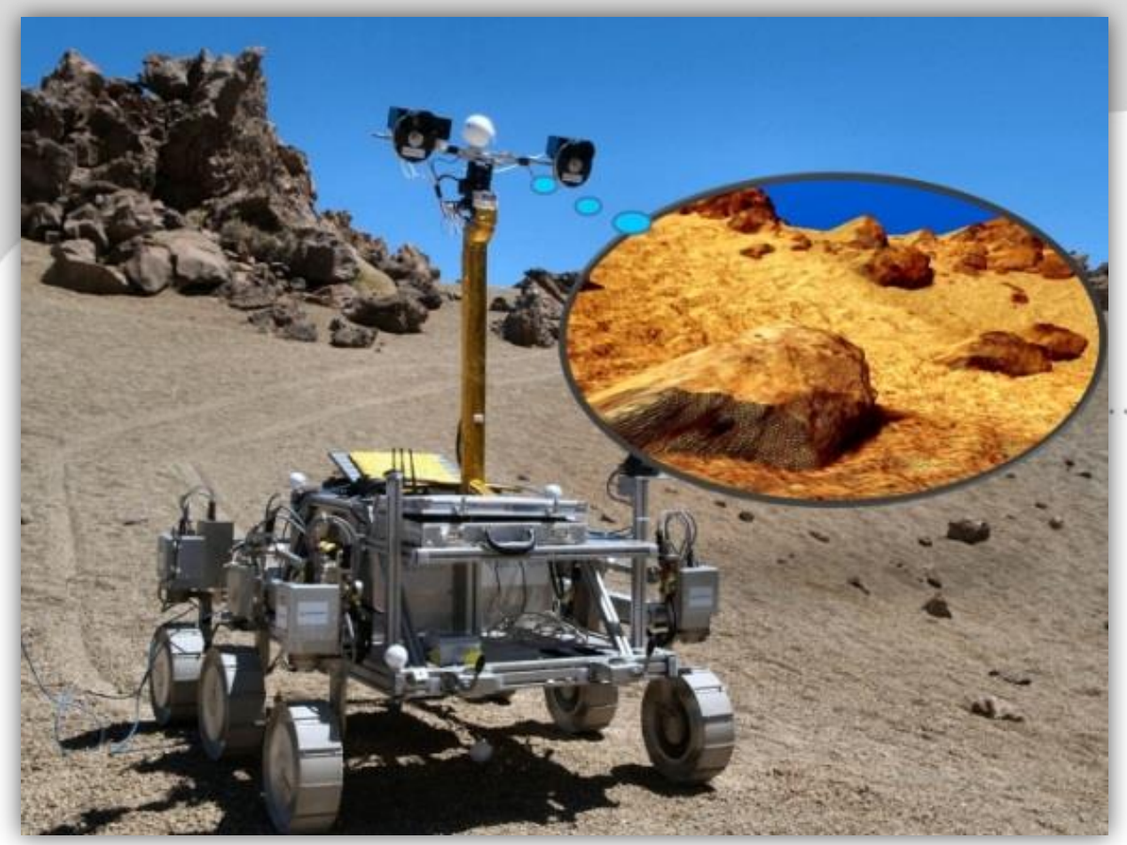
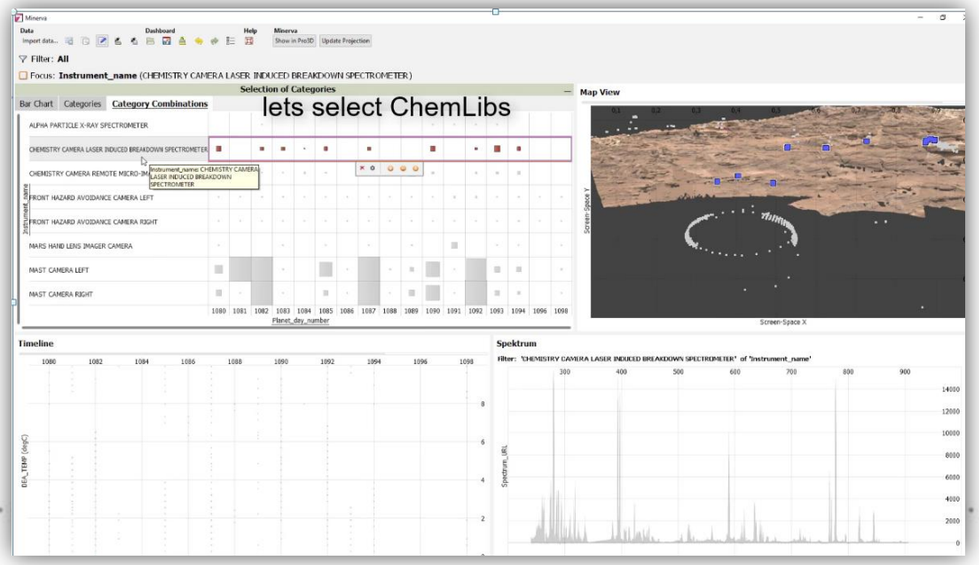


MINERVA: A 3D GIS and Visual Analysis Framework

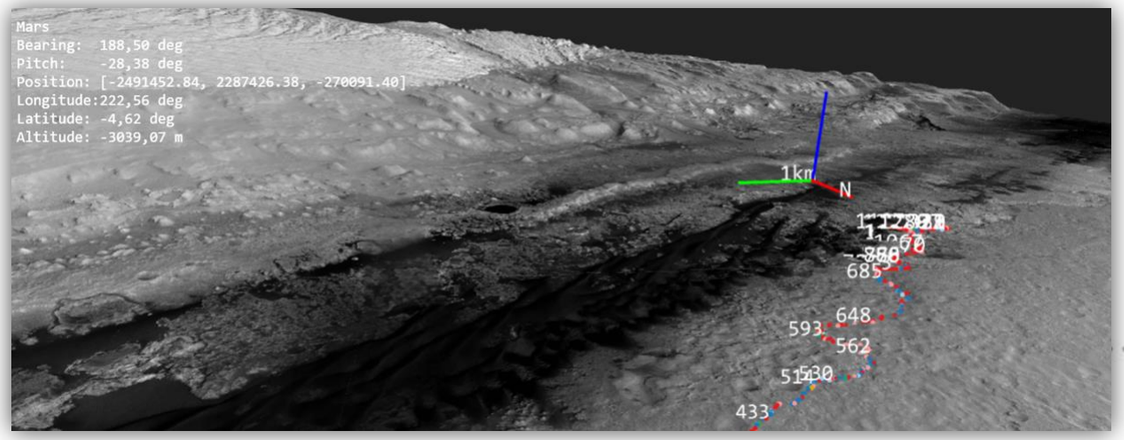
Gerhard Paar, Bernhard Nauschnegg / JOANNEUM RESEARCH

Thomas Ortner, Christoph Traxler, Harald Piringer, Laura Fritz, Maria Schimkowitsch / VRVis

Gerhard Triebnig, Fabian Schindler / EOX



2019-09-15



Motivation

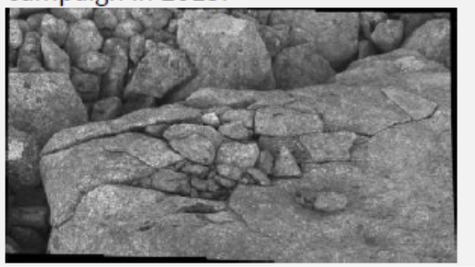
- MSL, ExoMars, Mars-2020 et al: Versatile suite of instruments – remote (Sat & Rover vision) / close-up / analytic
  - Collaboration of instrument teams requires a toolset to host instrument data in their spatiotemporal environment
- Experience from MER & MSL: Drawback on collaboration tools
  - Sharing of observations within & between teams not straightforward
- MINERVA to provide **Spatial & temporal cross-instrument data association**
- MINERVA to maintain a 3D GIS for all Mission instrument data
  - Complement to mission GIS
  - To include (processing) products

PROJECT GOALS:
MINERVA aims at researching enabling technology for a collaborative, holistic planetary science data infrastructure to allow members of different instrument teams to cooperate synergistically in virtual workspaces by sharing observation information, analysing and annotating the data, and also by discovering new modes of scientific exploitation through visual analytics. MINERVA will research and prototypically implement a novel framework of interoperable and collaborative components based on an interactive 3D Viewer with GIS functionality, a database that maintains the knowledge about spatiotemporal data products, and a visual analytics platform that will help find new interconnections between the data coming from different instruments. MINERVA will be evaluated in the course of the ExoMars Rover Mission (launched in 2020), which provides a heterogeneous set of scientific data captured by different instruments from the surface of the Red Planet. The MINERVA concept will bring about a significant game-changing advance in the field of planetary science data understanding and exploitation for the ExoMars Rover mission and beyond.

e.g. PPL Instruments

Table 16: ExoMars science teams' data (imaging instruments, *other laboratory instruments including ALD*)[15].

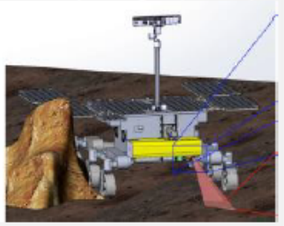
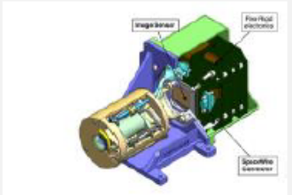
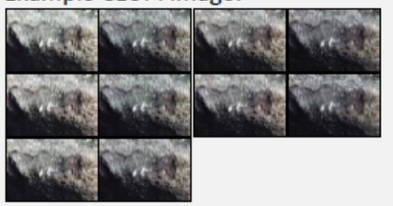
ExoMars Instrument	Characterization	Data as derived from **telemetry**, relevant for MINERVA maintenance	**Science Data blobs** to be maintained in MINERVA (each complemented by subsets of meta data listed in Table 4)	Typical Amount of Data per Sol	Data Examples[16]
Panoramic camera system: 2 wide angle cameras (**PanCam WACs**)	multi-spectral stereoscopic panoramic imaging using a miniaturized filter wheel	matrix of type integer and size 1024x1024, optionally times up to 11 spectra	• RGB & Multispectral Panoramas • DEM (Cartesian / Spherical) & monochrome / RGB / Multispectral Ortho image • Spectra at specific rock surfaces	1 RGB stereoscopic panorama (8 image pairs) + 1 full filter-set monoscopic view (11 images)	360° Spherical DEM (16 pan, 1 tilt) taken during AMASE campaign in 2013. Top: texturized wrl file, bottom: ortho image. 

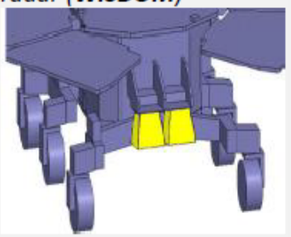
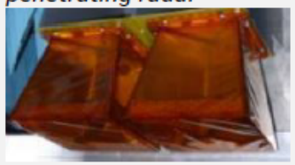
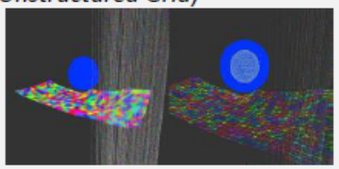
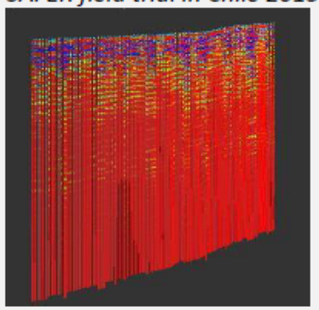
Panoramic camera system: high resolution camera (**PanCam HRC**)	high-resolution (on surface) color imaging. "stripe" interference filters, each directly bonded over part of the active area of the APS	matrix of type integer and size 1024x1024, optionally times up to 3 spectra (RGB).	• RGB Panoramas
			• Fusion product with PanCam WAC
			  ○ Multi-resolution Panorama
			  Multi-resolution Ortho Image
				1 RGB monoscopic panorama (12 images)	Single channel PanCam HRC panorama (10 images) taken during AMASE campaign in 2013. 

PanCam [11] has been designed to perform digital terrain mapping for the rover and to search for morphological signatures of past biological activity preserved on the texture of surface rocks. It will also support the scientific measurements of other instruments by taking high-resolution images of locations that are difficult to access, such as craters or rock walls, and by supporting the selection of the best sites to carry out exobiology studies.

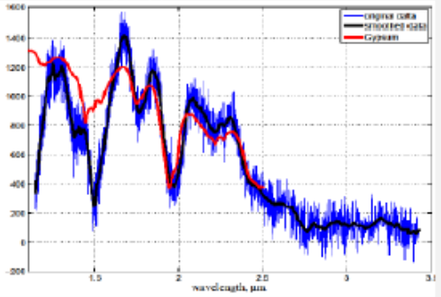
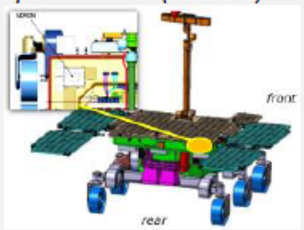
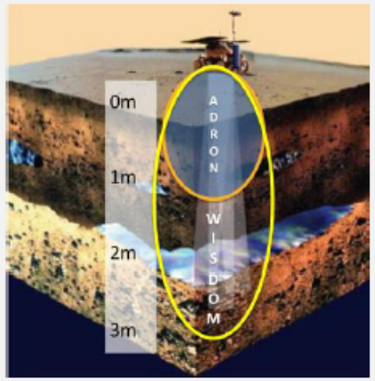
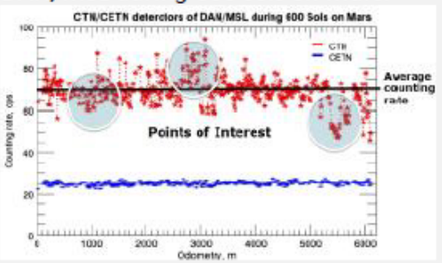
PPL Instruments

ExoMars Instrument	Characterization	Data as derived from **telemetry**, relevant for MINERVA maintenance	**Science Data blobs** to be maintained in MINERVA (each complemented by subsets of meta data listed in Table 4)	Typical Amount of Data per Sol	Data Examples[16]

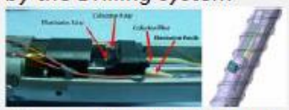
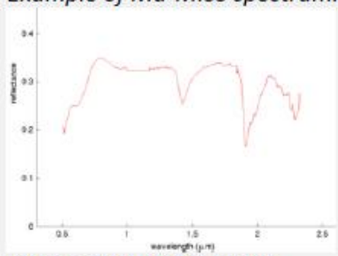
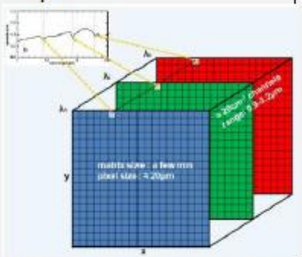
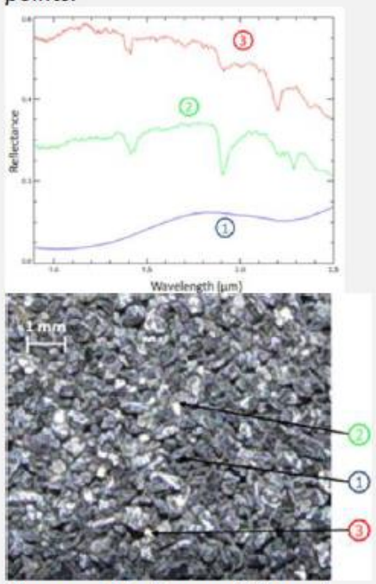
Close-Up Imager (**CLUPI**)
 
(source: CLUPI Team)
	high-resolution colour close-up imaging with variable FoV and focal length; beam splitting by mirror; pointing by drill box.
	 
	(source: CLUPI Team)
		2D * N matrix of type integer and size 1768x2652x3
		
		Imaging positions in GNC coordinate system/s
		Capturing meta data (focus positions, capturing window, …)
			• Focus stack
			  ○ 3D surface
			  ○ Focused image
			• Drilling observation time lapse
			• 3D data fusion with PanCam product
			• Resolution map / incidence angle map
				1 focus stack (6 images); 3 images across bracket mirror	Example CLUPI image.
					 
					(source: CLUPI Team)
					 
					(source: CLUPI Team / JR)

CLUPI [12] is a camera system to acquire high-resolution color close-up images (50 cm/20 in with sub-millimetre resolution) of rocks, outcrops, drill fines and drill core samples. The close-up imager has variable focusing and can also obtain high-resolution images at longer distances.					
*Ground penetrating radar (**WISDOM**)*  *(source: WISDOM Team [49])*	*Ultrawideband ground penetrating radar*  *(source: WISDOM Team)*	*Signal stream to be preprocessed by WISDOM Team; Relevant for display of "raw" data:* • *Rover track* • *Depth targeted for recording*	*(1) Contrast profiles* *(2) Interfaces / iso-surfaces* *(3) Objects* *All available in VTK xml format for unstruck-tured meshes vtk Unstructured Grid)*  *(Source: PRo3D. left: solid, right: wireframe)*	*5-10 Profiles with 4m in length each (TBD)*	*WISDOM Contrast Profile taken during SAFER field trial in Chile 2013 [51].*  *(Source: PRo3D)*
WISDOM [13] Water Ice and Subsurface Deposit Information On Mars: Explore the subsurface of Mars with a centimeter resolution up to a depth of 3 meters below the ExoMars Rover to identify layering and help select interesting buried formations from which to collect samples for analysis.					

