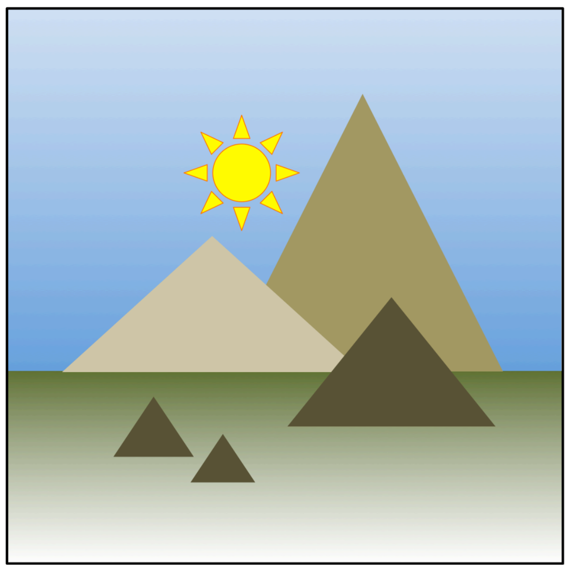
# Desktop Exploration of Remote Terrain



## User Guide for Version 1.0 Beta

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# Introduction

Desktop Exploration of Remote Terrain (DERT) is a scientific simulation application for exploring large Digital Terrain Models (DTM) of our world and other planets of the solar system in 3D. It aids in understanding topography and spatial relationships of terrain features, as well as performing simple analysis tasks relevant to the planetary science community. DERT employs an interactive virtual world for 3D visualization and navigation, and provides features for simulating lighting and shadows, display of multiple surface layers, color maps, landmarks, measurement, and terrain profiling. DERT can be found at https://github.com/nasa/dert.

DTMs are constructed from imagery acquired by satellites and other remote sensing platforms. They can be found on websites such as the NASA Planetary Data System, the USGS Earth Explorer, and the HiRISE site at the University of Arizona, among others. A DTM consists of layers of co-registered imagery that are spatially referenced to a body, usually including a Digital Elevation Model (DEM) and one or more orthoimages. These layers are typically very large raster files, and in order to facilitate rendering performance, they are preprocessed into a multi-resolution data structure. DERT ingests the structure (we will call it a *landscape*) and creates a virtual world, adding lighting and other elements.

A landscape is a directory holding the set of raster layers, each layer stored as a subdirectory that contains a multi-resolution tiled image pyramid. Using the pyramid tiles, DERT creates a 3D mesh from an elevation layer (a DEM) and drapes orthoimage layers on the mesh. As the user moves the viewpoint, DERT renders close terrain with higher resolution tiles and far terrain with lower resolution tiles. See the section on *LayerFactory* to learn more about layers and how to build a landscape.

With DERT, a desktop explorer can:

- View a remote landscape in 3D.
- Place landmarks at interesting locations.
- Measure the distance between landmarks.
- Simulate the sunlight and shadows on the terrain.
- View elevation color maps blended with orthoimage layers.
- Place a camera with a synthetic view of the terrain in the landscape.
- View an elevation profile.

## System Requirements

The primary platform for DERT is Apple Mac OS X 10.11.6 or later, but it has also seen limited testing on Linux Red Hat 6. It requires a 64-bit architecture, Java 1.7 or later, and OpenGL 2 or later. You should have at least 200 MB of disk space available and at least 2 GB of RAM.

DERT uses the left, middle, and right mouse buttons and the mouse scroll wheel. A 3-button mouse is recommended. The Mac track pad can be configured to use all but the middle mouse button in Apple System Preferences and works with a little practice. See *Appendix A* for instructions.

Landscapes may be very large, especially if they are color and/or have several layers. DERT manages memory usage with the multi-resolution tiled pyramid but sometimes more memory is necessary. You may see an “out of memory” error in the log. See README.txt in the DERT installation directory for instructions on how to increase the available memory.

Installing the Geospatial Data Abstraction Library (GDAL) is recommended for LayerFactory. It can be downloaded from www.gdal.org.

## Disclaimer

DERT is research software and may contain bugs. The techniques implemented in this application have not been systematically tested or rigorously compared to other methods. Use it at your own risk.

## Getting Started

For the examples in this user guide, we will use a relatively small landscape called Victoria Crater. Download the application and Victoria Crater zip files and unzip both. See the README file in the installation directory for installation and execution instructions.

A number of preferences are kept in a properties file (called *dert.properties*). See the README file to find the location of this file and how to edit it.

At startup, the main DERT window will appear on your screen. DERT's stash directory (called *dertstash*) will be created in your home directory the first time DERT is invoked. This directory contains session information and the log file. You may set the location of the stash directory in the properties file. If you used a previous version of DERT and have some problems with this one, try removing the dertstash directory.

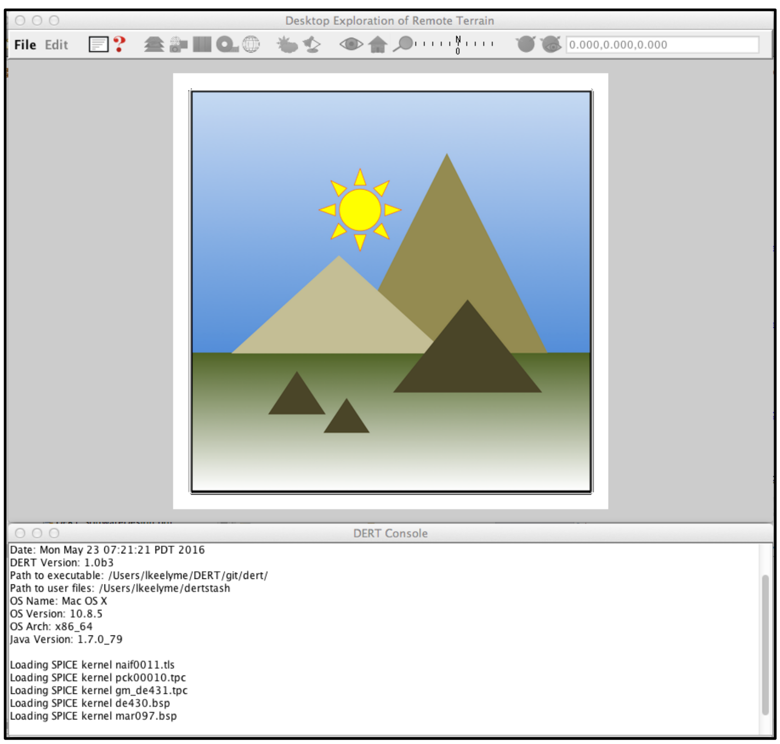



**Figure 1: DERT main window and console.**

The console is shown here positioned below the main window. Messages from DERT are displayed here during your session. This information is also logged to *dert.log* in the stash directory.

## View a Virtual World

At the top of the DERT main window you will see 2 menus: *File* and *Edit*. The Edit menu provides general application functions. The File menu handles file operations. We will use it in the following example to load the Victoria Crater landscape. DERT maintains a *configuration* for your current session. A configuration contains the viewpoint, which layers are displayed, and other attributes.

### Example 1: View a Landscape

1. Select *File>Open Landscape* and a file dialog will appear.
2. Browse to and select *VictoriaCrater* in the dialog. Landscapes are indicated with the icon .
3. Press *New Configuration*. The dialog will disappear and a view of Victoria Crater will appear in the DERT main window. NOTE: Double-clicking on *VictoriaCrater* will also load it.

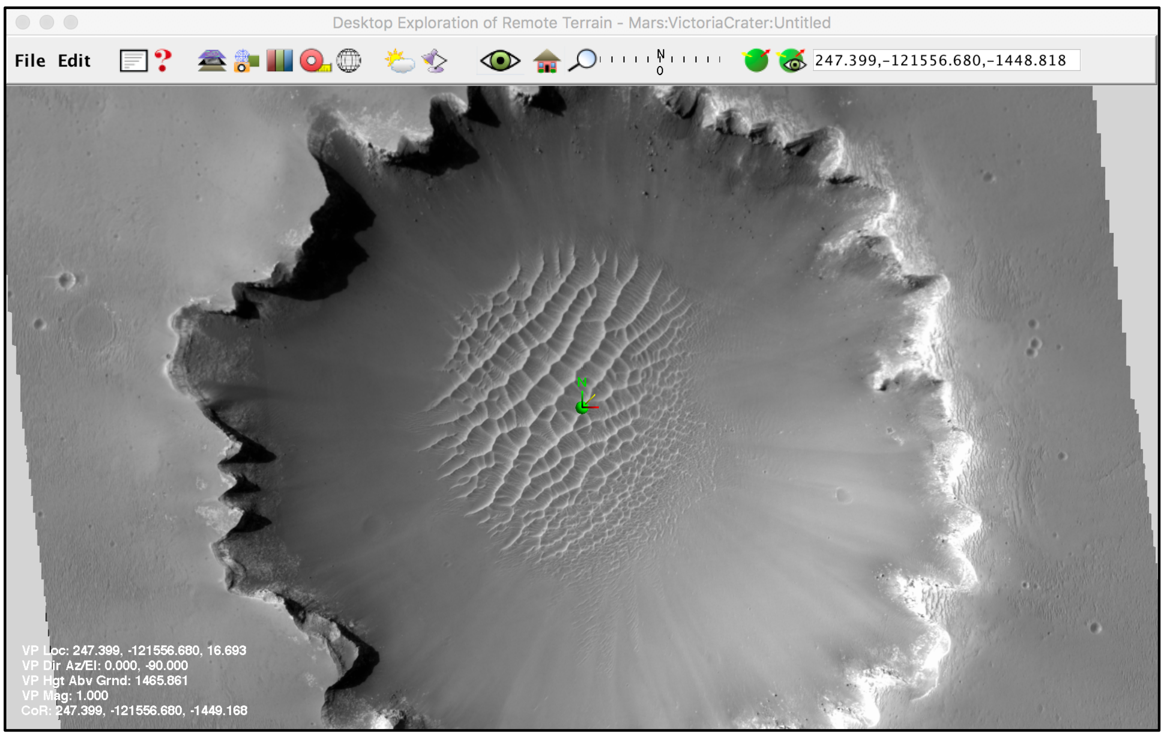



**Figure 2: The Victoria Crater landscape from the home viewpoint.**

The DERT main window displays a virtual world containing the Victoria Crater landscape in the *worldview*. The viewpoint starts out in the home position: overhead and looking down at the center of the landscape with North up and East to the right. A three-pronged crosshair, the center of rotation (CoR) crosshair, appears in the middle of the view. DERT rotates the world about the point under this crosshair. The prongs represent the 3 axes of the virtual world. The large green N indicates north (+Y), the red axis points east (+X), and the blue axis points up (+Z).

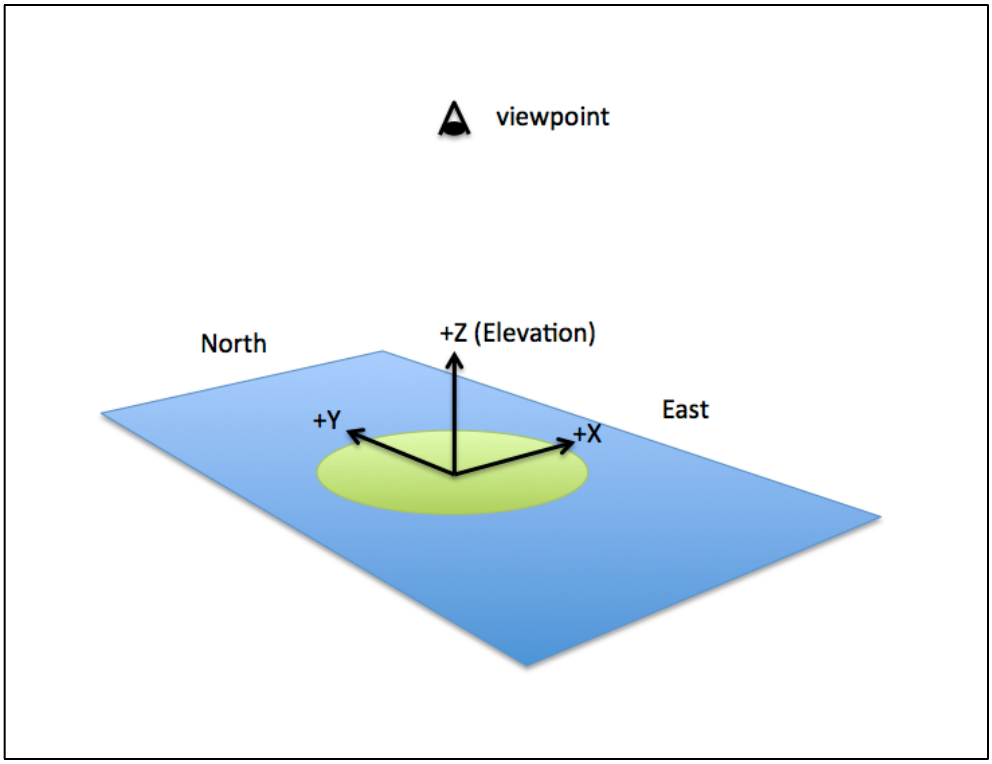



Figure 3: DERT coordinate system.

DERT uses the original projection from the raster files used to create the landscape. If the data are not projected (are in longitude/latitude), DERT applies either an equirectangular or polar stereo projection, depending on the maximum and minimum latitudes. Coordinates may be displayed in meters or longitude and latitude (degrees).

## Toolbar

Once a landscape is loaded, the menus and buttons in the toolbar along the top of the window will be fully enabled. Here is a quick synopsis of each control's function.

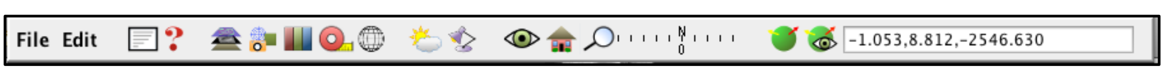



Figure 4: DERT toolbar.

- ***File***: A menu for handling file operations in DERT.
- ***Edit***: A menu for general application tasks including *Undo/Redo*.
-  ***Console***: Open the console view.
-  ***Help***: Open the help view.

