Site Selection and Field Logistics in Preparations for the 2012 ProViScout Field Trial

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ABSTRACT

PRoViScout was an EU FP7-SPACE project intended to demonstrate advanced vision-based technologies for long-range robotic scouting and exploration missions on terrestrial planets. The project culminated in a field trial and project demonstration in the Teide National Park, Tenerife. This paper summarises the work done in preparation for that trial, both in terms of site selection and logistical planning and preparation. We also discuss some of the trade-offs that were necessary to achieve a successful field trial.

Figure 1: AU rover platform Idris at PRoViScout field trial in Tenerife

1 INTRODUCTION

The PRoViScout project was intended to "demonstrate the feasibility of vision-based autonomous science target identification and selection, coupled with vision-based navigation, for a long-range robotic scouting and exploration mission on a terrestrial planet" [1]. The project ran from April 2010 until September 2012. During that time, several field sites were used to test different aspects of the system and validate its components, culminating in a major field test campaign and project demonstration in the Teide National Park, Tenerife. A detailed description of the activities and results of the field trial can be found in [2].

Prior to the field test, a number of potential sites were assessed and scored according to project criteria. For example, some were of very high scientific interest but difficult or impossible to reach with a rover platform, while others were ideal for rover activities but very limited from a scientific perspective. We found that the choice of scientific goals of the project, the instrument payload and the available rover platforms all acted to constrain each other and influence the choice of trial site. The final site chosen was a compromise between science requirements and technical feasibility, and some of the trade-offs made are examined in this paper.

The field trial itself required a large amount of logistical planning covering transport, permissions, welfare and publicity. Negotiating permits and broad organisation was largely the responsibility of Joanneum Research (JR), while Aberystwyth University (AU) took charge of providing and transporting the necessary field equipment and infrastructure. We discuss decisions made during planning, and lessons learned from the field trial experience itself.

2 INSTRUMENTS AND HARDWARE PLATFORM

2.1 Instrument payload

The specification of the rover platform to be used for the PRoViScout field trial was largely determined by the instruments that were to be carried by it. Initially, the instrument payload was to be as follows:

- Wide-Angle multispectral Camera (WAC)
- Experimental infra-red 3D Time-Of-Flight (TOF) camera with integrated zoom and RGB capability
- Panoramic camera (360° image capture)

It was planned that these instruments could be accommodated on a relatively small rover platform, such as the AU experimental mini Mars rover [3] or a Pioneer 3AT, several of which were available, and some mobility studies were carried out on these. During the project, however, additional science goals and uncertainties about the development of the TOF camera made it desirable to add the following to the payload:

- A second WAC, for independent stereo measurements and infra-red imaging
- A High Resolution Camera (HRC) for independent imaging of science targets

The two WACs and the HRC form part of AUPE-2 [4], an emulator developed at AU for the ExoMars 2018 PanCam instrument [5][6]. Two additional hyperspectral cameras were provided by MSSL – one covering the visible waveband and the other the near infra-red.

Altogether, this represented quite a considerable payload. In addition, the TOF camera turned out to be much larger and heavier (10 kg) than had been anticipated. The net effect was that a larger rover platform was required, with a considerably greater payload capacity and a heavy-duty pan-tilt unit (PTU) capable of accommodating the TOF camera.

2.2 The rover platform “Idris”

Given the constraints imposed by the instrument payload selection, it was decided to use the AU rover “Idris” as the primary rover platform for PRoViScout. Idris (fig. 1) is a 4 wheel drive, 4 wheel steering, electric vehicle with a maximum speed of around 10km/h. It is comparable in size to a small car. Idris was initially based on a robuCAR TT design but has been extensively modified by AU. On-board systems control movement and steering in both autonomous and teleoperated modes, and also implement safety features such as obstacle detection and emergency stop.

