

GAF-14-057

5th Earth Observing System Investigator Working Group
Calibration & Data Product Validation Panel

Apr. 7-9, 1992 at Broker Inn

**ASTER TIR Subsystem &
Calibration**

517-43
171308
P-24
N94-23612

Hirokazu OHMAE
FUJITSU LIMITED

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Outline

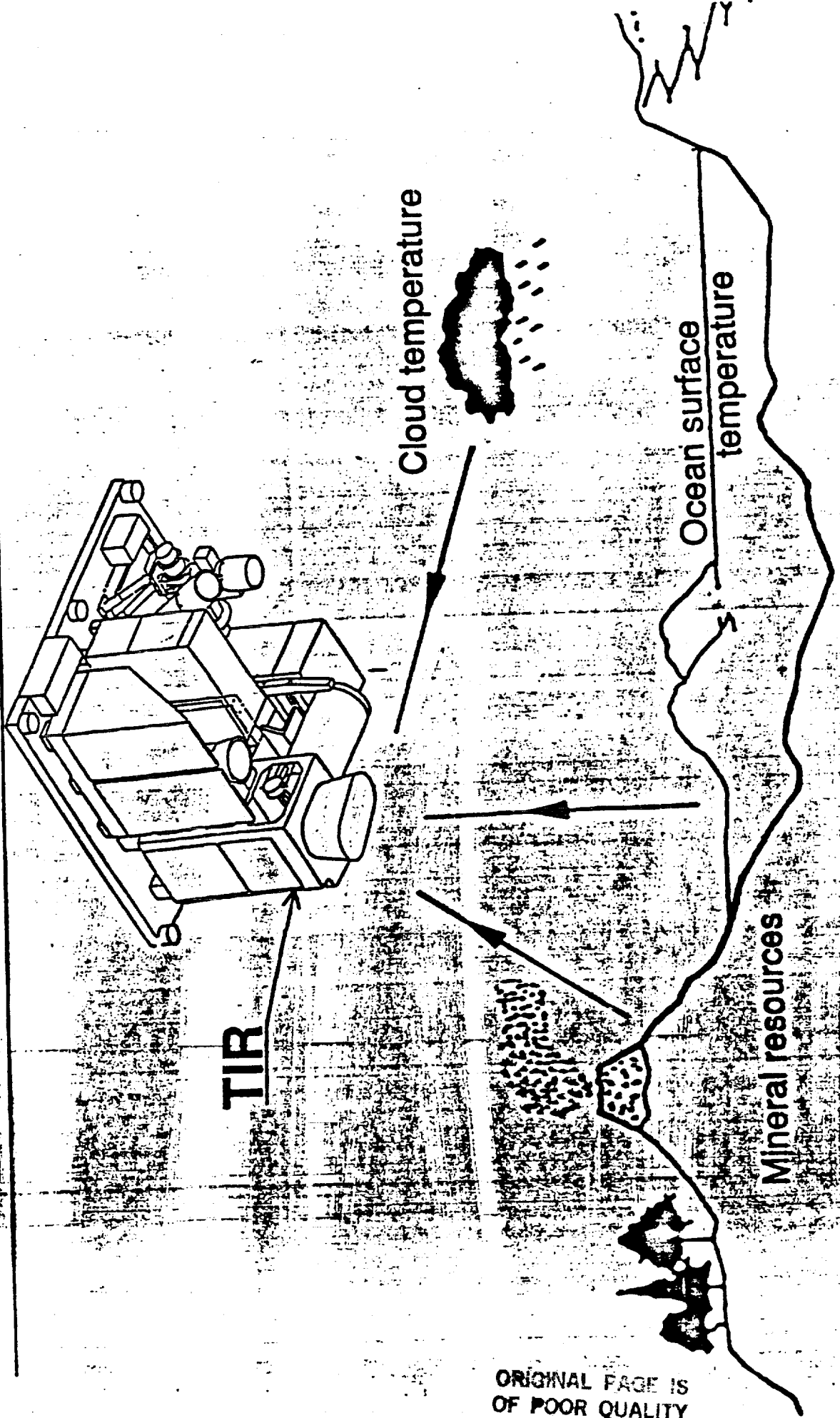
1. Purpose of TIR
2. Major functions
3. Characteristics and design of various components
4. Calibration

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Functions

- to acquire image data on the earth's surface in thermal infrared wavelength band, using mercury cadmium telluride (HgCdTe) detectors, the detectors are cooled about 80K
- to convert the obtained image data into the digital data to meet the Common Signal Processor(CSP) interface, and output the signals
- pointing function in cross-track direction to get the wide swath of 232km
- to calibrate the whole TIR with the blackbody on orbit, then the amplifier and subsequent transmission units are calibrated electrically

TIR General Specifications

| | | |
|--------------------------|---------------|--|
| Spectral coverage | Band10 | 8.125 to 8.475 μm |
| | Band11 | 8.475 to 8.825 μm |
| | Band12 | 8.925 to 9.275 μm |
| | Band13 | 10.25 to 10.95 μm |
| | Band14 | 10.95 to 11.65 μm |