- ***Surface and Layers***: Configure the landscape surface and layers.
- ***Map Elements***: Open a view for editing landscape map elements.
- ***Color Bars***: Open a view displaying the color maps currently in use.
- ***Tape***: Enable/disable the tape measure.
- ***Graticule***: Switch between display of unprojected (degrees lon/lat) and projected (meters) coordinates.
- ***Lighting***: Edit the light and shadow settings.
- / ***Light Position***: Indicates the current lighting mode (*Artificial* or *Solar*) and opens a window used for positioning the light.
- ***Viewpoint***: Change the viewpoint mode between *Model-centric*, *First-person*, and *Map,* or open the viewpoint list or animation control window.
- ***Reset***: Set the viewpoint to the home (overhead) position.
- ***Zoom***: When enabled, the mouse scroll wheel will change the magnification level instead of the distance from the viewpoint to the CoR.
- ***Compass:*** shows the current bearing of the viewpoint in degrees (0-360) from North.
- ***Marble View***: View landscape properties at the current marble location.
- ***Seek Marble***: Move the viewpoint close to the marble.
- 246.893,-121556.174,-1448.818 ***Marble Field:*** shows the current position of the marble. To change the marble location, enter a new position and hit return. If you omit the elevation it will be determined from the landscape.

Hover the cursor over a control to view a reminder of its function.

## Current Viewpoint

Now that you have a virtual world, you may traverse it by changing the viewpoint. Navigating in a 3D application can take some practice. If you get lost, press *Reset* in the toolbar and the viewpoint will move to the overhead position.

DERT uses several mouse movements to control the viewpoint location. Press the left mouse button down and drag the cursor to translate the viewpoint along the plane of the landscape. Given enough momentum, the viewpoint will continue to move after you release the mouse, and then slow to a stop. Press any mouse button down to stop the motion. Drag the cursor with the right mouse button down to rotate the viewpoint about the CoR. Drag the cursor with the middle button down to translate the viewpoint along the plane of the screen. Roll the mouse scroll wheel to dolly (change distance) the viewpoint away from or towards the CoR. The mouse scroll direction may be set in the properties file. Press *Zoom* in the tool bar to switch the scroll wheel from dolly to zoom (change magnification). In summary:

- To ***translate along the plane of the landscape***, drag with the *left* mouse button pressed.
- To ***translate along the plane of the screen***, drag with the *middle* mouse button pressed.
- To ***rotate***, drag with the *right* mouse button pressed.
- To ***dolly or zoom***, roll the *scroll wheel.*

For small single steps of rotation, press the arrow keys. Each step rotates 0.25 degree. Hold down the shift key while pressing an arrow key to translate the viewpoint instead. NOTE: Be sure the main window is the active window when using the arrow keys for navigation.

### Example 2: Create an Oblique View

1. Press *Reset* to place the viewpoint at the default position.
2. Place the cursor inside the bottom left corner of the screen over the terrain.
3. Press the right mouse button down. Drag the mouse up and right to rotate the scene to an oblique view and then release it. The *Compass* should change to indicate the current bearing.
4. Roll the mouse scroll wheel to move the viewpoint closer to the landscape.
5. Press the left mouse button down, drag, and then release to move the viewpoint along the plane of the landscape.

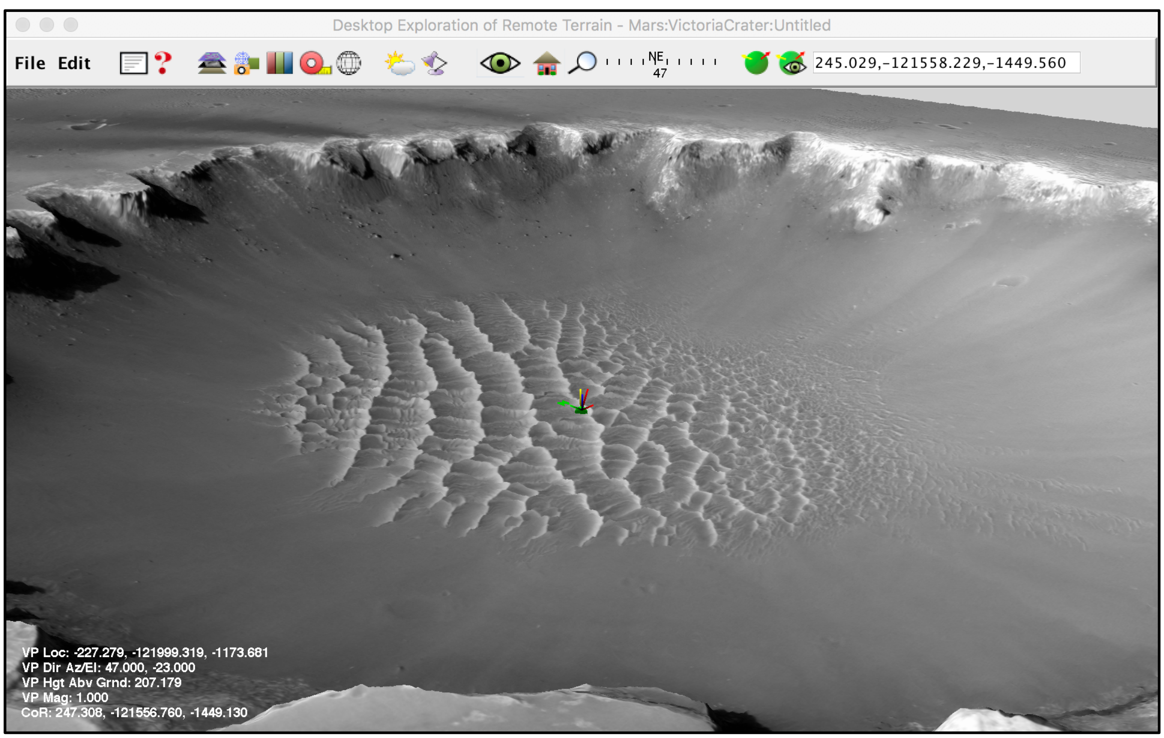



**Figure 5: Oblique view of Victoria Crater landscape.**

Note that the CoR crosshair always remains at the center of rotation. To hide/show the crosshair, select *Edit>Show Crosshair at Center of Rotation*.

Viewpoint information is displayed in a text overlay located in the bottom left corner of the worldview. This overlay shows the viewpoint location, direction, and the height above the ground.  It also displays the viewpoint magnification, and the location of the CoR. To hide/show the overlay, select *Edit>Show Text Overlay*. The current bearing (azimuth) is indicated in the compass in the tool bar.

### Example 3: Set the Center of Rotation

1. Single-click the right mouse button at the desired location and select *Set Center of Rotation* from the context menu. The center of rotation will move to the new location.
2. Place the cursor at a different location and single-click with the center mouse button.  The center of rotation will move to the new location.

The default scroll mode in DERT is *dolly* mode. In this mode, the scroll wheel moves the viewpoint in and out from the center. You may also use *zoom* mode to magnify the scene. Activate this mode by pressing *Zoom* in the toolbar. In this mode, scroll wheel movement will change the camera frustum for a true zoom instead of changing the location of the viewpoint. NOTE: The current magnification value is still applied to the scene when you exit zoom mode.

While in dolly mode the viewpoint passes through objects in the scene and may run into clipping planes. This does not occur in zoom mode but there may be some distortion at extreme magnification levels. Resetting the viewpoint will restore magnification to 1. NOTE: Zoom does not cause unneeded landscape tiles to be culled so exclusive use of this feature could cause memory to fill up, reducing performance considerably.

### Example 4: Using Zoom Mode

1. Press *Zoom* to change the mode. A check mark will appear in the icon to indicate the mode is enabled.
2. Roll the scroll wheel to change magnification level. The scene will change.
3. Press *Reset* to set the magnification level back to 1.0 and press *Zoom* again (the checkmark disappears) to disable zoom mode.

## Configurations

A configuration retains the state of the current DERT session including the viewpoint and the location and size of the worldview and other windows. Once a landscape is open, you may save or create a new configuration from the File menu. You may also delete configurations from the File menu as well as open recent ones.

You will be asked if you would like to save the current configuration when you exit DERT. You may abort your exit by pressing *Cancel*.

## Example 5: Saving and Restoring a Configuration

1. Select *File*>*Exit* to quit DERT and the configuration prompt will appear.
2. Press *Yes* and a name prompt will appear.
3. Enter a name and press *OK*.
4. Start DERT.
5. Select *File*>*Open Landscape…* and the file dialog will appear. Navigate to and select the Victoria Crater pyramid. You will see your configuration appear in the list at the bottom of the dialog.
6. Select your configuration and press *Open*. DERT will open the landscape with the same viewpoint and window layout.
7. Exit DERT. Select *No* when prompted to save the configuration.
8. Start DERT.
9. Select *File*>*Open Recent Configuration*>*VictoriaCrater*:*your config name* and DERT will open the landscape with the same viewpoint and window layout.
10. Exit DERT. Select *No* when prompted to save the configuration.
11. Start DERT.
12. Select *File*>*Delete Configuration*. A file dialog will appear.
13. Navigate to and select the Victoria Crater pyramid and your configuration will appear in the list at the bottom.
14. Select your configuration and press *OK*.
15. Press *OK* in the confirmation dialog. The configuration is deleted.

NOTE: Closing the DERT main window with the window close button will produce the same behavior as selecting *File>Exit*. However, using the Apple application menu *Quit* item will not. It simply closes DERT without prompting to save the current session. Your current session will be lost.

## Worldview

In addition to the text overlay and the compass, the worldview offers several other features. These include a last selection position indicator, measuring tools, view options, stereo rendering, and simple animation.

### The Green Marble

A green marble indicates the location of the last point selected on the terrain. Two arrows emerge from the marble. The yellow one points to the main light. The red one represents the direction of the surface normal at the marble location. The marble view provides information about the terrain at the location including:

- Projected coordinates (meters) and unprojected coordinates (Lon/Lat degrees).
- The surface normal vector.
- The direction vector, incidence angle and sub-solar azimuth for the main light source.
- The elevation (meters).
- The slope (the angle of the surface normal with the horizontal plane).
- The aspect (the azimuth of the surface normal).

Hide or show the green marble by selecting *Edit>Show Marble*.

#### Example 6: The Green Marble

1. Press *Marble View* in the toolbar. The marble view will appear.
2. With the left mouse button, single-click at an interesting point in the landscape. The green marble will appear at the picked point and the contents of the marble view will change. Additionally, the *Marble Field* in the toolbar will display the coordinates of the selected location.
3. Copy the contents of the *Marble Field*.
4. Single-click in the scene to move the marble.
5. Paste the saved contents into the *Marble Field* and press return. The marble moves back to the original position.
6. Press *Seek Marble* in the toolbar. The viewpoint moves to a close-up view of the marble.

### Tape Measure

The tape measure is a rubber band tool for measuring distances and slopes. Press *Tape* in the toolbar to enable it (a check mark will appear to show the tape measure is active). In addition to distance, it reports slope (degrees from horizontal), azimuth (degrees from north), and elevation change.

### Example 7: Using the Tape Measure

1. Press *Tape* in the toolbar. The cursor will change to a crosshair and the tape measure view will appear.
2. Single-click with the left mouse button on one side of the crater. A blue ball will appear at the point and a red rubber band with a second white ball will be attached to the cursor. The coordinates at the cursor and the distance, slope, and azimuth of the line are updated in the window as the cursor moves.
3. Single-click again with the left mouse button on the other side of the crater. The rubber band detaches from the cursor and the window stops updating.
4. Single-click with the left mouse. The anchor moves to the new point and the rubber band is attached to the cursor as before.
5. Rotate the scene with the right mouse button. The rubber band remains attached while the scene rotates.
6. Single-click again with the left mouse to detach the rubber band.
7. Press *Tape* or close the tape measure view. The tape measure and view disappear.

Sometimes rocks or ground will obscure parts of the tape measure and it can be helpful to see the full tape measure no matter where it is lying in the terrain. Select *Edit>Show Hidden Lines As Dashes* to view the obscured line segments as dashes. This is one of the advantages of exploring terrain using a simulation on your desktop!

## Viewpoint Modes

DERT provides 3 viewpoint manipulation modes: *Model-centric*, *First-person*, and *Map*. The model-centric mode has been described above. First-person mode places the viewer just above the surface of the terrain and moves the viewpoint as if on foot. The center of rotation changes to the viewer's position and the position follows the terrain surface as it is moved. In map mode, DERT renders the landscape in an overhead view. Rotation is turned off and all map elements are brought to the front. Press *Viewpoint* in the toolbar to select a mode.

## Center Scale Overlay

DERT provides an optional scale bar overlay in the center of the worldview to help you get a sense of the size of the features at the CoR. Select *Edit>Show Center Scale Overlay* to use this option. The number located above the scale line indicates the its length in terrain units (meters). The line is 100 pixels long. The number below the line is the distance from the viewpoint to the CoR. The scale numbers disappear when they are not being updated.

## Background Color

The background color of the virtual world can be changed to one of 3 predefined colors for Earth, Moon, or Mars or to a custom color. Colors are entered via a color chooser. The predefined and default backgrounds are specified in the properties file.

### Example 8: Changing Background Color

1. Select *Edit>Change Background Color*. The Background Color dialog will appear showing the current background color at the left.
2. Select *MarsSky* from the Predefined menu and then press *OK*. The worldview background color changes.
3. Select *Edit>Change Background Color*.
4. Press the *Color* button. A color chooser appears.
5. Select a color and press *OK*. Then *OK* in the background color dialog. The background changes again.

## World View Canvas Dimensions

You may set the width and height of the worldview canvas (the view excluding the toolbar). Select *Edit>Set World View Canvas Dimensions*. Enter width and height values separated by a comma and press OK.

## Stereo Viewing

For landscapes with gray surfaces, view the virtual world in anaglyph stereo. Red/cyan glasses are required. You may adjust the focal distance and eye separation (units are meters) for comfort.

