Mini-TES

Mini-TES is a Michelson interferometer that provides a spectral resolution of 10 cm^{-1} over the wavelength range from 5-29 μm (2000 - 345 cm^{-1}). The instrument is mounted inside the rover, and views the terrain around the rover by using the PMA as a periscope. A scan mirror assembly atop the PMA reflects radiation down through the PMA and into the telescope and interferometer. The scan mirror assembly allows Mini-TES to provide spectral image cubes over a 360° range in azimuth and from –50° to +30° in elevation. The scan mirror assembly also provides a view of internal and external, full-aperture calibration targets. The elevation mirror can be slewed to a stowed position in which a cover blocks the Mini-TES aperture in the PMA, protecting the optics from dust accumulation.

Mini-TES has two spatial resolution modes. A solenoid-activated field stop can be removed from the optical path to provide an IFOV of 20 mrad, or inserted to provide an IFOV of 8 mrad. Baffles in the PMA define the stray energy field of view and are designed to minimize stray energy from outside the 20 mrad IFOV from entering the interferometer. The inside of the PMA is designed to minimize the stray background energy from the PMA itself.

During data acquisition, the PMA's elevation mirror and azimuth actuator are sequenced to generate a raster image of the scene. The scan mirror assembly can also be commanded to allow Mini-TES to view the internal and external calibration targets regularly in order to maintain instrument calibration during an image acquisition. The elevation and azimuth servos move and settle to each commanded position ±1 mrad. Elevation steps of up to 20 mrad in size take place within the 200 msec retrace period of the Mini-TES interferometer, while azimuth steps may take as long as 1 second. Slews to the calibration targets take significantly longer..

The Mini-TES telescope at the base of the PMA is a reflecting Cassegrain configuration with a mirror diameter of 6.35 cm, a focal ratio of f/12, and an intermediate field stop that feeds an approximately collimated beam into the Mini-TES interferometer. The 6.35-cm telescope diameter defines the minimum size of the Mini-TES beam; the beam diverges further at an angle of either 8 or 20 mrad, depending on the resolution mode chosen. The optical design provides for more than 85% of the encircled energy to be contained in an area equal to a single IFOV, 98% within an area equal to 2×2 IFOV, and 99.8% within an area equal to 3×3 IFOV. Focus is maintained from 2 meters to infinity, with a blur of no more than 15% of an IFOV at infinity focus.

The Mini-TES Michelson interferometer uses the same flexure-mounted linear motor mechanism and drive electronics as the Mars Observer (MO)/Mars Global Surveyor (MGS) TES instrument. The system uses a 980-nm interferometer to generate interference fringes that control the linear drive servo and time the acquisition of the IR spectrometer data samples. The design is simplified from the TES by combining the infrared and visible counting interferometers into one interferometer at one end of the motor drive and replacing neon bulbs with redundant laser diodes. Double-sided interferograms at a spectral resolution of 10 cm^{-1} are obtained with a mirror travel distance of 0.55 mm in 1.8 sec. A voltage ramp is used to drive the mirror at a fixed velocity, and position feedback is obtained from a linear voltage displacement transducer. Optical switches sense beginning of scan and synchronize the interferometer with the elevation and azimuth drive motors.

Mini-TES uses a single uncooled deuterated triglycine sulfate pyroelectric detector sized to define the instrument's 20-mrad IFOV. The IFOV, dwell time, and interferometer scan rate have been selected to produce frequencies in the range of 15 to 120 Hz which is the range over which minimum noise equivalent spectral radiance (NESR) can be achieved. The detector provides the necessary performance over a temperature range from –10 to +20°C and with reduced performance from –40 to +35°C.

The NESR of the Mini-TES for a single spectral accumulation interval at 10 µm observing a scene at 270 K and 20 mrad will be $<1.25 \times 10^{-8}$ W cm^{-2} sec^{-1} sr^{-1}, corresponding to a signal-to-noise ratio (SNR) of at least 450 for co-addition of two observations. Radiometric calibration of Mini-TES over its full spectral range will be performed with an absolute accuracy of 5% or better and a relative precision (pixel-to-pixel) of 2% or better, viewing a 270 K blackbody. The internal calibration target is located inside the head of the PMA, and the external target is located on the deck of the rover. Both targets have V-grooved surfaces and are coated with high emissivity paint. Temperature sensors affixed to both targets have an absolute accuracy of ±0.2°C and a precision of ±0.1°C.

The instrument's electronics are based on the electronics of the MO/MGS TES. A 14.515 MHz internally-generated clock signal provides the control timing for the interferometer motor controller and synchronizes the scan timing and data collection events with the rover computer. Detection of start of scan by the optical switches also signals to the rover computer that data collection has begun. This signal triggers an internal timer that initiates retrace of the interferometer mirror after 1.8 seconds. Signals from the detector are fed through a pre-amplifier, variable gain post-amplifiers for each field of view, an analog multiplexer, a 16-bit A/D converter, and into an output buffer.

Mini-TES begins collecting data at the application of power. The instrument acquires data in a cyclic fashion, with a period of two seconds corresponding to the Michelson mirror scan followed by its retrace. Spectral integration is coordinated with the PMA elevation and azimuth drive mechanisms using the rover computer. On each two-second period (known as one ICK), the hardware fills up the Mini-TES data buffer with header data, interferogram data from the selected spectrometer field of view, and the telemetry data.

Mini-TES flight software controls the transfer of the data from the Mini-TES data buffer to the rover CPU memory. Once the Mini-TES data is available in the rover memory, the flight software performs a Fourier transform on the interferogram in order to generate a spectrum. It then performs data aggregation in order to reduce the total volume of data to be downlinked. Separate programmable data aggregation modes in the spatial domain (averaging spectra from consecutive ICKs) or in the spectral domain (averaging data from contiguous spectral points) are available. Data volume is further reduced via lossless compression using a Rice algorithm. Compressed data then undergoes final formatting, packetization, and transfer of the packets to rover data storage for downlink.

The rover computer issues commands to PMA motor driver circuitry in order to synchronize the mirror movements to the Mini-TES data acquisition. Direct commands from the rover computer control instrument power and selectable gain state, field of view, motor on/off, laser heater on/off, redundant start-of-scan optical switches, and redundant laser diodes.

Mini-TES operates primarily during mid-day (10 a.m. to 3 p.m. local time) to obtain high-quality spectral measurements of emitted infrared energy. Nighttime observations may be obtained to measure surface and atmospheric temperatures of the full diurnal cycle for thermophysical and boundary layer studies.