PRoViScout - Planetary Robotics Vision Scout
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EXECUTIVE SUMMARY

The EC FP7-SPACE Project ProViScout will demonstrate the feasibility of vision-based autonomous sample identification & selection as well as terrain hazard analysis for a long range scouting/exploration mission on a terrestrial planet along with the robotic elements required. It will bring together major groups currently working on planetary robotic vision, leading experts in planetary surface operations, and experienced planetary scientists, consisting of research institutions all over Europe, NASA-JPL in the US, and the industrial stakeholders involved in mission design, vision, navigation and data exploitation for robotic space missions (Table 1), convening to a final end-to-end demonstration. The **main PRoViScout objectives** can be summarized as follows:

- Populate a robotic vision on-board processing chain (PRoViSC) with representative components available at the proposing institutions, with minor adaptation and integration effort.
- Address and merge a representative set of sensors (including a novel zoom 3D-Time-of-flight camera) to fulfil important scientific objectives and prove the general applicability to the approach in different mission scenarios.
- Include the search for scientifically interesting targets as an essential component for mission success into the navigation chain by Autonomous Tasking (Goal based planning and re-planning).
- Compile a PRoViScout Demonstrator on a mobile platform that combines sensors, processing and locomotion on-board ready for an integrated outdoor demonstration.
- Integrate a monitoring function (PRoViM) to understand the behaviour of the system.
- Demonstrate the feasibility of long-term vision-based scouting making use of a representative outdoor test bed and the PRoViScout Demonstrator platform.

The search for traces of life – past or present – is at the centre of Europe's ongoing Planetary exploration programme. In the near future, robots with life science sensors will explore the surface of Mars and drill below its surface to look for signs of life, supported by recent data from Europe's Mars Express mission.

Robotic planetary space missions are unmanned missions performing in situ exploration of the surface and (if applicable) atmosphere for any planetary objects outside the Earth. Most such missions involve a means of mobility provided by either a surface vehicle ('rover') or by aerial vehicles (balloons, aerobots etc.). Mobile systems are among the most critical of all space missions in requiring a rapid and robust on-site processing and preparation of imaging data to allow efficient operations for a **maximum use of their limited lifetime**. In future the number and variety of such platforms will require more autonomy than is feasible today, particularly in the **autonomous on-site selection of and access to scientific and mission-strategic targets**.

	▪ Joanneum Research Institute for Information and Communication Technologies (JR), Austria ▪ SciSys UK Ltd. (SSL), United Kingdom ▪ German Aerospace Center (DLR), Germany ▪ Aberystwyth University (AU), United Kingdom ▪ Czech Technical Unviversity (CTU), Czech Republic ▪ GMV (GMV), Spain ▪ University of Leicester (ULEIC), United Kingdom

www.PRoViScout.eu © PRoViScout	▪ Swiss Center for Electronics and Microtechnology (CSEM), Switzerland ▪ TraSys (TRS), Belgium ▪ University College London (UCL), United Kingdom ▪ University of Strathclyde (UoS), United Kingdom

Table 1: PRoViScout Beneficiaries

ProViScout will provide the building blocks on board of such future autonomous exploration systems in terms of robotics vision and decisions based thereupon.

The project will demonstrate a novel, autonomous exploration system: **To make robotic rovers more independent and efficient, instead of waiting for instructions from Earth, PRoViScout implements an on-board vision-based identification and planning system. It will be able to identify objects of interest and interpret their relevance to various mission goals.** Rovers will "see" important scientific or navigation features in the terrain and task themselves to gather more detailed data about previously unseen targets, whilst carefully prioritising and allocating their limited resources and keeping track of possible hazards.
PRoViScout will help develop a unified and generic approach for robotic vision on-board processing, namely the combination of navigation and scientific target selection by addressing all relevant existing approaches to this topic and integrating them into a **framework ready for and exposed to field demonstration**. PRoViScout offers real research challenges (rather than mainly integration and trials), and inherently it has potential Earth based applications that do not and will not emerge over the next few years without such efforts. Mutual benefits are guaranteed by the proposers' involvement in major relating European initiatives such as ExoMars PanCam, Eurobot, EC-FP7 PRoVisG and the UK national CREST Project Autonomous Robot Scientist.

