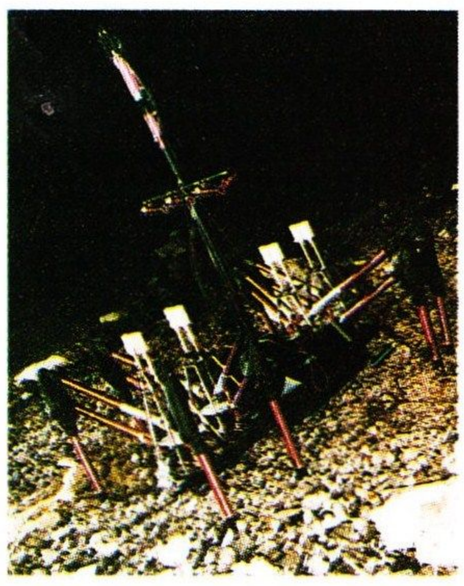
# Electronics AUSTRALIA WITH ETI

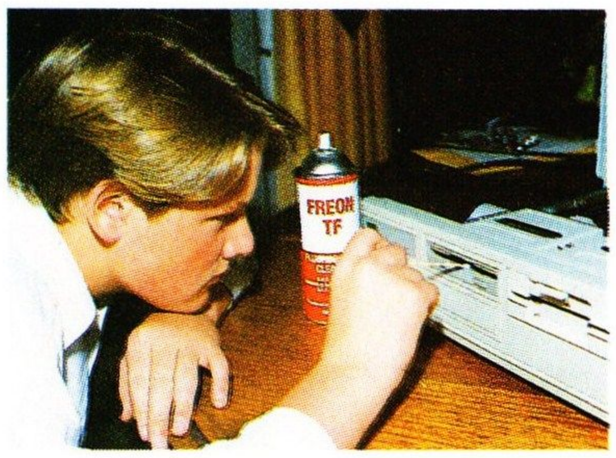
AUSTRALIA'S LARGEST SELLING ELECTRONICS MAGAZINE — ESTABLISHED IN 1922


### Dante's aborted descent



*Although NASA was ultimately forced to abort its project to send the eight-legged walking robot Dante down into the crater of Antarctica's live volcano Mt Erebus, quite a lot of things were learned nonetheless. Kate Doolan explains, in her story starting on page 24.*

### Rehabilitating old PCs...




*An old PC, XT or AT computer may not be up to running Windows, but it can still be very useful — providing you can maintain it properly. Tom Moffat tells you how, in his 'hands on' article starting on page 20.*

### On the cover

*Some of the more impressive late-model electronics products: The Philips DCC130 personal DCC player, held by Australia's triple aerobics champion Sue Stanley; Hewlett-Packard's new 'Benchlink' software and 500MHz DSO; and UPI's measurement transducers.*

