

Lunar LRO Data to SketchUp Landscape Using LMMP Maps & LODE Data & Excel Modules

For the [Big Moon Dig](#)

Tom Riley

Beta

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Copy write: Tom Riley

1. Purpose

This task is to download scientific data from the LRO lunar mission, then work that data into a friendly form for 3D map surface in Google SketchUp. The data is then saved in formats that can be used for:

- E-Games
- 3D Printing
- CNC Machine

This document will help you obtain lunar data and convert it into useful lunar landscapes for use in electronic media. It features the use the Lunar Mapping & Modeling Portal (LMMP) and Lunar Orbital Data Explorer (LODE) to develop landscapes of the Moon based on the Lunar Reconnaissance Orbiter (LRO) data. The raw data is then reduced and formatted for use in Google SketchUp graphics for our games and stories of the [Big Moon Dig](#). Custom Excel VBA Modules and existing SketchUp Ruby Plug-ins do the hard work.

This process is used to insure that the lunar landscapes used on the Big Moon Dig games and stories are as authentic as possible and is based on the latest scientific data.

The Big Moon Dig would like to thank NASA for the use of the LRO lunar data.

1.1. Requirements and Capabilities

If you have an Internet browser you will be able to:

1. Review lunar images

2. Download lunar altimeter data

If you have a spread sheet program, like Excel or OpenOffice, then you will be able to:

3. Read in data points
4. Reduce altimeter data to points to a well behaved surface
5. Edit the surface data points in a number of ways
6. Save a surface as a CVS file
7. Assemble blocks of files into a larger area mosaic file.

If you have access to SketchUp Version 13, you will be able to:

8. Read in a CVS file of points
9. Convert the points to a triangulated surface

If you have access to SketchUp any version, you will be able to:

10. Edit the triangulated surface
11. Save the surface in a format for e-games
12. Convert the surface into a printable block
13. Convert the surface into a CNC millable block

If you have access to SketchUp Version 15, you will be able to:

14. Save the block as a 3D printable file
15. Save the blocks as CNC milling files

If you have access to a 3D printer, like MakerBot, you will be able to:

16. Print out the blocks

If you have access to a CNC Router, like CNC Piranha, you will be able to:

17. Mill out the blocks

Similar processes could be developed for other graphics editing programs.

2. Process Outline

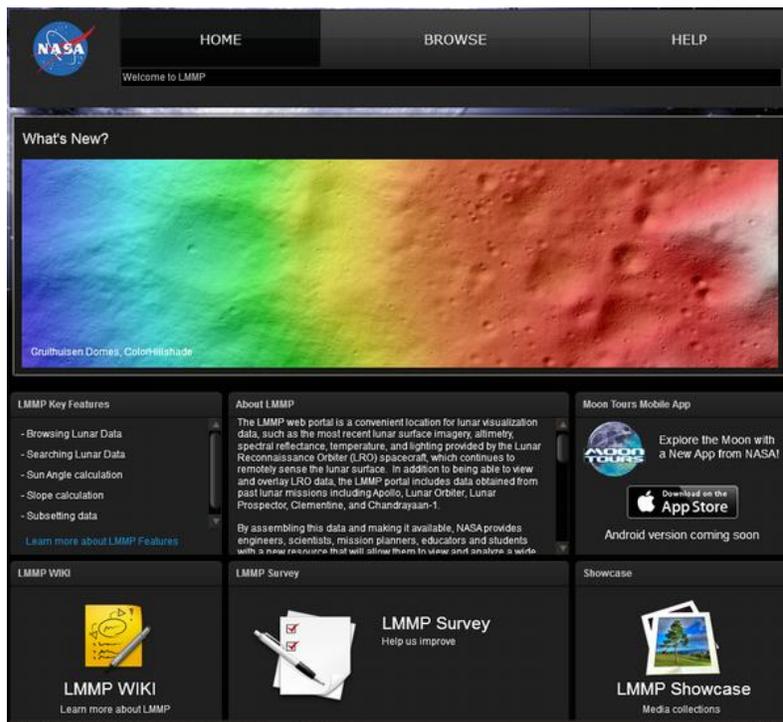
This process is rather complex and proceeds in a number of discrete steps:

1. Block out the location on a lunar map
2. Draw a layout graphic
3. Download available LRO data as a CVS file
4. Read the CVS file into Excel
5. Strip out unneeded data with a VBA Module
6. Add detailed calculations with a VBA Module

7. Assemble output data with a VBA Module
8. Export formatted data as a CVS file
9. Setup Google SketchUp
10. Read the data into Google SketchUp with a Plug-in
11. Add a triangular mesh with a Plug-in
12. Remove bad data passes
13. Edit the surface in a number of ways including:
 - a. Build a 3D printable block
 - b. CNC milling block
14. Save finished product

3. Working out the Location with LMMP

The first step is to work out the exact latitude and longitudes of the sites of interest. In the process we will also capture overhead shots of the area.



Lunar Mapper Web Page

3.1. Getting Started with LMMP

Our first task is to review to the available images and scientific data the lunar sites that we are interested in. Some of these sites are locations for possible lunar settlements and others are routes for exploration.

This work can be done with Lunar Mapping & Modeling Portal (LMMP) tool, "Lunar Mapper". This software works through your browser:

Lunar Mapping & Modeling Portal (LMMP)

http://pub.lmmp.nasa.gov/LMMPUI/LMMP_CLIENT/LMMP.html#

Click on *TOOLS* and then the Icon for [Lunar Mapper](#).

3.2. Locating Areas of Interest

The task now is to identify the exact location of the areas of interest and record their longitude range and latitude range in degrees and those of a center reference point.

For the examples, we set the image to *the South Solar Stereographic Projection*, and the map size to *Maximum*. We then centered the point of interest on the screen using the mouse and magnified the image as much as possible. We recentered with each step in magnification.