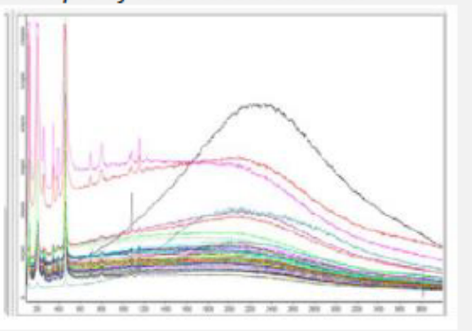
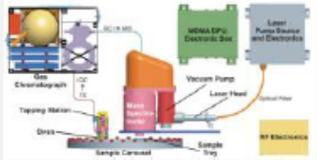
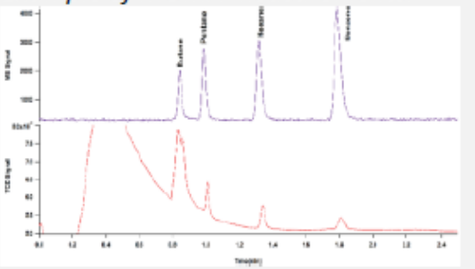
PPL Instruments

ExoMars Instrument	Characterization	Data as derived from telemetry, relevant for MINERVA maintenance	Science Data blobs to be maintained in MINERVA (each complemented by subsets of meta data listed in Table 4)	Typical Amount of Data per Sol	Data Examples[16]
*Infrared Spectrometer for ExoMars (**ISEM**)*	*AOTF-based single-pixel spectrometer with 1° FoV, within FoV of HRC*	*Spectrum consisting of 5000 points, preprocessed by ISEM Team.*	• *Spectra at specific rock surfaces* • *Fusion of spectra with PanCam WAC* • *Overlay of spectra on HRC / WAC 3D fusion*	*100 observations of full spectra*	*Example of Gypsum spectrum*  *(Source: ISEM Team)*
ISEM [14] is an infrared spectrometer for bulk mineralogy characterization, remote identification of water-related minerals and for aiding PanCam with target selection.					
*Adron Neutron Spectrometer (**ADRON**)*  *(Source: ADRON Team)*	*The instrument contains two detectors based on 3He proportional counters* 	*CTN / CETN along the Rover track*	• *Fusion with WISDOM visualization* • *Density of CTN/CETN along Rover track* • *Hot Spots / Points of interest highlighted, displayed on top of PanCam or HiRISE DEM* 	*1 Mbyte of counted Neutrons*	*Example: CTN / CETN detectors of DAN/MSL during 600 sols on Mars.*  *(Source: MSL Team)*
ADRON [15] [16] (see [17] for MSL heritage) is a neutron spectrometer to determine the amount of subsurface hydration, and the possible presence of water ice. It is further used to monitor radioactive environment of the Rover's vicinity, and to monitor Solar flares.					

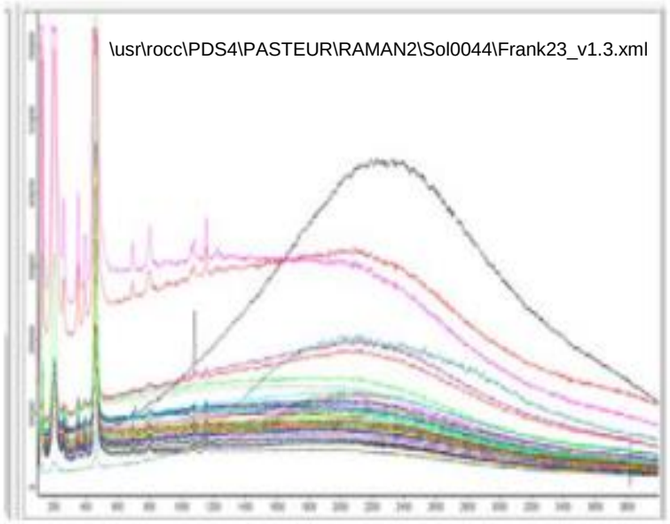
PPL Instruments

ExoMars Instrument	Characterization	Data as derived from **telemetry**, relevant for MINERVA maintenance	**Science Data blobs** to be maintained in MINERVA (each complemented by subsets of meta data listed in Table 4)	Typical Amount of Data per Sol	Data Examples[16]
*Mars Multispectral Imager for Subsurface Studies (**Ma_MISS**)*  *(Source: Ma_MISS Team)*	*VIS/NIR Spectrometer to observe the lateral wall of the borehole generated by the Drilling system*  *(Source: Ma_MISS Team)*	*Spectrum along the drilling trajectory through drill hole*	• *Drill hole 3D spectral response points* • *Fusion with WISDOM visualization*	*Spectral track through drillhole: Rings, vertical columns or even grids of spectra, several MB during one drill operation.*	*Example of Ma-MISS spectrum.*  *(Source: MA-MISS Team)*
Ma_MISS [18] is located inside the drill, the infrared spectrometer will contribute to the study of the Martian mineralogy and rock formation.					
*Infrared imaging spectrometer (**MicrOmega-IR**)*	*MicrOmega acquires reflectance spectra of 5 mm sized samples with a spatial sampling of 20 µm*	*Image cubes of spectral range between 0.9 and 3.5 µm*  *(Source: MicrOmega-IR Team)*	• *Spectra at specific rock surfaces* • *Fusion of spectra with PanCam WAC* • *Overlay of spectra on HRC / WAC 3D fusion* *applying to the original place & time of sample acquisition*	*Each probe: An image is acquired at different wavelengths (about 500 channels), building an image cube*	*Example of spectra for 3 measured points.*  *(Source: MicrOmega-IR Team)*
MicrOmega-IR [22] is an ultra-miniaturized near infrared hyperspectral microscope dedicated to in situ analyses, with the goal to characterize the composition of Mars soil at almost its grain size scale in a non-destructive way.					

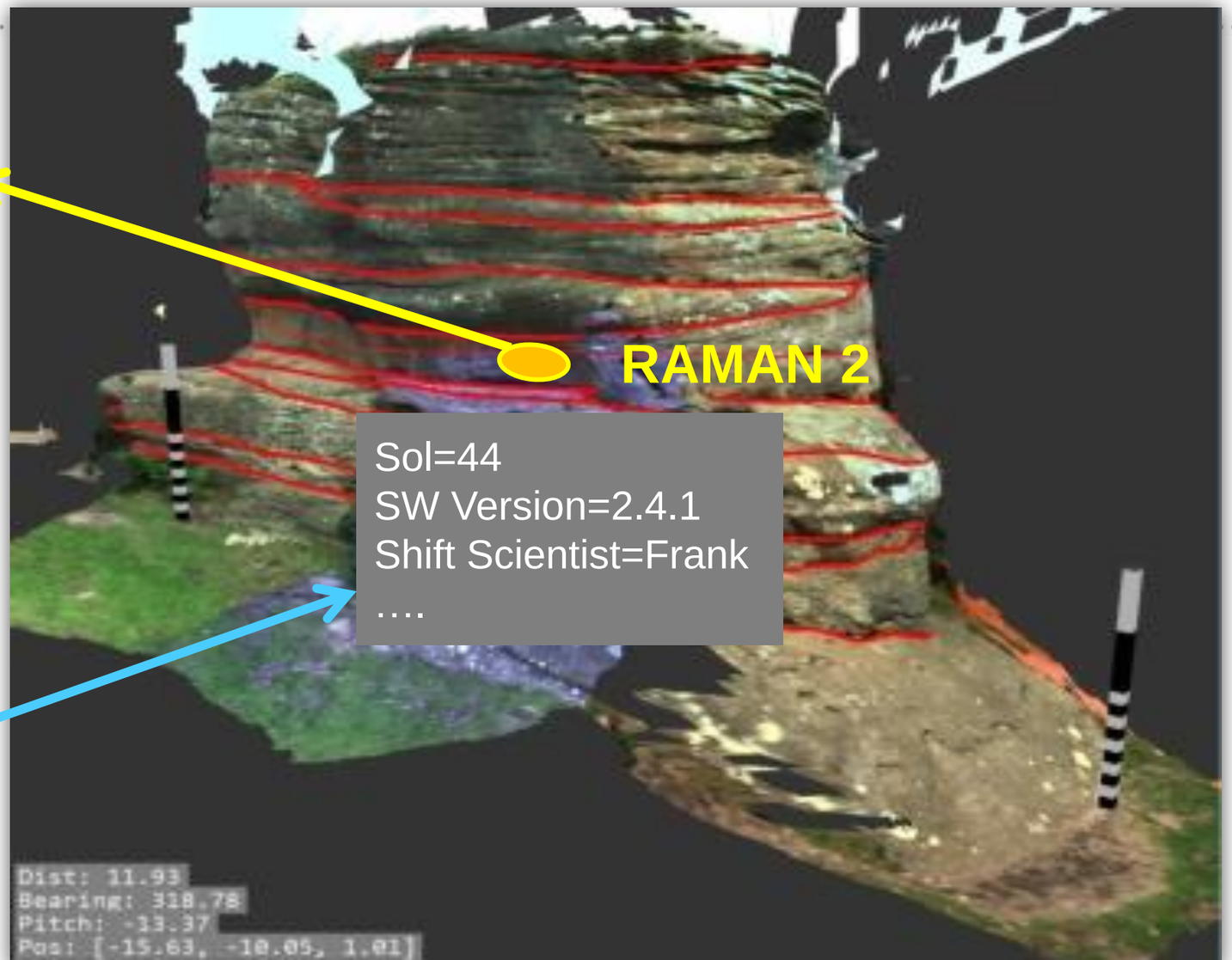
PPL Instruments

ExoMars Instrument	Characterization	Data as derived from telemetry, relevant for MINERVA maintenance	Science Data blobs to be maintained in MINERVA (each complemented by subsets of meta data listed in Table 4)	Typical Amount of Data per Sol	Data Examples[16]
*Raman Laser Spectrometer (**RLS**)*	*The Raman Laser spectrometer will analyze at the mineral grain scale samples crushed into a fine powder by means of an automatic crusher and a dosing station.*	*The spectrometer covers the spectral Raman shift from ~150 to 3800 cm^{-1} with an average spectral resolution of ~7 cm^{-1}*	• *Overlay of spectra on HRC / WAC 3D fusion applying to the original place & time of sample acquisition*	*(used only when probes are available). RLS will obtain Raman spectra on the flattened powder surface along a line, with a density of at least 20 points automatically selected on the surface at random positions. Such data will occur only sparsely during the mission and most likely be treated as a unique opportunity.*	*Example of RLS measurements.*  *(Source: RLS Team)*
As an element of the Analytical Laboratory of the Rover (ALD) the RLS [20] intends to establish mineralogical composition and identify organic pigments.					
*Mars Organic Molecule Analyzer (**MOMA**)*  *(source: MOMA Team)*	*Mass spectrometer capable of analyzing samples from pyrolysis / chemical derivatization gas chromatography (GC) as well as ambient pressure laser desorption ionization (LDI). The combination of the two analytical techniques allows for the chemical characterization of a broad range of compounds, including volatile and non-volatile species.*	*TBD*	• *Overlay of spectra on HRC / WAC 3D fusion applying to the original place & time of sample acquisition*	*(used only when probes are available). MOMA GC-MS and TCD signals will occur only sparsely during the mission and most likely be treated as a unique opportunity.*	*Example of MOMA measurements.*  *(Source: MOMA Team)*
MOMA will target biomarkers to answer questions related to the potential origin, evolution and distribution of life on Mars. It will conduct a broad-range, very-high sensitivity search for organic molecules in the collected sample providing two different ways for extracting organics: laser desorption and thermal 76olatilization, followed by separation using four GC-MS columns.					

Instrument data presentation: Initial simplistic view



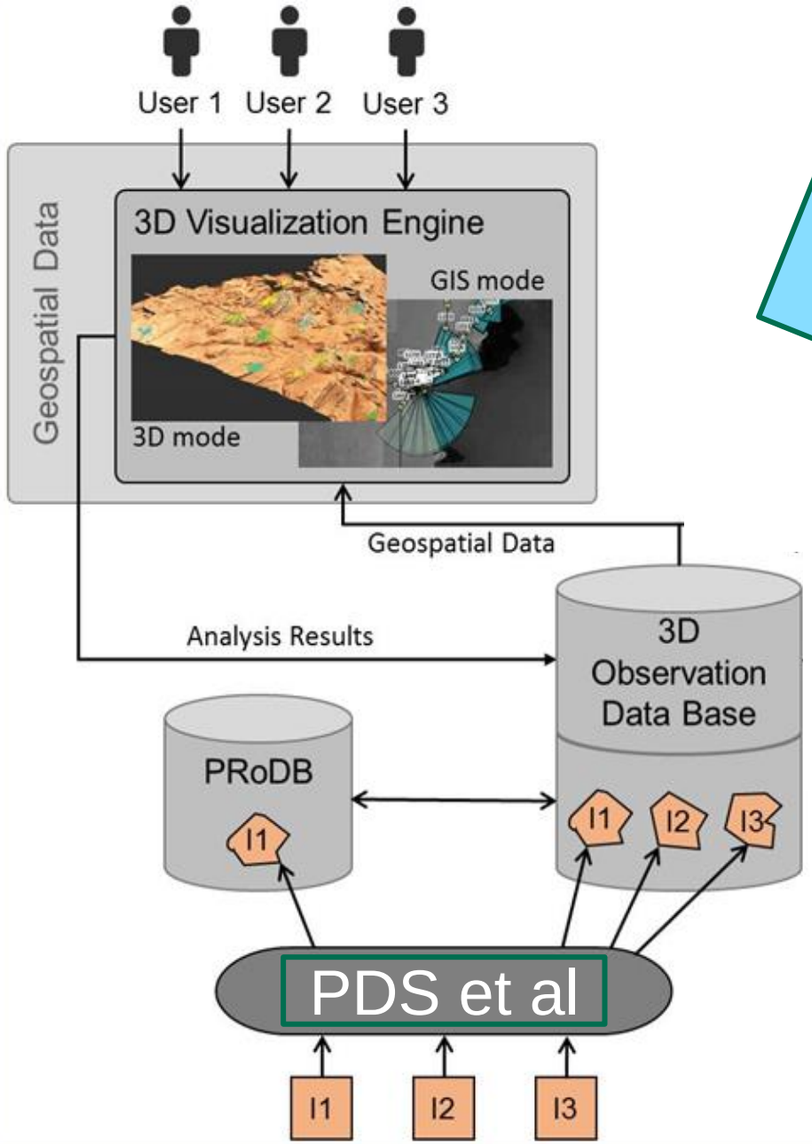
- Measurements are data blobs in 3D overview
  - Clicking therein results in
    - launch of custom presentation HMI
    - Read-out & Display of Generic Instruments Data



MINERVA Scheme

ExoMars Instruments‘ data:
- Footprints
- Frustrum
- GUID / PDS Link
- Relevant resources
  - Images
  - Spectra (ISEM, [Ma_MISS], ..)
  - H_2O% (ADRON)
  - vtk file (WISDOM)
  - Statistics
  - Specific Instruments‘ analysis SW Launching

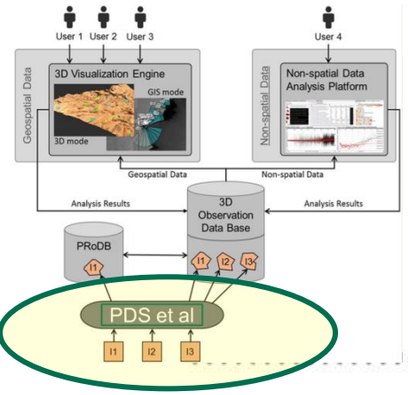
Interactive
Full 3D Viewing



Requires PDS4 spatial cues from each Instrument!

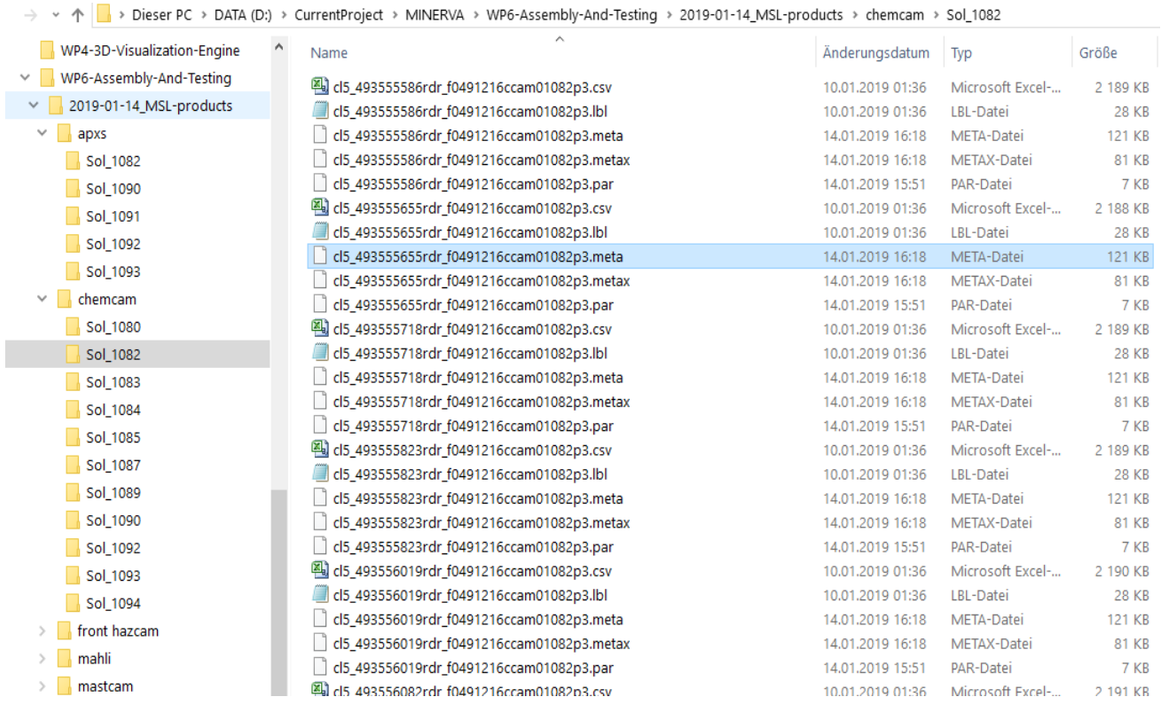
Associations Between Instruments‘ Observations

