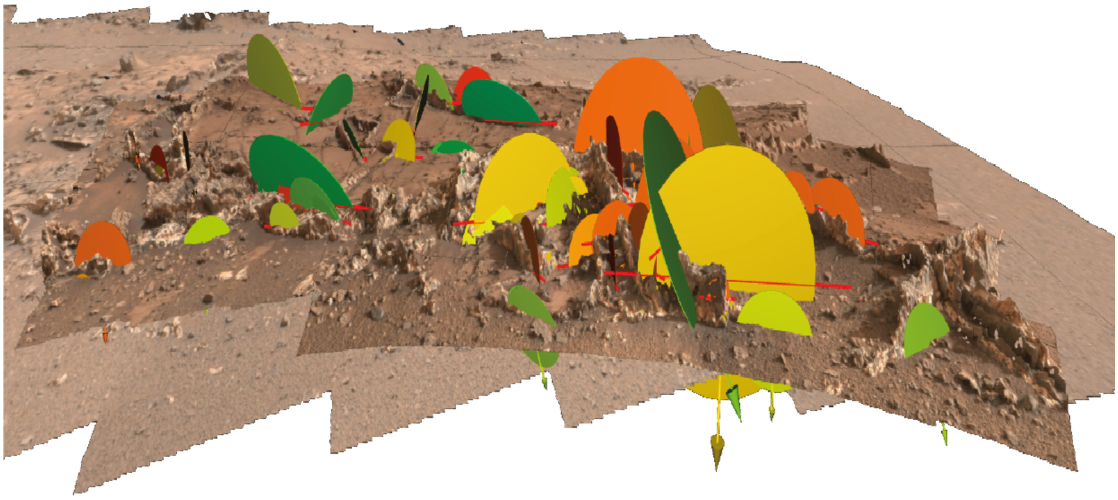
PRo3D 3.7.0 - HERA 1.4

USER MANUAL

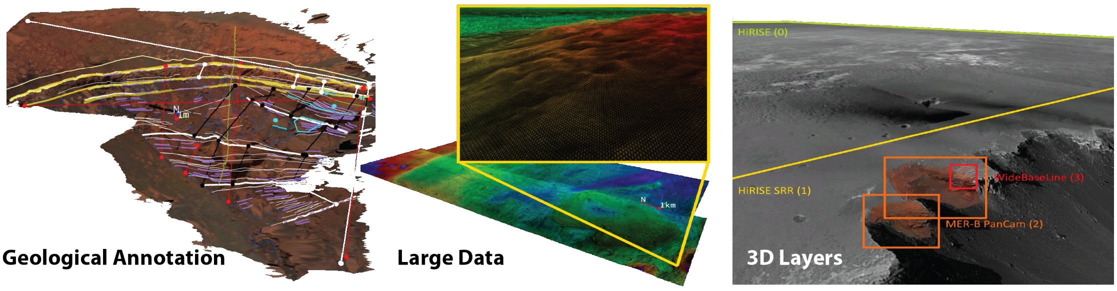


Authors:
Thomas Ortner, Laura Fritz, Rebecca Nowak

Last Updated: June 26, 2021

Contents

1 Introduction



PRo3D, short for **P**lanetary **Ro**botics **3D** Viewer, is an interactive 3D visualization tool to allow planetary scientists to work with high-resolution 3D reconstructions of the Martian surface.

1.1 Who uses PRo3D

PRo3D aims to support planetary scientists in the course of NASA's and ESA's missions to find signs of life on the red planet by exploring high-resolution 3D surface reconstructions from orbiter and rover cameras.
For the past 5 years the development of PRo3D has been geared towards providing planetary **geologists** with interactive tools to digitize geological features on digital outcrop models (DOMs) on the Martian surface. During our fruitful cooperation with geologists from the Imperial College of London, PRo3D has emerged as their main tool to conduct remote geological analysis which lead to many publications and talks at various geological science venues.
Planetary geology is the most elaborately supported use-case of PRo3D, however we strive to expand our user groups to other use-cases, so we have also developed features for supporting science goals in **landing site selection** and **mission planning**.

1.2 Features

- **Geological Annotation**: PRo3D lets users pick points on the 3D surface at the full resolution of the data present. Our tools contain point, line, and polyline annotations, while line segments are projected onto the surface. Various measurements are computed at the highest possible accuracy, such as the distance along a 3D surface (waylength) or dip-and-strike orientations of sediment structures.

- **Large Data**: Surface reconstructions from high-resolution satellite images can easily yield gigabytes of data in terms of geometry, imagery, and additional layers. With PRo3D users can explore huge datasets interactively and even perform measurements of topographic features. The displayed dataset on the right consists of 2GB of raw 3D position vectors, a 1GB elevation map, and 10GB of image data rendered at interactive framerates with commodity hardware, utilizing adjustable level-of-detail and out-of-core techniques.

- **3D Layers**: Although, PRo3D is not a GIS system, we need to provide our users with typical GIS features to solve their geospatial problems, such as evaluating topographic or geological features. Our 3D layering technique allows a seamless integration of different reconstructions present at a single location. Unlike image or DTM layering we allow users to blend full 3D data by assigning rendering priorities, which is crucial to explore reconstructions from multiple rover camera instruments.
- **Batch rendering of images:** PRo3D sports a command line interface that can be used to quickly render a large number of images without the hassle of using a graphical user interface.

1.3 Data

Currently, PRo3D only supports reconstructions in the proprietary data format OPC (Ordered Point Clouds), basically consisting of hierarchically organized surface patches. These reconstructions stem from orbiter images and rover images and are produced by Joanneum Research by using the PRoViP processing pipeline. Many surface reconstructions have been generated from, for instance: HiRISE, MER-A, MER-B and MSL missions from various instruments. An ongoing project evaluates terrestrial applicability of PRo3D and the PRoViP pipeline by capturing outcrops in the UK.

2 Start

Start the viewer by clicking the PRo3D.exe and open the Menu in the top left of the window, shown in Figure 1.

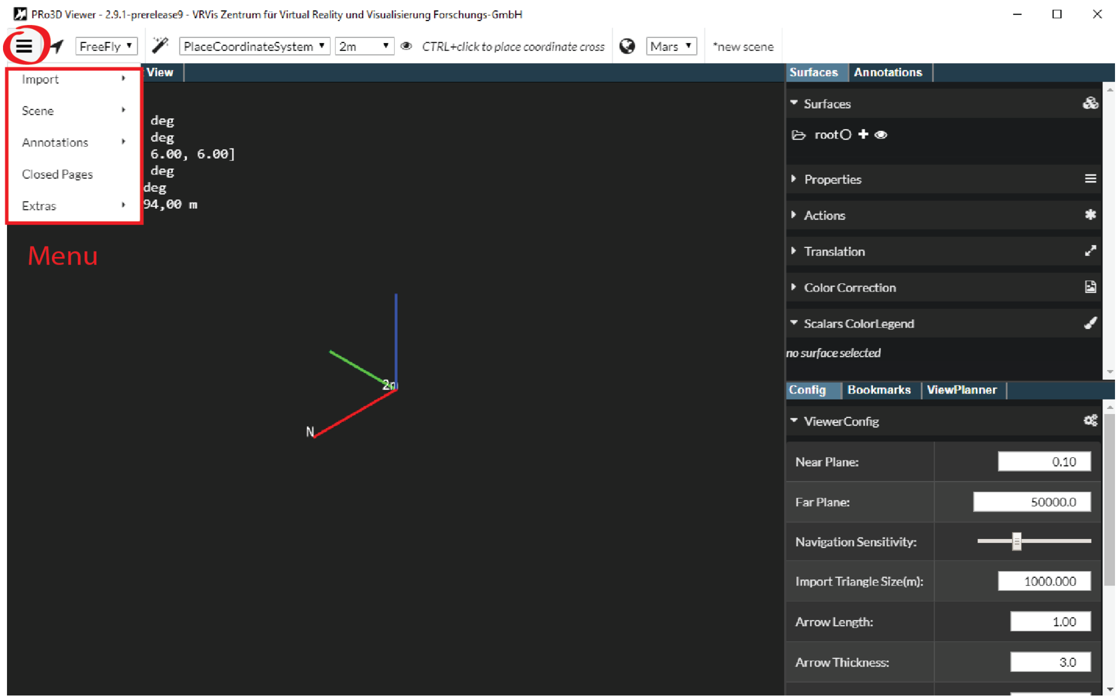


Figure 1: PRo3D Main Menu.

You have two options to start:

- Add one or more surfaces and create a new scene, as described in the next Section 2.1.
- Load an existing scene described in the Section 2.2.

2.1 Add Surface

To add a new surface move the mouse to the “Import” tab in the menu (Figure 1). Click on the “OPC” tab to choose a surface (with “OBJ” you can import object files). This opens the “Select Folder” window where you can choose one or more folders containing opc files as shown in Figure 2. Click the “Select Folder” button to confirm your selection. The surface is loaded into the viewer and listed in the “Surface” page in the right part of the window as shown in Figure 5, part A. You can add more surfaces in the same way.
Each surface has a little context menu below the surface’s name in the list (Figure 5, B). Click the “FlyTo” button to see the surface in the main window. To see the surface’s properties (Figure 5, C) click on the appropriate name in the list.
Finally, click “Scene -> Save as...” in the menu, name the scene and press the “Save” button (Figure 3) to save the surfaces and your settings in a “.scn”

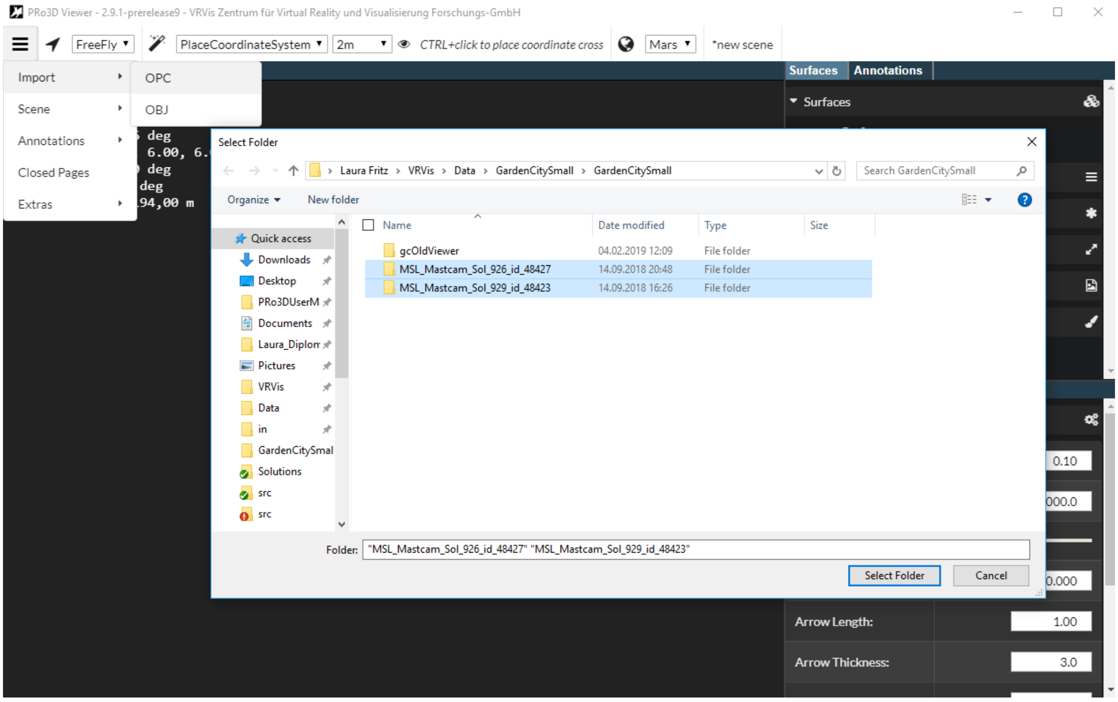


Figure 2: Add new surfaces to the scene.

file. The PRo3D viewer will load the scene automatically next time you start the viewer.

2.2 Load Scene

Load an existing scene by selecting "Scene -> Open" in the **Scene** tab in the start menu (Figure 1). Select the scene xml file in the directory of your choice and confirm your selection (Figure 4). Then the scene is loaded (Figure 5). You can also load recent scene files with the "Scenes -> Recent" tab in the Scene tab of the menu . By hovering with the mouse over the tab, a list of recent scenes opens. Click on the required scene name to load the scene.

