INFLIGHT EXPERIENCE WITH THE ESA STARMAPPER DURING THE GIOTTO MISSION

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ABSTRACT

ESA's GIOTTO spacecraft is the first satellite equipped with an ESA starmapper designed and built by TPD/TNO. The starmapper datates transit times of stars or planets through a Vee shaped detector slit pattern. The datated events are transmitted to ground for processing. A ground based starmapper attitude determination system which performs telemetry preprocessing, star pattern identification and attitude reconstitution has been developed at ESOC.
The present paper gives an overview of sensor flight hardware and ground processing software. The inflight performance of the overall starmapper attitude determination system is considered.

Keywords: starmapper, attitude determination, attitude algorithms, inflight performance.

1. INTRODUCTION

ESA's GIOTTO spacecraft was launched on the 2nd of July 1985 and encountered Halley's comet after an interplanetary cruise of about nine months on the 13th of March 1986. GIOTTO was the first satellite equipped with an ESA starmapper designed and built by the Technisch Physische Dienst (TPD/TNO) of the Netherlands. A ground-based software system for starmapper attitude determination has been designed and coded as part of the flight dynamics support provided by the Orbit Attitude Division of the European Space Operations Centre (ESOC). The present paper gives a narrative summary of starmapper related attitude operations during the GIOTTO mission, describes the starmapper flight hardware and ground processing software and outlines the operational experience with the overall system.

2. NARRATIVE SUMMARY OF GIOTTO ATTITUDE OPERATIONS

After launch, the GIOTTO spacecraft was injected into a geostationary transfer orbit. During three orbital revolutions, which lasted in total 30 hours, the satellite was checked out and reoriented for the firing of the solid propellant perigee boost motor. In order to stabilize the spacecraft attitude during the solid motor burn, the spin rate had to be temporarily increased to 90 rpm. Since the starmapper can only operate at spinrates between 10 and 20 rpm, the spacecraft had to be equipped with an additional attitude sensing system for the precise determination of the injection motor firing attitude at 90 rpm. Four mutually redundant infrared pencil-beam earth sensors and two redundant X-slit sun sensors had been chosen for this purpose. While earth sensor and starmapper data can only be transmitted to ground alternatively, depending on the telemetry mode, the data of the active sun sensor are always contained in the telemetry.

The earth sensors and the sun sensor were used as the prime attitude sensing system during the geostationary transfer phase of the mission. However, a temporary switch-over to the starmapper was already performed during this phase as part of the spacecraft check-out. This was a unique opportunity for crossverification between the starmapper and infrared earth sensor attitude determination systems.

The solid propellant motor was successfully fired at the third perigee passage and carried the vehicle into its heliocentric interplanetary transfer orbit towards the encounter with comet Halley at the ascending node of the cometary orbit. With the firing of the perigee boost motor, the near earth phase of the GIOTTO mission commenced. At the start of this phase, the spacecraft was spun down to 15 rpm which was the operational spin rate for the remainder of the mission. A possibly large orbit manoeuvre to be performed by the vehicle's axial hyrdazine thrusters was foreseen in order to correct for the dispersion of the interplanetary injection burn. Finally, the spacecraft had to be brought into its initial cruise attitude such that the earth could be acquired within the narrow beam of the satellite's despun high-gain antenna.

From near earth phase onward, the starmapper became the sole means for attitude sensing because the earth rapidly disappeared from the field of view of the pencil beams due to the high escape velocity. Also due to the high escape velocity, all operations in near earth phase were highly time critical because the telemetry link with the spacecraft through its omnidirectional antenna was

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only feasible for about four days after interplanetary injection. Telemetry acquisition through the despun high gain antenna had to be achieved within this period. The design driving requirements on the ground based star mapper attitude determination software resulted mainly from this time critical mission phase. Because a contingency during the solid motor burn or during one of the large attitude manoeuvres might have resulted in an unknown attitude, the capability for near real time autonomous star pattern recognition was required as part of the near real time starmapper attitude determination software.