We then noted the latitude and longitude ranges for the area of interest by moving the mouse and noting the readings on the screen *in Map Position (degree)*. Examples of these area include:

	Long to	Long	Lat to	Lat	Interest
Mt. Malapert Mosaic					
Malapert Area	-5.0	4.0	-85.8	-86.1	Eternal Light Mountain
Malapert ref	-4.0		-86.0		To Be Determined
Carter Haworth Mosaic					
Haworth Area	-10	20	-86.6	-88.20	Water source
Haworth ref	34		-85.0		Use other group ref
Scott A Massif					
Scott Area	20	45	-84.7	-86.1	Eternal Light Massif
Scott Ref	34		-85.0		Scott A 4
Marius Hills					
Marius Hills	-56.5	-49.0	9.5	17.0	Equatorial and volcanic

Marius Ref	TBD	TBD		
Marius Skylight	-56.6	-56.0	13.8	14.3
Marius Hole	-56.37		14.13	

Skylight area
Skylight

Latitude and Longitude ranges for areas of interest

For this Web site (and this is different for other sites we use), the 0.0 latitude and 0.0 longitude is the point on the Moon's equator on a line with the center of the Earth. The number for this Web page run minus -180 (West) to Plus 180 (East) degrees in Latitude and plus (North) to minus (South) 90 degrees in Longitude. Minus longitude numbers are West of 0.0 meridian (imagine a map of the USA). Minus latitude numbers are South of the Equator.

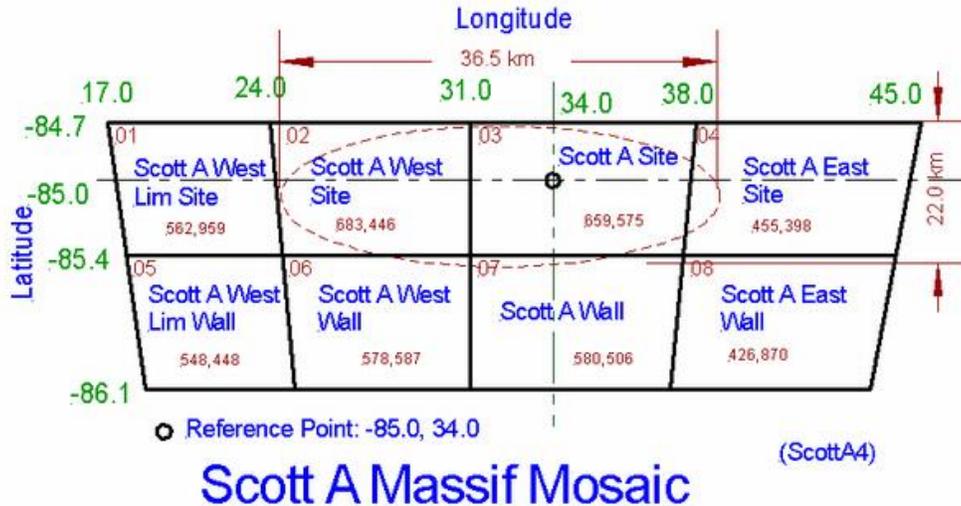
Note that the centering feature works well in the equatorial views but does not work in the polar view mode.

To save an image, work with the Lunar Mapper to generate good views with the study area and set the scale as large as allows the full area to be seen. Then move the mouse cursor around the image and work out the exact latitude and longitude you want for a rectangular area of study. Note the maximum and minimum latitude and longitude of interest to define a box. Also note that the location of the cursor is given in meters at the bottom of the screen and you can use this feature to estimate the size of the area of study.

Use the *menu bar --> Layers* feature to over lay other data sets on the image. The *Add LRO Other, [] LRO Diviner Surface Temp feature* is particularly good for showing dark craters. This is a thermal mapping that allows you to work out boxes for dark craters.

When you have a useful image displayed used the *Ctrl-PrtScn Key* to capture an image of the screen to the clip-board. Open a graphics program, such as Windows Paint, display the clipboard, and box in the area of interest on the image. Crop the image and save it in either the .jpg or .tiff formats.

Make a rough sketch of your area of interest and reference points. We will add more detail to this drawing in the next several steps.



4. Start a Layout Drawing

We now need to divide the area of interest into blocks of a size we can handle in a reasonable amount of time. The larger the area the more data you will have to deal with especially near the poles where many orbital passes converge. In our experience blocks with more than 700,000 points can hang up or take too long to process.

We therefore need to divide the area of interest into a mosaic of blocks none of which have more than 700,000 lines of Excel (OpenOffice is limited to 64,000 lines). The great majority of these lines will be eliminated as questionable points. Normally we end up with 12,000 to 45,000 actual verified data points for polar locations but many fewer for equatorial areas.

Later on the much reduced files can be reassembled into larger blocks if desired. To allow this, all the blocks must use the same reference point.

Note that one degree of longitude on the Moon is always 30.3 km (18.8 miles). Degrees of latitude vary in length with longitude $\{d = 30.3 * \text{Cos}(\text{Longitude}) \text{ in km}\}$. Adjusting these numbers is equivalent to flatten the surface of a large sphere onto a flat surface. The reference latitude and longitude are used for this adjustment and there is some resulting distortion of the image.

LODE Latitude/Longitude Entry

5. Getting Data from ODE

[The Lunar Orbital Data Explorer](#) (LODE) Web site allows us to actually get the scientific data.

