Further progress in the development of the ROBOVOLC system

G. Muscato, S. Guccione, N. Savalli
DEES Università degli Studi di Catania, Italy e-mail gmuscato@dees.unict.it

M. Coltelli, G. Puglisi
INGV Catania, Italy

P. Briole, C. Faucher
IPGP, Paris, France

G.S. Virk, A. Azad
University of Portsmouth, U.K.

A. Semerano, V. Duporque
ROBOSOFT, Biarritz, France

T. White, G.S. Rees
BAE SYSTEMS, Bristol, U.K.

ABSTRACT

The ROBOVOLC project aims to design and build a robotic vehicle to perform inspections in a volcanic environment. Due to the very unstructured and unusual nature of the environment a considerable effort was needed in the understanding of the requirement of the system. The initial phase consisted of the establishment of the specifications enabling the consortium partners to start the subsystem design process.

1 INTRODUCTION

The main objective of the EC funded project ROBOVOLC is the development and trial of an automatic mobile robotic system to explore and perform measurements in a volcanic environment.
A major aim of the proposed robot will be that of minimising the risk for volcanologists who are involved in work close to volcanic vents during eruptive phenomena.
The main innovative aspect of this project is the possibility of taking measurements during volcanic eruptions and the development of a robotic system for the exploration of one of the most difficult environments on the surface of the Earth.
Observations and measurements of the variables relating to volcanic activity are of greatest interest during paroxismal phases of eruptions, which unfortunately are also the time of greatest risk for humans.
The project duration is 39 months and the activities started on March 2000. During this first period a wide review of the state of the art concerning similar project and robots has been performed and the requirements and the specifications for the system have been stated [2]. The next steps are represented by; the design of the different subsystems; their realisation; the integration of the sub-systems to comprise the system; and the trials.
In this paper an update of some results obtained in this phase of the project is presented with particular reference to the measurements performed in the volcanic environment.

2 MEASUREMENTS OF PARAMETERS OF TYPICAL MISSIONS

In order to improve the understanding of the requirements needed for the ROBOVOLC project, an automatic probe has been designed to simulate the future robotic missions and to gather information about the ground and the environmental conditions of a typical volcano.
The approach adopted to gather a great quantity of information about the features of the ground was to build a simple mechanical structure with four wheels and to realise a case with the conditioning circuits for the different sensors.
The probe was manually driven into quiescent craters on the Etna volcano following suitable trajectories for a robot vehicle. Several measurements were performed during the path for post-processing including; the min and max slopes of the Etna volcano ground and craters; the altitudes; and the distance between different reference points on the volcano. In addition environmental parameters such as the ground and the air temperature, the humidity and the air pressure were measured.
The gathered data has been very useful and moreover the real experience of a typical volcanic mission was very important to identify the practical problems which will be experienced in the future field trials.
Details of the measurement system and the missions performed are described in the follow sections of this paper.

Fig. 1. The measurement probe.

3 THE MEASUREMENT PROBE

The mechanical structure for measuring the different characteristic parameters of a volcanic environment has been realised in the form of a simple aluminium framework with four wheels (fig.1).
Figure 2 shows a block diagram of the sensors present on board of the probe realised.

1) Sensor for Environment Temperature
2) Infrared Temperature Sensor for ground :
3) Humidity Sensor
4) Dual Axis Acceleration Measurement System for inclination measurement
5) GPS sensor
6) Two encoders mounted on two wheels as displacement sensors
7) Signal Conditioned ambient Pressure Sensor Transducers
8) A Video Camera (WEBcam) for image acquisition.

A user interface, has been designed to allow easy understanding of the measurement and data post-processing. The user can analyse all of the measurements performed at a selected speed while viewing the image acquired by the video camera.

