1. Publishable summary of PRoVisG Reporting Period 3 Report

The EC FP7-SPACE Project PRoVisG brings together major EU and US research institutions and stakeholders involved in space robotic vision and navigation to develop a unified approach to robotic vision ground processing.

PRoVisG stands for "Planetary Robotics Vision Ground Processing". It is a Collaborative Project in the frame of FP7-SPACE -2007-1. PRoVisG started in October 2008 with a duration of 45 Months until June 2012.

Partners are located in Europe and the USA www.PRoVisG.eu	▪ Joanneum Research Forschungsgesellschaft mbH (JR) Institute of Information and Communication Technologies, Austria ▪ Aberystwyth University (AU), United Kingdom ▪ Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Germany ▪ Ceské vysoké ucení technické v Praze (CTU), Czech Republic ▪ SciSys UK Ltd (SciSys), United Kingdom ▪ Astrium Ltd (ASU), United Kingdom ▪ Technische Universität Berlin (TUB), Germany ▪ University College London (UCL), United Kingdom ▪ The Ohio State University (OSU), United States ▪ University of Surrey (UNIS), United Kingdom ▪ Centre Suisse d'Electronique et de Microtechnique SA - Recherche et Developpement (CSEM), Switzerland ▪ Centre national d'études spatiales (CNES), France ▪ University of Nottingham (UNOTT), United Kingdom ▪ Marum – Univerity of Bremen (UNIHB), Germany

What does PRoVisG want to achieve ?

PRoVisG will build a unified European framework for Robotic Vision Ground Processing. State-of-art computer vision technology will be collected inside and outside Europe to better exploit the image data gathered during future robotic space missions to the Moon and the Planets. This will lead to a significant enhancement of the scientific, technologic and educational outcome of such missions.

Why is PRoVisG important for Europe?

At present, mainly the US have realized planetary space missions with essential robotics background. Europe needs to catch up with leading-edge technology and science. By joining institutions, companies and universities from different established groups in Europe and two relevant players from US, PRoVisG will demonstrate the European ability to realize high-level processing of robotic vision image products from the surface of planetary bodies. In such way Europe gains independence and reputation as competitive partner for international research and exploration missions to the Planets.

How does PRoVisG benefit European citizens?

PRoVisG will address the public by means of a final robotic field test in representative terrain. The European tax payers will be able to monitor the imaging and vision processing in a Mars

- similar environment, thus getting an insight into the complexity and methods of processing, the potential and decision making of scientific exploitation of such data and not least the elegancy and beauty of the resulting image products and their visualization. The educational aspect is addressed by a summer school, presenting robotic vision to the students who are future providers of European science and technology, inside and outside the space domain.
For a probe on another planet, **time is of the essence** since its operational life is often short. The harsh environment, extreme temperatures and pressures, dust and radiation threaten to damage the hardware and compromise the mission at any moment. Given the difficulty and cost of getting to other planets, obtaining **a high return on investment is crucial**. Accelerating the processing and improving the representation of visual data from such missions, the project PRoVisG aims at giving mission operators and scientists a better three-dimensional (3D) understanding of these new worlds, and showing all of us what it looks like to be there.

In order to maximize the use of a robotic probe during its limited lifetime, scientists immediately have to be provided the best achievable visual quality of 3D data products, and mission controllers need to minimize the time spent for planning the next activities. PRoVisG will facilitate this, developing technology for the **rapid processing and effective representation of visual data** by improving Planetary Robotic Vision Ground Processing facilities. Its ambition is to collect a tool set and integrate a versatile and flexible processing chain which can be easily adapted to the various tasks. Thereby, mission controllers and scientists on the ground profit from **improved situational awareness**, enabling them to identify targets of interest and send the next commands with minimum delay.

PRoVisG brings together **major EU and US research institutions and stakeholders** involved in space robotic vision and navigation to develop a unified approach for robotic vision ground processing. One main result will be a **web-based Geographic Information System (GIS)**, facilitating the comprehensive processing of visual data and the visualization of the context, history, vision data and products of robotic planetary missions. Prototypes of rovers and airborne probes will be used in terrestrial field test campaigns to demonstrate visual processing ability going beyond that currently available with the Mars Exploration Rovers and currently envisaged ESA missions.

The project builds upon knowledge both from **users of vision data** from planetary surfaces and from **computer vision and robotics experts**. Its main logistics is based upon a straightforward research and development chain reflected by its main **work packages**:

- Requirements to planetary robotics vision ground processing are identified by scientists and mission operators (**WP2: Requirements**)
- A consolidation and collection takes place, covering existing tools, data structures, commitments, and interfaces used within the planetary society on the one hand, and by computer vision and robotics on the other hand (**WP3: Interfaces**)
- The requirements and interfaces lead to an integrated robotic vision processing chain, namely “PRoViP” – Planetary Robotic Vision Processing. This is the core part, integrated from contributions by the computer vision and robotics experts (**WP4: PRoViP**).
- For easy access of the PRoViP processing tools, an overlay is provided by means of a web-based GIS (**WP5: PRoGIS**).
- In order to find out the impact and judge the elaborated knowledge and tools for usability, the traceability of the results back to the requirements is checked (**WP6: Evaluation**)
- Major outcome of such collaborative projects consists of publications, education, presentations and student grants. A dedicated work package emphasizes these actions and makes sure that the knowledge collected within PRoVisG is properly re-used and exploited in the society (**WP7: Dissemination**).