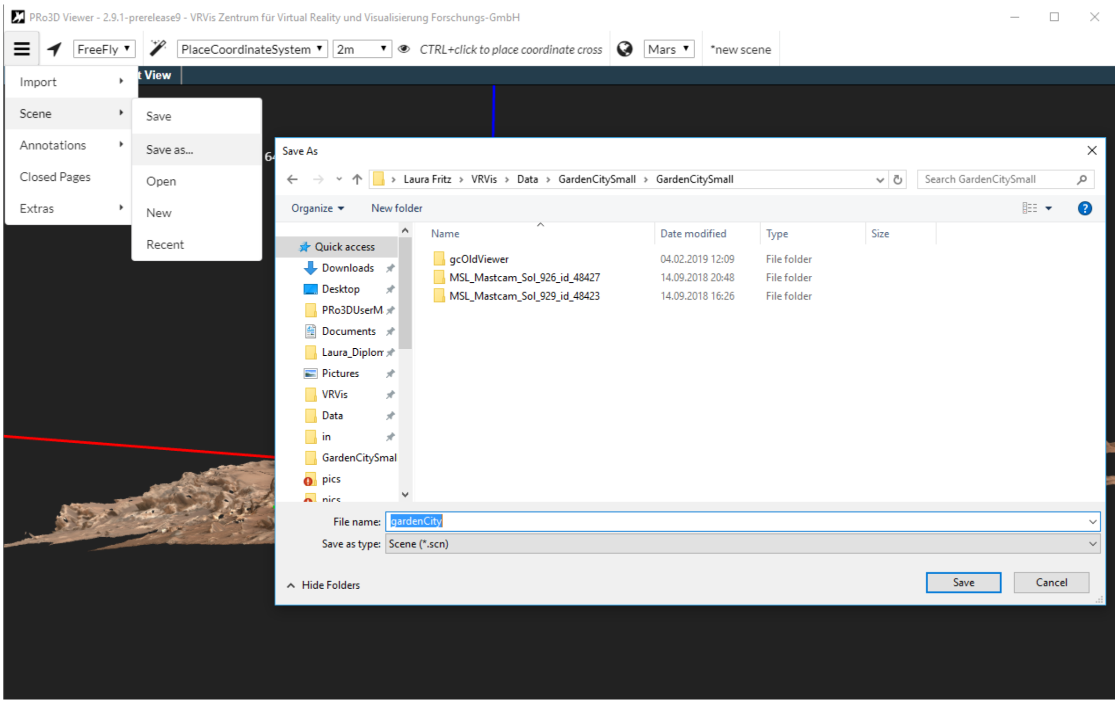


Figure 3: Save the surfaces and settings as a scene.

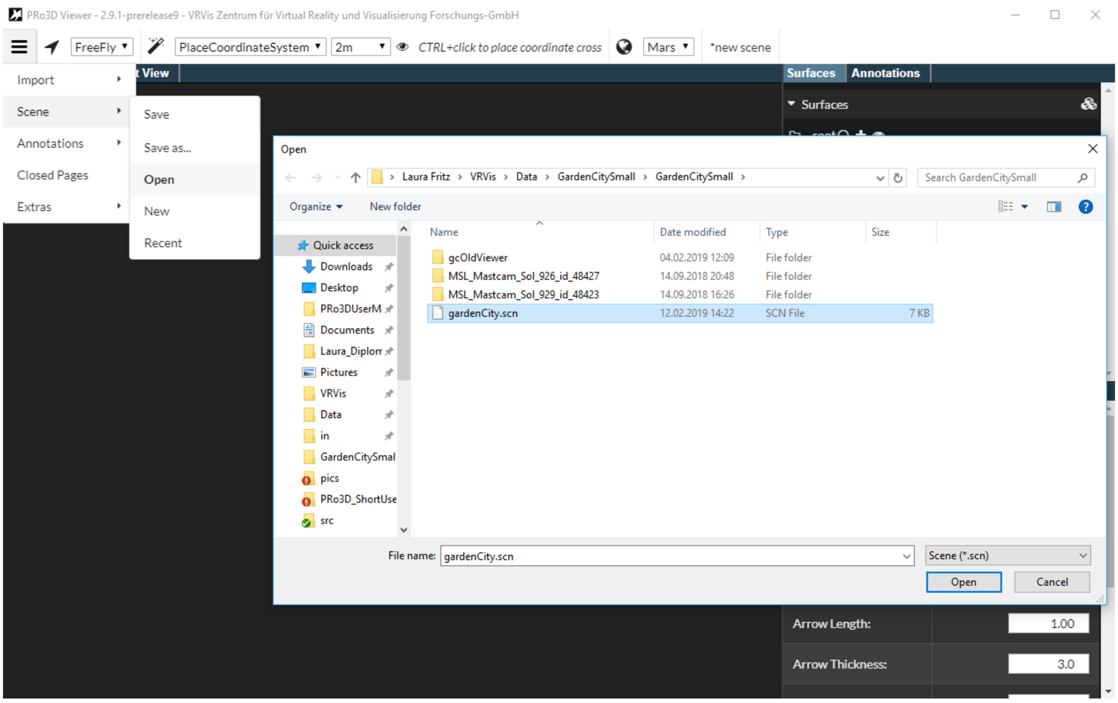


Figure 4: Open a scene with either the "Scene -> Open" or the "Scene -> Recent" tab in the scene tab of the menu.

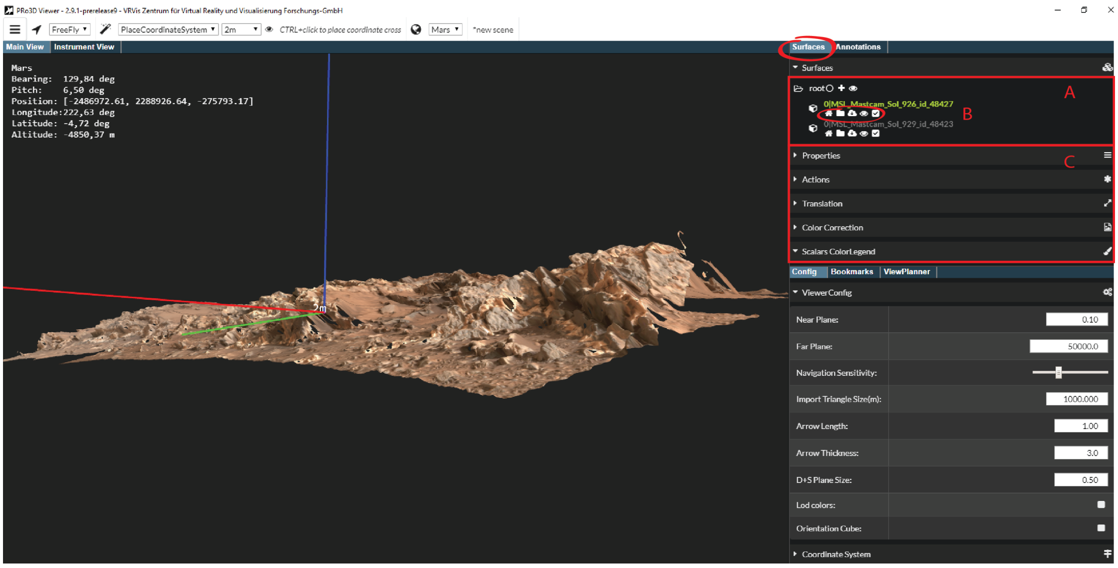


Figure 5: Loaded surface with open surface features (right).

3 Viewer Actions

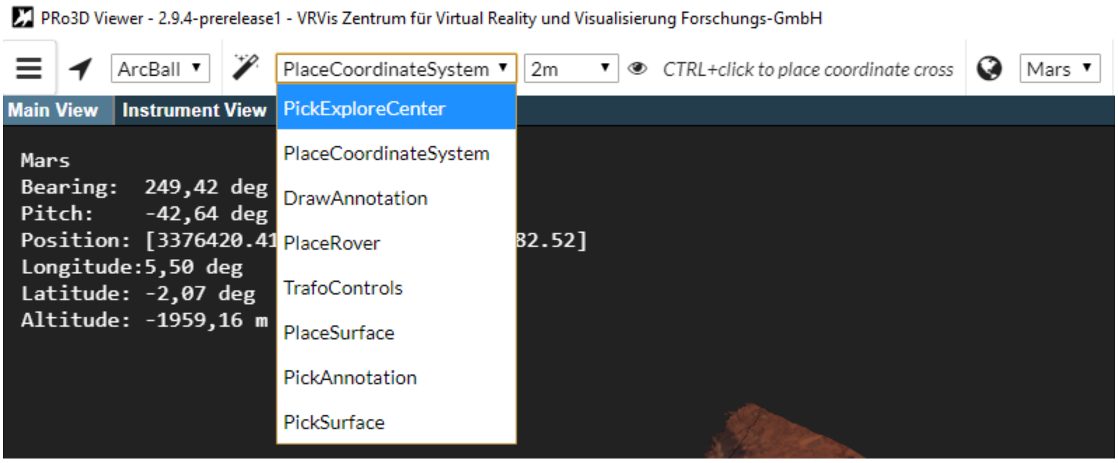


Figure 6: Viewer Actions.

Once the surface is loaded there are different actions to choose (Figure 6).

3.1 Pick Explore Center

The “PickExploreCenter” action concerns the **ArcBall** navigation mode. There are two navigation modes (Figure 7):

- **FreeFly** and
- **ArcBall**.

3.1.1 FreeFly

The Free Fly Mode is the standard 3D fly-through navigation, as for instance, in terrain visualization. WASD controls forward/backward and strafing movement, while the user can change the camera’s orientation by holding the LMB (= **L**eft **M**ouse **B**utton). Zooming in and out (forward/backward movement) is performed by turning the mouse-wheel or holding down the RMB (= **R**ight **M**ouse **B**utton). Additionally, the camera can be panned by holding down the middle mouse button.

3.1.2 ArcBall

When the viewer is in ArcBall mode the camera can be rotated around the explore center by holding down the LMB. Panning and strafing are possible as described above, but be aware that this moves the explore center (otherwise panning would break the view matrix of the camera). To set a new explore point, make sure the “PickExploreCenter” action is active (as shown in Figure 7) and press CTRL + LMB on the surface. The explore center is indicated by a pink dot.

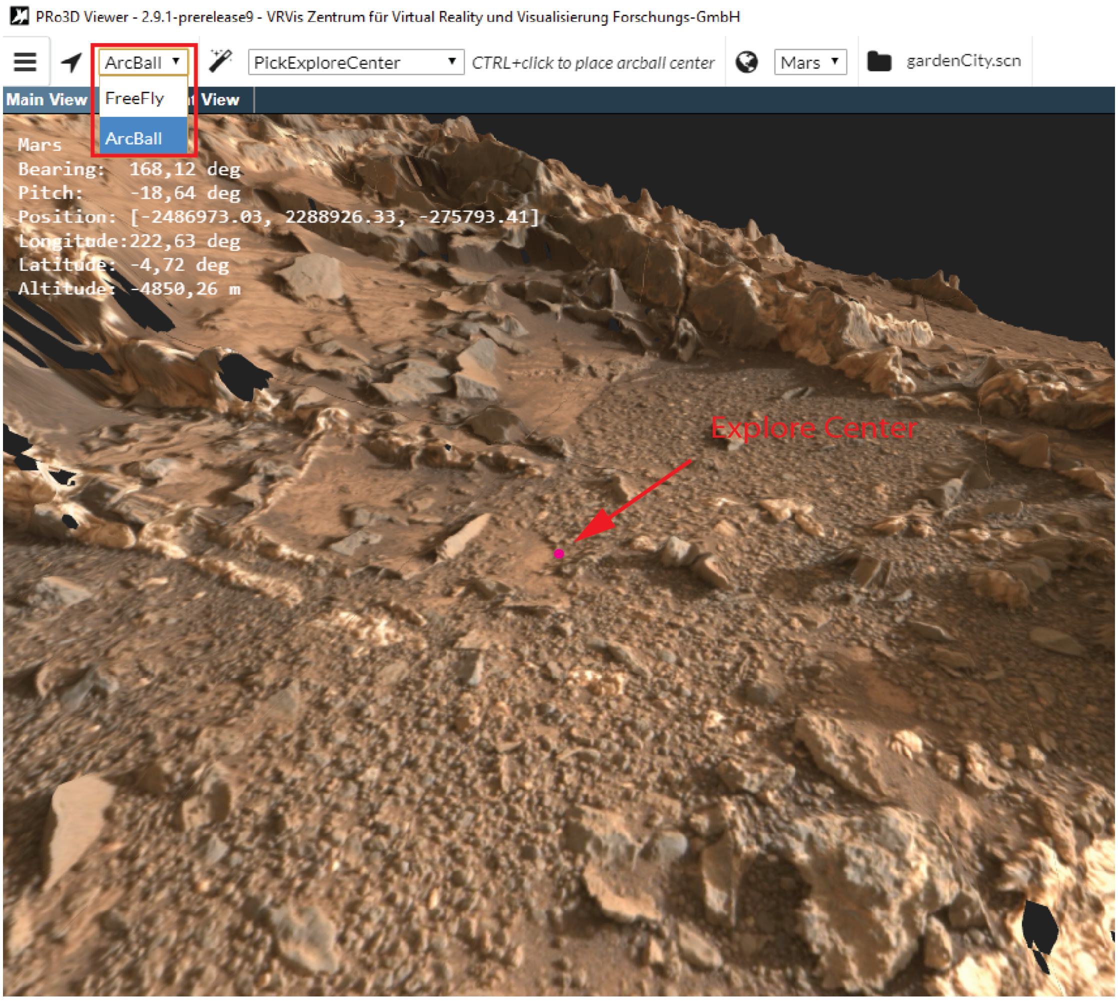


Figure 7: ArcBall navigation. Explore center is set with CTRL + LMB and indicated by a pink dot.

Forward and backward movement is performed either by the keys W/S, rotating the mouse wheel, or clicking the RMB.

3.2 Place Coordinate System

To set the coordinate system pick “PlaceCoordinateSystem” in the actions drop down menu, select a unit of measurement and press CTRL+LMB to pick a point on the surface. This marks the position as shown in Figure 8. Initially the up vector’s (blue) direction is set in the positive z-direction and the north vector’s (red) in the positive y-direction. You can manipulate the north vector manually for different data. The surface can be translated along the three directions of the coordinate system, as described in Section 4.1. The up- and the north vector are used for the projection measurements. The north vector is also relevant for bearing measurements, and the rover placement in the View Planner. The value for manipulating the north vector is shown in the Viewer Configuration described in Section 4.4.

