
PRoViDE:

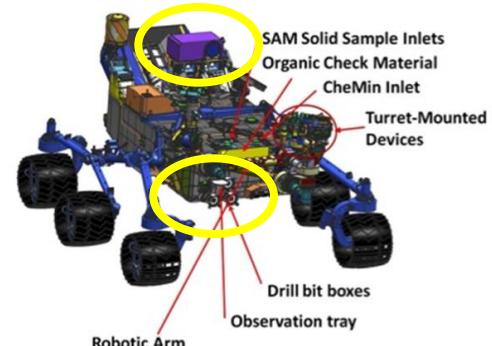
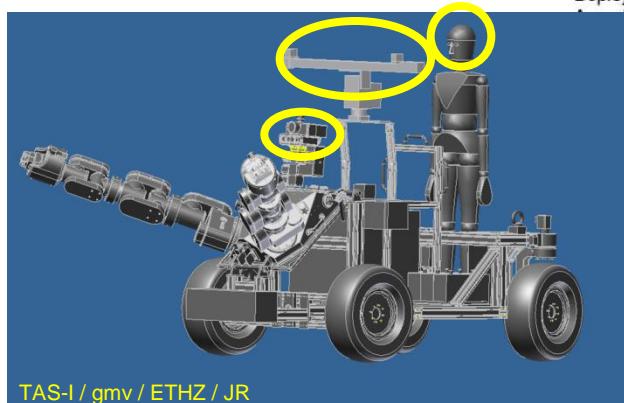
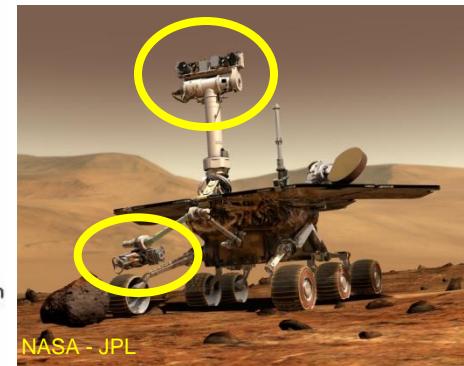
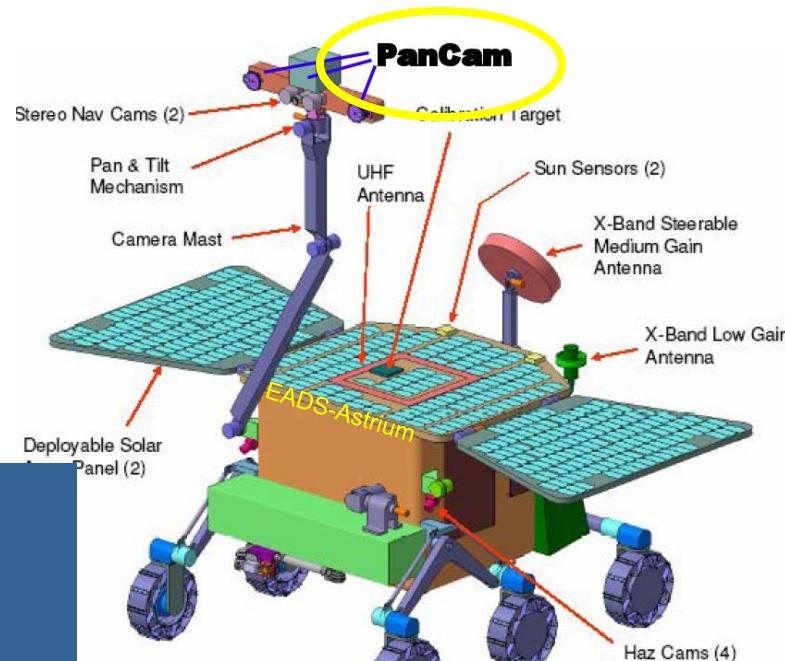
Planetary Robotics Vision Data Processing and Fusion

G. Paar (1), J.-P. Muller, Y. Tao (2), T. Pajdla (3), M. Giordano (4), E. Tasdelen (5), I. Karachevtseva (6), G. Traxler, G. Hesina (7), L. Tyler, D.P. Barnes (8), S. Gupta (9), K. Willner (10)

(1) JOANNEUM RESEARCH, A (Gerhard.paar@joanneum.at); (2) University College London, UK; (3) Czech Technical University, CZ; (4) University of Nottingham, UK; (5) Technical University Berlin, D; (6) Moscow State University of Geodesy and Cartography, RUS; (7) VRVis Zentrum für Virtual Reality und Visualisierung Forschungs-GmbH, A; (8) Aberystwyth University, UK; (9) Imperial College of Science, Technology and Medicine, UK.
(10) German Space Center, Berlin, D

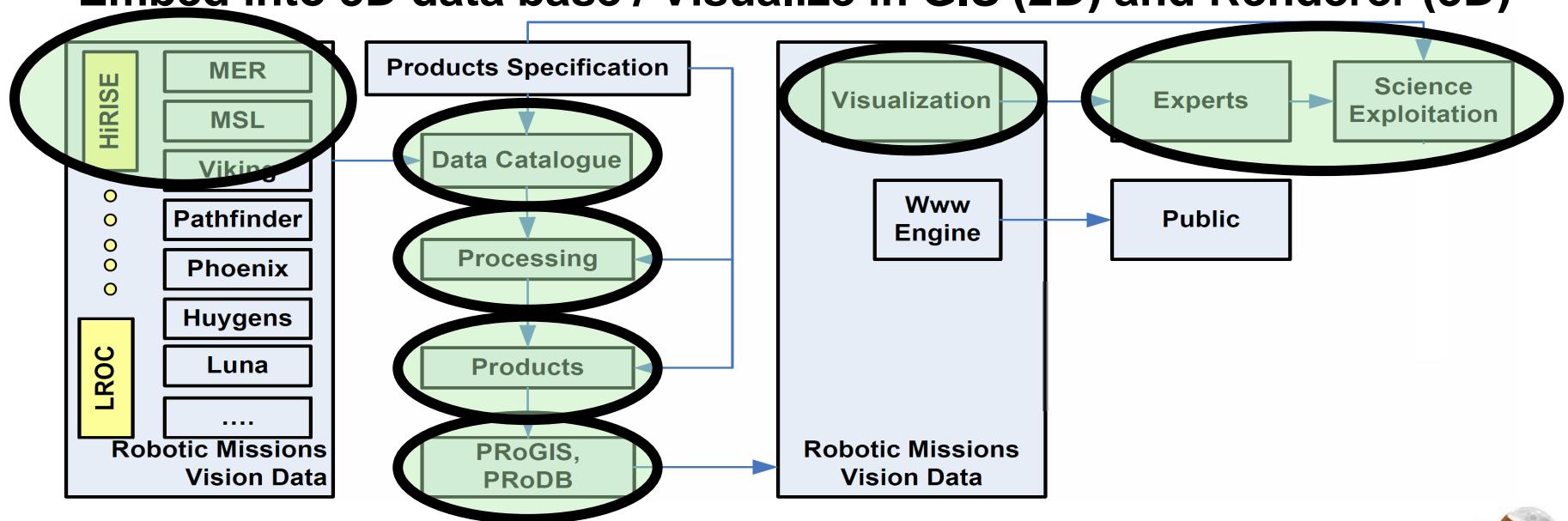


Dozens of Vision Sensors on Planets Hundred Thousands of Images

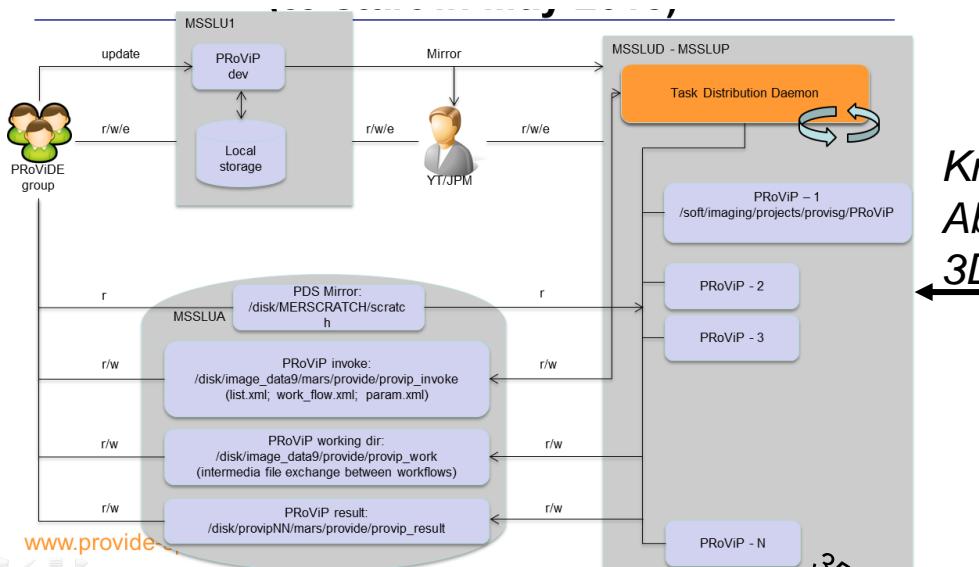


PRoViDE Objectives & Layout

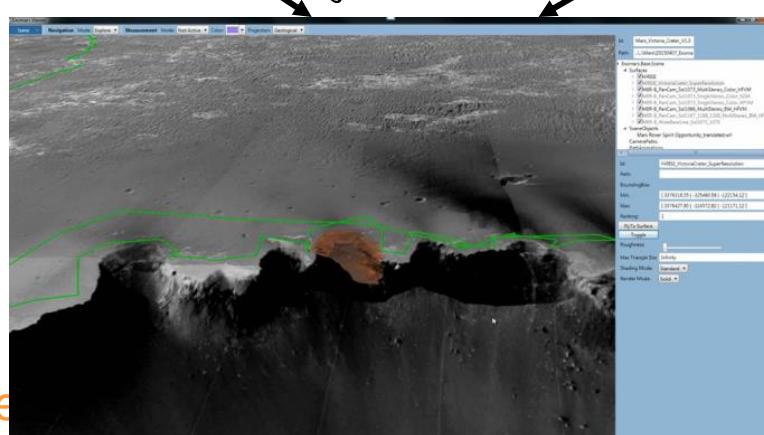
- Many of the images were only processed under mission-pressure without further exploitation →
- Harvest literally all [available] Planetary surface-captured vision data
- Process in 3D Vision terms for further scientific exploitation
- Embed into 3D data base / Visualize in GIS (2D) and Renderer (3D)



Processing & Data Presentation Environment



PRoViP: 3D Vision Mass Production



PRoGIS (2D & Context) Data Selection



Knowledge About 3D Products

3D Products

Select Products

PRo3D (3D Geologic Assessment)

Data Base: Relevant Surface Images....

Screenshot of a MySQL database interface showing the 'MSL_Rover_Image' table.

