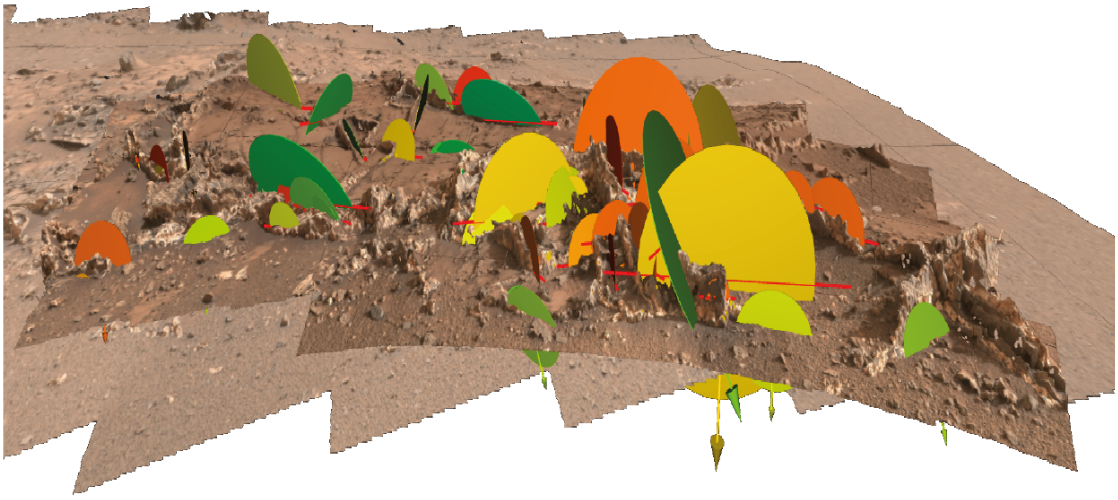
PRo3D 4.0.1

User Manual

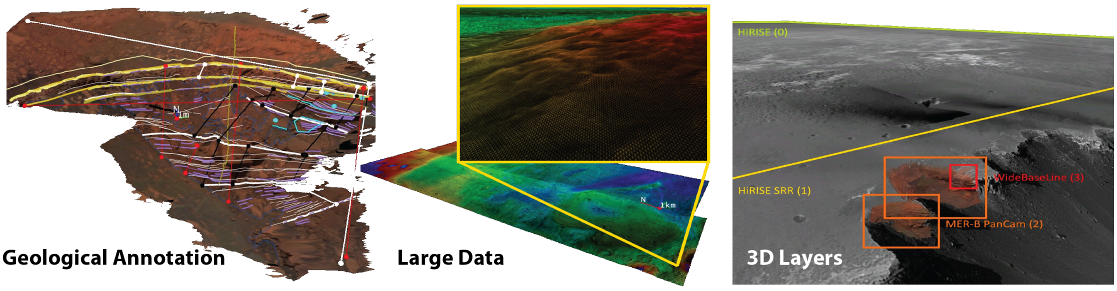


Authors:
Thomas Ortner, Laura Fritz, Rebecca Nowak

Last Updated: June 5, 2024

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.

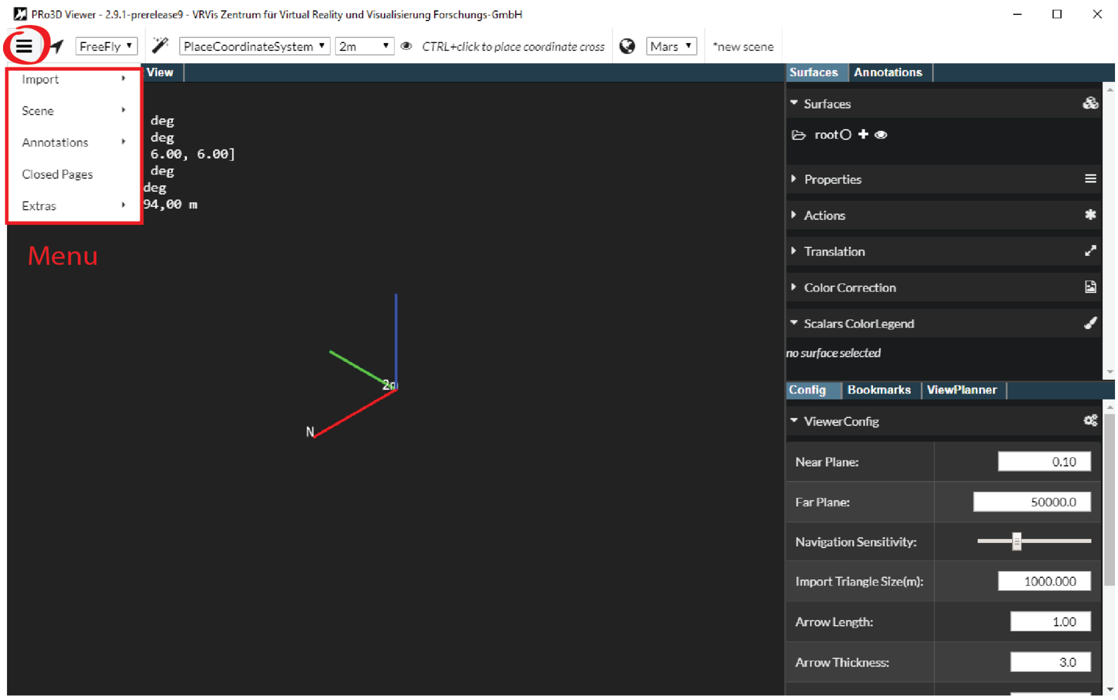


Figure 1: PRo3D Main Menu.

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”

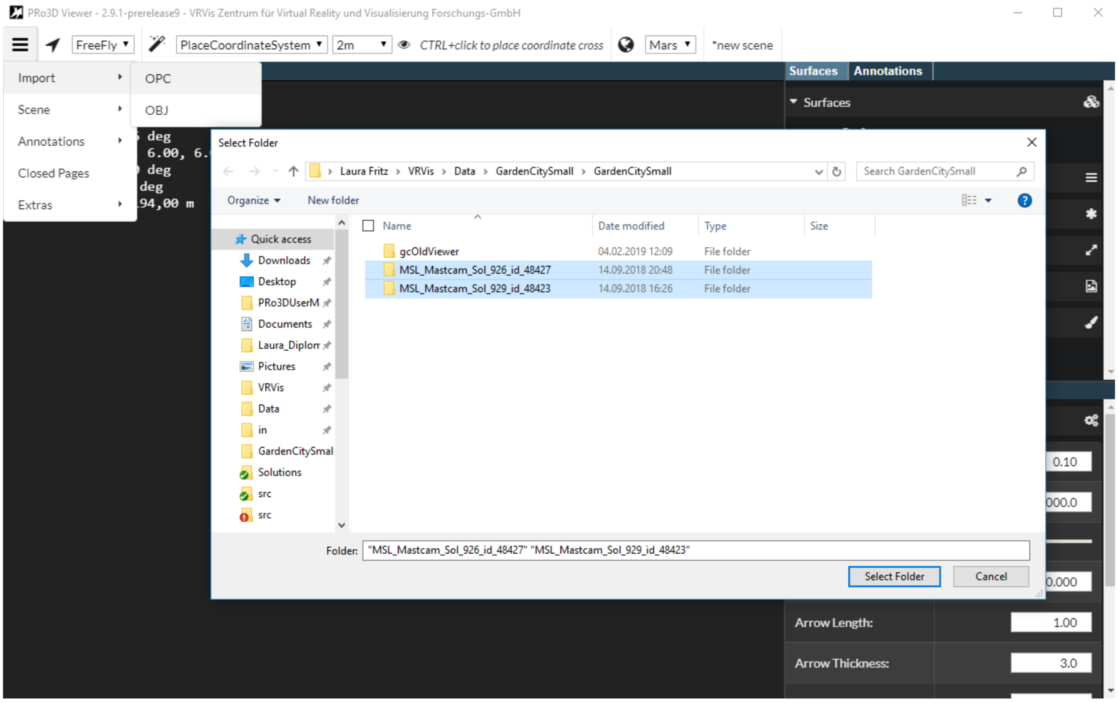


Figure 2: Add new surfaces to the scene.

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.

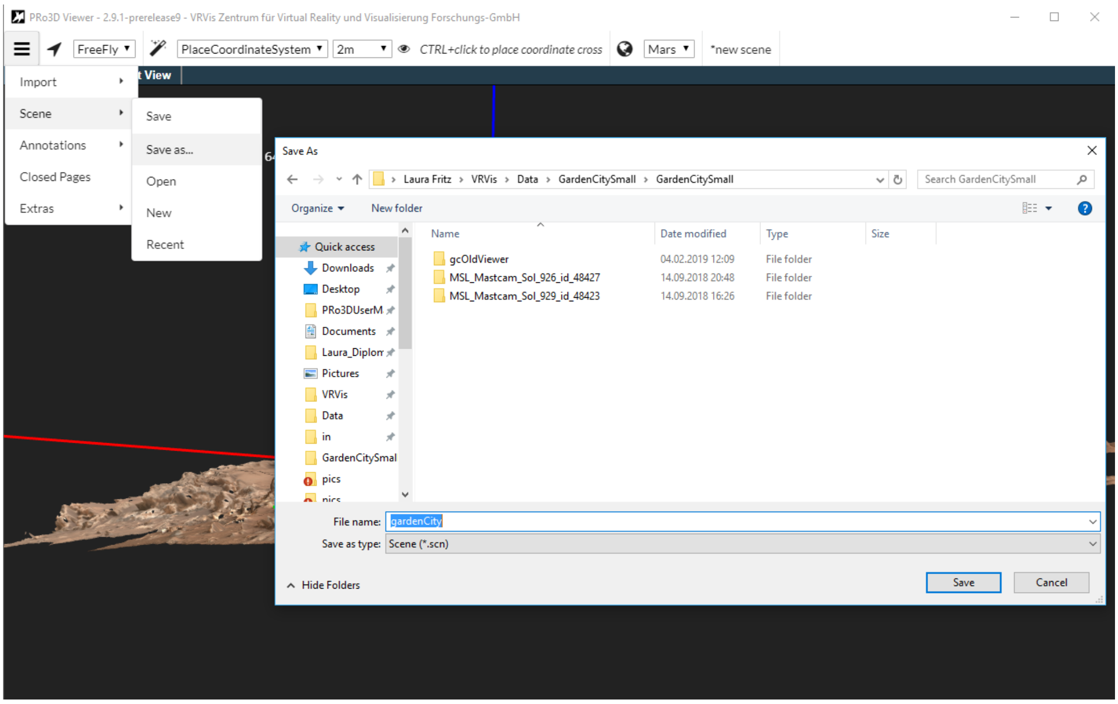


Figure 3: Save the surfaces and settings as a scene.

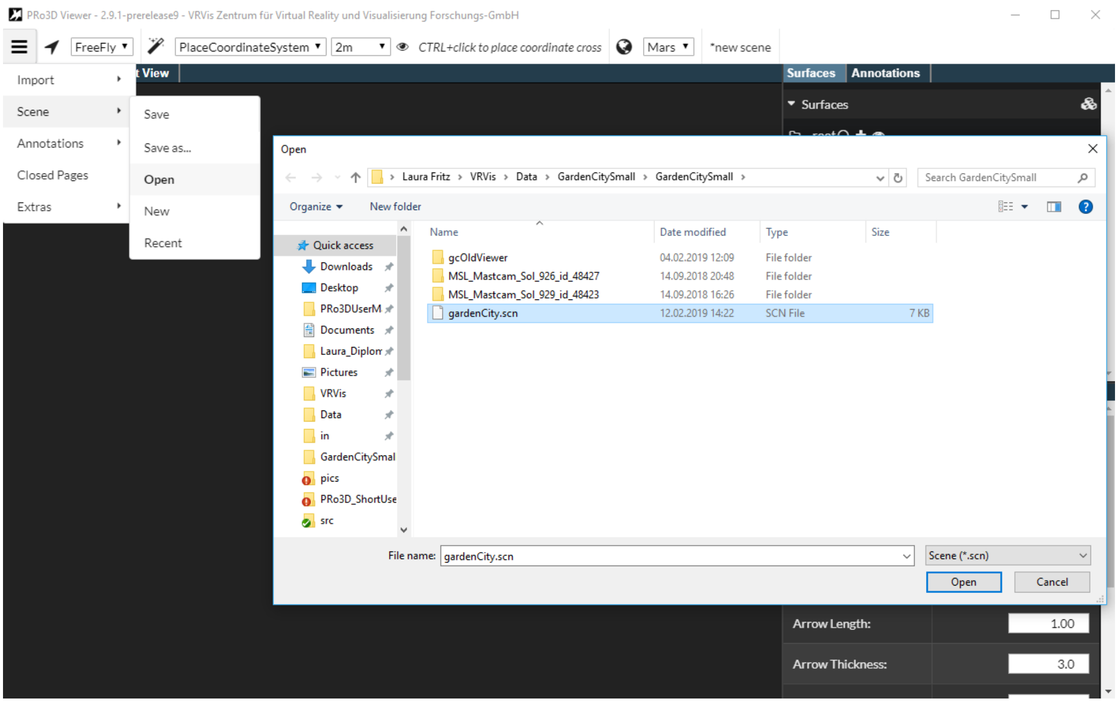


Figure 4: Open a scene with either the "Scene -> Open" or the "Scene -> Recent" tab in the scene tab of the menu.

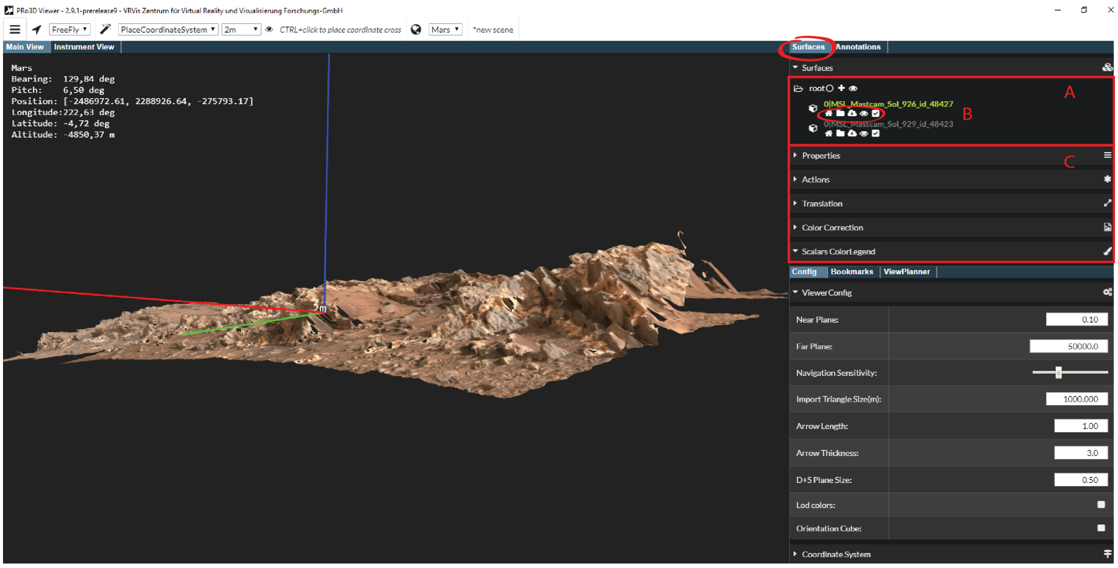


Figure 5: Loaded surface with open surface features (right).

3 Viewer Actions

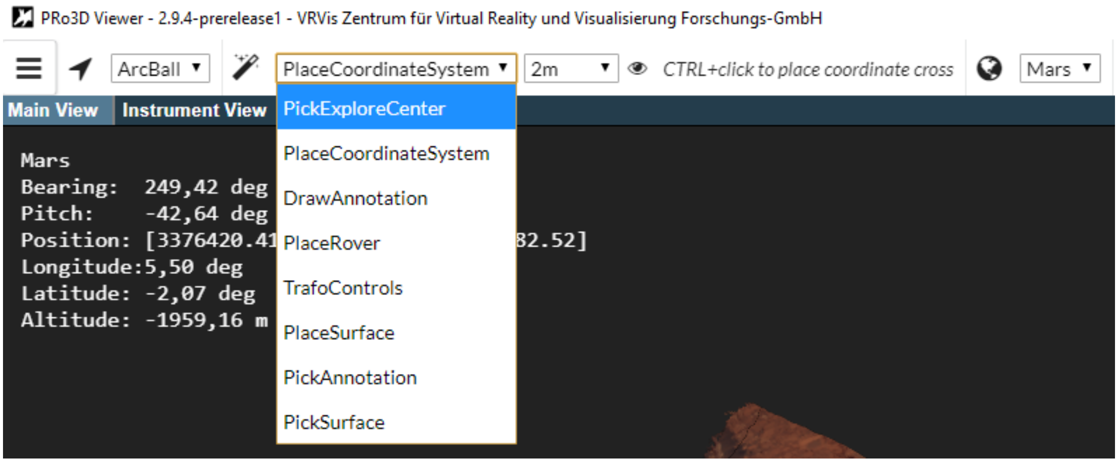


Figure 6: Viewer Actions.