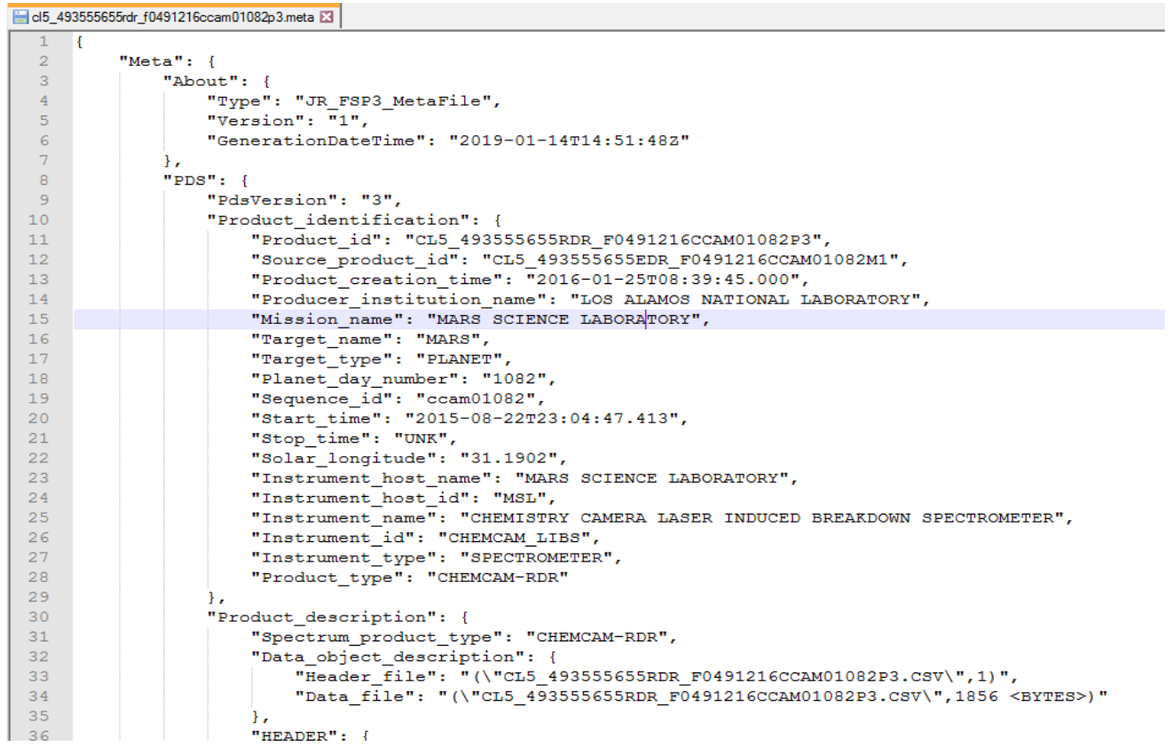
Figure 6: MINERVA concept. The Instrument Teams (I1…I3) use the generic importer tools (or – in the case of vision – the existing vision processing results as available to JR) to ingest mission data into the 3D Observation Data Base. From there it is available to the 3D Visualization Engine with integrated GIS functionality, and the Non-spatial Data Analysis Platform. Different users can share the same locations, observations, and launch visual analysis of different instruments at a time.

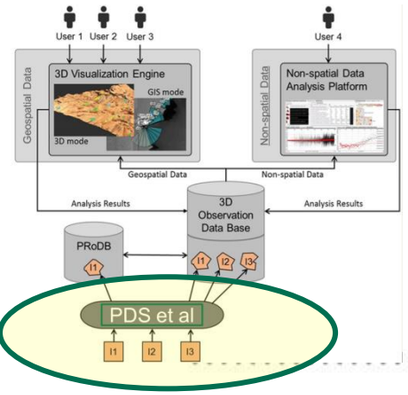


Ingestion into DBMS

- Conversion of PDS(3) schemes into json
  - Extraction of relevant information for the named use cases
  - Adding (SPICE-based) localization to keep it a „standalone“ data basis

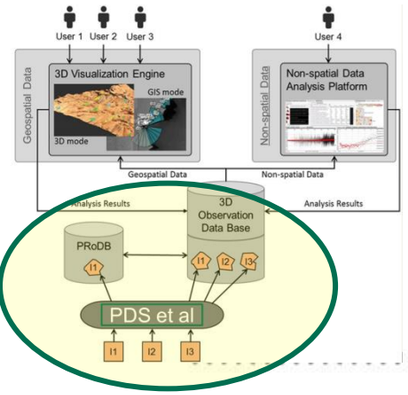






DBMS Concepts

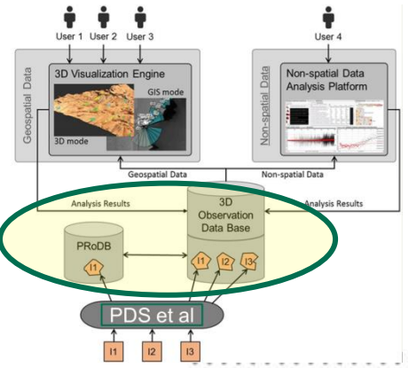
- Metadata:
  - Parsing: additional formats (XML/JSON)
  - Indexing: new database models to index metadata
  - Querying: configurable mechanism to map user supplied filters to database models
- Vector based protocol to edit annotations
  - Publish/subscribe infrastructure for live editing
- Access controls
  - Restrict access to services, collections, products (read/write) by user/group
- Python 3



Interfaces

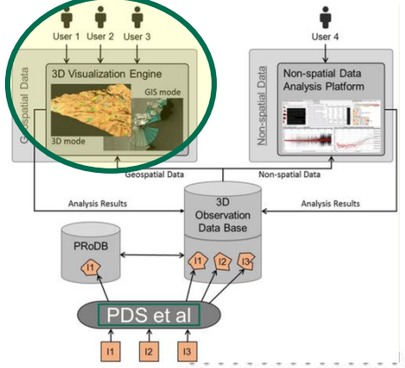
- CLI commands to manage collections/products
  - Create, delete, insert, exclude
- Access Control
  - User/group concept
    - Separate privileges to read from specific collections, products and read or write annotations
- WFS protocol to search for collections/products
  - Mapping of search parameters to database indices
    - Either KVP style: “parameter=value”
    - Or using the CQL language

```
https://minerva.eox.at/
  opensearch/collections/all/json/
  ?cql=(planetDayNumber>925 AND planetDayNumber<929)
```

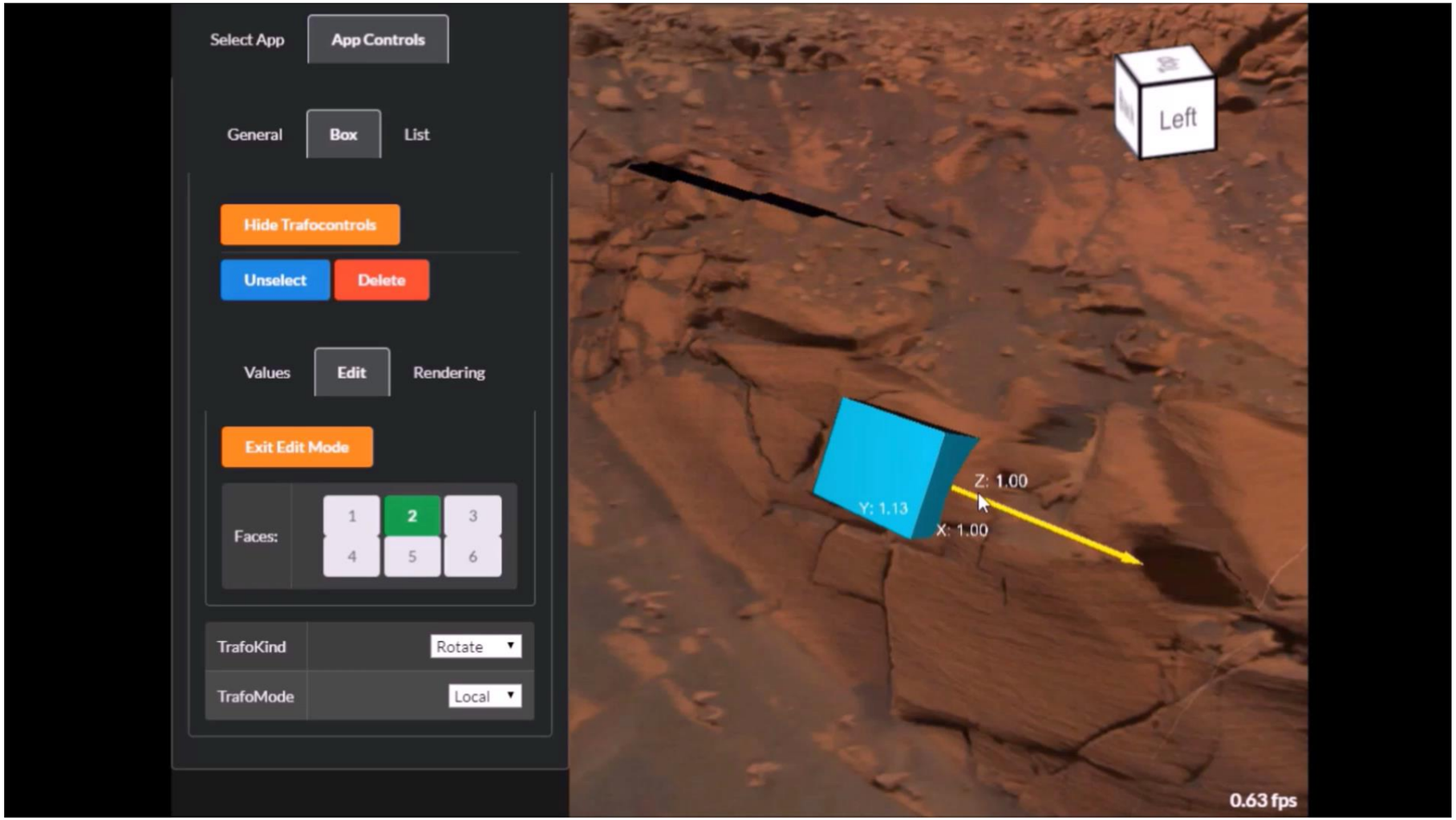


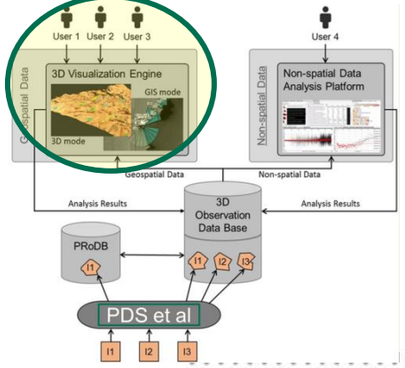
Operations Environment

- Deployment as a series of Docker containers
  - PostgreSQL
  - Apache Web Server with EOxServer + MINERVA extensions
  - Redis
- Using Docker Compose
- Require filesystem access (volume mount)
- Benefits:
  - Reproducible environment (development, production)
  - Container specific encapsulated environment
  - Minimal overhead

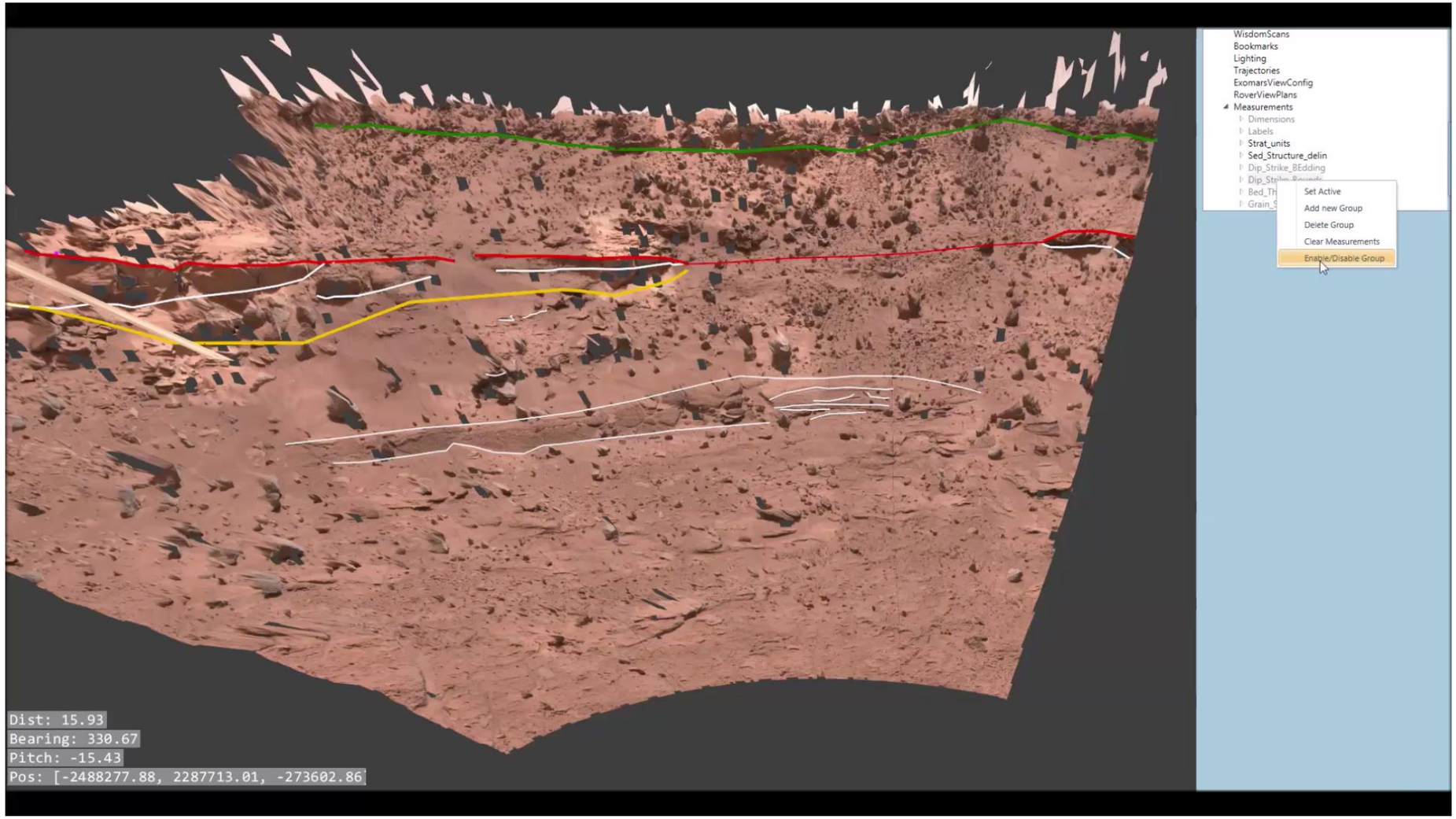


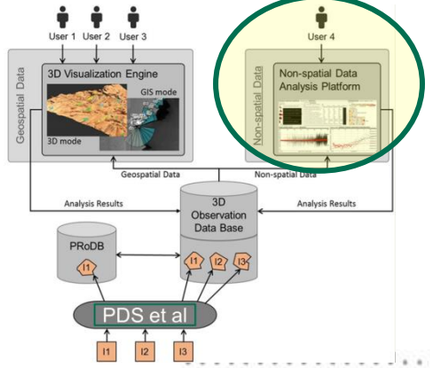
PRo3D: Exploit object representation assets to represent Instruments‘ Observations‘ footprints





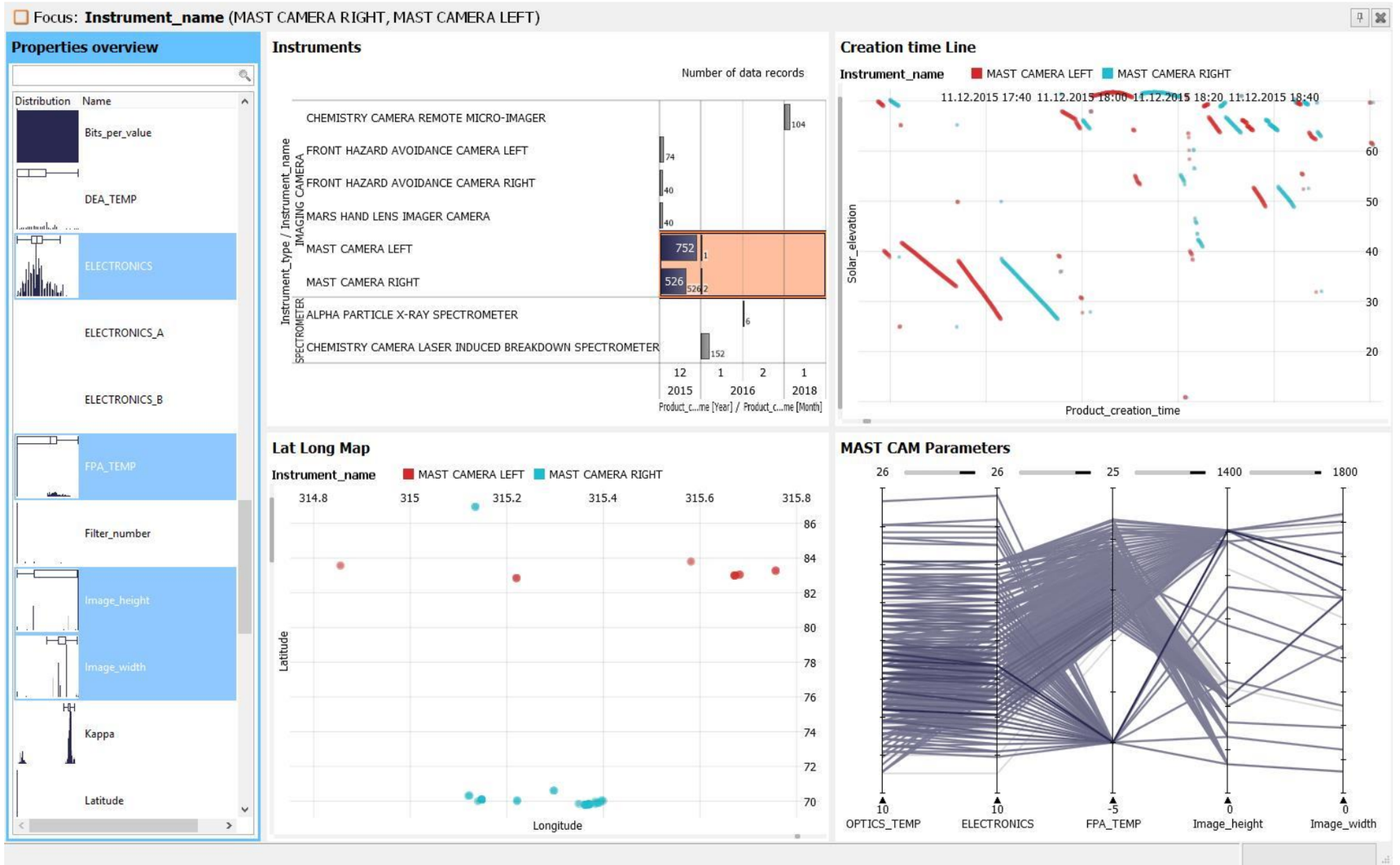
E.G. PRo3D Geologic Analysis



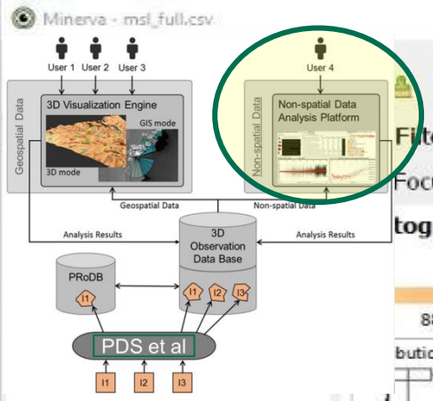


Visual Analytics: The Visplore Component

- Translating search patterns into DBMS I/F
- Direct use of meta & instrument data
- Cross references between data, meta data of different instruments
- Spatial & temporal relationship
- Finding new patterns in data
- ….Users will find out