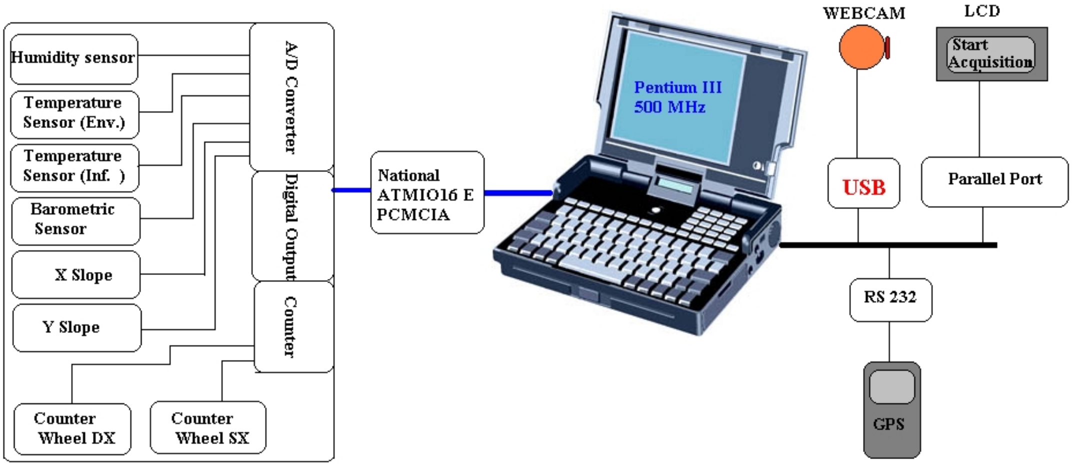

Fig. 2 Block Diagram of the Measurement System

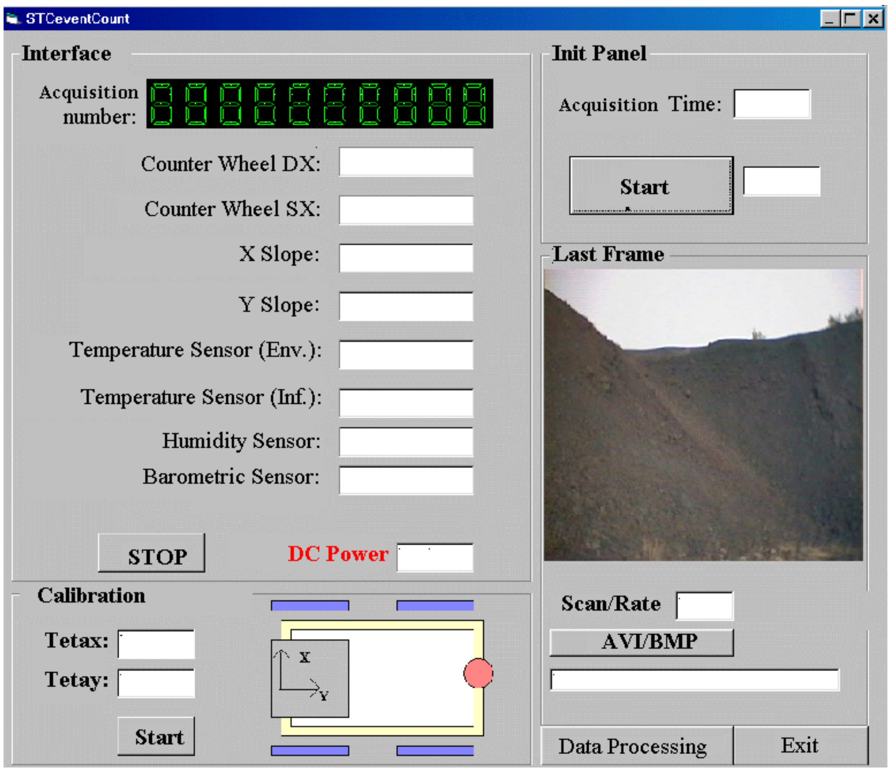

Fig.3. User interface for the measurement probe.