Database Structure:

- Prov12
- PROVIDE_13
 - Tables
 - New
 - Apollo_Image
 - DataType
 - Ground_DTM
 - Images
 - Image_has_Image
 - Instruments
 - IPR
 - MER_Rover_Image
 - Missions
 - MPF_Image
 - MSL_Rover_Image
 - Columns
 - New
 - Azimuth
 - Drive
 - Drive_Int
 - Elevation
 - Images_idlImages
 - Instruments_NaifID
 - KernelForAzEl
 - KernelForLatLon
 - RoverLatitude
 - RoverLongitude
 - Site
 - Site_Int
 - Start_Time
 - Stop_Time
 - Indexes
 - OrbitData_HRSC
 - OrbiterData_HIRISE
 - Panorama
 - Phoenix_Images

Table Data:

```

SELECT *
FROM `MSL_Rover_Image`
LIMIT 0 , 30
  
```

Images_idlImages	Instruments_NaifID	RoverLatitude	RoverLongitude	KernelForLatLon	Azimuth	Elevation	KernelForAzEl	Start_Time	Stop_Time	Site	Drive
87447	-76231	137.442	-4.5895	kernels_msl.txt	58.3494	86.6673	kernels_msl.txt	2012-08-07T04:50:59.5647	2012-08-07T04:50:59.5647	001	0008
87448	-76231	137.442	-4.5895	kernels_msl.txt	58.3494	86.6673	kernels_msl.txt	2012-08-07T04:51:05.5663	2012-08-07T04:51:26.5645	001	0008
87449	-76231	137.442	-4.5895	kernels_msl.txt	68.8831	25.4305	kernels_msl.txt	2012-08-08T04:27:46.3539	2012-08-08T04:27:46.3539	001	0008
87450	-76231	137.442	-4.5895	kernels_msl.txt	41.2704	26.0286	kernels_msl.txt	2012-08-08T04:28:16.3525	2012-08-08T04:28:16.3525	001	0008
87451	-76231	137.442	-4.5895	kernels_msl.txt	32.6165	29.8579	kernels_msl.txt	2012-08-08T04:44:43.3610	2012-08-08T04:44:43.3610	001	0008
87452	-76231	137.442	-4.5895	kernels_msl.txt	-172.889	35.5951	kernels_msl.txt	2012-08-08T04:45:42.3624	2012-08-08T04:45:42.3626	001	0008
87453	-76231	137.442	-4.5895	kernels_msl.txt	81.1048	76.252	kernels_msl.txt	2012-08-08T07:04:31.4413	2012-08-08T07:04:32.4391	002	0000
87454	-76231	137.442	-4.5895	kernels_msl.txt	109.745	78.2325	kernels_msl.txt	2012-08-08T07:05:04.4400	2012-08-08T07:05:04.4420	002	0000
87455	-76231	137.442	-4.5895	kernels_msl.txt	139.179	79.1281	kernels_msl.txt	2012-08-08T07:05:30.4401	2012-08-08T07:05:30.4420	002	0000

& Orbit Images

[Poster Program](#) / Attendance Tue, 29 Sep, 17:45–19:15 / Poster Area

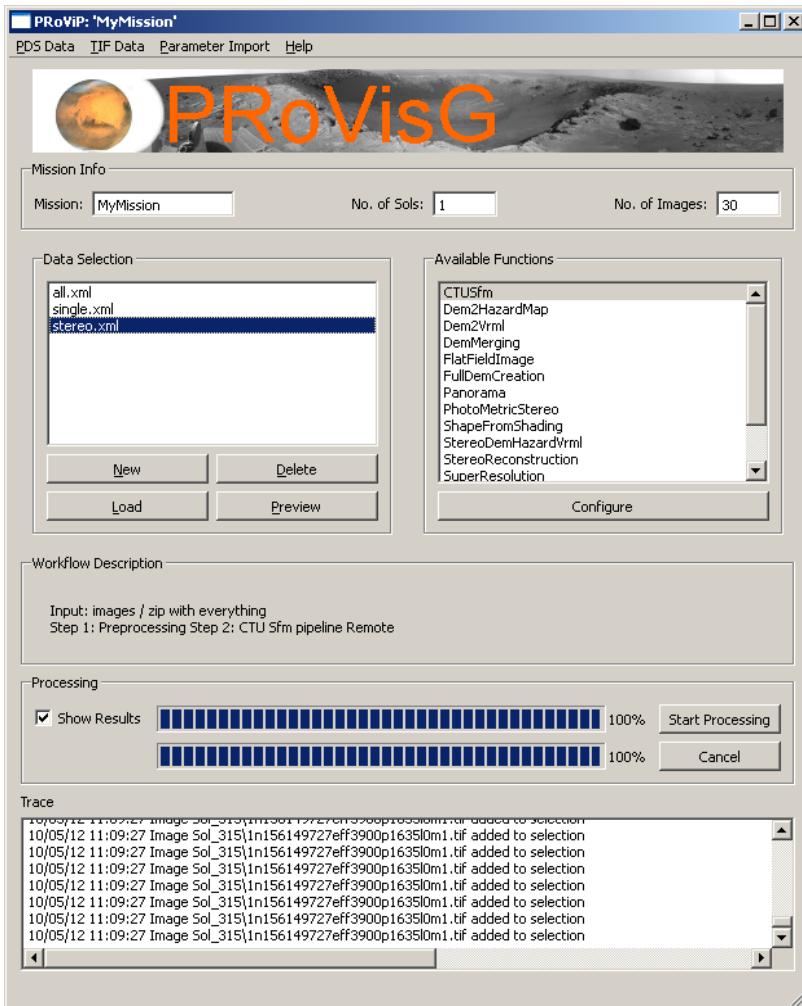
P66

[EPSC2015-291](#)

A spatial planetary image database in the context of processing
K. Willner, E. Tasdelen and the [ProVIDE project Team](#)

Processing Engine PRoViP

- **PRoViDE processing core**
(mainly developed during FP7-PRoVisG)
 - **“Framework for planetary robotic vision processing”**
 - **Integration of variety of 3D Vision algorithms (extendable)**
 - **Modular processing chains (workflows / steps)**
 - **Parallel processing**
 - **PDS data processing / Spice kernel integrated**
 - **Scheduler – based Processing directly from / to data base**