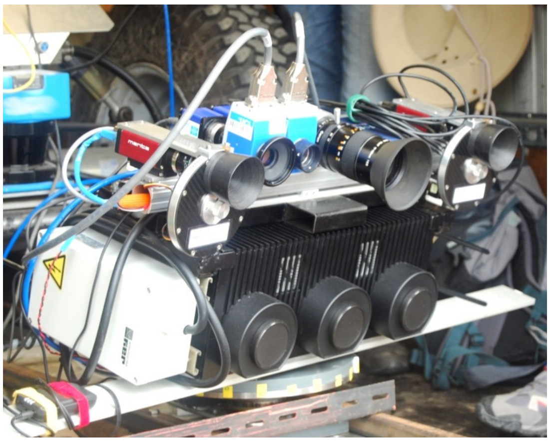

Figure 2: Heavy-duty PTU with full complement of instruments

The rover weighs about 350kg, has a substantial payload capacity of up to 150kg and can provide power and network services for a number of independent payload systems. In order to accommodate the large and heavy instrument payload of PRoViScout, a heavy-duty PTU was designed and built in-house (fig. 2).

2.3 Aerobot

The AU aerobot (fig. 3) is an autonomous aerial camera system, designed to capture area context images for mission planning and DEM generation [7]. A high resolution (5 Mpix) downward-pointing camera is mounted on a payload platform along with its control computer and supporting electronics. The payload platform in turn is suspended from a 2m diameter helium envelope by a stabilising system known as a “Picavet” suspension. The aerobot is a captive system, physically attached to the main rover chassis by a light but strong tether. An electric winch mounted on the main rover chassis aids aerobot launch and retrieval.

Figure 3: AU aerobot tethered to the rover Idris

Once the aerobot is deployed, the rover is driven along a pre-selected route while the aerobot takes multiple overlapping images from a height of up to 100m. The aerobot survey is a preliminary activity, to allow area DEM generation prior to the main autonomous rover traverse. During the aerobot survey phase, the rover is driven along a pre-set safe path through the terrain, and acts as a mobile anchor point for the aerobot. When the aerial survey is complete, the aerobot is retrieved and detached from the rover, in preparation for rover autonomous operation.

2.4 Effect of hardware choice on site selection

The choice of hardware platform and instruments had several implications for the selection of a suitable field trial site for the project:

- The large size and weight of the Idris rover and its required support equipment meant that transporting by air would be prohibitively costly. The possibility of sea transport by container was investigated, but the travel time would be many weeks, during which the rover would be unavailable for any other research work. Therefore, the field trial site had to be somewhere accessible by road and ferry.
- The TOF camera, when operating, is not eye-safe. It had to be possible to prevent casual access to the rover operations area while the TOF was active.
- Isolation was also desirable because of rover safety considerations. Idris has a number of safety mechanisms built in, but preventing the possibility of members of the public coming into direct contact with the rover was considered prudent.
- Idris and the supporting infrastructure are powered by rechargeable batteries. This limits the number of hours of operation possible per day, and also requires that an adequate source of power for recharging be available.

- The aerobot can only be flown in calm to very light wind conditions. Suitable conditions may occur, for example, early in the morning at some sites. A permanently windy or unsettled site would not be suitable.
- The aerobot also requires a supply of helium for envelope inflation. It must be possible to obtain helium at or near the field trial site, or to transport it there.
- Since aerial mapping and visual navigation are both important aspects of the project, a visually diverse terrain is desirable as opposed to “wide open spaces” with few obstacles encountered.

3 PRELIMINARY SITE ASSESSMENTS

Early in the project (November 2010), several alternative sites were assessed for suitability as field trial locations in a trade-off study. Sites were assessed from the points of view of both geology (for suitable science targets) and robotics (rover access & visual navigation). For some sites, existing image and digital elevation map (DEM) data were available from high-resolution stereo camera overflights.