By the time of writing this report, PRoViScout has been running for 12 Months. Beside the written deliverables (design documents and, reports, partly available at the PRoViScout Web Site www.proviscout.eu) the main results achieved so far are as follows:

- All requirements from science and operations have been collected and reported. This includes the definition of the target scenario planned for the field test during the final Project phase.
- System design has been finished. All interfaces between the components (rover, vision system, Hardware trade-offs, navigation system, decision module, execution control, and monitoring system) have been defined, and the main functions as well as distributed and shared data have been identified & reported in a design document.
- A new 3D-Time-of-Flight (3D – TOF) camera has been designed by CSEM (
- Figure **1**, left), which is able to zoom and integrates RGB high-resolution images.
- Preliminary tests to extract scientifically interesting image parts from training & classification indicate that an automatic system is able to detect meaningful targets.
- Candidate field test sites in Morocco, Tenerife, Wales and Iceland were investigated, assessed and discussed. The major result is a strong preference of Tenerife, due to accessibility, logistics, locomotion, climate and scientific aspects.

In early 2010 an assessment of scientifically interesting areas at Clarach Bay (Aberystwyth, UK) took place (
Figure **1**, right). The resulting report is publicly available via the PRoViScout download area. In January 2011 an aerobot test was conducted, to verify the concept of a tethered aerobot for Rover mapping & science target selection support. The definition of relevant training samples to test pattern recognition methodologies for automatic identification of scientifically interesting targets is ongoing, see
Figure **2** for an example. Key parameters for the operational scenario of the final field test have been assessed, and some recently implemented components have already been verified in simulated environment (Figure 3). Independently, components such as 3D reconstruction of the rover's environment or specific target recognition have started to develop.

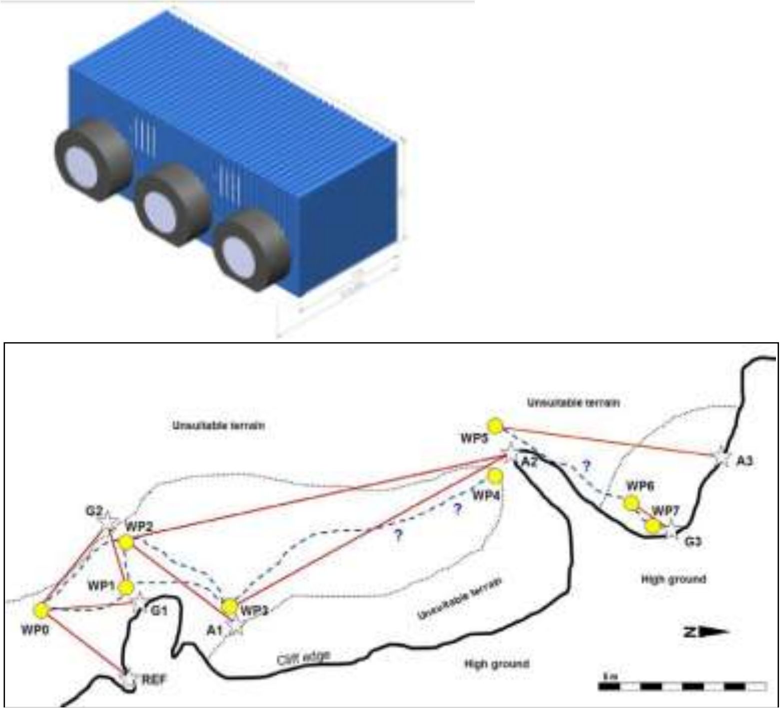

Figure 1: Early achievements of PRoViScout requirements definition & design work. Left: Dimensional layout of the zoom RGB 3D-TOF camera. © CSEM. Right: Example for waypoints and a globally planned rover trajectory in the area of Clarach Bay (Aberystwyth, UK). © Univ. Leicester.

