THE OFFICINE GALILEO AUTONOMOUS STAR TRACKER

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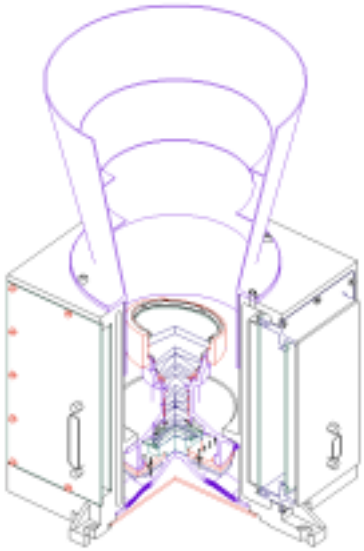
ABSTRACT:

Starting from 1995 Officine Galileo is working to develop a family of autonomous Star Trackers capable of providing attitude information without any a-priori attitude knowledge: a custom design combining autonomy with high pointing accuracy was developed for the ROSETTA Mission. Reacting to the increasing demand, from the space commercial market, for Autonomous Star Trackers to be used in Geostationary satellites and constellations (applications characterised by severe radiation orbits and long duration, and requiring production of large quantities at competitive prices) Officine Galileo developed and qualified a medium field of view AUTONOMOUS STAR TRACKER (called A-STR) integrated in a unique assembly and based on a radiation hardened design, capable to ensure robust and accurate three axis attitude determination in a mass and power consumption very low for such class of instrument. The modular design of the A-STR sensor allows an easy adaptation to the requirement of different missions. A basic version using commercial EEE parts and adopting "small missions' rules" for production and testing, can be made available at a competitive price.

OVERVIEW:

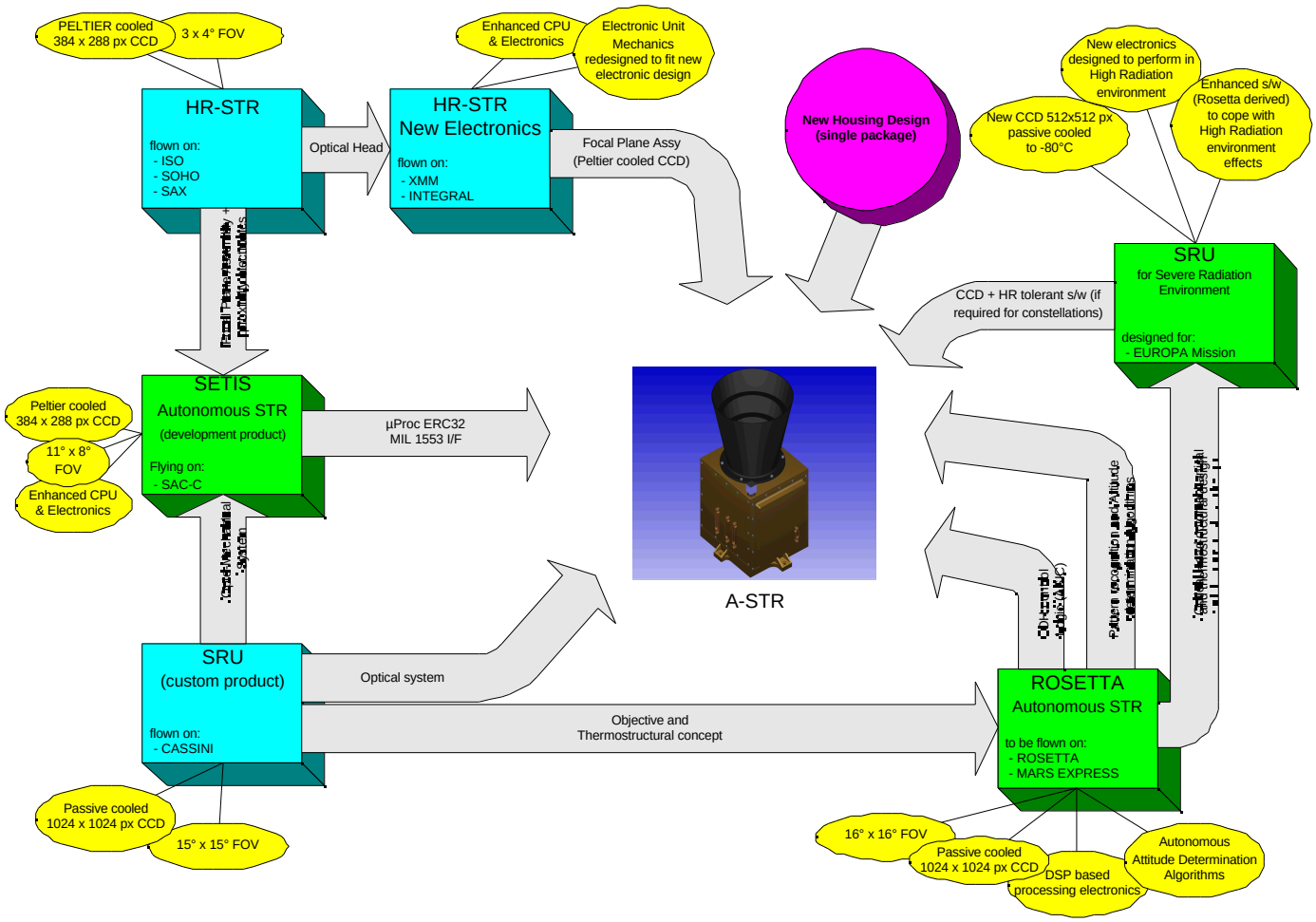
Galileo activities in the field of CCD Star Sensors started in the early 80ies, taking advantage of the experience on the problem of attitude measurement gained with the development of Earth and Sun sensors during the previous decade. Over the last decade Officine Galileo acquired a considerable experience in design, manufacturing and testing of CCD Star Trackers and accumulated an excellent flight heritage having to date 11 models flying. These Star Trackers have demonstrated accuracy exceeding the required performance of few arcsec and capability to acquire and track faint stars even in presence of false events during the crossing of the radiation belts or in presence of solar flares. Additional Star Trackers have been supplied to the INTEGRAL missions to be launched on April 2001.