## Video and Audio



## Features



## Projects and Technical

# DESCENT INTO HELL BY A MODERN DANTE

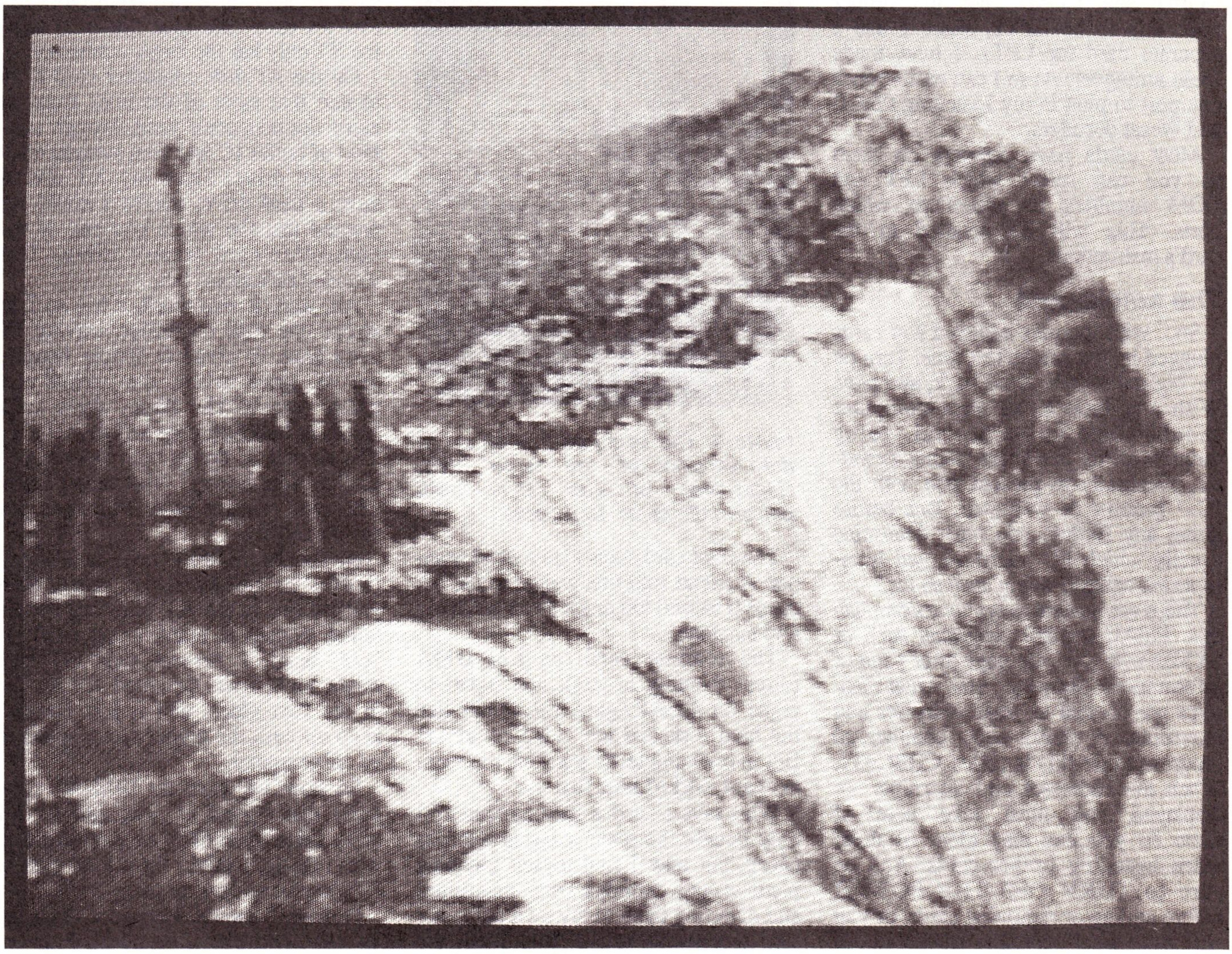
Late last year, you may recall, a team of scientists tried sending an eight-legged walking robot down into the crater of Mount Erebus — Antarctica's live volcano. The experiment struck problems and had to be aborted, but quite a lot was learned nonetheless. It has taken some time for Kate Doolan to find out the details and get hold of some pictures, but here at last is the story behind Dante's aborted descent...

**by KATE DOOLAN**

Sometime in the next 30 years, people will depart on the long awaited journey to the planet Mars. Depending on the technologies in use, the flight could take anywhere from one to three years. Travelling to and landing on the Martian surface will require a new approach in every aspect of flight, especially in the area of human and equipment adaptation to the new environment.

It is extremely difficult to simulate Martian conditions here on Earth, but one place is being increasingly used as an effective training ground: Antarctica. For many years now, the US National Aeronautics and Space Administration (NASA) have been sending both people and equipment down to Antarctica to gather data on the pressures of surviving and living in a harsh physical environment — which resembles conditions on Mars in terms of climate and isolation.

One recent project of NASA in conjunction with the National Science Foun-



dation (NSF) was Dante, a robot which in December 1992 attempted to descend into Mount Erebus, an active volcano located on Ross Island some 1500 kilometres from the South Pole. Although not a complete success, Dante is paving the way for sophisticated and detailed robotic exploration of the Solar System in years to come.

Dante was christened in honour of the 14th century Italian author Dante Alighieri, who is best known for his play *Divine Comedy*. Part of that play is the famous 'Inferno' in which the author describes his journey to the underworld — where Erebus is a cloud of dust that obscures the entry to Hell.

The twentieth-century namesake of Dante was developed, designed and constructed by the Robotics Institute at the Carnegie Mellon University in Pittsburgh, Pennsylvania.

The US$2 million dollar cost of the program was funded by NASA's Office of Aeronautics and Space Technology. It took only nine months for Dante to go from the drawing board to its journey down inside Mt Erebus.

## Eight legs

Dante is an eight-legged robot that weighs in at 400 kilograms. It stands 2.5 metres in height and is three metres in length, with a width of 1.7 metres and a central mast of 2.5 metres. The robot contains 12 electric motors, which can operate various experiments along with its walking motion at the impressive speed of two metres per minute. At the end of Dante's legs are feet which are equipped with proximity sensors to enable the robot to remain upright.