This site provides access to the Lunar Reconnaissance Orbiter (LRO) lunar data in a number of formats that can be used for making maps. Some of the formats available can be directly read by some graphics programs but this approach proved to have technical difficulties. The process we settled on allows working of the data to remove bad data points:

1. Read the data in several large CVS files
2. Work that file in Excel using three custom VBA Modules
3. Export each worked data in a file format friendly to Google Sketchup

5.1. LOLA RDR Query

To start, go to the LODE web site and click on the *TOOLS* tab. Then follow these steps:

Step 1. *Enter Latitude and Longitude into graphic*

Enter the maximum and minimum latitude and longitude that we worked out in the previous web site. Note the numbers are in a slightly different format (longitude reads 0 to 360 degrees):

If you get error messages on entering numbers, try blanking out all the boxes and then reentering the number starting at the top and left.

Press the *Show Area on Map* to find where you are. Very small study areas will not show up on the map. Bad entries will often show up as large blue boxes.

Step 2. Set Additional Filter Parameters (Optional)

No action needed in this block.

Step 3. Preview Results Count

Press [*Query Count*] to get an idea of the number of data points available in the defined area. This will take a minute or two for a large area.

Note the number of data points available for your study area. These large files contain a substantial amount of data you do not need and quite a bit of bad data. We have found that the maximum number of data points that can be provided without danger of hanging up a Windows system is about 700,000. Give this program a maximum of ten of minutes, but if the count query hangs, try a smaller area.

If your area of interest is too big, try dividing it into a mosaic grid. The Scott A Massif Mosaic shown above ended up with eight blocks none of which exceeded 690,000 points

Near polar areas also have a very large number of LRO data passes and therefore generate very large files. Most of the reduction steps take only a few minutes, but two steps (removing duplicate points, triangulation of points) can take tens of minutes for large files.

Step 4. Request Results

CSV Format [Generate Files] -- Press this button and wait for the files to be generated. CSV is a comma delimited text format that can be read by an Excel Spread sheet. Download specifically the third file down in the list entitled:

RDR(long number)_FramePerRow_csv_table.csv.

This can take several minutes depending on your system link speed.

Note that there a number of other file formats available. We do not now use them but list them for possible use under Future Work below.

Save all Files: Save all the files you just downloaded by moving them from the download folder to a specific project folder. Simplifying the names of the files helps. These can be large files.

6. Complete the Layout Drawing

Now go back and complete your layout drawing (see Scott A Massif diagram above). Show how you have divided up the area of interest. Number each block. Note the limits of latitude and longitude. Note reference latitude and longitude for the entire group. Add the number of raw data lines for each block. All this information will be needed later.

Note also that the process of flattening the blocks turns them into a keystone shape with the short end toward the pole and centered on the reference point.

7. Setup Folders

Make a main folder for this run with a name like *Malapert5*.

Make up the following subfolders:

- *nameRawData*
- *nameXLSM*
- *nameCVS*
- *nameSU13*
- *nameSU15*
- *nameSTL*

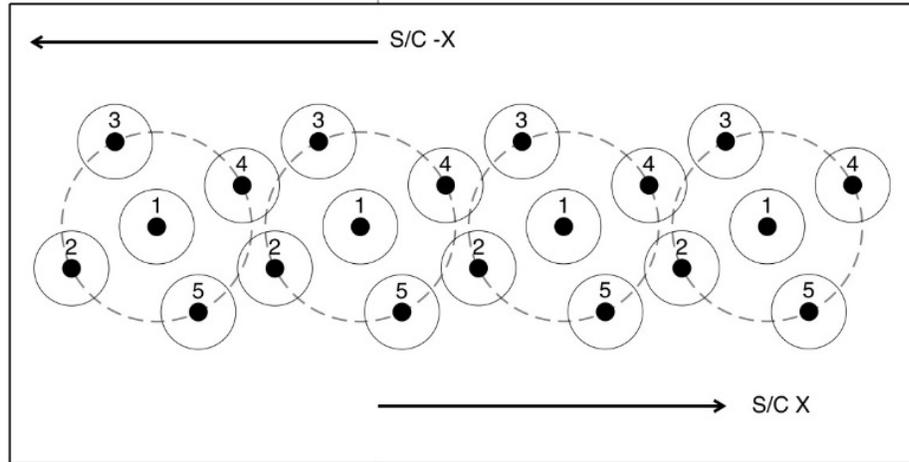
Move the raw data to the appropriate folder and reduce the length of the file names.

RDR(long number)_FramePerRow_csv_table.csv

Becomes:

RDR(long number)M601.csv

Figure 1: LOLA ground spot pattern sample of four successive shots, with channels numbered. Spacecraft may fly in either +X or -X direction.



LRO five ground spot layout, NASA

8. LRO Data meaning

The Lunar Orbiter Laser Altimeter (LOLA) instrument on the LRO Mission made precision readings of the distance from the spacecraft to the lunar surface using a laser. The readings for a figure of five spots (see illustration above). We will use Spot 1 as the official altitude reading and use the other four spots to indicate local slope and roughness.

The circle of points 2 through 5 is about 30 meters in radius. The distance between sequential Point 1's is about 64 meters. Typical spread of points along the flight path is about 120 meters.

The LRO satellite was in polar orbit so it tracks converged near the poles so it took an enormous number of readings there over its two year mission.

The raw data contains a large number of points that are simply bad data for our purposes (marked with 999) and we will delete these points. Typically we will end up with about 20% of the starting points and still have about as many as a PC can handle in a reasonable time.

9. Cleaning up Data with an Excel Spreadsheet

You have now reached a major bench mark in the process and can now read the raw CVS data file into an Excel work sheet, strip out unwanted data columns, remove bad data rows, calculate altitude point by point, and form a simplified data file that can be read by other programs. This can all now be done semi-automatically by using three VBA Modules for Excel that we have written especially for [The Big Moon Dig](#). For large files the full process can take several minutes to an hour.