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.

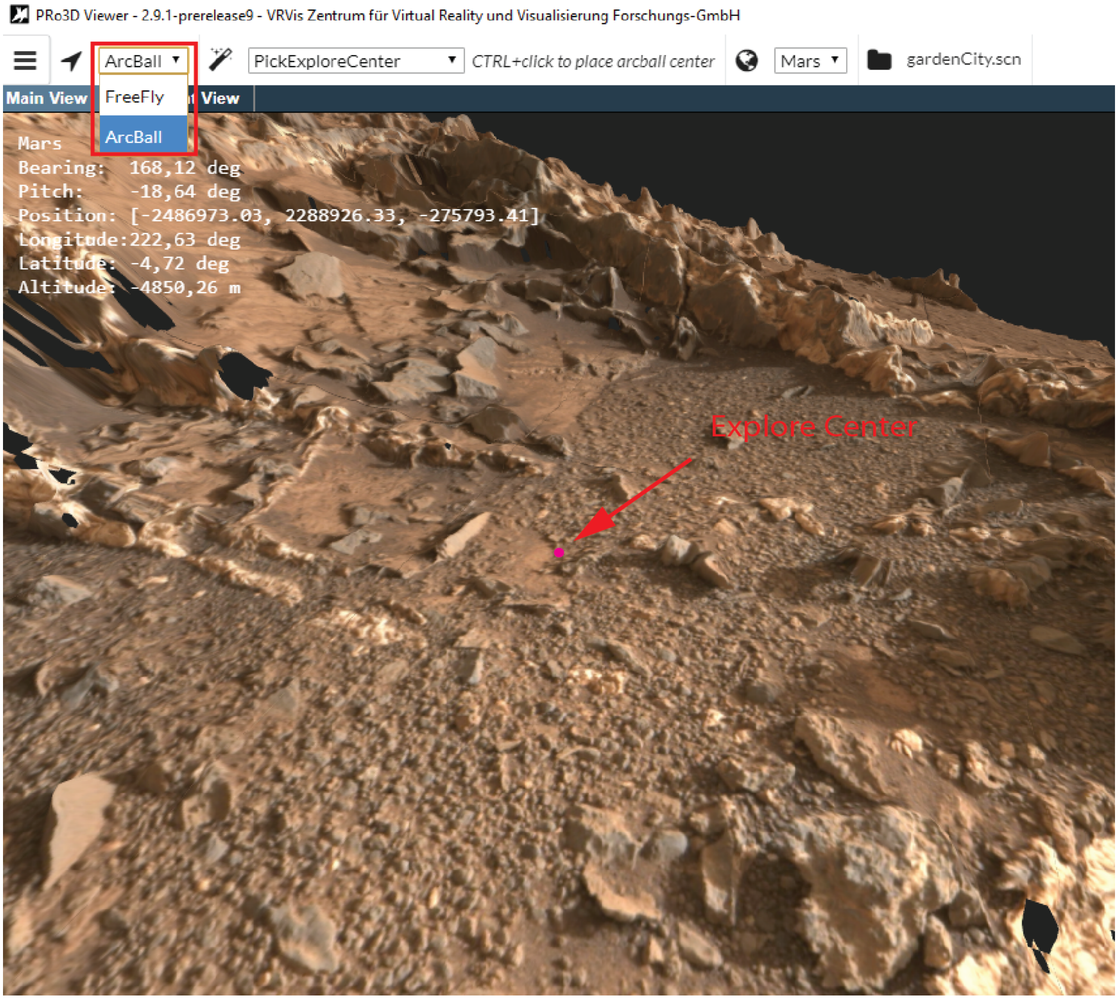


Figure 7: ArcBall navigation. Explore center is set with CTRL + LMB and indicated by a pink dot.

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 4.5.

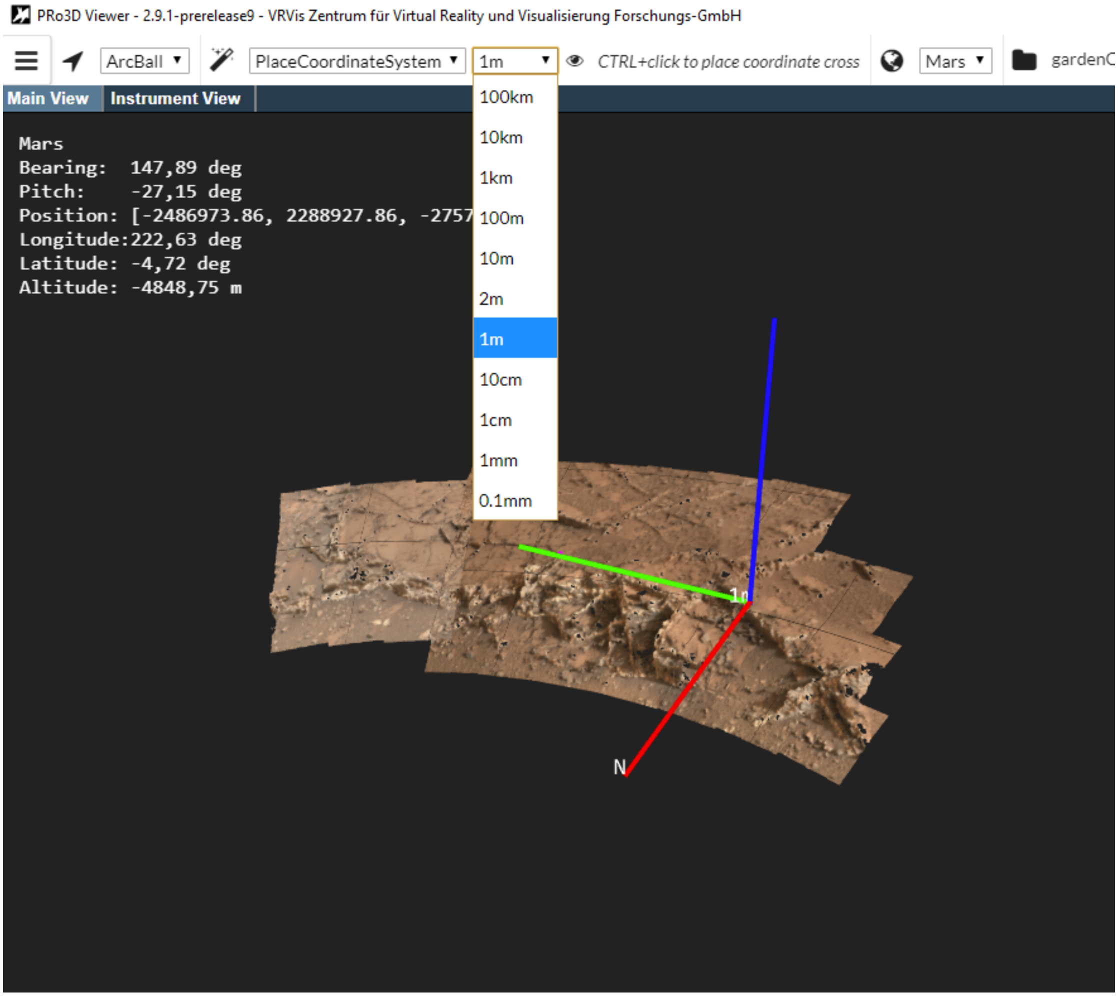


Figure 8: Coordinate System with scale bar functionality.

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.

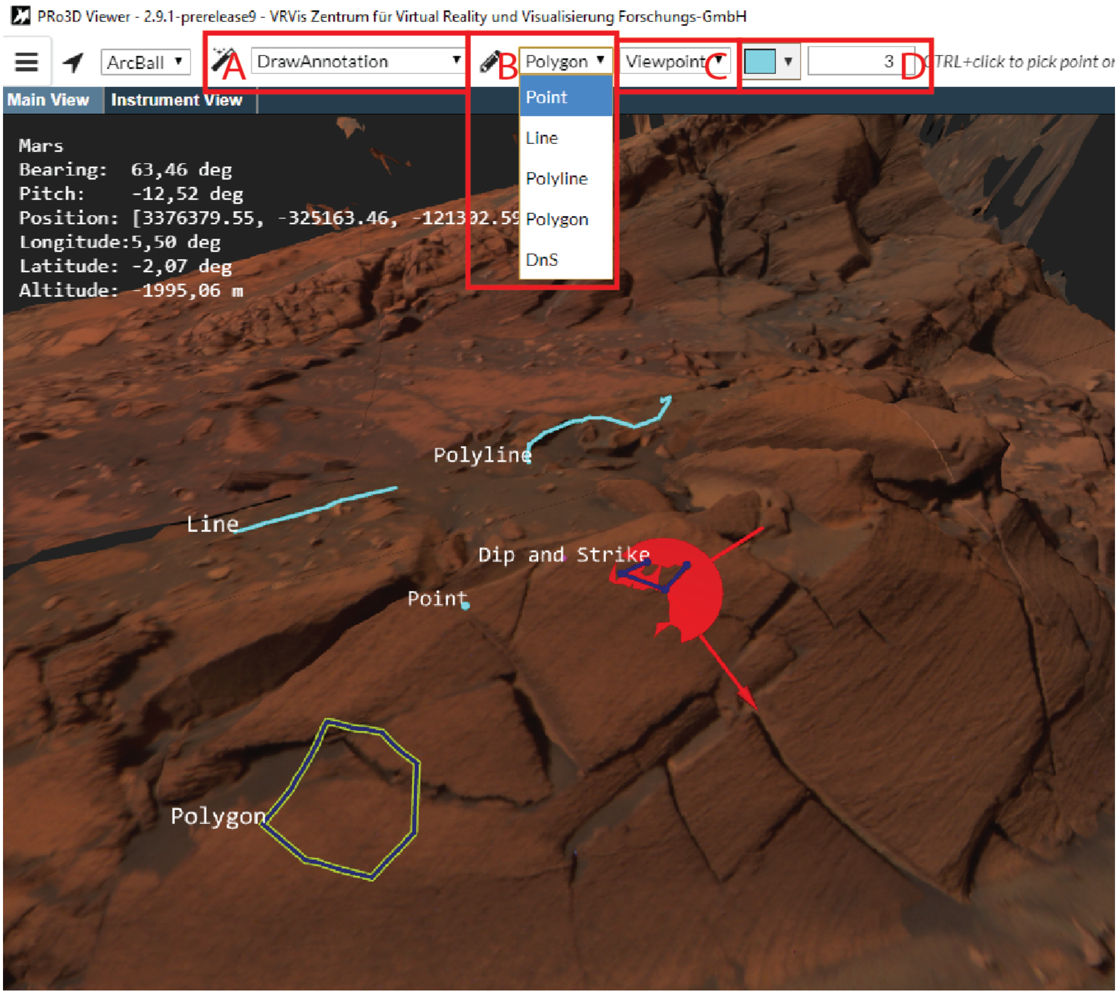


Figure 9: Annotation settings: **A**: set viewer action to "DrawAnnotation. **B**: select annotation mode. **C**: select projection. **D**: choose color and thickness.

- *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.

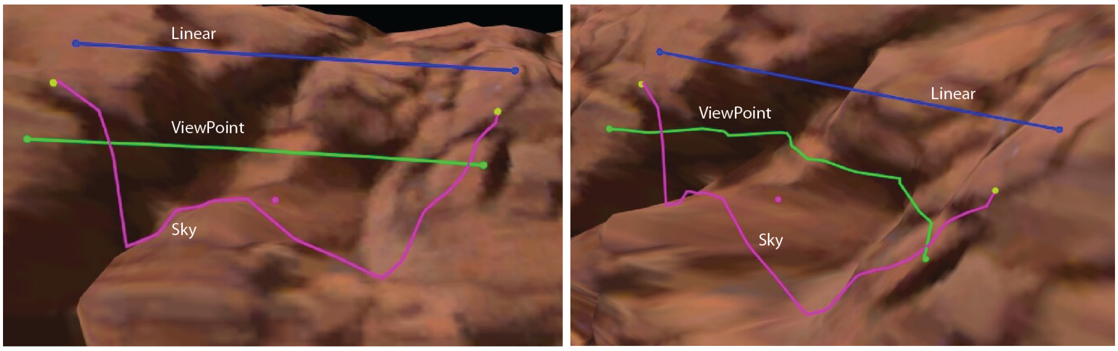


Figure 10: Three Lines taken from the same camera position (left) with the same camera settings but with different line projections.

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

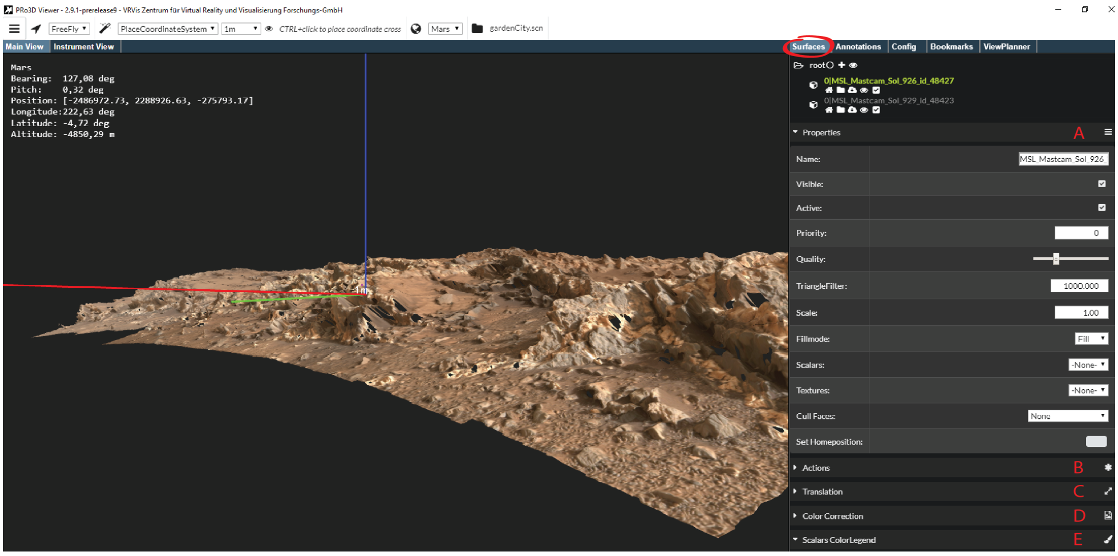


Figure 11: There are pages (right) for each feature in the viewer.

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 4.6.

4.1 Surfaces

The listing shows all surfaces in the scene. You can classify them in any group and subgroup layers, described in Section 4.6. 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, ...).

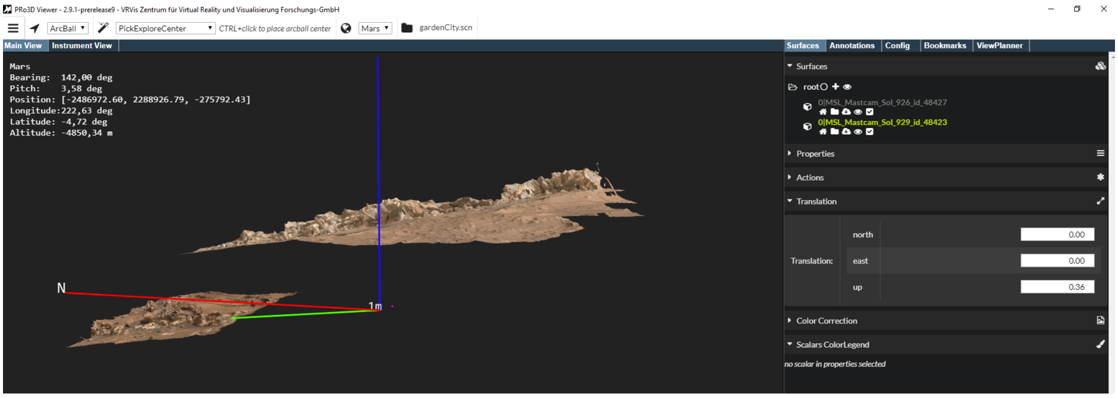


Figure 12: Translation of the selected surface along the axes of the coordinate system.