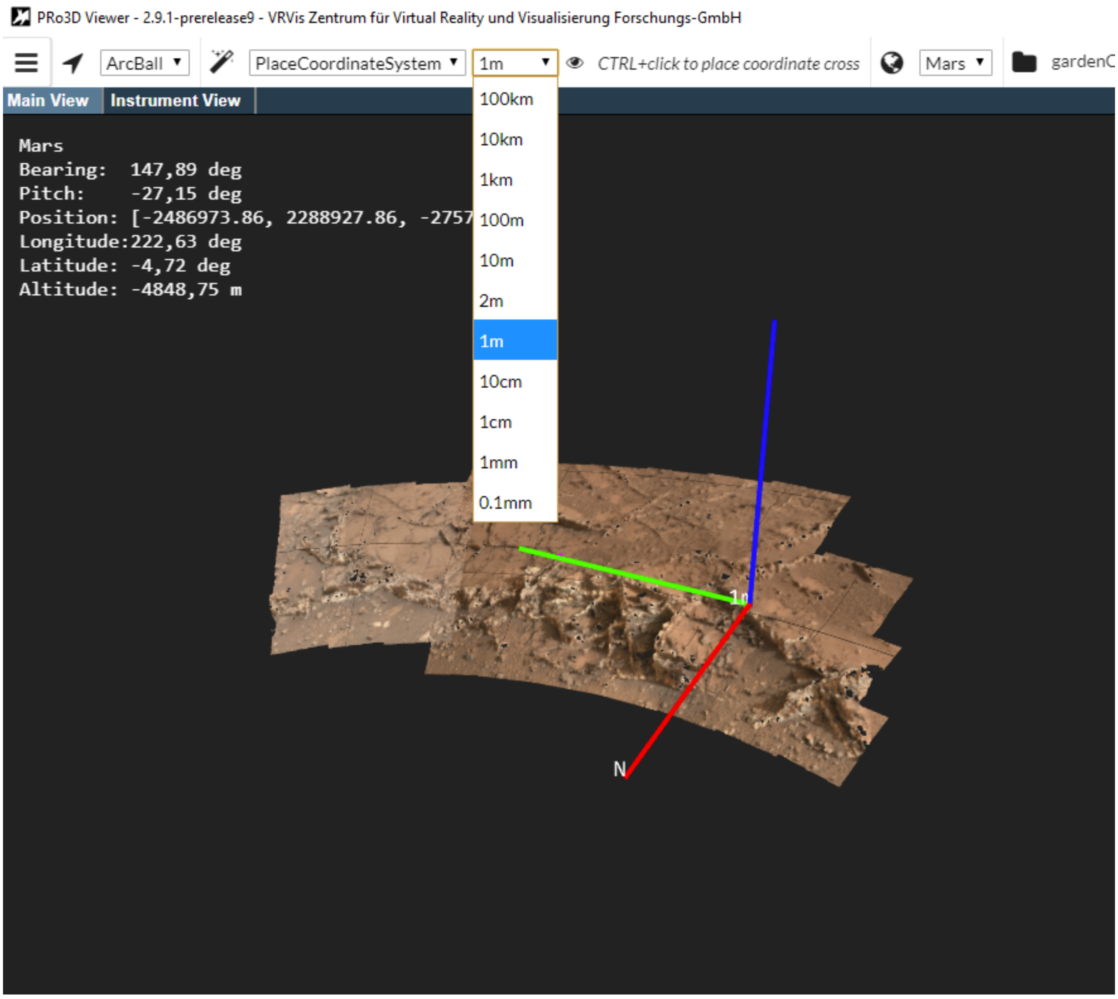


Figure 8: Coordinate System with scale bar functionality.

3.3 Draw Annotation

Figure 9 shows the settings for drawing annotations. First set "DrawAnnotation" in the actions menu (A in Figure 9). Then you can choose one of the following annotation modes (B in Figure 9):

- *Point*: A single point measurement on the surface.
- *Line*: You can pick two points on the surface. The connecting line depends on the projection mode explained in the table below.
- *Polyline*: An arbitrary number of points on the surface can be picked. The connecting line segments depend on the projection mode. The polyline is finished by pressing Enter.
- *Polygon*: An arbitrary number of points on the surface can be picked. The connecting line segments depend on the projection mode. The region of interest is closed and finished by pressing Enter.

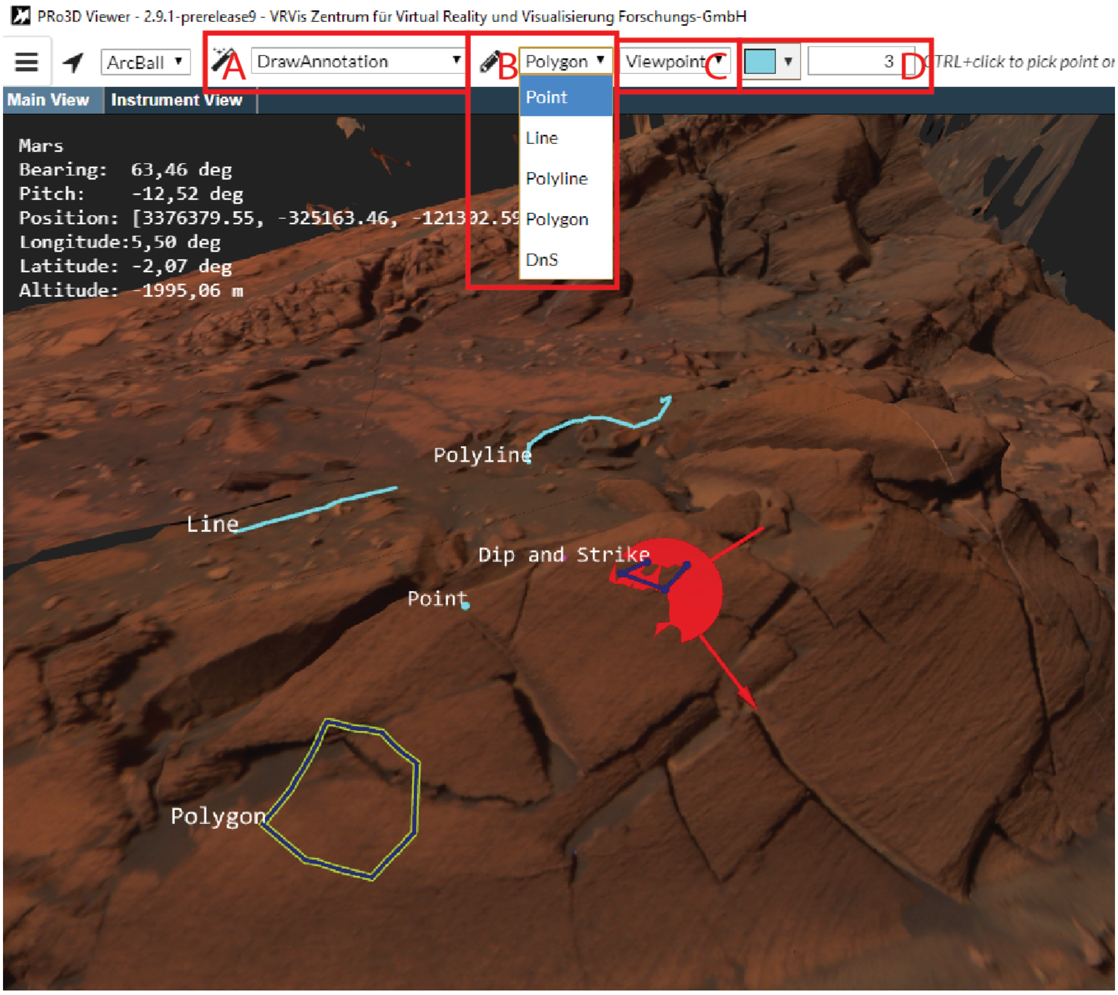


Figure 9: Annotation settings: **A**: set viewer action to "DrawAnnotation. **B**: select annotation mode. **C**: select projection. **D**: choose color and thickness.

- *DnS*: (= *Dip and Strike*) A polyline onto a surface, e.g. alongside a rock layer can be picked. After clicking Enter, a plane is fitted (least squares) to this polyline (blue), which is then intersected with a horizontal plane, which gives us the so-called strike vector (red). This vector represents the direction within the plane with the least inclination and orthogonal to it is the dip vector (green) which shows the direction of highest inclination as shown in Figure 9.

To pick an annotation point on the surface press CTRL+LMB.
For all annotations (except Point) you can choose between "Linear", "ViewPoint" and "Sky" projection which determines the direction of the picking ray (C in Figure 9):

- *Linear*: produces straight line segments as point-to-point connections with linear interpolation between them, no actual projection is performed (Figure 10, blue line). This is useful for line-of-flight distance measurements or measuring the height of a cliff or determining its slope.

- *ViewPoint*: between two points we sample the space by shooting additional rays to intersect with the surface, in this case along the view direction (Figure 10, green line). This is helpful to measure details in nooks and crannies of a rough surface and is the typical way to go for geological measurements.
- *Sky*: the same sampling happens as for the viewpoint projection but this time the rays are shot along the scene's up-vector (Figure 10, pink line). This mode is useful for geographical measurements to estimate the length of a path through a crater.

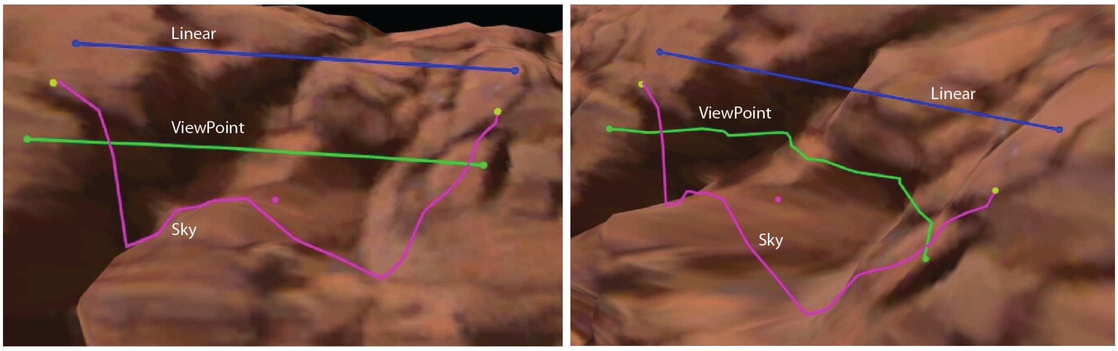


Figure 10: Three Lines taken from the same camera position (left) with the same camera settings but with different line projections.

Finally you can set the color and thickness of the annotation (D in Figure 9). Section 4.2 shows how to maintain, group and edit existing annotations.

3.4 Pick Annotation

There are two ways to select an annotation:

1. You can select an annotation by clicking on the annotation's name in the annotation's listing described in Section 4.2.
2. Or you set "PickAnnotation" in the actions menu, press CTRL+LMB and pick the annotation in the main view.

Then the annotation turns its color to green in the listing and gets a green border in the main view as shown in Figure 9, where the Polygon is selected. Once selected, you can explore and adjust the annotation's properties (see Section 4.2).

3.5 Pick Surface

There are two ways to select a surface:

1. You can select a surface by clicking on the surface's name in the surface's listing described in Section 4.1.

2. Or you set “PickSurface” in the actions menu, press CTRL+LMB and pick the surface in the main view.

Then the surface’s name turns its color to green in the listing. Once selected, you can explore and adjust the surface’s properties (see Section 4.1).

4 Viewer Features

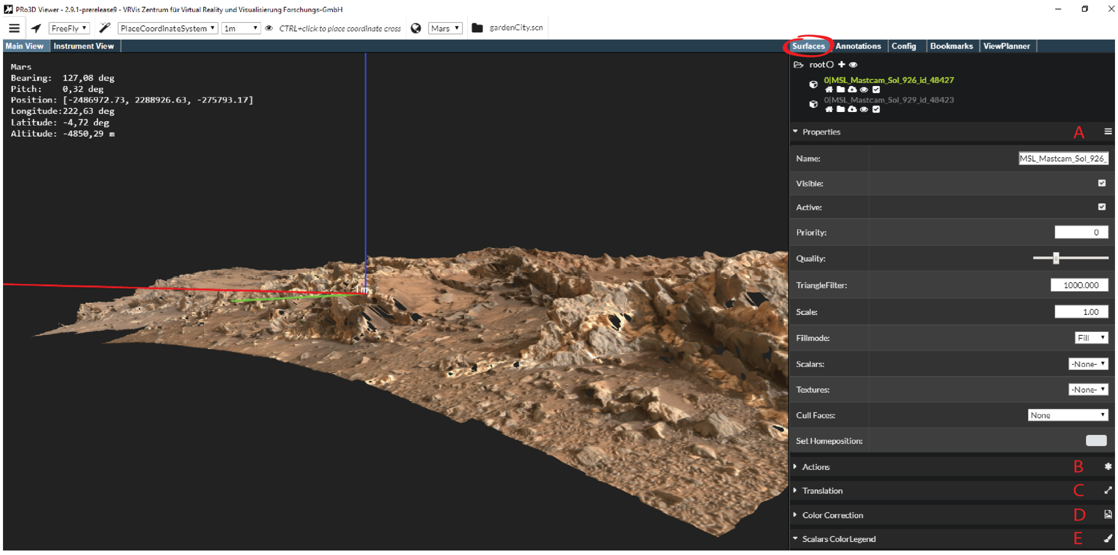


Figure 11: There are pages (right) for each feature in the viewer.

The feature pages show a list of the respective features, the properties of the selected feature from this list, and some actions for this feature. For surfaces, annotations, and bookmarks it is possible to group them, as described in Section 4.5.

