Martian Dust Devil Detection with the Beagle 2 Wind Sensor

Conference or Workshop Item

MARTIAN DUST DEVIL DETECTION WITH THE BEAGLE 2 WIND SENSOR

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Introduction: Beagle 2 is a Mars lander 'piggy backed' on the European Space Agency mission to Mars, Mars Express. Mars Express is due for launch in June 2003, with an expected landing date for Beagle 2 of December 26th 2003. Beagle 2 has a number of instruments on board, which will be looking for past or present signs of life. In addition there is the Environmental Sensor Suite (ESS). One instrument contained within the ESS is the wind sensor, which utilizes an ultrasonic technique, less affected by low atmospheric pressure than other methods. The wind sensor will be used with modeling techniques to characterize localized atmospheric phenomenon. One such phenomenon are dust devils, which are thought to be an important mechanism for injecting dust into the Martian atmosphere [1], and may explain the similarity between dust at the Viking and Pathfinder landing sites.

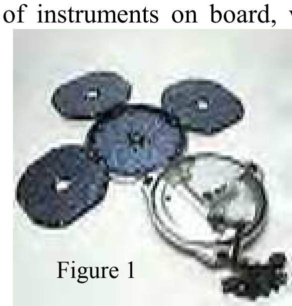
Figure 1

Environmental Sensor Suite [2]: The ESS consists of 7 sensors divided into three groups, Life Environment sub-system, which consists of a UV sensor, and the Mars Atmospheric Oxidant Sensor, (MAOS), provided by the NASA Ames Research Center and the Jet Propulsion Laboratory, the Meteorological sub-system consisting of air temperature, pressure, wind, and a dust impact sensor, and the Entry, descent, and landing substystem consisting of the accelerometers.

Wind sensor: On most previous Mars landers hot-wire techniques (see table 1) have been used to give an indication of wind speed, although some information was obtained by Mars 2 & 3 using radio science during descent. We will be using an acoustic resonance technique adapted from a commercially available anemometer [3]. This acoustic technique is not a new one, and was being used in the 1970's to measure wind speeds in dust devils on Earth [4], but has never been used on a planetary lander. The current design is shown in figure 2, which illustrates the commercial sensor. Modifications are being carried out to optimise the instrument for the Martian atmosphere. The sensor will be used in conjunction with the other environmental sensors to give details of atmospheric conditions encountered during the landers lifetime. The acoustic resonance technique will not only give detailed wind velocity measurements, but air temperature, and the speed of sound. This will also be a valuable technology test for future planetary missions.

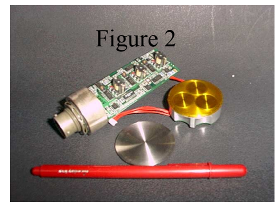
Figure 2

Operation. Acoustic waves are generated and received by the three vibrating diaphragms. Only one diaphragm is excited at any one time, over a narrow frequency band, and the individual reflections combine in phase. The net wave distribution can be thought of as a vertical quasi-standing wave, which in the horizontal behaves like a 2-D radial travelling wave. The airflow measurement is based on this travelling wave behaviour [3], (interference between two waves travelling in the same direction).

Spacecraft	Ultrasound	Thermal (hotwire)	Rotating vane
Viking 1		3 wire	
Viking 2		3 wire	
Pathfinder		6 wire	
Venera			√
Beagle 2	√		

Table 1

In-situ wind measurement techniques.

The wind sensor will have a wind speed accuracy of 0.01m/s, and a directional accuracy of 3 degrees, so will easily detect the variations caused by a dust devil passing over or near the Beagle 2 lander.

Dust Devils: Dust devils are a common occurrence both here on Earth and on Mars. They form when the correct conditions arise; these include convective plumes, and atmospheric vorticity. Convection occurs when the sun heats the ground, which in turn heats the air above. This heating will cause the air to become less dense and thus start to rise.

These phenomenon have been observed on Mars by the Viking Orbiters and landers [Ryan and Lucich, 1983; Thomas and Gierash, 1985], and by the Mars Pathfinder [Schofield et al., 1997; Metzger et al. 1999] and recently by the Mars Global Surveyor. The ambient wind, which travels around surface features, will rotate these columns of warm rising air. This rising rotating air column causes a low-pressure area at the central core; this central chimney increases rotation by drawing in more hot air, which results in more dust being taken aloft.

The dust devil will then move across the landscape with the nominal horizontal wind speed like a mini tornado, although tornados are connected to storm fronts and cloud cover. This movement across the terrain causes marks or scars on the surface. This is particularly noticeable on Mars where the surface matter is removed by the dust devil revealing a darker or lighter material underneath [1].

Characteristics. Dust devils have specific properties, which characterise them. These properties can be used to detect dust devils when using remote sensing instruments or when using planetary landers meteorological package.

	Earth	**Mars**
Rotational wind speed	Up to 10m/s	Up to 70m/s
Pressure drop	2.5-4.5mbar	10-45μbar
Time of day	10am-4pm	10am-4pm
Duration	Minutes	Minutes
Temperature rise	4-8K	1-5K
Dust particle size	10-40μm	3-5μm

Table 2

Earth information [Sinclair 1966][5], Martian data, [Ferri, 2000, private communication.]

Dust devil occurrence. By comparing data from Earth observations and those obtained from Mars, an optimum time for the formation of a dust devil can be determined.

Data Set	**Mean Time**	**Standard Deviation**
Pathfinder, Ferri	12:03	1.36
Sinclair, area 1	12:22*	1.48
Sinclair, area 2	12:36*	1.53

Table 3

**Sinclair's data adjusted due to U.S. summer time.*

From this data an optimum time to switch to the high sample rate of 2Hz can be determined.

Dust devil rotation. Dust devils are characterised by their intense rotation that enables them to pick up dust, which makes them visible. There is some debate although whether the direction of rotation is related to the direction of rotation of the planet. Below in table 4 is shown rotational data from the Viking landers.

If a 50% preference test [6] is carried out on this data it shows that statistically these values could occur by up to 10% of the time, implying no preference for a direction of rotation.

Diameter (m)	**Clockwise motion**	**Anti-clockwise motion**
0-49	16	15
50-99	8	15
100-199	13	11
200-299	10	10
300-599	5	10
>600	2	3
Total	**54**	**64**

Table 4 [7]

Dust devil detection. The wind sensor will be in high sample rate at specific times of the day, (optimum time shown in table 3). Average wind speeds on Mars are ~ 2-10m/s so an increase in wind speed of an order of magnitude, and backed up by changes in dust impacts, pressure and temperature will indicate a dust devil. The data will be compared to previous Viking/Pathfinder information, and by using the dust devil model being developed it will be possible to determine the dust devil diameter, ambient and rotational wind velocity, and how far the dust devil has passed to the Beagle 2 lander.

Future work: A dust devil model is being developed at the Planetary and Space Science Research Institute, The Open University, to characterise the wind speed and direction profiles for dust devils on Mars. The wind sensor is to be tested and calibrated using the Martian low pressure wind tunnel, Oxford University.

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