Tenerife – Teide National Park

- Geological themes: Volcaniclastics, lavas, pyroclastics, hydrothermal
- Pros: Accessibility, scale, weather, multiple sites, topography, local support, logistics
- Cons: Limited Martian analogues, no DEM data

Iceland - north of Laugarvatn

- Geological themes: Volcanics, hyaloclastites
- Pros: Feature-rich exposures, topography, scale, Martian analogues, DEM data available
- Cons: Accessibility, logistics, weather

Morocco - Anti-Atlas, West Sahara

- Geological themes: Sedimentary, carbonate mounds, travetines, stromatolites
- Pros: Martian analogues, scale, weather, multiple sites, topography, local support
- Cons: Accessibility, widely spaced sites, logistics, no DEM data, possible security issues

From a planetary analogue perspective, either Iceland or Morocco would have been preferred over Tenerife. However, Tenerife has excellent attributes for rover-based operations even though the geology is visually more complex. In addition, the logistical problems of rover and instrument transport & support favoured Tenerife as the primary choice.

4 DETAILED SITE SURVEY AND SELECTION

Having selected Tenerife as the most practical Martian analogue site for field testing, it was important to ensure that the most suitable locations were visited and assessed for scientific novelty.

A preliminary field visit to the area was carried out in June 2011 by several members of the project. The team included members with expertise in geology, robotics and imaging. The aim of the field visit was primarily to assess the suitability of selected locations around the Teide National Park for robotic exploration and geology. Sites were assessed for:

- Availability and accessibility of visually rich and diverse science targets.
- Characterisation of suitable sites/targets for a Field Target Catalogue.
- Local topography and nature of the terrain and materials.
- Potential for in-field testing with and without robotic hardware.
- Physical accessibility of the site, and any relevant restrictions on access to or activities on the site.

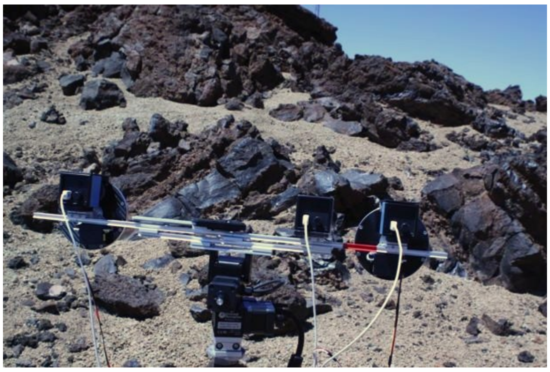

Figure 4: Possible targets were imaged with representative hardware

At each site, a network of proposed waypoints for the field trial mission was established, based on the available science targets and traversability of the terrain. Representative imaging products of potential science targets were captured for later study using the AUPE camera system (fig. 4)[4]. Two of the most promising sites were studied in detail.

4.1 Montaña Rajada

(Lat: 28.267402°, Long: -16.596726°) This is a very mixed area, with some relatively flat or gently sloping regions, some boulder fields, steep slopes, canyons, rocky outcrops and cliffs (fig. 5). There is the potential for varied mission scenarios. A number of interesting science targets were identified and catalogued by the survey team. The topography naturally divides the area into a series of linked sites with potential access routes between sub-sites. This is an ideal scenario for exploiting aerial imagery as part of the mission. Some of the access paths were deemed to be too hazardous for rover navigation.

Figure 5: Rock formations at Montaña Rajada

Montaña Rajada lies within a highly protected area of the national park. The site's protected status and remoteness from the road means that there are no people, vehicles or fixed visual intrusions to cause problems. However, access to the site requires special authorisation, and permitted activities are strictly controlled to avoid damage to the terrain or occasional rare plants. The access path is challenging for vehicles in places, and there was also doubt about the feasibility of transporting all the equipment and project members to and from the site and conducting tests each day while complying with all necessary restrictions.

4.2 Minas de San José

(Lat: 28.264416°, Long: -16.583816°) This is a more open area than the Montaña Rajada site. It is popular with visiting tourists and has easier road access and parking (fig.6). The terrain consists largely of loose pumice slopes and small valleys, with large outcrops of volcanic rock. Though still subject to stringent controls, this area of the national park has fewer access restrictions than Montaña Rajada.

Figure 6: Minas de San José – path to remote operations site

Within the general area of Minas de San José, it was possible to find a relatively isolated small valley that offered good possibilities for the field trial mission. The distance from the nearest road was sufficient to reduce the number of casual visitors, while the enclosed nature of the valley made it easier to restrict access during sensitive test runs. The terrain between the road and the valley was easy for the rover (and humans) to negotiate.

