14TH CONGRESS OF THE INTERNATIONAL SOCIETY FOR PHOTOGRAMMETRY

Commission n° VII
Groupe de travail n°G.VII/5
Genre : Communication

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"SPOT IN-FLIGHT CALIBRATION"

ABSTRACT

The french SPOT satellite designed by the Centre National d'Etudes Spatiales (CNES) will be launched by ARIANE in 1984. It includes two push-broom cameras called H.R.V. (Visible high resolution) using CCD (Charge Coupled Devices).

The in-flight calibration problems are :
- knowledge of the detectors spectral sensitivity
- comparison of the detectors sensitivity

The calibration method is to perform :
- an uniform illumination of all CCD by a lamp, which characteristics, in particular the spectral radiant flux, will vary during the flight and causes an in-flight lamp calibration to be required.
- a few CCD known illumination, coming from the sun, considered a spectral and absolute radiant flux standard.

The calibration device is set outside the camera and includes :

- a tungsten lamp
- a fiber optics assembly to collect the sun light
- some lenses.

INTRODUCTION

The SPOT project (Satellite Probatoire d'Observation de la Terre) is an Earth Remote sensing satellite designed by the Centre National d'Etudes Spatiales (CNES). The first mission of this satellite will be centred on the territory resources exploitation.

It includes, two push-broom cameras, called HRV (High Resolution Visible) the sensors of which are linear detector arrays (CCD). The detector elementary surface is 13 x 19 μm.

Each camera takes earth photographies 33 NM wide in the visible and near infrared bands (0,5-0,9μm) with a 60 feet sampling period for the multispectral bands (0,5-0,9μm, 0,61-0,69μm, 0,79-0,9μm) and a 30 feet one for the panchromatic band (0,5 - 0,9 m).

In each band, four CCD (1 CCD = 1728 detector units) are used to make linear detector arrays the length of which is 3,15 in. with 6000 detector units for the panchromatic band and 3000 for the spectral bands. The telescope focal plane surface occuped by these detectors is 0,79 x 3,15 in.

A light deviation mirror installed in front of the camera can be directed for the exploitation of a larger area (444 NM) and also for stereoscopic couple acquisition of the same area.

The HRV camera in-flight calibration device must compare the detector units sensitivity and also the spectral bands among them. It must give also an absolute calibration.

The first mission of the SPOT program will be a test for the equipments, so several systems will be used to calibrate the cameras during the flight like in board sources (internal and external) ground truth and processing statistical methods.

This paper will only present the in-board calibration system : aim, specifications design and also operational technical problems.

1. IN-FLIGHT CALIBRATION PROBLEMS

1.1 - IN-BOARD CALIBRATION SYSTEM ROLL

It must realize the following calibrations during two years time period, once a week.

. Detector Units relative Calibration in a spectral band

A correction of each detector signal in the same detector array must be made because they have different sensitivities. After calibration the camera response to an uniform exitance in a spectral band, must be uniform within an 1% accuracy.

The calibration unit will project on the sensors an uniform incidance to calculate for each detector a correction coefficient given by :

$$(g_j)_k = \frac{(V_j)k}{V_k}$$

and

$$V_k = \frac{1}{N(j=1)} \Sigma (V_j)_k$$

where $(V_j)_k$ is the j number detector signal in the k band and V_k is the overall signal mean value.

So the j number detector response to any landscape will be divided by $(g_j)_k$.

. Relative calibration between two spectral bands

A correction of detector signals in each spectral band must be made because they have different spectral sensitivities. After calibration, the camera response must be linear to the multispectral excitation, within a 3% accuracy.

The calibration unit will project a known incidance on the sensors in order to calculate for each spectral band a correction coefficient given by :

$$\lambda_K = \frac{V_1}{V_K} \cdot \frac{L_K}{L_1}$$

referred to the 1 band, where V_K is the overall signals mean value in the k band and L_k is the radiant sterance in the k band.