9.1. Setting up

To use VBA Modules in Excel on a Windows system, you must accomplish two steps:

1. Make *Developer* tab visible -- Right click on ribbon at top of Excel. Choose *Customize Quick Access Tool Bar*. Choose *Popular*. Check the box *Show Developer tab in the Ribbon*.
2. Enable macros on your machine -- Click on the four frames in a circle in the upper right hand of Excel. Select Trust Center. Click on Trust Center Settings in the lower right hand corner. The on Macro Settings. Now move the radio button in the top section to *Enable all macros (not recommended; potentially dangerous code can run)*. Clearly when you are finished with your micro work, you would be well advised to put this radio button back where it was, which is usually *Disable all macros with notification*.

9.2. Download the Modules and save them

Go to [the Big Moon Dig](#) Web site, *Why & What* where you got this document. Download the file small Excel file. This is a relatively small sized file that also contains the six VBA Modules.

Go to the Visual Basic tab a look for *Developer* and then click on the *Visual Basic* icon. This will open up the *Visual Basic Editor*. Find the *Project-VBAProject* window and click on *+ Modules*. This will show the three Visual Basic Modules:

1. LRODataVnn.bas – Removes unused and bad data
2. LROSlopeCalVnn.bas – Converts latitude and longitude to meters, calculates altitude and slope.
3. LROPoints3DVnn.bas – Removes bad strings of data and points on top of each other. Formats output file.
4. LROCratersVmm.bas – Adds simulated craters to terrain (not now commonly used).
5. LROPrintBotVnn.bas – Makes a file that can be father processed for a 3D printer or CNC machine.
6. LROMakeBotMosaicVnn.bas – Assembles Sheet03 from up to eight blocks into on larger mosaic.

Go to *File* tab and *Export* each of these .bas programs to a designated folder on your machine. Each of these programs has gone through a number of versions in development.

9.3. Read the CVS Data File

Open Excel and read one large raw data CVS file you saved earlier. Most spreadsheet software should be able to read this file and run the visual basic modules but may be limited in the size of files it can handle.

9.4. Import the VBE Models

Go to *Developer, Visual Basic* on the Excel sheet top tab bar. Click on *File, Import File* and find the VBA Modules you just saved. Select and import:

1. *LROData*
2. *LROSlopeCal*
3. *LROPoints*

Each of these will have been worked through several versions.

9.5. Remove unneeded data and save as .slxm file

The first routine, *LROData*, removes the unneeded columns and any data with bad data markers (999). This greatly reduces the size of the file. All the good data points are then written to *Sheet1*.

Enter *Ctrl-G* to bring up the *Immediate* window. Position this window up and out of the way so that you can see it even when other windows open and close. Also reduce the size of the main Excel window and the Visual Basic windows so that they do **not** completely block each other. Depending on how well the run goes you may either need to see a pop-up screen in the middle of the Excel window, which does not come to the front, or get to the *Run* tab in the *Visual Basic* window.

Go to the bottom of the Excel sheet and click on the tab to create six more empty sheets: *Sheet1, Sheet2, Sheet3, Sheet4, Sheet5, and Sheet6*. We will be using *Sheet1* for the main data file. *Sheet2* will contain worked data. *Sheet3* is the basic output file. *Sheet4, Sheet5, and Sheet6* are specialty output files.

Be sure that you end up with the first named file sheet selected. (If you omit this step you will get an error message when you run the first Module.)

Now start by double clicking on *Modules, LROData*. This will bring up the code in the window. Now click on the small green *Run Arrow* to start the Module running.

Click on *Yes*, to keep the Module running. This Module can take several minutes on large files. Note the progress being ticked off in the *Immediate* Window. When the action is complete a notice will appear.

Check to see that there is a copy of all the good data points now on *Sheet1*. The number of good data rows is usually about 20% of the number of raw data rows.

Note that there are about 40 columns in the raw data file but we need to keep only a few of them. The LROData VBE module will automatically remove the unneeded files. The keepers are:

Coordinated_Universal_time, Elapsed_Time, SC_radius, Geoid
 D1_Longitude, D1_Latitude, D1_Radius, D1_Range
 D2_Longitude, D2_Latitude, D2_Radius, D2_Range
 D3_Longitude, D3_Latitude, D3_Radius, D3_Range
 D4_Longitude, D4_Latitude, D4_Radius, D4_Range
 D5_Longitude, D5_Latitude, D5_Radius, D5_Range
 Offnadir

When this is complete, you can now click on the first tab with the long name and delete the entire tap. This removes the old raw data and makes the working file a lot smaller. All future action will be with the reduced data now in *Sheet1* and later in *Sheet2*.

Save As this file to a project folder as an Excel Macro-Enabled Workbook .xlsm. It will be much smaller than the original CVS file.

9.6. Calculate altitude

To run the second Module, go back to the Visual Basic Window and double click on *Modules > LROSlopeCal*. This will bring the second Module up in the window. Again click on the small green *Run Arrow* to start the Module running.

This Module will require a reference longitude and latitude. Groups of blocks should use the same reference longitude and latitude. For example:

	Lat	Long	
Scott A Massif	-85.0	34.0	Settlement Site
Mt. Malapert	-86.0	-4	Settlement Site
Crater Haworth	-85.0	34.0	Permanently shadowed
Marius Hills	307	14	Equatorial and Volcanic
Marius Hole	303.63	14.13	Skylight

Enter the Reference Latitude, and Reference Longitude for this particular block (see table above). If you are building a large mosaic of several data blocks, then they should all have the same references in this step.

The reference latitude and longitude constitute the origin point 0, 0 for the Google SketchUp program. All latitude and longitudes from here on out will be calculated in meters with respect to this reference point.

The software contains an internal reference of 49 degrees for the Maximum Slope. Lunar regolith will not stand at a steep angle for long periods of time. Over time small meteor strikes erode any steep clefts and reduce them to slopes of ground rock. Steep rock faces are very rare on the Moon. It is therefore safe to assume that any very steep slope is simply a bad data point and so are not copied to Sheet2. A small number, 0.001, is placed in the slope formula to prevent divide by zero errors.