MSL Mastcam (close range) left and right Input Images Examples

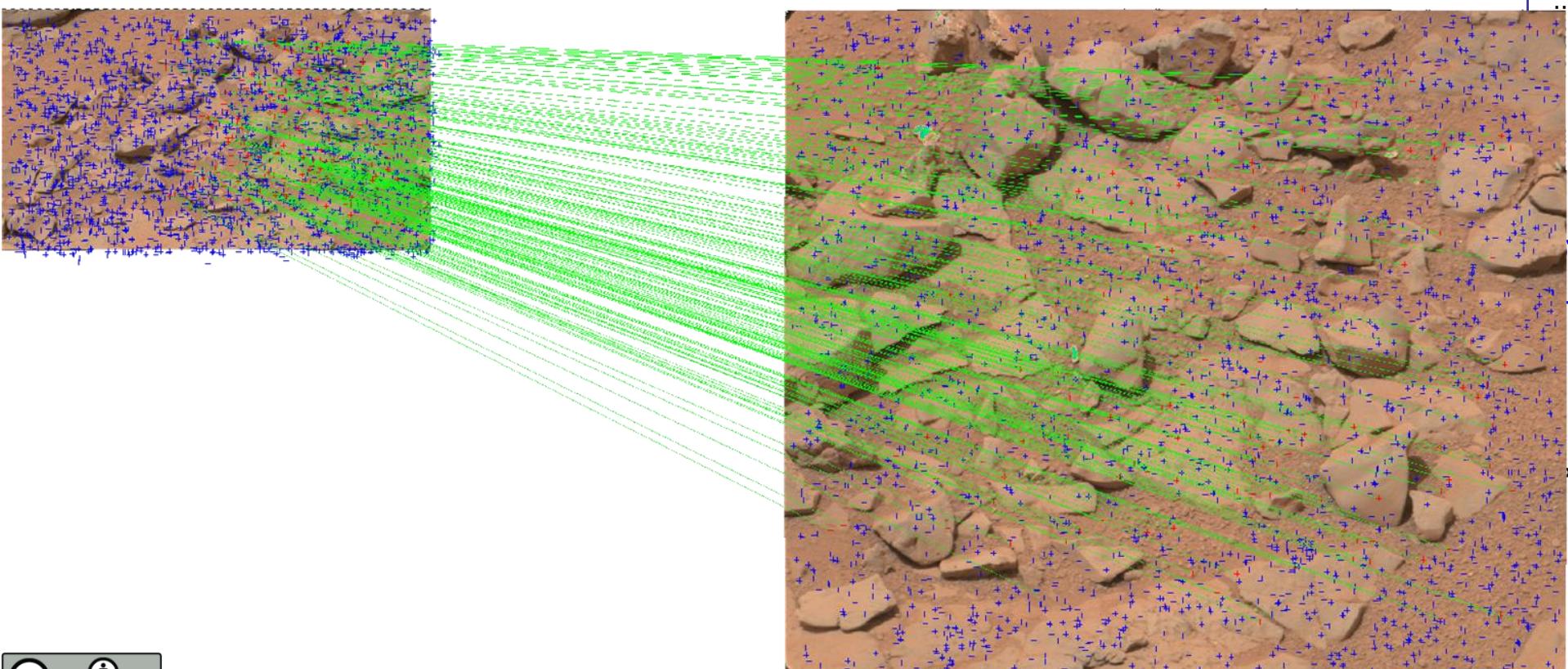


- **Left**
 - 769x433 px
- **Right**
 - 1402x1402 px

Reconstruction Process

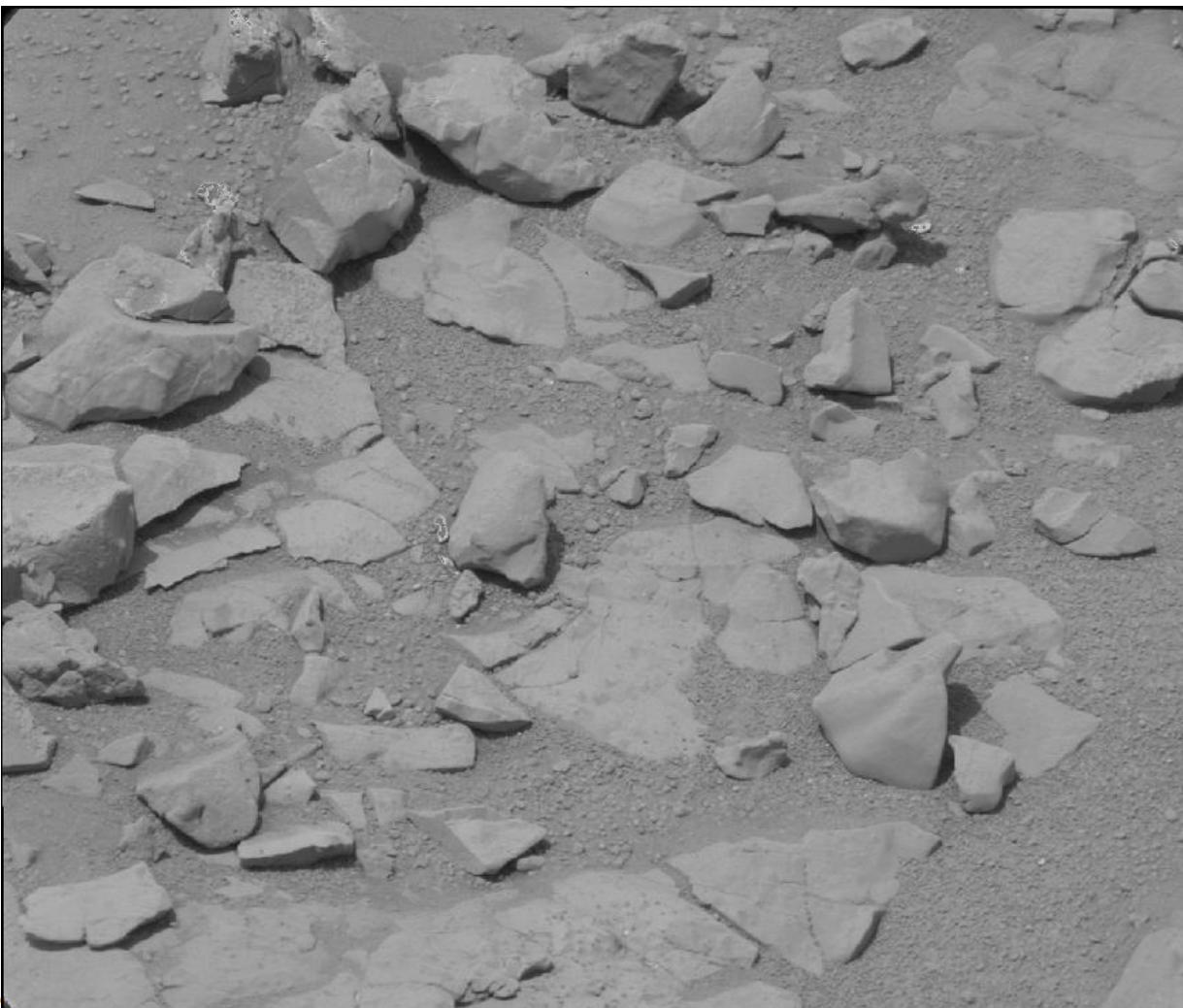
pre-registration

- Sparse point matching



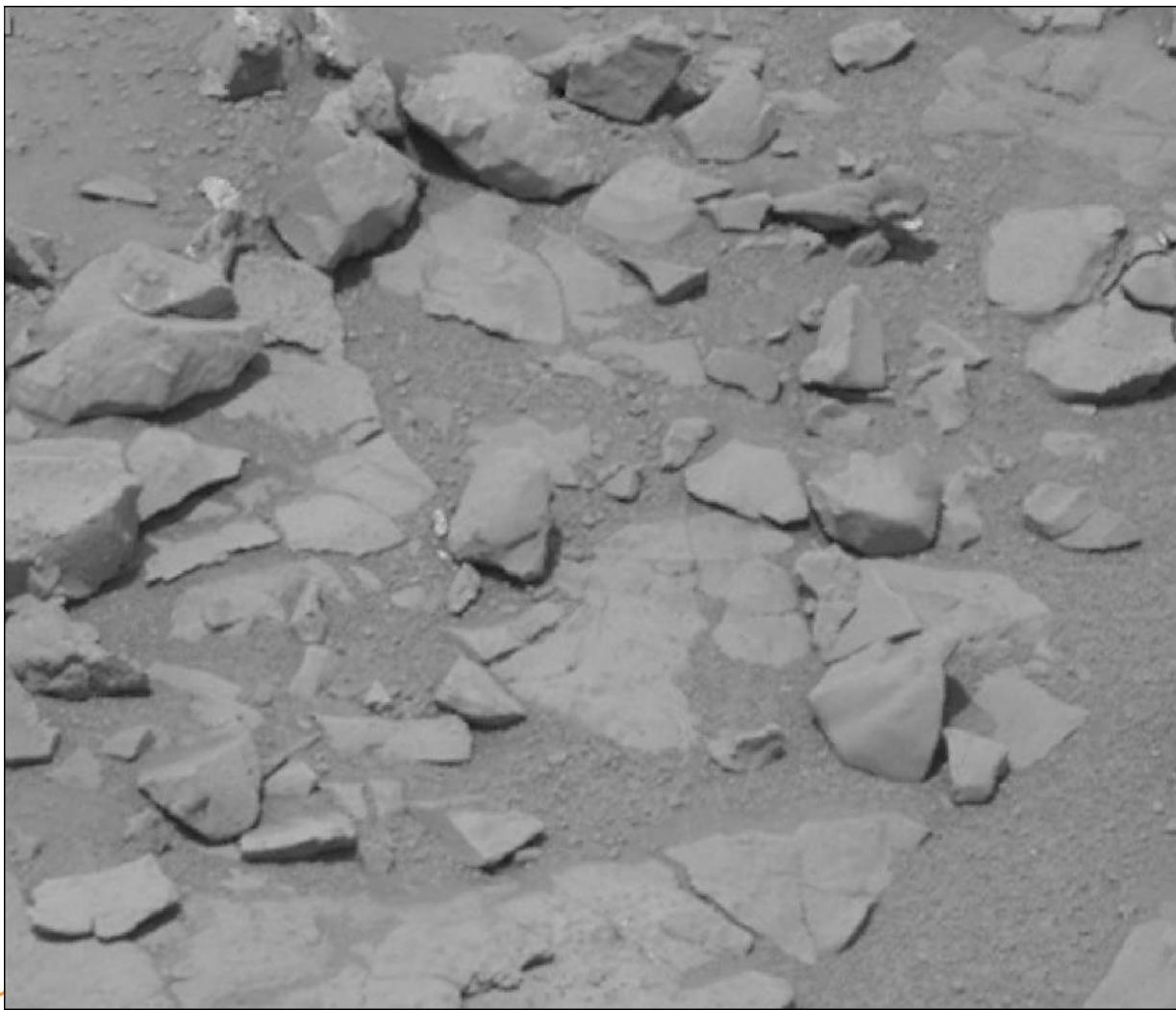
Reconstruction Process Registration / up-scaling

**mastcam right
(full image)**



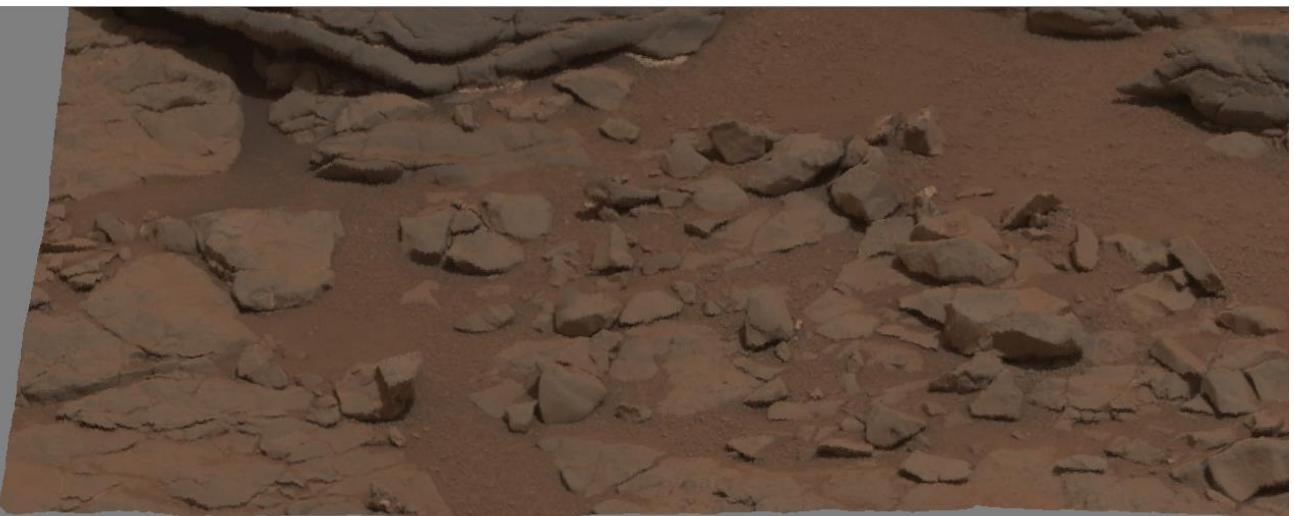
Reconstruction Process Registration / up-scaling

registered
mastcam left
(image segment)



Reconstruction Process

Stereo reconstruction and mosaicking



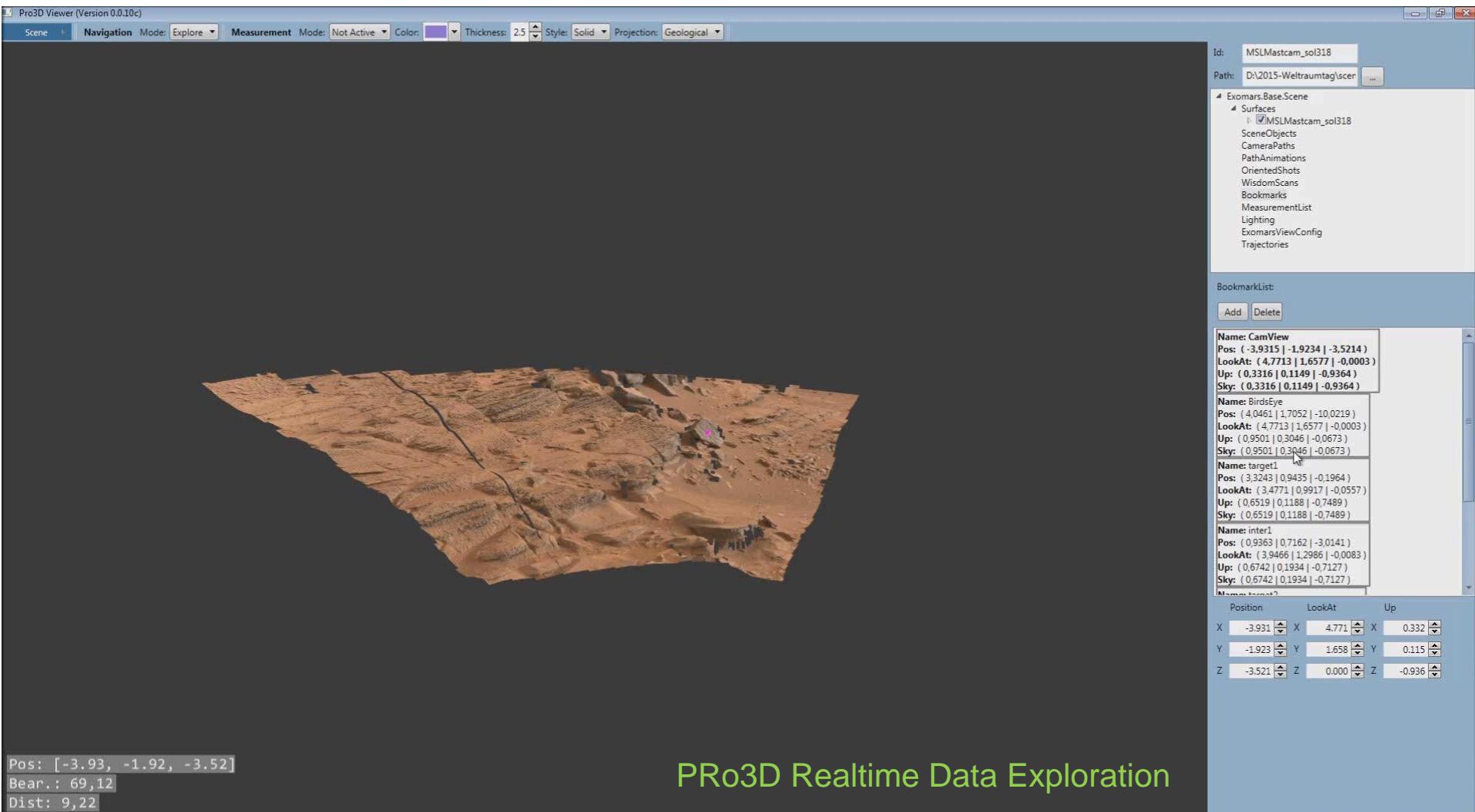
Cutout of
reconstruction

Ortho Image



DEM
(Distance Map)

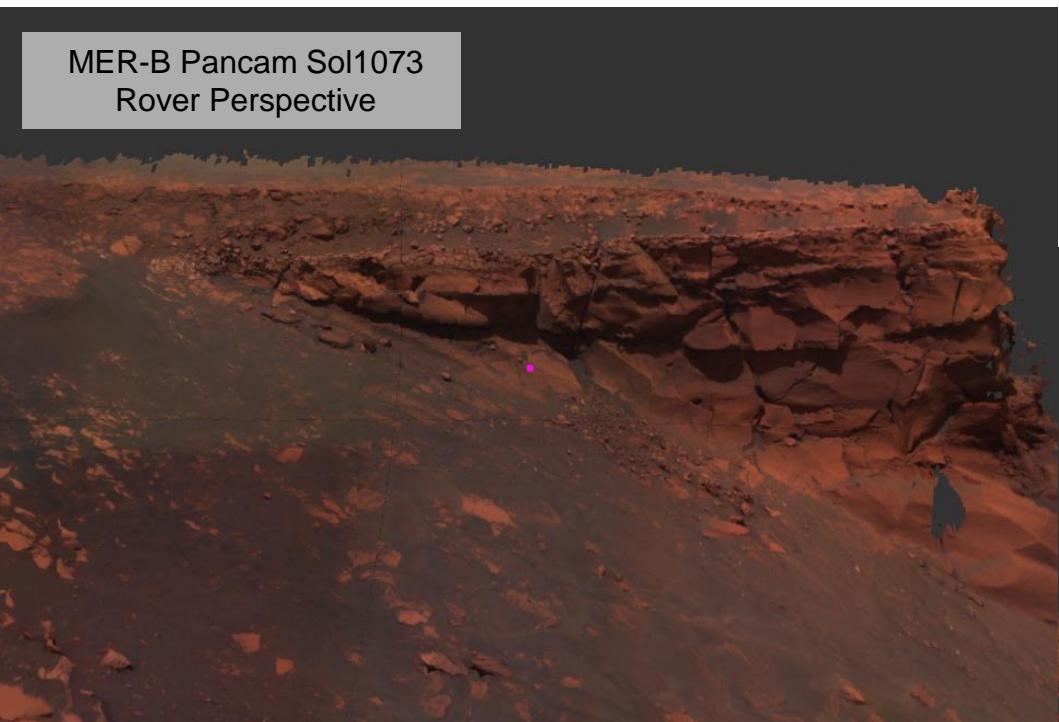
Combination of 99 Mastcam Pairs



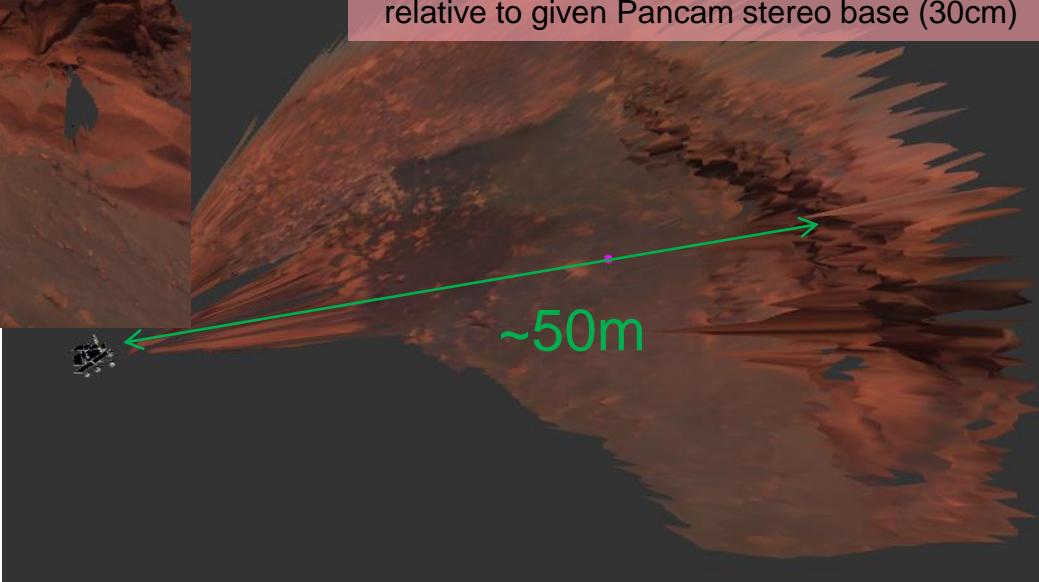
MER Pancam processing results

- Processing results using standard Pancam fixed baselength matching:
- Artefacts due to awkward stereo reconstruction geometry