So the j number detector signal in the k band to any landscape will be divided by λ_K.

. Absolute calibration

The detector sensitivity absolute value must be known to convert the camera signal into luminance at the telescope entry.

The calibration unit must give this value within a 10% accuracy.

1.2 - RADIOMETRIC SPECIFICATIONS

. Luminance at the telescope entry

Spectral bands	1	2	3	4 (panchromatic)
L ± 0 20%	31,5	28,4	28,8	126,8

(W/m^2xSr)

. Uniform illuminance on the sensors (W/m^2)

Surface 0,87 x 3,54 in.

Δ = + 5% for two points 3,54 in. apart

Accuracy

Δ = + 1% for two points 0,04 in. apart

. Absolute calibration

Minimum illumination area size 130 μm(10 detector units)

1.3 - CALIBRATION METHOD

To accomplish an uniform incidance on the CCD bars, the calibration unit includes a tungsten lamp which can be used every moment, in the case of testing or troubleshooting operations.

But the lamp's life causes it to be a spectral sterance secondary standard which must be calibrated during the flight by a primary standard. This primary standard is the sun which is collected by fiber optics cluster. This calibration could be realized once a month.

2. IN-FLIGHT CALIBRATION UNIT DESCRIPTION

2.1 - INSTALLATION (Fig.1)

The calibration unit is a 11,8 in. long and 3,5 in. diameter cylinder which includes the tungsten lamp and some optic devices being installed above the camera. Its radiant power is projected inside the camera with the light deviation mirror in the calibration position, that is to say 70° rotation referred to the earth photography position.

The fiber optics assembly installed outside the calibration unit, includes a fiber optics sensor, a cable and mode scramblers. It's coupled to the calibration unit by a special connector with two parallel linear fiber arrays.

The calibration unit radiant incoming power performs parallel path rays which are injected in the camera by the same way than the earth radiant flux except that it doesn't cover completely the entrance pupil the diameter of which is 13 in.(Fig.2).

2.2 - COMPOSITION

It includes an objective, a lens at his focus and the lamp which is the image of the objective referred to the lens.

It's possible with a two position mirror, to set the sun image from fiber terminations at the objective focal plane.

A lighting virtual plane, e.g. Koehler type lighting, is projected on the CCD bars by the objective and field lens.

2.3 - LAMP CHARACTERISTICS

A tungsten lamp, was selected, in spite of its low luminous efficiency, for its following characteristics :

- continuous spectral radiant flux
- long life time (to 1000 hours)
- life stability
- low price
- operational simplicity.

The lamp type is defined by :

- electrical characteristics:the electrical power is 20 watts, the luminous flux 400 lm for a 2500 K filament absolute temperature

- geometric characteristics:cylindrical shape 0,79 in diameter and 1,58 in. length with a 0,4 in. length rectilinear filament.

A tests program is been developped at present toward the lamp model definition as well as its characteristics parameters, mainly about the filament temperature which has some effects upon several lamp properties. Then, stability and life time increase when the filament temperature decreases. By opposite the spectral profile goes to be uniform and the energy relative quantity increases in the 0,5 - 0,9 μm spectral range as the temperature goes up.

Also the use of a halogen lamp is being evaluated in order to avoid the glass to become dark by $\simeq$ 3000 K filament high temperature which carries the lamp radiometric characteristics to be changed.

CONCLUSION

The concerning type lamp device allows the complet HRV camera calibration during a certain mission. To accomplish the lamp spatial and life time requirements, an evaluation test program, in particular short and long term stability time and reliability rate, will be realized.

The in-board fiber optics device will allow the correction of the lamp deviation characteristics during the mission as well as to keep the initial accuracy calibration.

The so defined calibration unit will be implemented by others calibration process. Thus, statistical calibration methods are being studied at the Centre National d'Etudes Spatiales and the development of Ground truth utilization is projected.