4 EXAMPLES OF MISSIONS

Several different environments were visited and measurements of roughness of the surface, gradients and distances were taken. The North East (NE) Rift is a peculiar zone of the

northern slope of Mt Etna where many recent craters are concentrated in a small area. From logistic point of view this area is easy accessible by a four-wheel drive vehicle. Among the geological features of the NE Rift, *Umberto and Margherita craters* represent a group of crater with their shape ranging from funnel-shape craters, produced by strombolian explosive activity, and pit craters, produced by crater collapse and freatic explosion occurring at the end of an eruption. These craters permit preliminary tests of the robot motion in a easy accessible and safe area with the same morphological characteristics of the most of active crater of basaltic volcanoes as the summit craters of Mt Etna. Other tests were performed on Sartorius craters.
In particular Fig. 4 show the path followed during a test on Sartorius crater, while Table 1 show the main features of the explored traces. One of the most useful information was the inclination of the terrain that together with the distance allowed to reconstruct the terrain. Figure 5 shows the measurement of inclination during track 1. The GPS measurement of the entire trajectory is also reported in Fig. 7.
Many other measurements have been carried out and their result adopted to obtain the specification for the locomotion system.

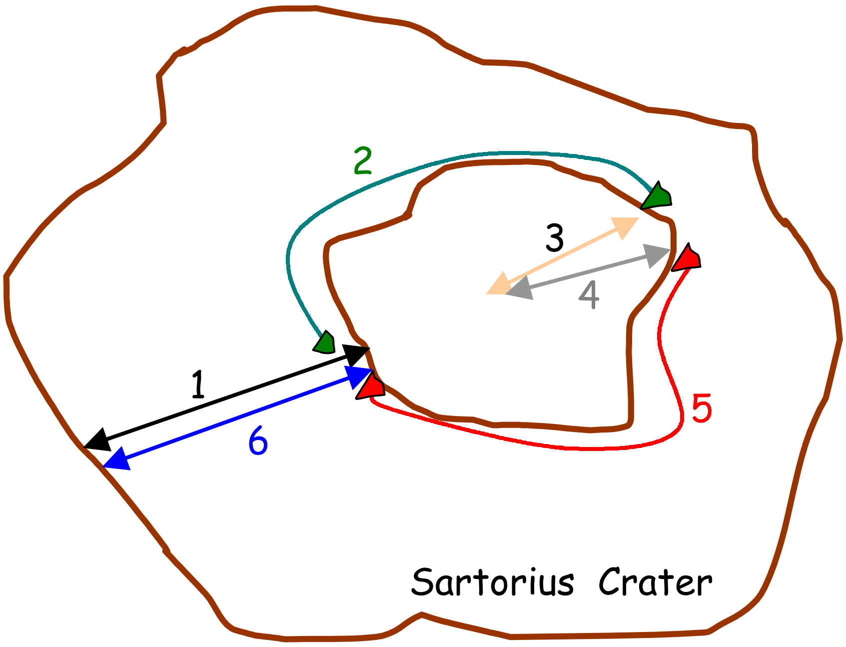

Fig.4 Sartorius Crater Traces

Trace	Length	Max Slope X (Pitch)	Max Slope Y (Roll)	Envir. Temp.	Ground Temp	Humidit y.	|ΔH| Altitude
1	75 m	27°	-12°	22 °C	34 °C	40 %	22 m
2	88 m	15°	13°	23 °C	33 °C	41 %	4 m
3	25 m	-20°	-18°	23 °C	30 °C	41 %	7.5 m
4	23 m	35°	10°	21 °C	33 °C	42 %	10 m
5	80 m	20°	20°	22 °C	31 °C	44 %	9 m
6	83 m	-25°	-15°	23 °C	34 °C	43 %	25 m