Swath width

60 km

Geometric Resolution

90 m

IFOV

127.6 μrad

MTF at Nyquist freq

0.25

Signal Quantization level

12bit

Pointing Coverage

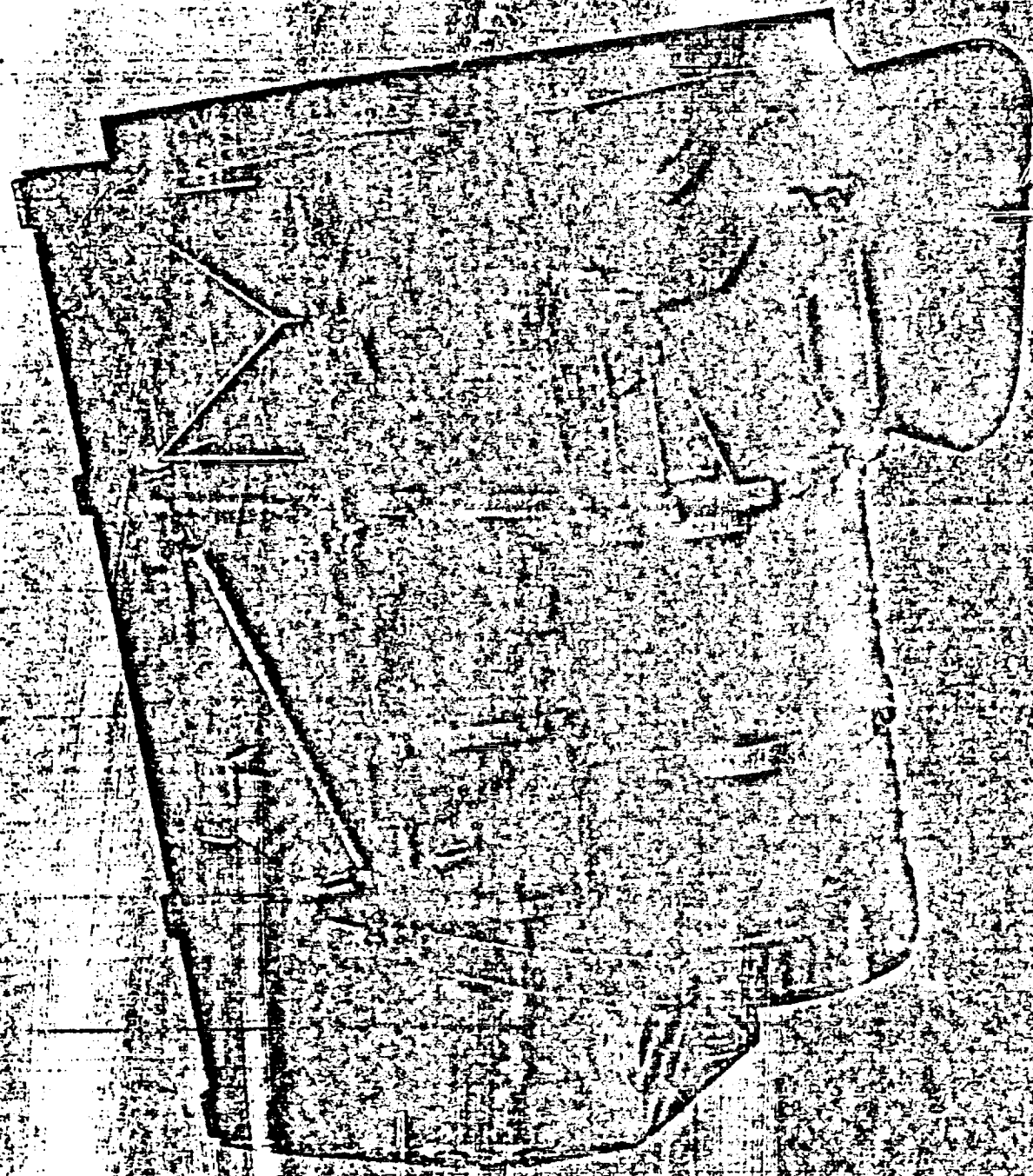
± 8.55 deg

Radiometric resolution

NEAT: < 0.3 K

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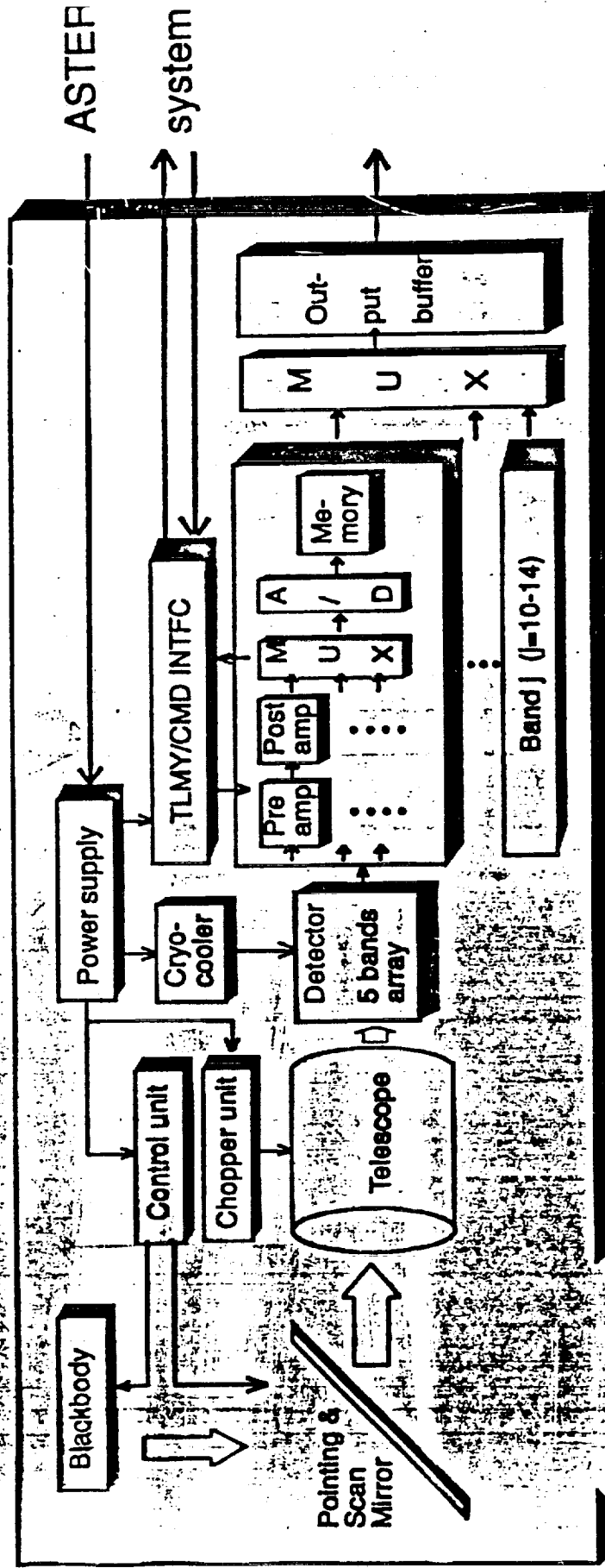
away view of the TIR