### Example 9: Stereo Viewing

1. Select *Edit>Stereo* to change the viewing mode to anaglyph stereo. A dialog will appear.
2. Select *Enable Stereo* and press *OK*. The view will change to anaglyph.
3. Select *Edit>Stereo* again and adjust the focal distance and eye separation.
4. Press *OK*. The color separation should change.
5. Open the dialog again, unselect *Stereo* and press *OK* to switch back to normal rendering.

## Viewpoint List

Open the viewpoint list view by selecting *Viewpoint>Open Viewpoint List*. At the left, this view provides a list of saved viewpoints. At the right, it displays the viewpoint location, the direction vector of the camera, the azimuth and elevation (pan, tilt) of the direction, and the magnification scale factor. These fields may be edited.

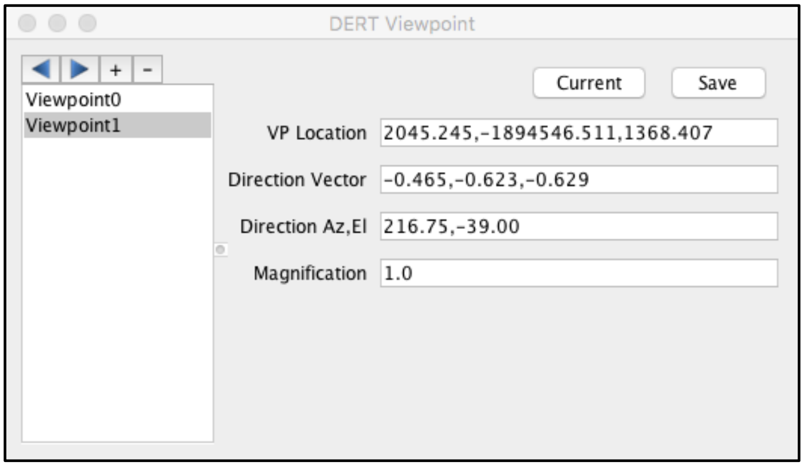



**Figure 6: Viewpoint list view.**

Add and remove viewpoints with the "+" and "-" buttons. Display viewpoint attributes by selecting one in the list. Double-click in the list or use the arrow buttons at the top to change the worldview directly to a different viewpoint.

### Example 10: The Viewpoint List

1. In the viewpoint list view, press "+" to add the current viewpoint to the list.
2. Enter a viewpoint name and press *OK*. Your name will appear in the list.
3. Move the viewpoint with the mouse.
4. Repeat steps 1-3 several times to add multiple viewpoints to the list.
5. Double-click an entry in the list to change directly to the viewpoint.
6. Select one of the names in the list and then press "-" to remove the viewpoint. You will be prompted for confirmation.
7. Press the right and left arrows at the top of the list to step through the viewpoints.

To edit a viewpoint first select it and then make changes to the viewpoint fields. You may press the *Current* button to load the fields with the current viewpoint properties. Press *Save* to save the changes to the currently selected viewpoint.

## Viewpoint Animation

DERT can make a simple animation from the viewpoint list or a Path. In the animation, the camera moves to each point, interpolating frames between. Given the number of total frames and the time between each frame, each point provides a key frame for the animation. Optionally, you may ask DERT to loop through the animation repeatedly.

### Example 11: Create an Animation

1. Press *Viewpoint>Open Animation Control Panel* and a dialog will appear.
2. Select *Subject>Viewpoint List*.
3. Press *Play* and DERT will play through the list creating 100 frames with 33 milliseconds between each (approximately 30 frames/sec).
4. Enable *Loop* and press *Play* again and the animation will continuously loop.
5. Press *Pause* and the animation will pause. Press *Play* and the animation will continue.
6. Press *Stop* to exit the loop.
7. Change the *Milliseconds Per Frame* field and press *Play*. The animation will proceed at a different rate than before.

You may create an image sequence where each frame is saved to a Portable Network Graphics (PNG) format file. Select *Image Sequence create*, create a directory to contain the images and enter its path in the *Image Directory* field. The files are written during play, ignoring the milliseconds field. NOTE: Use the keyboard arrow buttons to rotate the world without moving the CoR. Keeping the CoR the same between each key frame makes a smoother animation if you are circling an object.

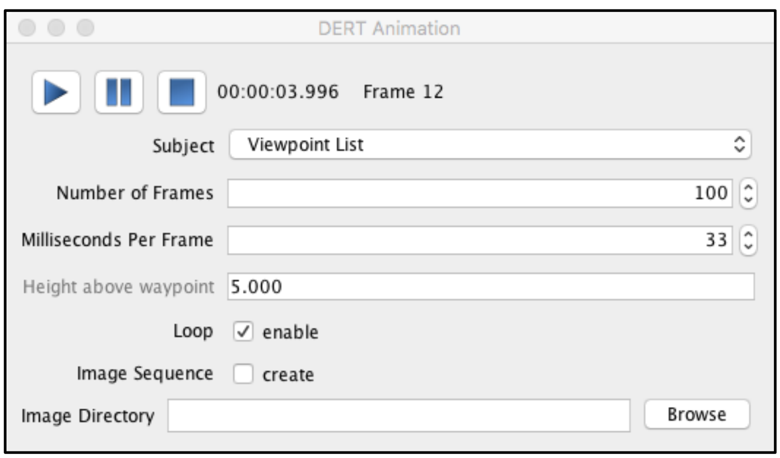



**Figure 7: Animation Panel.**

## Surface and Layers

The landscape consists of an elevation layer and one or more image raster layers. The elevation layer is a special raster layer and is visualized as a surface mesh whereas the other layers are draped on that mesh. There are a number of layer configuration options that are accessed through the surface and layers view. To open this view, press *Surface and Layers* in the toolbar.

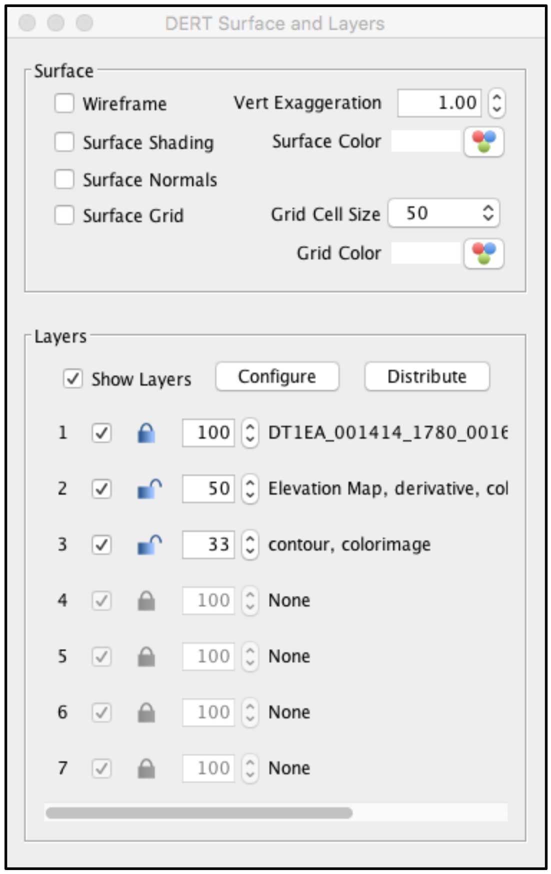



Figure 8: Surface and layers view.

### Surface

The landscape surface is rendered from the 3D mesh that was created from the DTM elevation layer. It is typically rendered in solid form but can also be displayed as a wireframe. Normally, the raster layers draped on the mesh provide all of the coloring and shading for the landscape.  However, if there are no raster layers, the surface can provide the shading as well as the color.

The Z coordinate of each vertex in the mesh represents the value of one pixel in the elevation layer. Exaggerated Z-axis scaling of the surface mesh enhances the visibility of terrain relief. The surface normal vector for each cell of the mesh may be displayed as an arrow.

Additionally, DERT provides a grid that covers the entire surface. It is draped like an image raster layer resulting in grid lines that follow the terrain. The cell size and color of this grid may be changed. The units of the grid are the same as the DEM.

### Example 12: Surface Options

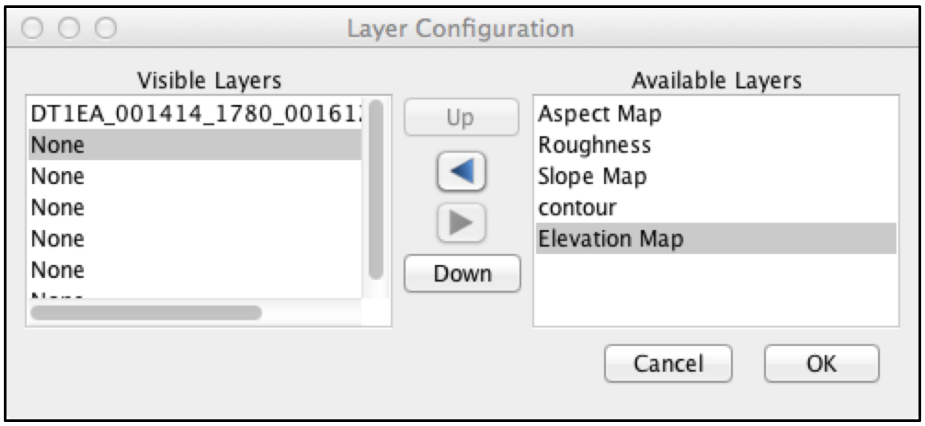
1. Press *Surface and Layers*. The surface and layers view appears.
2. Select the *Wireframe* checkbox. The landscape is drawn in wireframe.
3. Unselect the checkbox. The landscape returns to solid.
4. Select the *Surface Normals* checkbox. The surface normal vector for each mesh cell is displayed as a red arrow.
5. Unselect the checkbox. The surface normal arrows disappear.
6. Change the value in the *Vertical Exaggeration* field. The landscape stretches vertically.
7. Set the vertical exaggeration back to 1. The landscape returns to normal.
8. Select the *Surface Grid* checkbox. The grid appears.
9. Change the grid cell size. The grid changes.
10. Press the *Grid Color* button. A color chooser appears.
11. Select a color and press *OK*. The grid color changes.
12. Unselect the *Surface Grid* checkbox. The grid disappears.
13. Unselect the *Show Layers* checkbox in the Layers section. Only the surface is displayed.
14. Press the *Surface Color* button. A color chooser appears.
15. Set the color and press *OK*. The surface changes to the color.
16. Select the *Surface Shading* checkbox. The landscape will display shading from the surface. To see this better, press *Light Position* in the toolbar to open the light positioning view and adjust the elevation of the light (see the section on Light Positioning for more information).
17. Unselect the *Surface Shading* checkbox, reset the surface color to white and select the *Show Layers* checkbox.

## Layers

As seen in the above example, layers may be turned off so that only the surface is shown. The *Show Layers* button in the layers section is available for this purpose. Additionally, each layer may be hidden separately. Use the checkbox next to the layer number.

Image raster layers are draped on the surface of the 3D mesh. These layers include the orthoimage and field layers in the landscape directory as well as derivatives and camera viewsheds. Orthoimages are images that are co-referenced to the elevation grid. Fields layers are orthoimages that require a color map to be displayed. Derivatives are layers derived on the fly from the elevation layer and include color contour maps of elevation, a slope, and aspect. See the section on the Camera tool for a discussion of viewsheds.

You may have up to 7 layers displayed simultaneously. Layers are shown in the layer list and are configured with the Layer Configuration dialog.



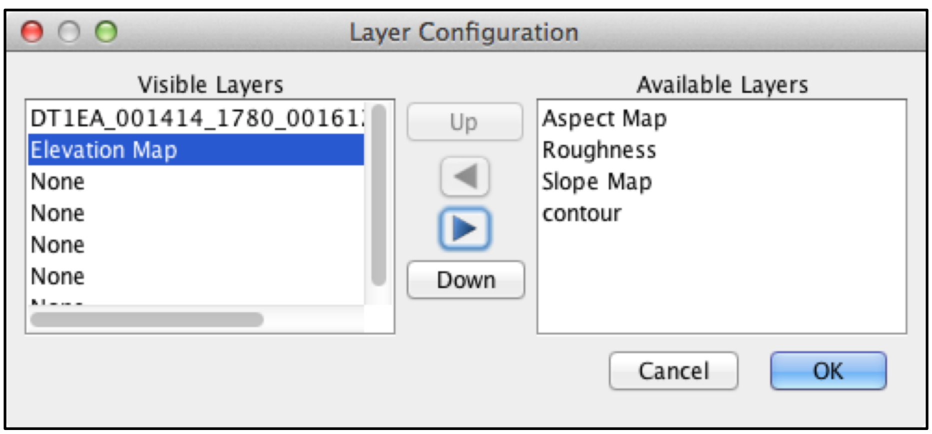




**Figure 9: Layer Configuration dialog showing default configuration with second layer and elevation map selected (top). After pressing the left arrow, the elevation map is configured for the second layer (bottom).**

The first layer must be an orthoimage or absent. The default is the first orthoimage layer in the landscape occurring alphabetically by name. The other layers may be an orthoimage, a field, a derivative, or a camera footprint/viewshed. Any layer may be absent (*None*). To change a layer, select it in the left column and then select the desired replacement in the right column. Press the *left arrow* to move the new layer to the configuration. Press *Up* and *Down* to change the order of the layers in the left column. To remove a layer, select the layer and then the *right arrow*.

The landscape layers are displayed in an additive manner. Layer 0 is added first and layer 6 is added last. The opacity of the layer is the field to the left of the layer name in the surface and layers view. It indicates the percentage of the pixel color from the previous layers that the layer blocks with its own color. When the opacity of an unlocked layer is changed, the values of all other unlocked layers adjust automatically (with the exception of the first layer). Pressing the lock toggle next to the opacity value will remove that layer from the auto-adjustment group. Press *Distribute* to distribute the opacity across all unlocked layers. Reducing the first layer opacity allows the surface color through.