The *LROSlopeCal* can take several minutes to run and the progress is shown in the *Immediate* window. There is a completion note at the end.

When it is done, check the right side of Sheet2 to see the calculation of the latitude, longitude, and altitude for each of LRO five spots. The slope calculated from Spot 1 to each of the other four spots, which are about 30 meters apart, and the largest value is taken as representative of the whole spot. This is good information as it indicates how difficult a spot will be to land on, build on, or even drive over.

Add the block name and number to Sheet1, D1.

In the top 10 rows of Sheet2, you can also find information about the input numbers, and the range covered by the data. Feel free to add any identifying labels in the first or second rows.

Save the file as .xlsm so that the Visual Basic programs will be included. Be sure that the save action is complete before taking any farther steps. You should be able to select squares on the sheet when it is done.

10. Test for Bad Passes

Most of the data points are good at this point but a few instrument passes, strings of data points, may be clearly out of calibration. In the next step we will identify this bad passes so we can remove them.

10.1. Run LROPoints, No

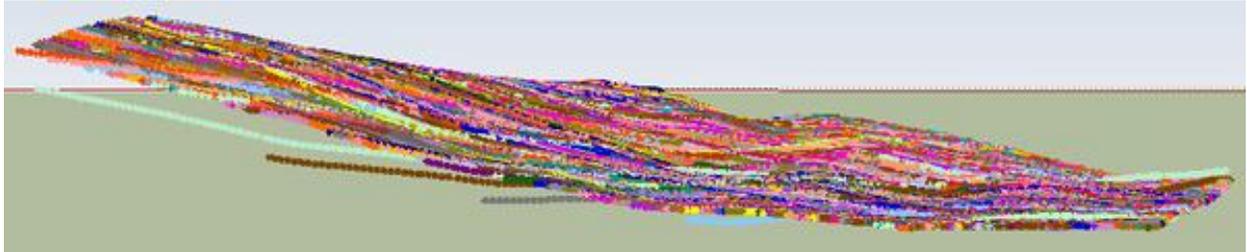
To run the third Module, go back to the Visual Basic Window and double click on *Modules > LROPoints*. Run this module but be very careful to answer “No” to the question about removing duplicate points.

With the “No” this module will only take a couple minutes to run. Later we will use the “yes” feature which can take much longer.

When the run is complete, save the file in .xslm.

Sheet4 now contains all the points but with the pass number for the readable information.

Go to Sheet4. Save Sheet4 as a .CVS file. Answer yes to both questions. You can then close the original Excel file without saving.



SketchUp Sheet4 with obvious bad passes

10.2. Read in Sheet4 points

Open SketchUp Version 13. (This is discussed in detail below.) Run the plug-in that reads in CVS points:

Plug-ins > Total Station Point Importer.

When the window opens select:

Units? Meters
Layout? ENZ/XYZ
First row header? Yes

Then browse to the Sheet4 CVS file we created in the previous section. Then answer the questions:

"No" to tags
"No" to marker
"No" to Path
"Yes" to color by layer

You now have the points in SketchUp but you probably cannot yet see them. Go to:

Camera > Standard View > Front

You should now see a mat of data points colored by pass number forming a surface.

Open up *Window/Layers* and *Window/Entry Info* so you can read the pass number. This should open up two small boxes. One gives the layer number and color. The other lets you get the pass number of any point.

Right Click on the mass of points and select *Edit Components*. This will let you get information for individual points.

Review the surface of points. Look for strings of points that are obviously away from the surface. Some may be high. Some may be low. On a good block there will not be any at all. On a bad block there may be eight.

Click on one point in each bad line and read the pass number from the *Entry Info* box. Make a written list.

Rotate the surface around and look at it from several angles just to be sure.

10.3. Record bad passes

Open the .xslm spread sheet again and find *Bad Pass* on Sheet2, A3. Enter the bad pass numbers you just recorded into line 3 starting with D3. You may keep or overwrite the 0.

Enter the total bad passes in Sheet2, B3.

The next time you run *Modules > LROPoints*, these entire passes will be removed.

Save the .xslm file.

10.4. Repeat Check

You may want to repeat this Sheet4 process to be sure you have gotten all the bad passes out.

You can also run the triangulate feature as the bad points really stick out when triangulated. To read a data point after triangulation, you have to unclick the triangles layer in the Layers box.

11. Remove Duplicate Points

When you are happy that you have removed all the bad passes. Reopen the .xslm file

Consider turning off your Internet connection and any other programs that generate interrupts (such as *Smart Firewall*). The next run for tens of minutes and can be spoiled by the wrong interrupt.

Now run *Modules > LROPoints*, and answer *Yes*. This will first remove the bad passes and then start the process of removing duplicate points. The latest software versions have enormously speeded up this process.

Many of the passes cross each other. If the calibrations is off even a few meters, then the close points can show sharp slopes that simply are not there. In bad cases these can even bomb the triangulation calculations. This module will look for any points within 100 meters of

each other, take an average for one and remove the other. This will remove up to 15% of the points and make the surface much easier to generate.

Allow the computer to run undisturbed for and watch the *immediate* window for progress. The software count up while giving the time for 100 points in minutes along with the elapsed time. Time steps over one minute indicate the program will run for hours. When you reach have way by the numbers, you will be 75% of the way by time. Once the time step gets below 0.1 minute, the end is near.

When the software completes, save the .xslm file. Save it again just to be sure and take your time. These saves may take several minutes.

Review that you have a good Sheet3 and look at the number of lines in it.

Go to Sheet3 and save it as a CVS file. Sheet3 gives the points and their slopes.

Close the file without saving.

12. Making a full Block

If you want a 3D block with sides and a bottom, for example for CNC or 3D printing, you will need to run:

1. LROPrintBotVnn.bas – Makes a file that can be further processed for a 3D printer.
Or,
2. LROMakeBotMosaicVnn.bas – Assembles Sheet03 from up to eight blocks into one larger mosaic.