4.3 Implications of site selected

The site at Minas de San José was finally chosen over that at Montaña Rajada, largely for practical reasons. The main advantages of this particular site were:

- Ease of access.
- Fewer restrictions from park authorities.
- Size – a clear 500m run for the rover to travel in “safe” conditions.

There were some disadvantages to choosing this site as well, in particular the relative lack of “good” science targets – for example, rocks showing a layered structure. There were numerous accessible examples of such targets at Montaña Rajada, and almost none at Minas de San José. To circumvent this problem, it was decided to create visually-realistic textured simulations based on real layered rock formations and to place them in the test environment in such a way as to blend in with the surrounding rocks. This proved to be a successful strategy, and allowed all parts of the PRoViScout systems to be exercised.

The choice of a site within the Teide National Park in Tenerife also had implications for the aerobot. The aerobot was originally designed for flight near sea level, with a 1.83m (6 foot) diameter envelope. This gave adequate lift to support attitude and location sensors and a small video camera in addition to the main camera and control computer. However, at the altitude of the proposed field trial site (approx. 2300m) it was realised that the lower density air would not provide enough lift. Calculations showed that it would be necessary to:

- Increase the size of the envelope to at least 2.13m (7 feet) in diameter
- Strip down the aerobot to reduce mass by only including vital functions (GPS, IMU and witness camera removed)
- Fly the aerobot early in the morning when the air was likely to be still and cool (therefore denser)

Even after adopting all of these measures, the predicted residual lift margin was only about 500g, so special care would need to be taken during launch and retrieval of the aerobot.

5 SUPPORT INFRASTRUCTURE

The aim of the project was to develop systems for a scouting type rover, so the emphasis was on remote operation with as much autonomy as possible. In addition, safety considerations required the rover to be

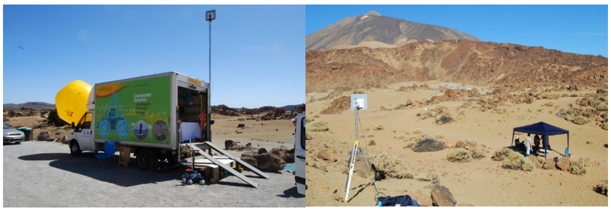

Figure 7: Mission control van & remote operations site

operated in a location that could be protected from casual visitors. Activity was divided between two main sites: the “mission control” van and the remote operations site (fig. 7). The two sites were connected by a high-speed directional data link.

5.1 Computing infrastructure

The rover Idris has its own control computer and sensors, with associated micro-controllers and devices. These are dedicated to the safe operation of the platform itself. To support the PRoViScout on-board software chain (PRoVISC) an entirely separate server-class PC was installed as payload on the rover. This GNU/Linux-based system provided adequate compute power and storage for the PRoViScout field trial activities.

Software components not intended to run on board the rover itself, such as the OVERSEER module, were run on team members' own laptops. Data communication services for the distributed software (using CORBA) and for remote management of the rover and instruments were provided by the network infrastructure described in 5.2. In addition to data network facilities, a networked file server was made available for bulk storage of data.

5.2 Communications infrastructure

To accommodate the distributed nature of both the software systems and the physical locations involved in the field trial, an elaborate network infrastructure was set up (fig. 8). At each of the two physical sites - mission control van and remote operations site - local networks with both wired and wireless connections were provided for team members to connect to. The networks at the two sites were joined by a high-bandwidth long-distance wireless link with a range of up to 20km. A dedicated wireless link at the remote operations site connected the base station to the rover payload network on board Idris. Payload devices such as AUPE and the payload server PC were connected to this on-board network. One further dedicated wireless link was set up to communicate directly with the rover computer for teleoperation and safety control.

With this arrangement all of the facilities and instruments, including the rover itself, were accessible from anywhere on the combined network. Using both 2.6GHz and 5GHz wifi devices in combination allowed better use of available channels and greater throughput to be achieved.

