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1. **Nature:** R = Report, P = Prototype, D = Demonstrator, O = Other
2. **Dissemination level:**

PU	PP	RE	CO
Public	Restricted to other programme participants (including the Commission Service)	Restricted to a group specified by the consortium (including the Commission Services)	Confidential, only for members of the consortium (excluding the Commission Services)

Executive Summary / Abstract:
Base mapping documentation and pipelines to support GMAP efforts are described. Services to support mappers include GMAP cloud infrastructure instances of open sources tools to support the creation of base maps, as well as web services provided by other projects and available to the GMAP infrastructure. Services and tools are documented on the GMAP wiki. Feedback and inputs to existing or new guides on the wiki will be collected from the GMAP VA community.

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- **Acronym list**

Acronym	*Description*
ADAM	*Advanced geospatial Data Management platform (developed by MEEO)*
API	*Application Programming Interface*
ASP	*Ames Stereo Pipeline (NASA Open Source Software)*
CTX	*ConTeXt camera (NASA MRO experiment)*
EOSC	*European Open Science Cloud*
ESA	*European Space Agency*
GDAL	*Geospatial Data Abstraction Library*
GIS	*Geographic Information System*
GMAP	*GEologic MAPping (Europlanet activity)*
HRSC	*High Resolution Stereo Camera (MEX experiment)*
ISIS	*Integrated Software for Imagers and Spectrometers*
JMARS	*Java Mission-planning and Analysis for Remote Sensing*
JRA	*Joint Research Activity*
MEEO	*Meteorological Environmental Earth Observation*
MEX	*Mars Express (ESA mission)*
MRO	*Mars Reconnaissance Orbiter (NASA mission)*
NASA	*National Aeronautics and Space Administration*
NEANIAS	*Novel EOSC Services for Emerging Atmosphere, Underwater & Space Challenges*
PDS	*Planetary Data System*
POW	*Processing On the Web (USGS cloud service for ISIS)*
USGS	*United States Geological Survey*
VA	*Virtual Access*

1. Introduction

Basemaps (e.g. Greeley and Batson, 1990; Hare et al., 2018) are the essential dataset for performing geologic mapping (see Nass et al., 2020). While basemaps on Earth consist largely of topographic maps, on which field data are being collected and interpolated/interpreted, for planetary geologic mapping basemaps mostly consist of remote sensing images, typically in mosaicked form. Basemaps can also be defined as *derived data products* (Skinner et al., 2019), such as controlled mosaics, digital terrain models, compositionally informative imagery, upon which units or terrains may be identified

• Documentation

GMAP base mapping datasets have a variety of sources, from processed experiment data, to higher-level mosaicked products and custom imagery. In order to support mappers (see also Rossi et al., 2021, D8.2), external resources are also used. The documentation pages on the GMAP wiki[1] aim at directing new users to relevant aggregated documentation. Additionally, web services have been set up on GMAP infrastructure in order to support users who have limited access to tools and computing resources. Overall, although the default process for mappers is to use their own systems, guidance is provided and also web services are provided based on resource availability, e.g. maximum number of concurrent users from VA community mapping projects vs. hardware limitations (computing, storage).

The set of documentation pages and links to resources for base mapping include:

- General base mapping resources and guides
- Base mapping resources with ADAM (See section **ADAM**)
- USGS / NASA resources

USGS and NASA tools are independently developed and maintained, including user support (see wiki documentation pages and links therein). GMAP provides to the community access to documentation (See Rossi et al., 2021, D8.2), tools and direct interaction with Europlanet GMAP partners. The documentation described here is intended to be available to the GMAP external community and maintained throughout the infrastructure, also based on the feedback from VA community mapping projects.