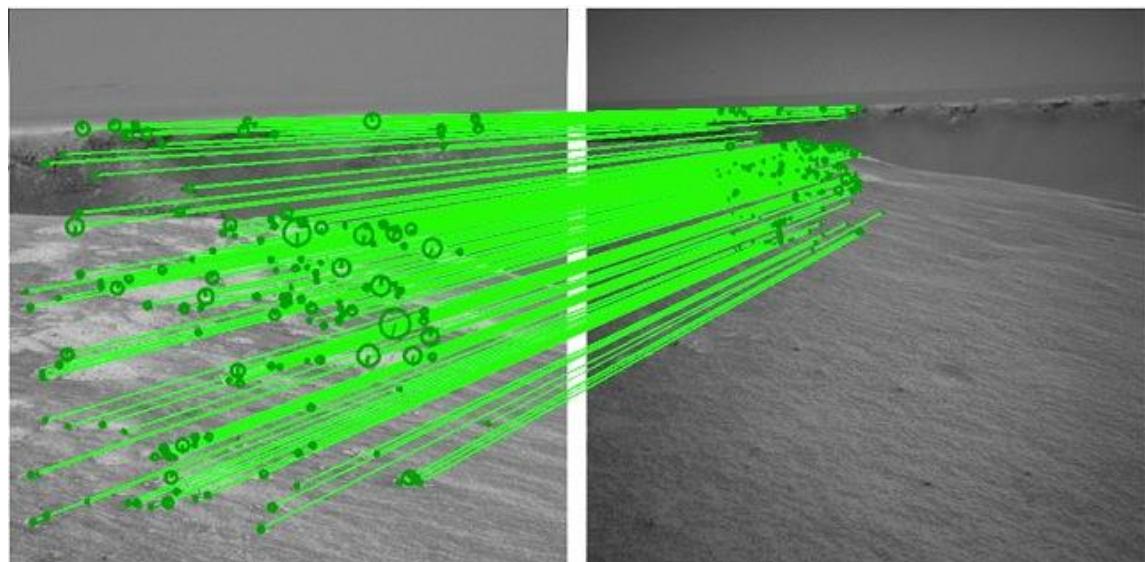
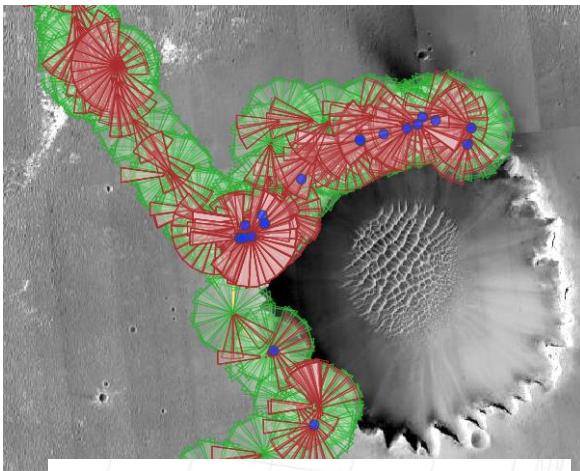
MER-B Pancam Sol1073
Rover Perspective



MER-B Pancam Sol1073 Bird's Eye perspective showing strong matching artefacts in big reconstruction distance relative to given Pancam stereo base (30cm)



Serendipitous Stereo Pairs: Victoria Crater – Matching overlapping views



Two different data sets with a view overlap

Enhancing far range quality by Wide Baselength Reconstruction: 1060/78/161 PanCam Sequence P2350

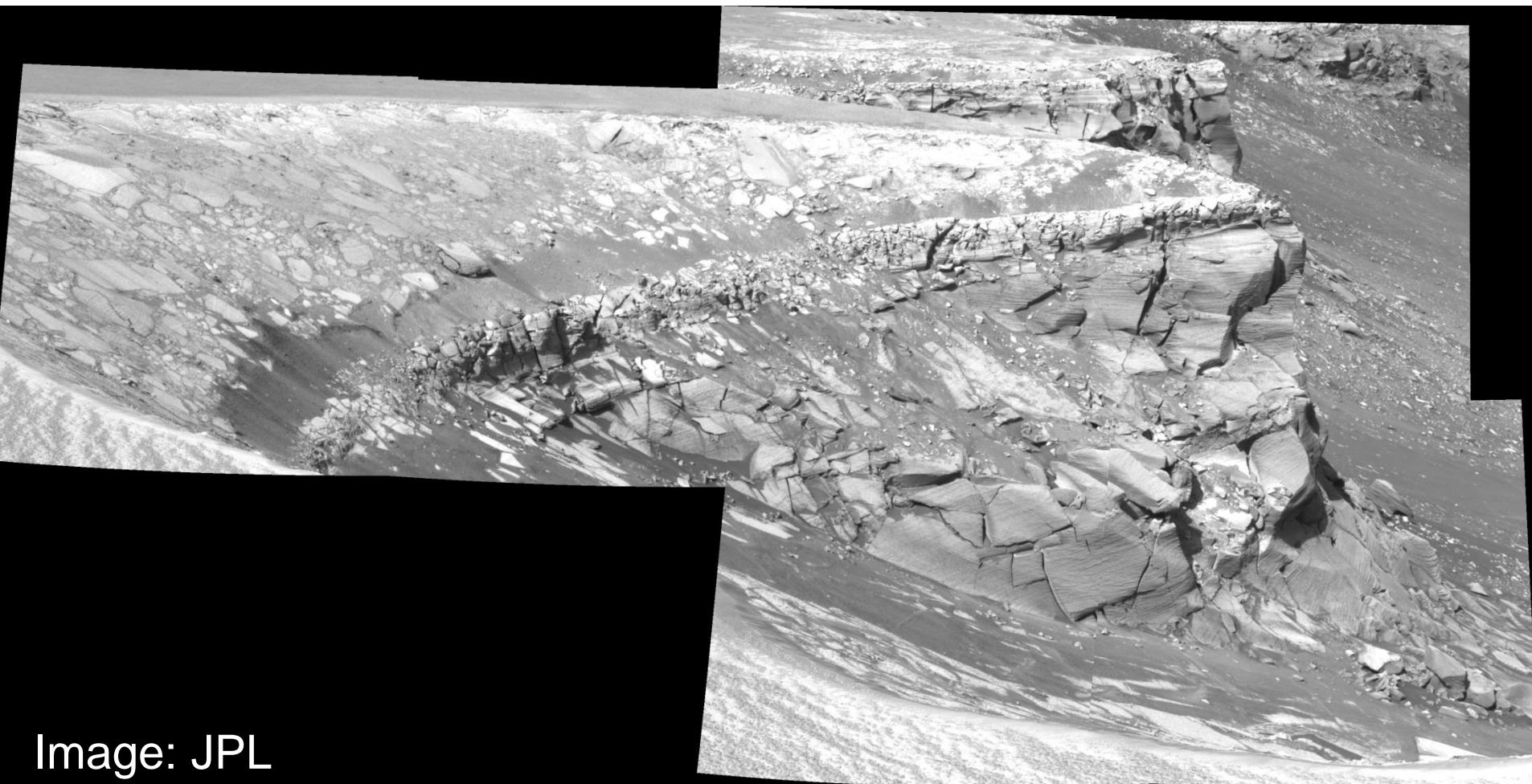


Image: JPL

1061/78/196 PanCam Sequence P2351

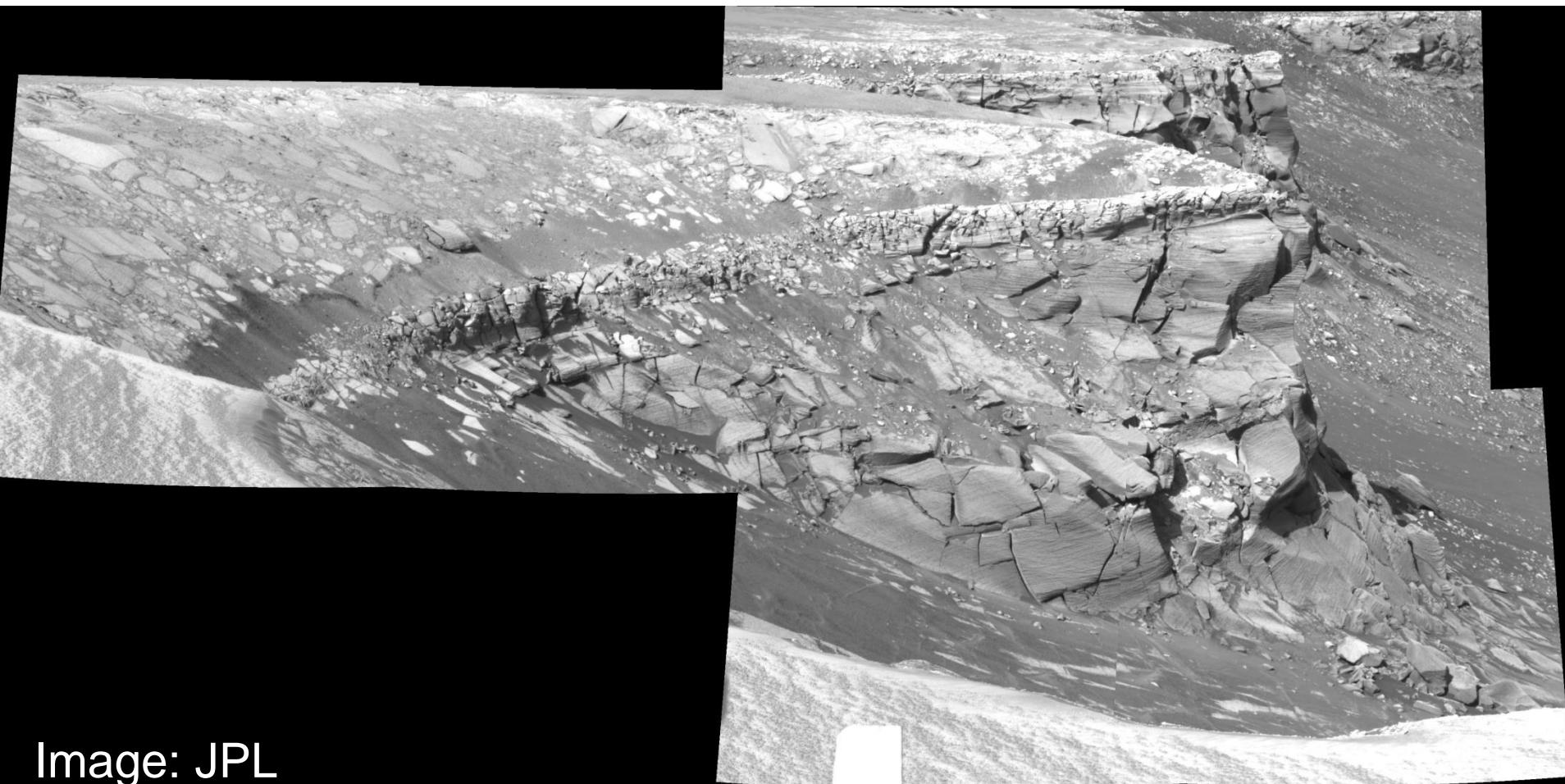
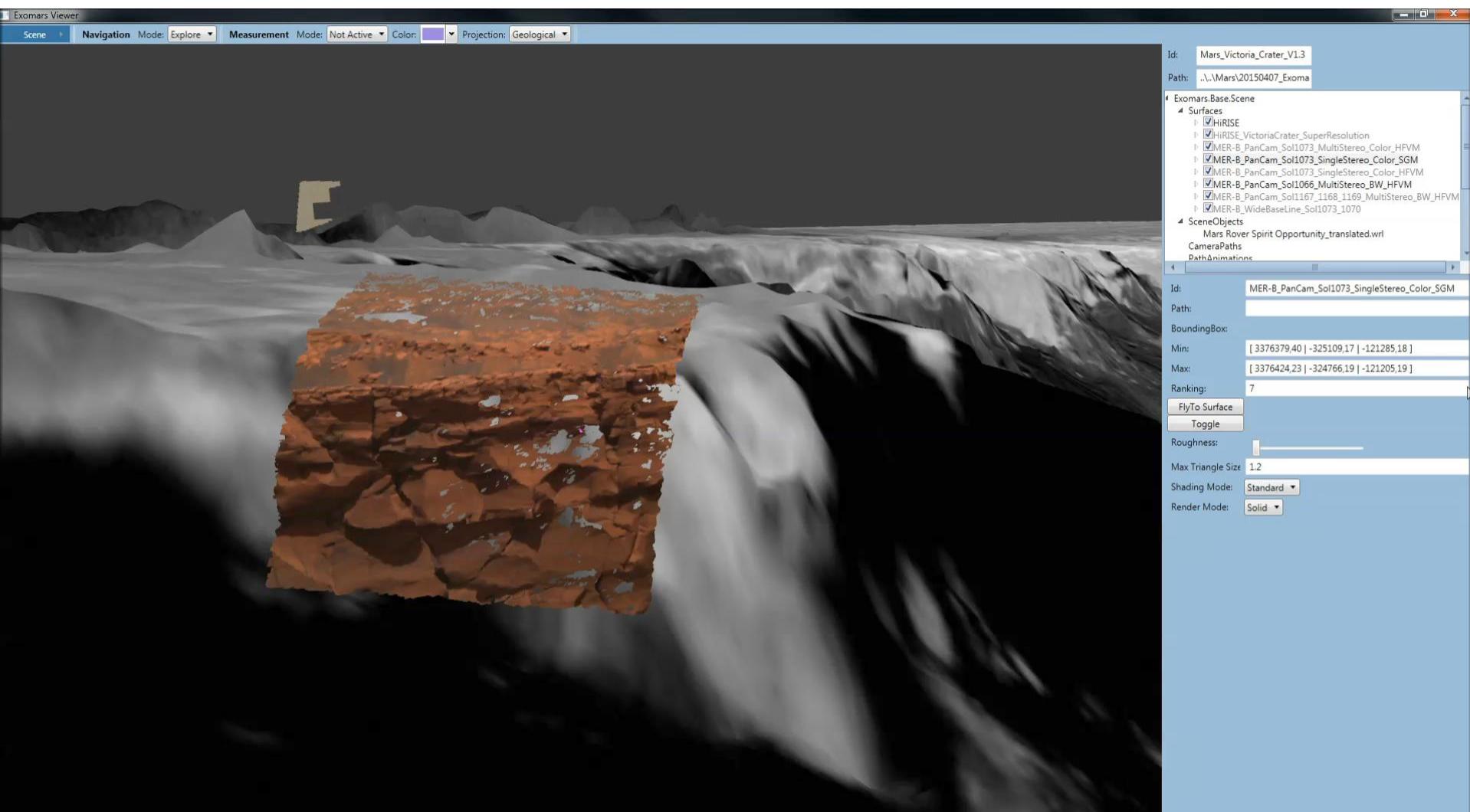


