MATE AND DART: AN INSTRUMENT PACKAGE FOR CHARACTERIZING SOLAR ENERGY AND ATMOSPHERIC DUST ON MARS. Geoffrey A. Landis[1], Phillip Jenkins[1], David Scheiman[1], and Cosmo Baraona[2], [1]Ohio Aerospace Institute, NASA Glenn Research Center mailstop 302-1, Cleveland OH 44135, e-mail geoffrey.landis@grc.nasa.gov, [2]NASA Glenn Research Center mailstop 302-1, Cleveland OH 44135, e-mail cosmo.baraona@grc.nasa.gov.

Introduction: The MATE (“Mars Array Technology Experiment” [1]) and DART ("Dust Accumulation and Removal Test" [2]) instruments were developed to fly as part of the MIP experiment on the [now postponed] Mars-2001 Surveyor Lander [3]. MATE characterizes the solar energy reaching the surface of Mars, and measures the performance and degradation of solar cells under Martian conditions. DART characterizes the dust environment of Mars, measures the effect of settled dust on solar arrays, and investigates methods to mitigate power loss due to dust accumulation.

MATE

MATE Purpose: Until Mars Pathfinder landed in July 1997, no solar array had been used on the surface of Mars. The MATE package is intended to characterize the environment of Mars in order to gather baseline information required for designing power systems for long duration missions, and to quantify the performance of advanced solar cells on the surface of Mars.

MATE will measure the performance of five different individual solar cell types and two different solar cell strings.

MATE Solar Characterization Sensors: To measure the properties of sunlight reaching the Martian surface, MATE incorporates two radiometers and a visible/NIR spectrometer.

The radiometers consist of multiple thermocouple junctions using thin film technology. These devices generate a voltage proportional to the solar intensity. One radiometer measures the global broadband solar intensity, including both the direct and scattered sunlight, with an approximately 130° field of view. The second radiometer incorporates a slit to make a measurement of the direct (unscattered) intensity radiation. The direct radiometer can only be read once per day, with the sun overhead.

The spectrometer measures the global solar spectrum with a 256-element silicon photodiode array, sensitive in the visible range (300 to 1100 nm), and an second InGaAs photodiode array, sensitive to the near infrared (900 to 1700 nm). The spectrometer range covers 86% of the total energy from the sun, in approximately 5 nm resolution. Each photodiode array has its own fiber optic feed and grating.

Although the purpose of the MATE is to gather data of utility to designing solar arrays for Mars surface power systems, the radiometer and spectrometer measurements are expected to also provide important scientific data in characterizing the properties of suspended atmospheric dust.

DART

DART purpose: Dust deposition could be a significant problem for photovoltaic array operation for long duration missions on the surface of Mars. Measurements made by Pathfinder showed 0.3% loss of solar array performance per day due to dust obscuration [4,5]. Thus, dust deposition is the limiting factor in the lifetime of solar arrays for power systems on Mars, and developing design tools to mitigate this deposition is important for extended mission duration.

The DART experiment is designed to quantify dust deposition from the Mars atmosphere, measure the properties of settled dust, measure the effect of dust deposition on the array performance, and test several methods of mitigating the effect of settled dust on a solar array. Although the purpose of DART is to gather information critical to the design of future power systems on the surface of Mars, the dust characterization instrumentation on DART will also provide significant scientific data on the properties of settled atmospheric dust.

Dust characterization on DART is done by two instruments: the dust microscope and the “MAE” commandable dust cover. The dust mitigation tests on DART consist of two tests: the tilted cell tests, and the electrostatic dust repulsion test. In addition, DART will have a set of sun position sensors.

Microscope. The DART microscope is a fixed-focus microscope, which images a transparent glass settling plate from below. As atmospheric dust settles on this settling plate, it is imaged. The microscope uses a 40X objective, which focuses onto a 512x512 pixel focal plane array. The microscope resolution is about 0.5 microns.

Total mass of the microscope is 200 grams.

The microscope is intended to furnish information about the size distribution of the settled dust. Since settled dust may be different in character from the dust, which remains suspended in the atmosphere, this information is of considerable interest to the design of dust mitigation strategies. For the larger particles, the DART microscope will also yield shape information.

Dust coverage measurement. The "MAE" dust cover is based on the experiment flown on Pathfinder [4], and consists of a transparent plate onto which dust settles. This plate is located above three small solar cells, used in short-circuit current mode as solar intensity measurement in three wavelength bands. A mechanism allows the cover to be rotated away from the cells. Comparison of the cell output with the dust-covered plate in position and removed measures the dust coverage independently of other changes in the cell performance or the atmosphere. By taking a spectrum of the sunlight through the MAE settling plate, we can also obtain a transmission spectrum of the settled dust.

Dust Mitigation Experiments. Measurements of the camera window on the Viking lander showed no dust adhering to the vertical surface. Observations of the thermal shell of the Viking landers seemed to show that dust also did not build up on the tilted surfaces. Unfortunately, no quantitative measurement of accumulation could be made. A high priority is therefore to see whether tilted solar cells avoid accumulation of dust, and to find what angle is required to avoid dust coverage. The tilted cell measurement consists of solar cells tilted at 30°, 45°, and 60°, plus a horizontal control, plus a solar cell tilted at 30° with low friction (diamond-like carbon) coating.

Martian atmospheric dust is expected to be charged. In order to test whether electrostatic fields can be used to mitigate the deposition of dust on solar arrays, the electrostatic experiment will test three configurations. A high-voltage solar cell provides a potential of about 80 volts to a transparent conductor on the front surface of the solar cell coverglass. Three configurations are tested: positive potential applied to the cell cover, negative potential applied to the cell, and transverse field across the cell. These will be compared to the control cell with no applied potential.

Sun Position Sensors. Finally, the DART experiment includes a set of three sun position sensors, each consisting of a cylindrical lens focusing light onto a 512-element linear photodiode array. The sun position sensors have a mass of 18 grams each.

Summary: The MATE and DART experiments, designed for the Mars-2001 Surveyor Lander mission, contain a capable suite of sensors which provide both scientific information as well as important engineering data on the operation of solar power systems on Mars. MATE will characterize the intensity and spectrum of the solar radiation on Mars. DART will measure the dust accumulation rate, the transmitted spectrum of the dust, and will image individual settled particles to determine the size distribution and the particle shape, as well as gathering information on electrostatic properties.

References:

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