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 4.6.2.

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!

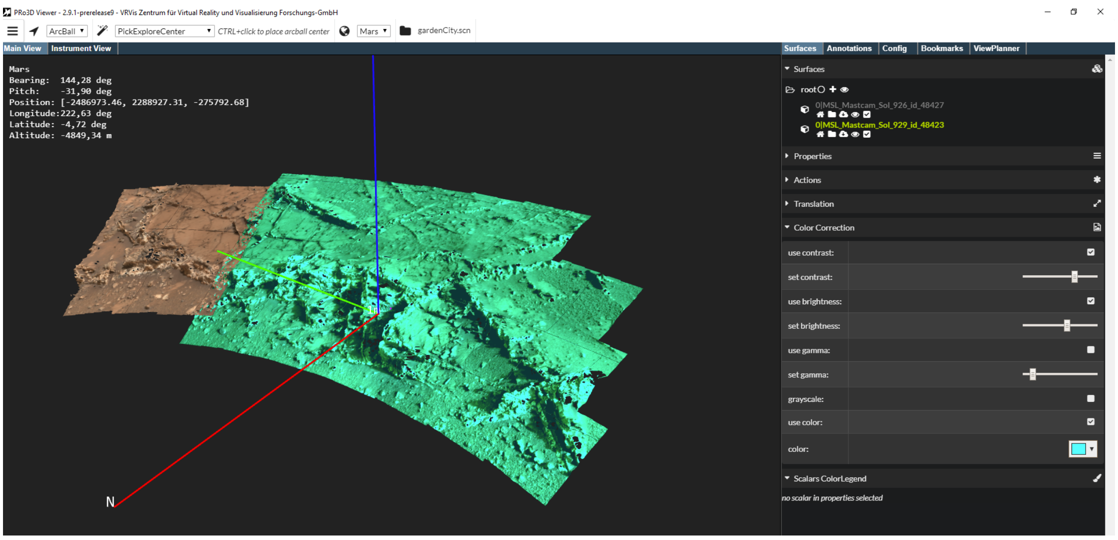


Figure 13: Contrast-, brightness- and color filters applied on the selected surface.

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).

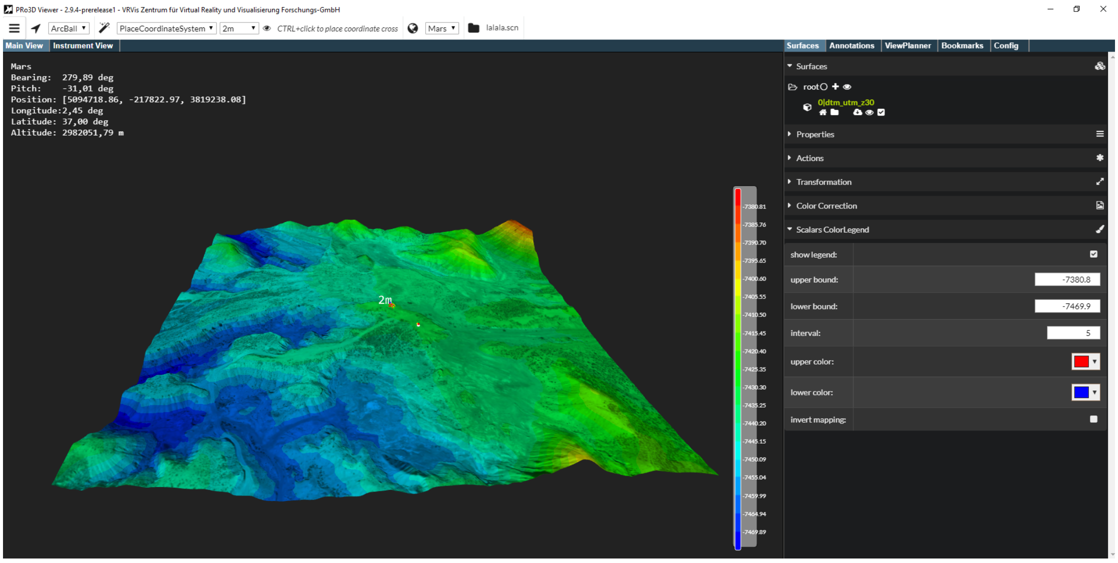


Figure 14: A height map visualized by false color mapping.

4.2 Annotations

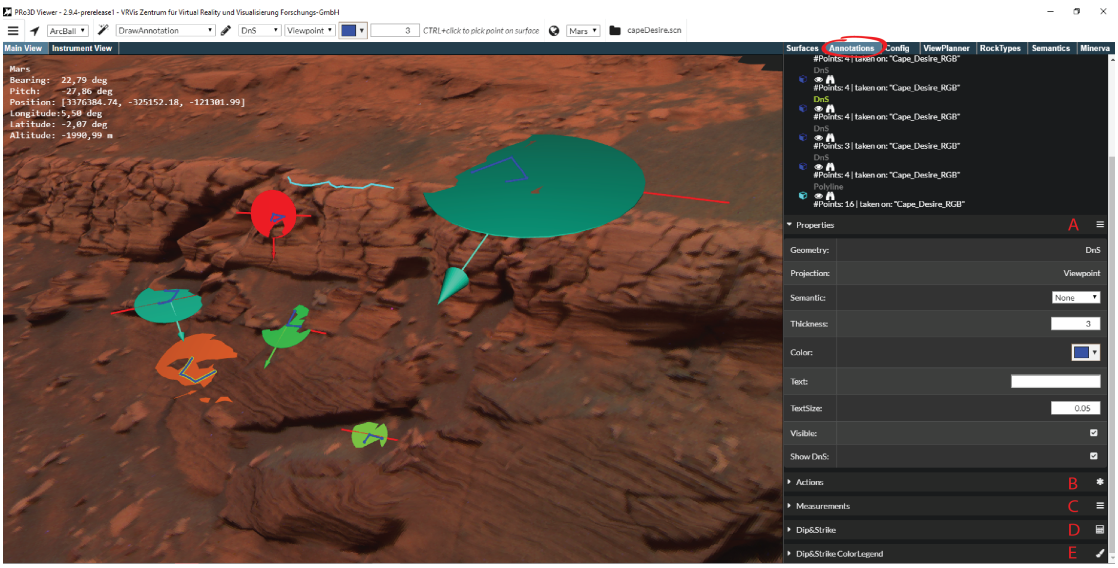


Figure 15: The annotations page.

The listing shows all annotations in the scene. You can classify them in any group and subgroup layers, described in Section 4.6. 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 4.6.2.

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.

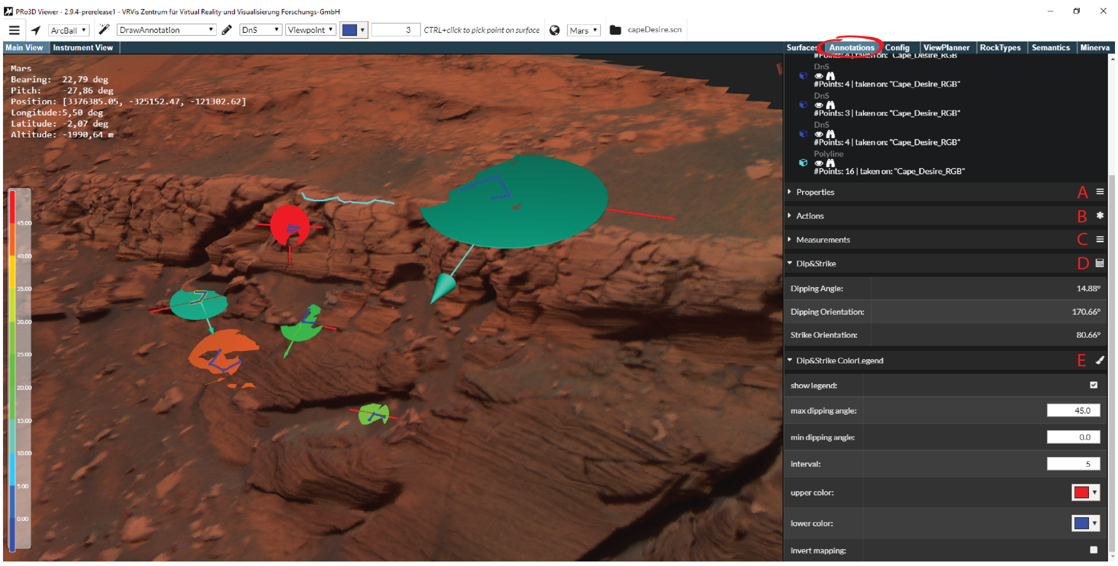


Figure 16: Colorcoding of the Dip&Strike annotations according to their dipping angles.

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 Sequenced Bookmarks

Sequenced bookmarks can be used to create, view, and record camera flight paths between bookmarks (Figure 17). Properties like visibility of surfaces, annotations, and scale bars (the *scene state*) are also recorded with bookmarks, and applied during animations.

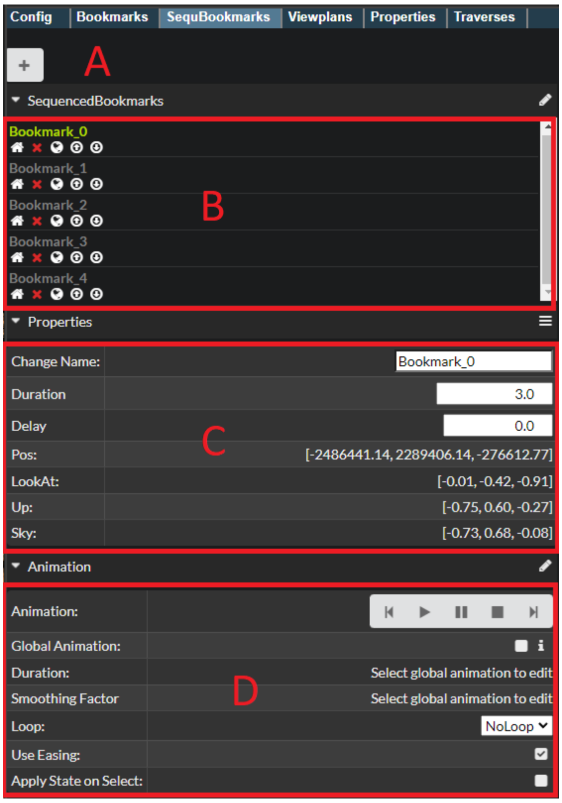


Figure 17: The sequenced bookmarks tab.

The scene state includes properties of surfaces, annotations and scale bars. It also includes general viewer settings in the *Config* tab.
Add bookmarks by clicking on the button with the plus icon at the top (A).

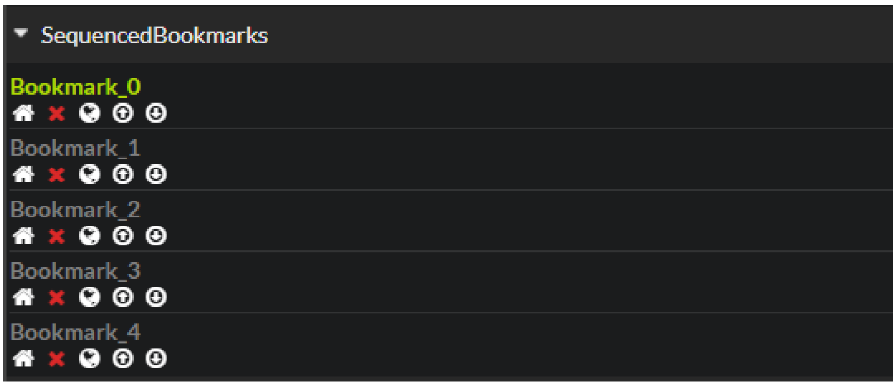


Figure 18: The list of all sequenced bookmarks.

In the list of bookmarks (B, Figure 18) you can (from left to right) move the camera to the bookmark, delete the bookmark, update the scene state, and

move the bookmark up and down in the list. Clicking on the label of a bookmark selects it. The selected bookmark is highlighted in green.
Updating the scene state for an annotation does not update its camera view.

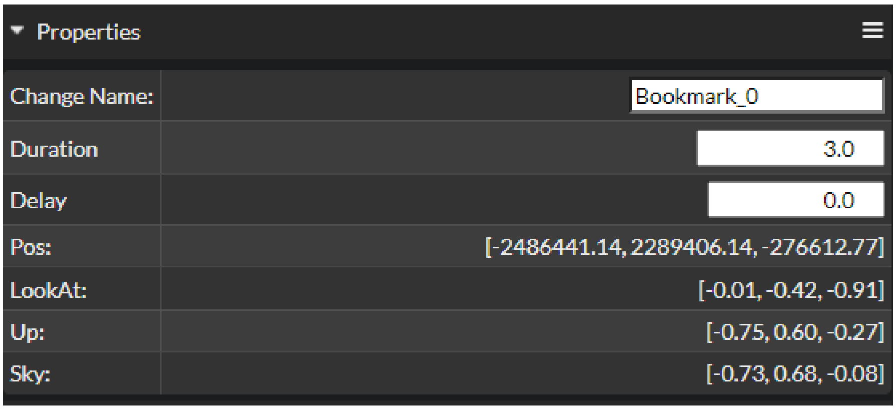


Figure 19: The properties of the selected bookmark.

You can find the properties of the selected bookmark (Figure 19) below the list of bookmarks (C). Here you can change the bookmark's name.
For each bookmark, you can set two values. The *duration* is the amount of time it takes the camera to move from the previous bookmark to this bookmark. The *delay* determines how long the camera pauses at the bookmark before moving to the next one.

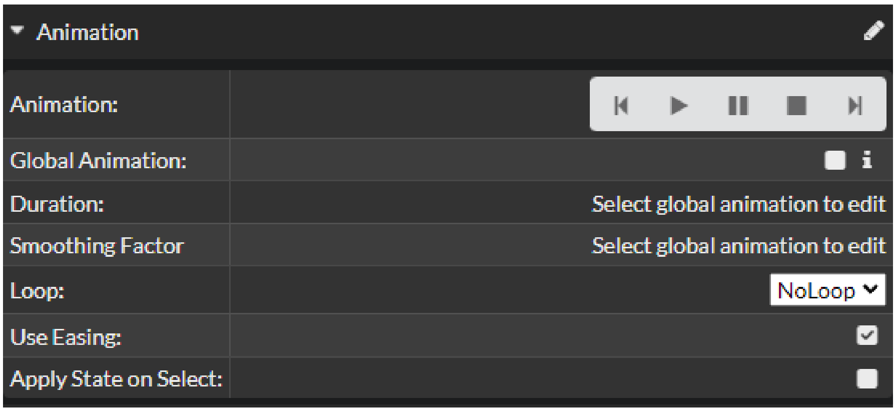


Figure 20: Animation settings.

You can animate the camera according to the list of bookmarks by clicking the play button in the *Animation* section (D). The animation control buttons from left to right: Move to previous bookmark, start camera animation along all bookmarks, pause camera animation, stop camera animation, move camera to next bookmark.
Selecting the checkbox *global animation* has the following effects:

- A spline is used to travel a path along all bookmarks. The smoothing factor determines how smooth the path is. A value closer to zero means that the path hits individual bookmarks more precisely while a larger in general means a smoother path.

- The duration is set for the whole animation and cannot be set for individual bookmarks.
- The delay for individual bookmarks can not be used.

If there are large changes in the scene (and depending on hardware) the animation might not be entirely smooth when proceeding to a new bookmark.
There are three settings for looping: No loop, mirror, and repeat.
If the checkbox *use easing* is selected, the camera animation speeds up in the beginning, and slows down at the end. When global animation is selected, easing is used at the beginning and the end of the whole path. When it is not selected, easing is used for each bookmark.