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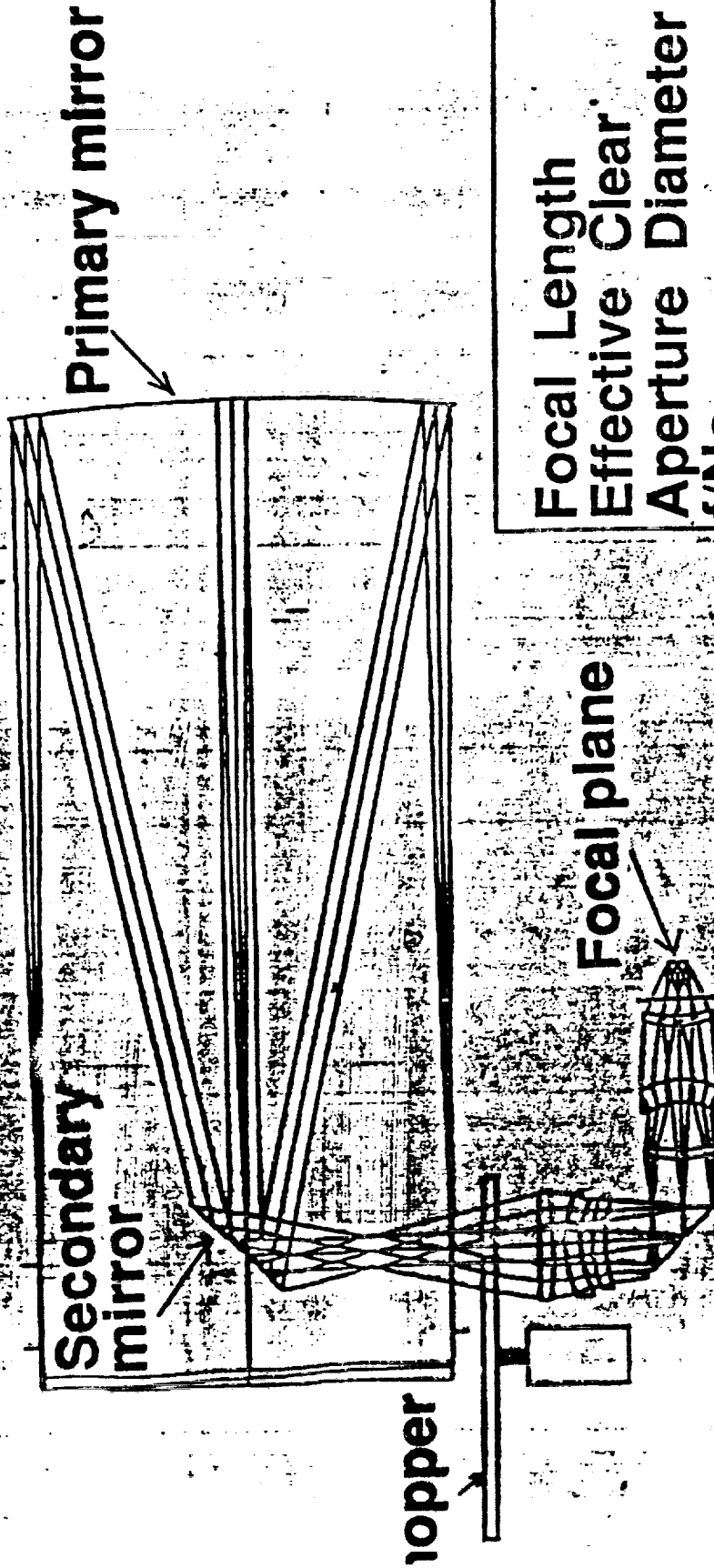
TIR block diagram