4.1 Surfaces

The listing shows all surfaces in the scene. You can classify them in any group and subgroup layers, described in Section 4.5. You can select a surface by clicking on the surface's name, which turns its color to green. Or you can set "PickSurface" in the actions menu (Figure 6), press CTRL+LMB and pick the surface in the main view. Then you can see the surface's properties in the properties panel and use the actions in the actions panel. It is also possible to select multiple surfaces by clicking the square icon in front of each surface. The selected surfaces have a green square in the list. The multiselection is used to move one ore more surfaces from one group to the active group. Under the surface's name is a little menu:

- *FlyTo*: A click on the button triggers a FlyTo animation.
- *openFolder*: Opens the folder where the scene file resides.
- *Cloud*: Creates new kd-tree files.
- *Toggle Visible*: Toggles the surface visible/invisible.
- *Toggle IsActice*: You can only pick on active surfaces (explore center, annotations, ...).

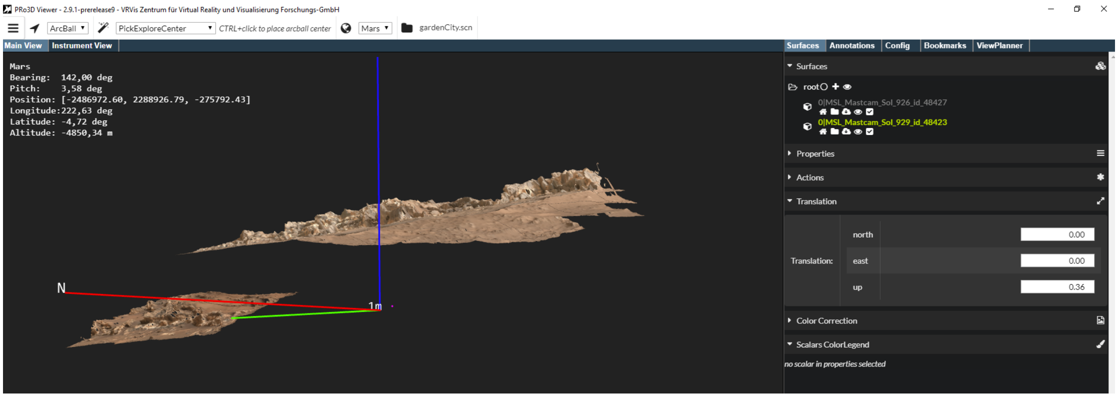


Figure 12: Translation of the selected surface along the axes of the coordinate system.

For each selected surface there are several panels as shown in Figure 11 A to E.
In the surface properties panel (Figure 11 A) some adjustments are possible:

- *Name*: The surface's name. You can change it in the text field and press "enter".
- *Visible*: The surface is visible (checked) or not (unchecked).
- *Active*: The surface is active (checked) or not (unchecked). You can only pick on active surfaces.
- *Priority*: Often multiple surfaces are available for a certain area on the planet surface. These surfaces represent the same piece of ground and typically overlap. This parameter allows you to assign a priority to a surface to tell the graphics card which surface should be rendered in front. Lower numbers mean a higher priority in rendering, with 0 being the highest priority. You can also give the highest priority surface a ranking of, for instance, 0.1 (= 10cm) to make annotations more visible. The priority can be dynamically changed via the surface properties so you can try out what works best.
- *Quality*:
- *TriangleFilter*: Excludes triangles with edges bigger than the entered value.
- *Scale*:
- *FillMode*: You can switch between solid/ wireframe/ point rendering of the geometry.
- *Scalars*: Select an attribute layer.
- *Textures*: Select a texture layer.
- *Cull Faces*:

- *Set Homeposition*: You set a new camera position for FlyTo.

The surfaces actions (Figure 11 B) are described in Section 4.5.2.

You can translate the surface along the north-, east and up axis of the coordinate system, described in Section 3.2. And you can rotate the surface around the up vector of the coordinate system. The Translation panel is shown in Figure 11 B and Figure 12.

NOTE: Translation and Rotation only work for surfaces. Annotations, Rovers, the Coordinate System, etc. will NOT move with the surface. You have to transform the surface first!

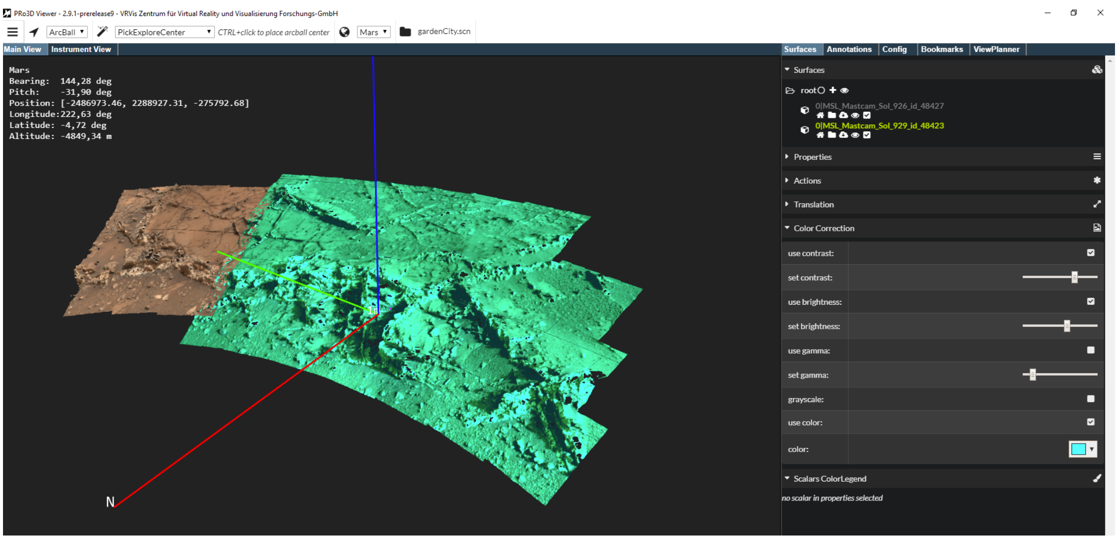


Figure 13: Contrast-, brightness- and color filters applied on the selected surface.

You can apply different color correction filters on the selected surface (Figure 13).

Within the effort of including more and more meta data for a surface we included the so-called SurfaceAttributes (see Figure 14), which are specified in an .opcx file carrying the name of the respective surface. For now, these surface attributes mainly contain additional layers, which can either be a texture layer or an attribute layer. Texture layers are just alternative texture maps that can be mapped onto the surface, such as images from different filters or even sensors (spectral image). Attribute maps on the other hand present an additional value for each position of a surface. If a surface has an .opcx file attached its layers are listed and can be selected in the *Scalars* and the *Textures* combo boxes as part of the surface's property control (Figure 11). In the Scalars ColorLegend panel, the color legend can be adjusted (Figure 14).

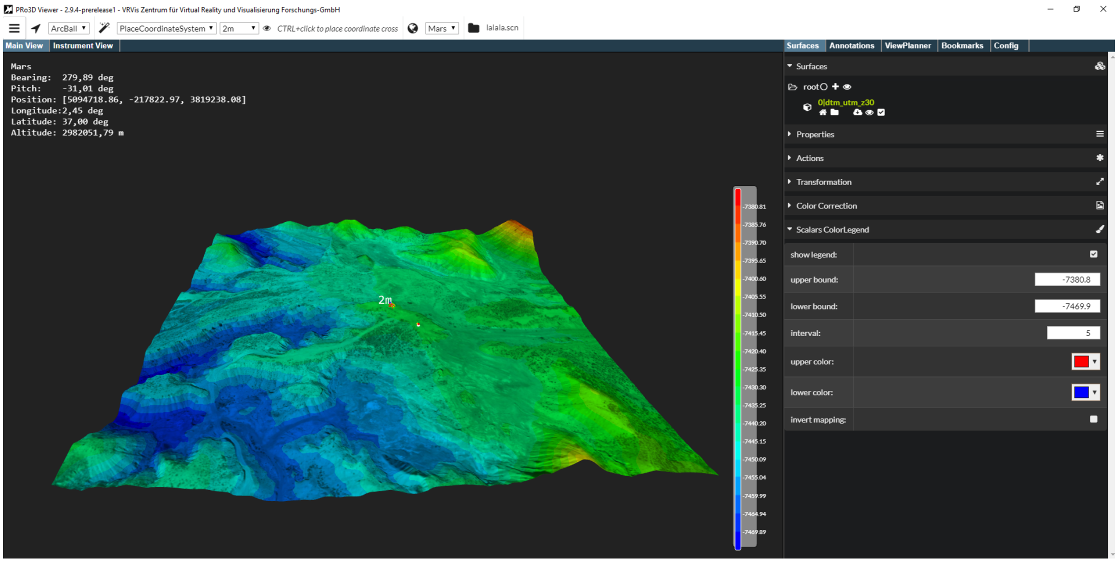


Figure 14: A height map visualized by false color mapping.

4.2 Annotations

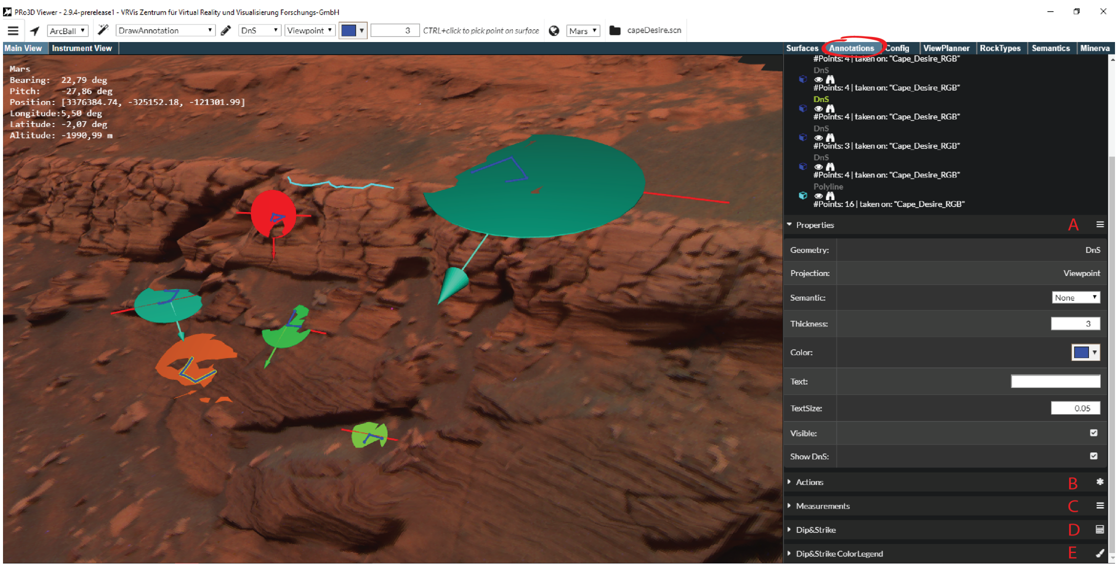


Figure 15: The annotations page.

The listing shows all annotations in the scene. You can classify them in any group and subgroup layers, described in Section 4.5. You can select an annotation by clicking on the annotation's name, which turns its color to green. Or you can set "PickAnnotation" in the actions menu (Figure 6), press CTRL+LMB and pick the annotation in the main view. Then you can see the annotation's properties in the properties panel and use the actions in the actions panel. It is also possible to select multiple annotations by clicking the square icon in front of each annotation. The selected annotations have a green square in the list. The multiselection is used to move one ore more annotations from one group to the active group.

Under the annotation's name is a little menu:

- *Toggle*: Toggles the annotation visible/invisible.
- *FlyTo*: A click on the button triggers a FlyTo animation.

For each selected annotation there are several panels as shown in Figure 15 A to E.
The properties of the selected annotation (click on annotation's name) are shown in Figure 15 A. There you can get information and change some of the settings:

- *Geometry*: Shows the annotation mode (described in Section 3.3). This is not changeable retrospectively.
- *Projection*: Shows the projection which determines the direction of the picking ray (described in Section 3.3, shown in Figure 10). This is not changeable retrospectively.
- *Semantic*:
- *Thickness*: You can change the annotation's line thickness.
- *Color*: You can change the annotation's color.
- *Text*: You can append a note. Write in the text field and press "Enter". The note will appear next to the annotation in the viewer.
- *TextSize*: You can change the textsize.
- *Visible*: The annotation is visible (checked) or not (unchecked).
- *ShowDnS*: For each annotation with more than three picking points Dip and Strike information (Section 3.3) is available. The DnS is visible (checked) or not (unchecked).

The annotations actions (Figure 15 B) are described in Section 4.5.2.

The measurements tab (Figure 15 C) contains some information:

- *Position*: Shows the position (only for point annotations).
- *PrintPosition*: Prints the position in the console window.
- *Height*: The height between the annotation's start and end point.
- *HeightDelta*: The height difference between the highest and lowest point of the projected line.
- *AvgAltitude*: The average altitude.
- *Length*: The sum of direct distances between the picking points.
- *WayLength*: The sum of projected distances between the picking points.

- *Bearing*: The annotation's bearing.
- *Slope*: The annotation's slope.
- *Vertical Distance*: The vertical distance between the annotation's start and end point in relation to the up vector of the coordinate system.
- *Horizontal Distance*: The horizontal distance between the annotation's start and end point in relation to the north- and right vector of the coordinate system.