In actual operations it turned out that the near earth phase sequence of events could be achieved without any problems. Post injection orbit determination showed that the injection attitude had been established extremely precisely, with a thrust vector offset of probably no more than 0.03° such that no subsequent trajectory correction was required at this point. This eased the operational load during near earth phase and the spacecraft could be configured for cruise, with the high gain antenna earth-pointing at about 63 hours after interplanetary injection. At this time the spacecraft was safely on course to its encounter with Halley's comet and a very demanding and exciting mission phase had been successfully concluded.

During the ensueing nine months of interplanetary cruise, the main objective of the attitude subsystem ws to maintain the narrow high gain antenna beam of about 1° half-width earth pointing and to control the solar aspect angle to values within an allowed corridor in order to guarantee equitable thermal and power conditions. At encounter, the spin axis of the spacecraft had to be aligned with the relative velocity vector spacecraft-comet such that the bumper shield at the bottom of the spacecraft was perpendicular to the flow of impinging dust. The mounting angle of the despun high-gain antenna was thus defined by the earth aspect at encounter which was 44.2°. The inertial attitude of the spacecraft spin axis during cruise was therefore constraint to a conical band at 44.2±1° around the earth direction. Due to the spacecraft and earth orbital motion, earth and sun as seen from the spacecraft appear to drift relative to the stellar background. For the starmapper, the same mounting angle had been chosen as for the high gain antenna, such that the antenna phase angle of rotation could be closed-loop controlled by the earth signal in the starmapper in order to compensate for the component of the earth apparent drift perpendicular to the spin axis direction. The change in earth aspect had to be compensated by attitude manoeuvres. During early cruise it was possible to optimize the attitude strategy such that the natural sun aspect drift was following the solar aspect deadbands and the earth aspect drift could be compensated primarily by onboard autonomous adjustment of the antenna phase angle. Thus attitude manoeuvres were initially required only rarely at intervals of up to several weeks. In this phase daily attitude reconstitution was performed by the starmapper attitude determination software in order to monitor the drift of the spacecraft spin axis due to solar radiation pressure.

Starting in November 1985, daily small attitude manoeuvres were required in order to steer the solar aspect angle through the now narrowing allowed corridor (see Fig. 1). The main objective of the starmapper attitude determination system was now to verify the attitude manoeuvre performance. If the deviation of actually achieved end attitude from the desired strategy exceeded permissible limits, the sequence of subsequent manoeuvres was updated in order to compensate for the combined effects of manoeuvre dispersion and solar radiation pressure torque. The starmapper attitude determination system was functioning nominally up to 136 seconds prior to closest approach, when the starmapper baffle was probably perforated by impinging dust. This resulted in a drastically increased susceptibility to solar straylight which degraded the star mapper performance. During and immediately after closest approach starmapper datation was lost such that the attitude disturbance due to cometary dust impacts could solely be monitored by the sun sensor. Six hours after closest approach valid starmapper datation could be regained by a new optimized selection of onboard starmapper control parameters and it was possible to reconstitute the post-encounter attitude.

In the following we shall consider the starmapper flight hardware and ground processing software and their performance during the GIOTTO mission in detail.