### Example 13.a: Layer Selection

1. Press the *Configure* button to open the layer configuration dialog.
2. Select the second layer in the left list.
3. Select *Elevation Map* in the right list and press the *left arrow*.
4. Select the third layer in the left list.
5. Select the *contour* in the right list and press the *left arrow*.
6. Press *OK*. You will see a color contour map of the elevation on the terrain and white contour lines. The contour lines file was created with GDAL for demonstration purposes and doesn't line up with the color map.
7. In the layers section, press the up or down arrows or type in a value to change the opacity of a layer. The other layers will adjust automatically.
8. Select the lock toggle on the second layer to lock it.
9. Increase the value of the opacity in the third layer. The other layer does not auto-adjust and the contour lines brighten.
10. Select the second layer lock toggle again to unlock it. Press the *Distribute* button to distribute the layers.
11. Unselect the checkbox next to the third layer. The contour lines disappear.
12. Reselect the checkbox to view the contour lines again.

## Color Maps

Derivative and field layers use color maps. Color map legends may be displayed by pressing *Color Bars* in the toolbar. Press the *Color Map* button above the color bar to edit the map settings.

The color maps are maintained as text files in the *colormap* subdirectory of the DERT installation directory. These files can be edited and new ones added and removed. They follow the GDAL color configuration file format which is similar to the one supported by the GRASS r.colors utility.

The color map text file contains a list of entries consisting of elevation value and corresponding colors. An entry contains either 5 or 2 fields separated by one of comma, space, tab, or colon. The first field is the elevation. The following fields describe the color either as red, green, blue, and alpha components (between 0 and 255) or as a color name. The supported list of color names includes: white, black, red, green, blue, yellow, magenta, cyan, aqua, grey/gray, brown, purple/violet, and indigo. If alpha is omitted, it assumed to be 255 (fully opaque). The elevation value is a floating-point value, or “nv” for no-data. The elevation can also be expressed as a percentage where 0% represents the minimum value of the raster and 100% the maximum value.

### Example 13.b: Color Map

1. Press *Color Bars* in the tool bar to show the elevation color map. The color bar view appears.
2. Press the *Color Map* button for the Elevation Map layer color bar. The color map settings dialog appears.
3. Select *Gradient*. The color map is shaded gradually between colors.
4. Lower the *Maximum* value in the color map settings dialog. The color contours change in the scene as the range narrows. Areas outside the color map range are rendered transparent.
5. Press *Default*. The contours return to the original setting.

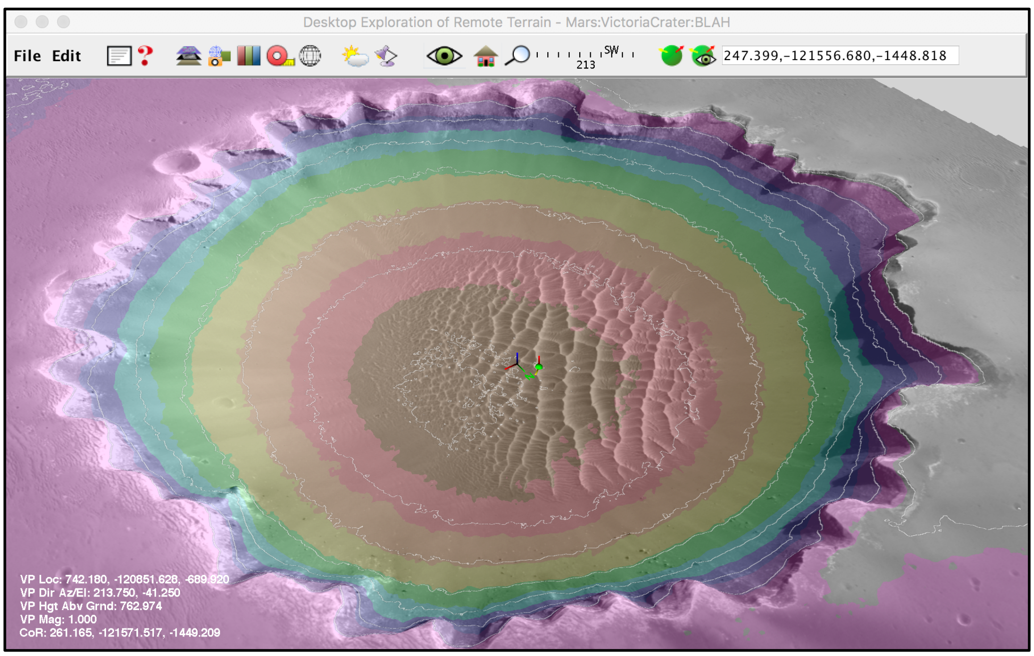



**Figure 10: Victoria Crater with orthoimage, elevation color map, and contour layers.**

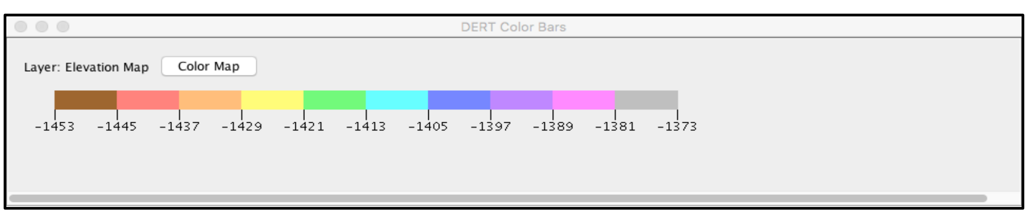



**Figure 11: Color Bars view.**

## Lighting and Shadows

### Lighting

Press *Lighting* in the toolbar to open the lighting view. DERT provides a single main light and an optional headlight. The headlight is attached to the viewpoint and always shines in the direction of the center of rotation. The main light has two modes: *Solar* and *Artificial*. In solar mode the position of the light is determined by the Sun's position at a given time. In artificial mode, the user positions the light by manipulating its azimuth (rotation about the Z axis) and elevation (rotation about the X axis). In both modes, the light source is represented as a disk in the virtual world.

You may change the diffuse (directed) and ambient (bounced and scattered) intensities of the main light. These values range from 0-1 where 1 is saturated. The global ambient intensity is the amount of ambient background lighting. This is most useful when the layers are not displayed or are entirely absent.

Additionally, this view allows you to configure the headlight. The headlight diffuse intensity is treated the same way as the main light. The headlight does not illuminate terrain that is shaded from orthoimages. Only the surface and 3D figures are affected.

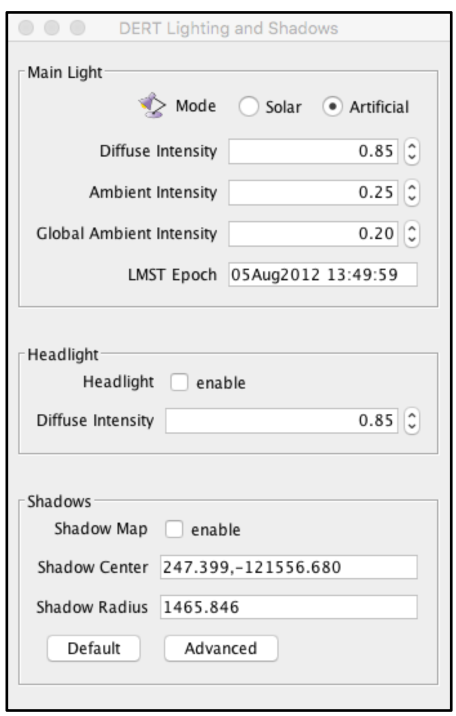



Figure 12: Lighting and Shadows view.

## Positioning the Light

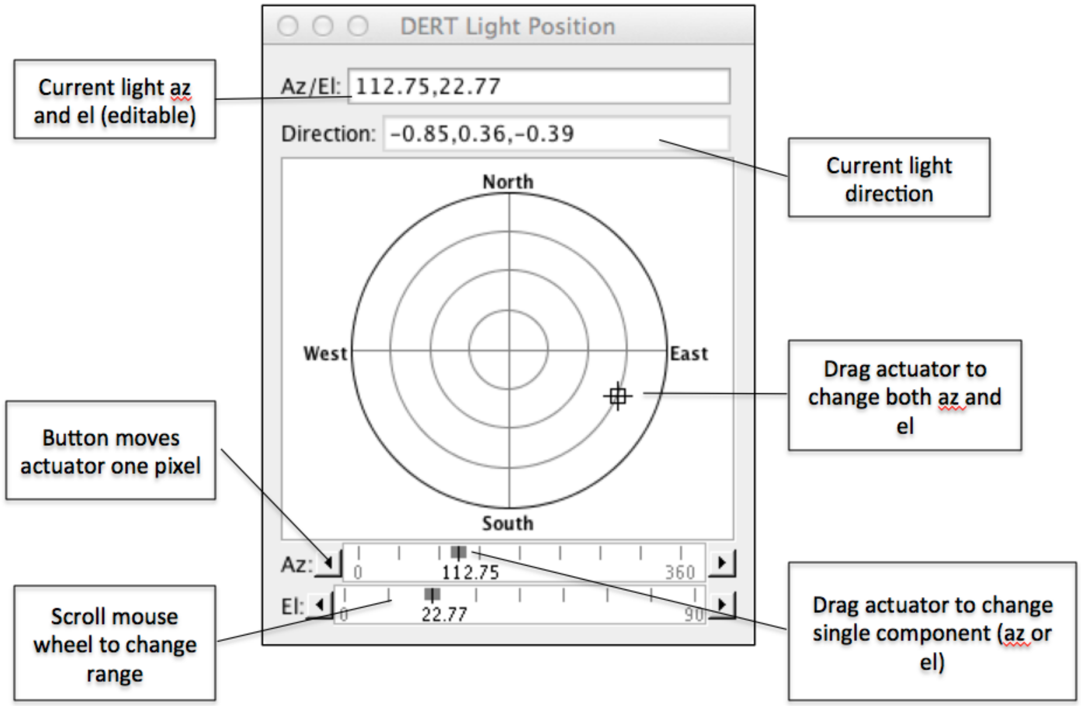



**Figure 13: Positioning the artificial light.**

### Example 14.a: Artificial Light Position

1. Press *Lighting* in the toolbar.
2. Set the lighting mode to artificial in the lighting and shadows view.
3. Single-click with the left mouse button on the landscape in an easily visible location. The green marble will move to the location where you clicked.
4. Press *Light Position* in the toolbar. The artificial light position panel will appear.
5. Drag the light position crosshair to the outer edge of the circles. The lighting will change on the marble and the yellow arrow will move.
6. Drag the puck in the *Az* and *El* fields. The crosshair will move and the *Az/El* and direction fields will change.
7. Type a new value into the *Az/El* field and hit return. The crosshair will move to the new position.
8. Change the *diffuse*, *ambient*, and *global* intensities of the main light in the lighting view.  You will see the affect on the marble.
9. Select *Enable* in the headlight section. The headlight will come on and light the marble.
10. Adjust the intensity of the headlight.
11. Disable the headlight.

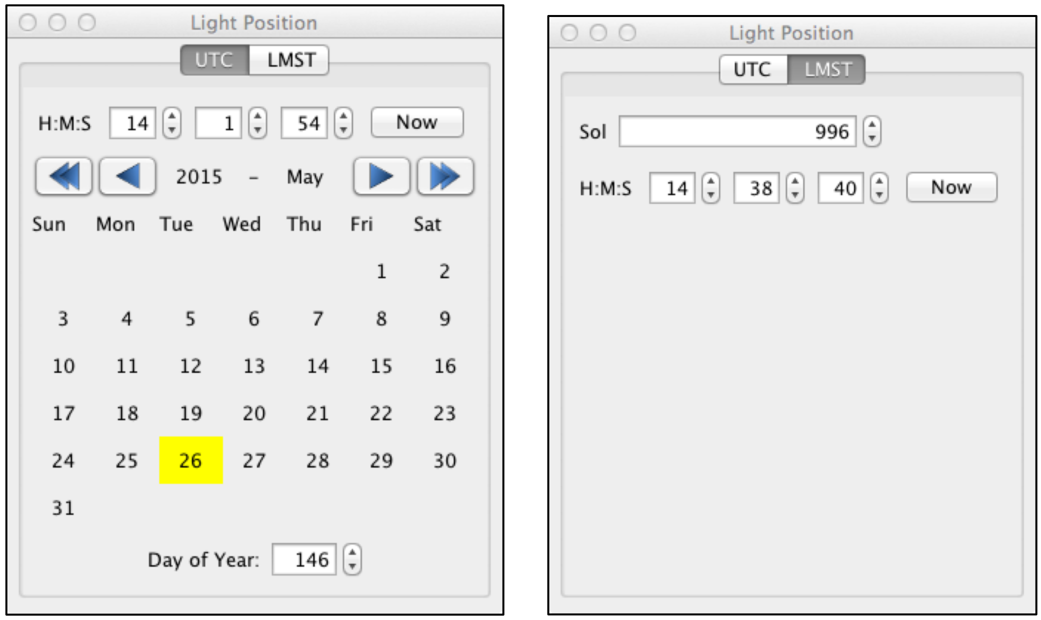



**Figure 14: Positioning the solar light. Left: UTC. Right: LMST.**

### Example 14.b: Solar Light Position - UTC

1. Set the lighting mode to *Solar* in the lighting and shadows view. The light position view will change.
2. Select *UTC* and a calendar will appear.
3. Press the single arrow buttons to change the month and the double arrow buttons to change the year.
4. Press *Now* to set the view to the current time and date.
5. Press the up and down buttons on the hour field and the yellow arrow on the marble will move as well as the disk representing the sun.

### Example 14.c: Solar Light Position - LMST

1. Enter the LMST epoch (the default is located in the properties file) in the lighting and shadows view.
2. Press the *LMST* tab in the light position view. The LMST panel will appear.
3. Press *Now* to set the view to the current time and date.
4. Press the up and down buttons on the hour and sol fields and the yellow arrow on the marble will move as well as the disk representing the sun.

## Shadows

DERT provides shadows with a software technique called *shadow mapping*. The shadow sphere is the volume where the shadow is applied. All objects within the sphere are subject to shadowing.  Anything outside the sphere will not contribute to shadows. A shadow map is an image, and reducing the radius of the shadow sphere will increase the resolution of the shadow map. The default sphere is the full landscape. The sphere center and radius may be edited in the lighting and shadows view. Be sure to hit return to enter the changes. NOTE: The sphere center point is used to calculate the light direction vector.