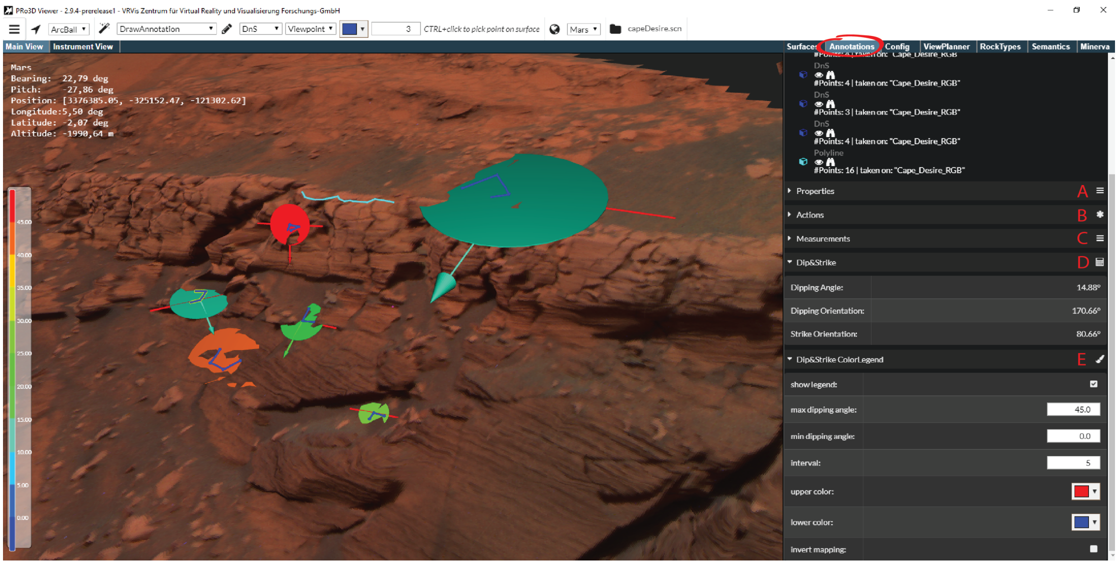


Figure 16: Colorcoding of the Dip&Strike annotations according to their dipping angles.

Measurements for the dip and strike annotations are shown in the Dip&Strike tab (Figure 15 D and Figure 16 D).

The color coding of the DnS annotation's discs and arrows is specified by the dipping angle. The color legend's parameters can be adjusted in the Dip&Strike ColorLegend tab shown in Figure 16 E.

4.3 Bookmarks

Bookmarks enable the user to record a certain camera viewpoint. To add a new bookmark click the "+" button on top of the page. The new bookmark is added to the active group in the bookmarks listing. To view the bookmark's properties and actions click on the bookmark's name. Clicking the "house" button beside the bookmark's name triggers a FlyTo. For multiselection click on the bookmark's square icons.

4.4 Viewer Configuration

To edit the viewer properties, select the "Config" page.

4.4.1 ViewerConfig

A set of major viewer properties can be adjusted:

- *Near/Far Plane*: The near- and the far clipping plane are automatically adjusted according to the data to be rendered. The set values are shown in the config panel and can be adjusted afterwards.
- *Navigation Sensitivity*: The navigation sensitivity can also be adjusted by PageUp and PageDown keys.
- *Arrow Length/Thickness*: The arrow length and thickness is set for up- and north vectors, dip and strike vectors and the up- and lookAt vectors in the rover view planner.
- *D+S Plane Size*: The dip and strike measurements plane size, described in Section 3.3 (Figure 9).
- *Min/Max Dipping Angle*: The dip and strike measurements dipping angle range. The dipping angle is coded into the color of the disc and arrow of a measurement (Figure 9).
- *Lod Colors*: The different levels of detail of the surface geometry can be colored in different shades of red. This helps to evaluate the export of OPC data.

4.4.2 Coordinate System

The coordinate system menu shows the position, Up- and North Vector of the coordinate system described in Section 3.2, shown in Figure 8. The Up- and the North Vector are used for the projection measurements (Figure 9). Initially the Up Vector's direction is set in the positive z-direction and the North Vector's in the positive y-direction. But you can manipulate the Up Vector manually for different data. Both vectors are computed automatically with picking of a new position for the coordinate system. The north vector is further relevant for bearing measurements.

4.4.3 Camera

The Camera submenu shows the Location, Forward- and Sky vector of the main camera.

4.5 Grouping

Grouping is possible for surfaces, annotations and bookmarks. The “root” group is the highest level where you can add leafs and subgroups. Each group has a context menu:

* *Set Active*: The active group gets the new leaf. Per default the “root” is active.
* *Add Group*: Adds a new and empty subgroup.
* *Toggle Group*: Sets all leafs in this group and its subgroups invisible.

4.5.1 Group Actions

* *Remove*: Removes the group with all its leafs and subgroups.
* *Clear*: Removes all leafs and subgroups from group but retains the empty group.
* *Selection: Move*: Moves all selected leafs (green squares) to the active group.
* *Selection: Clear*: Clears the selection (the leafs were not removed).

4.5.2 Leaf Actions

* *Remove*: Removes the leaf.
* *Selection: Move*: Moves all selected leafs (green squares) to the active group.
* *Selection: Clear*: Clears the selection (the leafs were not removed).

4.6 View Planner

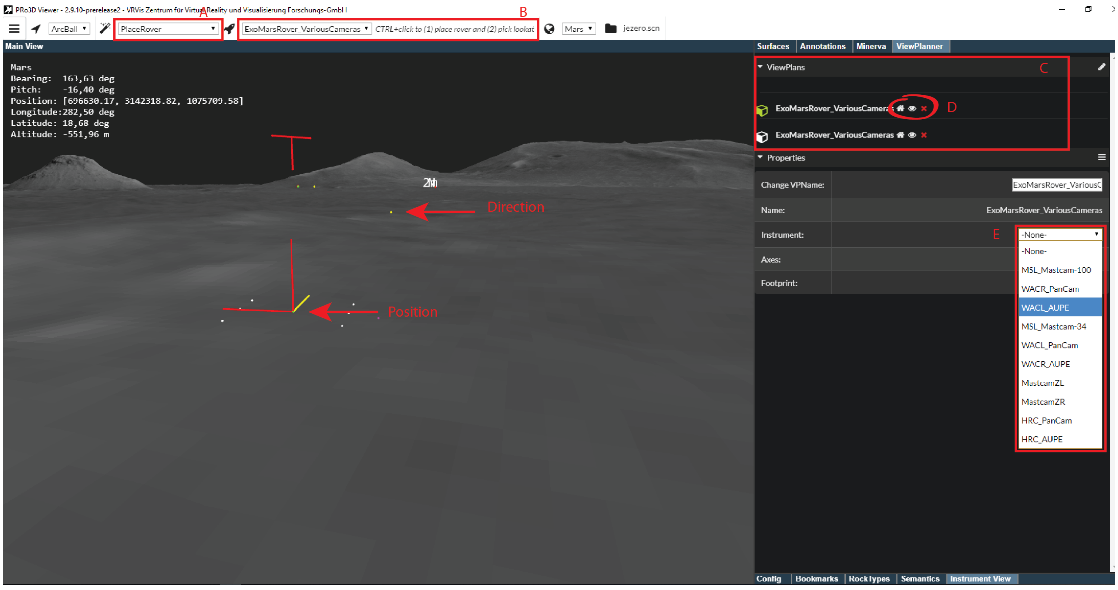


Figure 17: The view planner. The rover is placed on the surface in the main view (left). All rovers in the scene are listed in the ViewPlanner tab (right).

To use the View Planner make sure that a **rover.xml** file is in the **`Release\InstrumentStuff`** folder. Then you can place one or more rover into your scene. Therefore set "PlaceRover" in the actions menu (Figure 17 A), select a rover model in the rover menu (Figure 17 B), press CTRL+LMB and pick two points on the surface in the main view. The first point (green) is the position and the second point (yellow) the viewing direction of the rover. In the ViewPlanner tab is a listing that shows all ViewPlans in the scene (Figure 17 C). There is a little menu beside each ViewPlan shown in Figure 17 D:

- FlyTo: clicking on the "house button" triggers an animation to the camera position from where the rover placement happened.
- (In)Visible: switch the rover to visible\invisible.
- Remove: clicking on the red "x" removes the View Plan from the list and the view.

Select a view plan by clicking on the square icon in front of it to adjust it's properties:

- ChangeVPName: change the name and press the enter button.
- Name: shows the rover's name.
- Instrument: select an instrument (camera) from the list (Figure 17 E).

When a camera is selected you can change the instrument parameters as shown in Figure 18 A:

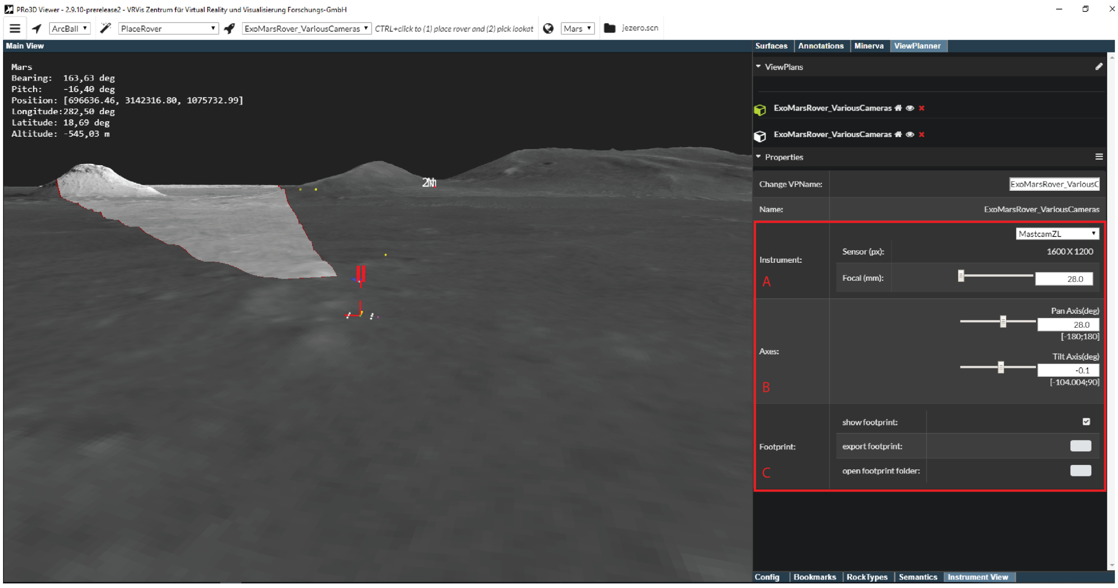


Figure 18: The footprint for the selected camera is shown in light gray on the surface in the main view. In the properties panel (right) you can adjust the rover and camera parameters.

- Sensor (px): the image size in pixel.
- Focal (mm): the focal length of the camera sensor (zoom).

You can also change the rover's pan- and tilt axis (in degree) (Figure 18 B). In the main view the footprint of the selected camera is shown in light gray. For the footprint there are following settings:

- show footprint: you can enable\disable the footprint in the main view.
- export footprint: you get one screenshot from the main view, one from the instrument view (Figure 19) and a ***.svx** file with diverse meta information.
- open footprint folder: opens the folder with the screenshots and the meta file.

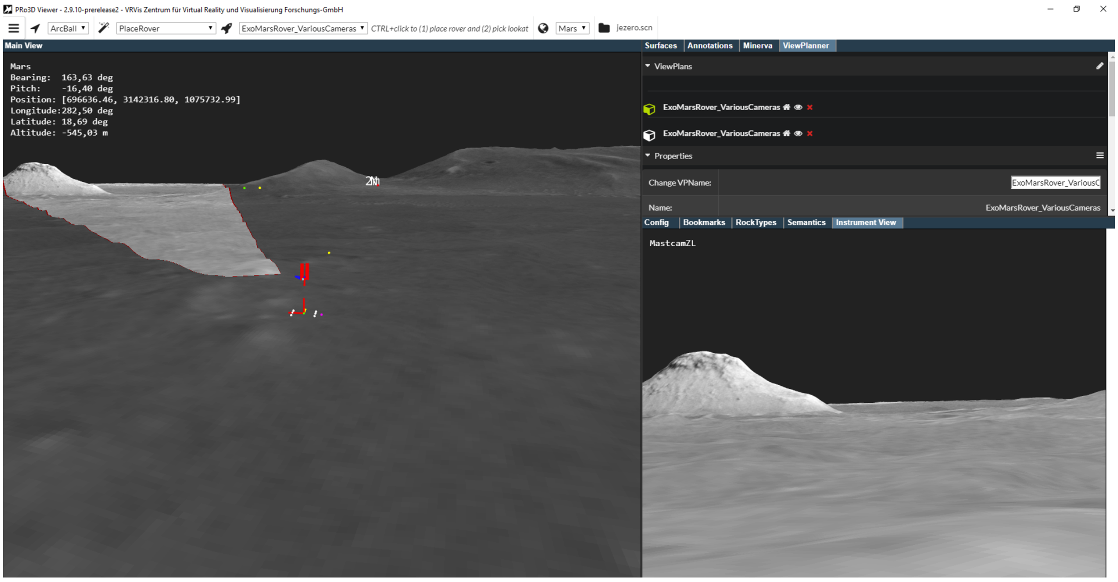


Figure 19: The instrument view (right) shows the instrument's camera view.

5 Minerva

Figure 20: The Minerva Application. The Main View (left) shows the surface data with the products. There are different interaction possibilities for the products in the Minerva tab (right). A: Visplore communication, B: Query App to reduce the shown products by the mean of different criteria, C: Product listing, D: Properties of the last selected product, E: Surface tab.

5.1 Start Minerva

Before you start the Minerva Application make sure that the **dump.csv** file is in the `Release\netcoreapp2.0\MinervaData` folder. Then start the viewer by clicking the PRo3D.exe as described in Section 2. The Minerva data from the dump.csv file is loaded and the products are listed in the "Minerva" tab as shown in Figure 20 C. Load the surface data as described in Section 2.1. How to explore and adjust the surfaces is described in Section 4.1. You can save the scene as described in Section 2.1.