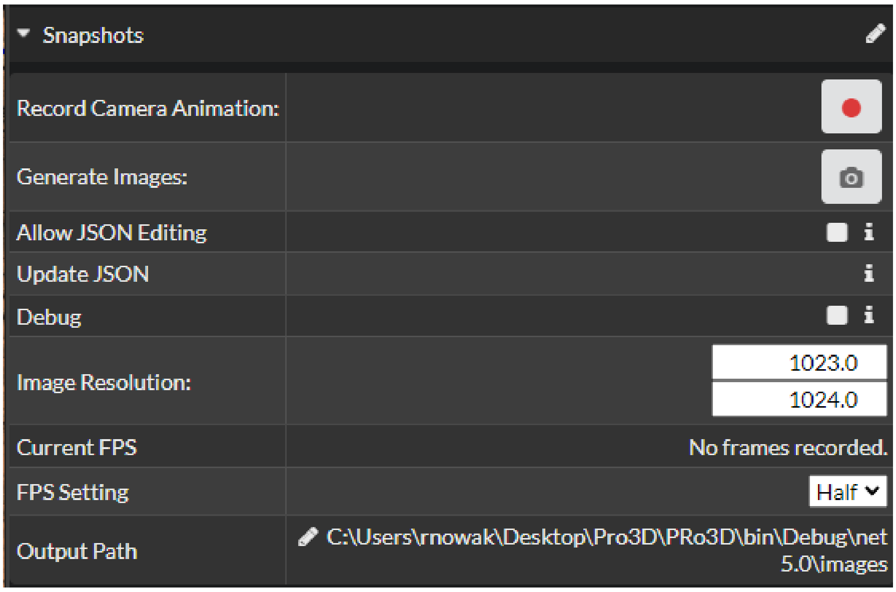


Figure 21: Creating images from sequenced bookmarks. Record camera animations as JSON snapshot files (red record button) and start generating images (camera button).

In the *snapshots* section (Figure **??**) you can record camera animations. The red button changes to a *stop* button when you start recording. If you now use the animation controls (D) to animate the camera, the camera movement is recorded. Once you click on the red stop button, a JSON file with the recorded camera animation is saved into the output folder specified in the *Snapshots* section (E). To start rendering images with the saved file, click on the button with the camera icon next to the red record button. PRo3D will start rendering the images in the background.
The following settings are available:

- ***Allow JSON Editing*** There are more options for generating images you can use if you edit the JSON file PRo3D creates (see section 6.1). Select this option if you want to edit additional properties in the JSON file (like the field of view) manually. If this option is selected, the JSON file is NOT regenerated when clicking on the *Generate Images* button. This means that settings changed after recording will not be taken into account. Click on the *Update* button if you want to update the JSON file, but be aware that all manual changes will be overwritten. Make sure to backup a JSON file once you have changed it manually, as PRo3D will write over it as soon as you record a new sequence. You can also start the generation process via the command line (Section 6) using an old JSON file.

- ***Update JSON*** Only available if *Allow JSON Editing* is selected. Updates the JSON file with the current settings. All manual changes to the JSON file are overwritten.
- ***Image Resolution*** Resolution of output images. Larger images take longer to render.
- ***Current FPS*** Once an animation sequence has been recorded, the FPS of that sequence are displayed here.
- ***FPS Setting*** You can select full or half FPS, the actual FPS depend on the value displayed as *Current FPS*.
- ***Output Path*** The path where the rendered images will be saved. Click on the path to change it.

To record an animation sequence follow these steps (the letters in parentheses refer to figure 17):

1. Add some sequenced bookmarks at different locations using the + button (A).
2. Set delay and duration to your liking (C). Press play to test your settings (D).
3. Set image resolution and other snapshot settings (E).
4. Click on the red record button in the snapshots section (E).
5. Click on play to start the animation (D).
6. Wait until the animation is finished.
7. Click on the red stop button in the Snapshots section (E).
8. Click on the button with the camera icon (E, *Generate Images*).

4.5 Viewer Configuration

To edit the viewer properties, select the “Config” page.

4.5.1 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.

4.5.2 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.

4.5.3 Camera

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

4.5.4 Frustum

In this menu the frustum can be adjusted.

4.5.5 Screenshots

This menu can be used to create screenshots of the current scene. Click on the button with the camera icon (left) to create a screenshot. Click on the button with the folder icon (right) to open the folder where screenshots are saved. Width and height can be specified in pixels. The output format can be selected as PNG or JPG. Screenshots are saved as `img` with a number suffix.

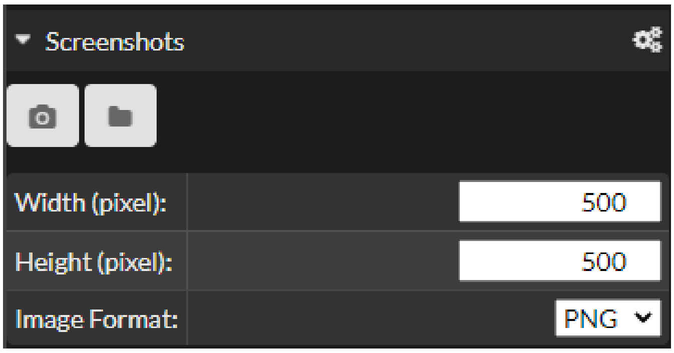


Figure 22: The screenshots menu. Click on the button with the camera icon (left) to create a screenshot. Click on the button with the folder icon (right) to open the folder where screenshots are saved.

4.6 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.

4.6.1 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).

4.6.2 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).

4.7 View Planner

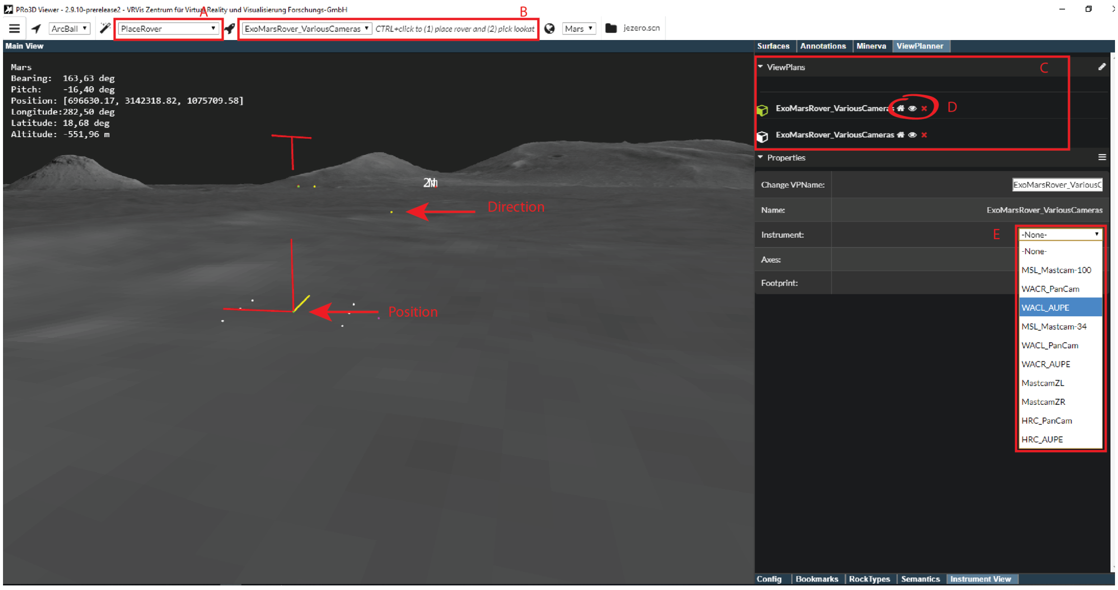


Figure 23: The view planner. The rover is placed on the surface in the main view (left). All rovers in the scene are listed in the ViewPlanner tab (right).

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 23 A), select a rover model in the rover menu (Figure 23 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 23 C). There is a little menu beside each ViewPlan shown in Figure 23 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 23 E).

When a camera is selected you can change the instrument parameters as shown in Figure 24 A:

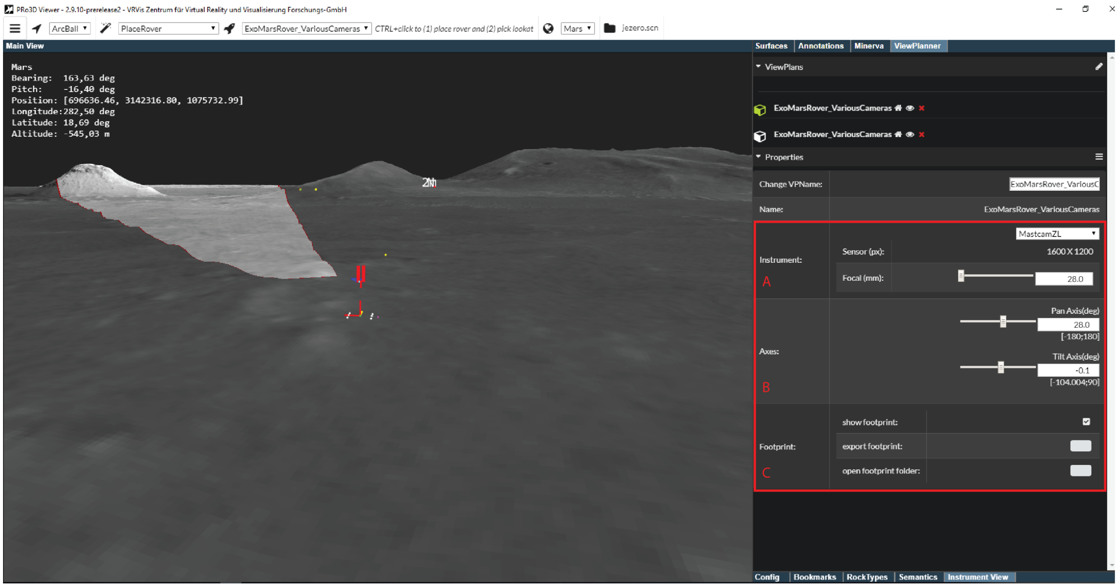


Figure 24: The footprint for the selected camera is shown in light gray on the surface in the main view. In the properties panel (right) you can adjust the rover and camera parameters.

- 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 24 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 25) and a ***.svx** file with diverse meta information.
- open footprint folder: opens the folder with the screenshots and the meta file.

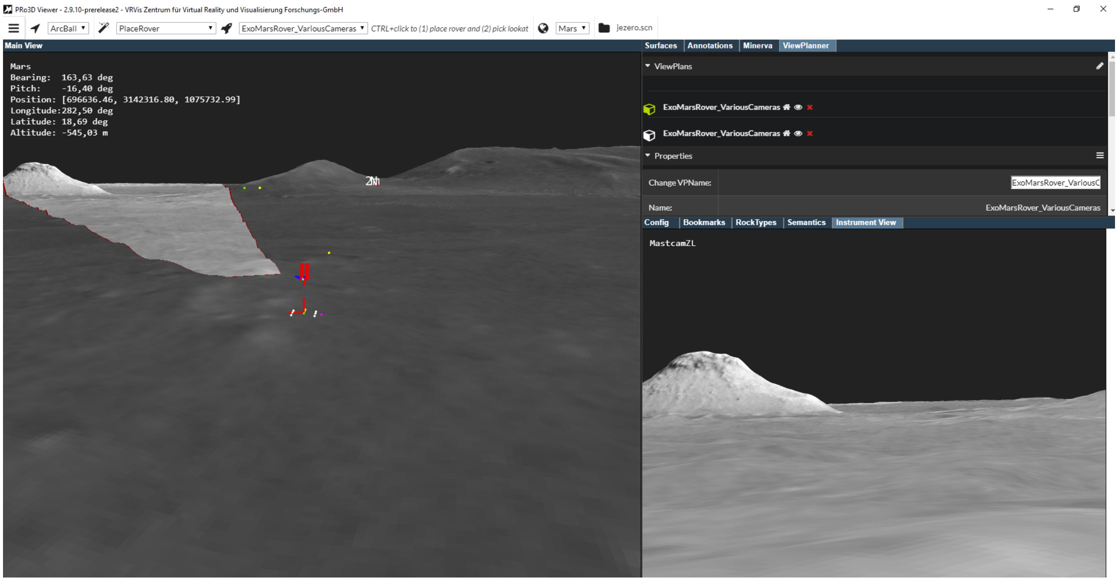


Figure 25: The instrument view (right) shows the instrument's camera view.

4.8 GIS View

Summary: This feature allows to interpret celestial bodies and surfaces from within pro3d and serves as a basis for GIS functionality in PRo3D. General concept: A new UI tab allows to assign coordiante frames and celestial body information to surfaces and GIS entities. By setting observeration time and by choosing an observer body, views or fly-by scenarious can be modelled.

4.8.1 SPICE

Pre-requisistes
Pro3d allows to load custom spice kernels. In this documentation we use the HERA spice kernels, which are also used in the solar-system demo
To follow the demo download or clone the repository.

Loading the kernel
There are two options to load SPICE kernels.

The command line

- by using the command-line argument `--defaultSpiceKernel path`, e.g. the path to the tm file: `"../hera/kernels/mk/hera_crema_2_0_LPC_ECP_PDP.tm"`, the SPICE kernel to be loaded at application startup can be specified.

The UI

1. Initially PRo3D with GIS view enabled looks like this:

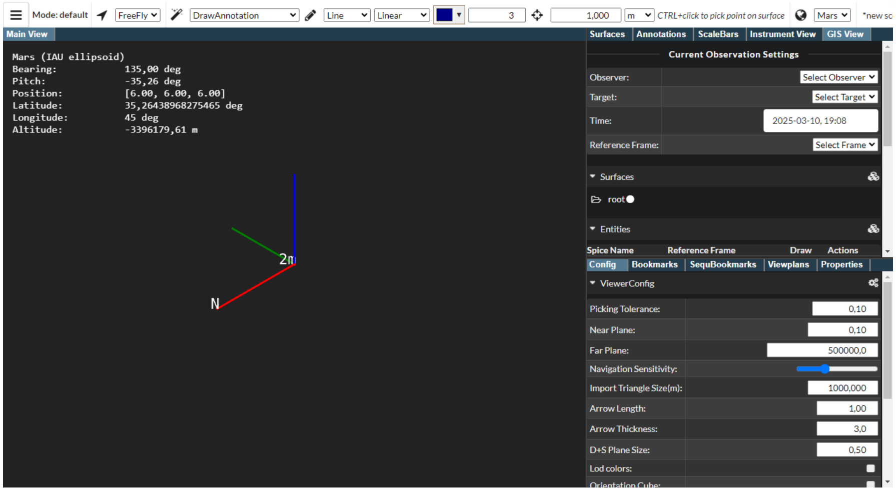


Figure 26: PRo3D with GIS View

2. Load the kernel via:

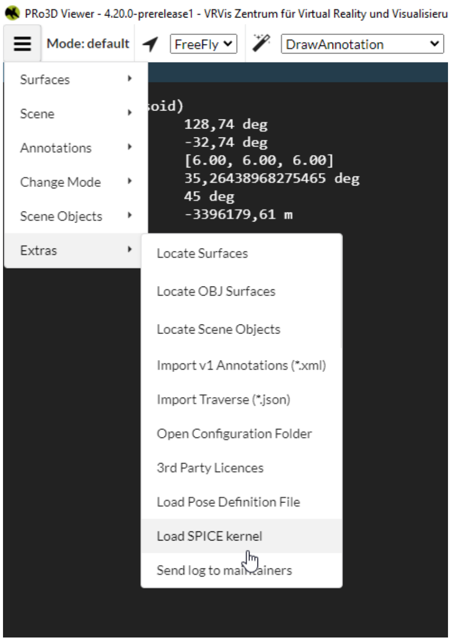


Figure 27: Loading the spice kernel.

3. Then the Gis View should print the path to the kernel. Scroll down, and look at the settings pane within the GIS view.

A green check mark appears below the path if loading the kernel was successful. If there is a red exclamation mark beneath the path loading was not successful. PRo3D's text output will give more detailed information why, it might be that the path to the kernel is not correct.