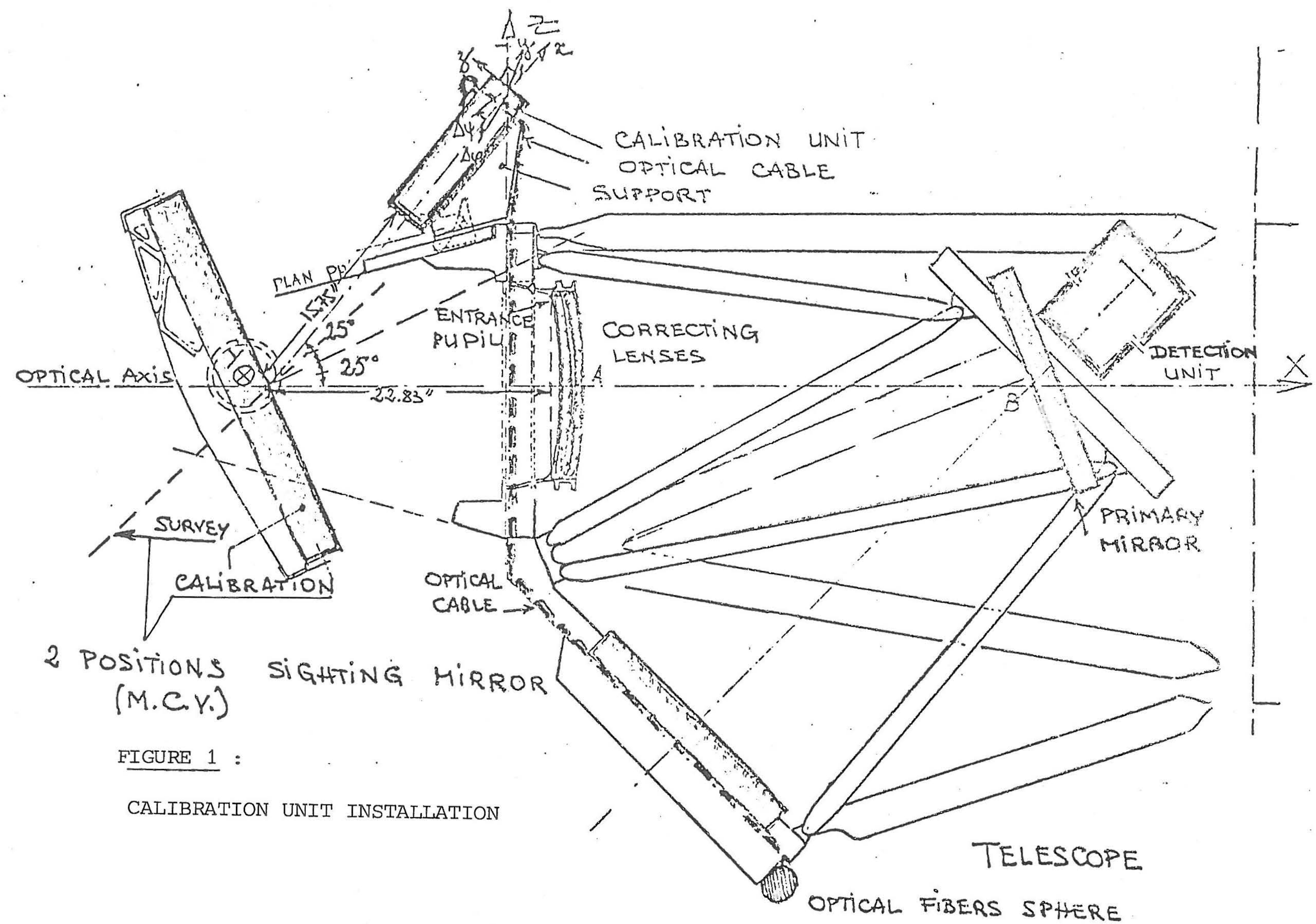

FIGURE 1 :