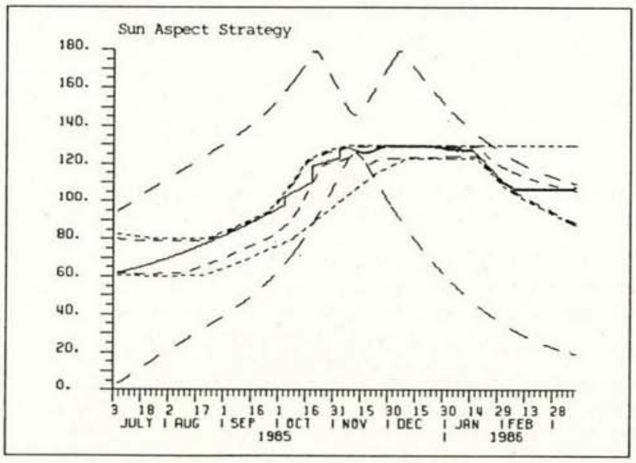

Figure 1. The solar aspect strategy as function of time during the GIOTTO mission. The large dashed lines are the communication constraints, the short dashed lines the power/thermal constraints. The inner deadbands result from a combination of these constraints, including margins in time and angle to enable adequate settings of parameters for the onboard autonomous recovery function. The full curve in the centre of the deadbands is the sun aspect strategy. Steps in this curve represent manoeuvres. From about November onwards daily manoeuvres were required.

3. FLIGHT HARDWARE

3.1 Starmapper Sensor Hardware

The starmapper sensor head comprises an optical head, shielded by a straylight baffle, which images a small section of the sky of about 9°x9° onto a silicon semiconductor detector.

The detector is a silicon photodiode masked by a metal layer in the shape of a double Vee slit pattern. The two pairs of meridian and inclined slits correspond to two redundant starmapper sections. As tilt angle of the inclined slit 51.4° has been chosen to optimise the dimensional limits of the slit pattern with respect to the starmapper field of view. The lay-out of the starmapper detector is shown in Figure 2.

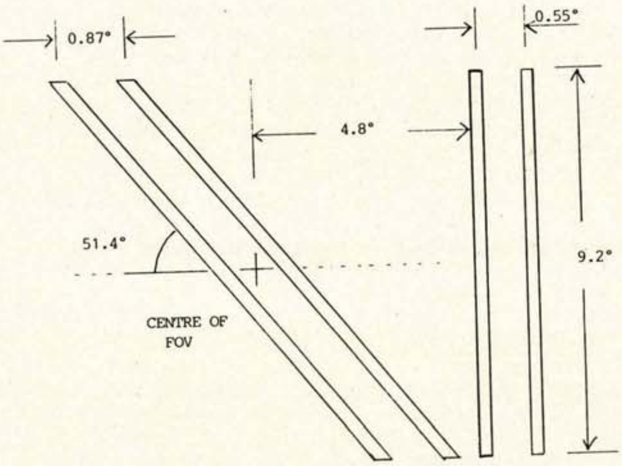

Figure 2. Lay-out and angular dimensions of the starmapper slit pattern.

The starmapper optical head is a Petzval lens system with a focal length of 92.5 mm (f=1.55). This lens projects the detector slits as great circle segments on the celestial sphere with the narrow end of the slit pattern directed towards the spacecraft +Z-axis (the rotation axis of the S/C, pointing from the dust shield towards the high gain antenna). The inclination angle of the starmapper optical axis w.r.t. the +Z-axis is 44.2° in order to match the inclination of the high gain antenna boresight. Thus, whenever there is a communications link through the despun high gain antenna, the earth is also within the starmapper field of view (FOV) and the closed-loop control of the phase angle of rotation of the despun antenna dish could be based on the starmapper earth signal. An autonomous maneouvre mode for link recovery in case of contingency was designed to control in its final step the earth aspect to the center of the starmapper FOV.

The full meridional extend of the starmapper FOV is 9.2°. During each revolution of the spacecraft the starmapper slit pattern sweeps over a band from 39.8° to 48.8° around the S/C spin axis direction on the celestial sphere. Any sufficiently bright celestial object triggers a starmapper event at its time of transit through a slit.

A baffle protects the starmapper against spurious events due to solar straylight. A two-stage baffle design has been selected. The first baffle stage prevents direct illumination of the baffle plates of the second stage, provided the angle between baffle axis and sun direction is larger than 55°. The edges of the first stage baffle plates cannot be seen by the optics. Consequently, the earth can be unambigously detected by the starmapper if its solar elongation is larger than 55°; the minimum solar elongation for star detection is 70°.