Table 1 Features of the explored traces

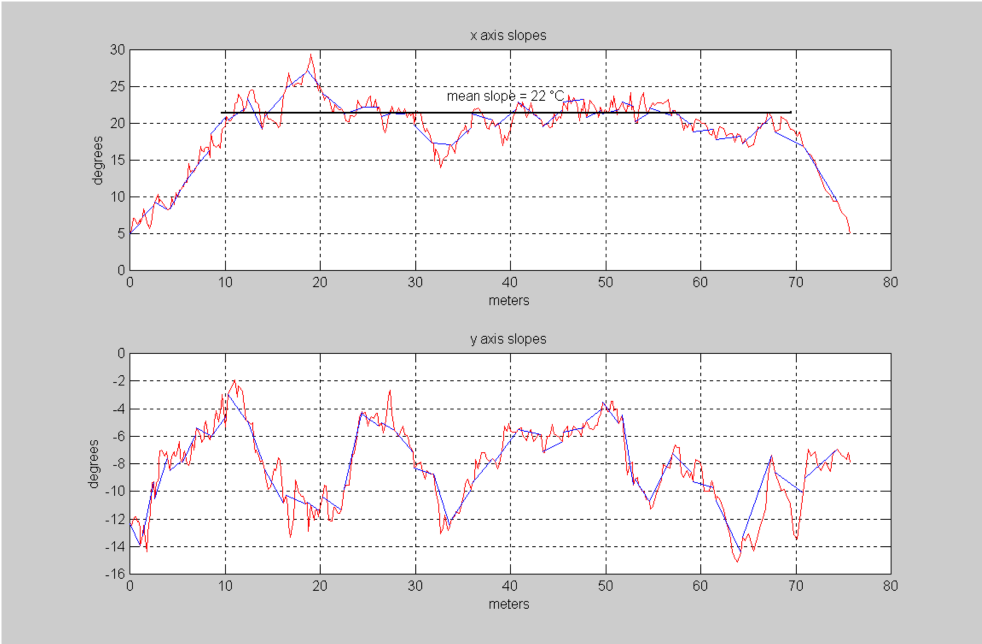

Fig. 5. Measurement of inclination for track 1.

Fig.6. (a) Camera Image (b) Web Cam Image

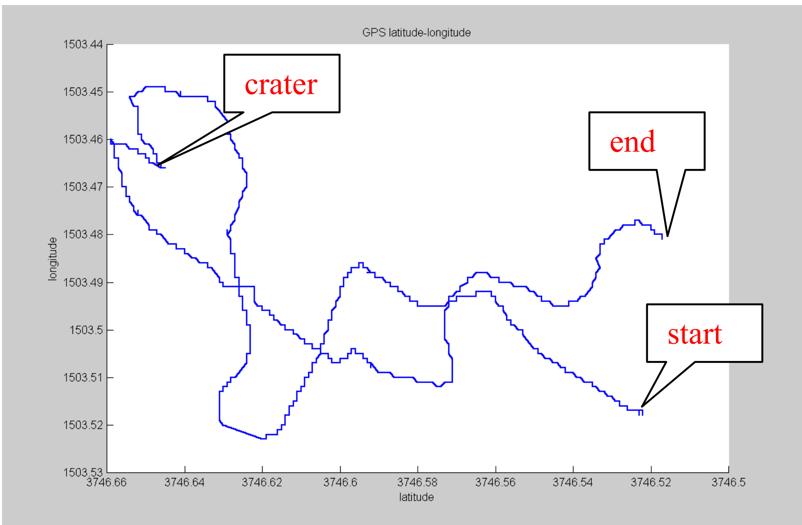

Fig. 7. GPS latitude-longitude measurement.

5. THE REQUIREMENTS

Using the measurements and following several discussions with the end users the main technical requirements for the ROBOVOLC robot effecting the selection of the platform were prepared:

- Modular component of system mass limit : 200Kg
- Maximum overall dimensions of modules: height- 0.8m, width- 1.2m, length- 1.7m
- Static Stability: 40°
- Maximum slope: 35° (minimum is 30°)
- Maximum lateral obstacle height: 0.4m
- Speed: > 0.5m/s
- Maximum payload: 30kg
- Travel time for a 24 hour mission: 1.5hours

The most appropriate locomotion technique for the ROBOVOLC system was then carried out by evaluating the most promising techniques by comparing their ability to satisfy certain criteria including reliability, rough terrain performance, suitability for purpose, etc.