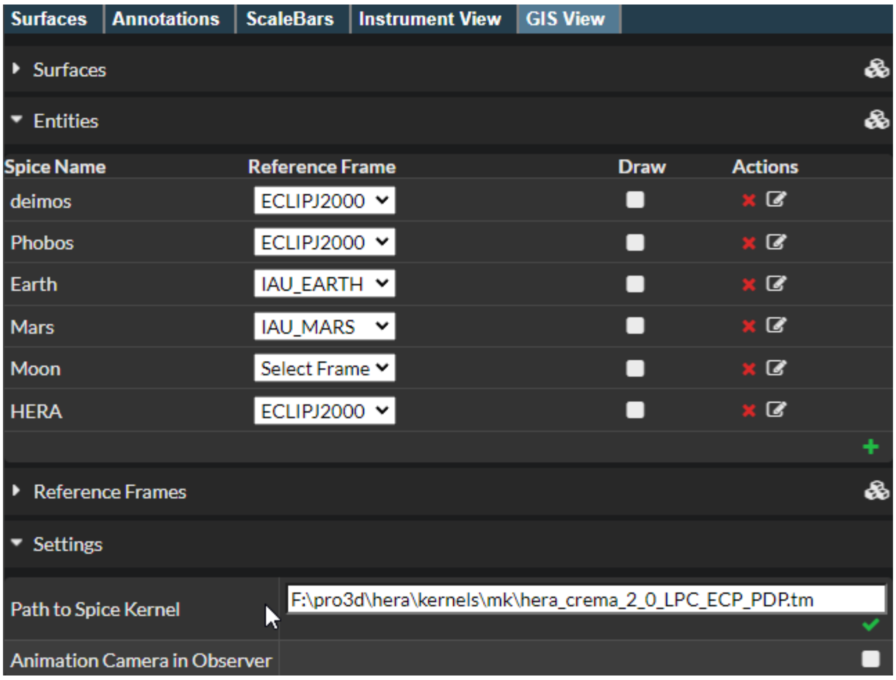


Figure 28: Kernel Path in the GIS View.

4.8.2 PRO3D GIS View Tab

Current Observation Settings

At the top of the GIS tab there is a section entitled “Current Observation Settings”. This is used to define an observer, a target, a point in time, and a reference frame.

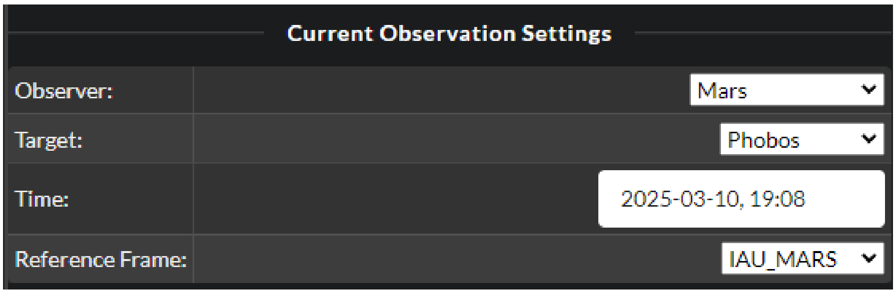


Figure 29: Current Observation Settings.

- Observer: The entity from which we want to observe a specific target. The camera will be placed at the location of the observer.
- Target: The entity we want to look at. The camera will look in the direction of the target.
- Time: The point of time at which we want to observe. The loaded spice kernel needs to have data for observer and target at the selected point in time!
- Reference Frame: The reference frame into which all other frames will be converted. Which frame is selected here should not change the visual result.

Surfaces

To use a surface with PRo3D's GIS functionality, it has to be associated with a reference frame, and can be associated with an entity. This reference frame in which the surface is defined is needed to transform the surface to the global reference system used by PRo3D. Assigning a reference frame and entity to a loaded surfaces is done in the "Surfaces" tab.

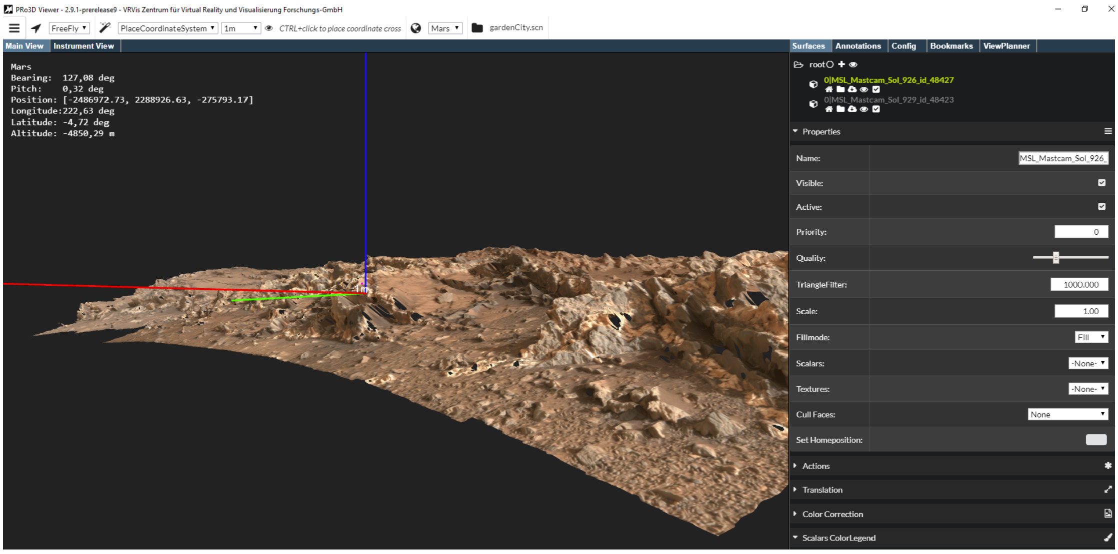


Figure 30: Surfaces in the GIS view.

Select the correct reference frame (and optionally entity) from the dropdown menu. If the entity or reference frame needed is not in the dropdown menu, it can be created in the "Entities"/"Reference Frames" tab.

Entities

Entities can be celestial bodies or spacecraft. To work with PRO3D's GIS functionality the Spice Name of the entity needs to be defined in the loaded spice kernel.

The entity tab lists all entities. There are some default entities already present in PRo3D.

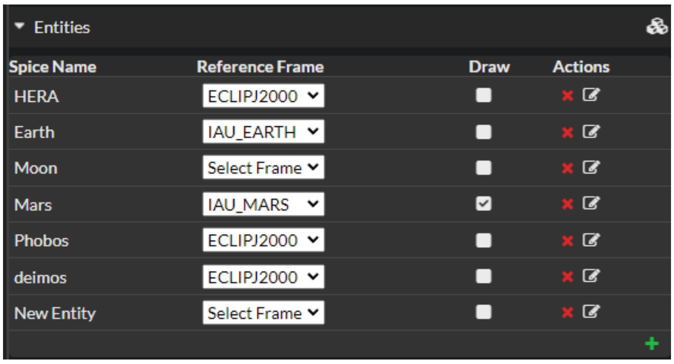


Figure 31: Entities in the GIS view.

An entity can be edited by clicking on the right hand icon in the "Actions" column. The icon used to edit the HERA entity is circled in red in the screenshot below.

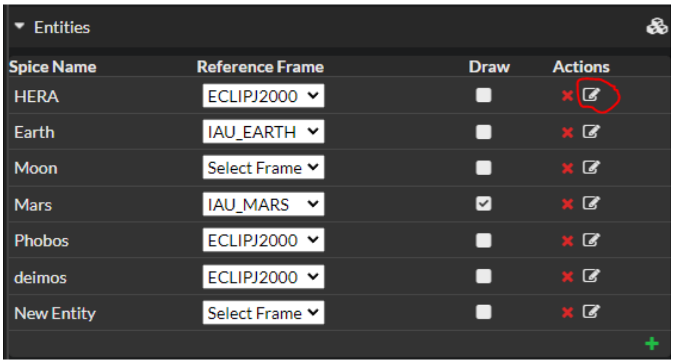


Figure 32: Editing Entities.

The red cross to the left of the edit icon deletes the corresponding entity.
Each entity can be assigned a reference frame in the column “Reference Frame”.
For each entity, a sphere can be drawn in the scene. Whether a sphere is drawn is determined by the checkbox in the “Draw” column.
A new entity can be created by clicking on the green plus icon at the bottom right hand side of the Entities tab. The spice name can only be set when creating an entity, it cannot be changed once the entity is created. To change a spice name you need to deleted the old entity and create a new one with the new spice name and the settings of the old entity. Spice names are unique, so you cannot create two entities with the same spice name.
Clicking on the edit icon of an entity (see above), opens a section for the entity:

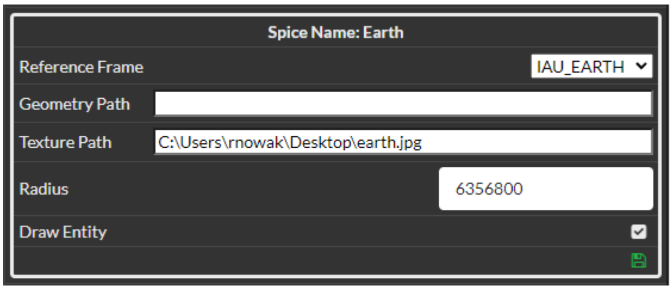


Figure 33: Editing Entities.

The reference frame and whether to draw an entity can be selected in this view as well as the following settings:

- **Geometry Path** (not yet implemented) path to a geometry that is displayed at the location of this entity instead of a simple sphere
- **Texture Path** The path to an image (for example a jpeg file) that is rendered onto the entity.
- **Radius** The radius of the sphere that is drawn in the location of the entity in meters.

The green save icon at the bottom right hand corner closes the edit view.
Below an example of the entity Moon with a radius of 1736000 meters and a texture path.

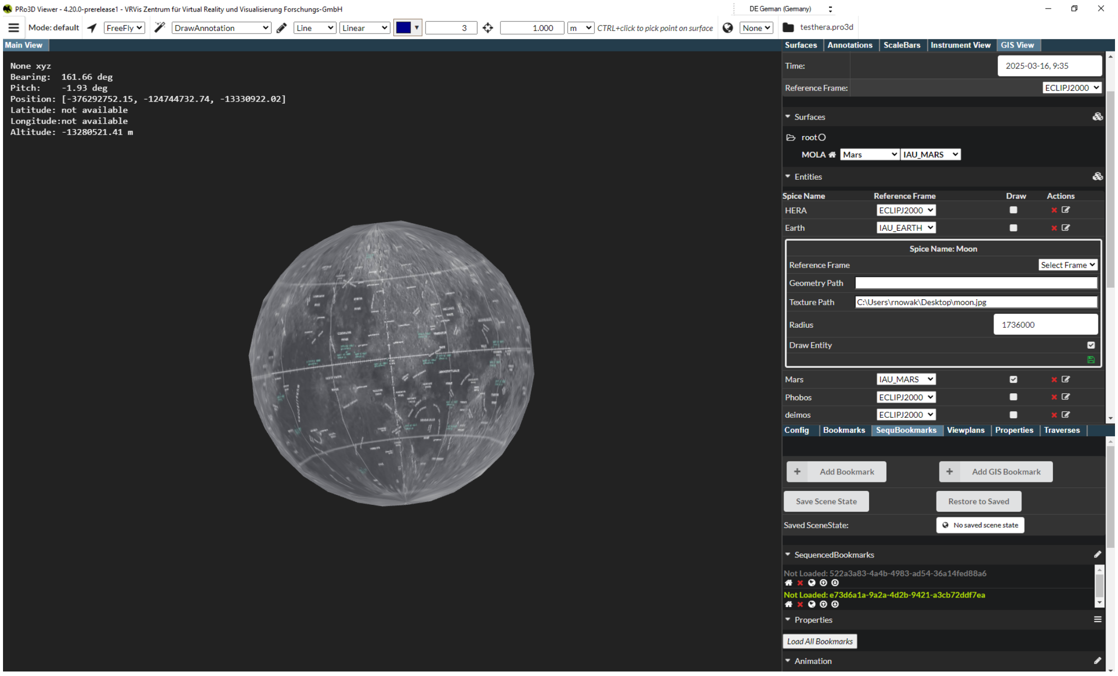


Figure 34: Textured Moon.

4.8.3 Reference Frames

Reference frames can be deleted (red cross icon) and created (green plus icon in the bottom right corner) in this view. They can also be assigned an entity which is associated with them.

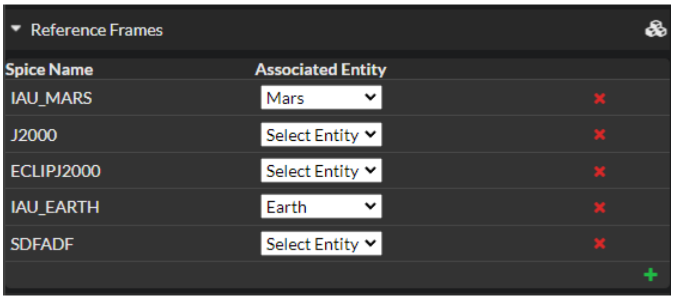


Figure 35: Reference Frames.

A new reference frame can be created by clicking on the green plus icon at the bottom right hand side of the Reference Frames tab. The spice name can only be set when creating a reference frame, it cannot be changed once the reference frame is created. To change a spice name you need to deleted the old reference frame and create a new one with the new spice name and the settings of the old reference frame. Spice names are unique, so you cannot create two reference frame with the same spice name.

4.8.4 Observing mars

Let us now observe mars from, say phobos.

1. Set the observation settings (including a time which is in available in the kernel)

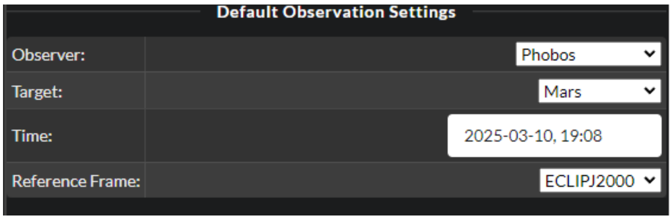


Figure 36: Observing Settings.

2. Next, make sure the proxy visualization for mars is enabled:

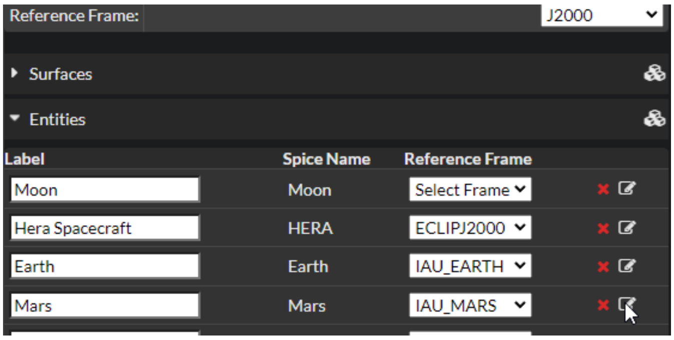


Figure 37: Proxy visualization for mars is enabled.

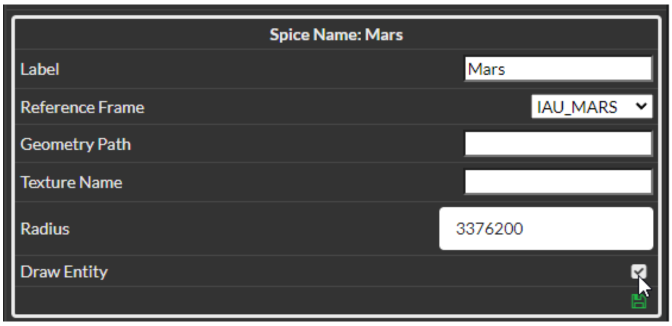


Figure 38: Mars is now visible.

Also make sure to have the far plane set far away for viewing mars from phobos. Ajust the near *and* far planes accordingly.
Now mars should be visible from the observation point of view.
By using the visualization properties in the entity list the element can be textured as well.
Next let us load the mola dataset. In the Surfaces pane witin the Gis View, now specifiy reference frame and celestial body for the surface (if it does not appear change the observation settings, e.g. by setting the time).
Since we have a full surface for mars now, we can switch off the proxy geometry:

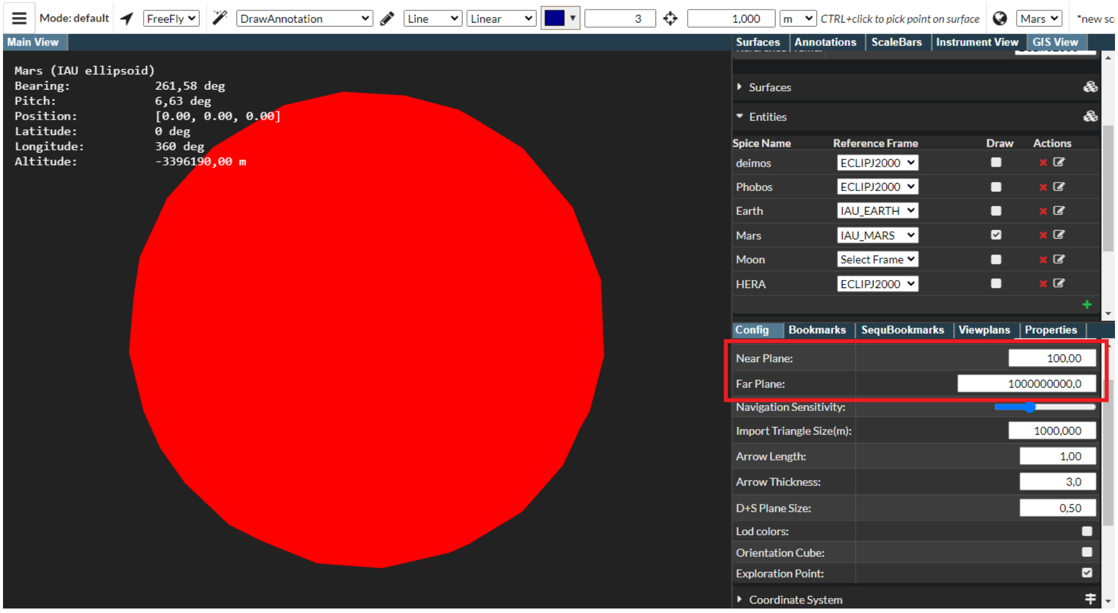


Figure 39: The far plane needs to be set far enough away so objects are visible.