Image: JPL

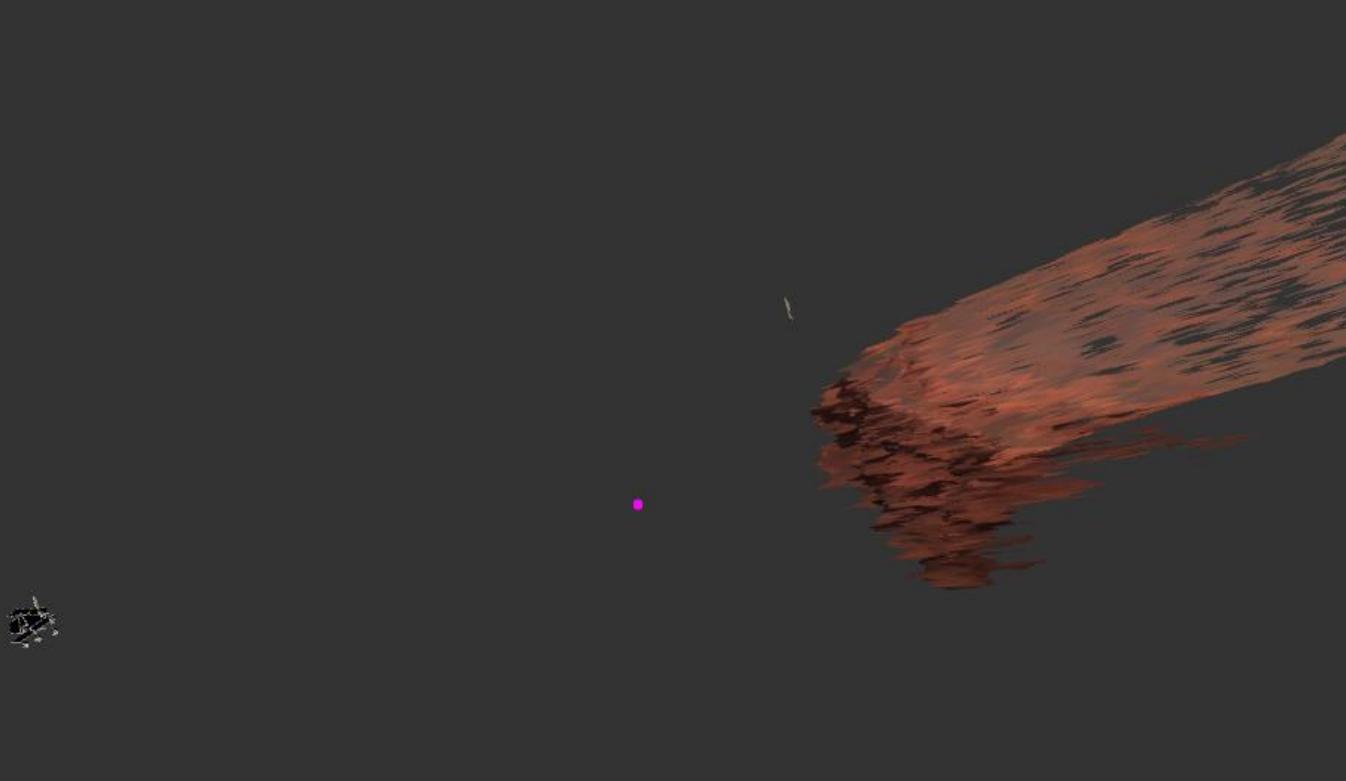
Showing Effect of Wide Baseline vs. Fixed: Changing viewpoint of fixed stereo 3D



Why wide baselength?

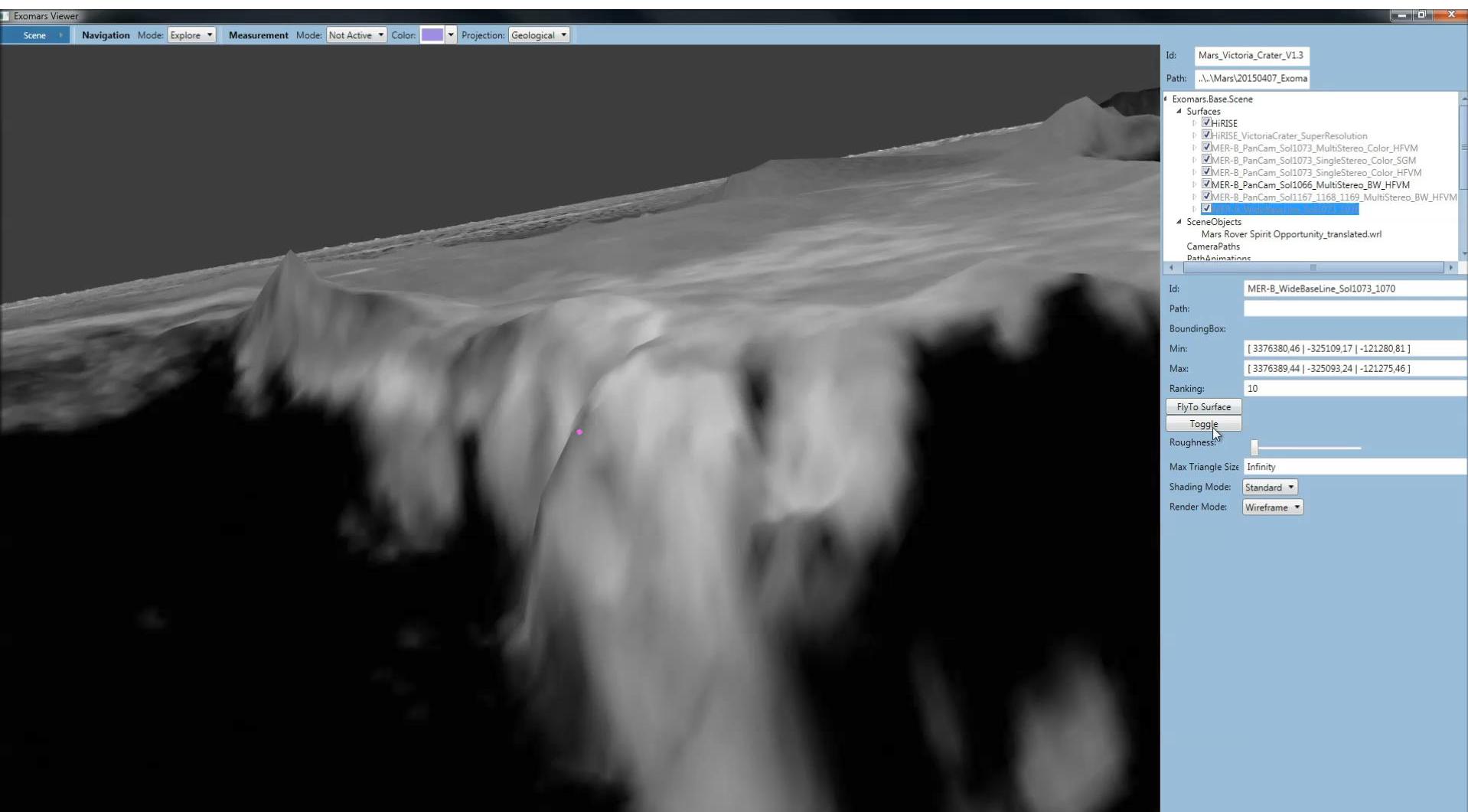
← MER Pancam processing results:

- Processing results using **HVFM** and **SGM** for matching



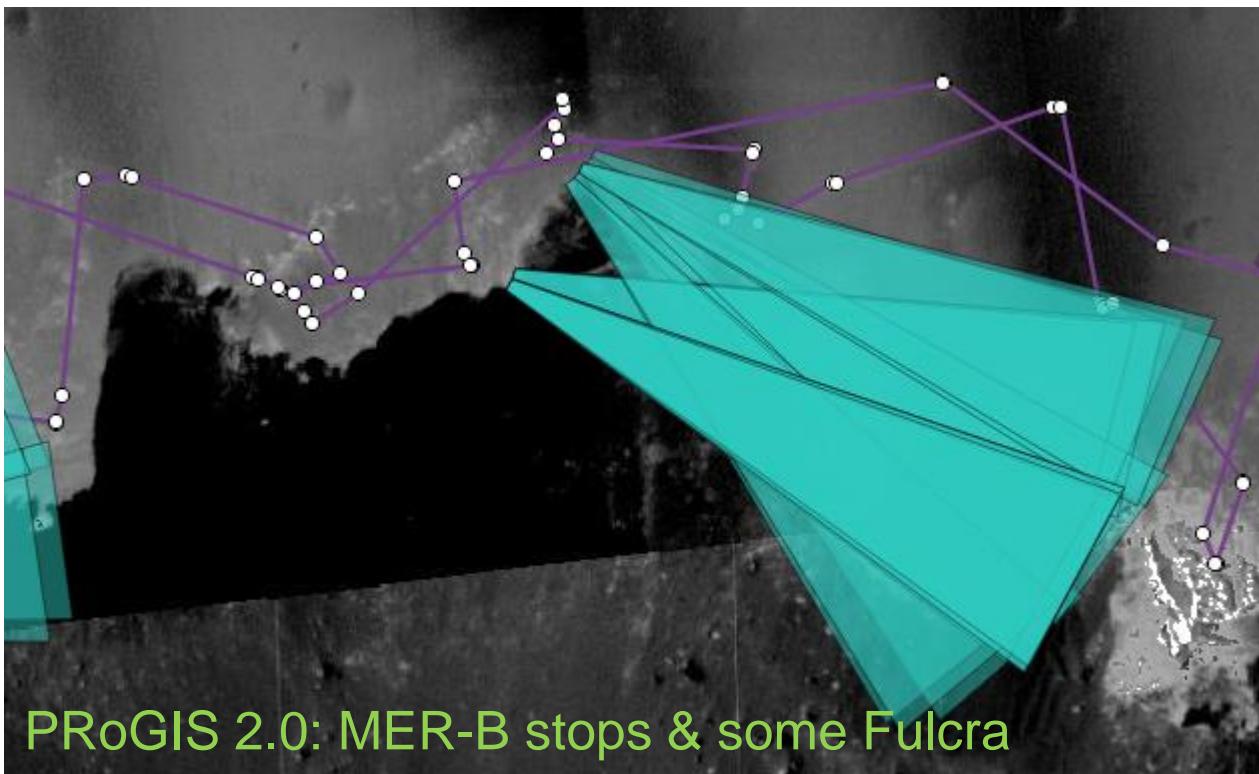
MER-B Pancam Sol1073 Single
Stereo Pair processed using SGM