MSL within Visplore



Minerva - msl_full.csv

Help

Minerva

Highlight Selection in PRo3D | Use as Filter in Pro3D | Download ChemCam Spectral Data

Filter: **On Map** (- All -) **Instrument_type** (- All -) **Instrument_id** (- All -)

Focus: **All** [in filter]

togram Overview | Statistics Overview

Moment: Unique

8890 17779 26669 35559 44449 53338 62228 71118 80007 88897

bution Name

Phi

Solar_azimuth

Kappa

Omega

Solar_elevation

Altitude

Solar_longitude

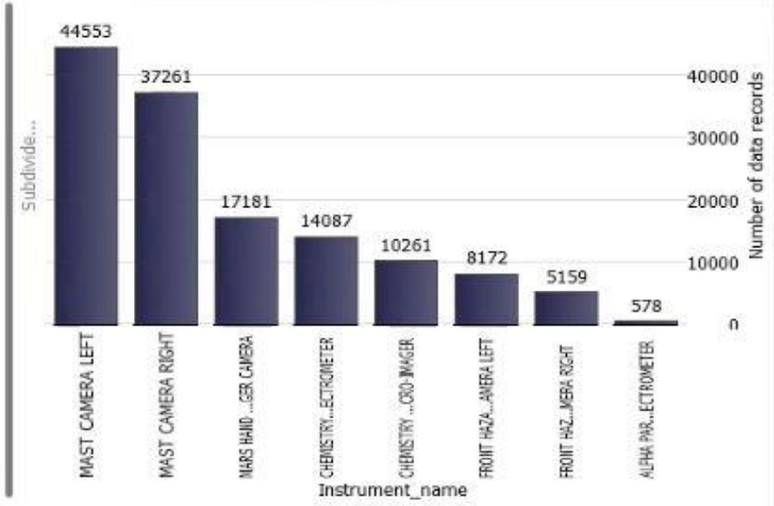
Latitude

Z (degC)

Y

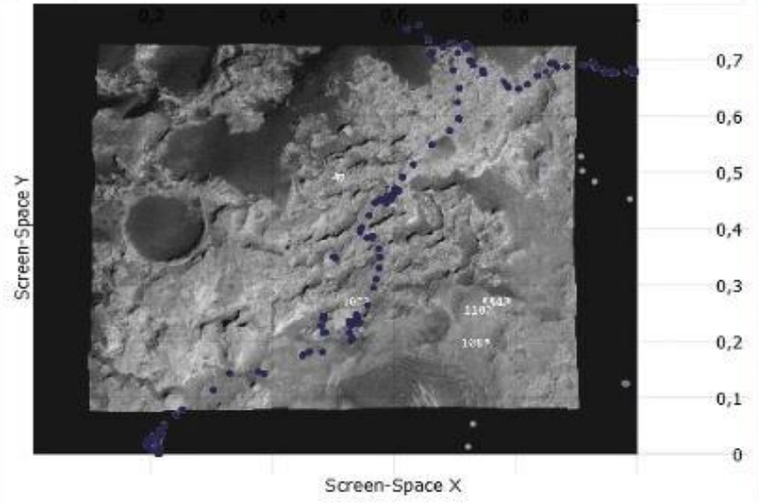
Selection of Categories

Bar Chart | Matrix | Categories

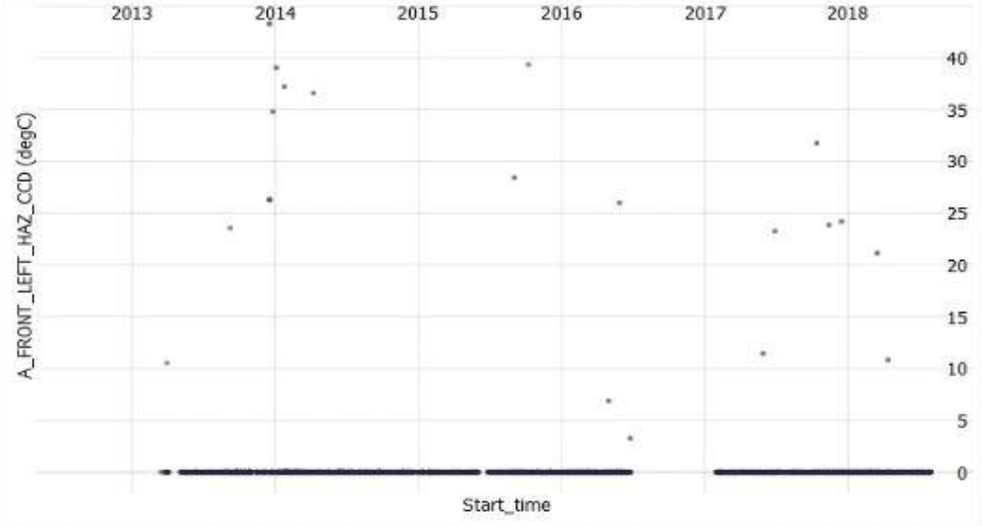


Map View | Trajectory

Color by: Focus



Timeline | Histogram | Scatter Plot | Parallel Coordinates



Spectral Data

Details

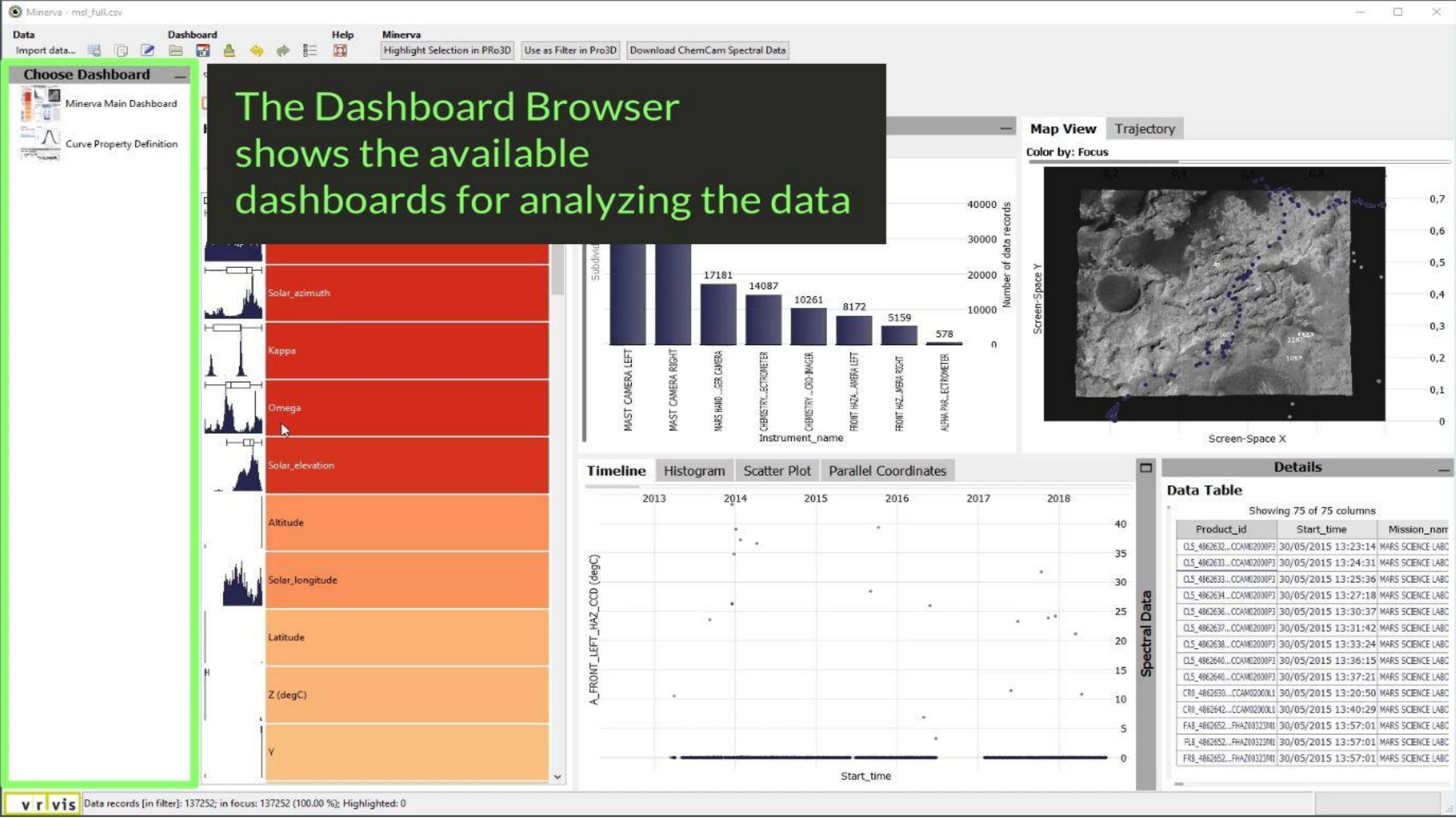
Data Table

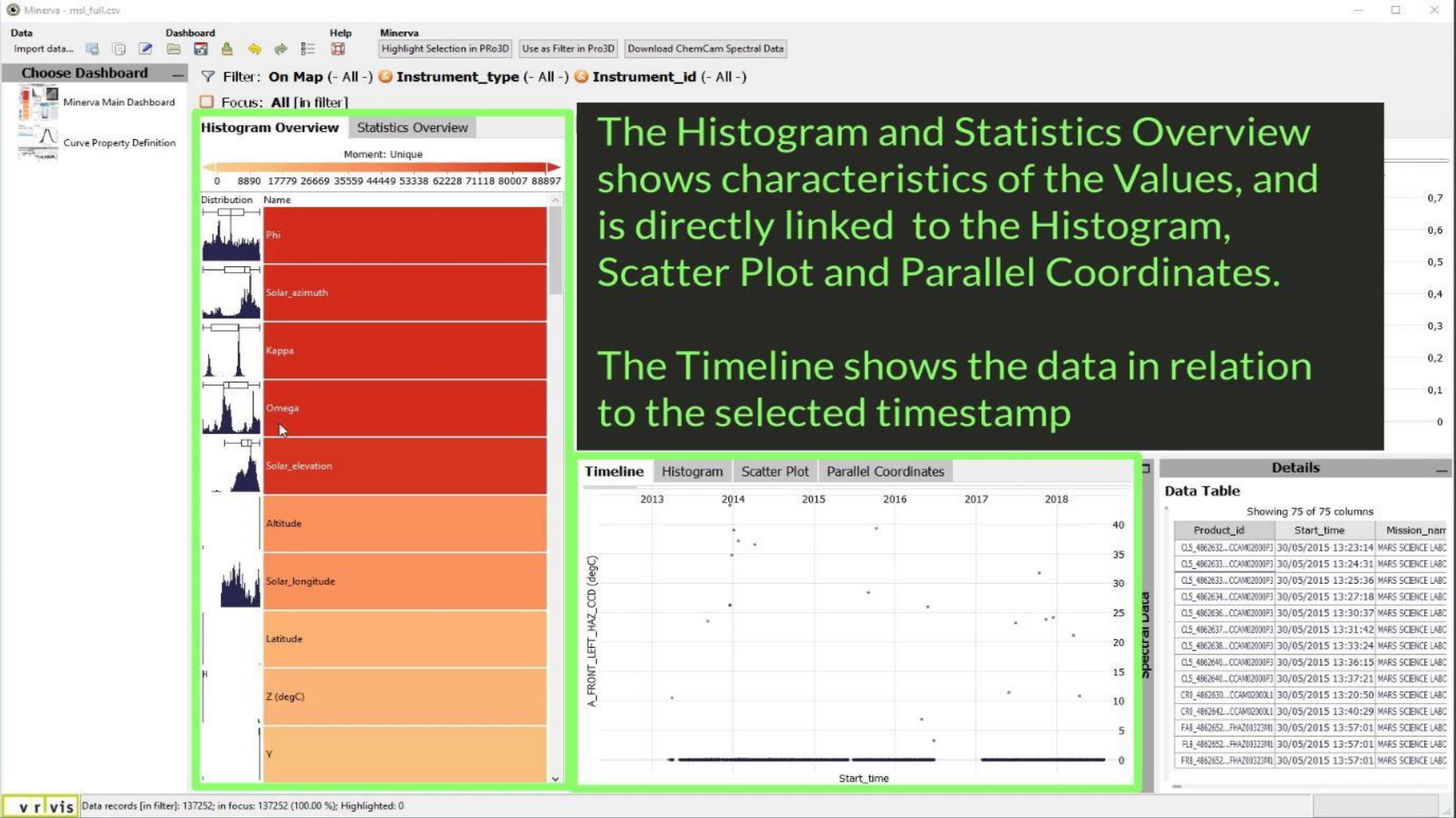
Showing 75 of 75 columns

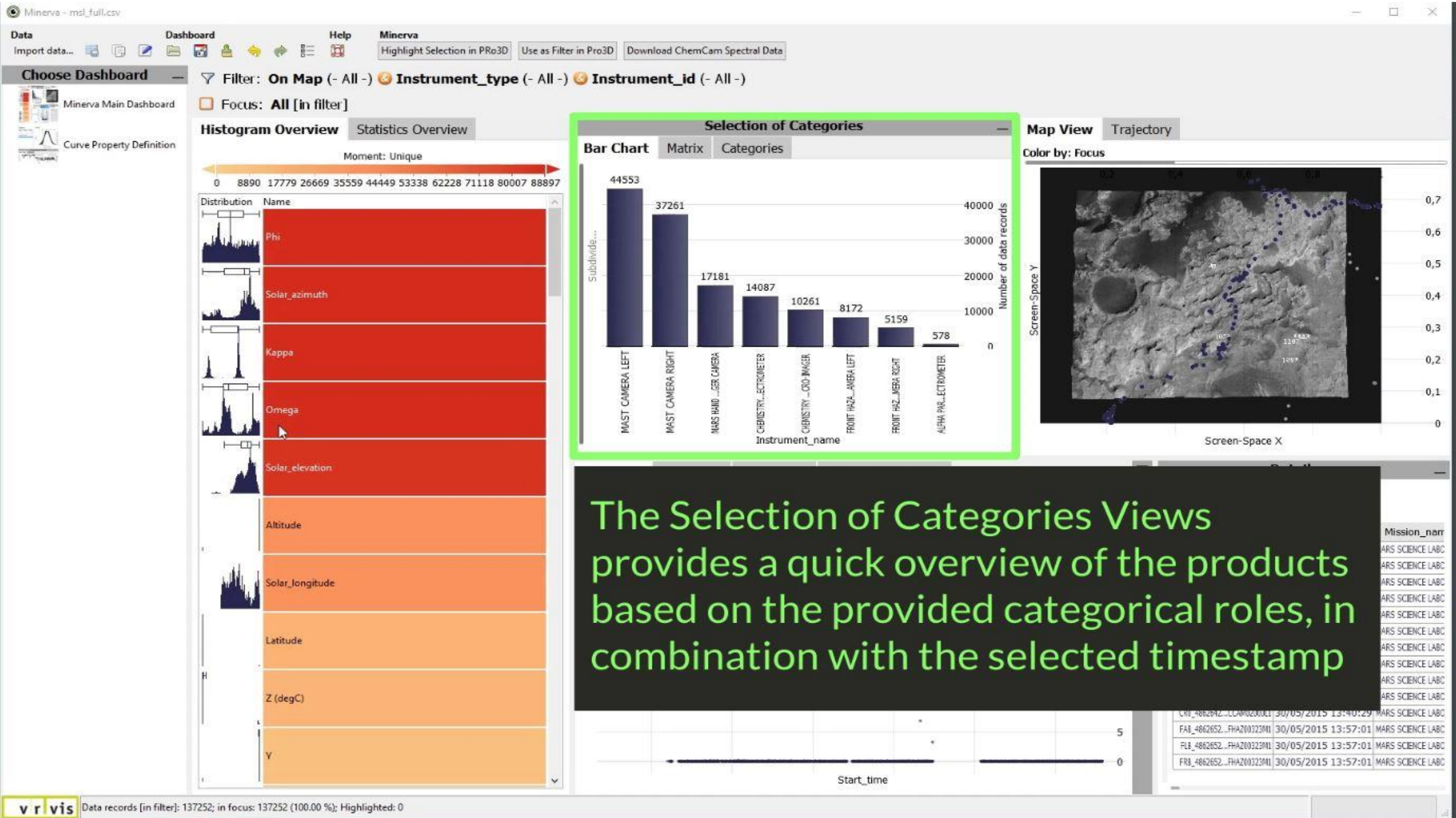
Product_id	Start_time	Mission_nam
CL5_4862632...CCAM02000P3	30/05/2015 13:23:14	MARS SCIENCE LABC
CL5_4862633...CCAM02000P3	30/05/2015 13:24:31	MARS SCIENCE LABC
CL5_4862633...CCAM02000P3	30/05/2015 13:25:36	MARS SCIENCE LABC
CL5_4862634...CCAM02000P3	30/05/2015 13:27:18	MARS SCIENCE LABC
CL5_4862636...CCAM02000P3	30/05/2015 13:30:37	MARS SCIENCE LABC
CL5_4862637...CCAM02000P3	30/05/2015 13:31:42	MARS SCIENCE LABC
CL5_4862638...CCAM02000P3	30/05/2015 13:33:24	MARS SCIENCE LABC
CL5_4862640...CCAM02000P3	30/05/2015 13:36:15	MARS SCIENCE LABC
CL5_4862640...CCAM02000P3	30/05/2015 13:37:21	MARS SCIENCE LABC
CR0_4862630...CCAM02000L1	30/05/2015 13:20:50	MARS SCIENCE LABC
CR0_4862642...CCAM02000L1	30/05/2015 13:40:29	MARS SCIENCE LABC
FA8_4862652...FHAZ00323M1	30/05/2015 13:57:01	MARS SCIENCE LABC
FL8_4862652...FHAZ00323M1	30/05/2015 13:57:01	MARS SCIENCE LABC
FR8_4862652...FHAZ00323M1	30/05/2015 13:57:01	MARS SCIENCE LABC