The advanced shadow options allow you to set some parameters for the shadow map. Normally, they are not needed but may be helpful in correcting shadow artifacts.

### Example 15: Setting Shadows

1. Enable *Shadow Map* in the lighting and shadows view. Depending on the position of the light, shadows will appear in the scene.
2. Open the light position view.
3. Move the light close to the horizon. The shadows will move.
4. Set the shadow sphere radius to 100 and hit return.
5. Copy the location from the marble field to the shadow sphere center and hit return.
6. The shadow area shrinks to the smaller region around the marble and the shadow resolution increases.
7. Press *Default*. The default shadow sphere values appear.
8. Disable *Shadow Map*. The shadows disappear.

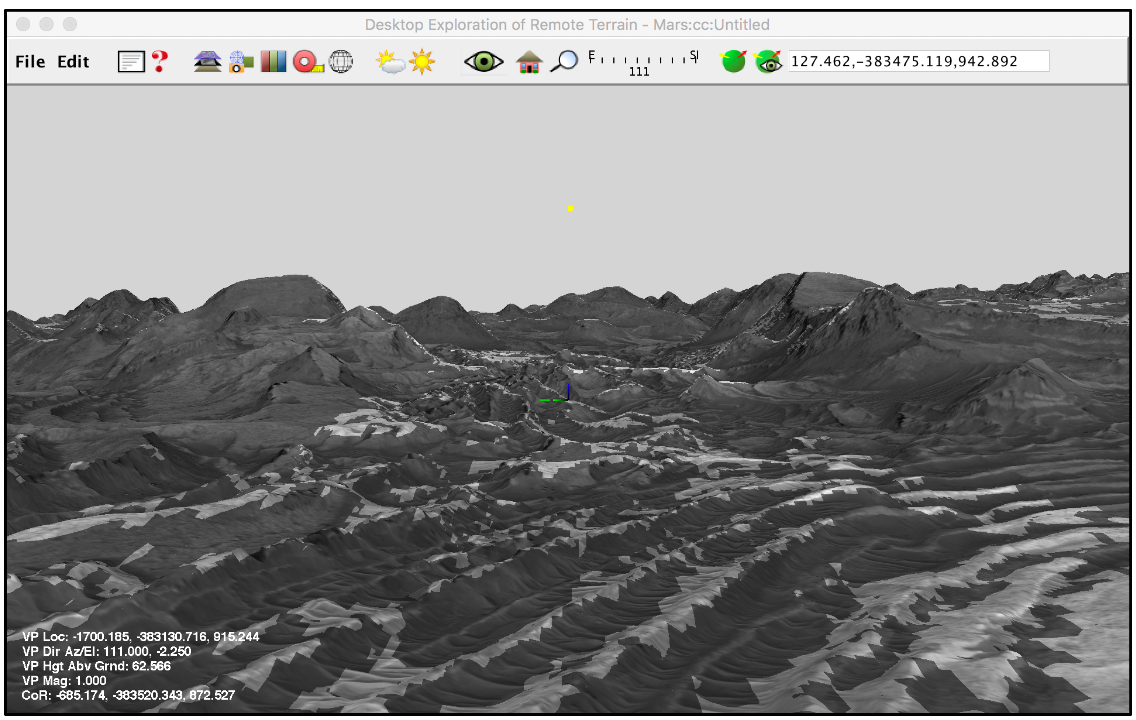



**Figure 15: Candor Chasma in shadow.**

This feature may not be entirely accurate for large projected landscapes from small bodies such as the Moon as the curvature of the body contributes to the location of the shadows. Modifying the shadow sphere can help in these cases.

You may see the following or similar message in the DERT log when using solar lighting mode:

CSPICE_N0065: CSPICE.spkpos: SPICE(SPKINSUFFDATA): [spkpos_c --> SPKPOS --> SPKEZP --> SPKSSB --> SPKGEO] Insufficient ephemeris data has been loaded to compute the state of ### (*body name*) relative to 0 (SOLAR SYSTEM BARYCENTER) at the ephemeris epoch *dateandtime*.

It is possible that you haven't loaded the required spk file for your body. See the NAIF website at http://naif.jpl.nasa.gov for instructions. The general rule is that you must add a kernel file for each body. See http://naif.jpl.nasa.gov/pub/naif/generic_kernels/spk/satellites/AAREADME_Satellite_SPKs for more information.

## Map Elements

*Map Elements* are objects placed in the landscape to aid in navigation, exploration and terrain analysis. All map elements use landscape elevation as the third (Z) component of their location. DERT provides 3 types of map elements, *Landmarks*, *Tools*, and *Feature Sets*:

- **Landmarks**: objects that mark a place in the landscape.
  - ***Placemark***: an icon representing a location. It has no depth and does not produce a shadow. It always faces forward and automatically scales so that it always appears to be the same size regardless of the distance from the viewpoint.
  - ***Figure***: a three-dimensional object representing a location. It has depth and will produce a shadow. Its size can be fixed or auto-scaled. Additionally, a figure's orientation may be adjusted.
  - ***Billboard***: a user specified image. It always faces forward and its size may be fixed or auto-scaled. The billboard image may be opened in the default image viewer for the user's platform.
- **Tools**: objects used to measure or otherwise analyze the landscape. Although tools are not auto-scaled, most of their actuators are.
  - ***Path***: a sequence of waypoints representing a path or region used for measuring distance, surface area, and volume.
  - ***Plane***: a plane defined by 3 points located on the terrain surface. This tool provides an elevation difference map as well as strike and dip.
  - ***Cartesian Grid***: a configurable rectangular grid.
  - ***Radial Grid***: a configurable grid of concentric circles.
  - ***Camera***: provides a separate view of the virtual world seen through a camera placed in the landscape. The field of view is articulated in azimuth and elevation (pan and tilt).
  - ***Profile***: provides an interactive transection line in the landscape with an associated graph of elevation along that line.
  - ***Scale***: provides a map scale bar that can be placed in the landscape.
- **Feature Sets**: objects created from GeoJSON vector files. NOTE: GDAL may be used convert ESRI shape files to GeoJSON.
  - ***Feature Set***: a GeoJSON LineStrip is displayed in the virtual world as a set of line segments using landscape elevation Z coordinates. GeoJSON Points are represented as small 3D figures.

Landmarks and tools are added to the scene via the context menu. They may be dragged along the terrain surface with the left mouse button. Hold the shift key down to change only the elevation. Use *Edit>Undo*, and *Edit>Redo* to undo/redo landmark and tool moves. NOTE: For Path, Plane, and Profile you may only drag actuators, not a line or polygon. Right-click on a map element to invoke its context menu. Here you may hide, edit, or delete the map element, or view its annotation.

### Example 16: Adding and Positioning a Map Element in the scene

1. Right-click with the mouse on the landscape and select *Add>Placemark* from the context menu. A yellow pushpin will appear at the point where you clicked.
2. Position the cursor over the pushpin and press the left mouse button down until you see the cursor change to a hand.
3. Continue pressing down and drag the pushpin. It will follow the terrain.
4. Release the mouse button to stop dragging. The pushpin remains at its position.
5. Select *Edit>Undo Move Placemark1*. The pushpin returns to its original position.
6. Select *Edit>Redo Move Placemark1*. The pushpin moves back to the last position.
7. Hold the shift key down and drag the pushpin again. The elevation of the pushpin changes. You may need to rotate the landscape to see the change.
8. Right-click on the pushpin to invoke its context menu.
9. Select *Ground Placemark1* from the menu. The pushpin returns to the surface.
10. Select *Show Notes for Placemark1* from the menu. A window for displaying notes appears.
11. Close the window.
12. Select *Lock Placemark1* from the menu then try to drag the pushpin. It doesn't move.
13. Select *Unlock Placemark1* from the menu and the pushpin can be moved again.
14. Select *Rename Placemark1* from the menu. Enter a new name for the pushpin in the dialog that appears and press *OK*. The label changes to the new name.
15. Select *Delete Placemark1* from the context menu. A confirmation prompt appears.
16. Press *OK*. The pushpin disappears.
17. Select *Edit>Undo Delete Placemark1*. The pushpin reappears.
18. Select *Hide Placemark1* from the context menu. The pushpin disappears.
19. Select *Edit>Undo Hide Placemark1*. The pushpin reappears.
20. Translate or rotate the view away from the pushpin. Right-click in the landscape and select *Place Here* from the context menu. A selection of map elements will appear. Select Placemark1 and press *OK*. The pushpin will move to the new location.

## Map Elements View

In addition to the context menu, map elements may be added to the landscape and edited via the map elements view. The map element will be added at the current marble location. Press *Map Elements* in the toolbar to open it. The view displays the current set of map elements in a list to the left, each under one of the categories of Landmarks, Tools, and Feature Sets. Add buttons for each element are listed at the bottom of the view. Once added, a new map element will appear in the list. Buttons on the right allow you to edit, open, delete, hide/show, lock/unlock, label/unlabel, seek, ground, and rename the element.  Changes will take place immediately. Select a category to apply a button to all elements that belong to it. Additionally, you may save a list of landmarks or set of path waypoints to a file in comma separated value format.

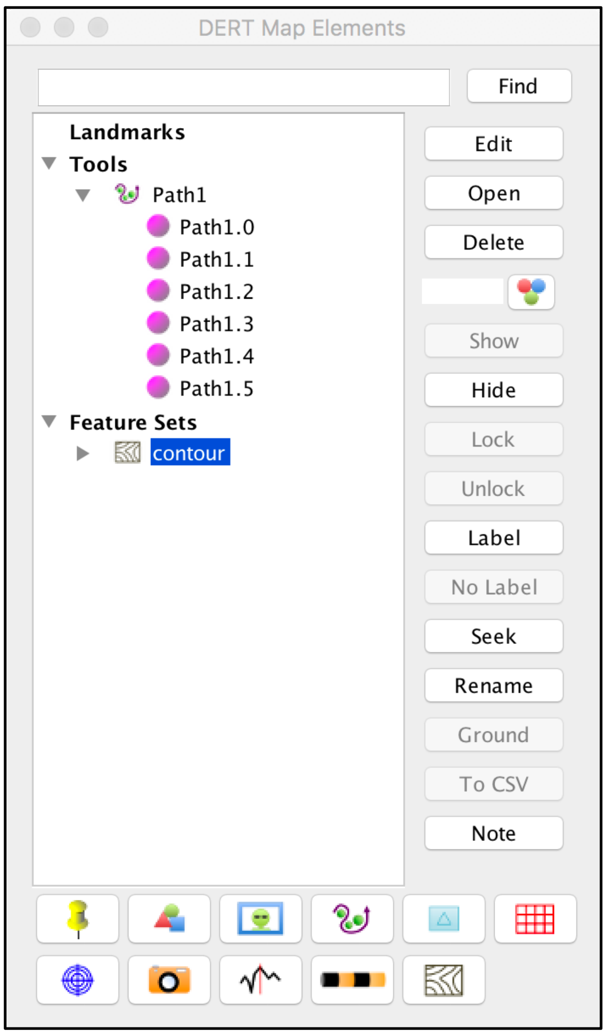



Figure 16: Map elements view.

To search for a specific map element by name, enter a string in the field at the top of the view and press *Find*. The first map element with a name containing the string will be highlighted.

### Example 17: Add and Edit a Map Element

1. Press the add button for 3D Figure and a red box will appear at the green marble location.
2. Press *No Label*. The box label will disappear.
3. Press *Label*. The label will reappear.
4. Press the *Color* button. A color chooser will appear.
5. Select a color and press *OK*. The color chooser will disappear and the box color will change.
6. Press *Lock*.
7. Try to drag the box. It doesn't move.
8. Press *Unlock*.
9. Try to drag the box again. It moves now.
10. Press *Edit*. The figure panel opens.
11. Change the *Location* field and press return. The box moves to the new location. If you enter only X and Y coordinates in the location field, the elevation will be provided for Z.
12. Select *Edit>Undo Move*. The box moves back to the original position.
13. Select *Edit>Redo Move*. The box moves to the new position.
14. Close the figure panel.

### Example 18: Hide/Show a Map Element

1. Select a map element from the list in the map elements view.
2. Press *Hide*. The map element will disappear.
3. Press *Show*. The map element will reappear.

### Example 19: Seek to a Map Element

1. Select a map element from the list.
2. Press *Seek*. The viewpoint will move to a close-up position for the map element.

### Example 20: Rename a Map Element

1. Select a map element from the list.
2. Press *Rename*. The name prompt will appear.
3. Enter a new name and press *OK*. The map element label will change.

### Example 21: Add annotation to a Map Element

1. Select a map element from the list.
2. Press *Note*. The note window will appear for the map element.
3. Enter notes and press *Save*.

## Additional Map Element Features

In addition to those previously described, each map element type offers additional features. These are accessed through its map element panel.

### Placemark

- Change the size of the placemark.
- Change the icon representing the placemark.

### 3D Figure

- Change the size of the figure and switch off/on auto-scaling.
- Change the orientation of the figure with the *Azimuth* and/or *Tilt* fields.
- Change the shape of the figure.
- Show the red surface normal arrow by selecting the *Show Surface Normal* checkbox.

### Scale Bar

- Change the orientation of the scale with the *Azimuth* and/or *Tilt* fields.
- Change the number of cells in the scale bar with the *Cell Count* field.
- The *AutoLabel* field indicates that the scale will automatically create the text for its label.
- Change the radius of the scale bar with the *Radius* field and the size of the cells with the *Cell Size* field.

### Grids

- Change the line width for a grid.
- In a Cartesian grid, change number of *Columns* and *Rows* with the respective fields in the panel. Columns or rows will be added to or subtracted from the grid.
- Change the size of Cartesian grid cells with the *Cell Size* field.
- Change the *Number of Rings* field in a radial grid. New rings will be added or subtracted.
- Adjust the gap between rings in the *Gap Between Rings* field.
- Display N, S, E, and W compass indicators in the radial grid by enabling *Compass Rose*.
- Normally, when the labels are enabled, a grid displays values relative to its origin. Enable *Absolute Coordinates* to display actual landscape coordinates.

## Billboard

- Press *Open* to display the image in the platform image viewer. You may also select *Open* from the context menu for the billboard.
- Change the size of the billboard.