CALIBRATION UNIT INSTALLATION

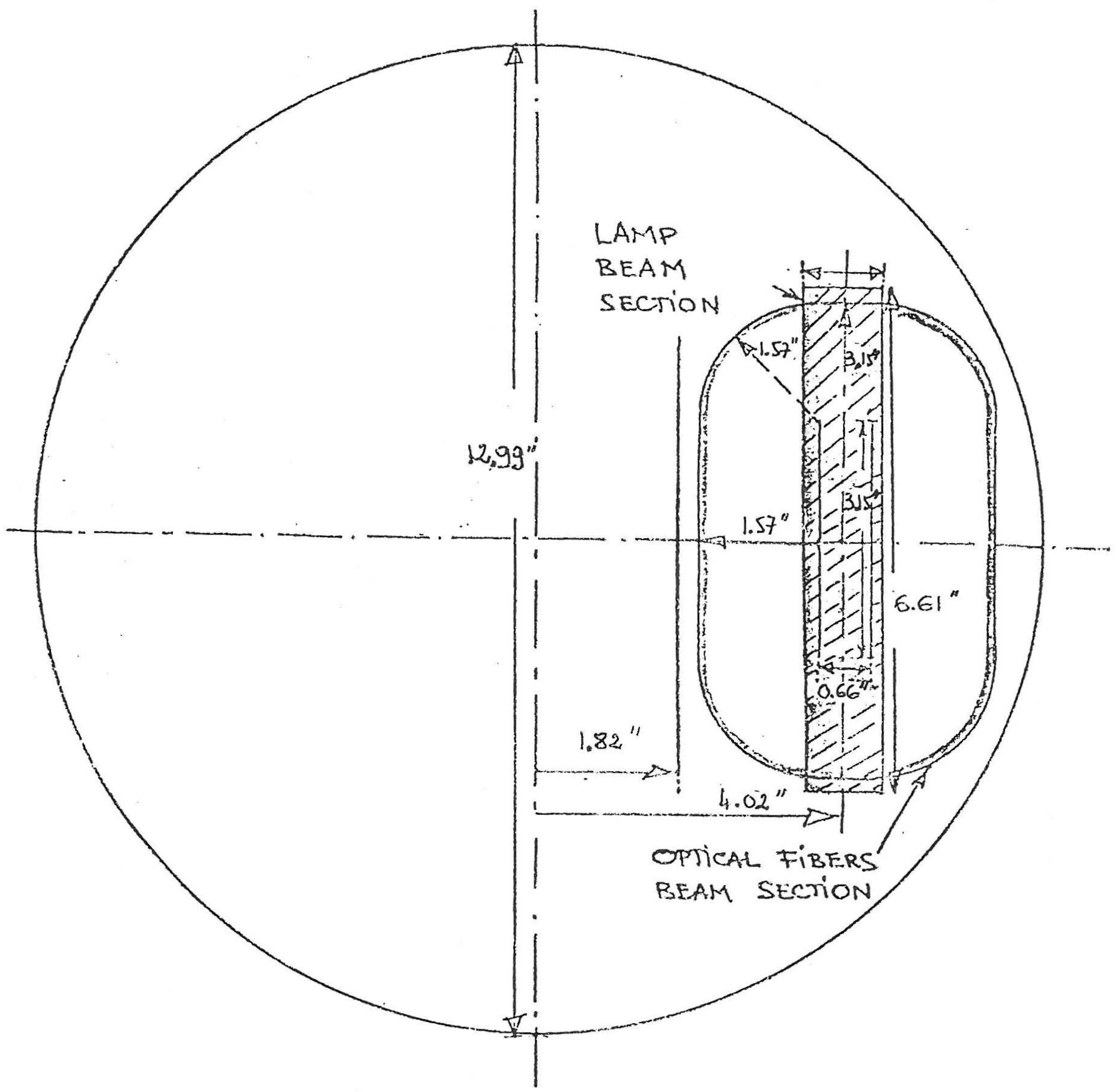

FIGURE 2 : CALIBRATION FLUX SECTION