To protect against closely spaced multiple events which could have resulted from secondary maxima in the signature of bright objects, a starmapper dead-time was implemented. For 30 msec after an event, the starmapper will not trigger another event in the same slit. This dead-time corresponds to a rotation angle of 2.7° at the nominal spin rate of 15 rpm.

Since due to limitations in the telemetry rate only up to four meridian and four skew events per spin can be transmitted to ground, facilities were implemented to allow for ground-controlled selection of the event pattern. Firstly, a starmapper threshold can be commanded in 16 steps. The lower eight thresholds were primarily intended for star detection (star mapper in star-mode) the eight higher thresholds correspond to earth-mode and are optimised to facilitate discrimination between earth and moon which was essential in early cruise phase. Table 1 shows the limiting star or planet silicon magnitude as function of the telecommanded starmapper threshold. All objects brighter than the telecommanded magnitude are detected. The threshold magnitudes are expressed as silicon magnitude to reflect the spectral response characteristics of the instrument which is relatively more red-sensitive than the visual spectral response on which the visual star magnitudes normally given in star catalogues are based. Consequently, a dedicated mission catalogue of all stars detectable by the starmapper had to be generated.

Telecommanded Threshold	Limiting Star/Planet Silicon Magnitude	
0	3.08	Star Mode
1	2.78	
2	2.51	
3	2.31	
4	2.15	
5	1.99	
6	1.87	
7	1.73	
8	-0.44	Earth Mode
9	-2.02	
10	-2.64	
11	-3.04	
12	-4.05	
13	-4.17	
14	-4.28	
15	-4.38	

Table 1 Limiting silicon magnitude versus starmapper threshold

As a further mechanism for elimination of unwanted events, a ground-commandable electronic window was implemented that can be set for an arbitrary width starting at an arbitrary phase angle of spacecraft rotation. Only events falling inside this window are datated.

3.2 Starmapper Telemetry

The telemetry of the GIOTTO attitude and orbit control system (AOCS) is packetised. The packets are generated synchronously with the spin rate at the rate of one packet for every second spin in the starmapper mode. The packet rate at the normal operational spinrate of 15 rpm is therefore 1/8 sec. The packets float in the AOCS housekeeping channels of the fixed housekeeping telemetry format which repeats every 45.33 seconds. The AOCS contains a datation clock which runs at a frequency of 138.24 KHz and is reset every 45.33 seconds by the format synchronisation pulse. At the time of an optical sensor event (sun transit through sun sensor meridian/inclined slit or star transit through a starmapper slit) the current value of the datation clock is copied to a 24 bit datation register. The telemetry packet contains for the respective spin the datated values of start and end sun meridian pulse, sun inclined pulse, and both up to four star meridian/inclined pulses. If more than four starmapper meridian or inclined events occur during a spin, which have not been elimnated by an approriate setting of threshold and phase window, only the first four events are telemetered.

Other starmapper systems perform a certain level of onboard preprocessing of the sensor data (compare ref. 1) This is not the case for GIOTTO. In particular, there was no onboard checking for spurious pulses. The meridian and skew pulses at same positions within the fields of four datated events are not necessarily due to the same celestial object. In fact quite frequently the number of telemetered skew events was different form the number of meridian events. Thus a careful preprocessing of the sensor data had to be performed by the ground based starmapper attitude determination system.

It is also important to note that the ESA starmapper does not provide any information other than the event times. In particular there is no information on the magnitude of the star causing an event which complicates the star pattern recognition.

4. THE GROUND-BASED ATTITUDE DETERMINATION SYSTEM

4.1 Systems Overview

The ground-based starmapper attitude determination system for GIOTTO was designed and coded at ESOC. In addition to the actual attitude determination software, the system comprises a suit of auxiliary programs for star coverage checking in support of the semi-manual selection of starmapper threshold and phase window. Two algorithmically identical versions of the starmapper attitude determination software have been generated, one to reconstitute the attitude in near-real time and another for batch attitude determination during an arbitrary past time interval.