Thermal emission from the earth

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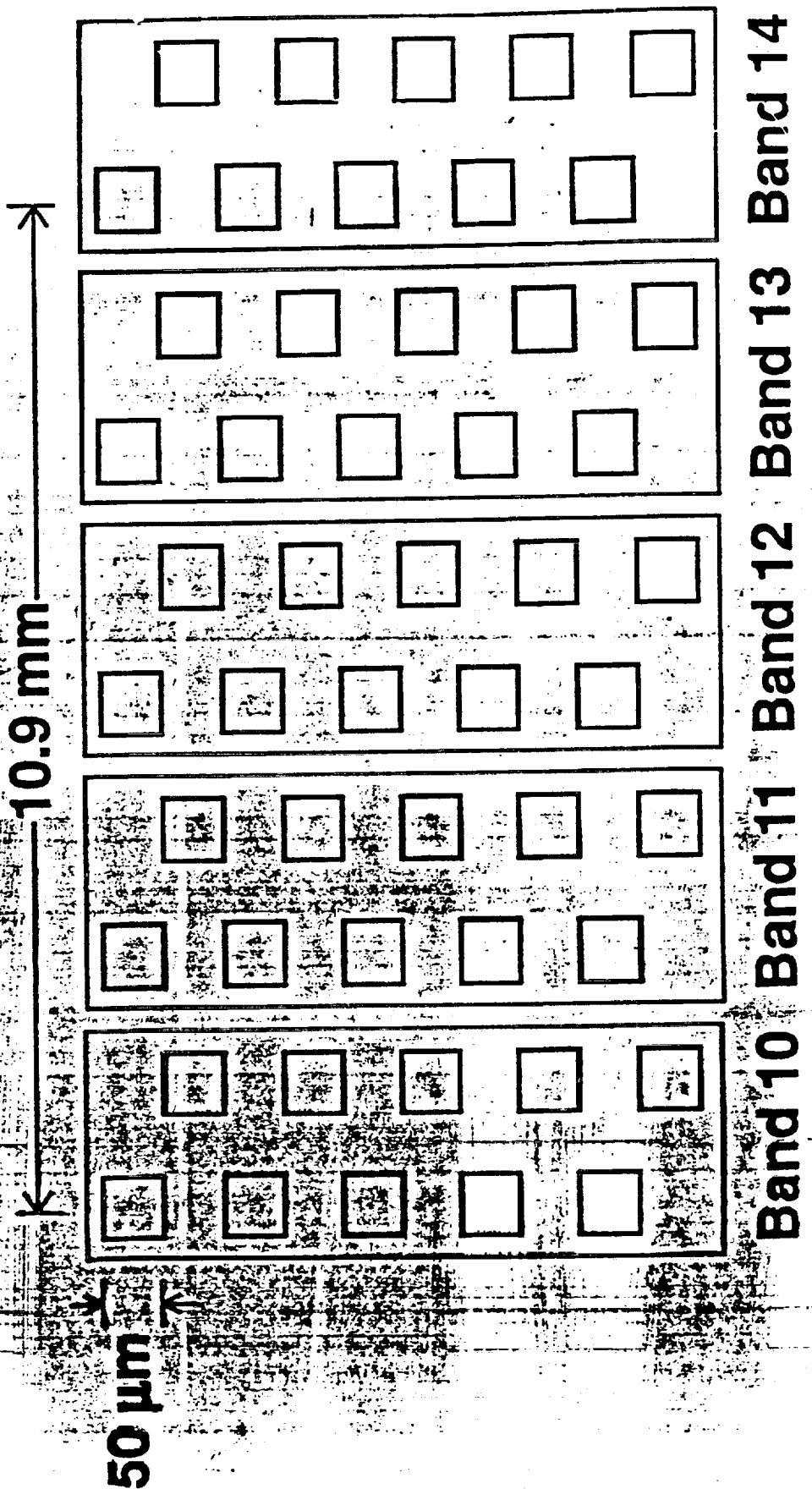
Telescope



| | |
|--------------------------|--------|
| Focal Length | 392 mr |
| Effective Clear Aperture | 240 mr |
| Diameter | 1.57 |
| f/No | 1.67 |
| FOV | de |

Newtonian Catadioptric

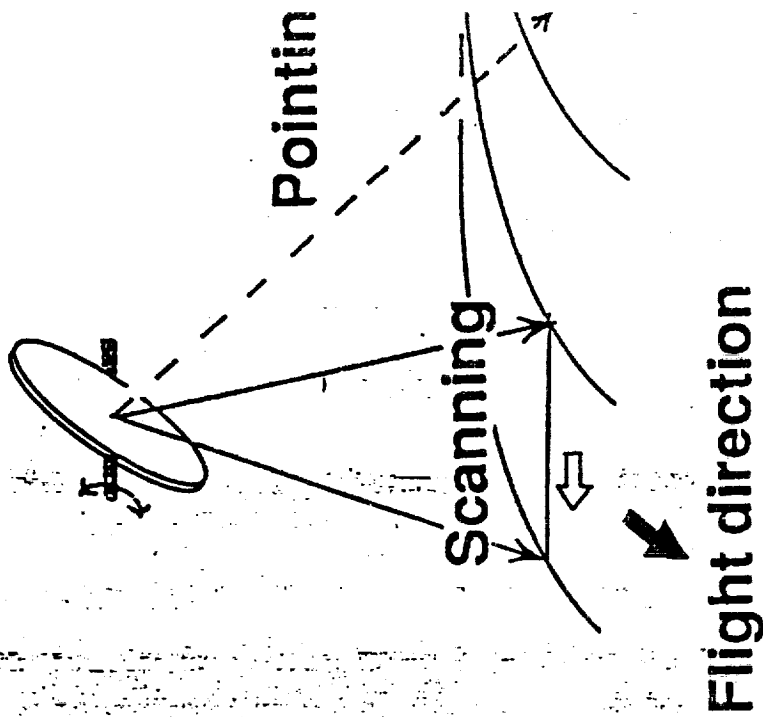
HgCdTe Detectors



Focal plane projection

Scanner

| | |
|-------------------------------------|--|
| <p>Pointing and Scanning</p> | <p>Scanning method Mechanical scan by vibration of scan mirror ± 3.4deg (at pointing center)</p> <p>Pointing(off-nadir) scan mirror ± 8.55 deg (off-nadir angle)</p> <p>Mirror size 460mm X 280mm</p> <p>Mirror material Beryllium</p> |
|-------------------------------------|--|



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Calibration Accuracy Requirement

| | |
|----------------|----|
| 200 K to 240 K | 3K |
| 240 K to 270 K | 2K |
| 270 K to 340 K | 1K |
| 340K to 370 K | 2K |

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Calibration methods

Pre-launch calibration

- TIR acceptance test(AT) ---> calibration data map ---> characteristics equation of TIR and data set of calibration
- Cross calibration with other EOS-AM1 sensors

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Calibration methods

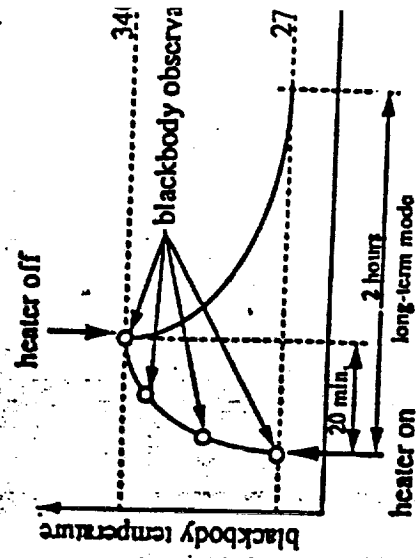
In-flight calibration

calibration methods

| calibration | mode | input |
|------------------------|------------------------|-----------------------|
| optical calibration | short-term calibration | blackbody radiation |
| electrical calibration | long-term calibration | blackbody radiation |
| | electrical calibration | step electric signals |

calibration data

| mode | blackbody temperature | calibration time |
|------------------------|--|--|
| short-term calibration | 270K | several ten seconds |
| long-term calibration | 270K, 340K | 20 minutes approx. (observation of blackbody) |
| | 3 temperature: 270K 300K 340K or more temperature | 2 hours approx. (heat-up & cool-down) |



