THE 1994 LABORATORY CALIBRATION OF TIMS

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1. INTRODUCTION

This summary describes the spatial, spectral, and radiometric calibration of Thermal Infrared Multispectral Scanner (TIMS) performed at the Jet Propulsion Laboratory (JPL) Thermal Infrared Calibration Facility (TIRCAL) between May and August, 1994. The 1994 calibration of TIMS was the first to make use of the new EXABYTE (8mm helical-scan tape) recording system. With the new recorder, the TIMS data tapes may be read directly on any computer system that has an EXABYTE tape drive. We analyzed the calibration data sets using image processing procedures written in Interactive Data Language (IDL, Research Systems, Inc., Boulder, CO 80303).

2. SPATIAL CALIBRATION

The purpose of the spatial, or geometric, calibration was to verify the instantaneous field of view (IFOV) of TIMS in the scan line, or horizontal, and flight line, or vertical, directions. The equipment required for the spatial calibration tests included a large flat mirror with a 45° mount, a collimator (1 m focal length), a translation stage (with controller), thin (0.3 mm diameter) nickel-chromium (NiCr) wire, an oscilloscope, and various power supplies. The accuracy and precision of the translation rate of the translation stage was determined with a micrometer and stop watch.

TIMS was mounted on a support frame approximately 0.3 m above the surface of an optical bench. The mirror was positioned beneath TIMS to reflect the output of the collimator into the instrument. The NiCr wire was mounted on the translation stage and heated to incandescence. The hot wire was positioned next to the input port of the collimator such that the image of the wire was in the focal plane of the collimator. The optimum alignment of the folding mirror was found by moving the mirror and checking the TIMS response with the oscilloscope.

The hot wire was translated in both the horizontal and vertical directions, relative to the collimator. The movement of the hot wire across the TIMS field stop mapped the field stop into the image data. Profiles of these data taken perpendicular to the TIMS scan direction resembled Gaussian functions. The width of these functions at half the maximum amplitude (full width-half maximum, or FWHM) was a measure of the IFOV of TIMS. The following table summarizes the results of the spatial calibration.

TIMS Channel	Horizontal IFOV (mrad)	Vertical IFOV (mrad)
1	2.65 $\pm$ 0.096	2.58 $\pm$ 0.093
2	2.66 $\pm$ 0.094	2.64 $\pm$ 0.093
3	2.62 $\pm$ 0.095	2.50 $\pm$ 0.093
4	2.61 $\pm$ 0.090	2.71 $\pm$ 0.095
5	2.54 $\pm$ 0.096	2.69 $\pm$ 0.095
6	2.49 $\pm$ 0.105	2.56 $\pm$ 0.094

3. SPECTRAL CALIBRATION

The equipment required for the spectral calibration of TIMS was similar to that required for the spatial calibration, with the substitution of a monochrometer and infrared glower (source) for the hot wire and translation stage. The spectral and radiometric characteristics of the monochrometer and glower were determined prior to the spectral calibration of TIMS. The accuracy and precision of the monochrometer scan rate was also determined.

The monochrometer was positioned at the input port of the collimator such that the monochrometer slit was in the focal plane of the collimator. The monochrometer was scanned between 7 and 13 μm. Profiles of the TIMS data taken perpendicular to the scan direction produced "raw" spectral response functions for each TIMS channel. Knowledge of the scan rates of the monochrometer (μm per second) and TIMS (scans per second) allowed us to determine the spectral output of the monochrometer at each TIMS scan line. The raw response functions were filtered to remove noise and corrected for the spectral and radiometric responses of the monochrometer and glower. The results of the spectral calibration are summarized in the following table, and a plot of the response functions is found in Figure 1. The tabulated response functions are available upon request.

TIMS Channel	FWHM (μm)	Peak Position (μm)
1	0.374 $\pm$ 0.011	8.402 $\pm$ 0.050
2	0.358 $\pm$ 0.013	8.766 $\pm$ 0.052
3	0.379 $\pm$ 0.016	9.212 $\pm$ 0.055
4	0.690 $\pm$ 0.021	10.012 $\pm$ 0.060
5	0.888 $\pm$ 0.028	10.630 $\pm$ 0.063
6	0.659 $\pm$ 0.035	11.512 $\pm$ 0.068

4. RADIOMETRIC CALIBRATION

For the radiometric phase of the calibration, an extended-area blackbody was positioned below the TIMS support frame. The large surface area of the blackbody completely filled the TIMS aperture. The purpose of the radiometric calibration was to determine if the TIMS estimates of the blackbody temperatures agreed with the temperatures set on the blackbody controller.

4.1. Radiometric Precision

The uniform temperature distribution across the surface of the extended-area blackbody allowed us to evaluate the radiometric precision of TIMS, which is usually reported as the noise equivalent delta temperature (NEΔT). The NEΔT is the smallest change in temperature that TIMS can discriminate in the presence of noise. Analogously, the deviation in TIMS temperature estimates over a surface with a uniform temperature distribution is a measure of the NEΔT.

Figure 2 is a plot of the standard deviations of temperature estimates in each of the six TIMS channels against the temperature of the extended-area blackbody (Channel 1 = +, 2 = $*$, 3 = $\diamond$, 4 = Δ, 5 = $\square$, 6 = X). At the level of one standard deviation, the NEΔT is better than 0.17 °C in all six TIMS channels.