## Path

The Path tool consists of a list of waypoints, each represented by sphere. The waypoints are listed under the path entry in the map element list. You may add a path through the context menu in the worldview or via the map elements view.

The path provides some simple statistics. These statistics are determined using samples from the highest resolution landscape tiles. Depending on the size of the path, statistics calculations can require a significant amount of time so they are not performed automatically when the path changes.

View the list of waypoints by clicking on the small triangle next to the path in the map elements list. Press *Edit* to change its location and elevation. Press *Add Points* in the edit dialog to add points directly after this waypoint. Use the *Path Complete* item in the context menu when you are finished to exit waypoint entry mode.

### Example 22: Create a Path

1. Open the map elements view and press the add button for Path. The cursor changes to a crosshair. A single waypoint will appear at the green marble.
2. Single-click in the worldview with the left mouse button at each desired additional waypoint position. Keep in mind you can move them later so they don't need to be perfectly placed.
3. Right-click and select *Path Complete* from the context menu to exit waypoint entry mode. The cursor returns to an arrow.
4. Press *Edit* in the map elements view.
5. Press *Add Points*. The cursor becomes a crosshair again.
6. Single-click a few more times. The new waypoints are added to the end of the path waypoint list.
7. Right-click and select *Path Complete*.
8. Select the second waypoint in the list.
9. Press *Add Points*. The cursor changes.
10. The waypoints added this time appear after the selected waypoint.
11. Right-click and select *Path Complete*.

Other Path features from the edit dialog include:

- Waypoint visibility.
- Visualization types of simple points, a connecting line, or polygon.
- Selectable label content including name, distance between points, cumulative distance, elevation, slope, or annotation.

- Press *To CSV* to save waypoint locations to a file formatted as comma-separated values.
- Press *Open* to view path statistics. You may select the *Volume* button to calculate volume of the terrain within the polygon defined by the path. There are two volumes reported:
    - Extending from the polygon surface or a given plane of elevation up to the top of the terrain
    - The empty space from the surface or plane to the top of the terrain below it.
- Press the *Refresh* button in the path view to recalculate after a waypoint is moved.

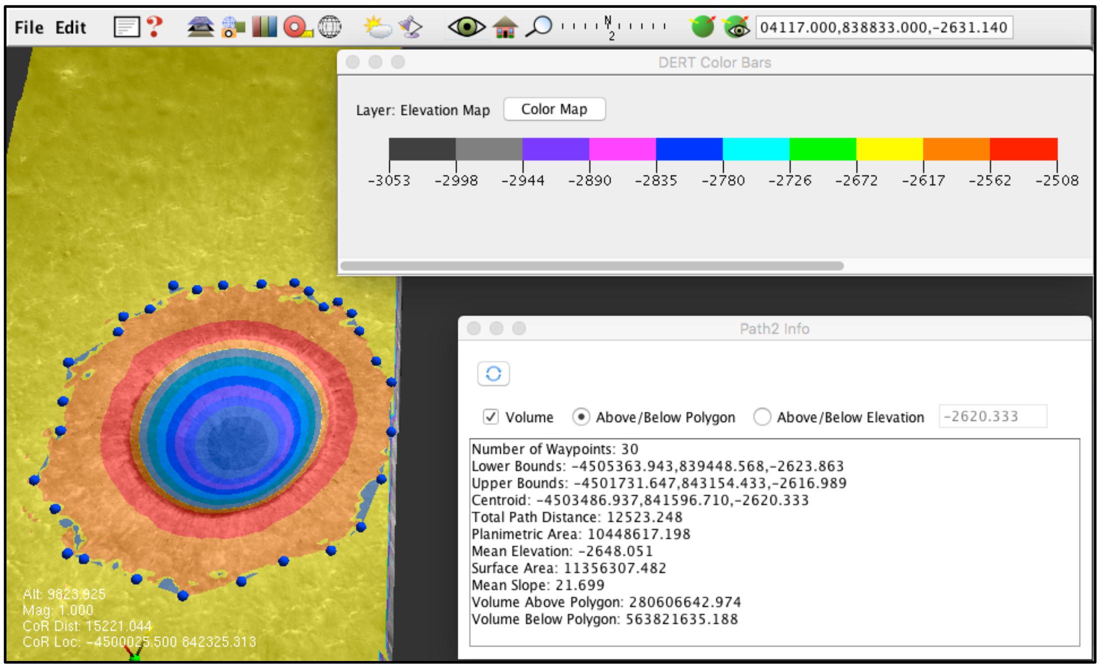



Figure 17: Path view with volume calculation for a lunar crater.

## Camera

A new Camera tool will open a view displaying the virtual world from its location. You may add a camera via the context menu or from the map elements view, the latter appearing at the green marble. You will see the inside of the marble in the new camera view. Single-click in the worldview to move the marble.

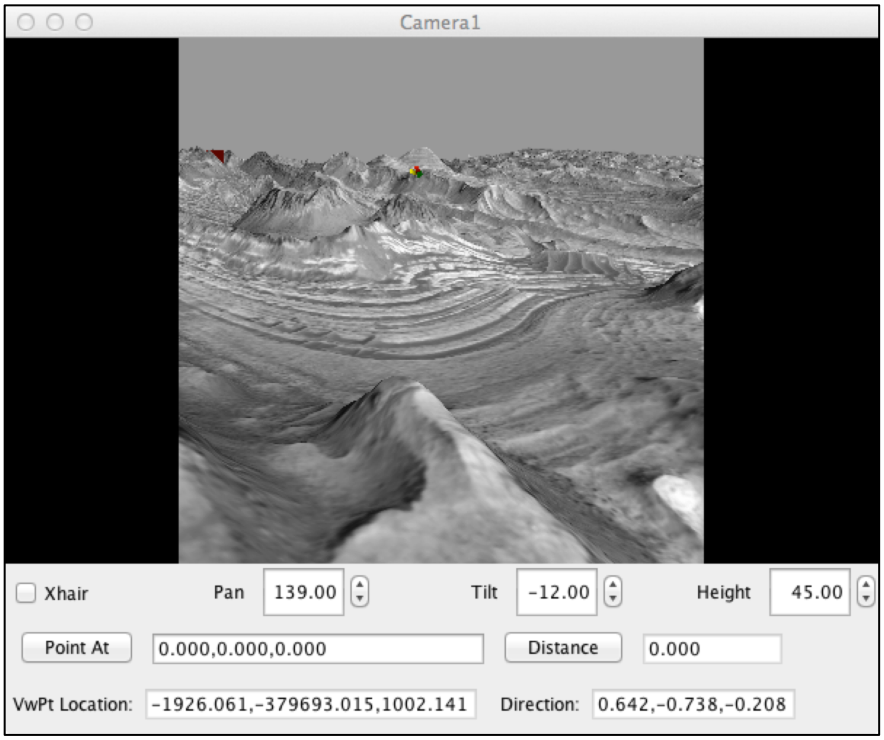



**Figure 18: View from a camera tool.**

The camera view control panel provides controls for changing camera pan or azimuth (North is zero), elevation or tilt (horizontal is zero), and height. Additionally, you may point the camera at a specific location or find the distance to the object at the center of the camera view.

### Example 23: Point a Camera

1. Create a new camera with the context menu or map elements view.
2. Copy the coordinates from the marble location field at the top of the worldview.
3. Paste the coordinates in the field next to *Point At* in the camera view.
4. Press *Point At*. The marble will appear in the camera view.
5. Select the camera in the map elements view and then press *Edit*.
6. Select *visible* for *Field of View* in the camera panel. The camera field of view will appear as a transparent frustum.
7. Select *visible* for *Line to Look At*. A line will be drawn to the point the camera is looking at.
8. Change the Pan, Tilt, and Height fields.

The location and direction of the camera viewpoint is available at the bottom of the view. The location is in the same coordinate system as the landscape. These two values may be used with other software. The positive Z-axis points up, the positive X-axis points to the right.

To see the camera footprint or viewshed on the landscape, configure it as a layer. Camera properties are defined in a file found in the *camera* subdirectory of the DERT installation directory.

### Example 24: Camera Footprint and Viewshed

1. Create a camera.
2. Open the surface and layers view.
3. Press *Configure*.
4. Move the camera footprint to the second layer.
5. Press *OK*. The footprint of the camera will be visible on the landscape.
6. Press *Configure* again.
7. Move the camera viewshed to the second layer.
8. Press *OK*.
9. The footprint will change to a viewshed.
10. Drag the camera. The viewshed will move and change with it.

## Profile

The Profile tool provides an interactive transection line in the landscape with an associated graph of elevation along that line. You may add a profile via the context menu or the map elements view. Additional options for the profile include line color and width.

### Example 25: Add a Profile

1. Add a profile with the context menu. A new graph view will appear on top of the DERT main window.
2. Move the widow aside. Two paddles will appear in the worldview.
3. With the left mouse button, drag the paddles along the terrain. A plot will appear in the graph view.
4. Unselect the checkbox labeled *Y/X = 1* to change the aspect ratio of the graph for optimal usage of the window.
5. Single-click in the graph view with the left mouse button at an interesting point. The green marble will be moved to the corresponding location in the worldview. The picked point will be displayed at the top of the graph window.
6. Open the map elements view, select the profile, and press *To CSV* to save the graph to a file in comma-separated value format.

## Plane

The Plane tool provides an interactive cutting plane with an optional map of elevation difference from the plane to the underlying terrain. The plane is at the "zero" elevation for the difference map. All terrain above the plane will display as positive and everything below will be negative. You may add a plane via the context menu or the map elements view.

### Example 26: Add a Plane

1. Add a plane using the button in the map elements view. In the worldview, three paddles will appear at the green marble.
2. With the left mouse button, press a paddle and drag it along the terrain.
3. Drag a second paddle with the left mouse button. A plane defined by the locations of the three paddles will appear in the worldview. A solid line representing the strike is drawn on the plane. A dashed line represents the dip.
4. In the map elements view, select the plane and press *Edit*. In the edit dialog, scale the plane along the dip and strike axes.
5. Press *Open* in the map elements view to display the elevation difference map and other plane details.
6. The point in the map under the cursor is displayed in the upper left corner. Single-click in the difference map with the left mouse button to move the green marble in the scene.
7. Use the mouse wheel to zoom the difference map image and drag the image with the left mouse button.

Due to performance issues, the difference map is not automatically recalculated each time a paddle is moved. Press the refresh button to recalculate. The elevation difference is calculated from the highest resolution landscape tiles. The size of the plane is limited by the amount of available memory.

## Feature Set

A *Feature Set* is a set of features from a GeoJSON file that are drawn as lines or points. Feature sets remain locked in place and cannot be moved. To avoid confusion, lines are never drawn as dashes as with other map elements. Options include color and point size. Properties are listed for each feature and a property may be selected for point labeling at file load time. Individual point labels may be hidden but will not remain hidden from session to session.

### Example 27: Add a Feature Set

1. Press the *Feature Set* add button in the map elements view.
2. Press *Browse*. A file dialog will appear.
3. Navigate to the VictoriaCrater pyramid directory and select contour.json.
4. Press *Choose (Open)*.
5. Select *Use landscape elevation for Z coordinate* and press *OK*.
6. A set of contour lines will appear in the worldview.

## Map Element Preferences

Open the Map element preferences dialog by selecting *Edit>Edit Map Element Preferences*. These preferences will be saved from session to session.

# LayerFactory

## Introduction

*LayerFactory* is a tool for building the layers for the terrain visualized in DERT. A set of raster layers, each represented by a multi-resolution tiled image pyramid is stored in a specialized directory called a *landscape*. These layers, a DEM or an orthoimage for example, are co-located, geo-referenced and displayed together. The DEM becomes a 3D mesh upon which the orthoimages are draped. Data sets used by LayerFactory can be found at the NASA Planetary Data System (PDS), USGS Earth Explorer, and other websites.

A landscape directory contains a file called ".landscape" to indicate its purpose. Each layer is found in a subdirectory of the landscape. Metadata for the layer is located in a Java properties file in its top directory. The pyramid for each layer employs a data structure called a *quad-tree*. A quad-tree is a series of magnification levels, each with a greater number of tiles, covering the same physical space. Each level represents a different resolution of the layer and has 4 times the number of tiles as the previous level. Each tile resides in a separate file formatted as PNG with a hierarchical name. As the level increases, a tile covers less physical space with the same number of pixels; thus, a pixel covers a smaller area. The lowest resolution level (0) consists of only one tile, level 1 has four tiles, level 2 has 16, etc. Each tile references the 4 tiles of higher resolution that covers its area in the next level. These are considered to be the tile's "children". When the camera comes closer to a tile, the children replace the parent in the scene, providing more detail. When the camera moves away, the parent returns, reducing the overhead of rendering unseen detail.

There are three types of layers: elevation, image, and field. The elevation layer provides the 3D mesh derived from a height map, and image layers are orthoimages that are draped on the mesh with no modifications. Field layers are also draped but require a color map for rendering. Tiles are rectangular in shape (not necessarily square) and are typically on the order of 129 x 129 pixels in size. The number of pixels on a side of a tile is 2^n+1. The extra row and column are used to stitch the tile to its neighbor. DERT uses bilinear interpolation when scaling tile images, avoiding pixelation and providing a smoother transition between tile edges. This means that the image layers display best when image tile dimensions are 4 or greater times the elevation tile dimensions. For example, if an elevation tile width is 128+1 pixels, an image layer tile width should be at least 512+1 pixels. Field layer tiles must be the same dimension as the elevation tiles.