Calibration methods

Usable data for calibration

- (1) Image data
 - digitized signal data (blackbody radiation) : same as observation data
 - blackbody temperature : inserted signal data
 - chopper temperature : ditto
 - detector temperature : ditto

| | | | |
|-----------------------------------|---------------|--------------|----------------|
| signal data (10-channel x 5-band) | detector temp | chopper temp | blackbody temp |
|-----------------------------------|---------------|--------------|----------------|

←----- 1 frame ----->

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Calibration methods

Usable data for calibration

(2) Monitor data/telemetry data

TIR temperature

a: primary mirror

b: secondary mirror

c: telescope barrel

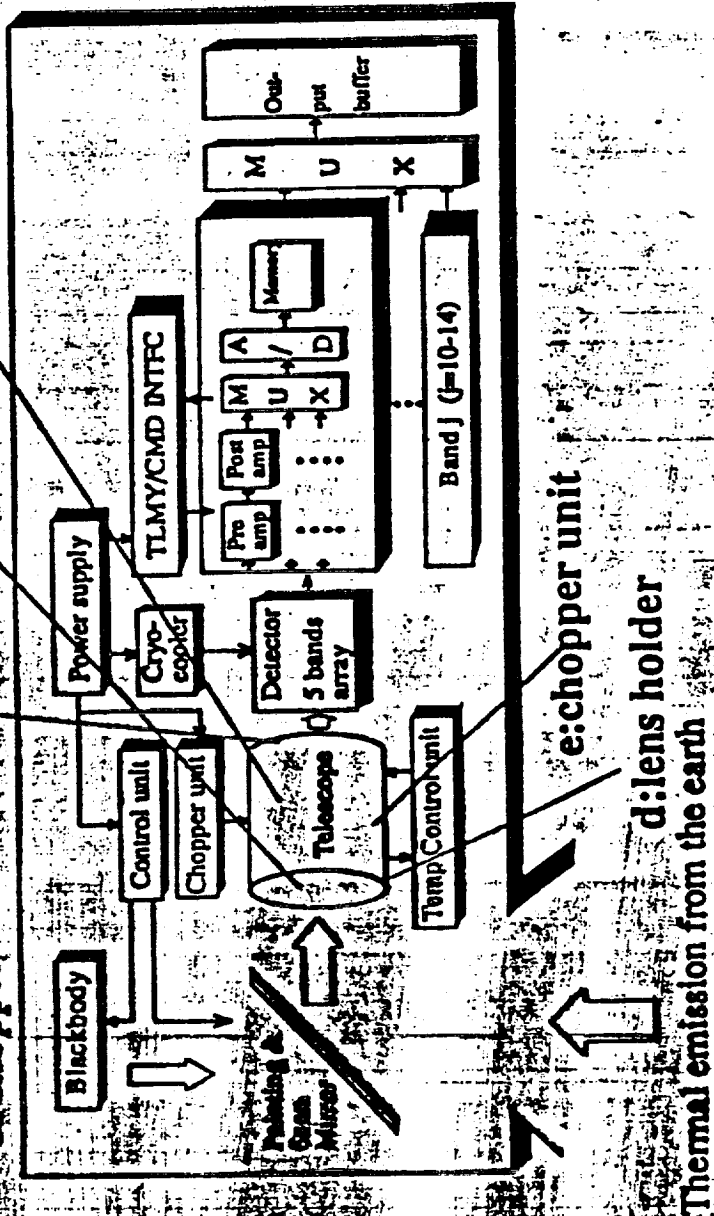
d: lens holder

e: chopper unit

a: primary mirror

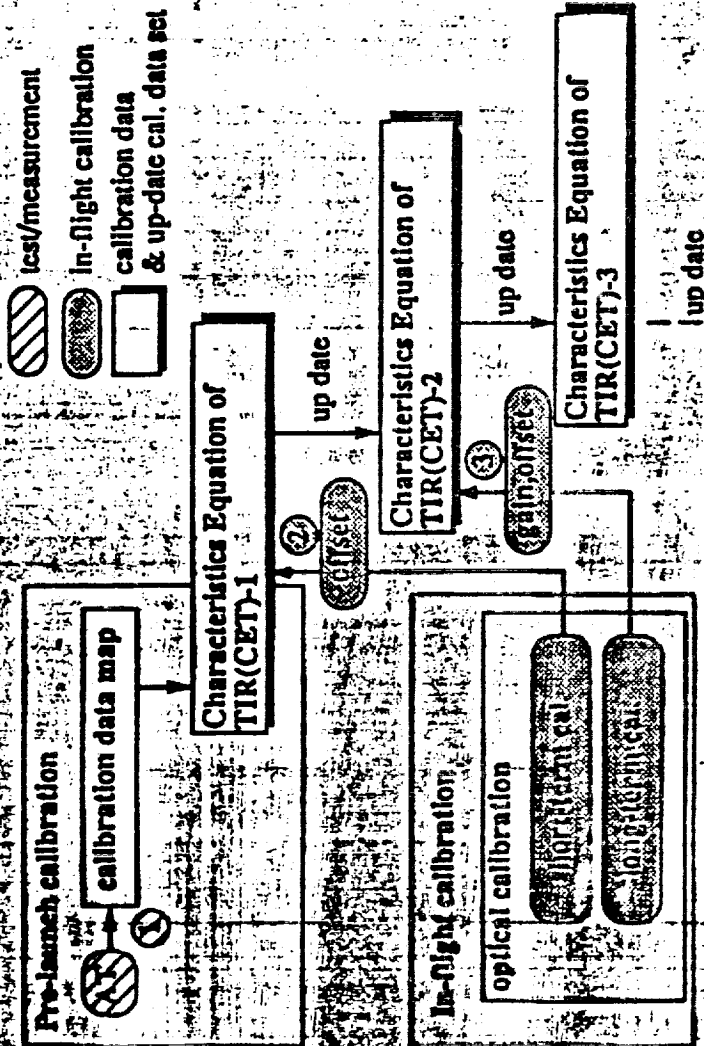
b: secondary mirror