5.2 Minerva Features

5.2.1 Visplore

Visplore is a powerful visual analytics tool that allows the handling of huge and heterogeneous data and provides different perspectives onto the data that help finding causalities and allow an easy examination of the data's plausibility. For this project an interface was implemented that allows an interconnected work-flow between PRo3D and Visplore. To communicate with Visplore use the tree buttons shown in Figure 20 A:

- **Connect:** Connect to Visplore.

- **Send Selection:** Send the selected products to Visplore.
- **Snapshot:** Send a snapshot of the MainView to the Visplore MapView.

For more information how to use Visplore for Minerva, please refer to the Visplore manual.

5.2.2 QueryApp

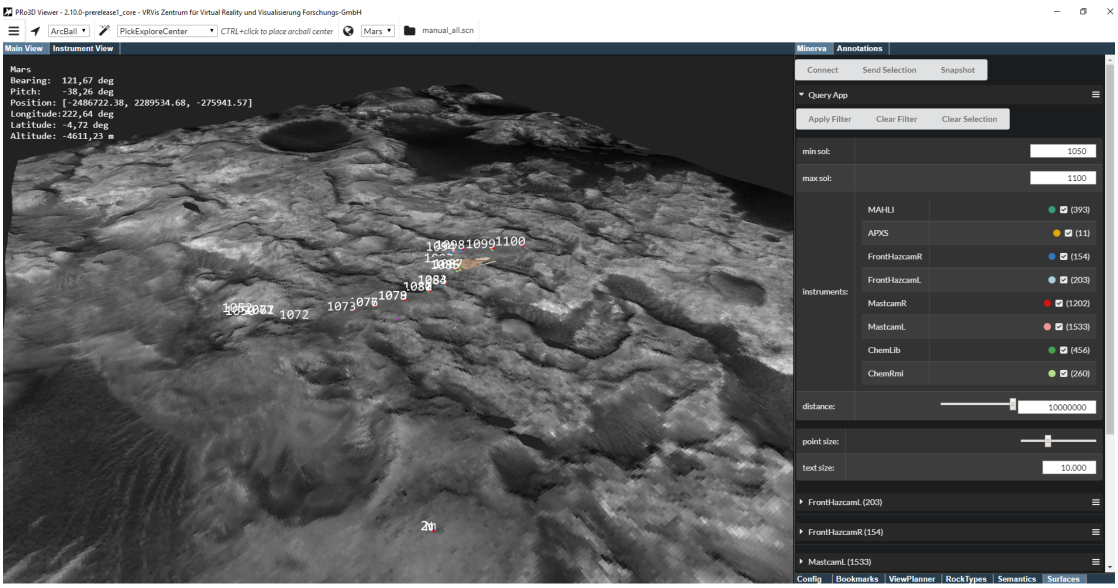


Figure 21: The Query App (right).

The Query App provides the possibility to cut down the number of shown products by the mean of different criteria. These criteria are:

- **min- and max sol:** All products with sol numbers in the given range are shown.
- **instruments:** Only the products with checked instruments are shown.
- **distance:** The distance between the camera location and the shown products is less than the entered distance value.

You can use one ore more criteria and press the **"ApplyFilter"** button in top of the Query App menu. Now only the filtered products are shown. Change the queries and click "ApplyFilter" again to change the shown products. To get all products click the **"ClearFilter"** button. You can also change the **point size** of the rendered products in the Main View, and the **text size** of the shown sol numbers.

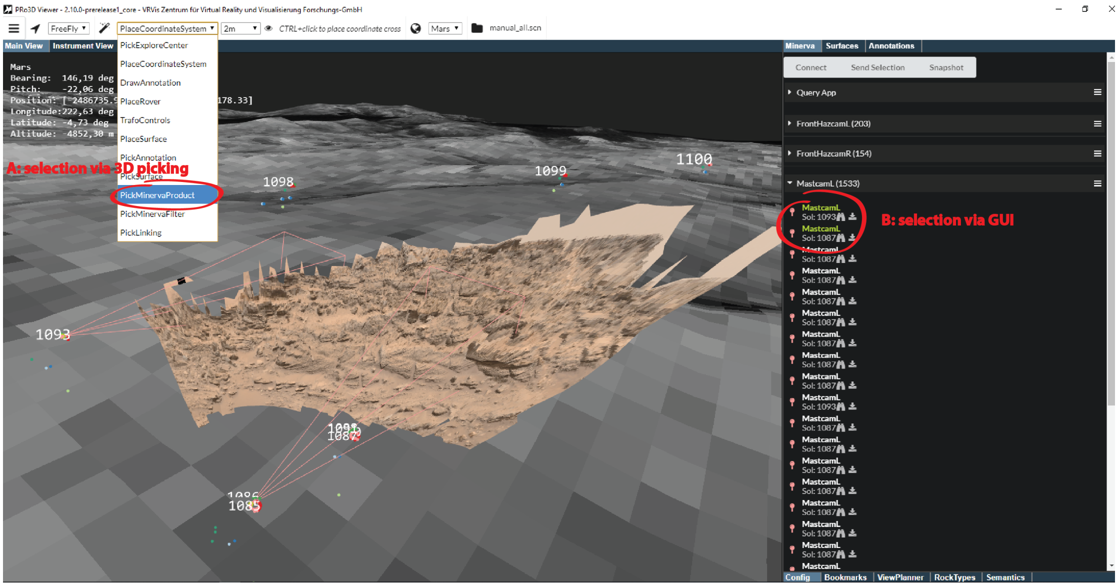


Figure 22: The products are grouped by instruments. A product can either be selected in the listing (B) or in the Main View (A).

5.2.3 Product Listing and Selection

The products are grouped in the gui by their instruments (Figure 20 C) where the first 20 products for each instrument are listed. You can select single products by clicking on the products's name, which turns its color to green. Or you can set "PickMinervaProduct" in the actions menu (Figure 22), press CTRL+LMB and pick the product in the main view. Then you can see the product's properties in the properties panel, described in the next Section 5.2.4.

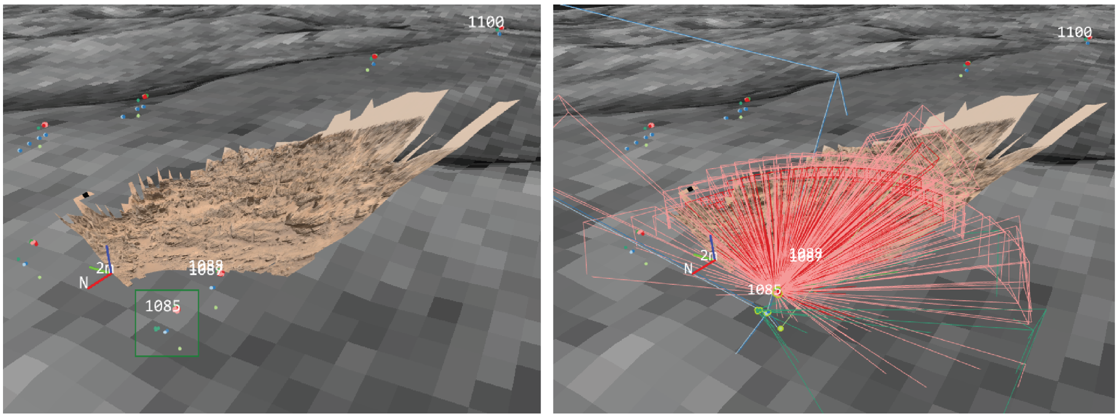


Figure 23: A rectangle is spanned over multiple products (left). All products selected by the rectangle (right).

It is also possible to select multiple products. Press SHIFT+LMB and drag a rectangle (Figure 23 left). When you release the LMB, all products in this area are selected (Figure 23 right).
Under the products's name is a little menu:

- **The Sol Number**

- **FlyTo**: A click on the button triggers a FlyTo animation.
- **GetTif**: Downloads the product's tif image.

5.2.4 Product Properties

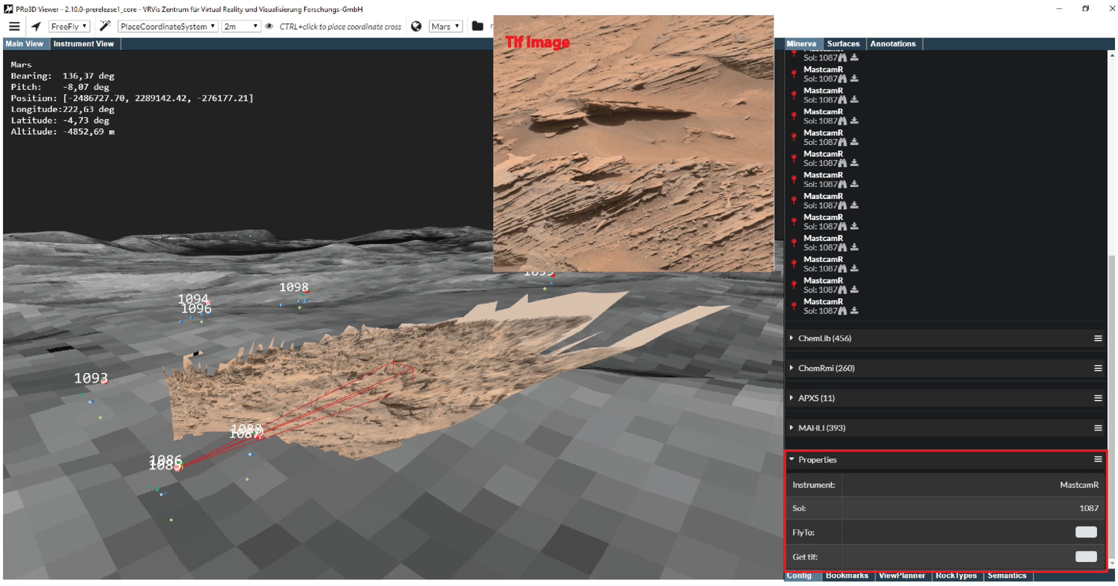


Figure 24: The properties panel shows the sol number and provides interactions for the last selected product.

The properties panel (Figure 20 D and Figure 24) shows

- **The Sol Number**
- **FlyTo**: A click on the button triggers a FlyTo animation.
- **GetTif**: Downloads the product's tif image. The image is stored in the `Release\netcoreapp2.0\MinervaData` folder.

of the last selected product.

5.3 Picking Actions

There are three minerva picking actions in the picking actions drop down menu shown in Figure 26.

- **PickMinervaProduct**: You can set "PickMinervaProduct" in the actions menu to select a product in the Main View as described in Section 5.2.3.
- **PickMinervaFilter**: Select "PickMinervaFilter" in the actions menu and press CTRL+LMB to pick a point on the surface. Then set a distance value with the distance slider in the Query App and click the "ApplyFilter" button. The products where the distance to the selected point is smaller than the selected distance in the Query App are shown (Figure 25).

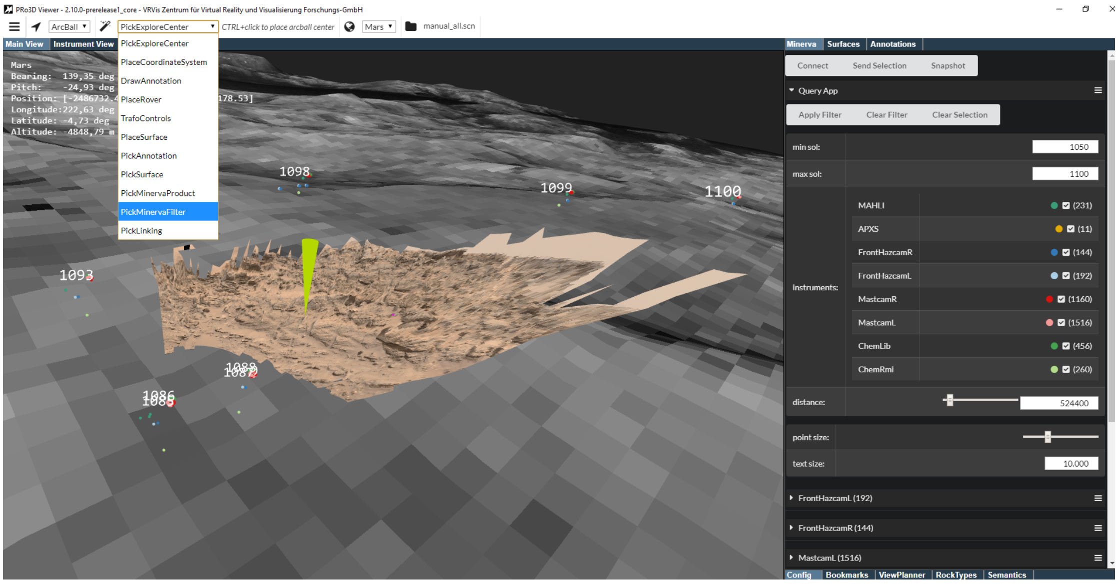


Figure 25: PickMinervaFilter

- **PickLinking**: Select “PickLinking” in the actions menu and press CTRL+LMB to pick a point on the surface. All camera frustums of the products that captures the selected point are shown (Figure 26).

