

# MODERN IMAGE PROCESSING OF ARCHIVE LUNAR PANORAMAS AND NEW MAPS FOR LUNOKHOD-2 AREA

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## Commission IV, WG IV/8

**KEY WORDS:** Moon, Lunokhod, LRO NAC, DEM, Planetary mapping, Photogrammetry

### ABSTRACT:

We present the results of image processing of archive lunar surface panoramas obtained during Soviet lander and rover missions. Apart from different Martian rover missions such as MER-A, B and MSL PRoViDE (Planetary Robotics Vision Data Exploitation) project is focused on lunar surface data ([www.provide-space.eu](http://www.provide-space.eu)). We have collected all imagery data remained since Soviet lunar missions, developed and implemented new techniques for digital processing of archive panoramic images and, additionally, LRO NAC data. It allowed us to obtain new products suitable for modern software and computer use, create a scheme of product levels and structure of lunar data catalogue, carry out geologic assessment of the landing sites and observation points, and visualize Lunokhod journeys in video clips to popularize the data (<http://www.provide-space.eu/new-video-the-journey-of-lunokhod-1/>). Based on processing of LRO NAC images new maps for study area have been prepared.

## 1. INTRODUCTION

PRoViDE (Planetary Robotics Vision Data Exploitation) aims to process the majority of rover image data of various missions. MIIGAiK Extraterrestrial Laboratory (MExLab) is responsible for processing of lunar surface panoramic images obtained during Soviet missions. The data represent a significant and important part of the study.

However, more than 40 years have passed since the missions, all technologies have changed, a lot of sufficient data was lost, so reprocessing of old lunar panoramas required developing of new methods and algorithms for processing as well as special software.

## 2. THE STUDY

The objectives of our work were to fully exploit the historic Lunokhod panoramas based on LRO NAC photogrammetry image processing and use the results for landing site selection for future lunar missions. Unfortunately, many of the relevant operational parameters of the Lunokhod missions are lost. The images are noisy, and image quality is low. Timing and positional information, as well as the geometric properties of the cameras are not known and have to be determined in the iterative process.

We have developed and implemented a technique for reconstruction of archive panoramas, determination of unknown exterior orientation and processing of panoramas that allowed us to include panoramas in a digital database and use them for further scientific exploitation (where possible).

To do this we have collected images obtained during Soviet Lunar missions (Luna-9, -13, -17, -20, -21) and supplementary data from all available sources: Russian State Archive of Scientific and Technical Documentation (then - Russian State Archive), old and recent publications (Dovgan, 2015). We have assembled all Lunokhod panoramas from original scanned fragments as they were obtained from Russian State Archive.

Further processing of panoramas is complicated by lack of some camera parameters and their calibration (principal point, distortion, other parameters, e.g. focal length and image size, not defined precisely), exterior orientation parameters

(coordinates of observation points; Lunokhod orientation – azimuth and tilts), parameters of scanning. So for panoramic image processing we have to use nominal interior orientation parameters of the cameras published in (Vinogradov et al., 1971) or some best fit parameters determined iteratively by means of a specially developed software (Fig 1).

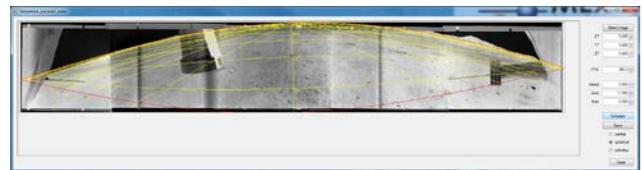


Figure 1. Determination of Lunokhod tilts using specially developed software

To support the study with modern data we have created detailed DEMs and orthomosaics of the Lunokhods landing sites based on stereo photogrammetric processing of LRO NAC images (Fig. 2). The manually digitized traverse of Lunokhod-2 route (Fig. 3) and the calculated covered distances (39.1 km) were refined (Fig 3) based on new images against mission measurements (37 km) and early published data (42 km) ([www.nature.com/news/space-rovers-in-record-race-1.13229](http://www.nature.com/news/space-rovers-in-record-race-1.13229)).