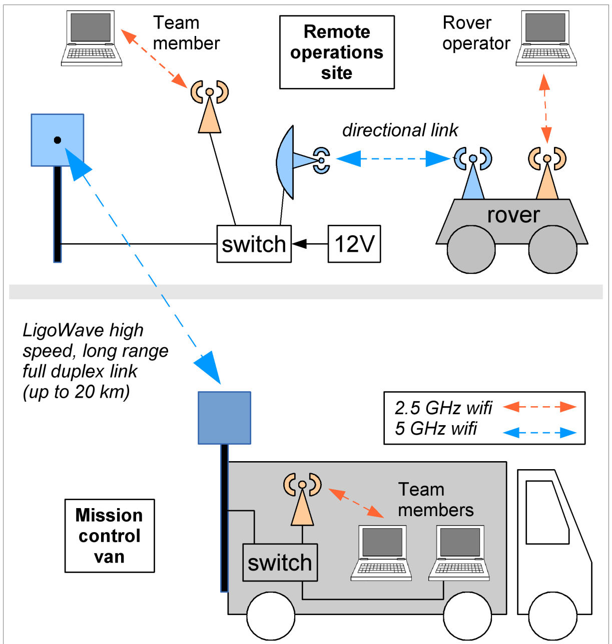

Figure 8: Network infrastructure

On the main field trial days, a satellite broadband link provided by a local company connected the PRoViScout local network to the wider Internet, allowing upload of gathered data to the project FTP site and upload of images and text to the public web site. It also enabled personal communications for team members, such as project dissemination via Facebook.

Monitoring webcams mounted in the field (or on the rover) enabled control centre staff to drive the rover remotely and allowed them to see, hear and be aware of what was happening in, on and around the rover during field trial operations. To aid communication between team members themselves and between the two sites, personal mobile radios were provided. Team members were given basic instruction in using voice radio communication protocols.

5.3 Human welfare factors

Experience gained during the field trials of the earlier PRoVisG project [8] in September 2011 underlined the importance of ensuring the comfort and well-being of all participating team members. The environment in the Teide national park is very harsh, with extreme heat during the day, little or no shade, high levels of UV and low oxygen levels. Before the start of the field trial campaign, all team members were provided with a document that described the various hazards, recommended what they should do (or not do) to mitigate the risks, and suggested what to bring as equipment and supplies.

As well as being uncomfortable and potentially dangerous to work in, operating any kind of display device (such as a laptop) in bright sunlight is extremely difficult. The mission control van was equipped with a long collapsible table and a number of folding chairs, power sockets, network connections and even an electric fan. This provided space for a number of team members to work in relative comfort (fig. 9). At the remote operations site, facilities were of necessity more limited. A gazebo-style tent was used for shade, with a tarpaulin, folding table and chairs. The remote site facilities had to be carried from the road each morning, and then removed at the end of each day's work – the rover itself was able to carry some of this load. Limited power at the remote operations site was provided by a 12V leisure battery and an inverter.

Figure 9: Mission control centre facilities in van

As well as shade, tables and seating, team members were kept supplied with food and drink in the field. This saved time while maintaining energy and hydration levels. A local logistics company was hired for the duration of the trials to provide this and other essential services, such as unscheduled transport of team members to/from their hotel when no project vehicles or drivers were available.

The rover, van and support staff were based at the nearest hotel to the trials site, to minimise the equipment transport distance each day. The hotel also provided a useful hardstanding area for equipment test and repair activity, and power for overnight recharging of batteries. Other team members were based at an alternative hotel which was approx. 40 minutes drive away down the mountain, located in a less harsh environment with access to town amenities.

6 HARDWARE INTEGRATION FIELD TRIAL

A software and hardware integration campaign took place some months before the main field trial. The number of days at the site approximated to the field trial duration that would be experienced in Tenerife. The chosen site was a disused quarry and mine workings at Ysbyty Ystwyth near Aberystwyth, Wales (Lat: 52.321042°, Long: -3.842002°, approx. 40 minutes drive from the University). A good deal of effort went into the selection of this site. We needed a location that was not too far away, but one that forced us to collect all of the equipment together and transport it away from Aberystwyth, thus ensuring that we could not be reliant upon local infrastructure. Most importantly, the site had to be sufficiently remote to allow the 3D-TOF to be powered and tested in an environment that would be safe to all humans in the area. Finally, the site had to sufficiently large and varied (slopes etc.) to exercise the Visual Odometry and Navigation software modules.