4.2. Radiometric Accuracy

Figure 3 is a plot of the TIMS temperature estimates for the extended-area blackbody against the set-point temperatures of the blackbody. The experiments were performed at two different combinations of settings for the reference blackbodies internal to TIMS. The solid line (Fig. 3) represents the TIMS temperature estimates recovered with internal settings of 20 and 45 °C, while the broken line represents the TIMS temperature estimates recovered with internal settings of 25 and 50 °C. The latter settings prevented TIMS from saturating when observing high-temperature surfaces.

In general, the TIMS estimates were slightly higher than the set-point temperatures. This effect was slightly more pronounced when the internal blackbodies were set to 25 and 50 °C. However, the TIMS temperature estimates were within 0.8 °C of the set-point temperatures for all of our calibration experiments.

5. CONCLUSIONS

The results of our calibration experiments indicate that TIMS is capable of estimating surface temperatures with an absolute accuracy of 1.0 °C. The instrument can detect changes in surface temperature of at least 0.2 °C for a surface temperature ranging between 20 and 45 °C. These conservative accuracy levels are based on the worst-case results of the calibration experiments.

It is important to realize that these accuracy levels were achieved in the absence of a turbulent wind blast (aside from the air-flow generated by the TIMS scan mirror). In addition, we had a short atmospheric path (< 0.5 m) and near-complete knowledge of the emissivity of our target surface. The in-flight accuracy of TIMS, with turbulent winds in the instrument bay, long paths through the atmosphere, and incomplete knowledge of the emissivity of the ground, will certainly be lower than the laboratory accuracy.

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FIGURE 1: TIMS SPECTRAL RESPONSE

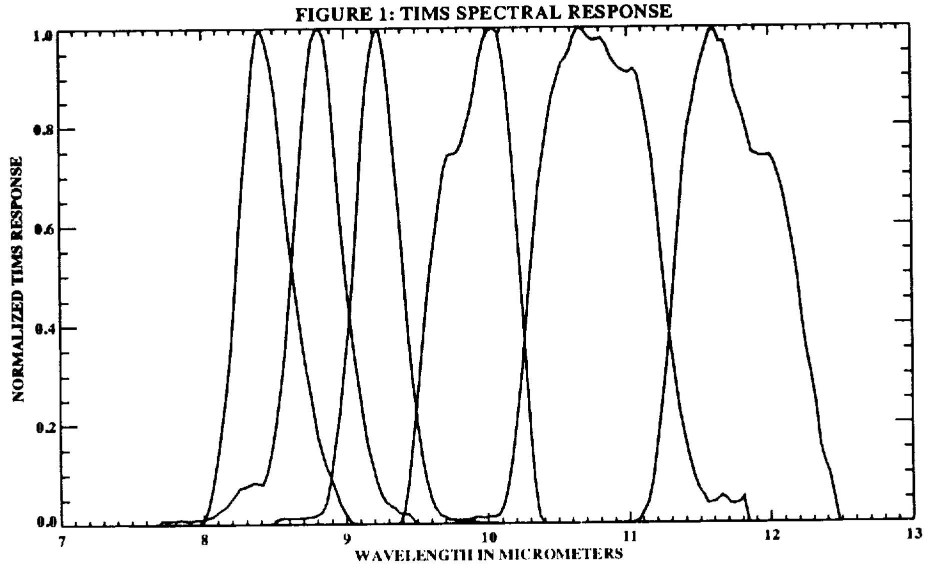

FIGURE 2: TIMS RADIOMETRIC PRECISION

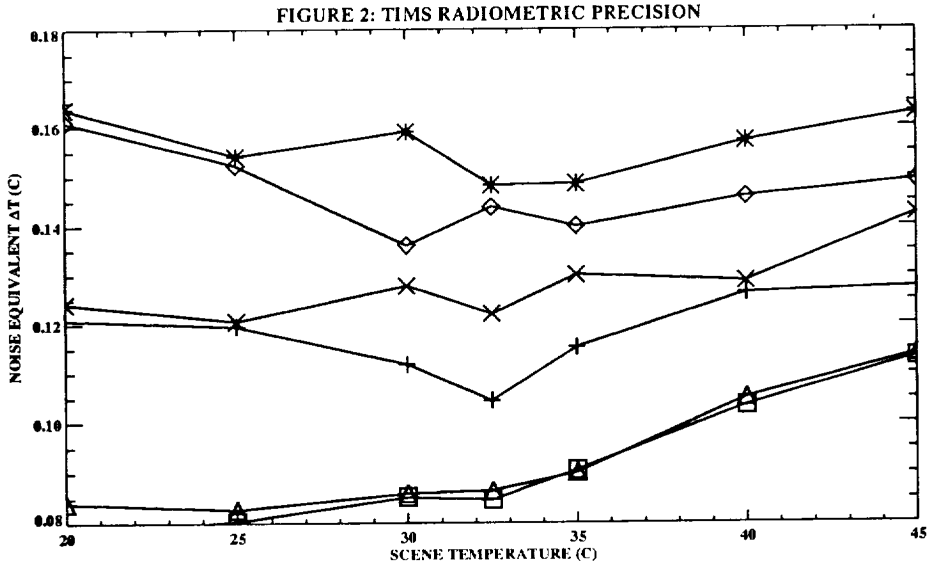

FIGURE 3: TIMS RADIOMETRIC ACCURACY