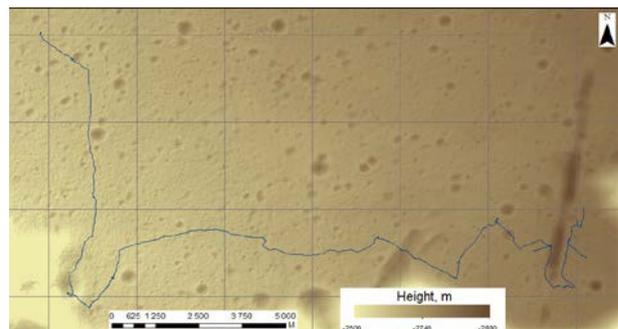


Figure 2. DEM for Lunokhod-2 landing site. Resolution: 2.5 m/pixel (created using the new LRO NAC images which became available in Dec 2013)

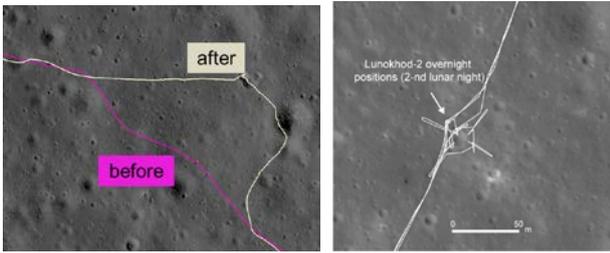


Figure 3. Examples of Lunokhod-2 track refinements based on new LRO NAC images, received in Dec 2013

Such processing allowed us to find the observation points for several panoramas while other panoramas were pinpointed to the track approximately (Fig. 4).

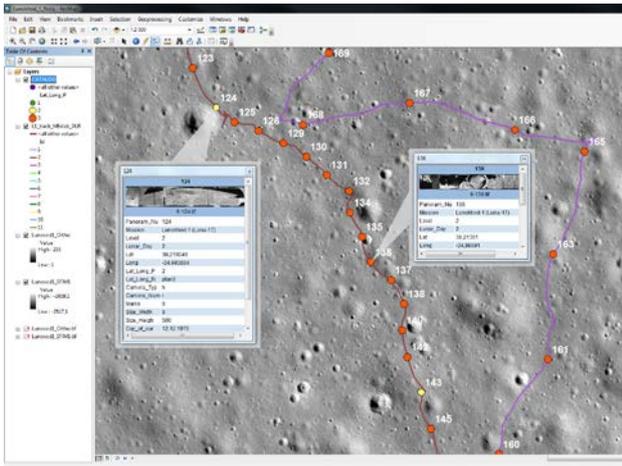


Figure 4. Determination of observation points of panoramic images using ArcGIS-tools (<http://www.esri.com/>): yellow marks (124 and 143) correspond to the identified panoramas, while the red ones to panoramas which were pinpointed to the track approximately

### 3. RESULTS AND CONCLUSIONS

As a result all the available lunar surface data was included into PRoViDE Data Catalogue. Lunar surface vision data for Lunokhod-1,2 routes have been processed and prepared for modern scientific exploitation, such as morphometry study (Basilevsky et al., 2014) or geology assessment (Abdrakhimov et al., 2013). All obtained products are uploaded into SQL database and are available via MIIGAiK Planetary Geoportal (Fig. 5). Base on the new updated metadata, which include spatial information (Fig. 6), users can exploit panoramas.

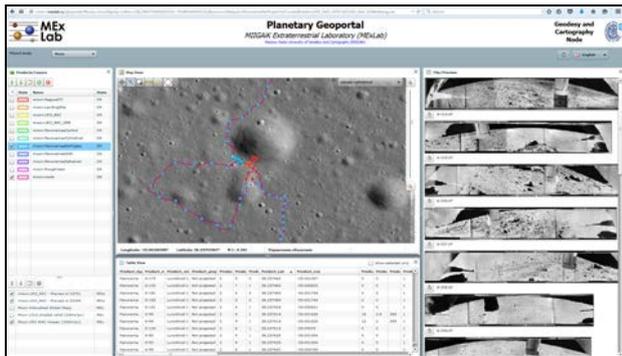


Figure 5. Lunar Surface data on Planetary data Geoportal (<http://cartsrv.mexlab.ru/geoportal>)

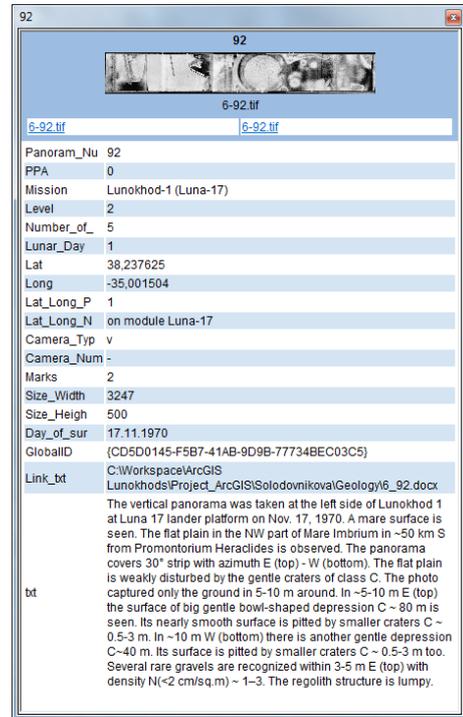


Figure 6. Example of archive lunar panoramas metadata, which were updated during a new digital image processing

Detailed maps for the Lunokhod-2 area have been created based on results of LRO NAC image processing. The maps gather both historic data and results of the current study (Fig.7-8).