This was the first serious outing for the AU rover transportation van as a “mission control” centre. Preliminary check-out work was conducted at the AU Robotics Workshop before packing and travelling to Ysbyty Ystwyth. Despite periods of mixed weather, this integration campaign provided the most realistic tests undertaken before the final field trial in Tenerife.

7 TRANSPORT LOGISTICS

Transporting the rover, van and support equipment from Aberystwyth to Tenerife and back again was a complex logistical operation involving two ferry crossings and driving across five different countries – Wales, England, France, Spain and Tenerife. A crew of two shared the driving on the outward journey, and a different pair made the journey home again at the end of the trial.

7.1 Route and timing

The van was driven from Aberystwyth to Portsmouth, then went by ferry to Le Havre (8 hrs). Then followed two full days of driving through France and Spain, to meet up with a ferry from Huelva to Santa Cruz de Tenerife on the third day. This second ferry crossing took 35 hrs. In total, 5 days were required for the journey.

The route chosen was intended to minimise travel time while not creating unnecessary complications. By staying technically within the EU, many potential border-crossing problems were avoided. An alternative route with a shorter ferry crossing – via Morocco – had been considered, but the extra road travel and paperwork this would have entailed made it an unattractive option.

A GPS tracking device (SPOT tracker) mounted in the van automatically reported the position of the van via satellite every six hours, and a live map was made available to team members. This proved very useful for tracking progress (or the lack of it) without having to contact the van crew directly.

7.2 Customs considerations

Since we would be transporting a large van full of valuable equipment across Europe and back, it was important to have all the necessary customs documentation to hand. In our case, this consisted of a carnet detailing every item of interest (to customs officials) in the van, its value and its country of origin. The carnet is to be produced at any customs inspection point, and essentially guarantees that all of the the equipment belongs to us (duty already paid) and that we will be returning with exactly what we took out with us.

Producing the list for this document was a large effort, and the document itself was a significant expense of the field trial. Possible consequences of not having this documentation, however, would very likely have included the impounding of the rover.

7.3 Problems on the journey

On the journey out, a failure of the van's water pump caused some delay (and anxiety). Using the tools on-board the van, a temporary repair was made, allowing the journey to continue. Later, a replacement part was sourced and fitted. The van crew had to drive through the night to make up for lost time, to be sure of catching the ferry to Tenerife.

Figure 10: A bit of van trouble

8 DIFFICULTIES ENCOUNTERED DURING THE FIELD TRIAL

8.1 Technical problems

- The aerobot was flown successfully early in the morning. However, a second flight attempt during the afternoon failed due to (a) lower air density as the atmosphere heated up, and (b) wind gusts as thermals built up later in the day. The residual lift margin was no longer sufficient for launch, and the flight had to be abandoned.
- There was a higher than anticipated demand on the local wireless networking links caused by streaming video from the remote operations site – something not initially planned for. This was mitigated by setting up a wired section of the network at the remote site.
- Despite taking care with equipment, there were some hardware failures during the trial. A failure of the server PC on the rover was traced to a loose cable which was quickly fixed. Tools and equipment were available in the mission control van to deal with most eventualities.
- More serious was a mechanical failure of the PTU tilt axis, believed to be caused by bumping of the rover over uneven ground while being driven manually back from the remote operations site with the camera systems still mounted. It should be noted here that the TOF camera did not in the end form part of the instrument payload, so a smaller and much more precise PTU was used for the trials, and it was this device that broke. A replacement PTU was not available, and despite intense efforts it was not possible to reliably repair the mechanism on-site. The PTU tilt axis was secured at a fixed angle, which had an effect on target and obstacle visibility for the rest of the trial.
- The electronic engine management system of the van used for transport and mission control did not cope well with the significantly lower air pressure and oxygen levels at the altitude of the test site. This caused a certain amount of engine misfiring and fuel wastage.