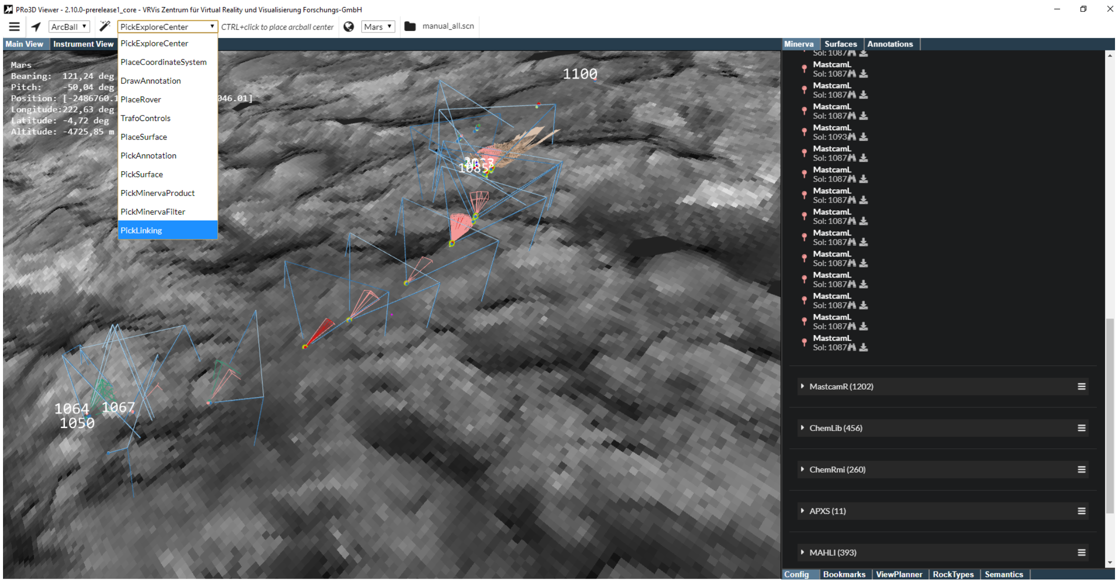


Figure 26: PickLinking

Parameter		Comment
fieldOfView	required	
resolution	required	resolution of the output image
snapshots	required	each entry in this list will result in one output image
filename	required	name of the output file
view	required	camera parameters
forward	required	forward vector of the camera
location	required	location of the camera
up	required	up vector of the camera
surfaceUpdates	optional	
opcname	required	name of the surface to be transformed
trafo	optional	transformation to be applied to the surface
visible	optional	visibility of the surface

Table 1: Available parameters for a PRo3D Snapshot file

6 PRo3D Command Line Interface

The PRo3D SnapshotViewer can produce rendered images in a batch process via the command line. For this process, *snapshot files* are used. They are in the JSON format, and contain transformations for each rendered image. There are two types of snapshot files: One type that only transforms camera parameters, and another that can be used to transform surfaces as well. This section describes the format of these files, and how they can be used with PRo3D to render an arbitrary number of images.

6.1 PRo3D Snapshot Files

Snapshot files have the JSON format, and need to follow a distinct scheme to be usable with PRo3D. Examples can be found in section 6.3.
Field of view and resolution of the resulting image are only specified once, at the beginning of the file. The parameter *snapshots* contains one entry for each output image. Table 6.1 lists all available parameters of the format.

6.2 Arguments and Features

The `-help` flag will provide you with a full list of possible command line arguments for PRo3D. Table 2 lists all available arguments.

```
PRo3D.SnapshotViewer.exe --help
```

The simplest way to start the rendering process is to start PRo3D from the command line with only the path to the OPC file(s) and the snapshot file:

Argument	Description
–help	show help
–obj [path];[path];[path];[...]	load OBJ(s) from one or more paths
–opc [path];[path];[path];[...]	load OPC(s) from one or more paths
–asnap [path\snapshot.json]	path to a snapshot file, refer to PRo3D User Manual for the correct format
–out [path]	path to a folder where output images will be saved; if the folder does not exist it will be created
–renderDepth	render the depth map as well and save it as an additional image file
–exitOnFinish	quit PRo3D once all screenshots have been saved
–verbose	use verbose mode
–excentre	show exploration centre
–refsystem	show reference system
–noMagFilter	turn off linear texture magnification filtering
–snap [path\snapshot.json]	path to a snapshot file containing camera views (old format)

Table 2: All arguments available for PRo3D's command line interface

```
PRo3D.SnapshotViewer.exe --opcs MyOPCs\firstOpc\;MyOPCs\secondOpc\ --
    asnap snapshots.JSON
```

The `-opcs` flag is followed by multiple paths to folders containing OPC surfaces separated with a semi colon. The `-asnap` flag is followed by the path to a snapshot file in the format described above, and as the examples in section 6.3. Make sure you are in the same directory as the *PRo3D.Viewer.exe* file or specify the path to that file in the command. Paths can be either absolute or relative. The root of relative paths is the directory in which PRo3D.Viewer.exe is located. The flag `-snap` is used for legacy files which do not contain surface updates, and do not group the view parameters under a *view* entry.

To specify an output folder use the `-out` flag:

```
PRo3D.SnapshotViewer.exe --opcs MyOPCs\firstOpc\;MyOPCs\secondOpc\ --
    asnap snapshots.JSON --out MyImages\Renderd
```

If no output folder is specified, the images will be placed in the folder in which PRo3D.Viewer.exe is located.

6.3 Examples

The examples listed below will result in two rendered images. By adding more blocks describing snapshots (beginning with curly brackets "filename", and ending with the corresponding closing curly bracket), any number of images can be produced.

Listing 1: Snapshot file example with camera- and surface transformations.

```
{
  "fieldOfView": 5.47,
  "resolution": "[1024, 1024]",
  "snapshots": [
    {
      "filename": "MySnapshot_01",
      "view": {
        "forward": "[0.88, -0.16, -0.42]",
        "location": "[-26657.72, 4862.62, 12890.12]",
        "up": "[0.42, -0.07, 0.90]"
      },
      "surfaceUpdates": [
        {
          "opcname": "FirstOpc",
          "trafo": "[[[-0.65, 0.75, 0.06, 0.0], [0.75, 0.65, -0.08, 0.0], [-0.10, -0.00, -0.99, 0.0], [0.0, 0.0, 0.0, 1.0]], [[-0.65, 0.75, -0.10, -0.0], [0.75, 0.65, -0.00, -0.0], [0.06, -0.08, -0.99, 0.0], [-0.0, 0.0, 0.0, 1.0]]]"
        },
        {
          "opcname": "SecondOpc",
          "trafo": "[[[0.70, 0.70, 0.06, 990.57], [0.70, -0.70, -0.08, 620.55], [-0.00, 0.10, -0.99, 16.95], [0.0, 0.0, 0.0, 1.0]], [[0.70, 0.70, -0.00, -11], [0.70, -0.70, 0.10, -264.70], [0.06, -0.08, -0.99, 0.00], [-0.0, 0.0, -0.0, 1.0]]]"
        }
      ]
    },
      {
        "filename": "MySnapshot_02",
        "view": {
          "forward": "[0.99, -0.08, 0.00]",
          "location": "[-26770.92, 2327.97, -260.80]",
          "up": "[0.42, -0.07, 0.90]"
        },
        "surfaceUpdates": [
          {
            "opcname": "FirstOpc",
            "trafo": "[[[-0.17, 0.98, 0.06, 0.0], [0.98, 0.17, -0.08, 0.0], [-0.09, 0.05, -0.99, 0.0], [0.0, 0.0, 0.0, 1.0]], [[-0.17, 0.98, -0.09, -0.0], [0.98, 0.17, 0.05, -0.0], [0.06, -0.08, -0.99, 0.0], [-0.0, 0.0, 0.0, 1.0]]]"
```

```
          },
          {
            "opcname": "SecondOpc",
            "trafo": "[[[-0.95, 0.28, 0.06, -1015.60], [0.27, 0.95, -0.08, 567.53], [-0.08, -0.05, -0.99, -114.30], [0.0, 0.0, 0.0, 1.0]], [[-0.95, 0.27, -0.08, -1139.05], [0.28, 0.95, -0.05, -263.01], [0.06, -0.08, -0.99, 0.00], [-0.0, 0.0, 0.0, 1.0]]]"
          }
        ]
      }
  ],
  "version": 0
}
```

Listing 2: Snapshot file example with camera transformations.

```
{
  "fieldOfView": 5.47,
  "resolution": "[1024, 1024]",
  "snapshots": [
    {
      "filename": "MySnapshot_01",
      "view": {
        "forward": "[0.88, -0.16, -0.42]",
        "location": "[-26657.72, 4862.62, 12890.12]",
        "up": "[0.42, -0.07, 0.90]"
      }
    },
    {
      "filename": "MySnapshot_02",
      "view": {
        "forward": "[0.99, -0.08, 0.00]",
        "location": "[-26770.92, 2327.97, -260.80]",
        "up": "[0.42, -0.07, 0.90]"
      }
    }
  ],
  "version": 0
}
```

Listing 3: Snapshot file example with surface transformations and visibility of the surfaces.

```
{
  "fieldOfView": 5.47,
  "resolution": "[1024, 1024]",
  "snapshots": [
    {
      "filename": "MySnapshot_01",
      "view": {
```

```
        "forward": "[0.88, -0.16, -0.42]",
        "location": "[-26657.72, 4862.62, 12890.12]",
        "up": "[0.42, -0.07, 0.90]"
      },
      "surfaceUpdates": [
        {
          "opcname": "FirstOpc",
          "trafo": "[[[-0.65, 0.75, 0.06, 0.0], [0.75, 0.65, -0.08, 0.0], [-0.10, -0.00, -0.99, 0.0], [0.0, 0.0, 0.0, 1.0]], [[-0.65, 0.75, -0.10, -0.0], [0.75, 0.65, -0.00, -0.0], [0.06, -0.08, -0.99, 0.0], [-0.0, 0.0, 0.0, 1.0]]]",
          "visible": true
        },
        {
          "opcname": "SecondOpc",
          "trafo": "[[[0.70, 0.70, 0.06, 990.57], [0.70, -0.70, -0.08, 620.55], [-0.00, 0.10, -0.99, 16.95], [0.0, 0.0, 0.0, 1.0]], [[0.70, 0.70, -0.00, -11], [0.70, -0.70, 0.10, -264.70], [0.06, -0.08, -0.99, 0.00], [-0.0, 0.0, -0.0, 1.0]]]",
          "visible": false
        }
      ]
    },
      {
        "filename": "MySnapshot_02",
        "view": {
          "forward": "[0.99, -0.08, 0.00]",
          "location": "[-26770.92, 2327.97, -260.80]",
          "up": "[0.42, -0.07, 0.90]"
        },
        "surfaceUpdates": [
          {
            "opcname": "FirstOpc",
            "trafo": "[[[-0.17, 0.98, 0.06, 0.0], [0.98, 0.17, -0.08, 0.0], [-0.09, 0.05, -0.99, 0.0], [0.0, 0.0, 0.0, 1.0]], [[-0.17, 0.98, -0.09, -0.0], [0.98, 0.17, 0.05, -0.0], [0.06, -0.08, -0.99, 0.0], [-0.0, 0.0, 0.0, 1.0]]]",
            "visible": true
          },
          {
            "opcname": "SecondOpc",
            "trafo": "[[[-0.95, 0.28, 0.06, -1015.60], [0.27, 0.95, -0.08, 567.53], [-0.08, -0.05, -0.99, -114.30], [0.0, 0.0, 0.0, 1.0]], [[-0.95, 0.27, -0.08, -1139.05], [0.28, 0.95, -0.05, -263.01], [0.06, -0.08, -0.99, 0.00], [-0.0, 0.0, 0.0, 1.0]]]",
```

```
              "visible": false
            }
          ]
        }
  ],
  "version": 0
}
```

7 Surface Comparison Extension

PRo3D can be used to compare features of two surfaces. To activate the surface comparison features, go to the menu and select *Change Mode* and then *Surface Comparison*. You will see the Surface Comparison features (figure 27). Make sure that the two surfaces have different names, or some features might not work as expected. You can rename a surface in the *Surface* tab in the *Properties* section.

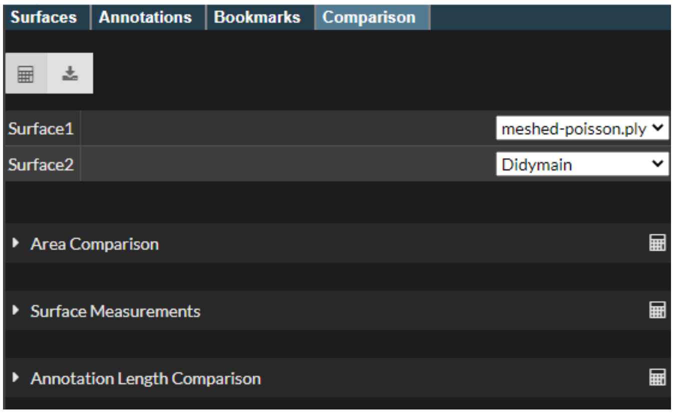


Figure 27: The Surface Comparison Interface.

In the drop down boxes labelled *Surface1* and *Surface2* you can select the surfaces you wish to compare. Once you have selected two surfaces, you can toggle their visibility using the `t` button on your keyboard. The calculation of surface measurements is also triggered by selecting two surfaces. You can update the measurements by clicking on the button with the calculator icon (figure 32). To export all measurements click on button with the download icon (figure 28). The measurements will be saved in the PRo3D home directory. The full path is printed on the console when exporting.

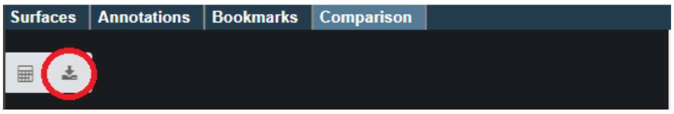


Figure 28: The *export* button is circled in red. Click on this button to export all listed measurements.