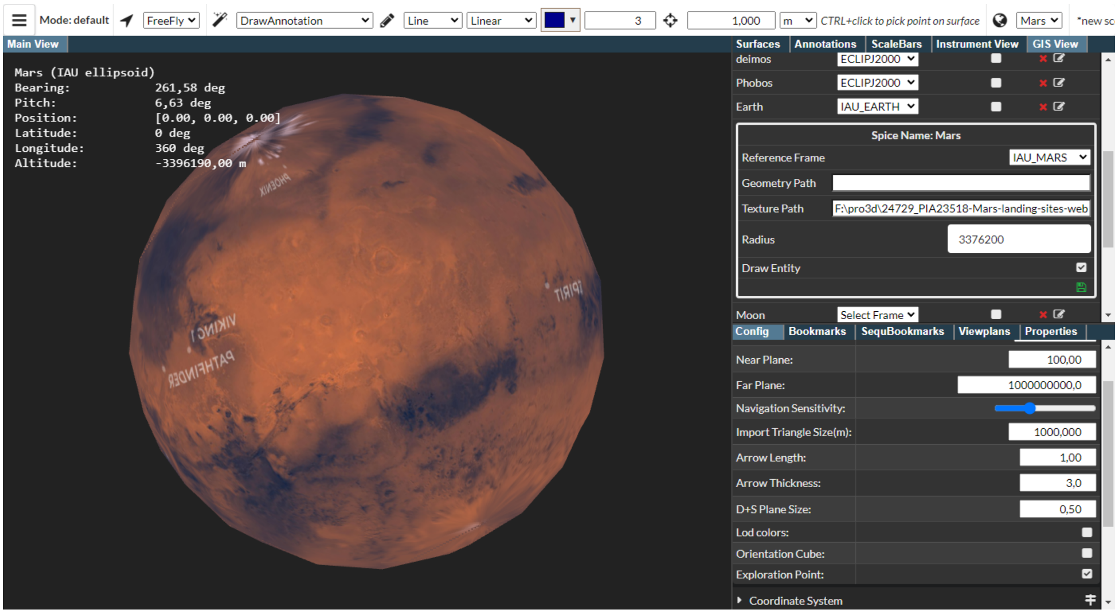


Figure 40: Textures can be specified and mapped onto entities.

4.8.5 Extended features

It is possible to add new celestial bodies, new reference frames.

4.8.6 Extended concept

For story telling, PRo3D also supports to create GIS bookmarks. Similarly to stories on surfaces this can be used to create movies and interactive presentations for science.

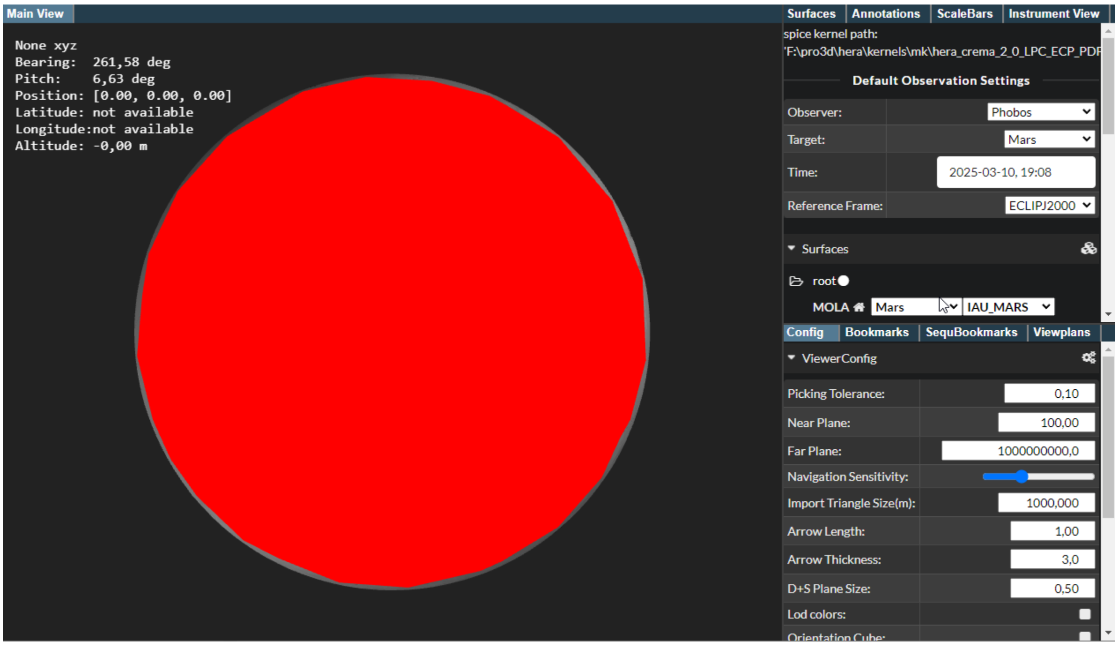


Figure 41: Specifiy reference frame and celestial body.

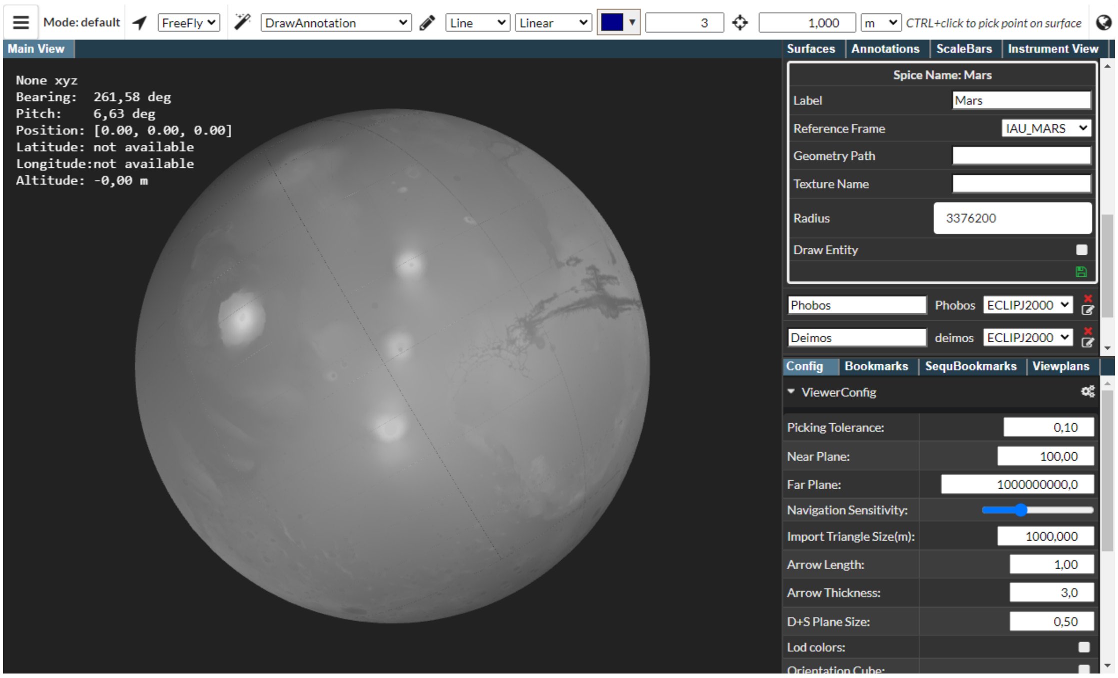


Figure 42: After switching off the proxy geometry, the loaded OPC is visible.

4.8.7 Caveats

Currently the GIS settings are not stored to scene files.

4.9 Contour Lines

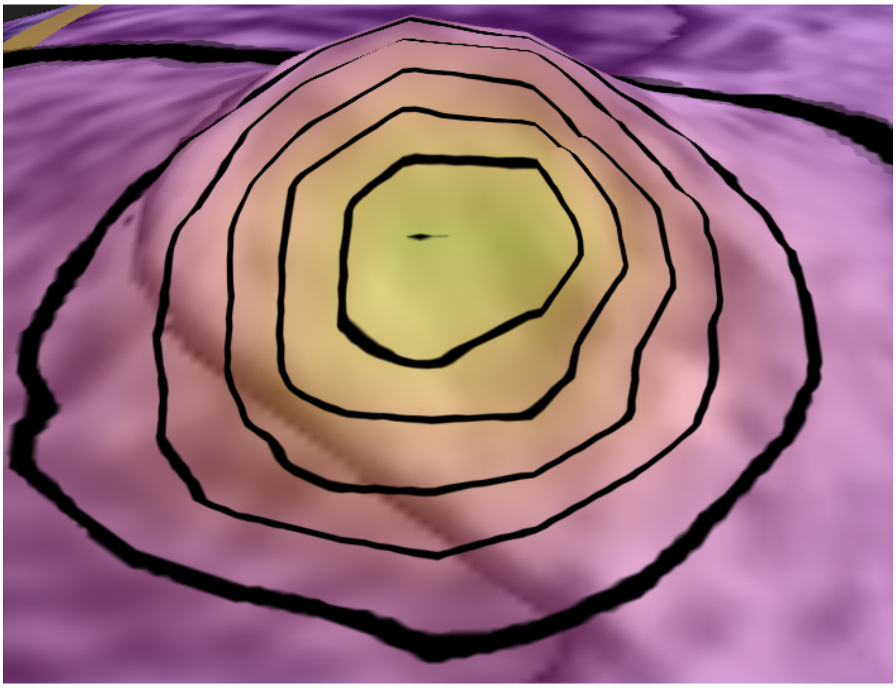


Figure 43: The contour lines feature.

The feature only works in combination with multilayer opcs. By using surface properties, choose a particular layer as a secondary texture:

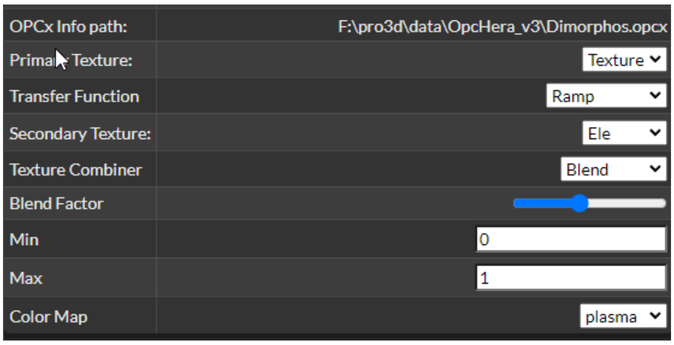


Figure 44: The multitexture UI.

Next, in the contour section, enable it and set distance of the lines, as well as line width and line border (both in the domain of the value chosen for texturing, here ‘Ele‘).

Figure 45: In the contour section, enable it and set distance of the lines, as well as line width and line border.

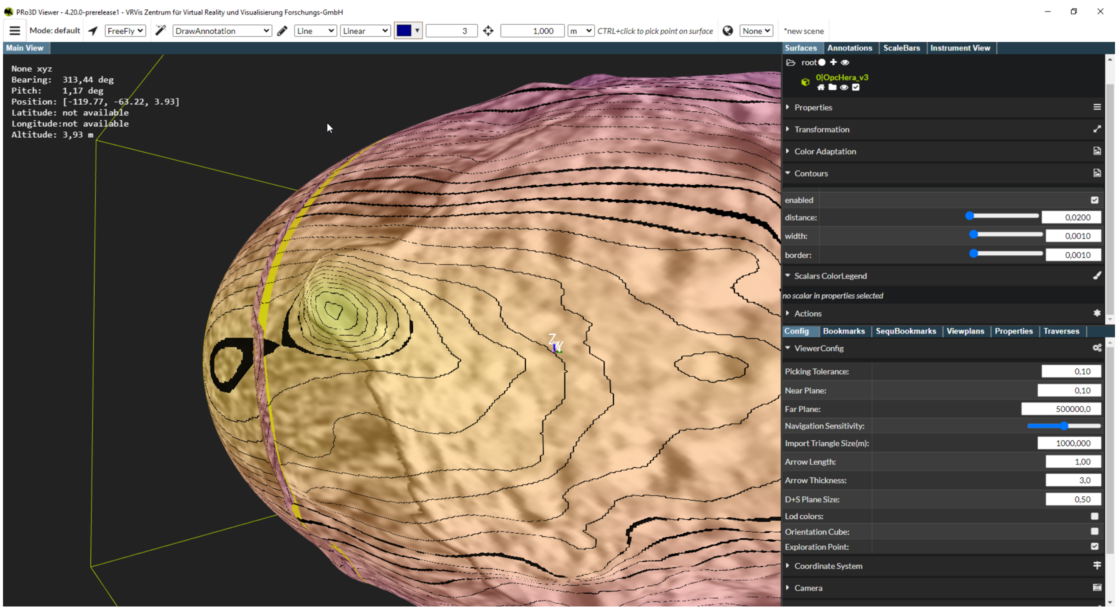


Figure 46: The whole setup looks like this.

4.10 Multitexturing

This feature allows to visualize multiple (opc) texture layers and control visualization properties.
Instrument data and reconstruction information for example can be mapped onto the surface and blended with the albedo texture (here an accuracy map of the reconstruction):

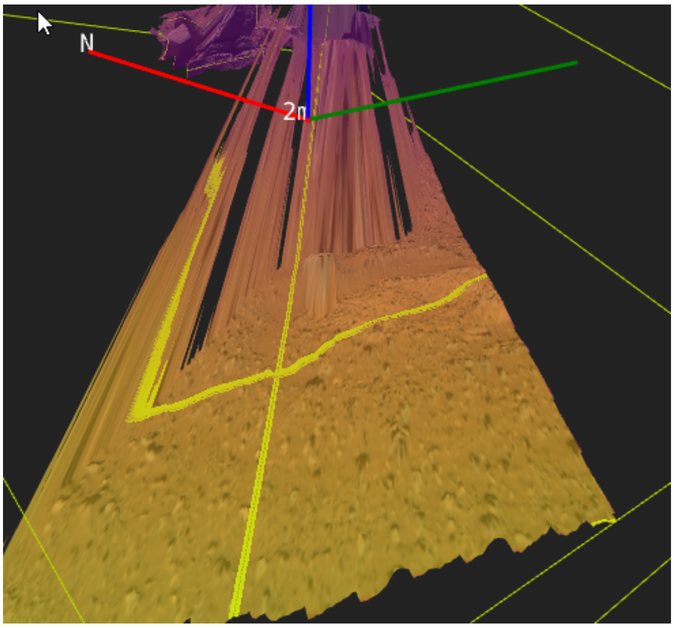


Figure 47: An accuracy map of the reconstruction.

By using query parameters and a transfer function specific attributes can be filtered (e.g. here the elevation):

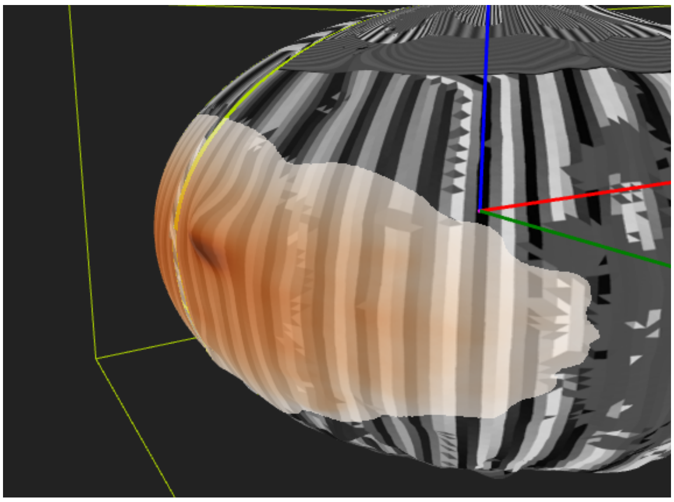


Figure 48: The elevation is filtered.