8.2 Environment problems

- High temperatures during the day affected both team members and equipment. However, there were no critical equipment failures due to the temperature during the trial. Staff were frequently reminded to drink water and to apply sun block.
- The low oxygen environment caused staff fatigue and tiredness, and impaired efficiency. This effect reduced somewhat during the trial as people became more acclimatised to the conditions.
- The site finally chosen (Minas de San José) offered many potential targets with low scientific value, and few to no targets with high value. This situation had been anticipated and simulated targets produced, but the abundance of complex, low-interest features made the autonomous science analysis process more difficult.
- The coarse pumice deposits underfoot result in quite a dusty environment, and this became a nuisance at times when afternoon gusts of wind raised the dust and spread it around the site. On at least two occasions during the trial, fully-formed “dust devils” swept across the area, causing brief but considerable discomfort to team members working at the mission control van.

8.3 Human factors

Operating outdoor rovers in an area popular with tourists naturally generates a lot of interest. This can cause problems during experiments, particularly for a visually-oriented project like PRoViScout. Among the problems encountered were:

- People moving visual markers that were being used as calibration points.
- People wanting to walk across the site, in full view of the cameras on the rover.
- People wanting to inspect the rover at close hand.

- People wanting to talk to team members while experiments were being conducted.

These and other human-related problems were largely dealt with by managing rather than preventing them. By basing the main rover experiments in a narrow valley some distance from the road and using tape to fence off the access points, casual visitors were discouraged from getting too close to the rover. Usually there were enough staff around that someone could take the time to talk to interested visitors without disrupting the main work. In addition, one day of the trial period was dedicated to the press, and this generated a great deal of interest in and publicity for the project. On that day, Idris and the SciSys mini-rover “Indie” were made available near the road for filming and interviews. Many members of the public came to see the rovers and talk to team members about the project and space robotics. The event was widely reported in the Spanish media and elsewhere.

9 LESSONS LEARNED

A major issue encountered during the PRoViScout project was the way in which the choice of science goals and instruments and the engineering constraints of the rover platform acted to restrict the choice of trial site and experiments that were possible. On the one hand, it was desirable to find a test site rich in “high value” science targets – such as layered formations – while on the other it was necessary to have good access to the site, and for there to be more open areas in which to test the visual navigation and other sub-systems.

This tension between scientific goals and engineering practicality is encountered to some extent in any field test scenario. In the end, the practicalities of transport and available permissions led us to use an area good for rover activities in conjunction with “plug-in” simulated high-value science targets based on real geological features. This proved to be a reasonable compromise, allowing a degree of scientific realism without making the engineering problems prohibitively difficult.

Equipment failure needs to be planned for – at least for critical components. In our case, the PTU was a critical component for which we should have had a backup. Although assorted tools and resources for repairing equipment were taken with us, they were not sufficient to fully repair the unit, and this had a knock-on effect on experiments during the trial. The van breakdown during the journey out may in hindsight have been preventable by a more thorough pre-trip checkout and servicing plan. Only the expertise of the van crew and the availability of tools in the vehicle meant that a temporary repair was possible that kept the journey on schedule.

It is definitely worth spending time and resources on planning for the welfare and comfort of team members during the field trial. In a difficult and unfamiliar environment, the ability to work efficiently together to debug code and solve problems proved vital to the success of the trial.

Planning the field trial and the transport of the rover and associated equipment represented a huge logistics effort. Preparations should be started as early as possible in a project. By doing this, we ensured that all of the necessary paperwork and permissions had been obtained well in advance of the trial. In particular, liaising with the national park authorities about permissions and permitted activities was started as soon as the general area for the trial was identified.

Publicity and outreach activities should be planned as part of a field trial, if appropriate. Having a specific press day generated much good publicity for the project, and avoided reporters disrupting work on critical experiment days. Public interest was high, and a number of young people made enquiries about our work, and about studying space science or robotics at university.

10 ACKNOWLEDGEMENTS

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