The attitude determination process was broken down into five major functional elements as shown in Figure 3. In the following we shall consider each of these functional elements in turn.

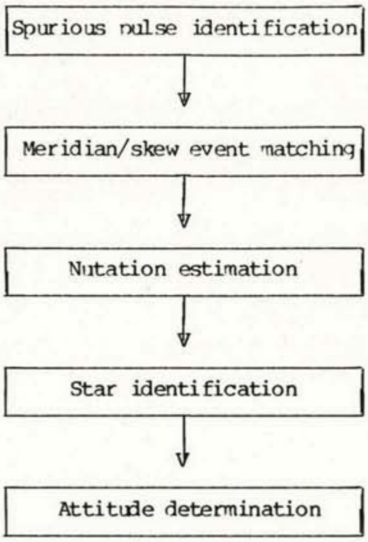

Figure 3. Top-level sequential breakdown of the starmapper attitude determination program.

4.2 Spurious Pulse Identification

Also in its real-time mode, the starmapper attitude determination program takes small batches of AOCS telemetry packets as input. This does not introduce an additional delay because all five or six packets of a format arrive simultaneously on the telemetry history file at the format period of 45.33 seconds rather than individually at the packet period of 8 seconds.

Initially, the starmapper event times of all packets are converted to event phase angles. This is easily possible because each packet contains the start and end sun meridian pulse of the respective spin and thus the spin period is known.

Spurious events are eliminated by setting of a small angular window around each event and requiring that an event should be present within this window for the majority of all packets in the batch. All pulses that do not pass this test are removed as spurious.

It is highly critical for a successful attitude determination that all spurious pulses are positively removed. An occasional loss of single real events is comparatively unproblematic.

4.3 Meridian/Skew Event Matching

The telemetry contains no a priori information as to which of the meridian and skew starmapper events correspond to same celestial references.

Any star or planet will be crossed by the starmapper meridian slit first. The corresponding skew event must follow within a rotation phase angle of 12° for the given starmapper slit geometry. The software considers a meridian and skew event as matching, if the above condition is is unambiguously fulfilled, i.e. if there is no other meridian or skew event within an angular range such that other matches could be possible. The algorithm positively precludes false event matching as this would lead to wrong relative star positions within the observed pattern with the likely consequence of false star identification.

4.4 Nutation Estimation

The nutation estimation submodule can be optionally switched on by the operator. If the spacecraft is nutating, the starmapper and sun sensor event phase angles of consecutive spins oscillate around a mean value. Amplitude and phase of this osciallation depend on the slit orientation in the spacecraft system, the celestial reference position in an angular momentum vector fixed inertial system and on nutation angle and phase. The nutation monitoring algorithm is based on a least squares method. Effectively, nutation angle and phase are derived such that the theoretical event phase angles based on these values are a best fit of the observed measurements in the least-squares sense.

For a near symmetrical spacecraft such as GIOTTO, the ratio of body nutation rate to spin rate solely depends on the ratio between axial and transversal moment of inertia. This dependence is quite sensitive to small changes in the moments of inertia. In actual operations it was found that the moments of inertia slightly deviated from their predicted values with the unfortunate effect that the body nutation period became almost an exact multiple of the spin period. Consequently, nutation angle and phase were very poorly observable.

On the other hand, the nutation monitoring was the least important out of the subfunctions of the starmapper attitude determinaton system. The initial main objective of the nutation monitoring module was to monitor the spacecraft dynamics during encounter because during cruise, precise attitude determination was always performed at times when no nutation was present. This objective could anyway not be achieved, because starmapper datation was lost already few minutes prior to closest approach due to dust impacts on the baffle.

After encounter, a large orbit correction was performed to retarget the spacecraft for earth fly-by in 1989. Due to the large fuel consumption of this manoeuvre, the moments of inertia changed and now the nutation became well observable. Thus, ironically, the nutation monitoring could be successfully tested in flight only after the completion of the nominal GIOTTO mission.