## File Requirements

There are a wide variety of geo-referenced file formats. Currently, LayerFactory supports only the commonly found NASA PDS (.img) and GeoTIFF (.gtif, .tif, .tiff, .gtiff) formats. GeoTIFF is loaded via libtiff. Other formats can be converted to GeoTIFF with GDAL (www.gdal.org). NOTE: The PDS file loader may not be able to handle all types of PDS files. Try converting your file to GeoTIFF if you have problems. Here are some additional file requirements:

1. The DEM and orthoimage files must cover the same physical area. Corner locations should be identical or very close. These values can be listed with gdalinfo. The raster type may be AREA or POINT as long as both files are the same (see the Raster Type section below).
2. Each dimension of the orthoimage file (width and height) must be a power of 2 multiple of the corresponding DEM file dimension. For example, if the DEM dimensions are 100 x 200, the orthoimage must be 100 x 200, 200 x 400, 400 x 800, etc. This requirement is dictated by the quad tree structure of the pyramid. See the section called *Preparing Files for Tiling* for an example of using GDAL to crop and resample a DEM and an orthoimage.
3. Again, due to the quad tree, the best file dimensions are powers of 2. Otherwise, LayerFactory must pad the landscape to the next highest power of 2 to accommodate the quad tree. This can enlarge the landscape significantly.
4. LayerFactory relies heavily on the metadata included in the geo-referenced file. This metadata must therefore be accurate. For example, if you are using Mars files and they are not projected, make sure the datum in the file is not for Earth.
5. DERT does not currently handle floating-point or 16 bit gray orthoimage layers. LayerFactory converts these files to unsigned byte. It uses the minimum and maximum pixel values to determine the range for the gray byte quantities.
6. Only one value may represent missing or "no data" values (not, for example, all negative values). This value must be specified in the metadata or as a parameter to the LayerFactory application.
7. LayerFactory uses memory-mapped files. You will need at least 2 times the disk space that a data file currently occupies and possibly more.
8. GeoTIFF files with more than one scan line per row are not currently supported.
9. Linear units other than meters are not currently supported.

## Level Generation

To minimize error, the DERT quad-tree scales by the integer 2. Starting with the full size of the original raster, each level ascending the pyramid is one quarter in size as the previous. Therefore the baseline DEM's and orthoimages must have dimensions that are a power of 2. For those that do not conform, LayerFactory adds a margin of missing values to the edges of the data set pad its dimensions to a power of 2. The missing value is *NaN* for elevation data sets and *0* for image data sets.

LayerFactory creates each level from an average of the full original data set. Each pixel is the mean value calculated from the region of the original that it represents.

## Raster Type

The GeoTIFF specification lists two raster types: *Area* and *Point*. The PDS format is typically *Point*. See [http://www.remotesensing.org/geotiff/spec/geotiff2.5.html#2.5.2](http://www.remotesensing.org/geotiff/spec/geotiff2.5.html#2.5.2) for an explanation. For our purposes, the difference is in the tie point value. It is offset by ½ pixel between the two types. Be sure to specify the raster type in the –mo parameter when converting a PDS file to a TIFF format with gdal_translate. For example, to convert a PDS file to a TIFF file:

```
gdal_translate –mo "AREA_OR_POINT=Point" image.img image.tif
```

## Unprojected Data

LayerFactory does not alter the projection of the landscape. If it is not already, you may want to consider projecting your data. DERT is not a virtual globe and to visualize an unprojected height map, it must be converted from longitude/latitude values to 3D Cartesian coordinates. As this technique adds significant complications, it has not yet been implemented. DERT will "project" an unprojected landscape in the following manner:

1. Project the upper left and lower right corners to obtain tie points using polar stereographic projection if the latitude > 85 or < -85, or equirectangular projection otherwise. This calculation is performed via the Proj.4 projection library.
2. Divide the range between the upper left and lower right by the number of pixels in the corresponding dimension to get the pixel scale.

## Edges

LayerFactory provides a skirt around the edge of the landscape. The bottom of this skirt is located at the minimum elevation. Artifacts (floaters) produced by the terrain reconstruction technique for the DEM may cause a very tall skirt. Change the property EdgeFillValue in the elevation layer properties file to adjust the skirt height. Note: shadows will not work correctly for parts of the landscape that occur below the bottom of the skirt.

## Preparing Files for Tiling

The DEM and orthoimage must cover the same physical area. Use an orthoimage with dimensions that are at least 4 times the size of the DEM for optimal rendering. If necessary, use the GDAL utilities to super-sample your orthoimage. Additionally, each dimension of the orthoimage file (width and height) must be a power of 2 multiple of the corresponding DEM file dimension. GDAL utilities *gdal_translate* and *gdalwarp* may be used to modify files that don't meet these requirements. For example, the following steps can be used to prepare the projected files dem.tif and img.tif for input to LayerFactory.

### Example 28: Aligning DEM and Orthoimage Boundaries

1. Using gdalinfo, find the corner coordinates of both dem.tif and img.tif. The corner coordinates are the physical boundaries of the file. We want to crop both files to the intersection of physical boundaries of the two files. Using the upper left and lower right coordinates of each file the intersection comes out to be:

   ```
   Upper Left ( -31406, 112740 )
   Lower Right (-22020, 102340 )
   ```

2. Crop the two files with gdal_translate to the intersection.

   ```
   gdal_translate –projwin -31406 112740 -22020 102340 dem.tif dem_cropped.tif

   gdal_translate –projwin -31406 112740 -22020 102340 img.tif img_cropped.tif
   ```

3. Use gdalinfo to find the width, height, and pixel size of the two files.
   a. dem_cropped.tif:

   ```
   Size is 469, 520
   Pixel Size = (20.000000000000000,-20.000000000000000)
   ```

   b. img_cropped.tif:

   ```
   Size is 4693, 5200
   Pixel Size = (2.000000000000000,-2.000000000000000)
   ```

4. The dimensions (width and height) of img_cropped.tif should be a power of 2 times that of dem_cropped.tif. Currently it is 10 times (20/2 = 10). Resampling dem_cropped.tif to a pixel size of 16 will make the dimensions of img_cropped.tif 8 times the size of dem_cropped.tif and 8 is a power of 2. The scale factor for the resampled file will be 20/16 so the new width will be 586 and the new height will be 650.

5. Use gdalwarp to resample dem_cropped.tif.

   ```
   gdalwarp –r bilinear –ts 586 650 dem_cropped.tif dem_cropped_16.tif
   ```

6. We now have an orthoimage that is 8 times the length of the DEM. Run LayerFactory using a tile size of 64 for dem_cropped_16.tif and a tile size of 512 (8x64) for img_cropped.tif.

## Parameters

LayerFactory has a number of required and optional command line parameters. If the required parameters are not provided, a graphical user interface (GUI) will appear. The GUI window provides two tabs for a Raster Layer and Vector Layer panels. The area immediately underneath the window title displays status messages to the user. The GUI and parameters are described below.

## Raster Layer

This panel of the GUI is for building one raster layer of a landscape pyramid. The area immediately underneath the window title displays status messages to the user.

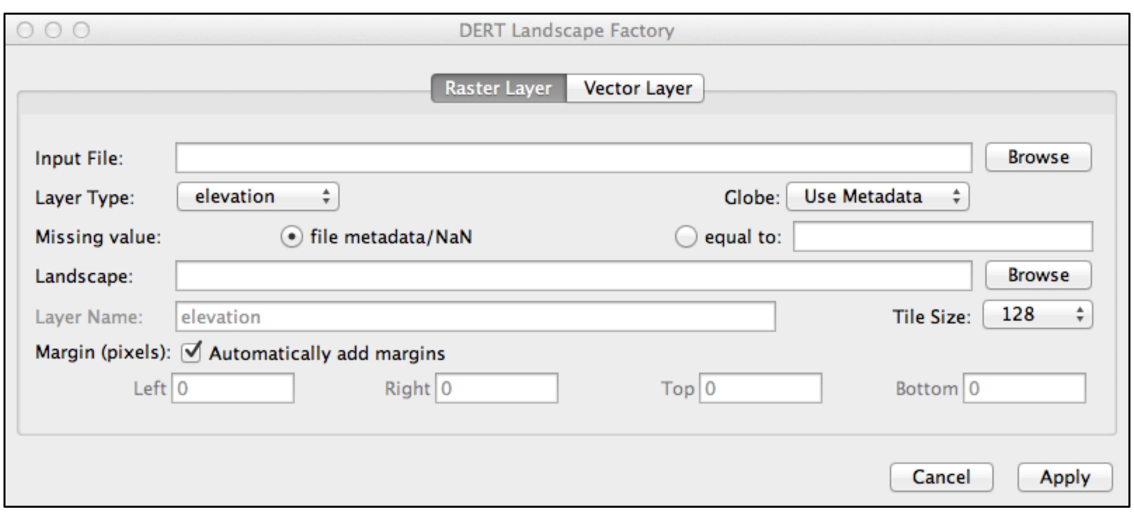



Figure 19: LayerFactory graphical user interface with raster layer panel.

*Input File*:  This is the layer (DEM, orthoimage, or field) file to use for the pyramid.  It should be in PDS or GeoTIFF format.

*Layer Type*:  Describes the type of layer to create.  Select one of *elevation* (for a DEM), *colorimage* (for an RGB orthoimage), *grayimage* (for a gray scale orthoimage), or *field* (for a float, int, or byte raster that requires a color map).

*Globe*:  Select the planet or moon for this layer.  If there is no selection, LayerFactory will examine the file metadata and use the default globe specified in dert.properties if nothing is found.

*Missing value*:  This field designates how to handle missing or no-data values.  Select *file metadata/NaN* to use whatever is found in the input file metadata or default to NaN values.  Select *equal to* and enter a number if the value is not found in the metadata.

*Landscape*:  Enter the landscape path here.  You may create a new landscape in the file browser dialog. LayerFactory will add a file named ".landscape".

*Layer Name*:  Enter the name of the layer. This will be used for the layer subdirectory in the landscape.  Note: elevation layers can not be named.

*Tile Size*:  Select the length of the longest edge of a tile.

*Margin*:  Normally, *automatically add margins* should be checked.  If necessary, LayerFactory places margins on all sides, centering the raster. If you are building a sub-pyramid you may not want margins on some sides. If so, uncheck this button and provide the margin amount to be added to each edge of the raster before creating the pyramid.

### Vector Layer

The vector layer tab provides the option to generate a multi-resolution image pyramid from vectors in a GeoJSON file. LayerFactory renders each tile and saves the raster. Note: GDAL translates ESRI shape files to GeoJSON.

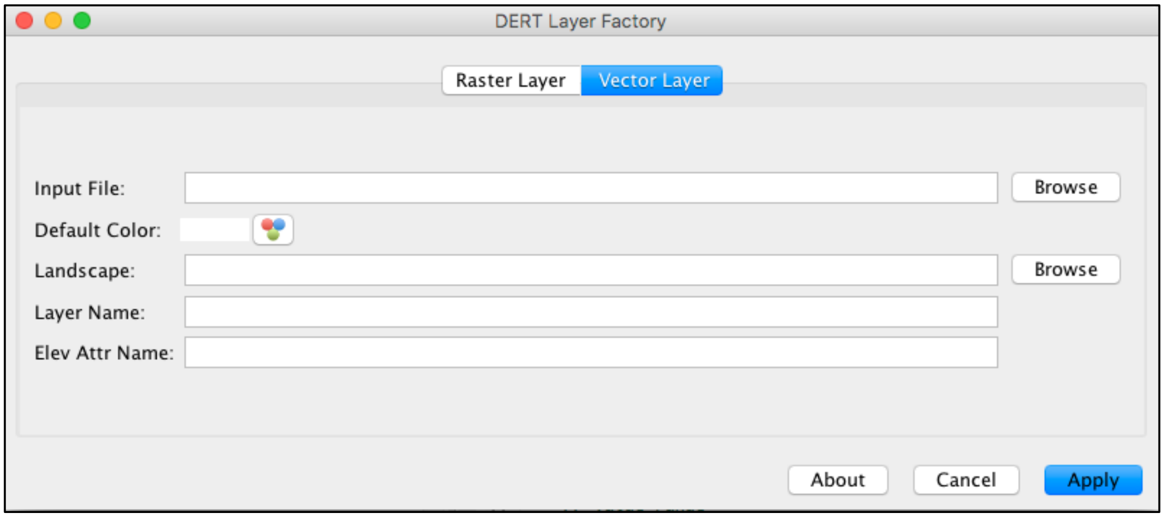



**Figure 20: LayerFactory graphical user interface with vector layer panel.**

*Input File*: This is the GeoJSON vector file to use for the pyramid.

*Default Color*: Select a color to use if there is none is found in the file.

*Landscape*: The landscape directory.

*Layer Name*: The name of this layer. This name will be used for the layer subdirectory in the landscape directory.

*Elev Attr Name*: (Optional) Enter the name of a property that identifies the elevation value for a contour map. This value will be used for labeling contour lines. Note: If you used gdal_contour to create your GeoJSON file, enter the argument used with the "–a" parameter.

## Command Line Execution

To invoke LayerFactory on the command line, enter:

layerfactory *parameters*

You may enter layerfactory –usage for a list of parameters. The following parameters are required:

-landscape =*landscape directory path*
-file=*input file path*
-type=*layer type (for raster only)*
-tilesize=*tile size*

The following parameters are optional:

-globe=*globe name (default is taken from dert.properties if not in metadata)*
-missing=*missing value (default NaN for DEM, 0 for image if not in metadata)*
-leftmargin=*number of pixels to fill left margin*
-rightmargin=*number of pixels to fill right margin*
-bottommargin=*number of pixels to fill bottom margin*
-topmargin=*number of pixels to fill top margin*
-name=*layer name (defaults to input file name)*
-color=*vector color (either r,g,b or r,g,b,a; each color component is in the range [0-255])*
-elevattrname=contour elevation attribute name

## Creating a Sub-pyramid

One pyramid can be added to another as a sub-pyramid. The edges of the sub-pyramid must match the neighboring tiles in the main pyramid. Add the sub-pyramid by replacing a tile in the main pyramid with the sub-pyramid directory. Normally, LayerFactory distributes padding (up to the next power of 2) equally on all sides of the landscape. Use the margin parameters to only add padding to one or two sides.

## Layer Pyramid File Format

A landscape is a directory that contains one or more layers. It must also contain a a file called ".landscape" to be identified as a landscape. This file is a Java properties file with a date and the login name of last user who wrote it. LayerFactory rewrites this file each time a layer is written in the landscape.

Each layer is a subdirectory consisting of a pyramid of tiles. The top level of a pyramid will contain a file called *layer.properties*. This file contains the metadata for the layer including projection, size, etc. Each tile is in PNG format. PNG does not support floating point thus the elevation and field tiles are written and read as RGBA. They will appear as images if examined in an image viewer.