Wide Baseline: Usable for Geologic Assessment



Data Fusion: HiRISE / MER

- HiRISE registered into unique MarsExpress HRSC Geometry
- MER Positions brought into same Context

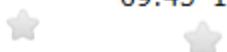


UCL: Muller & Tao

PRoGIS 2.0: MER-B stops & some Fulcra

09:15-09:30 09:45-10:00

[EPSC2015-359](#)

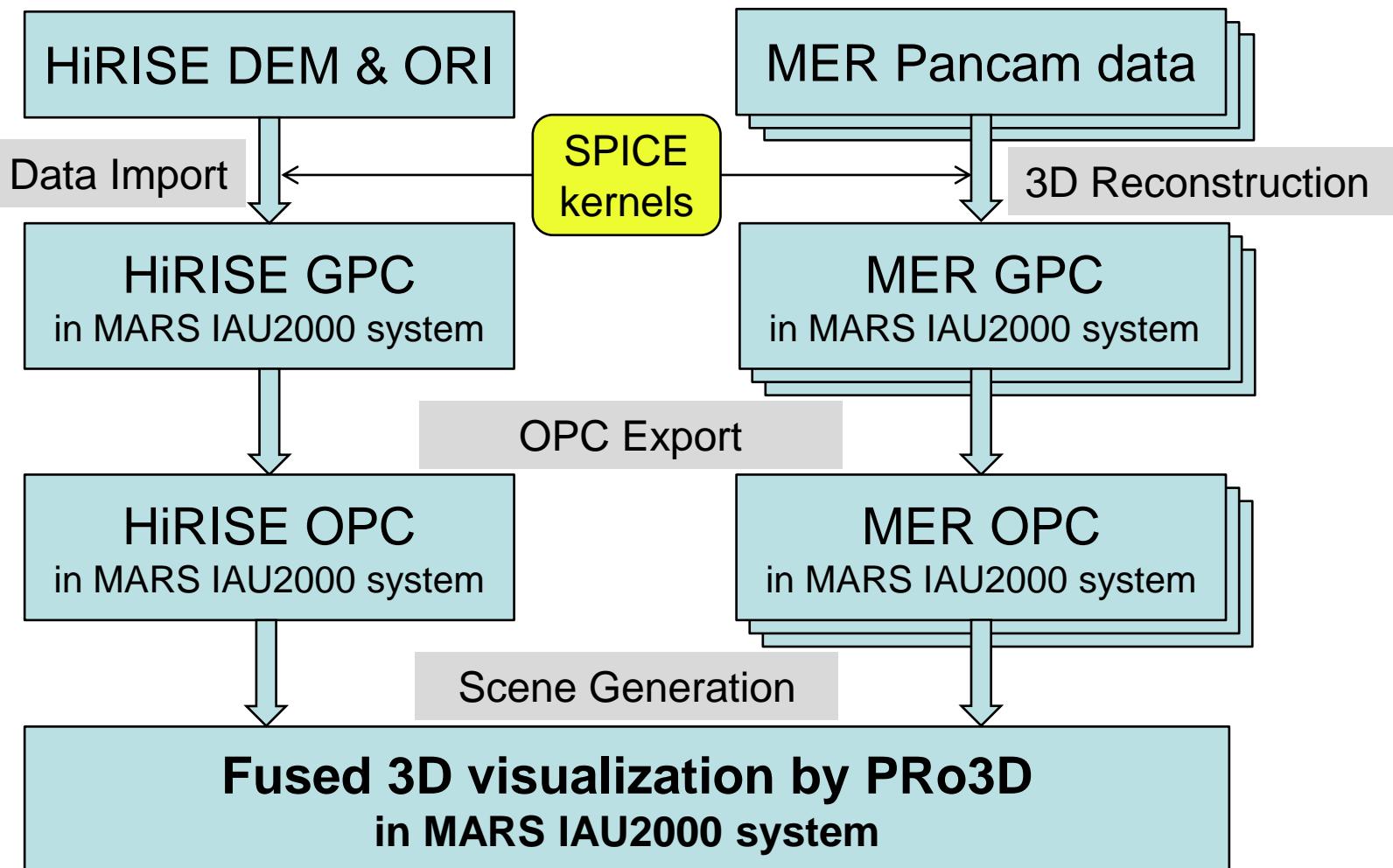


Towards a better understanding of Martian surface processes: zooming in for a quantitative assessment of key geomorphological features from super-resolution HiRISE images in comparison to overlapping rover Navcam image

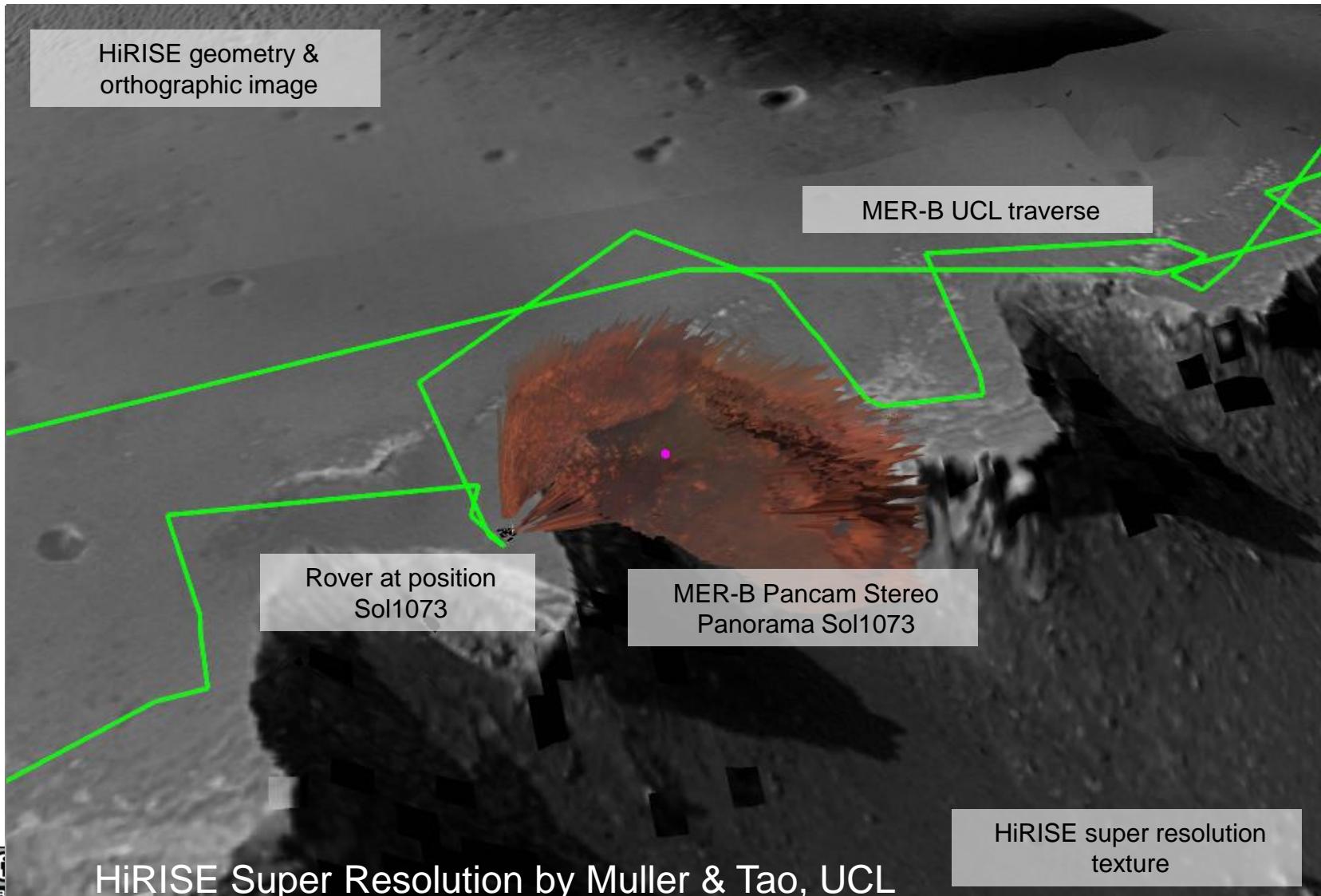
Y. Tao and J.-P. Muller



Overall Workflow of fusion

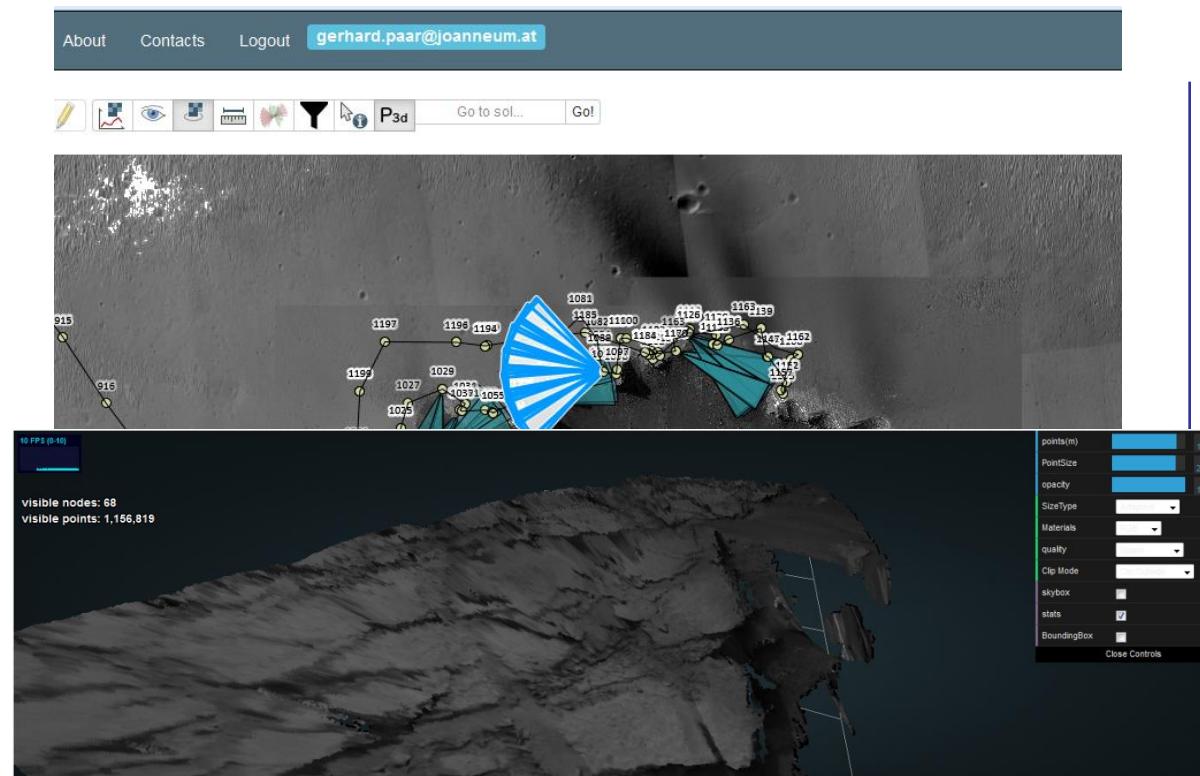


Coregistration & Fusion result



The PRoViDE Workflow

- Select 3D Vision Data Product from PRoGIS
- Visualize / Analyse in PRoGIS
- ★ Open PRo3D Viewer via Remote Rendering (Ortner 11:30)
- Perform Geological Analysis (Barnes 11:45)



11:30-11:45 [EPSC2015-23](#)



PRo3D – a tool for remote exploration and visual analysis of multi-resolution planetary terrains