Save the complete .xslm file.

Go to Sheet6 and save it as a CVS file. Sheet6 gives the points and their slopes and has added points to turn the surface into a block.

Close the main file without saving.

13. Make a Basic Lunar Surface in SketchUp

You have now achieved a major benchmark in the process. You can now read in the LRO data into SketchUp and use it in 3D drawings by using standard Ruby plug-ins.

You can then use this process to make a number of refinements to the surface.

13.1. Getting the Ruby routines

(Unfortunately these Ruby routines only work in Google SketchUp 13. We need to find routines that work in SketchUp 15 or upgrade these plug-ins.)

Two Ruby Plug-ins for Google SketchUp are needed for this work:

1. "[Total Station Point Importer](#)" by CMD (Ruby Plug-in)

This plug-in lets you read in the CVS file we created with Excel and display it as a sheet of points in a group.

The download produces a zipped folder with the extension .ribs. SketchUp has an automated process for loading this form of file. However, this folder can be opened with whatever program your use that opens .zip files. It may be simplest to change the extension to .zip and then open the folder.

The open folder contains one program with an .rb extension and a folder. Copy both these to the *Sketchup/Plugins* folder on your computer.

2. "[Points cloud triangulation](#)" C. Fale, D. Bur (Ruby Plug-in)

This plug-in converts a cloud of points into a triangulated surface grid. Download both the program and it required supporting program. This produces two files with Ruby .rb extension, but does not have an auto loading zip file. Copy both these files to the *SketchUp/Plugins* folder on your computer.

13.2. Reading in the Sheet3 CVS file

If you have placed the Ruby Plug-in files in the correct directory, when you reboot SketchUp, (sometimes you need to reboot Windows too) you should now have an entry in the top ribbon, *Plug-Ins*. Click on this tab and select:

Plug-ins > Total Station Point Importer.

When the window opens select:

Units? Meters
Layout? ENZ/XYZ
First row header? Yes

Then browse to the Sheet3 CVS file we created in the previous section. Large files will take a minute or two to load. Then answer the questions:

"No" to tags
"No" to marker
"No" to Path
"Yes" to color by layer

You now have the points in SketchUp but you probably cannot yet see them. Go to:

Camera > Standard View > Front

This process can take a minute or two for large files.

Save the file in the *nameSU13* folder with the block name.

13.3. Making a grid

The gridding process only takes about ½ hour for small files but can run for a very long time for large files and mosaics. The process can be hung up by external interrupts. Be sure that you can let the machine run for up to 2 hours for large files.

Turn off all other programs that might interrupt progress, like e-mail. Click on the Internet control icon in the lower left corner and turn off the Internet connection.

This program starts off fast but makes two passes and slows down at the end. You can judge the progress by watching the numbers in the lower left.

Select the component you just make for editing with:

Edit > Component > Edit Components

Now select all the points inside the component. Selecting the component is **not** enough, you must select the points inside the component.

If you are making a block with a bottom and sides, do not select the bottom four points that make the bottom but do select the four rows of points along the sides.

Select the gridding plug-in:

Plug-ins > Cloud point triangulation.

Accept putting the triangles in a layer called *Triangles*.

The gridding program will now run for 10 to 45 minutes for normal sized files but can run for hours for 50k files. You can watch progress in the lower left-hand corner as the program runs through all the points several times.

Save the SketchUpV13 file.

Reboot your computer to turn back on anything you turned off.

13.4. Open in SketchUp V15

After rebooting, open the file with SketchUp Version 15. Save the file into the SketchUpV15 directory with the name addition V15. This file will no longer be readable by Version 13.

13.5. Editing the Surface

The finished grid can be edited to remove obviously high or low points and then fix the triangles. This is a slow manual process.

Inspect the grid surface to see if there are any very high or low points. You can rotate the grid around until you frame the bad points against the sky.

To remove an unwanted pointy hill, select the entire grid and go to:

Edit > Edit Group

Erase Icon

Carefully place the little circle on the *Erase Icon* directly over the point or line you wish to erase and left click. This will select both the point or line and the surrounding triangles leaving a hole.

This will punch an obvious hole in the grid. Now use the *Pencil icon* to draw lines between the points around the edge of the hole to make new triangles. You must be exactly on existing points and you cannot cross lines. When you have a new triangle the skin will fill in automatically. If the new triangle does not appear, look carefully to see if you missed a point.

If you find long strings of very high or low points, then you have missed a bad pass and have to go back several steps.

Save your SketchUp V15 file.

13.6. Completing the Skirt

If you are making a three dimension block, and not just a surface, you will need to complete the sides and bottom. This will take three editing passes along the four sides:

1. Complete edge triangles – Draw lines with the *Pencil Icon* to complete any missing triangles along the edge. Sometimes it will take two lines to make two triangles. Also draw lines from the four low corner points up to the surface to make sets of two or three triangles to define the corners.

2. Complete the Bottom – Draw in lines complete the bottom and the lower four edges. Draw enough lines to make large triangles.
3. Clean up the edge – Go around the edge looking for sharp indentations. These are hard to build in 3D. Erase one or two lines coming up the side into such indentations and then draw lines across the top redefining a few large side triangles and smaller top surface triangles.
4. Inspect for holes – Sometimes you can miss drawing a line while editing. Turn the surface different ways and look for holes. You may have to erase and redraw a line or two to patch a hole.

13.7. Layer Meaning

As you said "Yes" to color, the points will have layer colors indicating the slope binned in 5 degree increments. The colors can be turned on and off as needed. The bins mean:

0 – Good – A good place to build. Easy to travel. Easy to land.

