails. Each thumbnail has a checkbox and a download icon (a white arrow pointing down). The first thumbnail is selected, and its download icon is circled in red.
- Stereo Matches Section:** Below the "Download or Process" section, there is a section titled "Stereo Matches" with a list of image pairs. Each pair has a checkbox, a description of the images, and a download icon. The first pair is selected, and its download icon is circled in red.

To download an individual image as a .IMG (PDS native image format) file, click on the white down **arrow** beneath the thumbnail. To download more than one image at a time, or to process before downloading, select one or more images using the box above the thumbnail and choose from the download options. The first option will download a CSV (comma separated values table) file with some metadata about each image and a link to download the .IMG file. The second option will give you a script to download the images with a BASH script using wget. The third option will take you to Projection on the Web (POW).



If you select Projection on the Web (POW, see <https://astrocloud.wr.usgs.gov/>), you will be directed to a site to create a user account and log in before submitting your job. POW allows users to submit up to 50 selected images to be processed by ISIS at USGS before returning the processed images to the user. Typical processing steps are radiometric calibration and map-projection. Please refer to the POW site linked above for more information on that tool and how to use it.