Eight techniques were evaluated, these are Tracked, Purely wheeled, Articulated and Cartesian walking robot, Frame walker, Hybrid "legs with wheels", Flying (Fixed wing and rotary) and a High adaptive chassis. The final contenders for the locomotion system were: Wheeled Rover with High Adaptive Chassis, Hybrid "leg with wheels" and Tracked Robot and finally a Wheeled rover with an adaptive chassis was chosen as the best solution for these requirements.

A preliminary block diagram for the global proposed system has been prepared. In this system the robot will be operated/monitored from a portable command system through a communication relay station. The main systems are reported on Fig.9. These can then be further broken down into sub-subsystems which can be further studied to adopt appropriate designs.

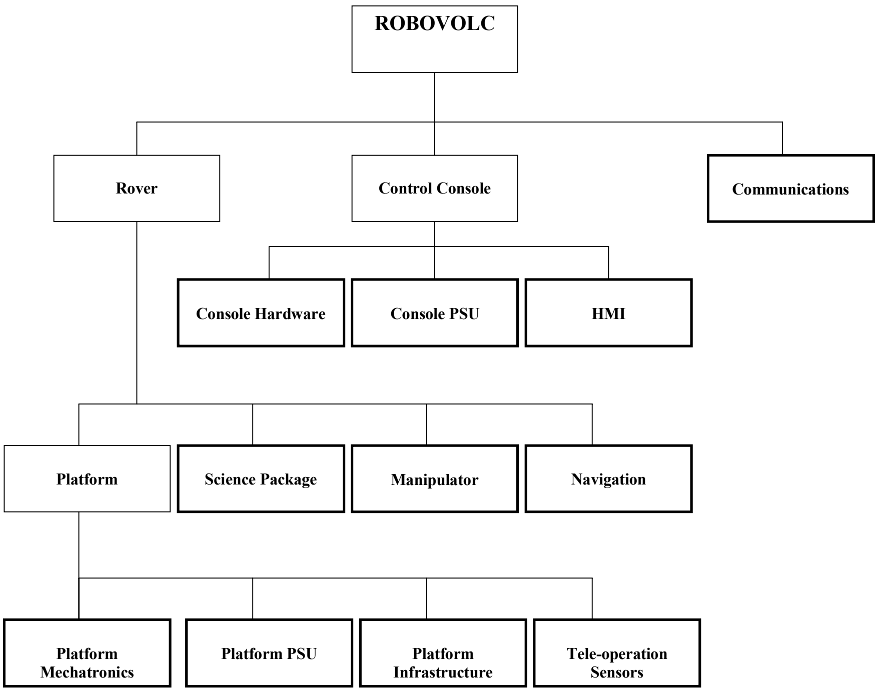

Fig.8 Block diagram of the ROBOVOLC system.

5. Conclusions

In this paper we focused on measurements performed on volcanic environment to improve the understanding of the requirements and consequently of the specifications for the Rover of the Robovolc system. Considering all the tasks and constraints, general specifications for the ROBOVOLC robot have been identified.

6. Acknowledgements

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7. References

[1] G. Muscato, G. Nunnari, S. Guccione, "Robots for Volcano Exploration: A New Perspective", World Automation Congress (WAC2000), Eight International Symposium on Robotics with Applications, Maui (Hawaii, USA), 11-16 June 2000.

[2] S. Guccione, G.Muscato, G.Nunnari, G.S. Virk, A.K.M. Azad, A. Semerano, M. Ghrissi, T.White, C. Glazebrook, "Robots for Volcanos: The State of the Art", Proceedings of the 3rd International Conference on Climbing and Walking Robots (CLAWAR 2000), pp.777-788, Madrid (Spain), 2-4 October 2000.

[3] A.K.M. Azad, G.S. Virk and M. Qi, G. Muscato, S. Guccione, G. Nunnari, T. White, C. Glazebrook, A. Semerano, M. Ghrissi, P. Briole, C. Faucher, M. Coltelli, G. Puglisi, R. Cioni and M. Pompilio, "ROBOVOLC: Remote Inspection for Volcanoes", Workshop on Autonomous artificial systems exploring hostile environments, International NAISO Congress on Information Science Innovations (ISI'2001), Dubai, March 18th, 2001