C. Traxler, G. Hesina, and T. Ortner

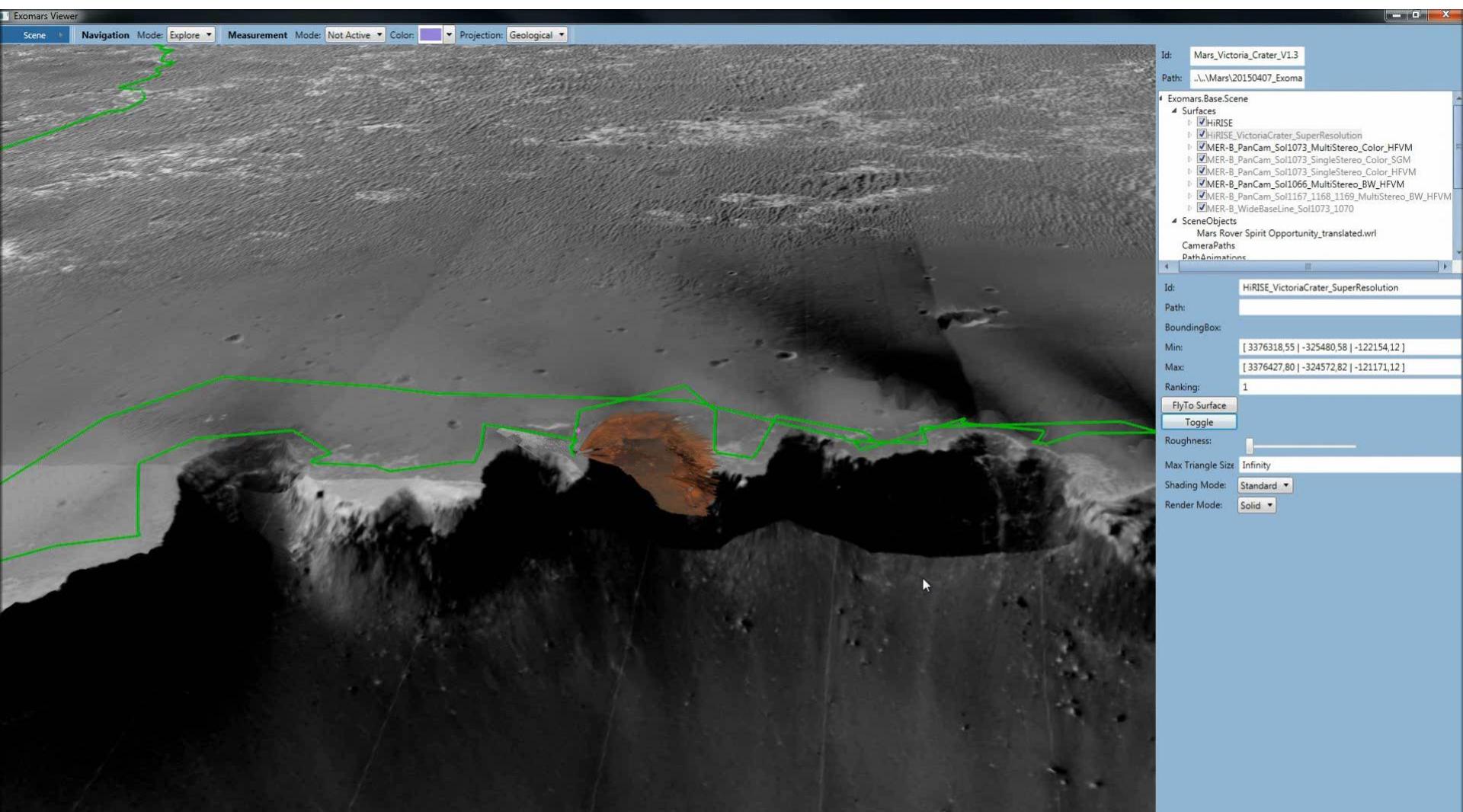
11:45-12:00 [EPSC2015-375](#)



Geological interpretation and analysis of surface based, spatially referenced planetary imagery data using PRoGIS 2.0 and Pro3D.

R. Barnes, S. Gupta, M. Giordano, J.G. Morley, J.P. Muller, Y. Tao, J. Sprinks, C. Traxler, G. Hesina, T. Ortner, K. Sander, B. Nauschnegg, G. Paar, K. Willner, and T. Pajdla

PRo3D: Embedding in full context of HiRISE DEM:Tens of Gbytes of data / scene

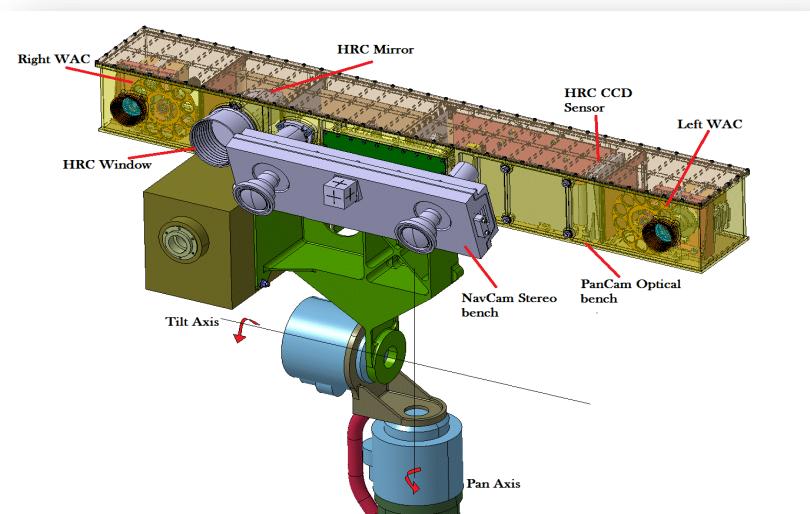


Further Exploitation of PRoViP / PRo3D

- NASA Mars 2020
Mastcam-Z

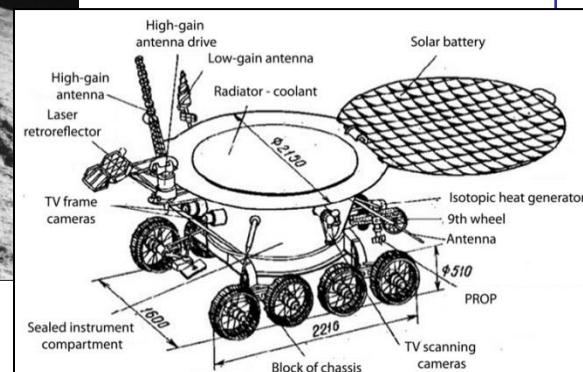
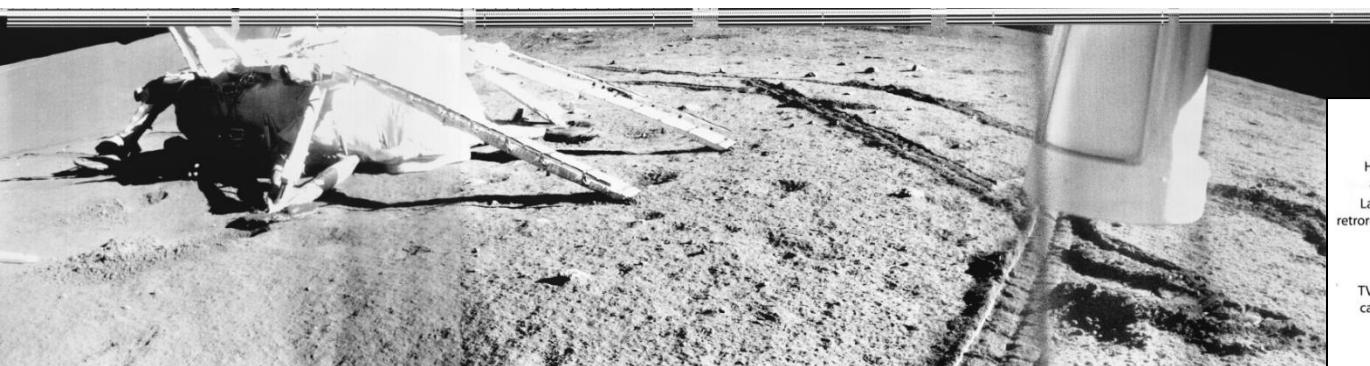


- ExoMars PanCam



And the Moon...

- Lunar surface data processing (new orbital images and rover's archive panoramas);
- Science exploitation of lunar data;
- Lunar data import engine;
- Access to Lunar data via MExLab Planetary Geoportal.



■ [Poster Program](#) / Attendance Thu, 01 Oct, 17:45–19:15 / Poster Area

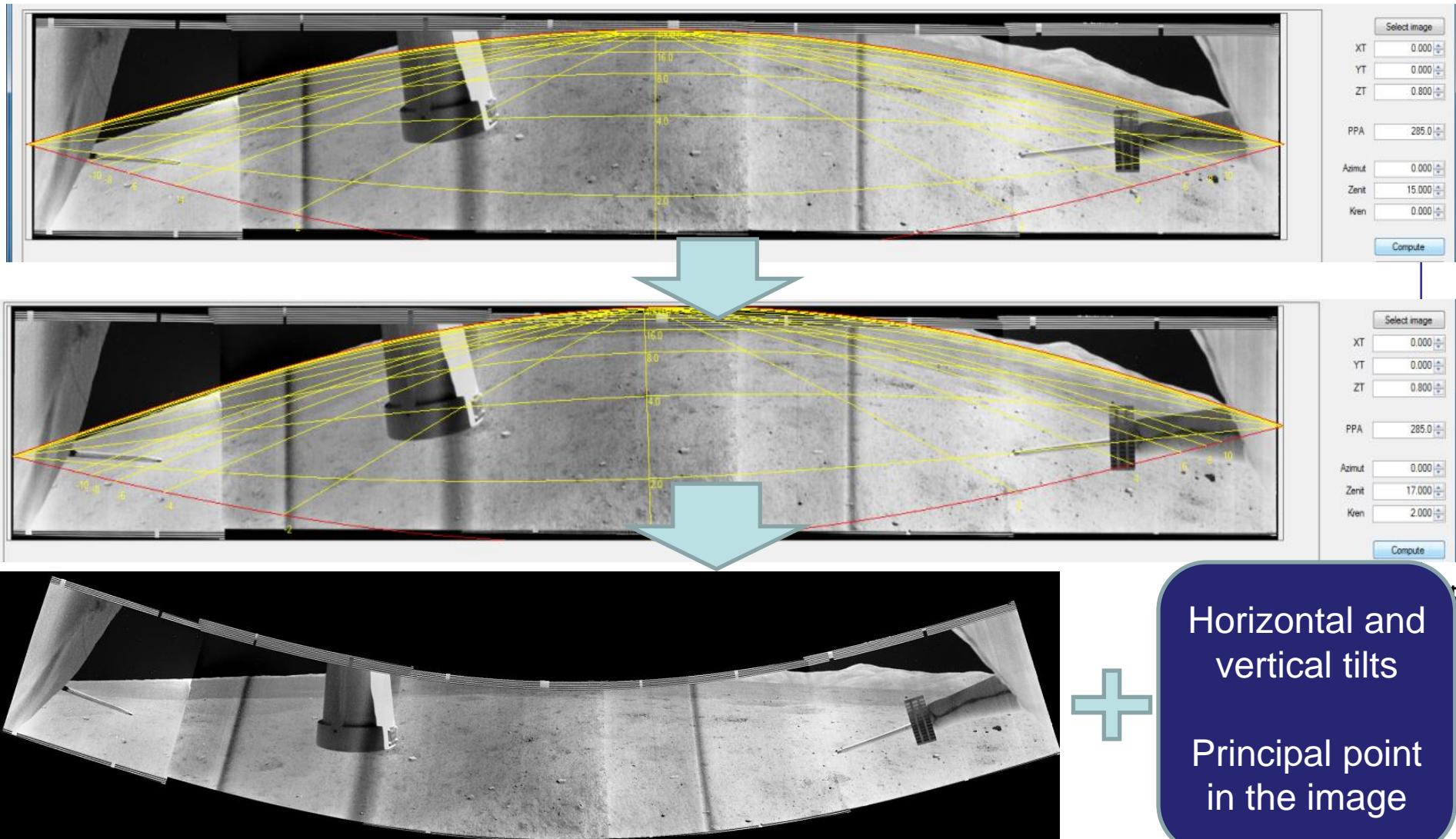
P36

[EPSC2015-532](#)

Lunar rovers and archive panoramas: Past for the Future

N. Kozlova, A. Zubarev, A. Solodovnikova, Yu. Rybakin, A. Garov, A. Abdurakhimov, and I. Karachevtseva

Determination of Lunokhod tilts and geometric corrections



Determination of observation points in ArcGIS

Screenshot of ArcGIS software interface showing the determination of observation points for the Luna-17 Lander Module.

