Why Star Trackers On-Board the CryoSat Satellite?

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Three fully autonomous Terma HE-5AS Star Trackers provide the precise pointing knowledge required for the main instrument, the SIRAL interferometer, on-board the CryoSat satellite. All three Star Trackers are mounted directly on the payload antenna bench of the CryoSat satellite for optimized structural stability between the star sensors and the payload sensors measuring frames. The Star Trackers are in principle lightweight, low power consuming digital cameras, equipped with high reliability components and ultra stable optical systems. This article gives you some insight to the engineering challenges around the design and testing of a Star Tracker with sub-arcseconds accuracy.

The Star Tracker camera head has a 1024 x 1024 pixels frame transfer CCD with optics providing a field of view of 22°x 22°. Autonomous operation is guaranteed through a 'Lost in Space' mode, in which the Star Tracker within 2 seconds calculates a coarse attitude by matching triangles of stars with patterns stored in its star catalog, containing more than 5000 star directions. After two consecutive successful coarse attitude determinations, it autonomously jumps to 'Tracking Mode'. In 'Tracking Mode' the precise Attitude is calculated in a repeated optimization process using the exact centroid position of a large number of observed stars. Tracking a large number of stars, requires the ability to observe faint stars. Faint star observation with short integration times is a very challenging task for the read-out electronics and the optical system. Longer integration times would result in bad tracking performance at higher satellite slew rates. The Terma CryoSat Star Tracker is able to track stars down to Magnitude 6.2 at a slew rate of up to 1°/sec with an accuracy better than 1 arcsecond (pitch/yaw) and 5 arcsecond (roll).

The complete Star Tracker assembly has been through an extensive qualification test program ensuring optimized and reliable performance as a mission critical subsystem on-board CryoSat. All electrical components are fully space qualified according to ESA requirements and independent validation of the on-board software has furthermore been conducted. ESA has also performed extensive validation of the on-board tracking algorithms.

Figure 1. The CryoSat Terma Star Trackers during integration testing at EADS Astrium GmbH (courtesy Thomas Usbeck, EADS Astrium GmbH). The three camera heads in the background are mounted onto their thermo-mechanical stable brackets. Straylight rejection baffles are mounted on top of the brackets. The Star Tracker data processing units visible in the foreground are mounted in satellite body. Note that a star field simulator is mounted inside the middle baffle. This simulator offers a very accurate optical stimulus for the Star Tracker in test enabling complete test of all software modes such as initial acquisition (lost-in-space) and tracking. Testing with the star field simulator requires no special test mode being implemented in the Star Tracker software and can thus also be used during last minutes testing prior to launch.

Figure 2. The CryoSat Star Tracker mounting brackets (courtesy Thomas Usbeck, EADS Astrium GmbH). A key feature of the Terma Star Tracker on-board CryoSat is the thermo-mechanical stability between the Star Tracker camera heads and the primary payload SIRAL. Therefore special mounting brackets have been designed by EADS Astrium GmbH using a combination of carbon fiber and titanium rings. Dedicated camera radiators (also visible in the figure) guarantees cold camera CCD detectors independent of the orbit sun angle (from noon-midnight to dawn-dusk). The bracket also ensures that no mechanical deformations will occur as a consequence of thermal baffle deformations.

Peter Davidsen, Terma A/S, has been involved in Danish space activities since 1993 where he graduated from the Danish Technical University. He has primarily been involved as systems engineer in small satellite projects such as the Danish Ørsted and the Norwegian NSAT-1 satellites. Current activities include technical lead of the Terma Star Tracker.