The controls can be found in the surface properties when selecting a surface.

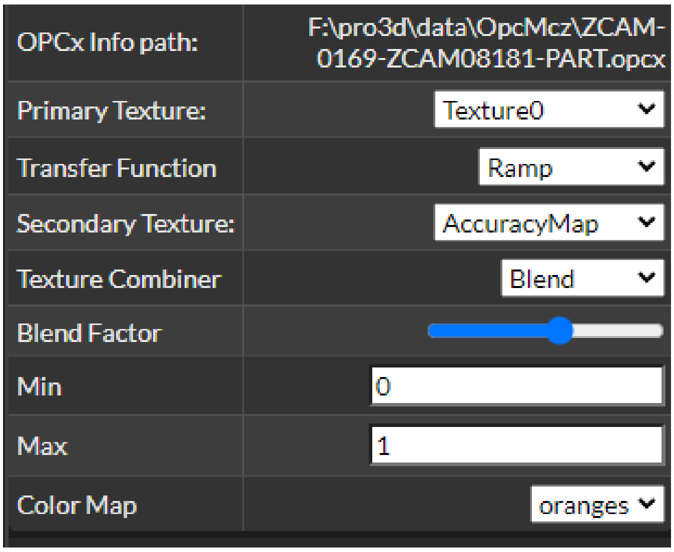


Figure 49: The multitexturing controls in the surface properties.

Caveats and missing features Currently we only read opcx files as opposed to opcx.json files which also provide a friendly name for the texture layers. In favor of reduced complexity we opted for the simpler, established opcx solution which could also be extended to contain a friendly name for the layer.

Data Example An example of currently available data can be found in the Appendix 9.1.

5 Minerva

Figure 50: 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 50 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 workflow between PRo3D and Visplore. To communicate with Visplore use the tree buttons shown in Figure 50 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

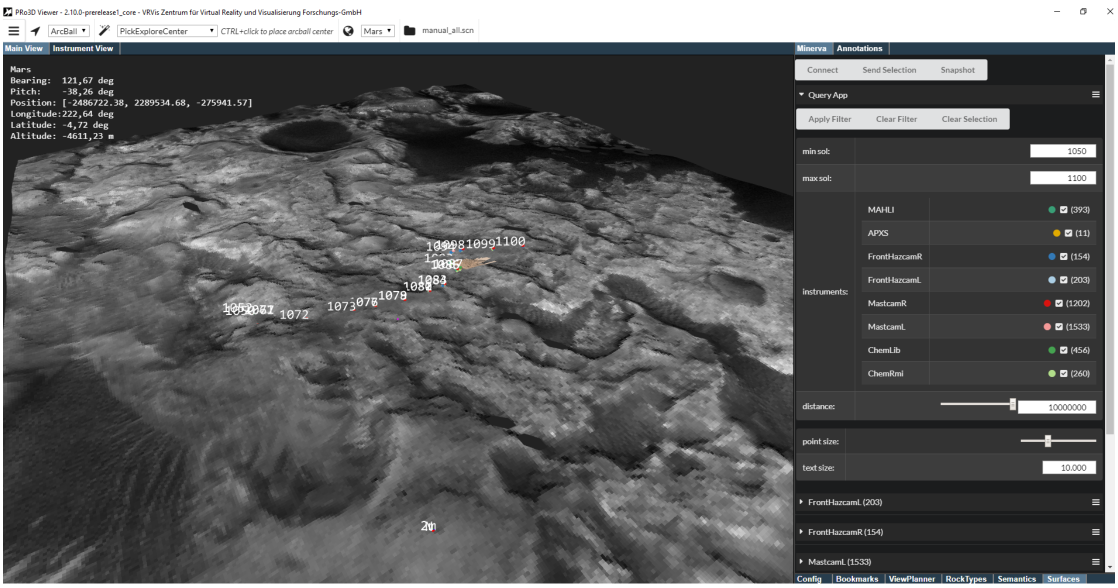


Figure 51: The Query App (right).

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.

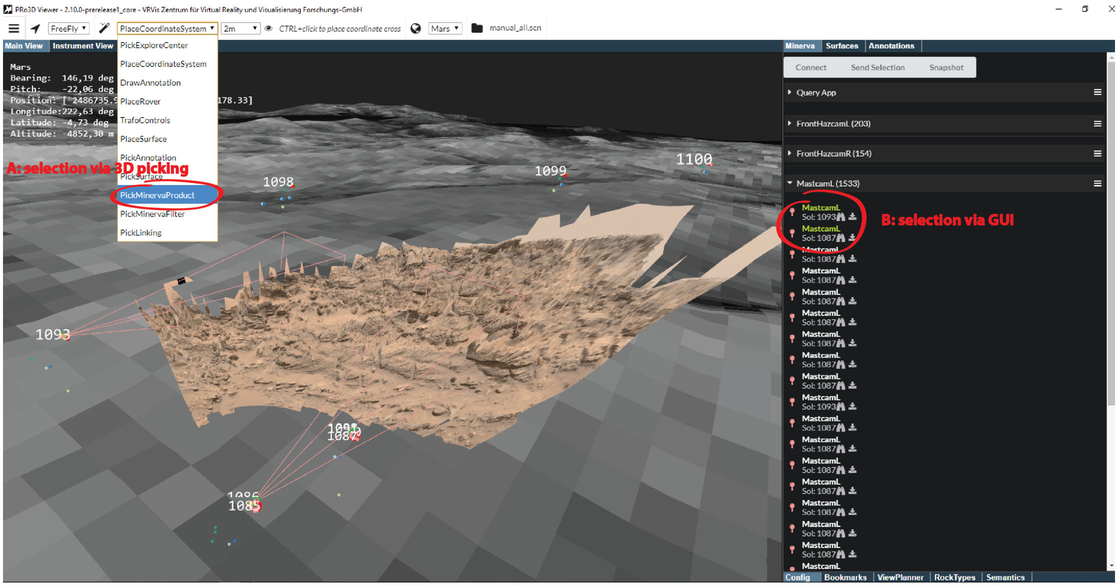


Figure 52: The products are grouped by instruments. A product can either be selected in the listing (B) or in the Main View (A).

5.2.3 Product Listing and Selection

The products are grouped in the gui by their instruments (Figure 50 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 52), 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.

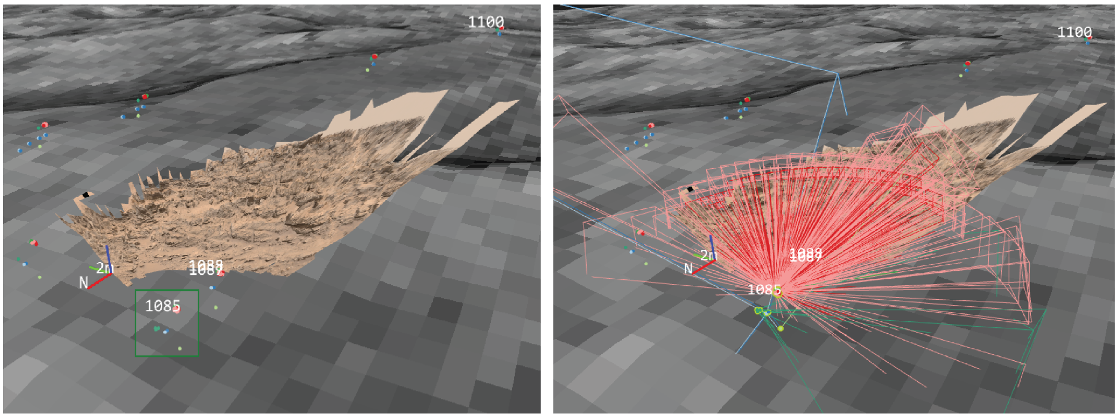


Figure 53: A rectangle is spanned over multiple products (left). All products selected by the rectangle (right).

It is also possible to select multiple products. Press SHIFT+LMB and drag a rectangle (Figure 53 left). When you release the LMB, all products in this area are selected (Figure 53 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

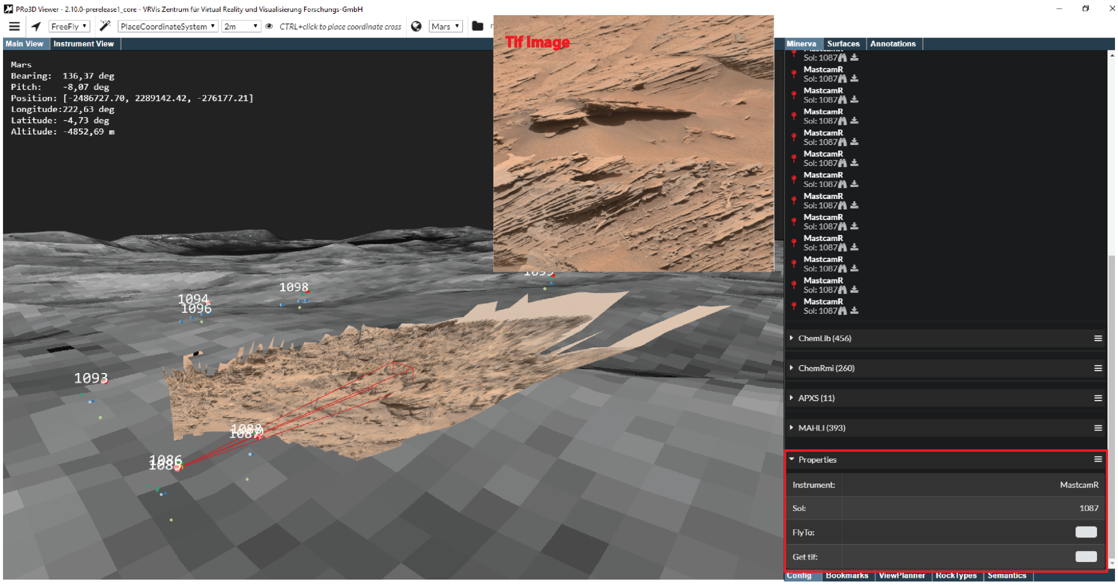


Figure 54: The properties panel shows the sol number and provides interactions for the last selected product.

The properties panel (Figure 50 D and Figure 54) 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 56.

- **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 55).

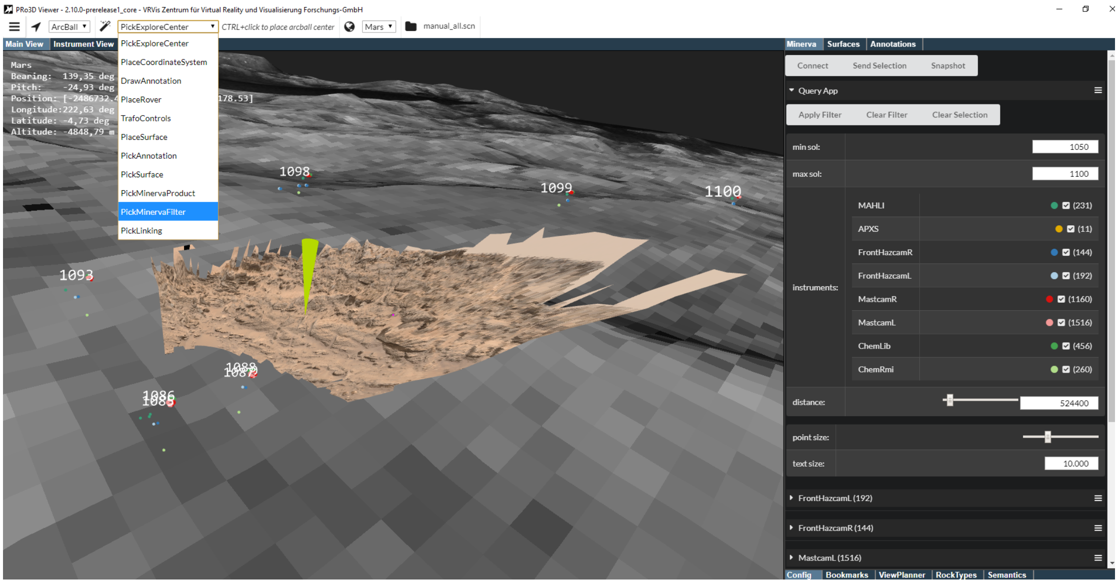


Figure 55: PickMinervaFilter

- **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 56).

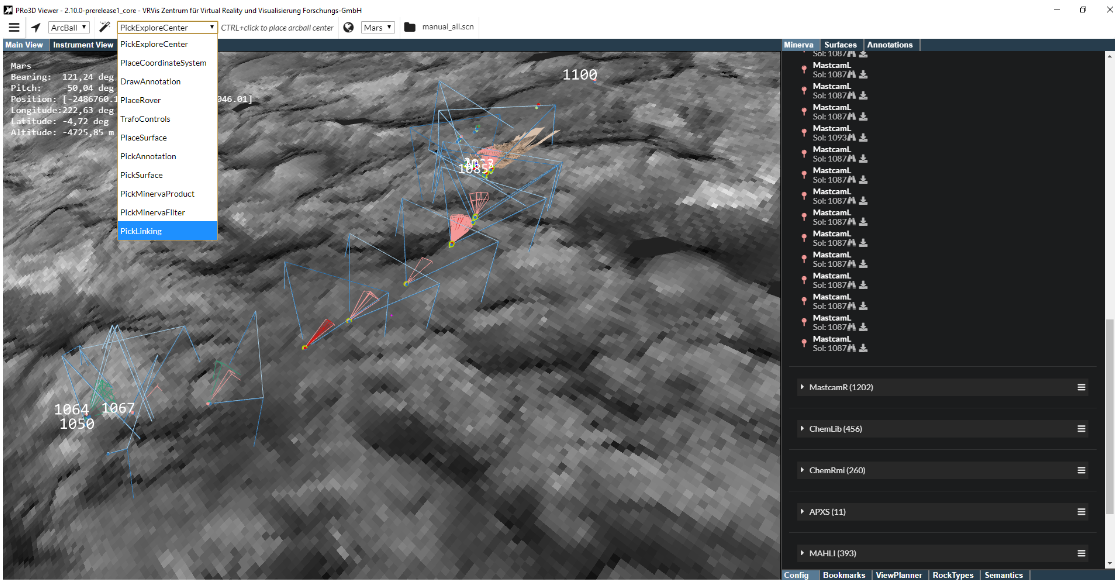


Figure 56: PickLinking

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

With the executable `PRo3D.Snapshots.exe` you 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.Snapshots.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
--scn [path]	path to a PRo3D scene
--obj [path];[path];[...]	load OBJ(s) from one or more paths
--opc [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.Snapshots.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.Snapshots.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 57). 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.

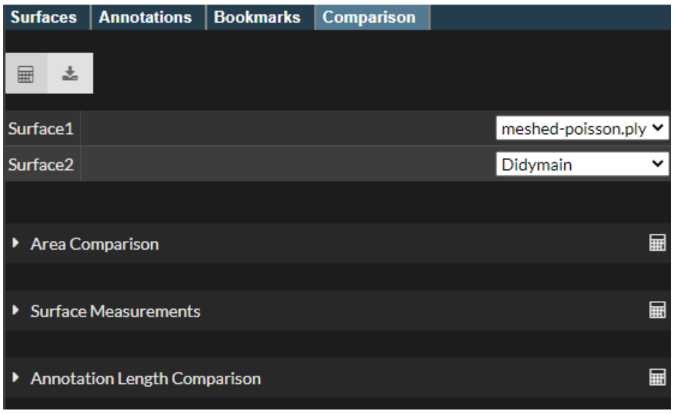


Figure 57: The Surface Comparison Interface.

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 62). To export all measurements click on button with the download icon (figure 58). The measurements will be saved in the PRo3D home directory. The full path is printed on the console when exporting.

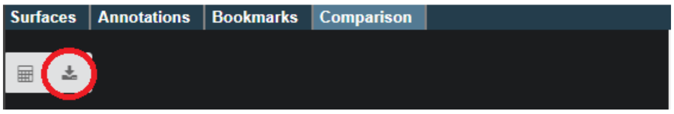


Figure 58: The *export* button is circled in red. Click on this button to export all listed measurements.

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 59).
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 60). You can make this sphere smaller by pressing the *minus* key,

Figure 59: 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).