vrvis

Data records [in filter]: 137252; in focus: 137252 (100.00 %); Highlighted: 0


Minerva - msl_full.csv
Data
Import data...
Dashboard
Help
Minerva
Highlight Selection in PRo3D
Use as Filter in Pro3D
Download ChemCam Spectral Data
Choose Dashboard
Minerva Main Dashboard
Curve Property Definition
The Dashboard Browser shows the available dashboards for analyzing the data
Solar_azimuth
Kappa
Omega
Solar_elevation
Altitude
Solar_longitude
Latitude
Z (degC)
Y
40000
30000
20000
10000
0
Number of data records
17181
14087
10261
8172
5159
578
MAST CAMERA LEFT
MAST CAMERA RIGHT
MARS HAND ...GSR CAMERA
CHEMISTRY...ECTROMETER
CHEMISTRY ...CRO IMAGER
FRONT HAZA...AMERA LEFT
FRONT HAZ...MERA RIGHT
ALPHA PAR...ECTROMETER
Instrument_name
Map View
Trajectory
Color by: Focus
Screen-Space Y
Screen-Space X
Timeline
Histogram
Scatter Plot
Parallel Coordinates
2013
2014
2015
2016
2017
2018
A_FRONT_LEFT_HAZ_CCD (degC)
Start_time
Spectral Data
Details
Data Table
Showing 75 of 75 columns
Product_id
Start_time
Mission_nam
Data records [in filter]: 137252; in focus: 137252 (100.00 %); Highlighted: 0


Minerva - msl_full.csv
Data
Import data...
Dashboard
Help
Minerva
Highlight Selection in PRo3D
Use as Filter in Pro3D
Download ChemCam Spectral Data
Choose Dashboard
Minerva Main Dashboard
Curve Property Definition
Filter: On Map (- All -) Instrument_type (- All -) Instrument_id (- All -)
Focus: All [in filter]
Histogram Overview
Statistics Overview
Moment: Unique
0 8890 17779 26669 35559 44449 53338 62228 71118 80007 88897
Distribution
Name
Phi
Solar_azimuth
Kappa
Omega
Solar_elevation
Altitude
Solar_longitude
Latitude
Z (degC)
Y
The Histogram and Statistics Overview shows characteristics of the Values, and is directly linked to the Histogram, Scatter Plot and Parallel Coordinates.
The Timeline shows the data in relation to the selected timestamp
Timeline
Histogram
Scatter Plot
Parallel Coordinates
2013
2014
2015
2016
2017
2018
A_FRONT_LEFT_HAZ_CCD (degC)
Start_time
Spectral Data
Details
Data Table
Showing 75 of 75 columns
Product_id
Start_time
Mission_nam
vrvis
Data records [in filter]: 137252; in focus: 137252 (100.00 %); Highlighted: 0


Minerva - msl_full.csv
Data
Import data...
Dashboard
Help
Minerva
Highlight Selection in PRo3D
Use as Filter in Pro3D
Download ChemCam Spectral Data
Choose Dashboard
Minerva Main Dashboard
Curve Property Definition
Filter: On Map (- All -) Instrument_type (- All -) Instrument_id (- All -)
Focus: All [in filter]
Histogram Overview
Statistics Overview
Moment: Unique
0 8890 17779 26669 35559 44449 53338 62228 71118 80007 88897
Distribution
Name
Phi
Solar_azimuth
Kappa
Omega
Solar_elevation
Altitude
Solar_longitude
Latitude
Z (degC)
Y
Selection of Categories
Bar Chart
Matrix
Categories
44553
37261
17181
14087
10261
8172
5159
578
Subdivide...
Number of data records
40000
30000
20000
10000
0
MAST CAMERA LEFT
MAST CAMERA RIGHT
MARS HAND ...SER CAMERA
CHEMISTRY...ECTROMETER
CHEMISTRY...CRO-IMAGER
FRONT HAZ...ANERA LEFT
FRONT HAZ...MERA RIGHT
ALPHA PAR...ECTROMETER
Instrument_name
Map View
Trajectory
Color by: Focus
Screen-Space Y
Screen-Space X
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
The Selection of Categories Views provides a quick overview of the products based on the provided categorical roles, in combination with the selected timestamp
Start_time
5
0
Mission_nam
MARS SCIENCE LABO
FA8_4862652...FHAZ00323M1 30/05/2015 13:57:01 MARS SCIENCE LABO
FL8_4862652...FHAZ00323M1 30/05/2015 13:57:01 MARS SCIENCE LABO
FR8_4862652...FHAZ00323M1 30/05/2015 13:57:01 MARS SCIENCE LABO
vrvis
Data records [in filter]: 137252; in focus: 137252 (100.00 %); Highlighted: 0

Minerva - msl_full.csv

Data | Dashboard | Help | Minerva

Import data... | Highlight Selection in PRo3D | Use as Filter in Pro3D | Download ChemCam Spectral Data

Choose Dashboard

Minerva Main Dashboard

Curve Property Definition

Filter: **On Map** (- All -) **Instrument_type** (- All -) **Instrument_id** (- All -)

Focus: **All** [in filter]

Histogram Overview | Statistics Overview

Moment: Unique

0 8890 17779 26669 35559 44449 53338 62228 71118 80007 88897

Distribution | Name

Phi

Solar_azimuth

Kappa

Omega

Solar_elevation

Altitude

Solar_longitude

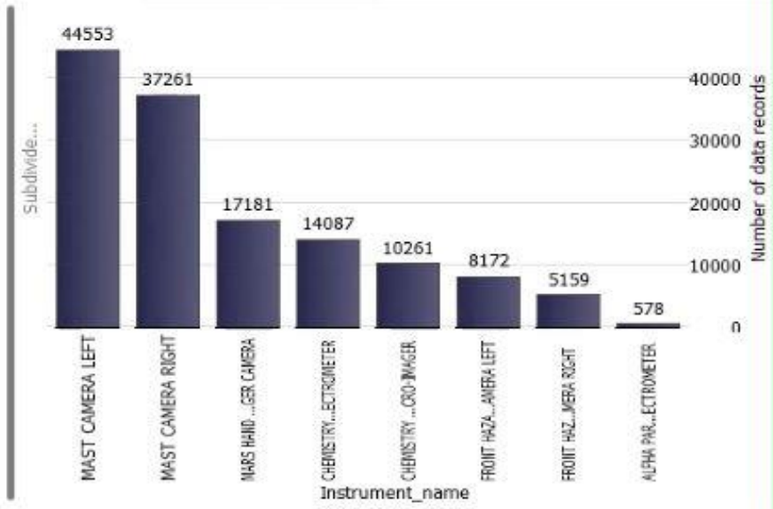
Latitude

Z (degC)

Y

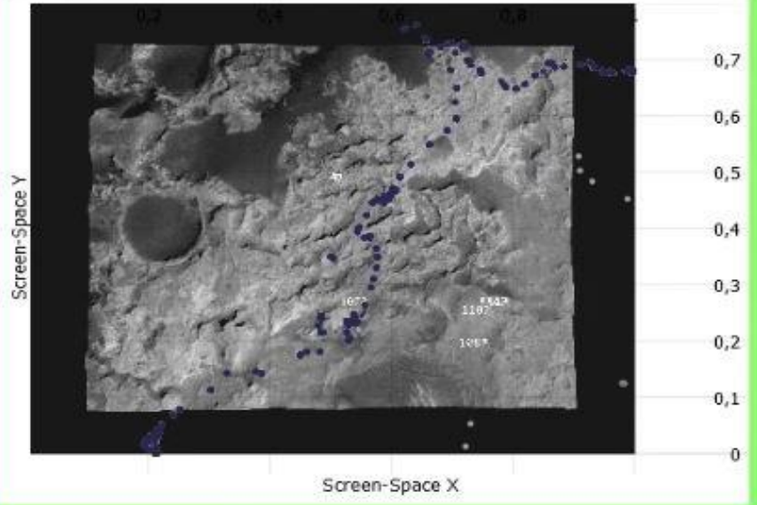
Selection of Categories

Bar Chart | Matrix | Categories

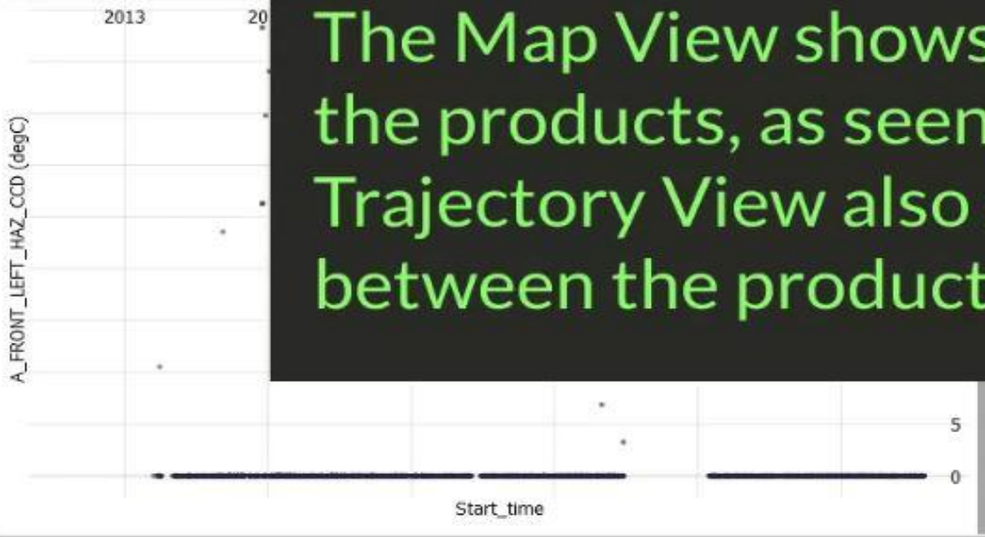


Map View | Trajectory

Color by: Focus



Timeline | Histogram

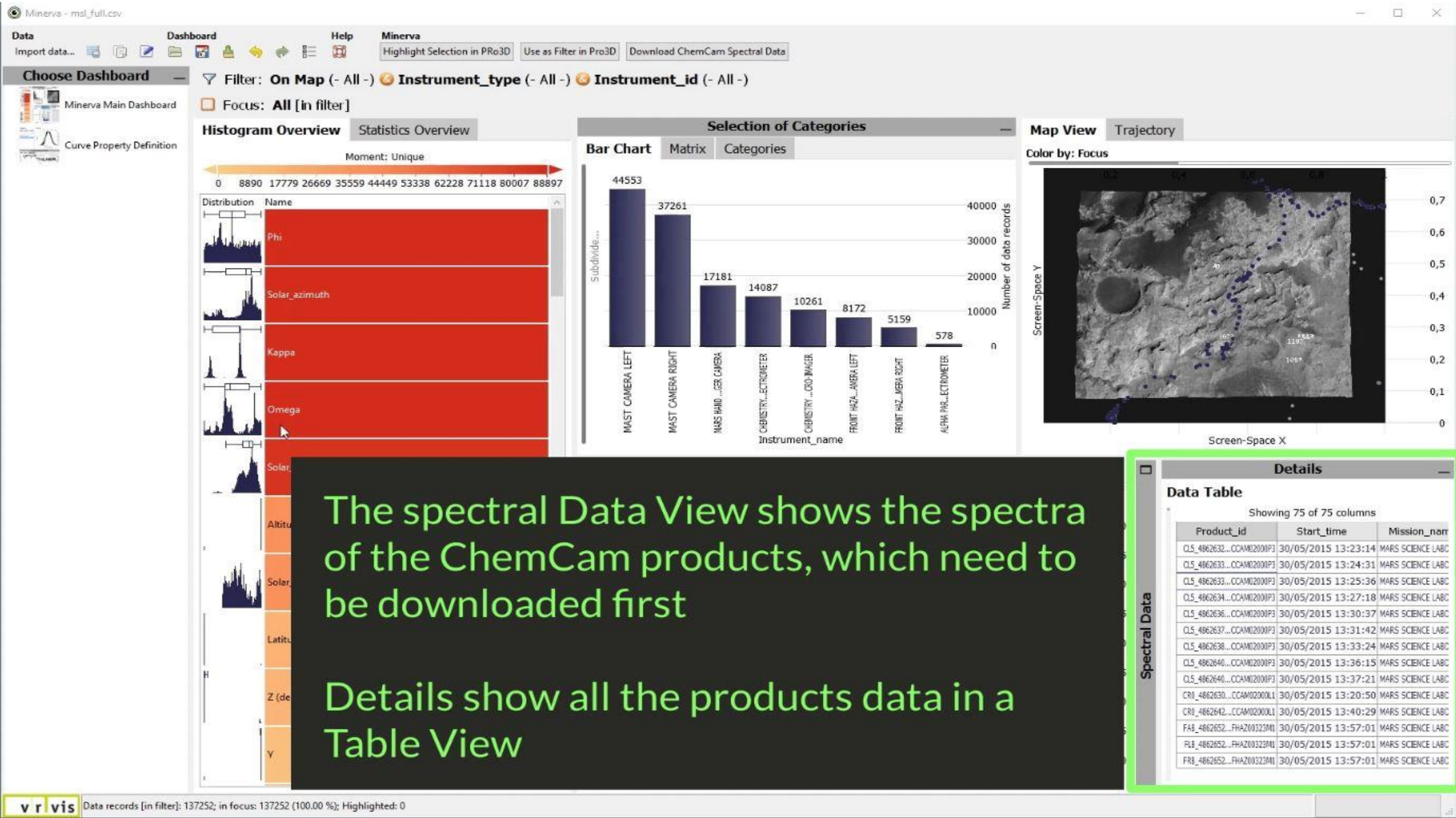


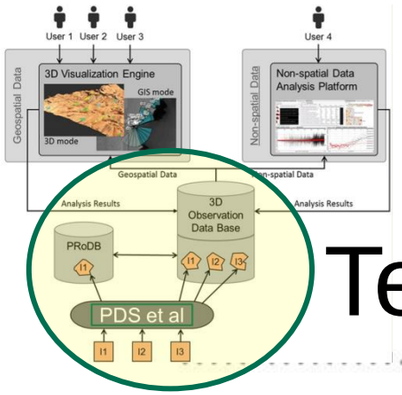
The Map View shows the locations of the products, as seen in PRo3D
Trajectory View also shows the path between the products

CR1_4862642...CCAM02000L1	30/05/2015 13:40:29	MARS SCIENCE LABO
FA8_4862652...FHAZ00323M1	30/05/2015 13:57:01	MARS SCIENCE LABO
FL8_4862652...FHAZ00323M1	30/05/2015 13:57:01	MARS SCIENCE LABO
FR8_4862652...FHAZ00323M1	30/05/2015 13:57:01	MARS SCIENCE LABO

vrvis

Data records [in filter]: 137252; in focus: 137252 (100.00 %); Highlighted: 0


Minerva - msl_full.csv
Data
Import data...
Dashboard
Help
Minerva
Highlight Selection in PRo3D
Use as Filter in Pro3D
Download ChemCam Spectral Data
Choose Dashboard
Minerva Main Dashboard
Curve Property Definition
Filter: On Map (- All -) Instrument_type (- All -) Instrument_id (- All -)
Focus: All [in filter]
Histogram Overview
Statistics Overview
Moment: Unique
0 8890 17779 26669 35559 44449 53338 62228 71118 80007 88897
Distribution
Name
Phi
Solar_azimuth
Kappa
Omega
Selection of Categories
Bar Chart
Matrix
Categories
44553
37261
17181
14087
10261
8172
5159
578
Subdivide...
Number of data records
40000
30000
20000
10000
0
MAST CAMERA LEFT
MAST CAMERA RIGHT
MARS HAND ...GER CAMERA
CHEMISTRY...ECTROMETER
CHEMISTRY ...CRO-IMAGER
FRONT HAZ...AMERA LEFT
FRONT HAZ...MERA RIGHT
ALPHA PAR...ECTROMETER
Instrument_name
Map View
Trajectory
Color by: Focus
Screen-Space Y
Screen-Space X
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
The spectral Data View shows the spectra of the ChemCam products, which need to be downloaded first
Details show all the products data in a Table View
Spectral Data
Details
Data Table
Showing 75 of 75 columns
Product_id
Start_time
Mission_nam
CL5_4862632...CCAM02000P3 30/05/2015 13:23:14 MARS SCIENCE LABO
CL5_4862633...CCAM02000P3 30/05/2015 13:24:31 MARS SCIENCE LABO
CL5_4862633...CCAM02000P3 30/05/2015 13:25:36 MARS SCIENCE LABO
CL5_4862634...CCAM02000P3 30/05/2015 13:27:18 MARS SCIENCE LABO
CL5_4862636...CCAM02000P3 30/05/2015 13:30:37 MARS SCIENCE LABO
CL5_4862637...CCAM02000P3 30/05/2015 13:31:42 MARS SCIENCE LABO
CL5_4862638...CCAM02000P3 30/05/2015 13:33:24 MARS SCIENCE LABO
CL5_4862640...CCAM02000P3 30/05/2015 13:36:15 MARS SCIENCE LABO
CL5_4862640...CCAM02000P3 30/05/2015 13:37:21 MARS SCIENCE LABO
CRI_4862630...CCAM02000L1 30/05/2015 13:20:50 MARS SCIENCE LABO
CRI_4862642...CCAM02000L1 30/05/2015 13:40:29 MARS SCIENCE LABO
FAI_4862652...FHAZ00323M1 30/05/2015 13:57:01 MARS SCIENCE LABO
FLI_4862652...FHAZ00323M1 30/05/2015 13:57:01 MARS SCIENCE LABO
FRI_4862652...FHAZ00323M1 30/05/2015 13:57:01 MARS SCIENCE LABO
vrvis
Data records [in filter]: 137252; in focus: 137252 (100.00 %); Highlighted: 0