IN THE TELESCOPE ENTRANCE PUPIL

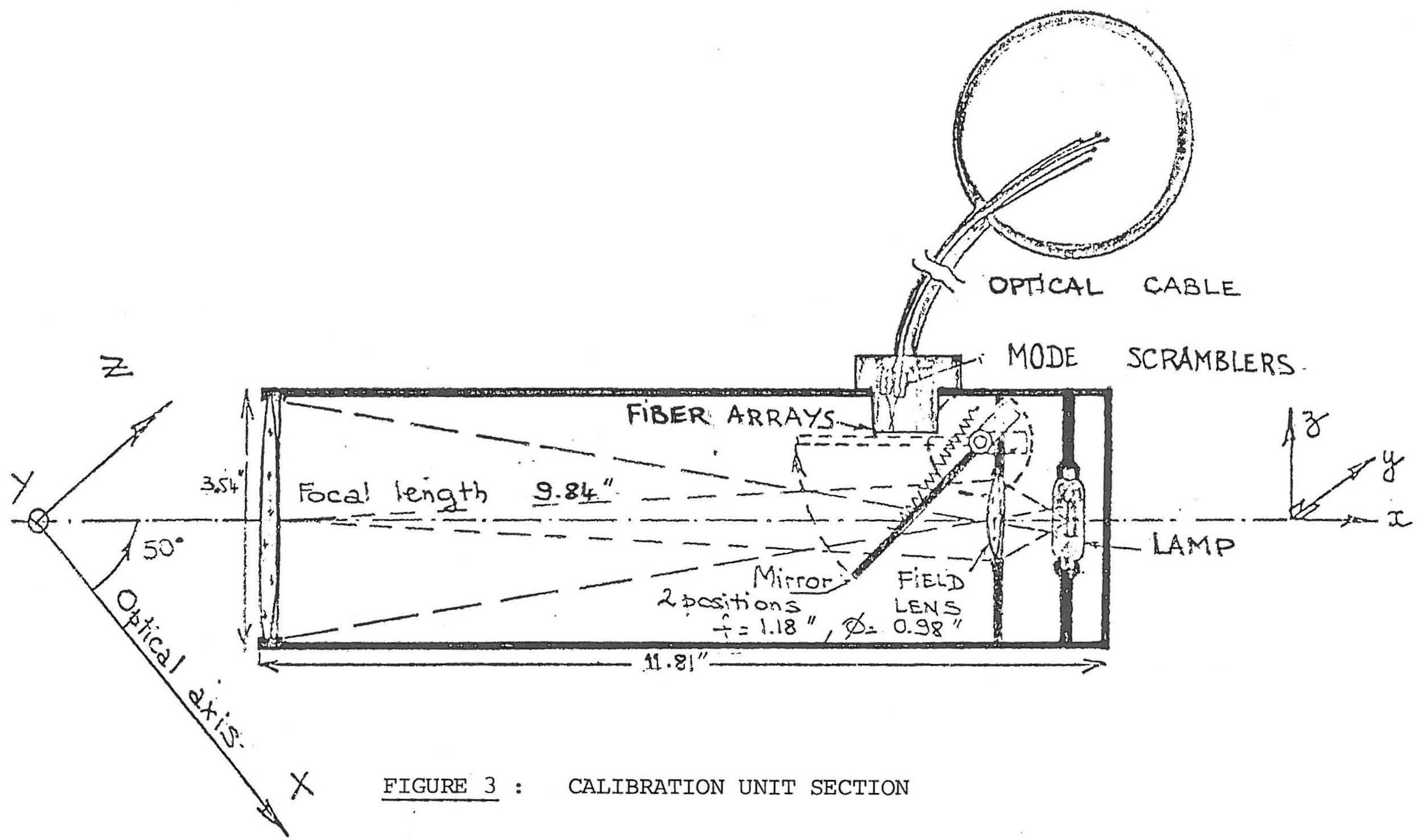

FIGURE 3 : CALIBRATION UNIT SECTION