THE STELLAR AND SOLAR TRACKING SYSTEM OF THE GENEVA OBSERVATORY GONDOLA

Daniel Huguenin
Geneva Observatory, Sauverny, Switzerland

ABSTRACT

Sun and star trackers have been added to the latest version of the Geneva Observatory gondola. They perform an image motion compensation with an accuracy of \( \pm 1 \) minute of arc. The structure is held in the vertical position by gravity; the azimuth is controlled by a torque motor in the suspension bearing using solar or geomagnetic references. The image motion compensation is performed by a flat mirror, located in front of the telescope, controlled by pitch and yaw servo-loops. Offset pointing is possible within the solar disc and in a \( 3^\circ \times 3^\circ \) stellar field. A T.V. camera facilitates the star identification and acquisition.

PLATFORM

The platform has been conceived as a multi-purpose and light instrument with a moderate pointing accuracy of 1 minute of arc on the sun and on stars down to the 6th magnitude. It can carry a \( 0.5 \) m\(^3\), 60 kg scientific payload. The fine pointing system is completely independent of the payload (heliostat or siderostat). The structure contains the necessary housekeeping systems, i.e.:

- 28V / 40Ah battery with 9 power buses.
- Quartz time base with power outputs.
- PCM telemetry encoders with 70 analog and digital channels.
- On-board punched tape programmer with momentary, latching and numerical commands.
- Coarse attitude control (\( \pm 1^\circ \)) for multiple observations to any point of the celestial sphere.
- All the interface wiring mounted on a removable harness for quick change of the scientific payload.
- Weight: 200 kg without scientific payload.

Figure 1 gives the disposition of the modules in the gondola. The lay-out is practically the same for solar and stellar flights.

SUN TRACKER

The motion compensation flat mirror is made of "Haeräus" alveolate quartz foam for thermal stability. Two sun sensors, using silicone solar cell bridges, control the pitch and yaw axes of the mirror. They are mounted on the side of the scientific telescope and aligned with its optical axis. The azimuth axis of the gondola is held within \( \pm 1^\circ \) of the sun's azimuth by
Figure 1. Schematic outline of the gondola.

auxiliary sun sensors. Sun search is made by a slow rotation of the flat mirror around its pitch axis. When the sun presence is detected, the servo-system switches to the track mode. This equipment was designed by Compteurs Schlumberger in Paris, and made three flights.

STAR TRACKER

The keystone of the stellar acquisition and tracking system is the AD-104 photon counting detector developed at the Geneva Observatory. This unit includes a photomultiplier, signal conditioning electronics with pulse shaping, discriminator and transmission line driver, and a H.V. power supply. It counts up to $6 \times 10^6$ photoelectrons per second. It is corona free at all pressures and consumes 2 watts. With this detector, it has been possible to use essentially digital electronics for the star tracker and for the TV camera.

The optical schematics of the star tracker is given in figure 2, and the block-diagram in figure 3. The modulator is a classical rotating knife edge driven by a D.C. motor at 8000 RPM.
In the acquisition phase, the field iris defines a 2° circular field of view. When the tracking mode is initiated by telecommand, the field iris reduces slowly the field of view, in five seconds, down to 22 arc minutes, thus lowering the sky noise by a factor 30 and occulting background stars. The rotating knife edge is mounted slightly behind the focal plane, thus creating a linear zone, 6 minutes of arc in diameter, in the center of the field of view. The magnitude counter integrates the photoelectric signal over 4 revolutions of the modulator. The content of the counter at the end of the integration time is proportional to the star magnitude. The result is stored in a buffer memory and updated after every fourth revolution. In the tracking mode, the content of the magnitude memory is frozen. The signal applied to the rate divider is constantly divided by the star magnitude. Therefore, the instantaneous signal is independent of the star brightness in the range $m_v = 0$ to $m_v = 6$. The signal is then integrated over four 90° rotations of the modulator. Thus the field of view is divided in four orthogonal pseudo-quadrants, called up-left-down-right, defined by a photoelectric pick-up mounted on the hollow shaft of the modulator. The up-down and left-right signals are subtracted from each other respectively by the pitch and yaw up/down counters. The result of these subtractions are the pitch and yaw error signals. This type of modulation and axes separation has two advantages. The star follows a short radial path directed toward the center of the field of view. The detector sensitivity is kept constant over the field of view by a Fabry lens and by the quadrant by quadrant photon integration, thus target ambiguity caused by background stars is eliminated. We found that the guide-star is acquired without ambiguity if it...
Figure 3. Block diagram of the star tracker electronics.
is 20% brighter than the total brightness of all other objects in the field of view. Bright background stars are occulted by the field iris in the tracking mode if their angular separation from the guide-star is more than 15 minutes of arc.