Test Case: Ingesting & analyzing Full MSL Mission

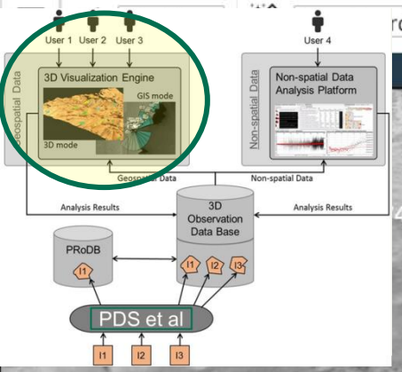
- 137.000 product entries
- > 2000 Sols
- 200 Gbytes
- 5 Instruments
  - Mastcam
  - Front Hazcam
  - MAHLI
  - APSX
  - Chemcam
- Emphasis on meta data, images & spectra
- PDS3 – to – json for ingestion preparation

```
PythonInterpreter.exe D:\Dev\ImproApps\Source\
  ImproApplications\Applications\Tools\MINERVA\
  ImportMsl.py
    --pds-root-directory
      "D:\Projects\MINERVA\data products"
    --python-run-exe
```


```
  "Image": {
    "Image_height": "1200",
    "Image_width": "1632",
    "Bits_per_value": "8",
    "Number_of_bands": "3"
    "Start_time": "2015-09-02T06:54:29.277",
    "Stop_time": "2015-09-02T06:54:30.623"
  },
  "Instrument": {
    "Name": "MARS HAND LENS IMAGER CAMERA",
    "Type": "IMAGING CAMERA",
    "Focal_length_in_pixel": "4645.2010830481 4644.8426406147",
    "Pose": {
      "Frame": "Mars",
      "Position": "-2486639.762959 2289259.7627105 -276249.60945501",
      "Position_unit": "meter"
      "Orientation": "86.499884 7.048773 -50,392477"
      "Orientation_unit": "degree"
    },
  },
  "Mission": {
    "Name": "MARS SCIENCE LABORATORY"
  },
  "Product": {
    "Version": "V1.0",
    "Creation_time": "2015-12-08T20:19:34.823",
    "Product_ID": "1092MH0003060010400939C00_DRCX",
    "Producer": "MALIN SPACE SCIENCE SYSTEMS"
  },
  "PDS": {
    "Original": {
      "PDS_VERSION_ID": "PDS3",
      "RECORD_TYPE": "FIXED_LENGTH",
      "RECORD_BYTES": "1632",
      "FILE_RECORDS": "3600",
      "IMAGE": "(\"1092MH0003060010400939C00_DRCX.IMG\")",
```

PRo3D Viewer - 2.10.0-prerelease1_core - VRVis Zentrum für Virtual Reality und Visualisierung Forschungs-GmbH

rdinateSystem | 1km | CTRL+click to place coordinate cross | Mars | gale2_core.scn



Minerva | Surfaces | Annotations

Apply Filter | Clear Filter | Clear Selection

min sol:		0
max sol:		3000
instruments:	MAHLI	(8734)
	APXS	(317)
	FrontHazcamR	(3686)
	FrontHazcamL	(5332)
	MastcamR	(25730)
	MastcamL	(33576)
	ChemLib	(8751)
	ChemRmi	(7690)

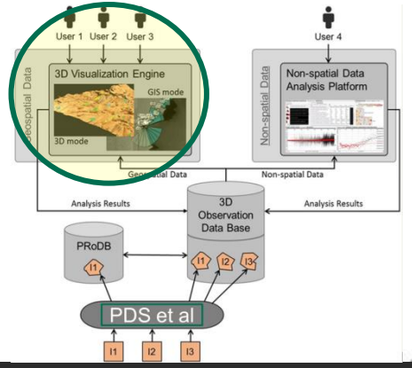
Config | Bookmarks | ViewPlanner | RockTypes | Semantics

ViewerConfig

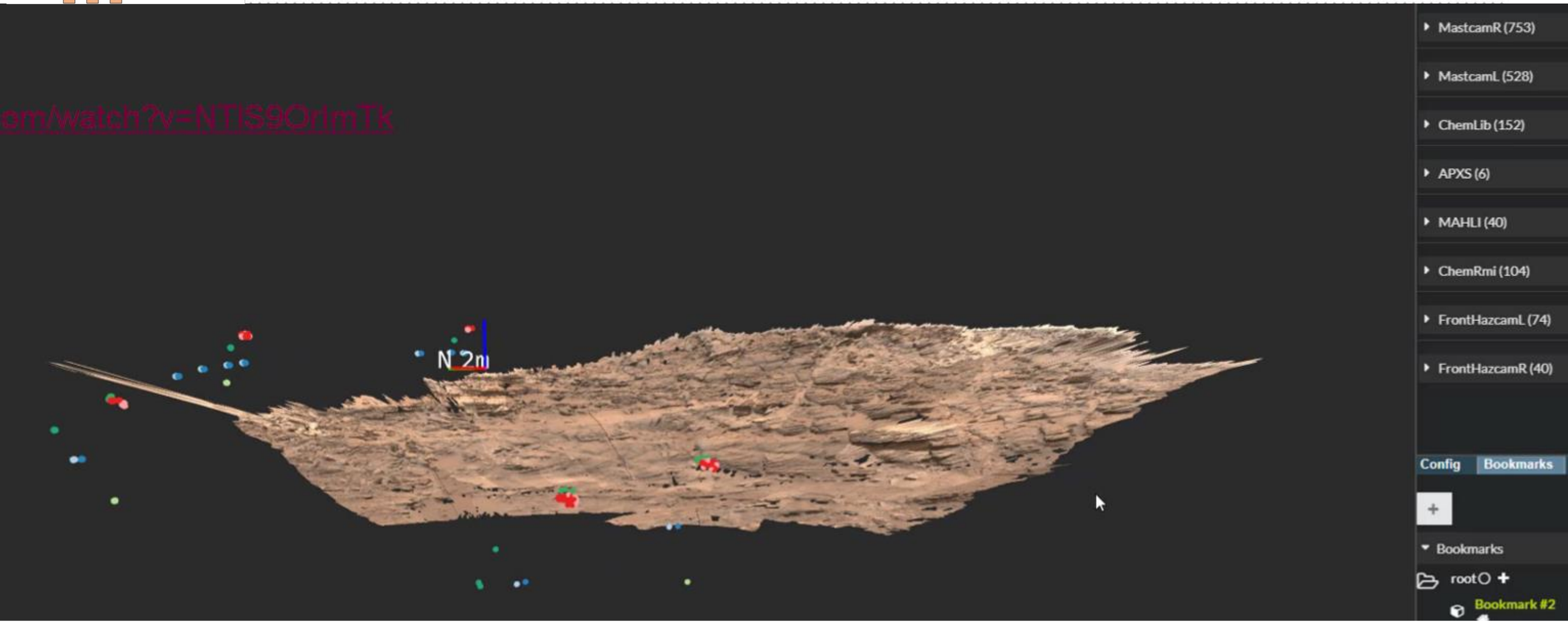
Near Plane:	0,10
Far Plane:	150000,0
Navigation Sensitivity:	
Import Triangle Size(m):	1000,000
Arrow Length:	1,00
Arrow Thickness:	3,0

HiRISE Base Map
~150 Gbytes 3D Data

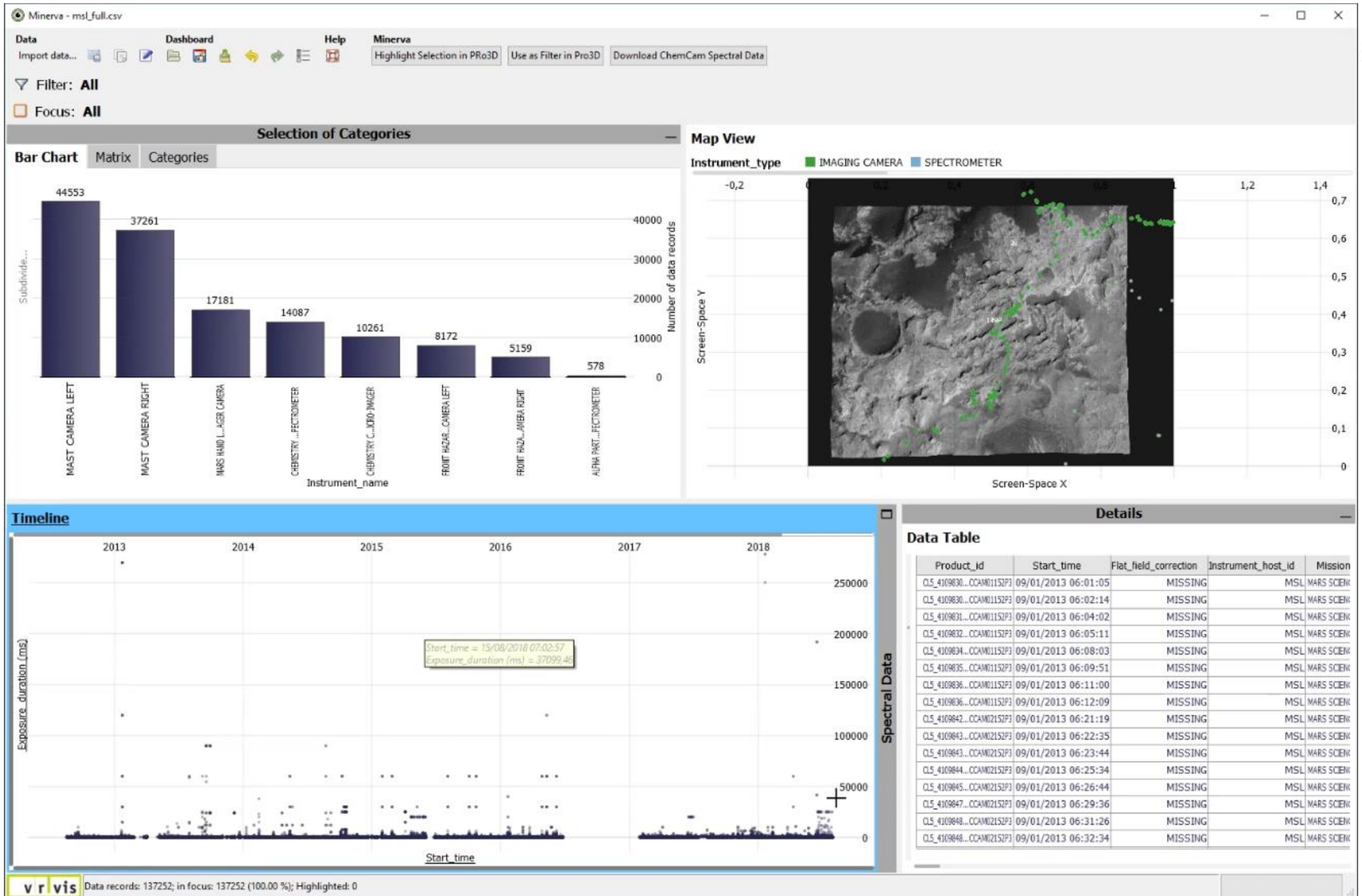
Overview of ingested MSL data, displayed in PRo3D



MINERVA In Operation: Stimson Formation & Instrument Data



Example: Look for MAHLI night data sets in entire MSL mission



Minerva - msl_full.csv

Data | Dashboard | Help | Minerva

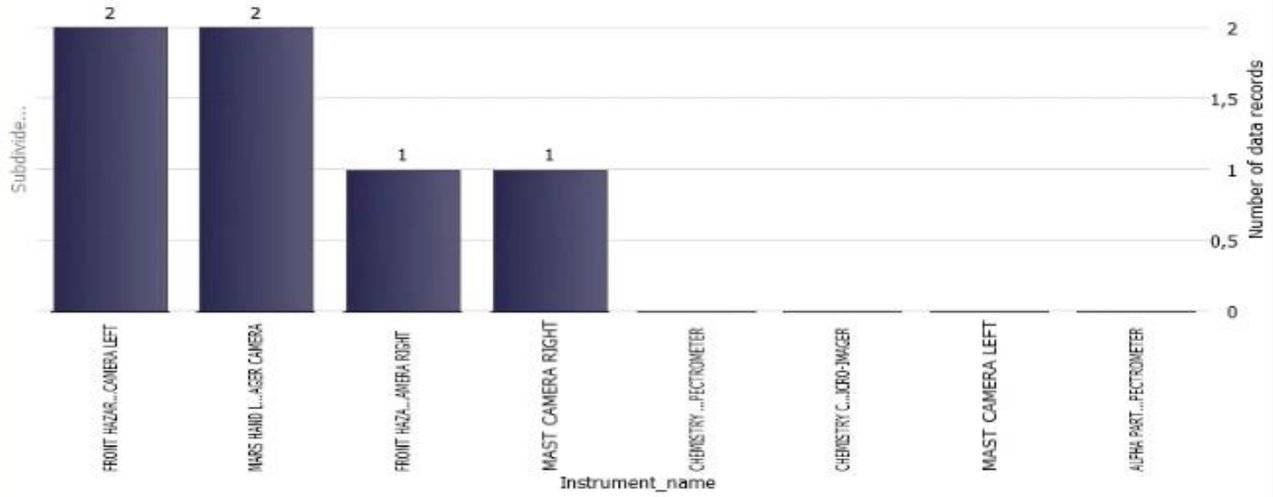
Import data... | Highlight Selection in PRo3D | Use as Filter in Pro3D | Download ChemCam Spectral Data

Filter: **All**

Focus: **Start_time** [31.5.2012-6.8.2018] × **Exposure_duration** [34708 ; 49852]

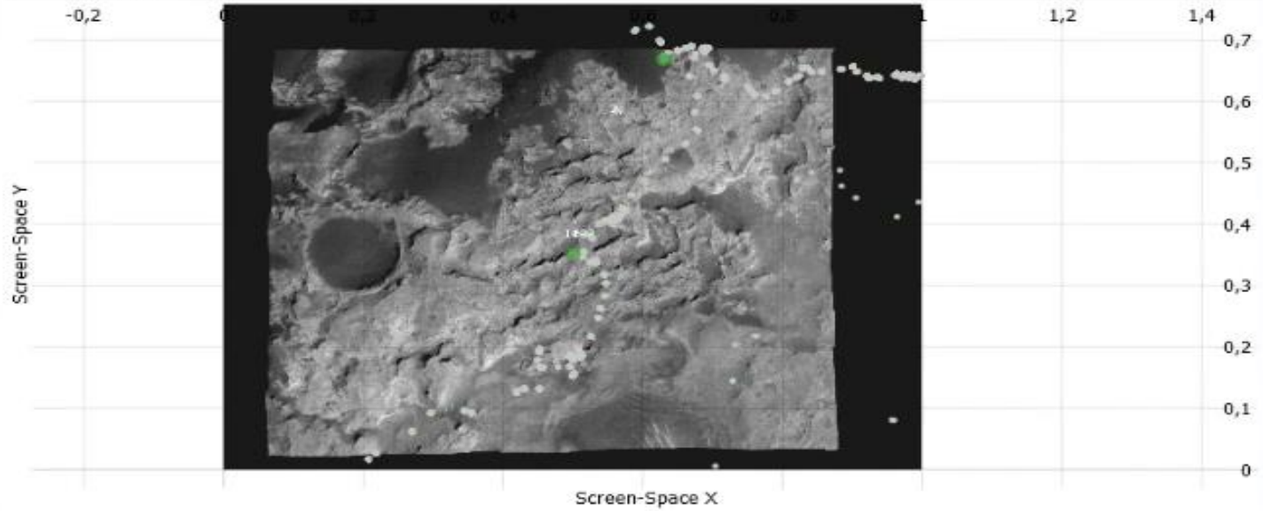
Selection of Categories

Bar Chart | Matrix | Categories



Map View

Instrument_type: IMAGING CAMERA, SPECTROMETER



Timeline

Details

Data Table

Product_id	Start_time	Flat_field_correction	Instrument_host_id	Mission
1230MH00056...504C0E_DRCX	22/01/2016 06:14:43	False	MSL	MARS SCIEN
1230MH00056...505C0E_DRCX	22/01/2016 06:15:30	False	MSL	MARS SCIEN
FAE_5824275...FHAZ00206MI	16/06/2018 13:57:13	False	MSL	MARS SCIEN
FLE_5824275...FHAZ00206MI	16/06/2018 13:57:13	False	MSL	MARS SCIEN
FRE_5824275...FHAZ00206MI	16/06/2018 13:57:13	False	MSL	MARS SCIEN
0543MR00213...674C0E_DRCX	14/02/2014 18:06:32	False	MSL	MARS SCIEN