Dante's legs are organised into two groups of four, with an inner and outer frame coupled with a drivetrain which provides the robot with a unique walking motion. To walk, four legs simultaneously lift and reach forward whilst the other four legs propel the body. Each leg can be individually adjusted in height to avoid obstacles.

The two leg frames are rotated with respect to each other, to change the robot's direction. On the steep slopes that Dante was to encounter, a tether system provided a reaction force to gravity and also assisted in maintaining equilibrium — allowing the robot to rappel like a mountain climber. In addition to providing Dante with support, the tether delivered power through six conductors in its inner weave.

Communications with Dante were through a single fibre-optic line, over which seven video, one Ethernet and two serial data communications links were multiplexed. For future missions, radio telemetry may be possible but for the initial trial, the use of a tether was dictated by the steep slopes of Mt Erebus.

***This photo shows the Dante robot making a test climb up a slag pile at Carnegie Mellon University, Pittsburgh, PA, in preparation for its Antarctic expedition. Our rather dramatic lead photograph is a screen shot showing the Dante robot in place on the rim of the crater ready for its descent into the Mount Erebus volcano.***

The technical objectives of Dante were to demonstrate an exploration mission, environmental survival and self-sustained performance in the harsh Antarctica climate. By working there, it is hoped that scientists will learn what is necessary in a robot whose mission is extended exploration of the Solar System.

Although only a prototype, Dante was not a laboratory-only device. Its components were designed to withstand both the conditions of Antarctica as well as being inside Mt Erebus.

To protect the robot, its metallic surfaces had been anodised to harden them and the computers were rated to stand both extreme cold and heat. Dante was also equipped with sensors that could sense its environment and also 'proprioceptive' sensors to sense its own

# Descent into Hell by a modern Dante

status. The on-board computing system provided the robot with basic capabilities for motion. Dante also had sufficient sensing in its feet alone to allow it to feel the terrain and adjust its motions accordingly.

Using a task communications package named TCX, Dante had an integrated software system that enabled project participants to observe, instruct and modify it as the project progressed.

Processes used included perception, planning and control on real-time boards communicating point-to-point via messages. TCX abstracted the coding, transmissions and decoding of messages, making inter-process communications look like function calls. TCX also greatly reduced the time required to integrate a software package and allowed for the addition of new modules when required.

To communicate with the Goddard Space Flight Centre (GSFC) in Greenbelt, Maryland and also the Carnegie Mellon University back in the United States, NASA on a daily basis provided five 20-minute live video links to the Dante team in Antarctica, via feeds from its Tracking and Data Relay Satellite-West (see *EA* June 1993).