The flat mirror rests on 3 points defining the pitch and yaw axes. At the intersection of these axes the mirror is attached to its frame by a ball-joint. The two other points are materialized by pitch and yaw precision screw-jacks driven by DC servomotors. A fourth attachment, with four degrees of freedom, prevents the mirror from rotating in its own plane. The angular motion range of the mirror about each axis is ± 4° (optical).

The mirror itself is made of two 6mm Pyrex plates separated by a bundle of tubular spacers ground and cemented together with epoxy. This construction made the mirror 60% lighter than a solid plate of the same dimensions (31 x 31 x 6cm).

The mirror control electronics is represented in Figure 4. In the stand-by mode, the mirror is maintained in its median position by the error signals of two linear position transducers mounted on the screw-jacks. In the tracking mode, the mirror is controlled by the star-tracker. The star tracker has an offset pointing range of ± 1.5° with regard to the telescope.
Figure 5. Block diagram of the TV camera.
Coarse pitch orientation is made by rotating the whole mirror assembly around a horizontal axis. Coarse azimuth orientation is controlled by a magnetometer acting on the suspension bearing. Coarse azimuth and pitch angles are programmed on the onboard punched tape and updated by telecommand.

**TV CAMERA**

The stellar TV camera is used for star identification and acquisition. The tube is an ITT FW-130 image dissector used as a photon counter (Figure 5). The image definition is 32 points per line by 32 lines. The X and Y sweeping signals are produced by digital staircase generators. The exposure time is 0.8 second per frame. The number of photoelectrons produced by one picture element is stored in a memory and converted into an analog signal after logarithmic compression. With its 50mm objective the camera covers the magnitude range $m_V = -0.5$ to $m_V = 6.5$. The camera generates a reticule (centered cross). The reticule signal is also used on the ground as a luminance reference signal. Each frame begins with a synchronisation pulse. The video signal

---

**Figure 6. Block diagram of the TV receiver.**
can be transmitted to the ground on a regular IRIG FM/FM channel with a 1.2kHz bandwidth.

On the ground the video signal is stored in a random access memory and displayed at the rate of 50 frames per second on any laboratory oscilloscope having a Z modulation input. The star brightness can be measured with a calibrated video amplitude discriminator. Background stars can be eliminated from the picture. The field of view is 100 x 100 minutes of arc. It can be magnified by 2 by telecommand in the star search phase.

FLIGHTS

P. Stettler's solar infra-red interferometer (1972) has been flown three times on this platform with the solar tracking system. Pointing errors never exceeded 1.5 minute of arc in the worst case. The gondola made three stellar flights with coarse attitude control only. Navach et al. (1973) took 50 spectra of hot stars with a prism-objective Schmidt camera. One flight failed because of a short-circuit in the scientific payload. Rigaud and Steiger (1973) studied the effect of ozone absorption in the near-UV spectrum of hot stars. They were able to measure the ozone thickness above the balloon at sunrise. The stellar tracking system and the TV camera were tested in flight for the first time in France, in October 1973; both performed well.

We would like to take this opportunity to thank CNES (France) and NCAR (USA) for their kind assistance and advice since the beginning of this program, in 1963.

REFERENCES

Rigaud, P., 1973. Mesure de la variation de l'ozone crépusculaire au moyen d'un photomètre stellaire embarqué à bord d'une nacelle stratosphérique. Thesis No. A.0.9045, Université de Paris VI.

4.1-8

174
DISCUSSION SUMMARY — PAPER 4.1

In answer to a question about the type of circuitry used, the speaker described it as essentially CMOS technology except for the first two stages of the photon counters which used high speed analog circuits.

The scientific objectives were stellar photometry in the mid-UV and measurements of variations in the atmospheric ozone content at sunrise. Both types of measurements are made with a 15-centimeter Cassegrain with six channels between 2,000 and 3,000 angstroms.