Use the Timeline View to find products with long exposure durations

vrvis

Data records: 137252; in focus: 6 (0.00 %); Highlighted: 0

Minerva - msl_full.csv

Data | Dashboard | Help | Minerva

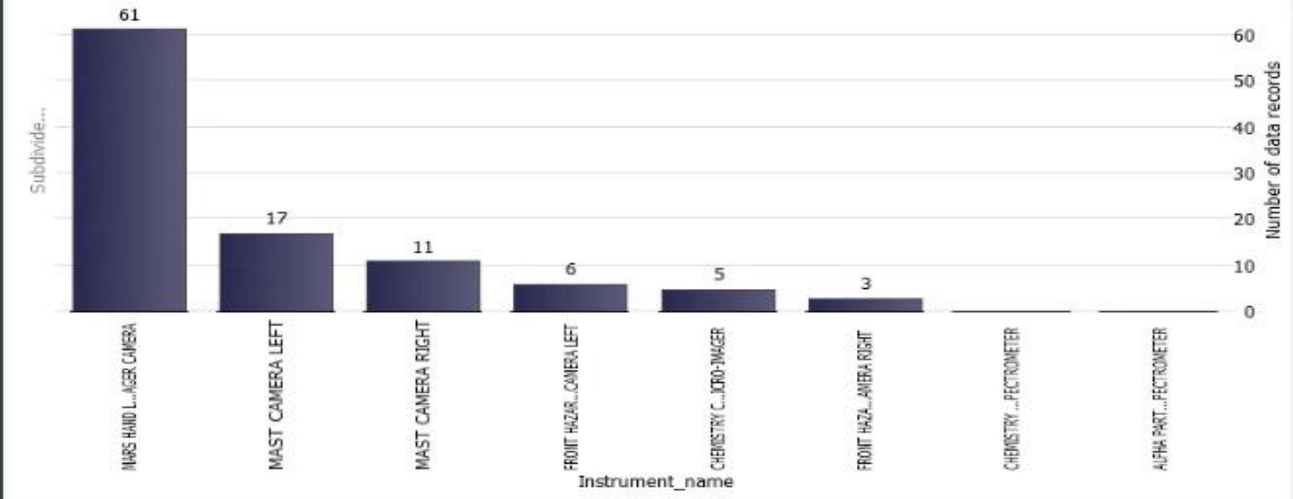
Import data... | Highlight Selection in PRo3D | Use as Filter in Pro3D | Download ChemCam Spectral Data

Filter: **All**

Focus: **Start_time** [12.7.2012-6.8.2018] × **Exposure_duration** [34708 ; 291361]

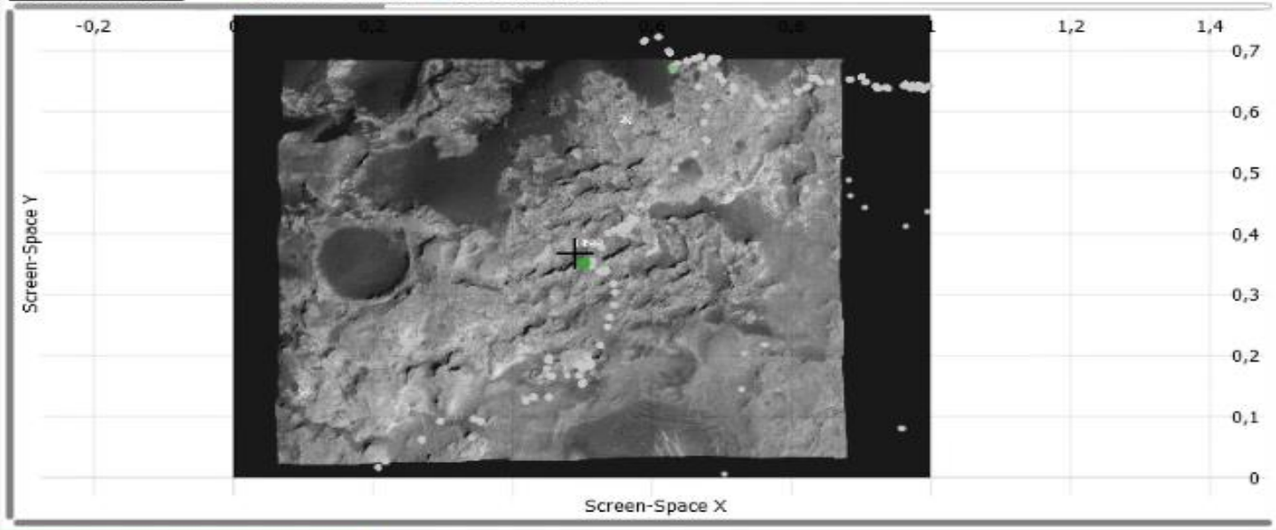
Selection of Categories

Bar Chart | Matrix | Categories

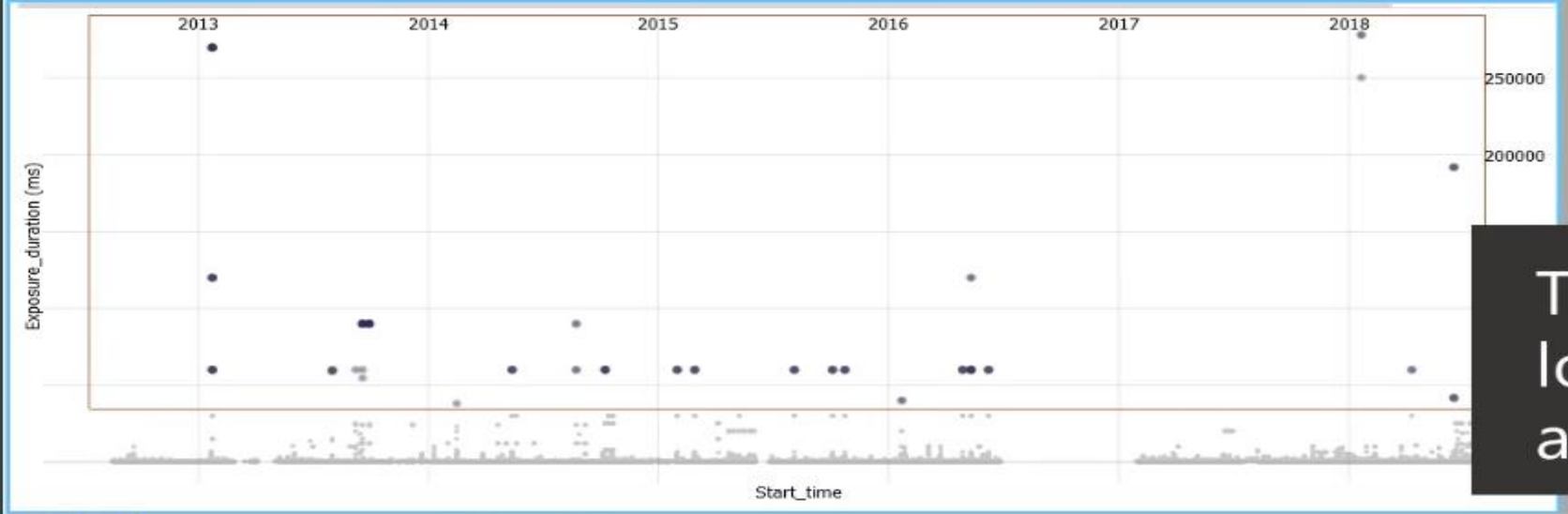


Map View

Instrument_type ■ IMAGING CAMERA ■ SPECTROMETER



Timeline



Details

Data Table

Product_id	Start_time	Flat_field_correction	Instrument_host_id	Mission
1064MH00047...554COE_DRCX	04/08/2015 17:47:18	False	MSL	MARS SCIEN
1064MH00047...555COE_DRCX	04/08/2015 17:48:27	False	MSL	MARS SCIEN
1064MH00047...570COE_DRCX	04/08/2015 17:56:13	False	MSL	MARS SCIEN
1064MH00047...571COE_DRCX	04/08/2015 17:57:20	False	MSL	MARS SCIEN
1123MH00047...615COE_DRCX	04/10/2015 09:03:13	False	MSL	MARS SCIEN
1123MH00047...616COE_DRCX	04/10/2015 09:04:20	False	MSL	MARS SCIEN

The MapView shows the location of the products as seen in PRo3D

vrvis Data records: 137252; in focus: 103 (0.08 %); Highlighted: 0

Minerva - msl_full.csv

Data | Dashboard | Help | Minerva

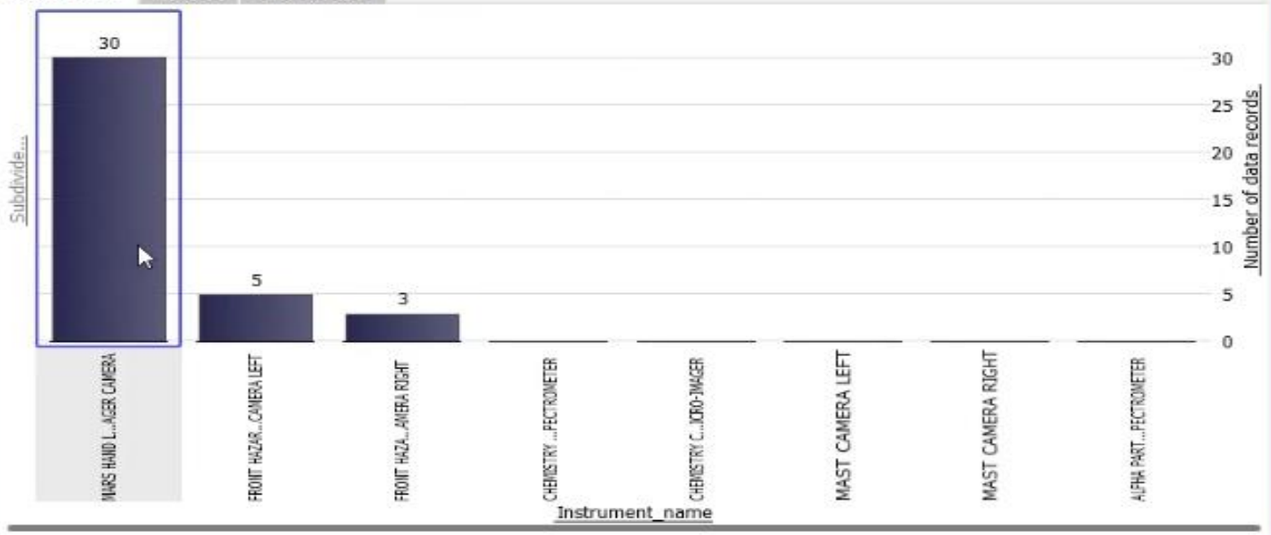
Import data... | Highlight Selection in PRo3D | Use as Filter in Pro3D | Download ChemCam Spectral Data

Filter: **All**

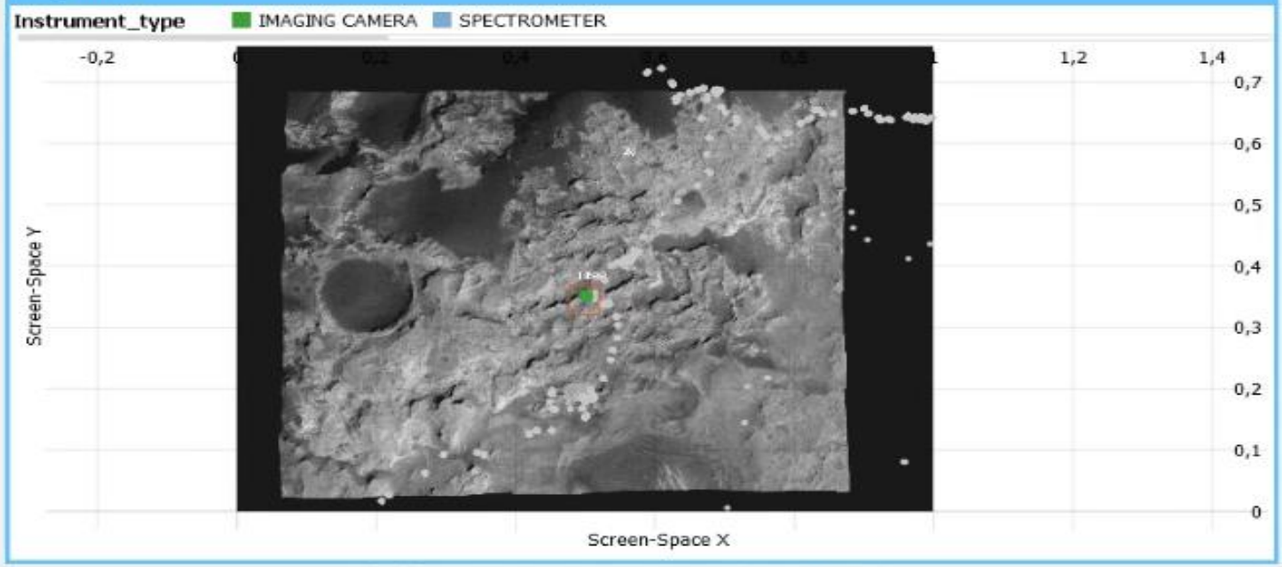
Focus: **Start_time** [12.7.2012-6.8.2018] × **Exposure_duration** [34708 ; 291361] **Screen-Space X** [0,47836 ; 0,52045] × **Screen-Space Y** [0,32234 ; 0,36935]

Selection of Categories

Bar Chart | Matrix | Categories



Map View



Timeline

Spectral Data

Details

Data Table

Product_id	Start_time	Flat_field_correction	Instrument_host_id	Mission
1064MH00047...554C00_DRCX	04/08/2015 17:47:18	False	MSL	MARS SCIEN
1064MH00047...555C00_DRCX	04/08/2015 17:48:27	False	MSL	MARS SCIEN
1064MH00047...570C00_DRCX	04/08/2015 17:56:13	False	MSL	MARS SCIEN
1064MH00047...571C00_DRCX	04/08/2015 17:57:20	False	MSL	MARS SCIEN
1123MH00047...615C00_DRCX	04/10/2015 09:03:13	False	MSL	MARS SCIEN
1123MH00047...616C00_DRCX	04/10/2015 09:04:20	False	MSL	MARS SCIEN

The Selection now only contains a handfull products

vrvis | Data records: 137252; in focus: 38 (0.03 %); Highlighted: 0

Minerva - msl_full.csv

Data | Dashboard | Help | Minerva

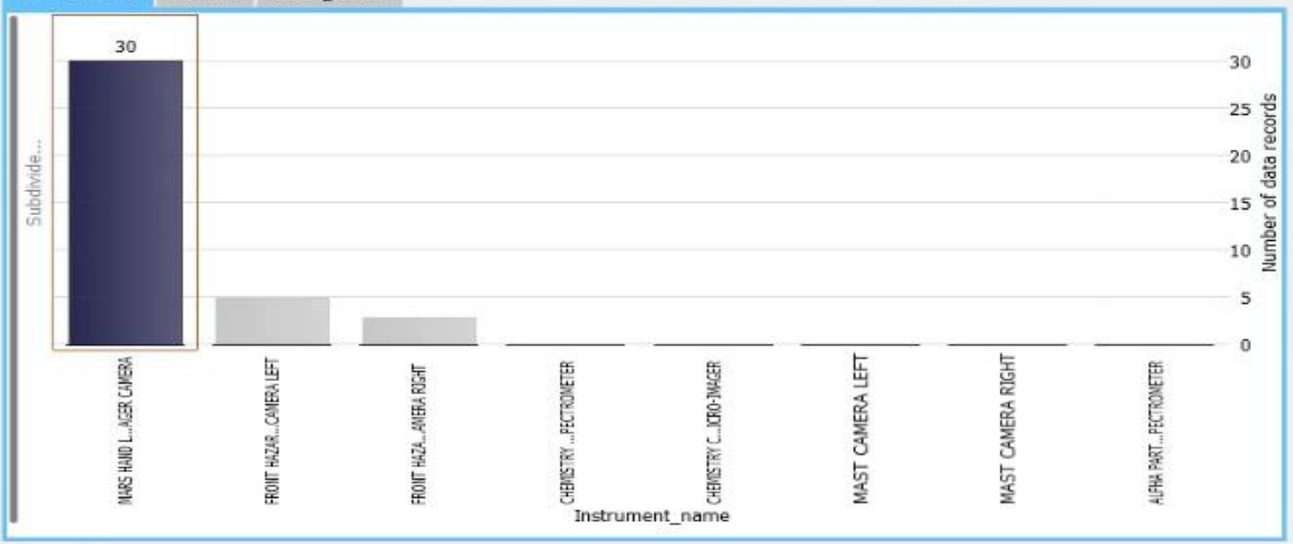
Import data... | Highlight Selection in PRo3D | Use as Filter in Pro3D | Download ChemCam Spectral Data

Filter: **All**

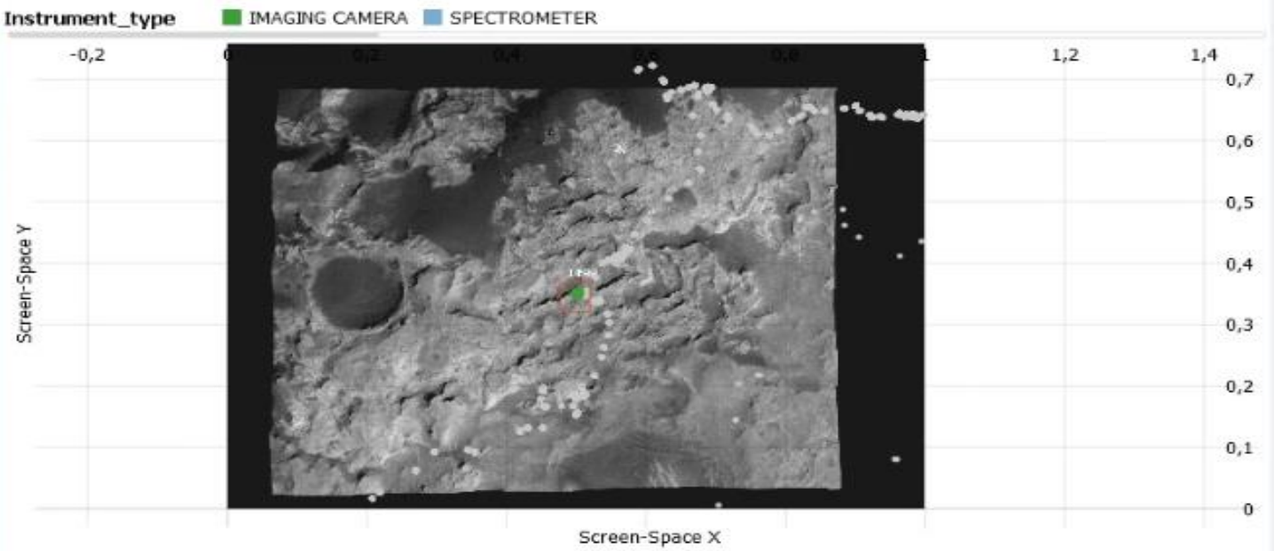
Focus: **Interval: Start_time × Interval: Exposure_duration** **Interval: Screen-Space X × Interval: Screen-Space Y** **Instrument_name** (MARS HAND LENS IMAGER CAMERA)