7.1 Comparing Selected Areas

Make sure that two surfaces are loaded and selected in the *Comparison* tab. In the menu bar above the 3D-View, choose *Select Area* from the drop down (figure 29).
Hold the control key on your keyboard and click on a point on a surface to choose a location. You might need to click twice, if the 3D-View is not in focus. Once you have selected a location, a translucent sphere indicates the selected area (figure 30). You can make this sphere smaller by pressing the *minus* key,

Figure 29: Selecting an area to compare.

bigger by pressing the *plus* key on your keyboard. You can only change an area's size if *Select Area* is selected. All vertices within a certain distance to the selected location are taken into account (in other words, the area is spherical).

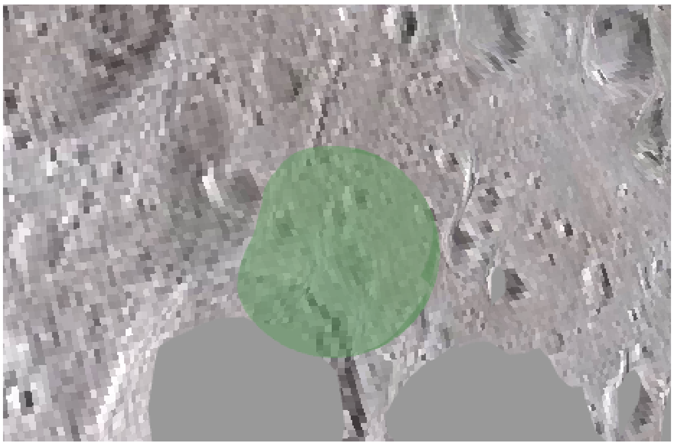


Figure 30: A selected area.

All areas you have created are displayed in a list (figure 31). If you wish to change the location of an area, simply delete it by clicking on the red cross and select a new location.

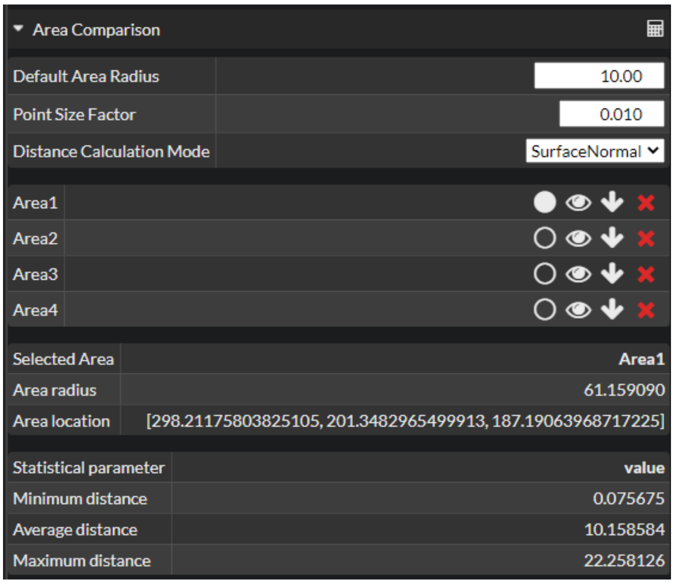


Figure 31: The interface for area comparison.

The following settings area available for area comparison:

- **Default Area Radius** The initial radius of an area when it is created. Set this according to the scale of your models.

- **Point Size Factor** The size of the little coloured spheres in the visualisation of differences between the two surfaces. Given an area size a, and a factor f, the size of the coloured spheres is $a * f$. Increase this factor to make the coloured spheres bigger and decrease it to make them smaller.
- **Distance Calculation Mode** The SurfaceNormal mode can be used for any surfaces, if in doubt use this mode. Use the Spherical Mode only for spherical surfaces. *Technical Note: Distances are calculated by sending rays from the vertices of one surface towards the other surface and calculating the distance between the original vertex and the intersection of the ray with the other surface. In the default mode* SurfaceNormal*, the ray direction is determined by fitting a plane to the vertices in the selected area. In Spherical mode, the direction is calculated for each vertex individually based on the centre of the bounding box of the surface. For large areas on spherical surfaces this might be more suitable.*

In figure 31, *Area1* is selected. With the eye icon button you can set the visibility of an area. The arrow icon can be used to toggle the resolution of the vertex statistics analysis between lower and higher. This has a big effect if the two surfaces have a very different resolutions, and determines the vertices of which surface are used as a basis to calculate and visualise the differences between the two surfaces.
Once an area is to your liking, update the measurements by clicking on the calculator button (figure 32). Depending on the size of the area and the resolution of the surfaces, this might take a few seconds.

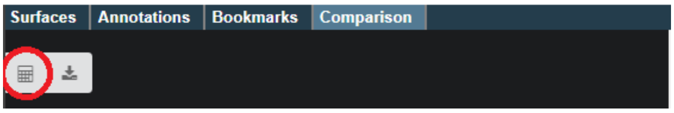


Figure 32: The *update* button is circled in red. To update all comparison calculations and visualisations click on this button.

Each location that was used to calculate the distance between the two surfaces is visualised with a coloured sphere (figure 33). The colour of the sphere encodes the distance, with red encoding large distances and green small distances. The concrete values assigned to each colour can be seen on the legend on the left. Area size, area location, and statistic parameters are displayed on the right hand side for the selected area. The legend is always valid for the selected area.
To explore the differences between the two surfaces in more detail, set one or both areas to invisible (in the surfaces tab, use the eye icon). Figure 34 shows the difference visualisation with both areas set to invisible.
Created areas are saved and loaded with the scene. Surface selection is not loaded, so make sure that two surfaces are selected before updating surface comparison calculations, or the calculations will not be updated.

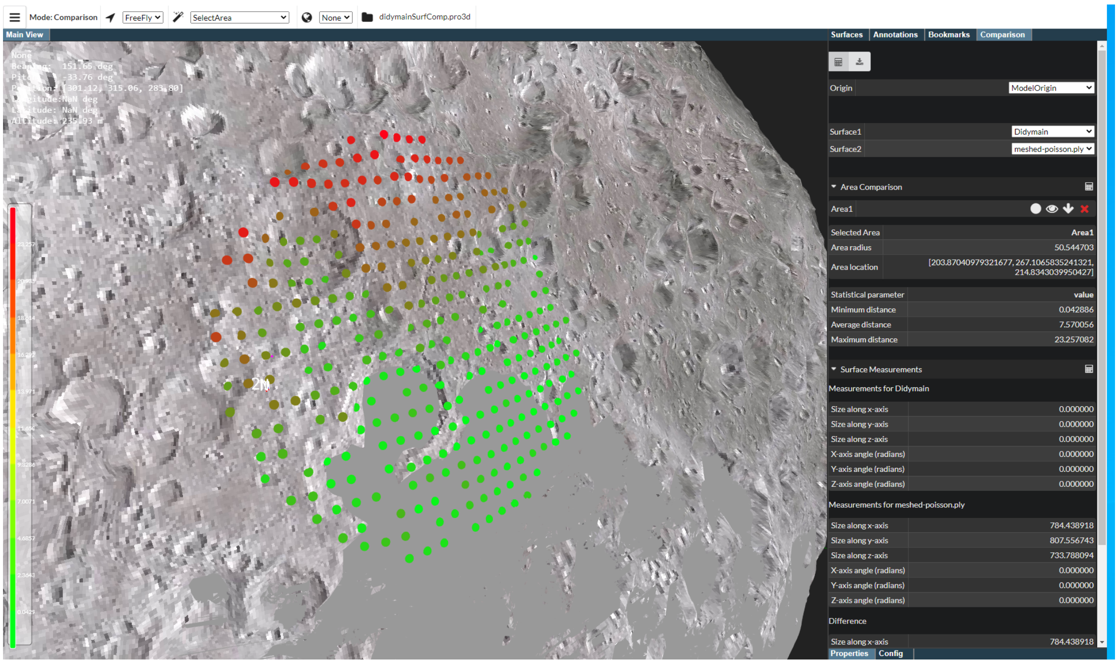


Figure 33: Comparing an area of two surfaces.

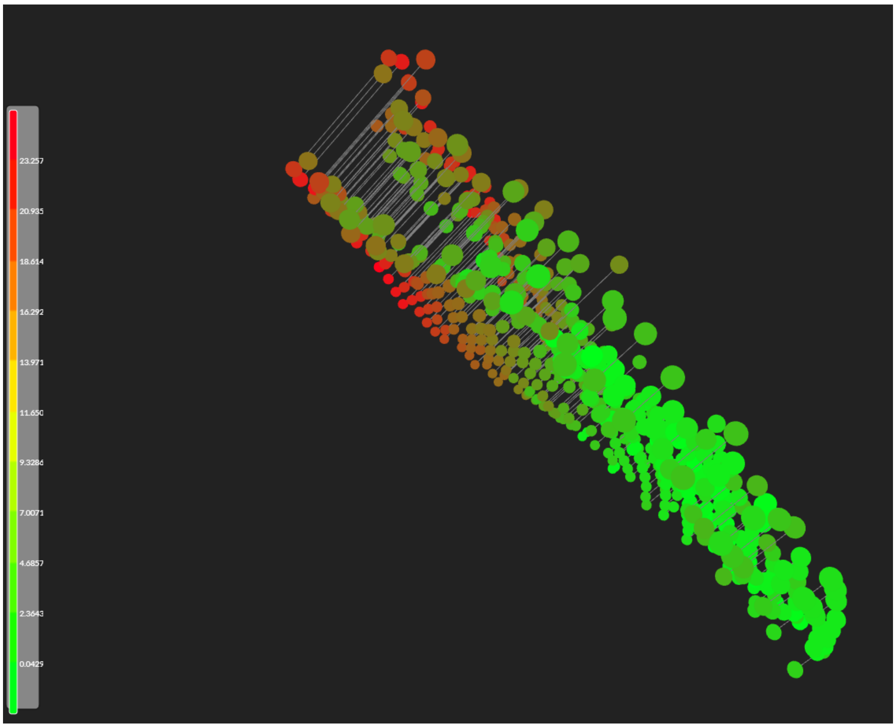


Figure 34: Visualising the differences between two surfaces on a vertex level. The surfaces have been set to invisible.

7.2 Surface Measurements

The size along the coordinate axes and the angle of the axes of the local coordinate systems of two surfaces can be compared in this section. The measurements for each surface are listed separately and below them the difference between these measurements.
Use the drop down labelled *Origin* to select which point should be used as the centre of a surface for various calculations. If there are holes in the model the calculation might fail. Choosing a different Origin in the drop down menu can help in these cases.

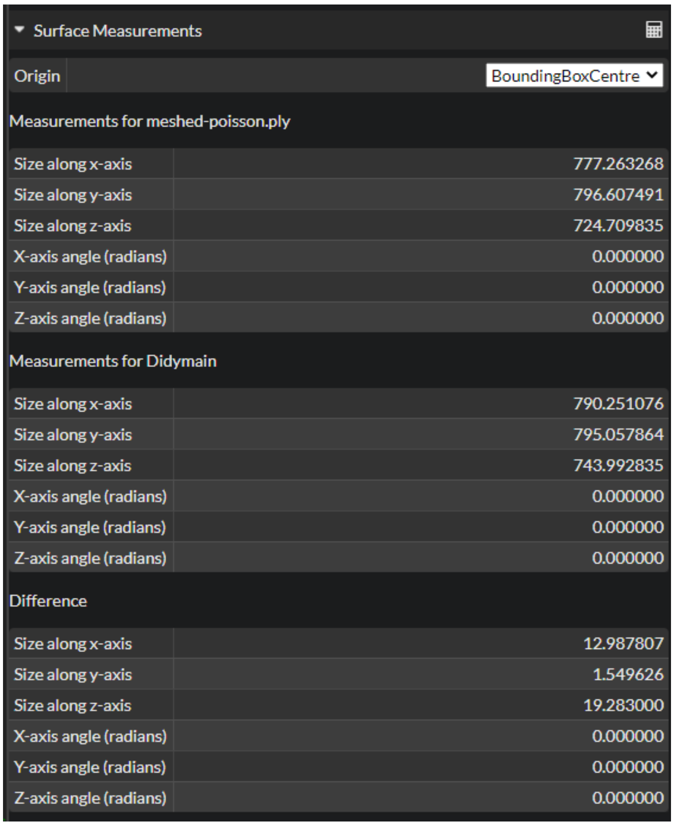


Figure 35: Surface Measurements. These measurements are only valid for *spherical* models. If there are holes in the model the calculation might fail. Choosing a different Origin in the drop down menu can help in these cases.

7.3 Comparing Length Measurements

To compare length measurements, create a bookmark and make sure it is selected. This bookmark can now be used as a projection point for annotations. For this, select the Bookmark projection mode for annotation drawing (figure 36).

Figure 36: The Bookmark projection mode for comparing length measurements on two surfaces. Make sure a bookmark is selected when using this mode.

Now draw one annotation on each of the two surfaces while the same bookmark is selected. Use the `t` button on your keyboard to toggle visibility between the two surfaces. Return to the comparison window and click the button with the calculator icon to update the calculations. The measurements for annotations are listed under the heading *Annotation Length Comparison*.
Bookmarks can be exported and imported using the menu. Select the main menu (top left), then *Bookmarks*, then *Import* or *Export*.

8 PRo3D Keyboard Shortcuts

Shortcut	Description
f	toggle linear texture magnification filtering
p	show/hide exploration point
t	toggle visibility between two surfaces selected in the Comparison window
page up/down	raise/lower navigation sensitivity
ctrl s	save existing scene (use the menu to save a new scene)
ctrl c	print current camera parameters in snapshot format on the command line
space	save waypoint
F1	Interaction: Pick Explore Center
F2	Interaction: Draw Annotation
F3	Interaction: Pick Annotation
F4	Interaction: Place Coordinate System

Table 3: A List of keyboard shortcuts in PRo3D