PRoVisG has been operating more than two years. In the period from Project start to the end of the second reporting period (26 Months duration) a set of **achievements and results** were successfully finalized:

- Following the Project logistics, collections of information on vision sensors' data and their processing were collected, and **specifications** on implementation, functional interfaces and use cases were formulated and integrated into relating **reports**.
- The collection of **necessary information for interfacing** existing planetary data bases, exploiting various vision sensor geometries, identifying relevant 3D data structures and finding the necessity for newly developing missing items has been finalized, resulting in a set of **reports**.
- The **Vision processing chain PRoViP has been compiled**. High-level vision tools from the relevant PRoVisG partners were collected and are currently integrated into PRoViP. **Remote processing abilities** were realized to ensure the integration of components protected by intellectual property right.
- PRoVisG contains the development of a specialised **sensor suite for panoramic stereo imaging**, as well as the adaptation of an active range sensing sensor (3D-Time-of-Flight: **3D-TOF**). They were **delivered to the PRoVisG Consortium and successfully tested** during a field test (see figure to the right: Bridget equipped with three different sensor systems).
- Relevant **vision processing steps were already adapted**, such as multi-view reconstruction, shape from shading, as well as rock modelling and reconstruction.
- The roadmap & reference data for the forthcoming **Announcement of Opportunity** has been settled.
- The PRoVisG Consortium and most of its members have already **published** more several tens of abstracts and papers at relevant conferences such as the European Planetary Science (EPSC) Congress, the European Geoscience Union (EGU) Conference, and computer vision as well as 3D vision conferences. In addition, **press releases, YouTube Videos**, and **Fair demos** could be accomplished. Various public presentations and Press conference presentations as well as more than 20 **public scientific presentations** in the frame of PRoVisG Plenary meetings were held. Another **workshop and robotic vision field test at AU**, organized by PRoVisG, brought together members from the PRoVisG Consortium, ESA scientists, and scientists of the ExoMars PanCam instrument. See some representative published illustrations below. www.PRoVisG.eu is the official PRoVisG web site, where in July 2010 a Newsletter was released.

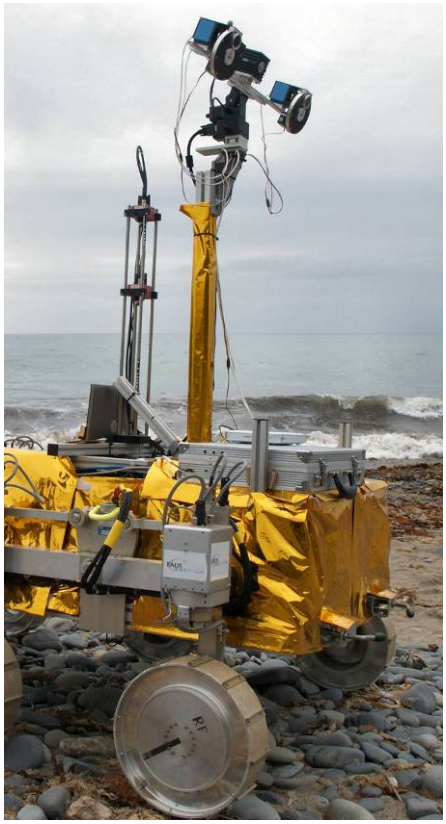

Figure 1 CSEM Catadioptric sensor & 3D-Time-of-Flight camera mounted on ASU Bridget Rover during field test at Clarach Bay, Aberystwyth, July 2010

- Various high-level tests were performed and data products were generated that show the ability of 3D vision to exploit planetary surface imagery. The **field test at AU** in Summer 2010 resulted in a high-resolution 3D reconstruction of parts of the Clarach Bay area, based on panoramic stereo from the AU ExoMars PanCam simulating camera system mounted on Bridget. A rendering is shown in Figure 2. A YouTube video shows a simulated walk through the reconstructed terrain.
- The roadmap & reference data for the forthcoming **Announcement of Opportunity** has been settled.

At present the **PRoViP functional chains are filled by PRoVisG Partners' contributions.** In parallel, after recent clarification of interfaces to PRoViP, the **PRoGIS is under development at our new Partner University of Nottingham.**
An important action in the near future will be the **verification of the PRoViP / PRoGIS collaboration**, and the **compilation of user manuals**. Further to that, PRoVisG will launch its announcement of opportunity, continue its dissemination activities, prepare for the final field test in Tenerife using Bridget, continue its synchronization actions with the JPL Stereo Work Station development, and finalize specifically needed high-level tools for vision processing to be fit into the PRoViP chain.