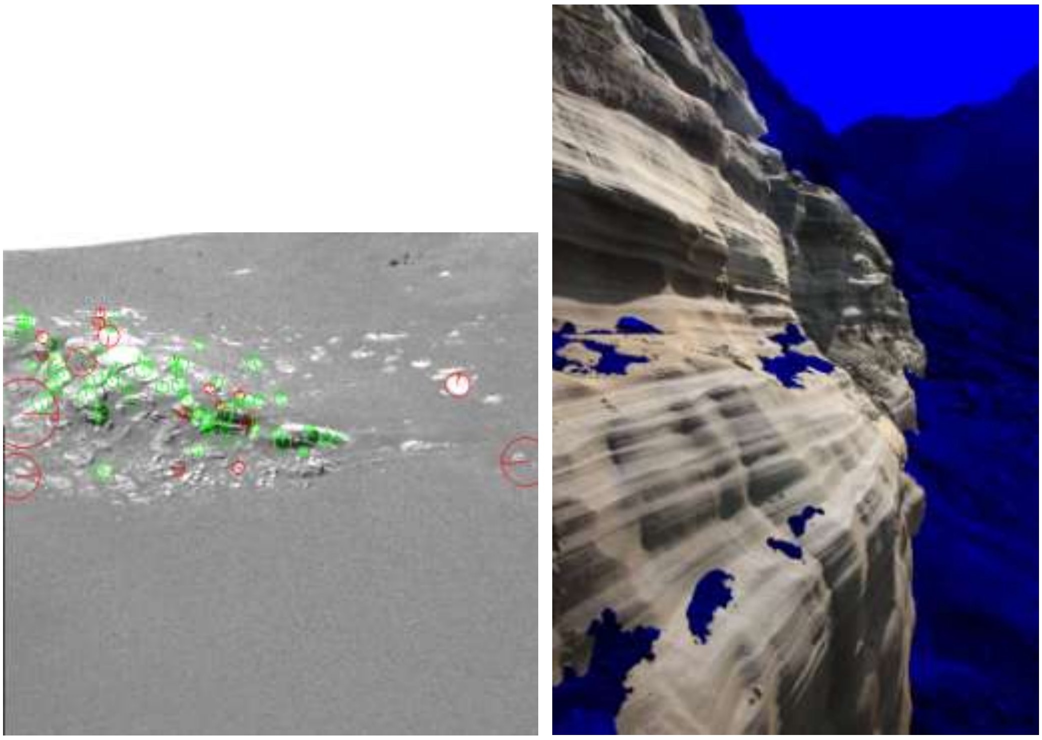

Figure 2: Left: Classification result for an image captured on Mars: A binary classifier was trained on extracted SIFT keys from images with geological structures. These structures where manually labeled by experts into an interesting and one background class. Here, green keys indicate some interesting regions while red keys denote background. The scale of the region is indicated by the diameter of the circle, while the line starting in the centre of the key point

location signals the orientation based on image gradients around the key point. © NASA-JPL/JR. Right: Training image (one out of several tens), with interesting areas kept coloured; other areas are marked dark blue. © DLR.