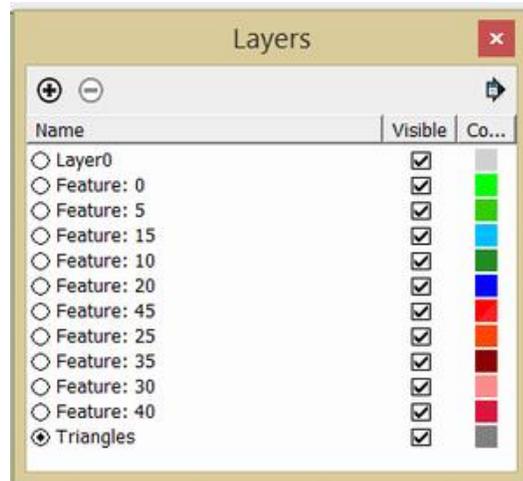
5 – OK -- OK to build. Easy to travel. OK to land.

10 – Workable -- Hard to build. Travel possible with care. Landing questionable.

15 – Limit for Travel -- Travel difficult, but not impossible. Don't build. Don't land.

20 – Danger -- Dangerous to travel, possible only with special equipment

25 or greater – Useless -- Just plain dangerous for any activity.



Layer Colors in SketchUp

13.8. Changing Layer Colors

The colors of the individual layers can be adjusted. First open the layers window:

Windows > Layers

Click on the Color Box of the layer you want to change. This should open the material box where you can edit the color or add a surface material from a graphic (see next step).

The table below provides a list of named colors for the standard Big Moon Dig layers. The layers may not be in this order. The number are decimal.

Layer	Red	Green	Blue	Name	Description
Layer 0	211	211	211	LightGray	Excellent, any use
Feature: 0	0	255	0	Lime	Good, most uses
Feature: 5	50	205	50	LimeGreen	OK, most uses
Feature: 10	34	139	39	ForestGreen	Travel, but take care
Feature: 15	0	191	255	DeepSkyBlue	Limited use
Feature: 20	255	0	255	Fuchsia	Danger, poor footing
Feature: 25	255	69	0	RedOrange	Danger
Feature: 30	255	140	140	DarkOrange	Danger
Feature: 35	139	0	0	DarkRed	Danger
Feature: 40	220	0	60	Crimson	Danger
Feature: 45	255	0	0	Red	Danger
Feature: 99	128	0	128	Purple	Marker, not slope
Triangles	128	128	128	Gray	Surface

Standard Layer Names using HTML Named Colors

13.9. Adding a surface material

To add surface texture based on a photograph, for example a lunar regolith shot from Apollo or LRO NAC image, go to:

Windows > Materials

Click the + Box, the third icon down on the right side.

Texture > Check Use texture image.

Browse to find the image.

Set the size as 2.00 by 2.00 or larger and give the new material a name.

Click OK.

Click on the *Paint Can* Icon in the top tool bar.

Select the new material icon and move the Paint Can to the surface and click. The surface and points should now change color. A close inspection will show that the surface is now painted with the new material.

If you do not want to see the points, now black dots, you can go through the *Layers* window and uncheck any or all of the slope bin layers.

Save the SketchUp file.

Congratulations, you now have a section of lunar surface, based on real science data that you can use in most graphics programs.

14. Advanced Surface Techniques

You have now reach a major benchmark in this process and can take a number of actions depending on what you need. Each of these actions is detailed in a sub-section below:

1. **Add Craters** – This action adds small craters to area that are read as rough. This process is now obsolete and is being replaced by painting with actual LRO NAC images.
2. **Assembling a Mosaic** – You can now assemble the smaller block files back into a large file.
3. **3D Printer** – This process produces a file that can be read by a 3D printer.
4. **CNC Milling Machine** – Very like 3D printing only milling from wood.

Specific CVS files can be saved for each of these processes.

14.1. Add Craters

When you have the surface exactly how you want it, you can run the Craters Module to add typical craters. This action is optional and is now considered obsolete. A much better approach is now becoming available by low loading actually images from the LRO Narrow Angle Camera. The random craters added are less than 60 meters in diameter and would only show up as roughness in the LRO Data. They add interest to the otherwise overly smoothed surface.

The fraction of points getting craters can be set and only craters with less than 15 degrees are allowed to have craters. The craters are drawn in three rings of new points around an existing point. All point locations and altitudes are slightly randomized to create a fractal effect. The outer ring is tipped slightly along the north/south axis to better fit into slopes.

14.2. Assembling a Mosaic

If you want to end up with one large mosaic you can do this with a special VBE module *LROMakeBotMosaic.bas* . You need all the blocks of data referenced to one reference point. Open a new Excel file and add 10 sheets. Copy the basic information required in the text at the start of the module onto Sheet1. Most of this is on Sheet1 of each of the blocks. This includes the Reference Longitude and mosaic Reference Latitude (typically the reference for the main site) in the slope generation routine, and LROSlopeCal.

You will need the most northern latitude, most southern latitude, most eastern longitude, and most western longitude for the entire mosaic.

Then cut and paste the entire Sheet3 from each block run into one of the pages of the new file. Block 01 to Sheet2 etc..

Run the LROMakeBotMoasic module to generate a full block with lower points. The module contains a bottom off set number, nominally -4000 m, to insure that the points do not go below zero.

The program can save every second or fourth data point to reduce the size of the final file. This saves a lot of time and the 3D printing and CNC processes cannot handle more detail than this.

Save the file and then save Sheet10 as a CVS file.

Read the CVS file with the SketchUp V13 modules. Triangulating this large file in SketchUp can take several hours if there are than 20,000 points.

You then need to complete the process as above using the smaller scaling factor of .0025 so that the mosaic block will fit the printer table.