c: telescope barrel



Calibration methods

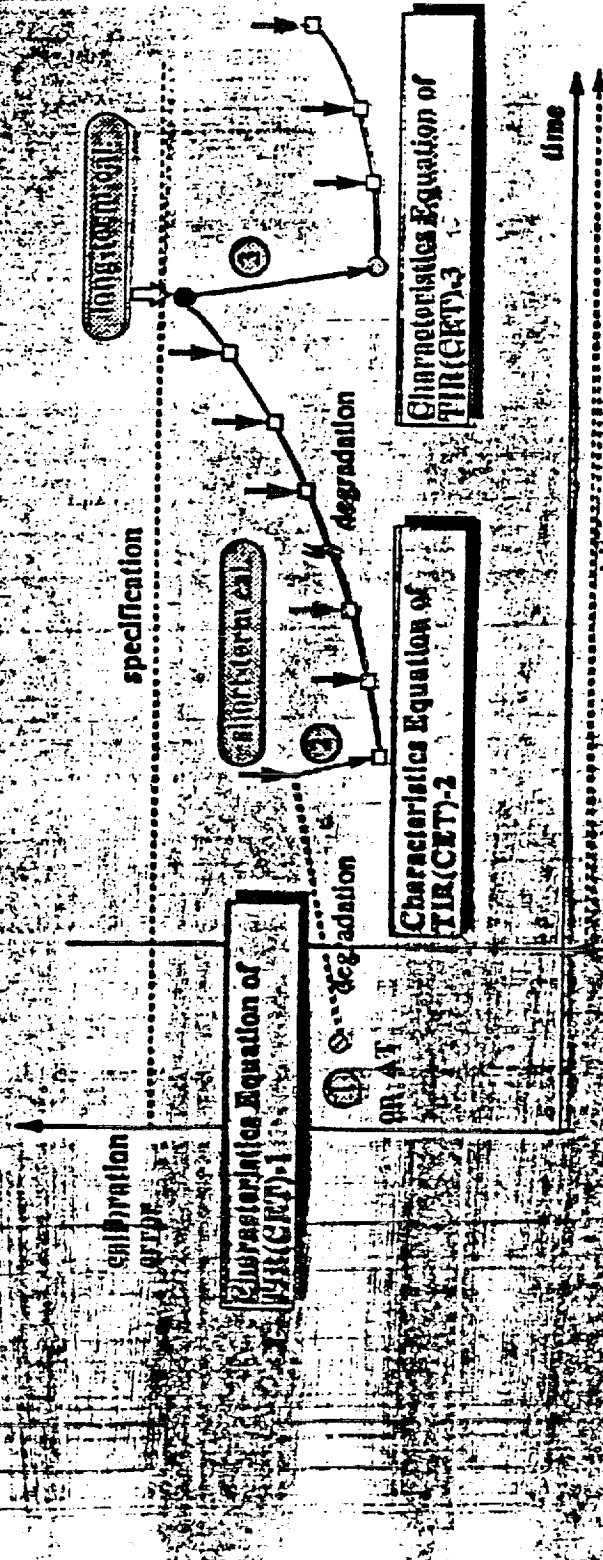
Calibration data management



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Calibration methods

Calibration data management



TIR calibration concept

Calibration methods

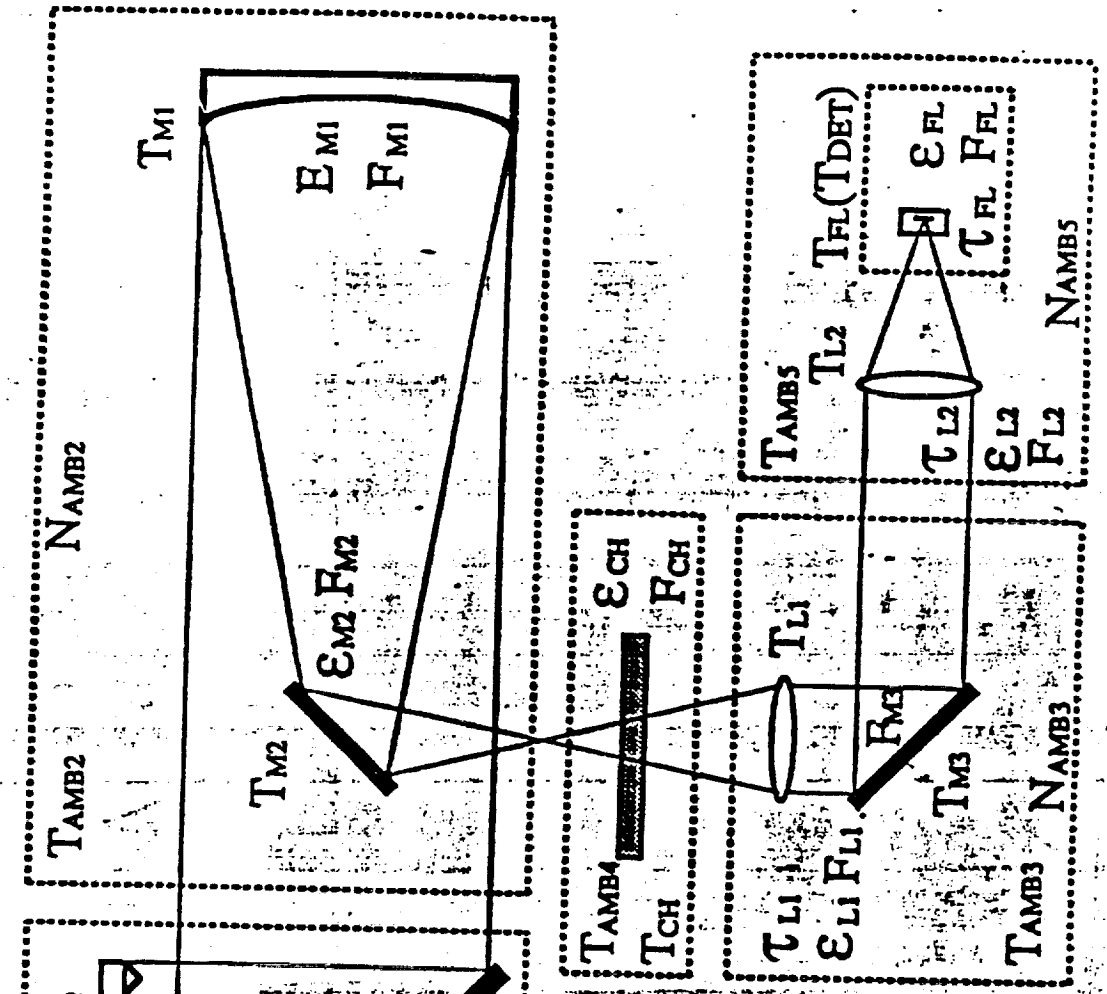
Summary of calibration methods

| stage | usable data | calibration |
|------------------------|--|--|
| Pre-launch calibration | calibration data map | <ul style="list-style-type: none"> - remove the fixed error - determine the characteristics equation |
| In-flight calibration | <ul style="list-style-type: none"> - image data - 1-temperature radiation - monitor data | <ul style="list-style-type: none"> - update of the data map ---> improve offset |
| | <ul style="list-style-type: none"> - image data - 3- or more temperature radiation - monitor data | <ul style="list-style-type: none"> - update of the data map ---> improve offset and gain and the characteristics equation |