4.5 Star Identification

Star identification forms together with spurious pulse identification and meridian/skew event matching one of the most critical building blocks of the starmapper attitude determination software.

The first prerequisite of star identification is a mission catalogue of potential celestial references. Because the starmapper spectral response differs from the spectral response curves of the usual UBV magnitudes, a dedicated mission catalogue had to be generated which contains the instrumental or silicon mangitude of each star. This mission catalogue of 528 stars is complete to about silicon magnitude 4; there are 285 stars brighter than the lowest starmapper threshold of m_{SI} = 3.08 (compare Table 1).

The silicon catalogue has been generated in part by the NASA GSFC computer program which includes a database containing 13-colour photometric data on 450 stars. The silicon magnitude has been calculated by convoluting the spectral distribution of each star with the starmapper spectral response. The result is devided by the convolution of the star spectral distribution with the V-magnitude spectral response. The difference between V-magnitude and silicon magnitude (the colour index) is derived by normalizing the resulting ratio such that the silicon manqitude of an averge A0 star of V-magnitude zero is also zero. Unfortunately, the GSFC catalgoue is incomplete. The colour indices of the missing stars have been obtained under the assumption that they are equal to the colour index of the star with the closest match of the spectral type within the GSFC catalgoue (Ref. 2).

An algorithm for the calculation of the silicon magnitudes of the planets and the earth moon, as function of distance and phase, has been derived under ESOC contract (Ref. 3).

A manual and an automatic option for star identification has been implemented. The manual option can be used if the attitude is roughly known a priori. In this case, the operator generates a predicted event pattern by auxiliary S/W. For each star or planet to be identified, an event phase window and the Yale catalogue number of the respective star are input to the attitude determination S/W. If there is one and ony one event within the window, the program will identify the event as being due to the respective star or planet.

The automatic option was implemented mainly for use in near earth phase. During this very time critical mission phase a fast response of the attitude determination system was required. Large omnidirectional manoeuvres were carried out and had to be monitored. A contingency during a manoeuvre or during the solid propellant transfer system burn may have resulted in an initially unknown attitude. In these cases the automatic star identification algorithm has to select the correct stars from the mission catalogue solely based on the sun sensor information and on the observed star event pattern.

Manually, star pattern recognition at an a priori unknown attitude could be done as follows: From the sun sensor inclined slit event phase angle and starmapper meridian/inclined event phase angles the solar elevation and the stellar azimuth and elevation angles are calculated in a coordinate system whose Z-axis is along the S/C spin axis and the XZ-plane contains the sun vector. The star coordinates are transformed from this system to a sun-pointing system with the sun direction along the Z-axis, and the S/C spin axis within the XZ-plane. The result is the observed star pattern relative to the known position of the sun. Manually, one could generate from this information a circular search mask, with the sun at the centre and small search windows at the star positions. The inertial star positions are also plotted on a starmap in sun-pointing coordinates, with the zero azimuth now defined by the celestial north. This plot is time dependent, because the sun appears to move in front of the stellar background. The search mask is overlayed to the starmap such that the sun positions match and rotated around the sun until the maximum number of search windows contains a star. The stars within the windows are thus identified as sources of the respective events. If there are different azimuthal positions of the mask where the same maximum number of windows contains a star, no unambiguous star identification is possible.

The automatic star identification module is a fully automatic software emulation of the above manual procedure. The main advantage of this algorithm is that it excludes the danger of an ambiguous star identification. The identified stars are always a best match of the observed pattern. The coded version of the algorithm is highly efficient both in terms of memory required and execution time. The automatic star identification S/W has worked flawlessly throughout the mission such that the manual option was very rarely used.