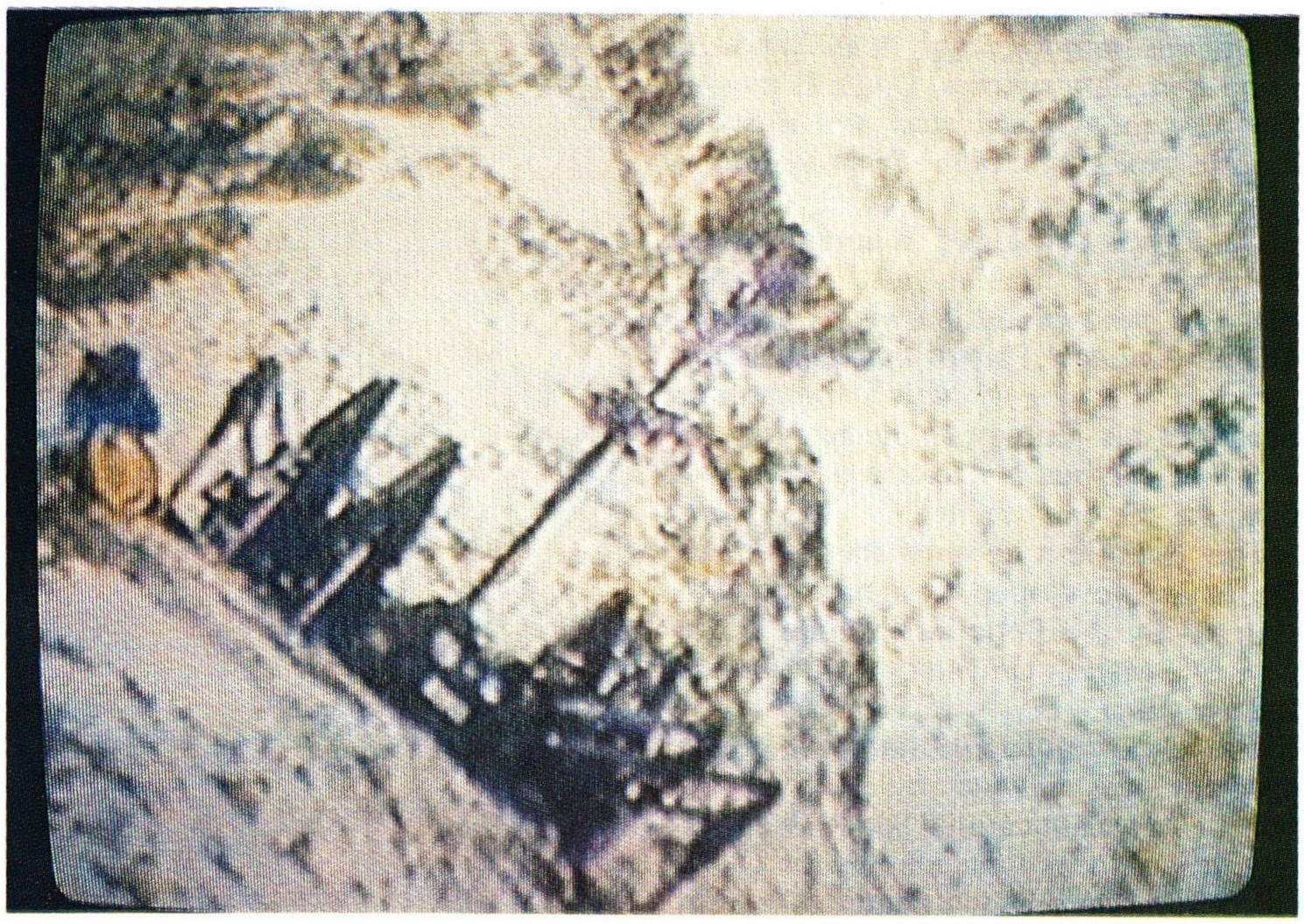
A TDRS S-band transportable uplink system was placed at the foot of Mt Erebus for this purpose, and GSFC provided several TDRS specialists for technical communications support. Five Carnegie Mellon staff members were stationed at the Goddard Payload Operations Control Centre, to provide on-line computer support and if required, robotic and engineering support.

## Three video cameras

The Dante project was equipped with three video cameras. Mounted on Dante itself was a colour CCD (charge-coupled device) camera which could look either forward or rearward.

Another similar camera was mounted on Dante's carrier, which remained at the rim of Mt Erebus, while one of the team members had a hand-held video camera for either live action footage or for recording material to be played back at a later date. The quality of the video footage was comparable to that of home video system recordings in terms of colour and resolution.

The frame rate of the TDRS digital video transmission was only six frames per second, which is one fifth the required speed to create effective and smooth full-motion video. So the footage had a moderately jerky appearance, similar to the quality of television transmissions from the space shuttle. It was not technically feasible to provide live audio with the transmissions, but this problem is being worked on for future projects.



***The information about this photo was rather confusing, but we believe it shows Dante descending into the crater of the Mount Erebus volcano.***

Dante was fitted with a 'trinocular stereo' rig which used a new 'sum of sum of squared differences' algorithm, capable of generating depth maps of visible terrain. In addition, a scanning laser rangefinder sensed terrain depth in a 360° circle around the robot. Depth information from sensors was used to generate an accurate model of the terrain.

The stereo system used has a large range and high resolution, but is susceptible to a lack of texture and the resolution comes at the expense of processing time. In contrast the laser system has high accuracy with a scan acquisition of three to five seconds, but it is delicate and sensitive to variations within the terrain.

Dante's software system reflected the basic 'sense, plan and act' cycle that enabled the robot to walk and operate autonomously. The terrain mapper transformed depth maps in the co-ordinate system of a particular sensor into a common elevation map.

An operator gave Dante instructions to walk, roll, yaw and lift the robot. These instructions were in the form of the trajectories that were to be followed. The operating system then took those trajectories and broke them down, working out all of the body motions required to follow the trajectory.

That meant if Dante was operating autonomously, the body motion was adjusted to avoid colliding with the terrain. Next, the basic leg motions required to propel the body along the trajectory were generated and by sensing the terrain, all the leg motions were adjusted to avoid contacting the terrain during the stepping phase — while at the same time ensuring correct contact with the terrain during the support phase. This process is known as 'gait generation', and results in a detailed plan to make Dante walk along the commanded trajectory.

