

# **TROPOSPHERIC EMISSION SPECTROMETER**

**(TES)**

## **INSTRUMENT ACCEPTANCE CRITERIA**

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# INTRODUCTION

- **Before being declared “ready for flight”, the P.I. must certify that TES will provide the necessary science.**

**Consequently, a number of acceptance criteria have been established that must be met prior to this date**

- . **The necessary tests, characterizations and calibrations will occur at different stages in the evolution of the instrument and are identified on the following pages.**

# TEST DEFINITIONS

## ● SUB-SYSTEM LEVEL

Tests that can be performed on the bench at room temperature.

## ● INTEGRATION & TEST LEVEL

Tests that must be performed at operating temperatures (cryogenic) in a Thermal Vacuum Chamber (TVC) but requiring internal adjustments. System can be incomplete. Remote control is very helpful.

## ● CHARACTERIZATION LEVEL

Tests in the TVC with a partially-completed system. No adjustments should be necessary.

## ● CALIBRATION LEVEL

Tests in the TVC with the complete system.

# ACCEPTANCE CRITERIA (I)

## TESTS AT SUB-SYSTEM LEVEL

### Pointing Control System (PCS) Calibration

**It is essential to the retrieval process that we know where TES is looking. From real-time knowledge of the spacecraft attitude, we shall determine the angles and rates to which the PCS must be set for both nadir and limb observations.**

#### *Acceptance Criterion*

*That the relationship between the boresight vector direction and the PCS encoders be known to 6  $\mu$ rad.*

# ACCEPTANCE CRITERIA (II)

## TESTS AT INTEGRATION & TEST LEVEL

### Interferometer Alignment

In order for TES to operate as a Fourier Transform spectrometer (FTS), it must first function as a 2-beam interferometer (at 180 K).

### *Acceptance Criteria*

- 1) That the visible fringe pattern (following alignment) consists of uniformly-illuminated concentric rings whose vertical and horizontal diameters are the same to within 10%.*
- 2) That the end-to-end shift of the center of the fringe pattern be less than 25% of the diameter of the central fringe at maximum path difference.*

## ACCEPTANCE CRITERIA (III)

### Detector Focus

Obviously, in order to maximize signal-to-noise ratio, TES must be in focus. This is non-trivial for us because we have 4 independent 1x16 detector arrays, each element of which must be simultaneously in focus

### *Acceptance Criterion*

*That no further improvement in Strehl Ratio can be achieved (theoretical values are not yet established).*

### Detector Co-Alignment

TES is an imaging system. We want equivalent pixels from each of the 4 detector arrays to be seeing the same scene (optically conjugate).

### *Acceptance Criterion*

*That all pixels are co-aligned to within 25% of a pixel width ( $\equiv 188 \mu\text{rad}$ ).*

## ACCEPTANCE CRITERIA (IV)

### TESTS AT CHARACTERIZATION LEVEL

#### Pixel Uniformity

Non-uniformity of pixel response (within a single pixel) impacts the Instrumental Line Shape (all TES pixels are off-axis). We need to know what this is in order to correct for the effect.

#### *Acceptance Criterion*

*That all pixels be mapped to a precision of not worse than 10%, to be verified by repeating the mapping of at least 1 pixel.*

## ACCEPTANCE CRITERIA (V)

### Modulation Index

**Modulation Index (compounded from the 4RT product, beam shear and wavefront non-uniformity), is one of the most important parameters for an FTS because it directly impacts the signal *without* reducing the noise.**

### *Acceptance Criterion*

*That the average modulation index over the range 650-3050 cm-1 exceed 0.7*

## ACCEPTANCE CRITERIA (VI)

### TESTS AT CALIBRATION LEVEL

#### Instantaneous Field of View (IFOV)

**IFOV directly affects the retrieval process (indeed, is an input parameter)**

#### *Acceptance Criterion*

*That the IFOV be known to a precision of 10%, verified by repeating the measurement of at least 1 pixel.*

## ACCEPTANCE CRITERIA (VII)

### Cross-Talk

With detector arrays, there is always the problem that radiation which *ought* to fall on a given pixel in fact falls on” adjacent ones. Aberrations and diffraction make this inevitable, but electrical coupling can also occur. It must be known so that appropriate corrections can be applied.

### *Acceptance Criterion*

*That the signals in unilluminated pixels be less than 10% of that in the illuminated pixel.*

## ACCEPTANCE CRITERIA (VIII)

### Noise Equivalent Source Radiance (NESR)

**Our calculations of expected TES performance are based on a radiometric model of the system. We need to know that our expectations are being met.**

#### *Acceptance Criterion*

*That the NESR be no more than 10% greater than that predicted by the system radiometric model.*

## ACCEPTANCE CRITERIA (IX)

### Instrumental Line Shape (ILS) and Frequency Accuracy

Essential elements of the retrieval process are a) knowledge of the real ILS and b) correction of the frequency scale for off-axis effects and, at the limb, for Doppler Shifts.

#### *Acceptance Criteria*

*1) That the spectral line frequencies observed by each pixel are no more than  $0.00025 \text{ cm}^{-1}$  from the positions predicted by the pixel model (modified by the information from the pixel non-uniformity test);*

*2) That the Instrumental Line Shapes extracted from these data deviate no more than 5% in relative amplitude from that predicted by the pixel model (modified by the information from the pixel non-uniformity test).*

# ACCEPTANCE CRITERIA (X)

## Internal Black-Body Accuracy

Emission-mode instruments such as TES require accurate radiometric calibration if the retrievals are to succeed. The internal black-body source is an essential ingredient of this (we use space as a cold reference).

### *Acceptance Criteria*

- 1) That the temperature error of the internal Black Body be known to  $\pm 0.1$  C;*
- 2) That the emissivity errors of the internal Black Body be known to  $\pm 0.005$*

## ACCEPTANCE CRITERIA (XI)

### Channeling Stability

Despite our best efforts (wedging beamsplitter/compensator and all windows & filters), our aircraft instrument (AES) still shows channeling that clearly changes with instrument temperature (cause still unknown). We are therefore concerned that TES will also, and we need to be able to calibrate it out.

### *Acceptance Criteria*

- 1) That the channeling amplitude be less than 10% at any frequency;*
- 2) That the smallest channeling period be greater than  $1 \text{ cm}^{-1}$ ;*
- 3) That the channeling at high and low resolution be identical in frequency and amplitude to 1%.*