As the lunar landing sites have been intensively studied recently (Basilevsky et al., 2014; Abdrakhimov et al., 2013; Karachevtseva et al., 2013) we have proposed new names for small lunar craters along the Lunokhod-2 route and Fossa Recta graben (Fig. 7).

Suggested names have been discussed and agreed by participants of the Soviet lunar program (G.A. Burba, A.T. Basilevsky and V.G. Dovgan), and sent to the IAU. We hope that after the IAU approval the new names of the small lunar craters will be widely used in scientific discussions, as well as the names which were proposed during the mission of Lunokhod-2 (Florensky et al., 1974) for several geological and relief features (Fig. 8).

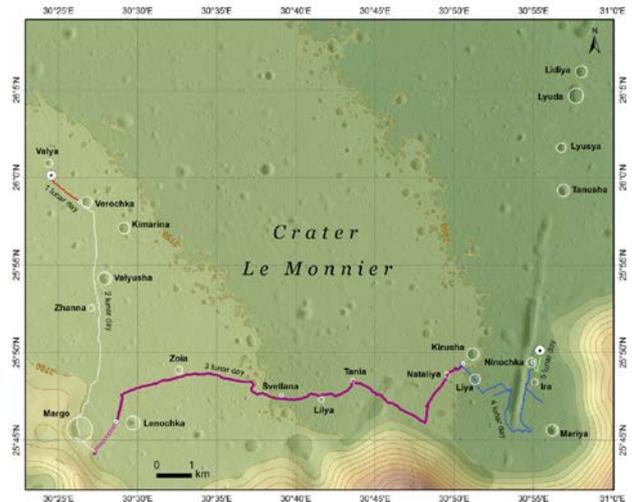


Figure 7. Hypsometric map of Lunokhod-2 landing site with proposed names for small lunar crater (background: LRO NAC orthomosaic)

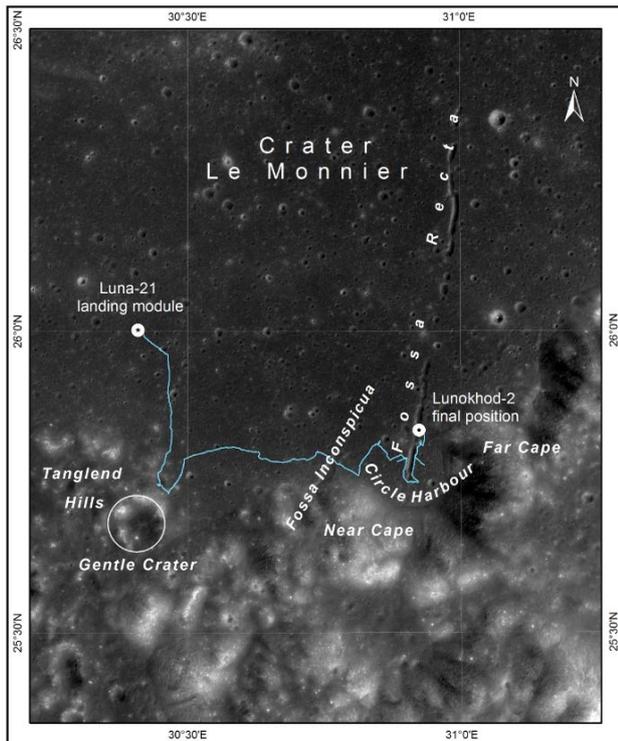


Figure 8. Global map of Lunokhod-2 landing site area with historic unofficial names (background: Kaguya orthomosaic)

#### ACKNOWLEDGEMENTS

We greatly acknowledge G.A. Burba, A.T. Basilevsky and V.G. Dovgan for invaluable information, suggestions and fruitful discussions.

The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement № 312377 PRoViDE.

Detailed lunar mapping was carried out at MIIGAiK and supported by Russian Science Foundation, project 14-22-00197.

We also would like to acknowledge Russian State Archive which provided image fragments of archive lunar panoramas for our research.

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