In addition to the layers, a landscape may have a *dert* subdirectory, created by DERT itself. This subdirectory contains information useful to DERT including user supplied landscape configurations, color maps, and camera definitions. Its subdirectories include:

- colormap (directory for user supplied color maps)
- config (directory for landscape configurations)

- camera (directory for camera property files).

Additionally, the depth tree file for the pyramid is stored in the dert subdirectory as *depth.obj*. This file should be removed (DERT will recreate it) if a sub-pyramid is added or other changes are made to the pyramid structure.

## Example 29: Create a Landscape of Mars Candor Chasma

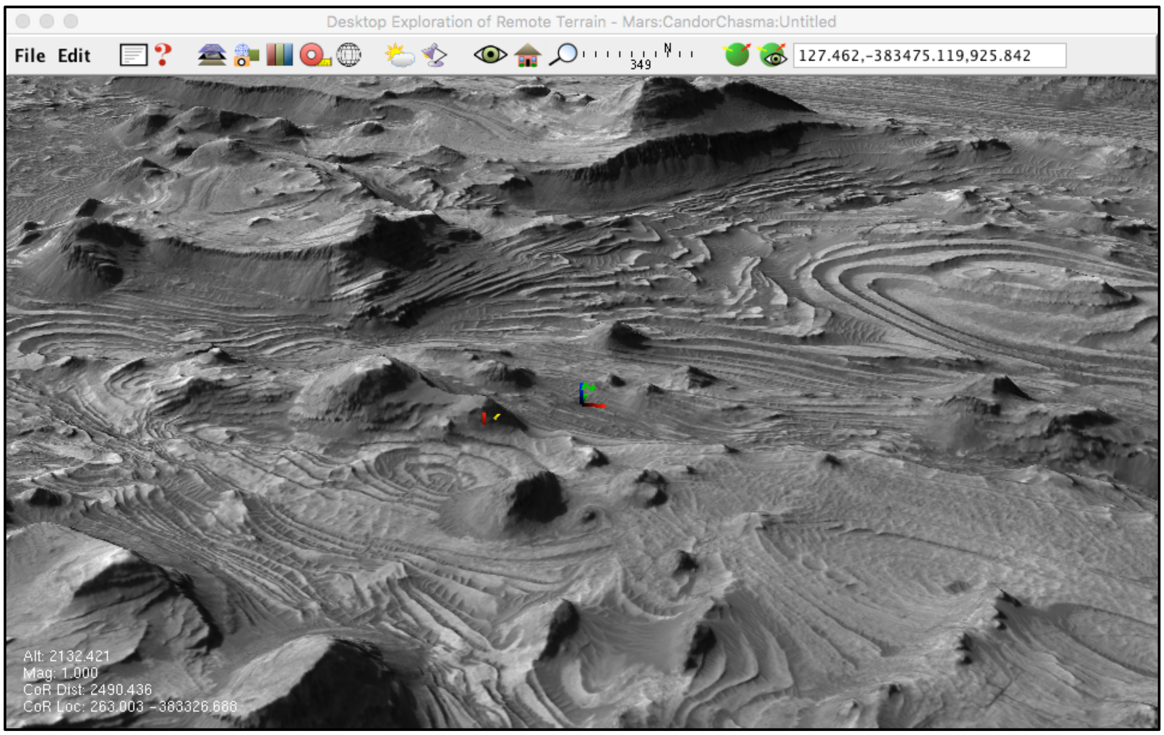



**Figure 21: Candor Chasma, Mars.**

The Candor Chasma data products can be found here:

http://hirise.lpl.arizona.edu/dtm/dtm.php?ID=PSP_001918_1735.

1. Go to the HiRISE website and select "full directory listing" link.

2. Download DTEEC_001918_1735_001984_1735_U01.IMG. This is the DEM file. Run gdalinfo to see the DEM pixel scale is 1 m.

3. Download PSP_001984_1735_RED_A_01_ORTHO.JP2 and the corresponding .LBL file. This is the orthoimage. Run gdalinfo to see that the orthoimage pixel scale is 0.25 m, 4 times that of the DEM.

4. Convert the orthoimage JP2 file to a GeoTIFF file with gdal_translate (see appendix D).

5. Create a directory called CandorChasma.

6. Run layerfactory to create the elevation layer:

```
layerfactory -type=elevation -file=DTEEC_001918_1735_001984_1735_U01.IMG -tilesize=128
    -landscape=yourpath/CandorChasma
```

7. Run layerfactory again for the gray orthoimage:

```
layerfactory -type=grayimage -file=DT1EA_001918_1735_001984_1735_U01.TIF -tilesize=512
    -landscape=yourpath/CandorChasma
```

8. View the CandorChasma landscape with DERT.

9. Create a contour file with gdal_contour (first unproject the DEM with gdalwarp):

```
gdalwarp –t_srs '+proj=longlat +a=3396190.0 +b=3396190.0 +no_defs' DTEEC_001918_1735_001984_1735_U01.IMG dem.tif
gdal_contour -a elev -I 50 -f GeoJSON dem.tif contour.json
```

10. Create a contour raster layer with layerfactory:

```
layerfactory -landscape=yourpath/CandorChasma -file=contour.json -elevattrname=elev -color=0,0,192,255
```

11. View CandorChasma in DERT. Open the surface and layers view and add the contour layer to the scene.

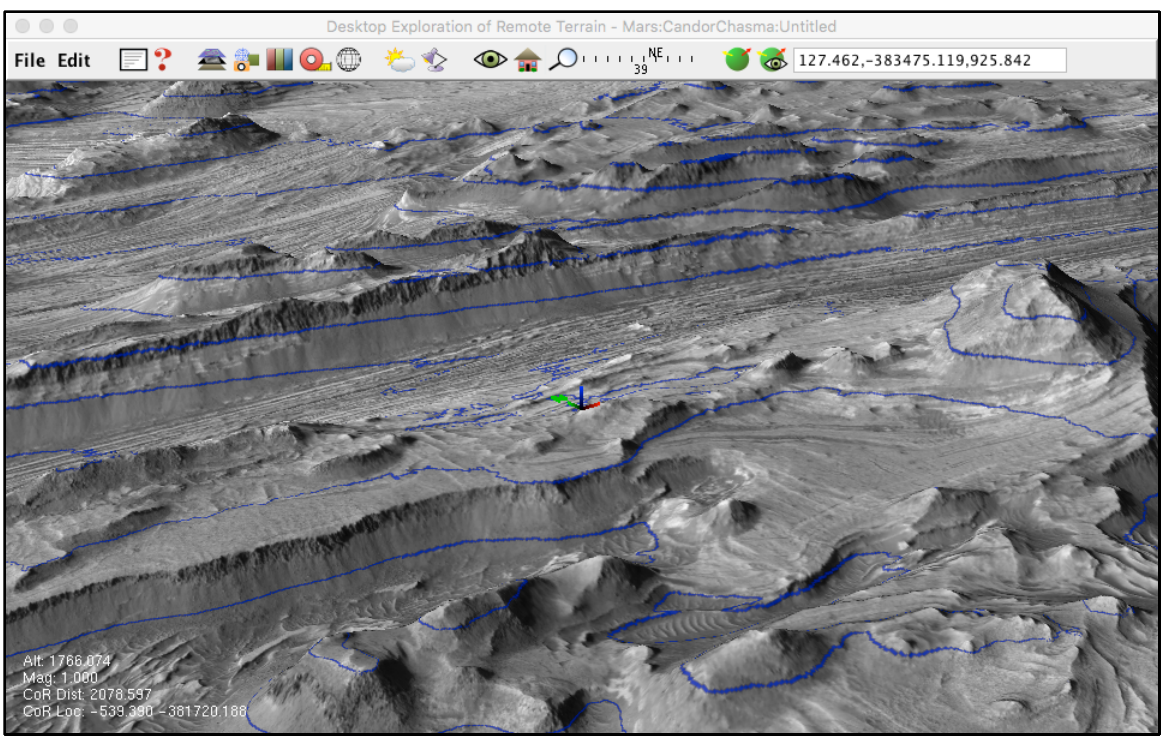



Figure 22: Candor Chasma with contour lines.

12. Create a roughness map with gdaldem:

```
gdaldem roughness DTEEC_001918_1735_001984_1735_U01.IMG roughness.tif
```

13. Create a field layer with layerfactory:

layerfactory -type=field -file=roughness.tif -tilesize=128 -landscape=*yourpath*/CandorChasma

14. View CandorChasma in DERT. Add the roughness layer to the scene and change the color map to *default3*.

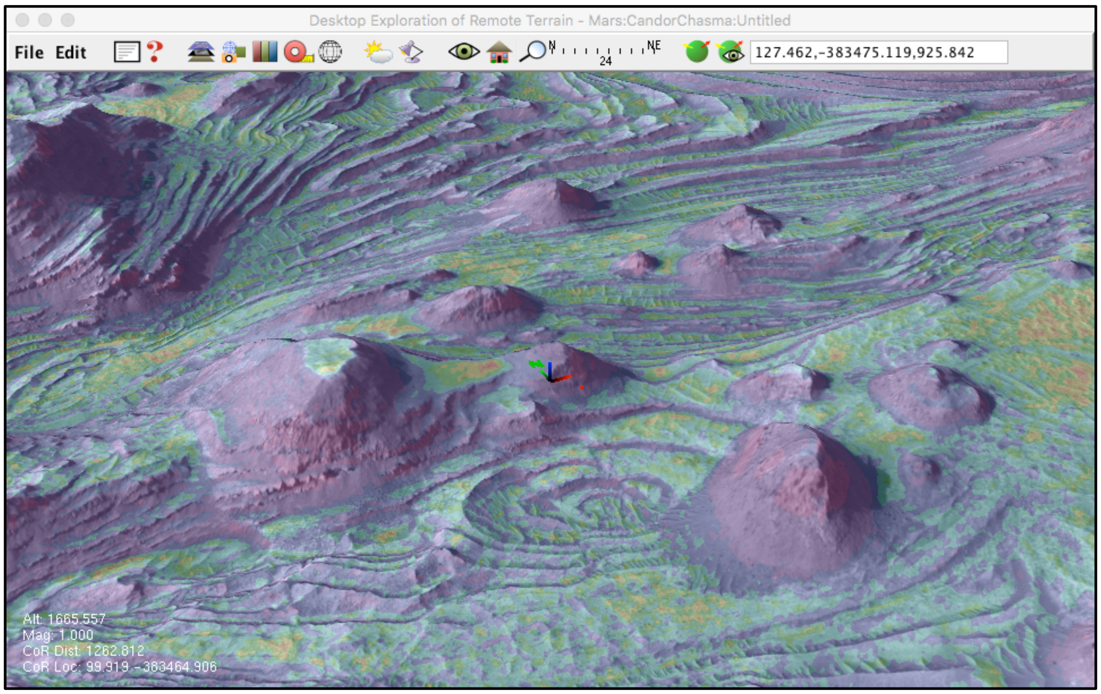



**Figure 23: Candor Chasma with contour lines and elevation map.**

# Appendices

## Appendix A: Configuring the Mac Trackpad

- Open System Preferences.
- Select the trackpad icon.
- Disable “Tap to click”.
- Enable “Secondary click”.
- Close System Preferences.
- Use one finger for the left mouse button and two fingers for the right mouse button.
- Translate: press down with one finger until you hear a click, then drag.
- Rotate: press down with two fingers until you hear a click, then drag.
- Context menu: single-click with two fingers.
- Dolly or Zoom: swipe or drag (no click) with two fingers.

## Appendix B: Create a Ground Plane

1. Find an existing DEM that you like and crop it.

```
gdal_translate -mo="AREA_OR_POINT=Point" -outsize 1024 1024 DTEEC_001414_1780_001612_1780_U01.IMG DEM.tif
```

2. Get the minimum and maximum elevation using gdalinfo.

```
gdalinfo –stats DEM.tif
```

3. Use gdal_translate to scale the elevation values to zero.

```
gdal_translate -scale -1452.89453125 -1373.3200683594 0 0 DEM.tif elevation.tif
```

4. Create a pyramid from the new DEM.

## Appendix C: Adjust HRSC Colors

1. Convert the red and blue components from byte to floating point.

```
gdal_translate -ot Float32 H0360_0000_re4.IMG re4.tiff
gdal_translate -ot Float32 H0360_0000_bl4.IMG bl4.tiff
```

2. Scale the red and blue components from 0-255 to 0-1.

```
gdal_translate -scale 0 255 0 1 re4.tiff re4_01.tiff
gdal_translate -scale 0 255 0 1 bl4.tiff bl4_01.tiff
```

3. Scale the red and blue components exponentially.

```
gdal_translate -scale 0 1 -exponent 0.6 re4_01.tiff re4_scaled.tiff
gdal_translate -scale 0 1 -exponent 2.2 bl4_01.tiff bl4_scaled.tiff
```

4. Convert the red and blue components back to byte.

```
gdal_translate -ot Byte re4_scaled.tiff re4_256.tiff
gdal_translate -ot Byte bl4_scaled.tiff bl4_256.tiff
```

5. Create the RGB image file.

```
gdal_merge.py -separate re4_256.tiff H0360_0000_gr4.IMG bl4_256.tiff -o rgb.tiff
```

## Appendix D: Convert HiRISE JP2 files to GeoTIFF

1. Convert the JP2 file to GeoTIFF with gdal_translate.

```
gdal_translate -mo “AREA_OR_POINT=Point” input.lbl output.tif
```

2. Some drivers do not handle very large files well. If you get a segmentation fault you may need to skip a driver. For example the JP2OpenJPEG driver in GDAL v1.11.4 on Mac OS 10.11.6 does not handle a very large JP2 file. Run the following command to list the drivers in order.

```
gdalinfo --formats
```

3. Convert the JP2 file to GeoTIFF with gdal_translate, skipping the JP2OpenJPEG driver.

```
gdal_translate -mo “AREA_OR_POINT=Point” --config GDAL_SKIP JP2OpenJPEG input.lbl output.tif
```