Selection of Categories

Bar Chart | Matrix | Categories



Map View



Timeline

Spectral Data

Details

Data Table

Product_id	Start_time	Flat_field_correction	Instrument_host_id	Mission
1064MHI00047...554C00_DRCX	04/08/2015 17:47:18	False	MSL	MARS SCIEN
1064MHI00047...555C00_DRCX	04/08/2015 17:48:27	False	MSL	MARS SCIEN
1064MHI00047...571C00_DRCX	04/08/2015 17:56:13	False	MSL	MARS SCIEN
1064MHI00047...571C00_DRCX	04/08/2015 17:57:20	False	MSL	MARS SCIEN
1123MHI00047...615C00_DRCX	04/10/2015 09:03:13	False	MSL	MARS SCIEN
1123MHI00047...616C00_DRCX	04/10/2015 09:04:20	False	MSL	MARS SCIEN

From those we only select the MAHLI products

vrvis | Data records: 137252; in focus: 30 (0.02 %); Highlighted: 0

Minerva - msl_full.csv

Data | Dashboard | Help | Minerva

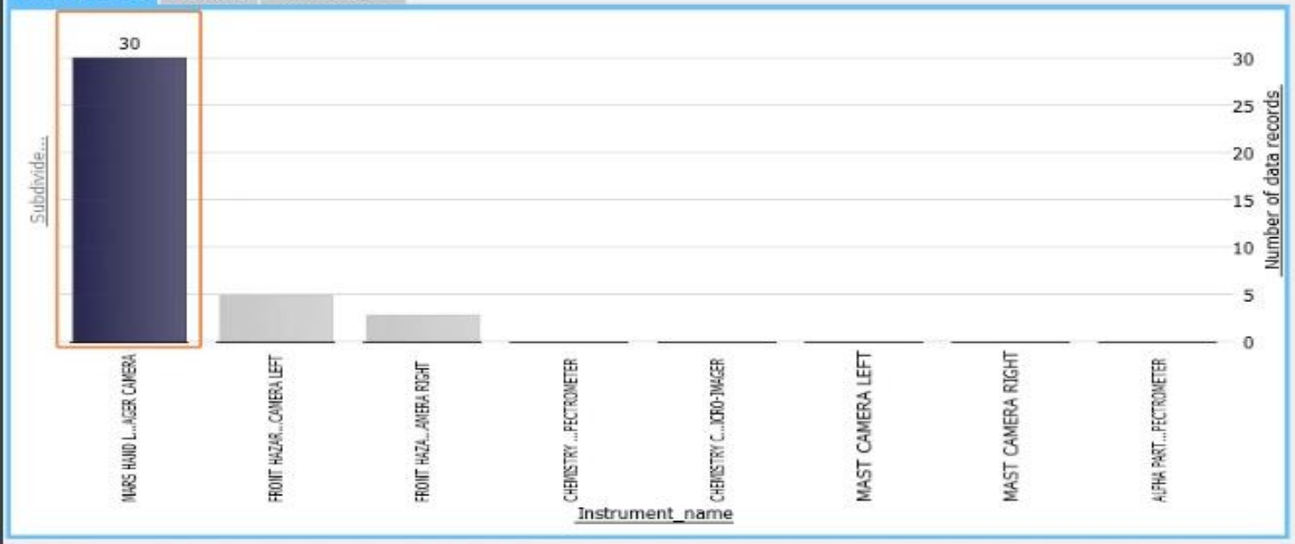
Import data... | Highlight Selection in PRo3D | Use as Filter in Pro3D | Download ChemCam Spectral Data

Filter: **All**

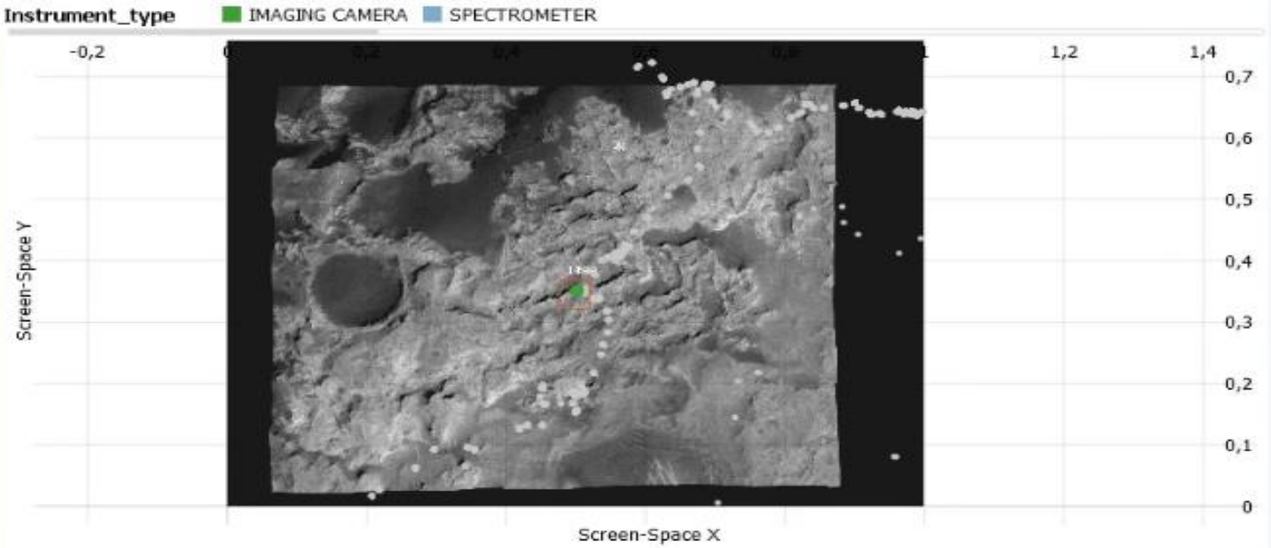
Focus: **Interval: Start_time × Interval: Exposure_duration** **Interval: Screen-Space X × Interval: Screen-Space Y** **Instrument_name** (MARS HAND LENS IMAGER CAMERA)

Selection of Categories

Bar Chart | Matrix | Categories



Map View



Timeline

Spectral Data

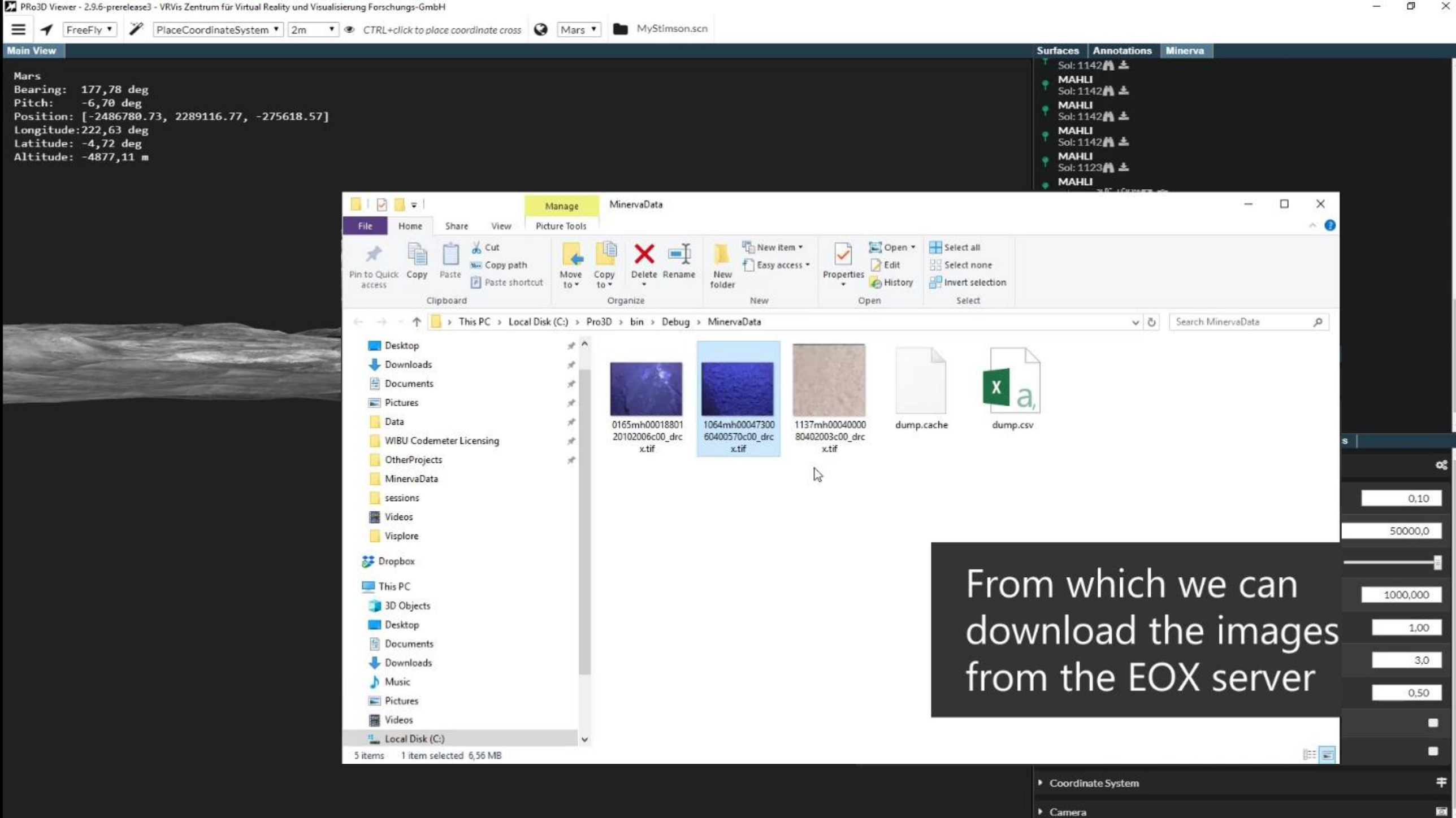
Details

Data Table

Product_id	Start_time	Flat_field_correction	Instrument_host_id	Mission
1064MH00047...554C0E_DRCX	04/08/2015 17:47:18	False	MSL	MARS SCIEN
1064MH00047...555C0E_DRCX	04/08/2015 17:48:27	False	MSL	MARS SCIEN
1064MH00047...570C0E_DRCX	04/08/2015 17:56:13	False	MSL	MARS SCIEN
1064MH00047...571C0E_DRCX	04/08/2015 17:57:20	False	MSL	MARS SCIEN
1123MH00047...615C0E_DRCX	04/10/2015 09:03:13	False	MSL	MARS SCIEN
1123MH00047...616C0E_DRCX	04/10/2015 09:04:20	False	MSL	MARS SCIEN

And use them as Filter in PRo3D

vrvis | Data records: 137252; in focus: 30 (0.02 %); Highlighted: 0


PRo3D Viewer - 2.9.6-prerelease3 - VRVis Zentrum für Virtual Reality und Visualisierung Forschungs-GmbH
FreeFly
PlaceCoordinateSystem
2m
CTRL+click to place coordinate cross
Mars
MyStimson.scn
Main View
Mars
Bearing: 177,78 deg
Pitch: -6,70 deg
Position: [-2486780.73, 2289116.77, -275618.57]
Longitude:222,63 deg
Latitude: -4,72 deg
Altitude: -4877,11 m
Surfaces
Annotations
Minerva
Sol: 1142
MAHLI
Sol: 1142
MAHLI
Sol: 1142
MAHLI
Sol: 1142
MAHLI
Sol: 1123
MAHLI
Manage
MinervaData
File
Home
Share
View
Picture Tools
Pin to Quick access
Copy
Paste
Cut
Copy path
Paste shortcut
Clipboard
Move to
Copy to
Delete
Rename
Organize
New folder
New item
Easy access
New
Properties
Open
Edit
History
Open
Select all
Select none
Invert selection
Select
This PC
Local Disk (C:)
Pro3D
bin
Debug
MinervaData
Search MinervaData
Desktop
Downloads
Documents
Pictures
Data
WIBU Codemeter Licensing
OtherProjects
MinervaData
sessions
Videos
Visplore
Dropbox
This PC
3D Objects
Desktop
Documents
Downloads
Music
Pictures
Videos
Local Disk (C:)
0165mh0001880120102006c00_drcx.tif
1064mh0004730060400570c00_drcx.tif
1137mh0004000080402003c00_drcx.tif
dump.cache
dump.csv
5 items
1 item selected 6,56 MB
From which we can download the images from the EOX server
0,10
50000,0
1000,000
1,00
3,0
0,50
Coordinate System
Camera

MINERVA Use Cases

ID	Actions	Envisaged Results / technical comments	MINERVA components
[UC-1]	Add ExoMars science team data and meta information to the DB; emphasize PDS format.	ExoMars instrument data are held in the DB and can be accessed by scientists.	DBMS
[UC-2]	Add ExoMars PanCam 3D Vision ing results to the DB.	Surface image data can be immediately explored in a spatial manner.	DBMS
[UC-3]	for arbitrary data,	Outcomes of typical database queries.	DBMS, PRo3D
[UC]		data is visualized. Overview of available are overlaid that can be	DBMS, PRo3D
[UC-5]	Select any data blob or in the "spatial" map or e.g. on a time line. Multi-selections of data blobs are allowed.	of the largest data data are listed in a data explo view plane.	DBMS, PRo3D, Visplore
[UC-6]	Measure / annotate on 3D surfaces in PRo3D.	Measurements/annotations are available in DB and be accessed by other users in PRo3D	
[UC-7]	Store the actual product selection and e.g. camera views as "session profile" that can be re-loaded and manipulated at a later time.	User specific application entry. Set pointer onto product on server DBMS[8] as being specific selection. Na	
[UC-8]	user handling: different users c nt rights for loading a rofiles".		
[UC-9]	transform registering differen		DBMS, PRo3D/Visplore

[8] Client generates query, user selects what is and client can act on this subset, such as download, display, mark as component or a Visplore. Server supports viewing protocol (e.g. Viewing of OGC-WMS delivering RGB h Visplore only requiring meta data and spectra (both for download). WFS supports down

[9] Minimal version: Storage locally of a dedicated file

[10] List of users. Authentic Client regis OAut speci Narro peopl or user onship. er- ed. discussed. Only small group of

ID	Actions	Envi	ERVA ponents
[UC-10]	Search the data of laboratory instruments (spectrome spatial and temp		S, PRo3D e
[UC-11]	Ma_MISS su		PRo3D patial
[UC-12]	i		/ Visplore
[UC-13]	Ge pro (e.g, and/ types, etc.	of products with coverage per instrument / on / etc., possibly to inform taking further amples with particular characteristics	DBMS, PRo3D, Visplore
[UC-14]	C	E.g., get timelines of previous exploration	DBMS, Visplore
		nds of the	DBMS, Visplore
	a pairwise comparison of particular products, and the clustering of products by their characteristics (e.g., the shape of their spectrum)	• Identificati • May inform the extraction o	
[UC-16]	Context-aware selection of products by location/time/rover orientation /instrument specific meta-information/etc. as well as by features extracted from the produc height of a	Significant speedup of the analysis and tasks like annotation of pro	ore
[UC-17]	Bi loc cha		3D,
[UC-18]	User- spectr at thei	between	DBMS, Visplore
[UC-19]	Annota have be context-	persistent knowledge representation about the products as tags, e.g., tagging subsets of images as place where water has flown, where particular chemical elements prevail, etc.	DBMS, Visplore

[UC-15] Simultaneous inspection of ensembles of spectra / images. This may include a characterization of the overall dispersion, a pairwise comparison of particular products, and the clustering of products by their characteristics (e.g., the shape of their spectrum)

Spectra comparison / overlay (at least from one single instrument)

[UC-17] Bidirectional relation of product locations to corresponding product characteristics

[UC-3] Search the data base for arbitrary data, e.g. list all PanCam WAC images, available spectra etc.

[UC-11] Ma_MISS – to – ISEM correlation of surface and/or drill material

[UC-13] Get spatial overview of the locations of products having certain characteristics (e.g., a spectrum with a certain shape) and/or particular meta-information, e.g., types, rover orientations, focal length, etc.

[UC-8] Multi user handling: different users can be given different rights for loading and manipulating "session profiles".

MINERVA is receiving funding from the Austrian Space Applications Programme (ASAP14) funded by BMVIT. JR, VRVis and EOX co-finance the activity.

Demo on Wednesday:

40

SMW1.13

3D GIS MINERVA Interactive Demo – Geospatial overview of full MSL mission with instrument interrelations

Convener: Gerhard Paar | Co-convener: Thomas Ortner

Wed, 18 Sep, 13:30–15:00 Ceres (Room 14)

MINERVA (see https://meetingorganizer.copernicus.org/EPSC-DPS2019/EPSC-DPS2019-496.pdf being presented in MIT9, Mon Sept 16th, 13:45-14:00 in Room Moon) provides a 3D data base, an interactive 3D viewer with GIS functionality and a visual analytics platform that helps find correlations between data coming from different instruments to discover new modes of scientific exploitation. We demonstrate the system with emphasis on data presentation and interaction of five instruments of the full MSL mission. You will see how to find out new correlations between instrument data, associate across instrument and telemetry data (spatially, temporally and in the multitemporal space of meta data), and find new and astonishing patterns in the data. All is visualized in real-time, based on the multiscale 3D vision data products from HiRISE and Mastcam.

Approaching Virtual Environments & …Thanks!

- MINERVA: www.minerva-space.at
- PRo3D: www.pro3d.space
- Visual Analytics: https://www.vrvis.at/research/projects/visplore/