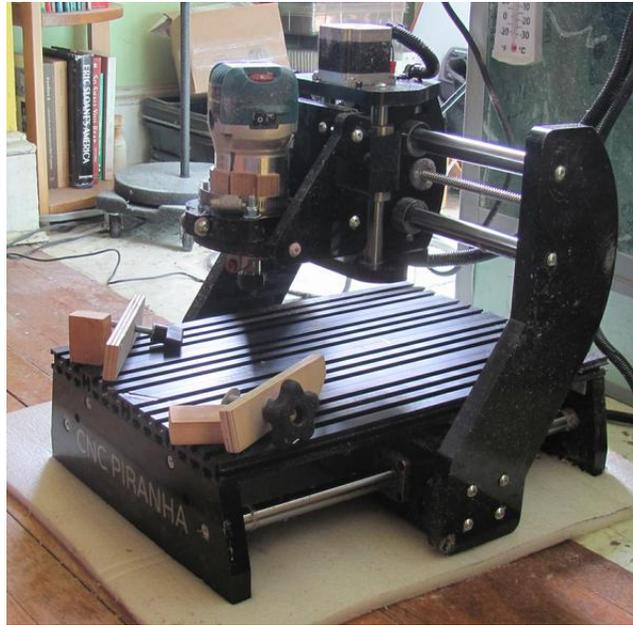
Scott A, Site 3D Printer Block

14.3. Full 3D Printer Process

A detailed description of how to print out these files with a 3D printer is provided on our Web site at:

“Lunar LRO Data to 3D Printer”

<http://bigmoondig.com/Games/BMD3DPrint.pdf>



CNC Piranha Machine

14.4. **CNC Machine Milling**

A detailed description of how to mill out these files with a CNC Machine is provided on our Web site at:

“Lunar LRO Data to CNC Machine”

<http://bigmoondig.com/Games/BMD3DCNC.pdf>

15. Future Work

The finished lunar surfaces can now be assembled into larger mosaics. The mosaic surfaces can then be used in graphics and games.

Beyond the Scott A Site, we need to build surfaces for other sites of interest. These include:

1. **Marius Hills** -- This best site on the Moon with a candidate for a skylight to an open lava tube. It deserves detailed study.
2. **Circumnavigate the Moon** -- Another grad MOVE expedition has been proposed. If a long-distance rover started at Malapert and rolled steadily due west, it could stay in good sunlight and moderate temperatures for about a month and a half by following the Sun. The challenge is to circumnavigate the Lunar South Pole in that

time. This would be a real trail blazing expedition and will take an enormous number of lunar surfaces for the planning and execution on the Virtual Moon.

3. **Apollo Sites** – There is interest in 3D printing and CNC blocks of the Apollo to the Moon sites.

15.1. Recent Completions

We have recently completed the following:

1. **Mt. Malapert** -- Right next door to Scott A, this site was our first site studied and can be identified with telescopes from the Earth. With the lessons learned to date and the recalibrated data, we need to rework this area. Its value, visa-vie Scott A, depends on which site has the best access to the permanently dark craters. This can only be judged by exploration on our Virtual Moon.
2. **Crater Haworth** – This large crater lies at the base of both Mt. Malapert and the Scott A Massif. It is a permanently shadowed crater and what's more its east rim looks collapsed allowing easy access.

15.2. Improvements Needed

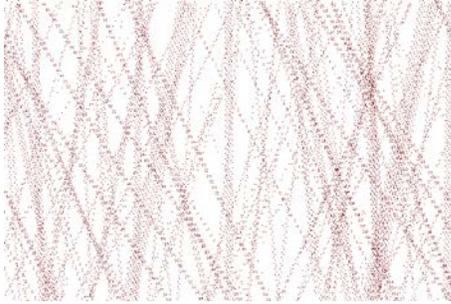
Clearly we need your help on the following tasks:

1. SketchUp Version 15 plug-in – This is a simple upgrade of two plugins (written in Ruby on Rails) for the latest version of SketchUp.
2. Custom program to reduce data size – If we wrote a custom stand-alone program that striped the excess data like the first two Excel plug-ins, then the file would be small enough to run on Open Office (a free program limited to 64K files).
3. Reading data with other Graphics programs – A wide variety of data file extensions are available. Some of these should be readable by open graphics programs like GIMP. The problems is figuring out how to add slope data and remove bad passes. It may be possible to use other data formats more easily:

[Shapefile](#) *Format [Generate Files]* -- The shape file format can be read by some graphics programs. This would save a lot of the steps below but means you may not have direct control of the data reduction which may not be needed after the major recalibration in the summer of 2014. Check your graphics programs, such as GIMP, to see if you can read any of these files:

Shape extensions: .shp .shx .prj .dbf .shp.xml .z.shp .zi.shx z.dbf .z.shp

These files too can be big. Nothing more on this approach will be covered in this paper but if you can make any of them work for you, it would be a big help.



Example of Binned Image near pole

Binned Image [*Generate Image*] -- This creates an image with all the satellite passes covered. This image is not very helpful, but may be worth downloading. It gives you an idea of the number of data passes that are available and how well they cover the area. Again determining if your graphic program can read the files would be a big help: **Binned Image extensions:** .txt .cg.sci .png. cg_pnp.pop

You may choose the file entitled: *RDR (Long number)cg_png.png* for download. There are graphics programs that can turn this type of file into a landscape, but nothing more on this approach will be covered in this paper.

4. Reading Narrow Angle Camera images – The LRO NAC images are also available online with a resolution of about 1 meter per pixel. We need to download these images and edit them to exactly fit our altimeter data blocks.
5. USGS free programs – NASA provides a number of other programs to make space data accessible. We need to explore this. For example: [USGS / ISIS](#) .

16. Conclusion

This may be only a start, but it is a start. There are certainly better, less laborious, ways to get the LRO data available for use. Simpler processes are certainly possible.

We can now take real scientific data about the Moon and use it as the foundation for our Virtual Moon in [The Big Moon Dig](#).

We can do this.

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