4.6 Attitude Determination

The output of the attitude determination submodule is the inertial direction of the S/C spin axis, expressed as right ascension and declination in the mean equatorial system of 1950. Since both sun sensor meridian pulses and the sun sensor inclined pulse are always available in each telemetry packet, a single additional starmapper pulse (meridian or inclined) would suffice to determine the attitude. Generally, if more than a single starmapper event is available, the S/C attitude is the solution of an overdetermined system of equations.

The attitude determination submodule solves this overdetermined system by a classical least-squares differential correction algorithm. First, an initial approximate attitude is calculated using only sun data and the starmapper events of the 'best' star (the star closest to 90° from the sun direction). The theoretical starmapper event phase angles at this attitude are calculated. An improved attitude estimate is derived by a least-squares method from the differences between theoretical and actual measurements. This procedure is iteratively continued until convergence has been achieved.

Frequently theoretical studies into attitude determination pay considerable attention to the noise filtering characteristics of the state estimator (e.g. Ref. 4). In our practical experience, this aspect turned out to be of very little importance because both the starmapper and sun sensor measurements were almost free from random measurement noise. We therefore find, somewhat paradoxically, that the attitude determination submodule itself is much less critical with regard to attitude accuracy than spurious pulse removal, event matching and star identification.

Our design driving objective for the state estimator was algorithm robustness, i.e. the algorithm should converge to the correct attitude whenever it was observable from the available measurements. Operational experience has shown that this objective was achieved. The chosen attitude determination algorithm has performed satisfactorily under all circumstances encountered in flight.

5. INFLIGHT PERFORMANCE

In the following we shall consider the first starmapper data take in GTO as a respresentative example for the inflight performance of starmapper flight hardware and ground-processing software.

The first starmapper data take was performed as part of the satellite check-out in the geostationary transfer phase of the mission. It commenced at 14:11:51 on 2nd of July 1985 and lasted for about 43 minutes. The electronic window was set from a rotation angle of 333.41° to 92.94°. The commanded threshold was 7, which corresponds to a limiting silicon magnitude of 1.73. The starmapper thermistor output was 106 (14°C).

According to our prediction, four stars were observable by the starmapper at the launch separation attitude for the given setting of threshold and window. Yale catalogue number, silicon magnitude and meridian/skew event phse angles of the predicted stars are shown in Table 2.

Yale Number	m_{SI}	Event Phase Angle	
		Meridian /	Skew
5288	1.62	29.84	32.82
5459	0.02	65.22	75.33
5267	0.69	65.79	71.69
5056	1.04	348.42	351.05

Table 2. Predicted star pattern during first starmapper check-out

The meridian/inclined starmapper event phase angles actually observed in the telemetry are shown in Figs. 4 a,b. There is a substantial percentage of spurious pulses, in fact about 18% out of the total number of pulses are spurious for the meridian slit and 11% for the inclined slit. Later in the mission, spurious pulses were observed even in earth-mode and resulted in short transient high-gain antenna depointing.
The star with Yale number 5288 and silicon magnitude 1.62 is not observed. This implies that either the starmapper is less sensitive than predicted or the catalogue silicon mangitude of this star is in error. Statistical evidence from later starmapper data indicates that the first assertion must be true. The meridian event of star 5267 is lost, because it occurs within the dead-time after the meridian event due to star 5459. All other events appear in more than 95 % of the packets as predicted.

Already this first test shows very clearly the performance characteristics of the sensor: a possibly substantial rate of spurious data, no obvious relation between meridian and skew pulse pattern (in the present case the number of meridian pulses differs from the number of skew pulses) but on the other hand low measurement