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Mathematical model

Outline of mathematical model



- T_i : temperature of TIR components
- ϵ_i : emissivity of TIR components
- τ_i : transmittance of TIR components
- F_i : shape factor of TIR components
- N : radiation power

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Mathematical model

Value of mathematical parameter

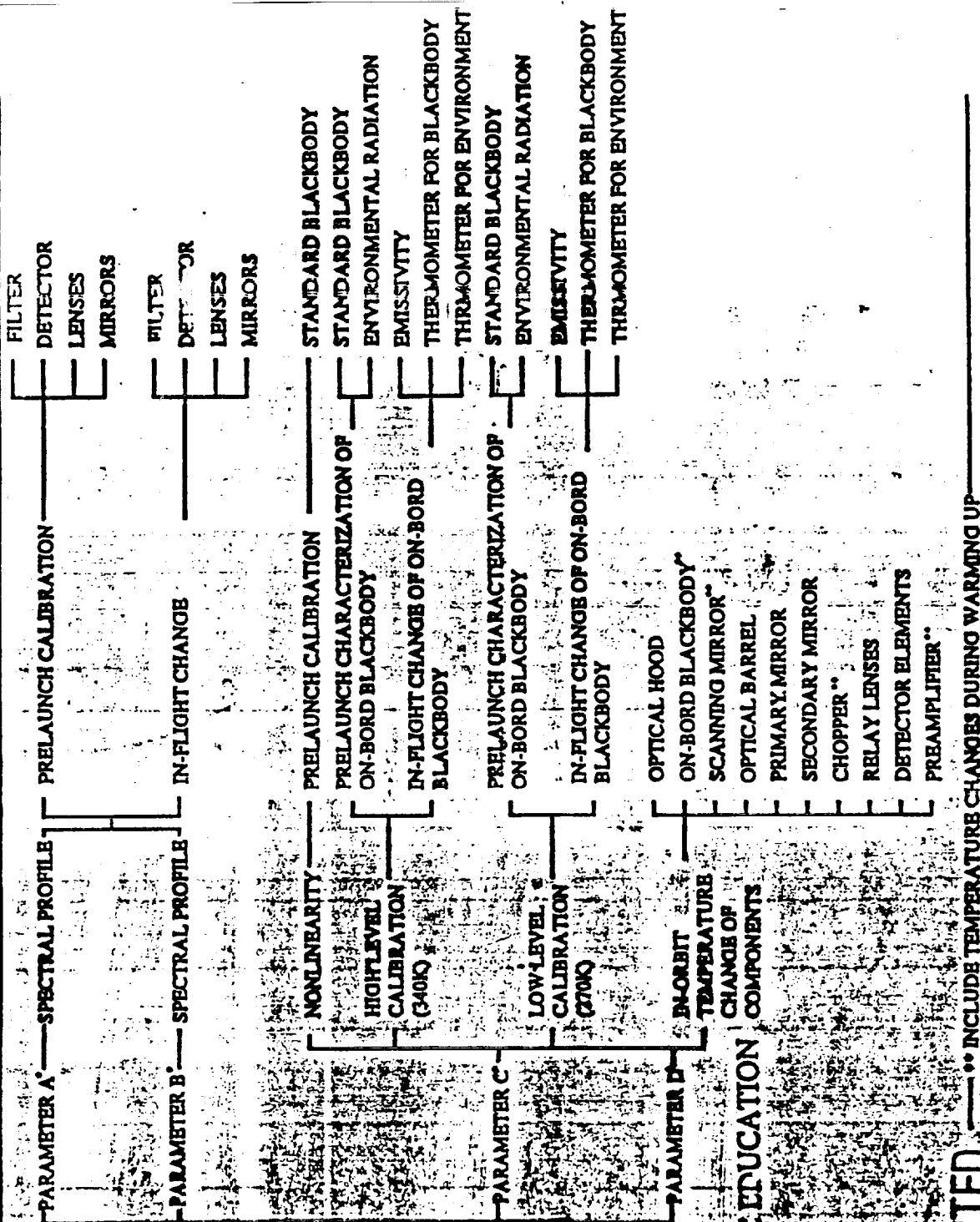
| stage | critical parameters | | comments |
|------------------------|--|--|--------------------------------------|
| | items | value for model | |
| Pre-launch calibration | emissivity accuracy of standard blackbody | $\epsilon=0.995$ $\Delta\epsilon=0.005$ | |
| In-flight calibration | emissivity degradation of on-board blackbody | BOL=0.990 EOL=0.980 | degradation test by using test piece |