The Dante control system is a real-time process that runs onboard the robot. It co-ordinates the actuators and reads status from encoders and other sensors. A graphic simulator was developed to act as a 'virtual robot'. Its message interface is identical to that of the actual controller so plans generated by the gait planner can be simulated to observe the outcome.

A user interface display periodically polls the controller for status information about Dante. It displays a three-dimensional kinematic view of the robot, with readouts of all actuators and sensors.

## Slag heap testing

Before leaving for Antarctica, the Carnegie Mellon robotics staff used a 'slag heap' to test the responses of Dante walking over rough ground. Tests were performed in a fully autonomous walking mode, using perception in a rolling terrain. A number of tele-operated tests evaluated the robot walking under ten-

sion control, ascending and descending hillsides. Materials used on the slag heap included rock, gravel, sand and loose blocks. After these tests, Dante was given a 'clean bill of health' to operate in all environments.

## A frozen inferno

In early December 1992, Dante and its team of researchers were flown down to McMurdo Station by the United States Air Force. On arrival, the team spent several days adjusting to the environment before being sent to an altitude acclimatisation site to get used to heights and the weather. Following that, the team were then flown to Mt Erebus by helicopter where they set up a base camp.

Snowmobiles were then used to haul Dante and its supplies up to the outer slope of the mountain. Then both people and equipment were shifted to the summit by foot.

Mt Erebus is the only active volcano in Antarctica. It rises from the Ross Ice Shelf on the east coast and stands 3794 metres tall. On Erebus, the summer temperature is a cool -20°C. The summit of the mountain opens into a main crater 150 metres in depth and holds one of the few magma lakes — which are a rare example of volcanic equilibrium, in which the volcano maintains steady activity but it does not violently erupt. Fresh hot magma rises to the surface as cooler magma sinks down.

The scientific goals of the Dante project were to determine the composition of gas generated by Erebus and to measure the temperature of the magma lake. Insights into the composition and nature of the magma within the Earth's crust are possible by studying the lake inside Erebus. By identifying the composition of the gases released from the lake and nearby vents, the effects of volcanoes on the atmosphere can be better understood.

Dante carried five scientific experiments, one of which was to collect samples into a set of collection bottles. Gas would have been pumped into the bottles through a 2°-of-freedom titanium sampling probe, which if close enough, could have drawn gas directly from the magma lake.

Also linked to the robot were a set of filters which could have been used to sample fine particles suspended within the volcano. At various times during the exploration of the crater, filter samples would have been taken.

A Gamma Ray Spectrometer (GRS) was also included in the science package. The GRS measures the radioactivity of materials, and by recording the gamma ray spectrum of material was designed to collect data about the increasingly younger lava as Dante descended into the crater.

If Dante had reached the crater floor, the GRS would have been used to analyse sublimates that drop out of gases as they exit the crater and hit the cold air. The GRS is similar to the same instrument on board the Mars Observer spacecraft, which arrived at Mars in August 1993 and then lost contact.

The last experiment on Dante was an infrared thermocouple, a device which measures the temperature of bodies from a distance by measuring the infrared radiation that they produce. The infrared thermocouple would have been trained on the magma lake whenever possible, in the hope of observing large gas bubbles breaking the surface of the lake and revealing the liquid magma underneath.

## On the day...

There was a day's delay to the start of Dante's descent, caused by a minor eruption at the rim of the volcano. No damage was done to the robot, but clouds of gas would have made it difficult to see. It was expected that Dante would take between 24 and 36 hours to make the 280-metre descent to the crater floor. After a short stay, the plan was that it would rappel itself back up the crater wall where it would be recovered.

However all of these plans were abandoned, when Dante broke a fibre-optic cable after travelling six and a half metres. The robot had two spools at its rear, which play out the optical cable linking Dante's onboard sensors and motors with its brain — the computers that provide its depth perception and ability to self navigate. The first spool successfully laid down cable from the team's control centre to the crater rim.

The second spool, which resembles a ball of string, was to release cable during Dante's descent. That cable proved to have a kink in it every five metres, and it was one of these kinks that snapped and brought the mission to its premature end. The team did not anticipate this happening, and did not have a spare cable readily available.

It was decided to end the mission, as it was not known how long it would take to get a replacement cable.

With the short Antarctica summer, it was expected that the Dante team would have another *really* 'white Christmas' before sending their charge on another descent into hell...

In closing, the author would like to thank Jim Elliott of the Goddard Space Flight Centre for his assistance in the completion of this article. The photographs used are courtesy of Goddard Space Flight Centre. ❖