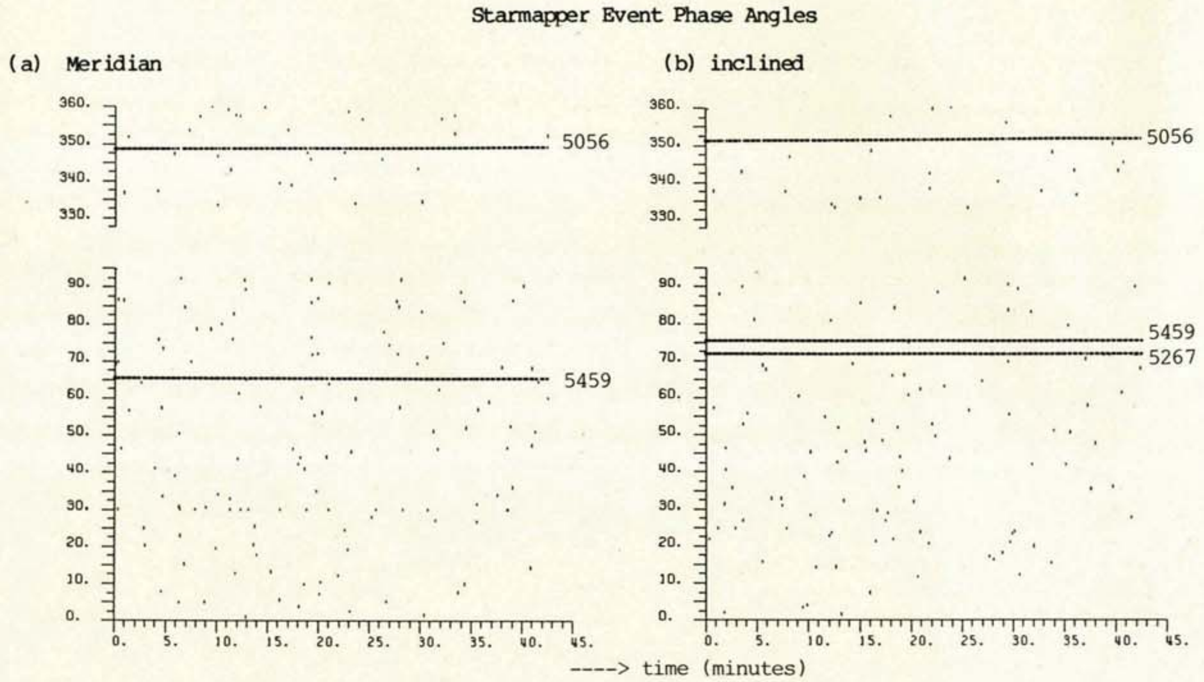

Figure 4a, b. Starmapper telemetry during the first inflight check-out. Angular range outside the electronic datation window is suppressed. The reproducable events are due to stars; the Yale catalogue numbers of the respective stars are shown.

noise on the real events.

The ground-based real-time attitude determination S/W was running at the time of first starmapper switch on. Automatic star identification had been selected and no a priori attitude information was input to the program. Immediately after the first full event pattern was available, the software succeeded in identifying stars 5056 and 5459. The attitude determined by the starmapper attitude reconstittuion subsystem agreed to within 0.1° with the result from the infrared pencil-beam earth sensor data.

The performance characteristics of starmapper flight hardware and ground processing software which was observed during the first check-out is representative for the remainder of the mission. Starmapper attitude determiantion kept functioning nominally throughout the mission with an estiated accuracy of 0.1° up until 136 seconds prior to closest approach. At this time, cometary dust must have perforated the straylight baffle which was not protected by the dust-shield and starmapper datation was lost. About six hours after closest approach, valid starmapper data were reacquired by an optimized setting of threshold and phase window. From this time onwards, stars or planets could only be observed in the antisunward direction. This severely reduces the number of observable celestial references and there were periods post-encoutner, when no stars could be observed. A contingency attitude determination procedure was developed ad hoc for use during such periods, which emulates a conescan system and determines the attitude from the sun sensor data and the downlink signal strength.

6. CONCLUSION

The ESA starmapper has shown very satisfactory performance throughout the GIOTTO mission. The main sensor characteristics are low measurement noise, but susceptibility with respect to spurious events. Real-time star pattern recognition and attitude determination with an accuracy of about 0.1° was easily feasible at all times during the mission with the ground processing software developed at ESOC.

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