Error Budget for TIR Temperature Scale Calibration

UNCERTAINTY OF TEMPERATURE SCALE
INTERPOLATION AND EXTRAPOLATION

| | |
|-------------|-------------|
| ± K at 200K | ± K at 300K |
| ± K at 240K | ± K at 340K |
| ± K at 270K | ± K at 370K |

at 8.3µm, 8.65µm, 9.1µm, 10.6µm, and 11.5µm



AMETERS IN CHARACTERISTIC EDUCATION

$$T = \frac{C}{\exp\left(\frac{C_2}{AT+B}\right) + D}$$

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— ** INCLUDE TEMPERATURE CHANGES DURING WARMING UP —

Error Budget for TIR Temperature Scale Calibration



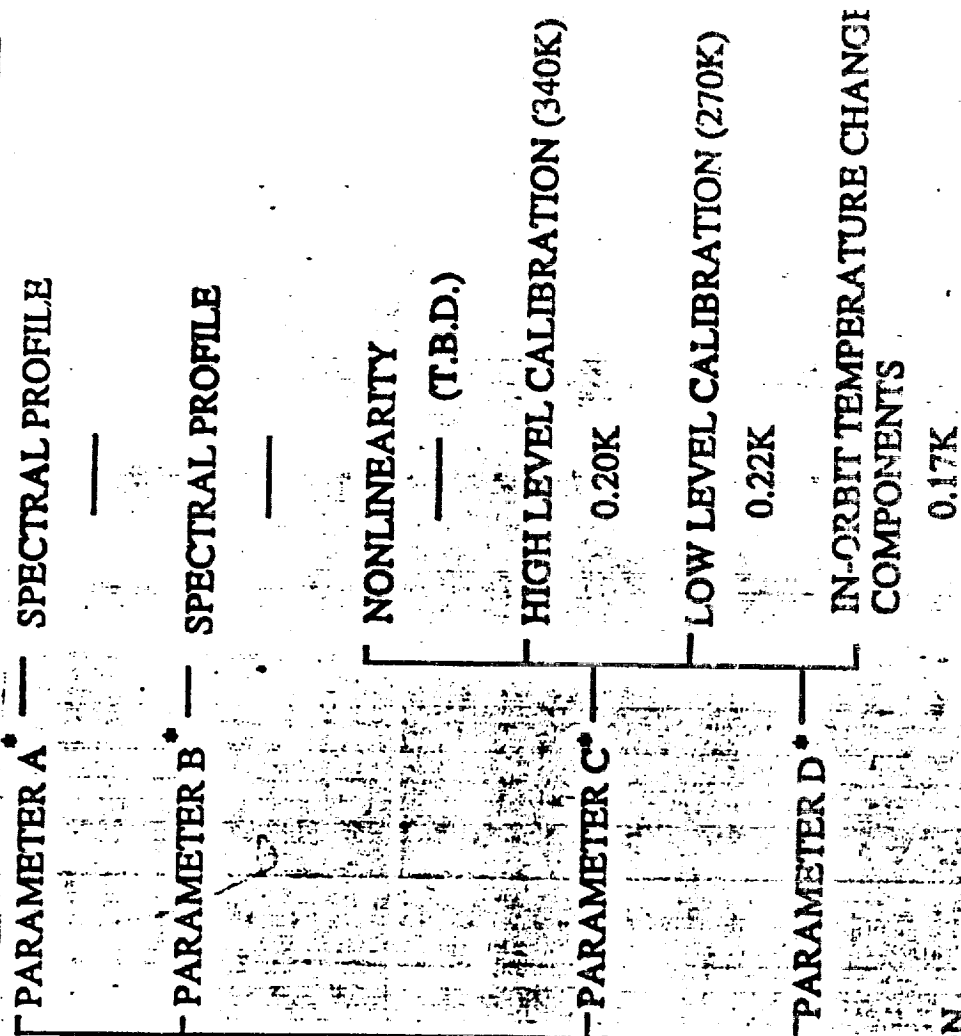
UNCERTAINTY OF TEMPERATURE SCALE BY INTERPOLATION AND EXTRAPOLATION

DISTRIBUTED VALUE

ACCURACY

| | |
|------------------|------------------|
| ± 2.9 K at 200K | ± 0.26 K at 300K |
| ± 0.79 K at 240K | ± 0.26 K at 340K |
| ± 0.27 K at 270K | ± 0.43 K at 370K |

at 8.3µm, 8.65µm, 9.1µm, 10.6µm, and 11.3µm.



* PARAMETERS IN CHARACTERISTIC EDUCATION

$$V(T) = \frac{C_1 - C_2}{AT+B} + D$$

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Cross-calibration

Application of cross calibration data

- Cross calibration is very effective method for validation of observation data
- Some requirements for TIR are shown as follows:
 - temperature range for cross calibration : 200K-370K
 - the minimum size of the cross calibration blackbody :
 - larger than 400 mm for full aperture which include pointing and scanning.
 - 330mm-diameter for just scanning

Cross-calibration

Kendall radiometer

- NASA/GSFC recommends to use the Kendall radiometer for round robin measurements of the instrument manufacture's standard blackbodies.
- Kendall radiometer includes the radiometer and measuring system.
- Our comments for using Kendall radiometer are as follows:

- It is better to use Kendall radiometer with the standard blackbody together with a transfer blackbody

- Kendall radiometer needs to fit configuration of the instrument manufacture's standard blackbody

- standard blackbody specifications and conditions for TIR as follows:

size : larger than 13-inch X 15-inch plate

surface figure : Hexaprismatic surface

temperature range: 100-400K

setting position : just in front of TIR aperture with hood

- We need Kendall radiometer in EM and PFM phase

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