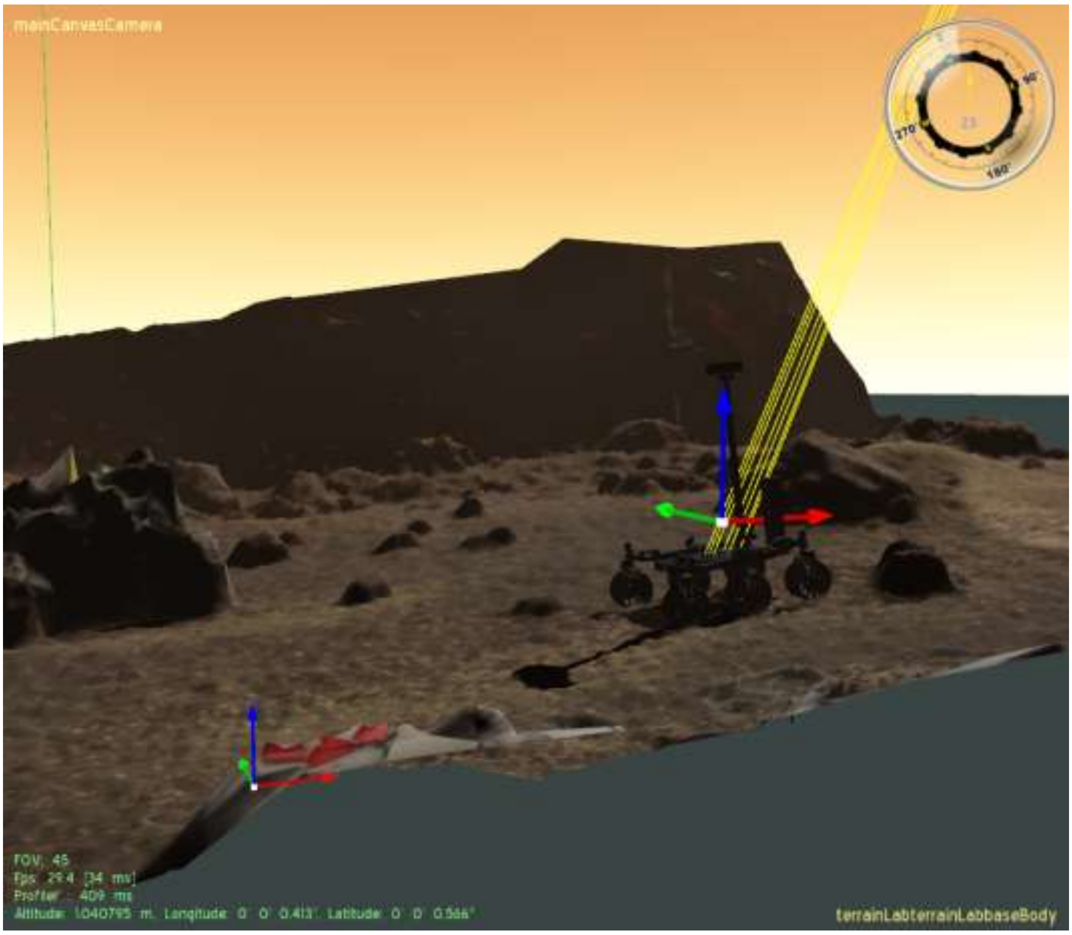

Figure 3: Visualisation of the robotic system inside its environment as planned during the field test, considering the terrain, the sun position, real-time shadows, the display of system key parameters and a rover simulation. © TraSys.

ProViScout supports the development of **more autonomous space vehicles**. Vision based sample identification enables such rovers to act more independently, which is needed for more efficient scientific mission outcomes. The PRoViScout project objective is to **increase the amount of quality science data** that remote planetary rovers can deliver on behalf of Earth based science teams. This will be obtained by prototyping intelligent technologies which increase their autonomy and therefore exploration efficiency.

The major project goal is a **field test** that demonstrates the ability to autonomously traverse terrain whilst "keeping an eye open" on potential scientifically interesting targets passed on its way – and change the global plan in favour of additional observations. The first year of the Project has paved the way to such a system by identifying the key parameters of a scenario, specifying the system components and their interfaces, and already detailed designing and implementing major components such as a novel 3D-Time-of-Flight sensor, and aerobot mapping strategies.

PRoViScout will effectively **increase the amount of data returned per Euro spent** on European space missions thereby ensuring good value for European Taxpayers

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