• Base mapping services

GMAP base mapping services support users who do not run locally basemap producing pipelines, with a set of options:

- Basic usage (on Mars) via mosaicking services via the ADAM Space Explore platform (courtesy NEANIAS[2])
- Jupyter Hub[3] access to GMAP instance of USGS ISIS[4]
- Jupyter Hub access to GMAP instance of NASA ASP[5]

[1] https://wiki.europlanet-gmap.eu
[2] https://www.neanias.eu/
[3] https://jupyter.europlanet-gmap.eu/
[4] https://isis.astrogeology.usgs.gov/

- Jupyter Hub access to GMAP instance of Python GIS

GMAP Jupyter Hub[6] services provide a web-accessible notebook[7] interface to underlying Open Source software installed on GMAP infrastructure (e.g. ISIS, ASP instances) or external web services (e.g. ADAM).

Users have a variety of other choices for gathering or producing basemaps, as linked from the GMAP wiki, including, but not limited to:

- USGS POW[8] (e.g. Hare et al., 2014)
- JMARS[9]
- Quickmap[10]
- NASA Treks[11]

The GMAP mapping workflow could make use of any of those services, within the geologic mapping process (see also Nass et al., 2020; Rossi et al., 2021).

2. ADAM

GMAP makes use of services developed within external projects, such as NEANIAS providing access to data and mosaicking capabilities (Figure 1). The ADAM Space Explore platform provides in particular access to Mars imagery, MEX HRSC and MRO CTX for basic basemap and mosaicking services. The access is provided through a web interface and, primarily, via ADAM API access through Jupyter/Python.

5 https://ti.arc.nasa.gov/tech/asr/groups/intelligent-robotics/ngt/stereo/
6 see also https://jupyter.org/hub
7 https://jupyter.org
8 https://astrocloud.wr.usgs.gov
9 https://jmars.mars.asu.edu
10 http://www.actgate.com/quickmap.html
11 https://trek.nasa.gov

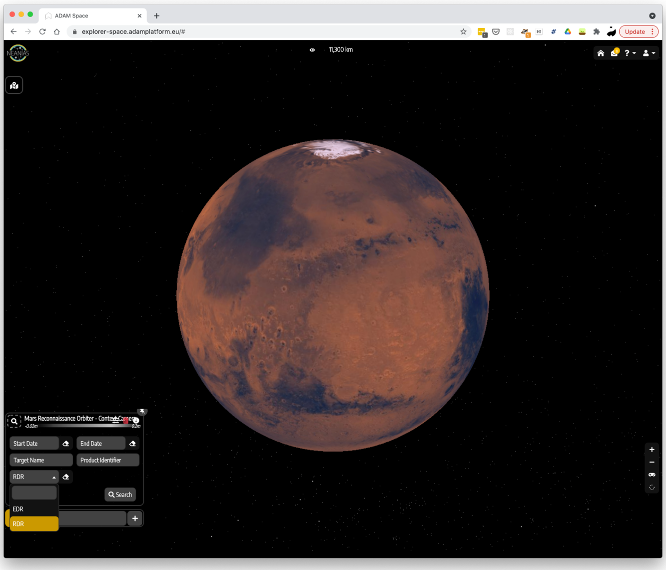

Figure 1: The service for interactive mosaicking and basemap making on Mars is provided by ADAM space explore[12], from the NEANIAS project.

Through ADAM interactive graphical interface, users can explore the large volume of imagery datasets, select images based on location as well as product acquisition time. The interface provides previews to help users to identify the best images for their tasks. Once the datasets are selected, identified, and explored the users can connect to the provided Jupyter Hub instance to further process and customize the images for custom mapping purposes.