Table Of Contents:

- Layers
 - Points_panoramas
 - < all other values>
 - Precision
 - 1
 - 2
 - 3
 - L1_track_MElab_DLRL
 - Point_Plan
 - Plan_1.tif
 - Plan_2.tif
 - Plan_3.tif
 - Plan_4.tif
 - Plan_5.tif
 - Plan_6.tif
 - Plan_7.tif
 - Lunoxod1_Ortho.tif
 - Lunoxod1_DTM1.tif

Map View:

Inset Map:

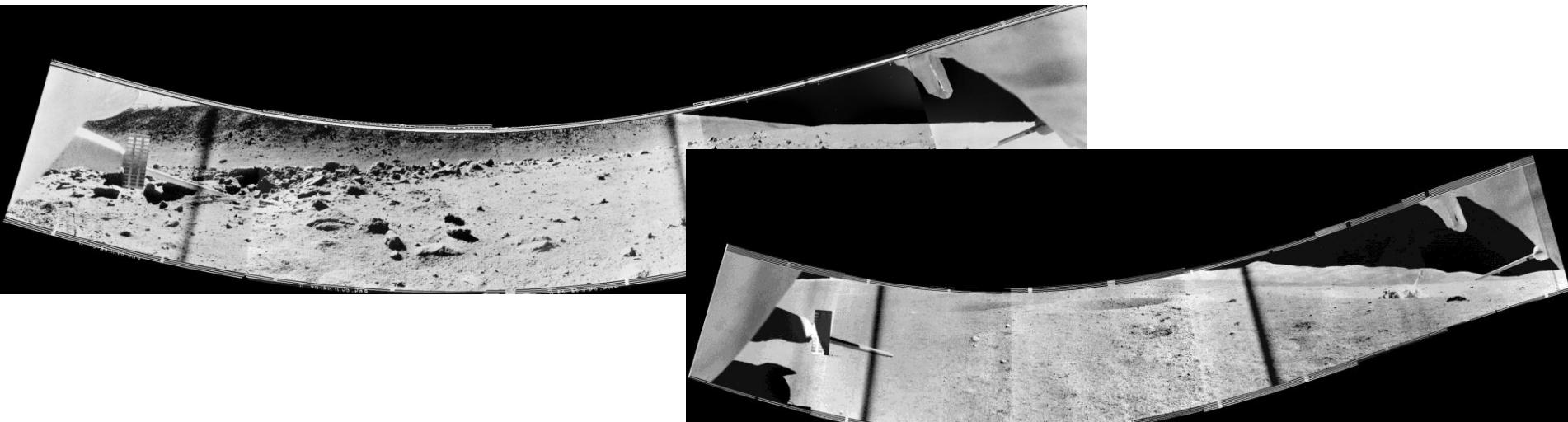
Table View:

FID	Shape *	Id	Pan name	Note	Camera	Lat y	Long x	Precision
0	Point	0	6-092	From Luna-17	v	38.237625	-35.001504	1
1	Point	0	6-093	From Luna-17	v	38.237625	-35.001504	1
2	Point	0	6-095	with Luna-17	h	38.237614	-35.001626	1
3	Point	0	6-102	measurable_track_7m long	h	38.237463	-35.000823	2
4	Point	0	6-098	with_L17_and_track	h	38.237703	-35.000793	1
5	Point	2		?pl1		38.236749	-34.998775	3
6	Point	3		?pl1		38.236622	-34.99881	3
7	Point	0	6-100	track's turn	h	38.237615	-35.00078	2
8	Point	0	6-101	Luna17, track	h	38.237524	-35.000821	1
9	Point	0	6-099	between 98 and 100	h	38.237657	-35.000769	1
10	Point	0	6-123?	test1 using track	h	38.230617	-34.996324	3
11	Point	0	6-120??	track turn in small crater, reverse	38.218877	-34.993227	3	
12	Point	0	6-121?	track along crater	38.230929	-34.996342	3	
13	Point	0	6-125?	test1, t turn, big crater	38.216236	-34.991487	3	
14	Point	0	6-125?	test2 slow turn	38.218627	-34.992676	3	
15	Point	0	6-181	Luna17	38.237484	-35.001744	1	
16	Point	0	6-182	Luna17	38.237484	-35.001744	1	
17	Point	0	6-185	Luna17	38.237784	-35.001813	1	
18	Point	0	6-184	Luna17	38.237784	-35.001813	1	
19	Point	0	6-183	Luna17	38.237484	-35.001744	1	
20	Point	0	6-178	Luna17	38.237363	-35.001447	1	
21	Point	0	6-179	Luna17	38.237363	-35.001447	1	
22	Point	0	6-180	Luna17	38.237363	-35.001447	1	
23	Point	0	6-186	Luna17	38.237849	-35.001724	1	
24	Point	0	6-153	Southern point	38.19845	-34.980829	1	

Bottom Status Bar:

File Edit View Bookmarks Insert Selection Geoprocessing Customize Windows Help
 1:300
 Snapping Editor
 Table Of Contents
 Layers
 Points_panoramas
 L1_track_MElab_DLRL
 Point_Plan
 Plan_1.tif
 Plan_2.tif
 Plan_3.tif
 Plan_4.tif
 Plan_5.tif
 Plan_6.tif
 Plan_7.tif
 Lunoxod1_Ortho.tif
 Lunoxod1_DTM1.tif
 (0 out of 38 Selected)
 Points_panoramas | Point_Plan | L1_track_MElab_DLRL

Science exploitation of archive panoramas



The geologic description of panoramas includes next characteristics:

- 1) The general description of terrain around - mare, highland.
- 2) Characteristics of environment: characteristics of relief, such as flat smooth plains, or rugged terrain.
- 3) Prominent geologic objects - big craters, mountains, large rock fragments.
- 4) The description of neighboring craters, including their size, class, type.
- 5) The description of rock fragments, including their size, class, type.
- 6) The description of the ground, including their structure, the characteristics of rover tracks.

References:

Karachevtseva I., Kozlova N., Nadezhina I., Zubarev A., Abdrikhimov A., Basilevsky A., and Oberst J. New processing of Luna archive panoramas and geologic assessment of the Lunokhod landing sites // European Planetary Science Congress, London, United Kingdom, [EPSC2013-532], September 08-13, 2013. <http://meetingorganizer.copernicus.org/EPSC2013/EPSC2013-532.pdf>

Abdrakhimov A., Basilevsky A., Karachevtseva I. Geological review of Lunokhod-1 area // 4M-S3, IKI RAS, Moscow, Russia, 14-18 October 2013.

Access to Lunar archive data via Geoportal



Planetary Geoportal

MIIGAiK Extraterrestrial Laboratory (MExLab)
Moscow State University of Geodesy and Cartography (MIIGAiK)

Geodesy and
Cartography
Node



The screenshot displays the MIIGAiK Extraterrestrial Laboratory (MExLab) Planetary Geoportal. The interface includes:

- Products/Layers:** A list of available planetary data layers for the Moon, including KaguyaTC, Landing Site, LRO_NAC, LRO_NAC_DEM, PanoramasCentral, PanoramasCylindrical, PanoramasNoProject, PanoramasOrth, PanoramasSpherical, and moon:route.
- Map View:** A grayscale map of the Moon's surface showing a highlighted route. The route is a pink line with blue dots, and a yellow dot marks a specific location. The map includes coordinates: Longitude: -34.94679093° and Latitude: 38.23458373°.
- File/Preview:** A vertical stack of thumbnail images showing various lunar surface scenes, labeled with file names such as 6-93.tif, 6-175.tif, 6-95.tif, 6-181_prev.JPG, 6-181.tif, 6-99.tif, and 6-185.tif.
- Table View:** A table listing mosaics with their corresponding mission names, projections, and lunar days.

Poster Program / Attendance Tue, 29 Sep, 17:45-19:15 / Poster Area

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EPSC2015-804

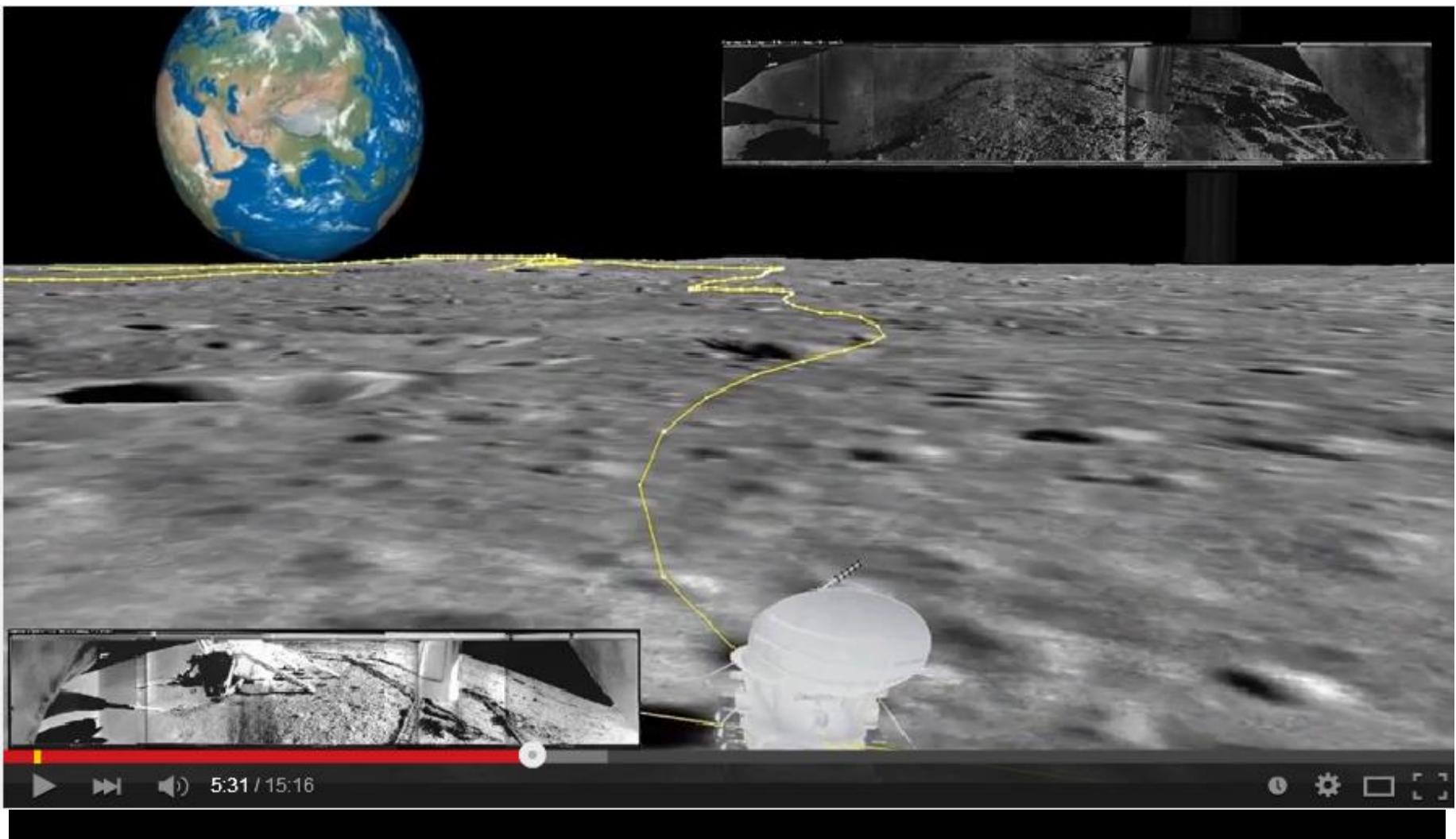
MExLab Planetary Geoportal: 3D-access to planetary images and results of spatial data analysis

I. Karachevtseva and A. Garov

BY



Lunokhod-1 journey on Youtube



<https://www.youtube.com/watch?v=QXKkmpsWPuQ>

www.provide-space.eu

Wrapup: PRoViDE Innovations into Planetary Science Community

- Surface Image 3D Batch Processing, based on Scheduler / processing everything in Data Base directly from PDS
- MSL Mastcam processed 1st time fully in batch
- PRoGIS 2.0: 2.5 D GIS for pre-assessment
- Lunokhod Image Data & Web Portal
- PRo3D: 3D Geologic Assessment / Remote Rendering
- Fusion Satellite & Rover 3D Data / Super Resolution
- Serendipitous stereo / wide baselength stereo / multistereo
- FIRST INTEGRATED AUTOMATIC PROCESSING / DATA BASE / GIS / 3D RENDERING SYSTEM FOR PLANETARY SCIENCE

Dealing with Data & Software only...



SMW1.8

Demonstration - Zooming in-and-out of Mars: new tools to interact with multi-resolution Mars datasets (public) Wed, 30 Sep, 16:00-17:30 / Room Mars

Convener: K. Willner 