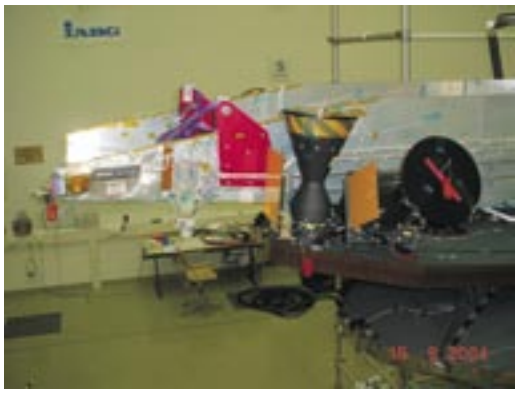

Figure 3. Two of the three Terma Star Trackers mounted on the CryoSat SIRAL bench (courtesy Thomas Usbeck, EADS Astrium GmbH). Low operational camera CCD temperature obtained by the use of forward looking radiators ensures not only high accuracy due to lower image noise but also longer operational lifetime. The primary Star Tracker degradation factor in-flight is the proton bombardment in-orbit. For CryoSat this mainly happens during passages through the South Atlantic Anomaly and the poles especially during solar eruptions. The proton degradation will be mitigated by the low operational CCD temperature and the use of robust software algorithms.

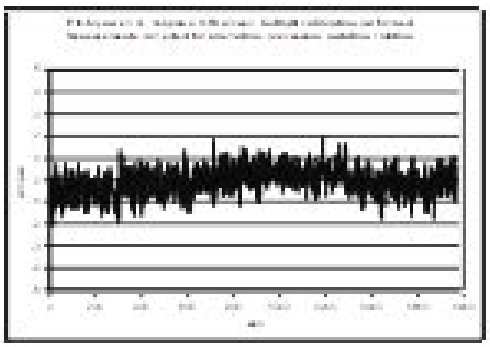

Figure 4. The Terma Star Tracker pitch/yaw pointing accuracy measured during night sky testing. The measurements include the disturbance effects caused by the atmosphere. The high accuracy has been accomplished by a combination of ultra low camera electronics noise and the use of a very sensitive frame transfer CCD. High CCD sensitivity combined with a near perfect optical system ensures tracking of a very high number of stars (down to visual magnitude 6.2). The night sky performance has also been confirmed by single star measurements performed in the Terma optical laboratory.

Figure 5. CryoSat during mass properties testing at IABG in Munich (courtesy Thomas Usbeck, EADS Astrium GmbH). The three Terma Star Trackers are mounted on the SIRAL bench shown to the right. Using three Star Trackers guaranties not only redundancy, but also the possibility of having multiple camera's tracking simultaneously independently of potential sun and/or moon blinding.

The Terma Group

The Danish company Terma is a system and service provider with key clients among aerospace companies (US and European) and European/International Agencies and operators. Terma has a wide product range within Space, Radar Systems, Air Traffic Management, IT Services and Defense. In the fiscal year 2003/2004, Terma employed 1,050 people, of which 150 work with space systems development and applications. The total revenue of the group was 150 MEuro with an export share of 70%.

For space applications Terma offers several specialised platforms and products:

Star Trackers focusing on fully autonomous attitude determination with high accuracy, ranging from satellites with short mission life times to satellites having long life times and stringent requirements for radiation tolerance.

Electrical Power Management focusing on state-of-the-art power designs covering power conditioning units with Maximum Power Point Tracking, power distribution units with solid state switches and customised CD/CD converters.

Satellite Checkout comprising products for integrated EGSE systems at all levels of AIV including satellite, instrument platform and payload level testing, and incorporating modern open Satellite Control and Operations Systems e.g. a SCOS 2000 kernel or earlier ESA variants.

Satellite Control and Operations Systems designed based on SCOS 2000 to provide the latest Spacecraft Control Infrastructure for the European Space Agency as well as commercial customers.

On-Board Software encompassing on-board software for cost efficient on-board data processing. The software architecture supports the ESA Packet Utilisation Standard including: Mission specific software, Standard application software, and Operating system plus basic services.

Software Validation Facilities comprising facilities to examine software execution in its target processor environment. The facilities include features to support debugging, performance analysis and Independent Software Validation of embedded software.

Terma headquarters are located in Lystrup, Denmark. The Space Division headquarters are based in Herlev, just north of Copenhagen with subsidiaries in Leiden, The Netherlands and Weiterstadt, Germany.