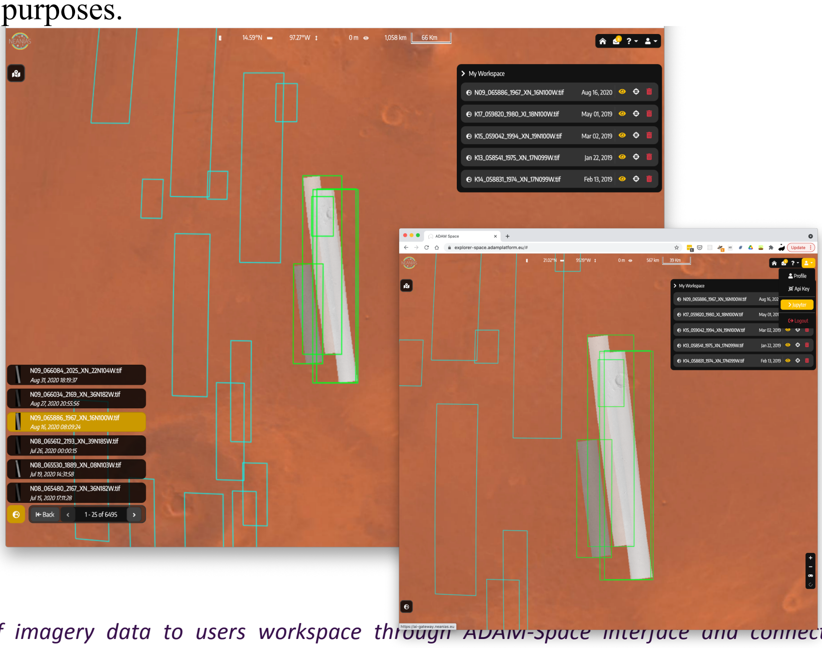

Figure 2: Selection of imagery data to users workspace through ADAM-Space interface and connection to exemplary notebook for custom data visualization and processing.

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12 https://explorer-space.adamplatform.eu

Interactive mosaic services are not publicly available on the ADAM platform yet, but they are scheduled for public release later in 2021 as part of the NEANIAS external project activities. In the meantime, in GMAP, extensive documentation is provided through exemplary Jupyter notebooks[13]. Tutorials are planned with the GMAP VA mapping community.
A complete workflow from data selection (Figure 2) data download through ADAM API, ISIS, GDAL and Python libraries are all available on the GMAP BasemappingUtils GitHub repository[14].

3. ISIS (USGS)

USGS ISIS is the main Open Source tool for processing imager and radiometers data acquired during Solar System scientific missions (e.g. Gaddis et al, 1997; Anderson et al., 2004; Sides et al., 2017; Sucharski et al., 2020). ISIS access, in addition to its individual use, is provided to the GMAP community via GMAP Jupyter Hub, using also community-developed tools (e.g. Beyer, 2020).

4. ASP (NASA)

As described in D9.1 (Nass et al., 2020), GMAP basemap data can make use of custom digital elevation models obtained by stereo imagery. The Open Source tool of choice is NASA ASP (e.g. Broxton and Edwards., 2008; Moratto et al., 2010; Shean et al., 2016; Beyer et al., 2018). ASP access is provided from the GMAP web services through Jupyter Hub, and tools, workflows and procedures developed by the community are going to be used or made available (e.g. Annex and Lewis, 2021; Mayer and Kite, 2016).

- **Tools**

Tools for individual use of mappers or to be used within web services such as exemplary Juptyer notebooks are provided. Base mapping utilities and exemplary scripts and notebooks are included in the BasemappingUtils GitHub repository[15] of GMAP. Additional repositories supporting GMAP JRA tools and services are present in the GMAP GitHub organisation[16].

- **Basic mapping community support**

While the geologic mapping process is the core of GMAP (see Rossi et al. 2021, D8.2), base mapping and related processing pipelines include a vast number of external tools and resources, typically well-documented.

While the documentation of GMAP points to such resources, users within ongoing GMAP mapping projects can seek advice and support by the GMAP partners via dedicated channels, i.e. the repository that each mapping project / mapper is going to

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[13] e.g. https://github.com/europlanet-gmap/BasemappingUtils/blob/master/notebooks/ADAMAPI_examples/adam_mosaic.ipynb
[14] https://github.com/europlanet-gmap/BasemappingUtils
[15] https://github.com/europlanet-gmap/BasemappingUtils
[16] https://github.com/europlanet-gmap

have on GMAP to share and discuss materials, or the GMAP Discord community (see D8.2 Rossi et al., 2021).

Moreover, technical and scientific interaction with the VA community (see D8.2, Rossi et al., 2021) occurs via monthly GMAP open teleconferences for mappers and interested parties[17]. Those individuals can be former or future participants to the GMAP Winter School and workshop, as well as other potentially interested parties.

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