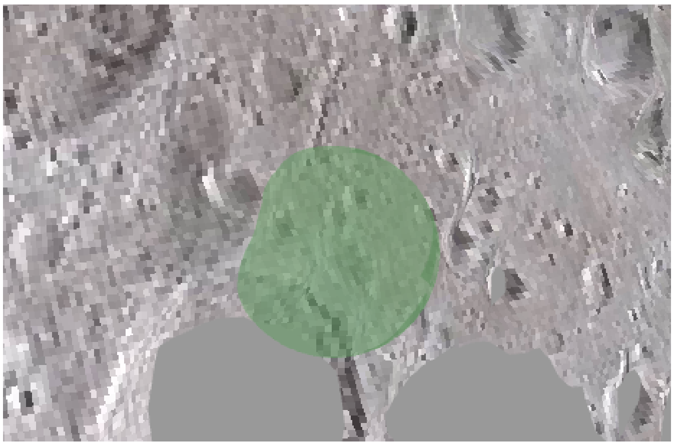


Figure 60: A selected area.

All areas you have created are displayed in a list (figure 61). If you wish to change the location of an area, simply delete it by clicking on the red cross and select a new location.

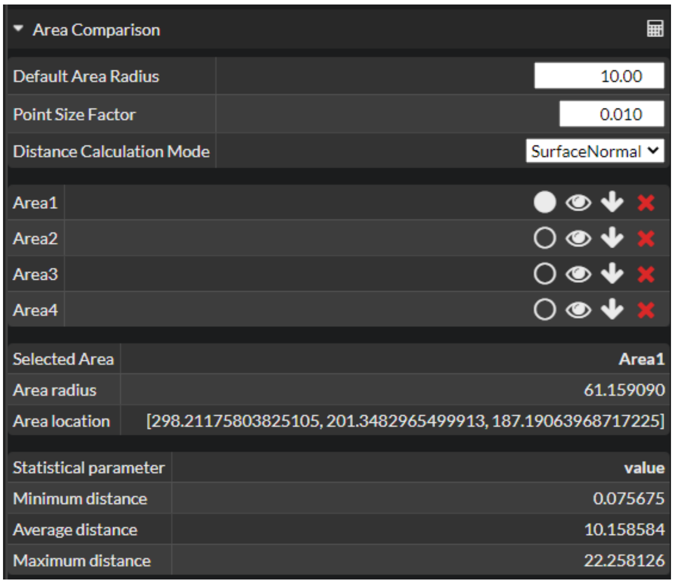


Figure 61: The interface for area comparison.

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 61, *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 62). Depending on the size of the area and the resolution of the surfaces, this might take a few seconds.

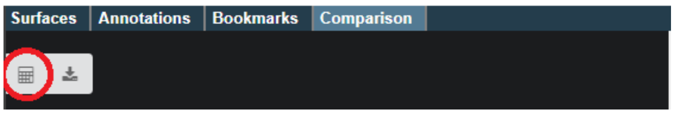


Figure 62: The *update* button is circled in red. To update all comparison calculations and visualisations click on this button.

Each location that was used to calculate the distance between the two surfaces is visualised with a coloured sphere (figure 63). 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 64 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.

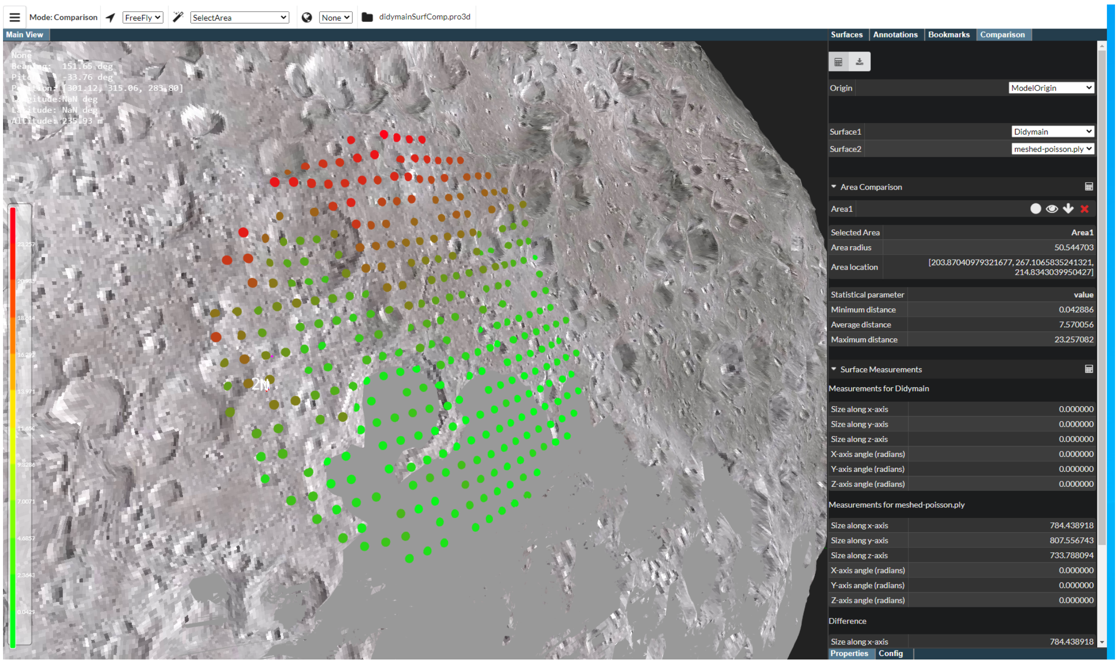


Figure 63: Comparing an area of two surfaces.

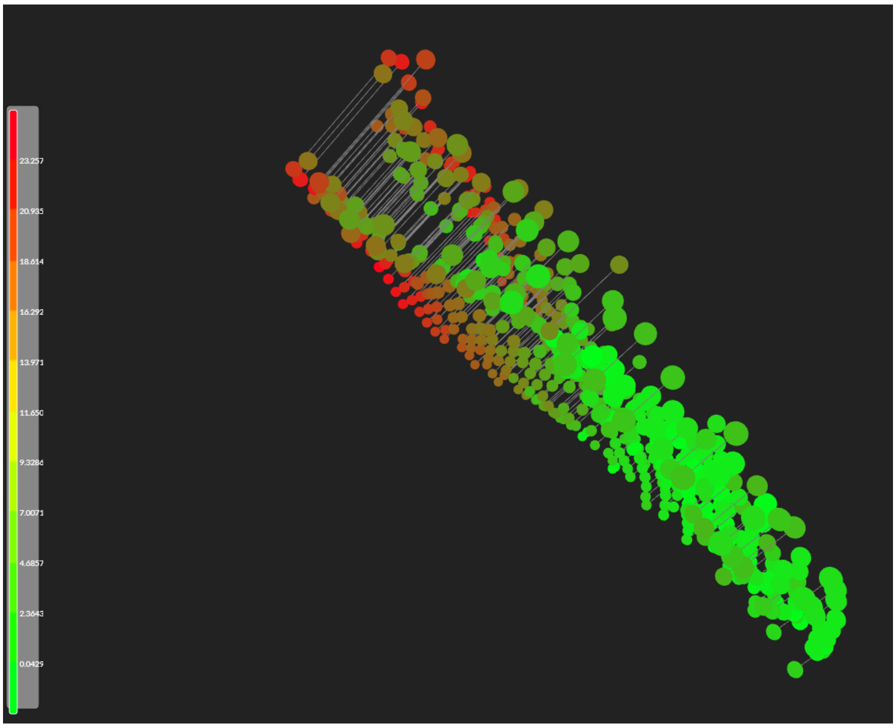


Figure 64: Visualising the differences between two surfaces on a vertex level. The surfaces have been set to invisible.

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.

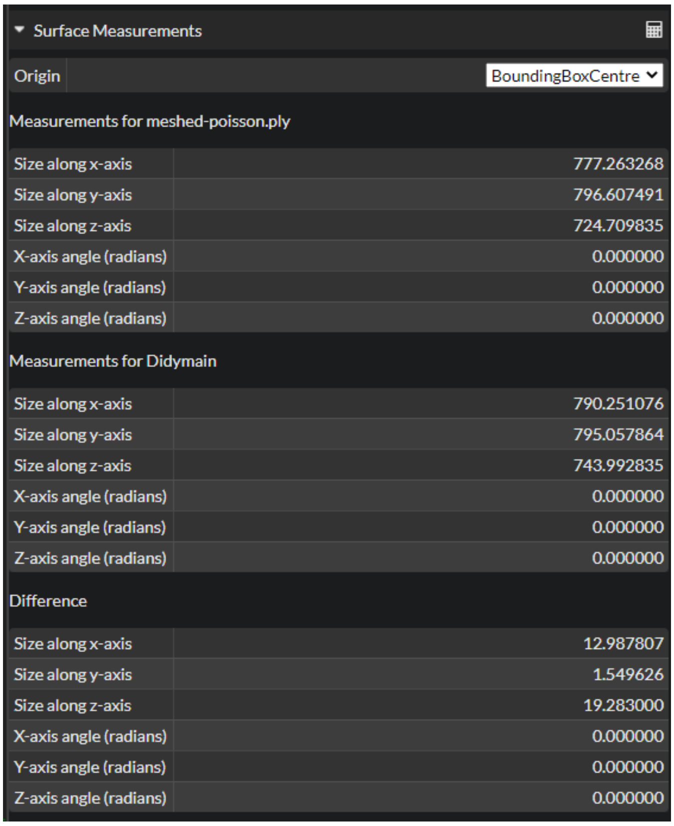


Figure 65: Surface Measurements. These measurements are only valid for *spherical* models. If there are holes in the model the calculation might fail. Choosing a different Origin in the drop down menu can help in these cases.

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 66).

Figure 66: 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

9 Appendix

9.1 Multitexturing: Example of the currently available data

```
"attribute_layers": [
        {
            "label": "Texture0",
            "channels": 3,
            "channel_meaning": [
                {
                    "meaning": "Red channel",
                    "unit": ""
                },
                {
                    "meaning": "Green channel",
                    "unit": ""
                },
                {
                    "meaning": "Blue channel",
                    "unit": ""
                }
            ]
        },
        {
            "label": "Are",
            "channels": 1,
            "channel_meaning": [
                {
                    "meaning": "Area",
                    "unit": "km^2"
                }
            ],
            "no_data_value": 0,
            "pixel_value_scaling": [
                {
                    "scaling_factor": 7.9786402926316e-09,
                    "value_offset": 1.042114604388189e-06
                }
            ]
        },
        {
            "label": "Ele",
            "channels": 1,
            "channel_meaning": [
                {
                    "meaning": "Elevation",
                    "unit": "Meter"
                }
```

```
            ],
            "no_data_value": 0,
            "pixel_value_scaling": [
                {
                    "scaling_factor": 0.48938430490074897,
                    "value_offset": 0.0037061963230371475
                }
            ]
        },
        {
            "label": "GrM",
            "channels": 1,
            "channel_meaning": [
                {
                    "meaning": "Gravitation Magnitude",
                    "unit": "m/s^2"
                }
            ],
            "no_data_value": 0,
            "pixel_value_scaling": [
                {
                    "scaling_factor": 5.19640585609279e-08,
                    "value_offset": 3.759760147659108e-05
                }
            ]
        },
        {
            "label": "GrP",
            "channels": 1,
            "channel_meaning": [
                {
                    "meaning": "Gravitation Potential",
                    "unit": "J/kg"
                }
            ],
            "no_data_value": 0,
            "pixel_value_scaling": [
                {
                    "scaling_factor": 1.8399184034389305e-05,
                    "value_offset": -0.0058954209089279175
                }
            ]
        },
        {
            "label": "GrX",
            "channels": 1,
            "channel_meaning": [
                {
                    "meaning": "Gravity Vector X",
```

```
                    "unit": "m/s^2"
                }
            ],
            "no_data_value": 0,
            "pixel_value_scaling": [
                {
                    "scaling_factor": 3.1842884752444746e-07,
                    "value_offset": -3.989627293776721e-05
                }
            ]
        },
        {
            "label": "GrY",
            "channels": 1,
            "channel_meaning": [
                {
                    "meaning": "Gravity Vector Y",
                    "unit": "m/s^2"
                }
            ],
            "no_data_value": 0,
            "pixel_value_scaling": [
                {
                    "scaling_factor": 3.634925053306437e-07,
                    "value_offset": -4.6144461521180347e-05
                }
            ]
        },
        {
            "label": "GrZ",
            "channels": 1,
            "channel_meaning": [
                {
                    "meaning": "Gravitaty Vector Z",
                    "unit": "m/s^2"
                }
            ],
            "no_data_value": 0,
            "pixel_value_scaling": [
                {
                    "scaling_factor": 3.9970011960927717e-07,
                    "value_offset": -5.078775211586617e-05
                }
            ]
        },
        {
            "label": "Lat",
            "channels": 1,
            "channel_meaning": [
```

```
                {
                    "meaning": "Latitude",
                    "unit": "deg"
                }
            ],
            "no_data_value": 0,
            "pixel_value_scaling": [
                {
                    "scaling_factor": 0.7086614173228346,
                    "value_offset": -90.0
                }
            ]
        },
        {
            "label": "Lon",
            "channels": 1,
            "channel_meaning": [
                {
                    "meaning": "Longitude",
                    "unit": "deg"
                }
            ],
            "no_data_value": 0,
            "pixel_value_scaling": [
                {
                    "scaling_factor": 1.4166667067159817,
                    "value_offset": 0.0
                }
            ]
        },
        {
            "label": "NmX",
            "channels": 1,
            "channel_meaning": [
                {
                    "meaning": "Normal Vector X",
                    "unit": ""
                }
            ],
            "no_data_value": 0,
            "pixel_value_scaling": [
                {
                    "scaling_factor": 0.00786956393812585,
                    "value_offset": -0.9992351531982422
                }
            ]
        },
        {
            "label": "NmY",
```

```
            "channels": 1,
            "channel_meaning": [
                {
                    "meaning": "Normal Vector Y",
                    "unit": ""
                }
            ],
            "no_data_value": 0,
            "pixel_value_scaling": [
                {
                    "scaling_factor": 0.007865285075555636,
                    "value_offset": -0.9980932474136353
                }
            ]
        },
        {
            "label": "NmZ",
            "channels": 1,
            "channel_meaning": [
                {
                    "meaning": "Normal Vector Z",
                    "unit": ""
                }
            ],
            "no_data_value": 0,
            "pixel_value_scaling": [
                {
                    "scaling_factor": 0.007873622920569472,
                    "value_offset": -0.9999253749847412
                }
            ]
        },
        {
            "label": "Rad",
            "channels": 1,
            "channel_meaning": [
                {
                    "meaning": "Radius",
                    "unit": "Meter"
                }
            ],
            "no_data_value": 0,
            "pixel_value_scaling": [
                {
                    "scaling_factor": 0.00014005184877575853,
                    "value_offset": 0.05649212002754211 4
                }
            ]
        },
```

```
        {
            "label": "Slo",
            "channels": 1,
            "channel_meaning": [
                {
                    "meaning": "Slope",
                    "unit": "deg"
                }
            ],
            "no_data_value": 0,
            "pixel_value_scaling": [
                {
                    "scaling_factor": 0.18442003839597929,
                    "value_offset": 0.3605306148529053
                }
            ]
        },
        {
            "label": "XCo",
            "channels": 1,
            "channel_meaning": [
                {
                    "meaning": "X Coordinate of vertices",
                    "unit": "km"
                }
            ],
            "no_data_value": 0,
            "pixel_value_scaling": [
                {
                    "scaling_factor": 0.00069638095268114434,
                    "value_offset": -0.08918076008558273
                }
            ]
        },
        {
            "label": "YCo",
            "channels": 1,
            "channel_meaning": [
                {
                    "meaning": "Y Coordinate of vertices",
                    "unit": "km"
                }
            ],
            "no_data_value": 0,
            "pixel_value_scaling": [
                {
                    "scaling_factor": 0.00068455682260783364,
                    "value_offset": -0.08715743571519852
                }
```

```
            ]
        },
        {
            "label": "ZCo",
            "channels": 1,
            "channel_meaning": [
                {
                    "meaning": "Z Coordinate of vertices",
                    "unit": "km"
                }
            ],
            "no_data_value": 0,
            "pixel_value_scaling": [
                {
                    "scaling_factor": 0.00045456527548981464,
                    "value_offset": -0.056789569556713104
                }
            ]
        }
```