The most important subsystems of the new A-STR have a traceability to previous Officine Galileo products with a successful flight history. The A-STR design takes advantage of the experience gained by OG in the frame of previous star tracker programs (i.e. ISO, XMM, SRU CASSINI), recent developments (i.e. ROSETTA Autonomous STR) and studies (i.e. Stellar Reference Unit for Europa Orbiter mission under JPL contract). In particular, although of new development, the A-STR architecture derives directly from the autonomous Star Tracker of the ROSETTA Program, with application of all design solutions oriented to reduce mass, power and manufacturing/assembling complexity and with the final objective to realise a competitive product on

the commercial market.

The overall Reliability of the A-STR is extremely high, taking into account the wide heritage on which the new development has been based:



Activities on the Autonomous Star Tracker for the ROSETTA mission of ESA started in May of 1998 with the Engineering Qualification Model, delivered in January 2001 (flight models to be delivered in June 2001). In parallel, two additional flight models will be delivered for the MARS EXPRESS mission. All of this experience is culminating in the A-STR commercial product being offered to the Commercial Market.

The SW of the new product is largely based on the SW of ROSETTA STR, which has been designed, tested and qualified in accordance to the ESA tight rules for “Platform Items” and, according with the ROSETTA requirements, is finally going to be verified by an external software validation facility. Thanks to this approach, the software development process, which is for any equipment and for a Star Tracker in particular a high risk area, is fully under control in the frame of ROSETTA, and the same software quality is ensured for the new sensor.

The High Accuracy Star Trackers family (i.e. ISO, XMM) provides to the new product the design of the focal plane assembly which ensures high positional stability, high cooling efficiency and resistance to severe vibration environments.

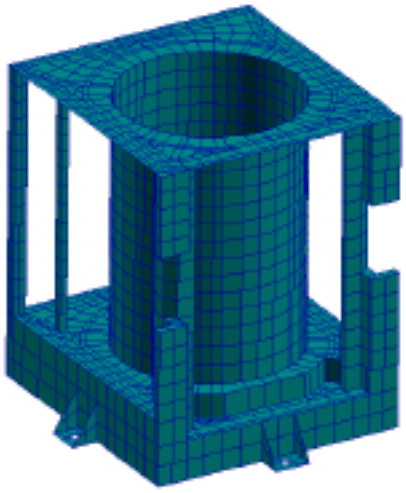
From the SRU CASSINI the opto-mechanical design and the algorithms used in the SW to correct the low frequency errors have been taken. Calibration parameters of the optical distortion and the focal length variations are determined by using on-ground calibration procedures refined in the frame of this program.

The CCD detector selected for the new product was especially developed by ATMEL (France) for space applications. Design, technology (i.e. MPP) and packaging are based on ATMEL long-term know-how and are oriented to the realisation of a rad-hard device. Officine Galileo has collaborated with ATMEL to the definition of the device specification and in the frame of EUROPA program, the two companies have fruitfully collaborated to the characterisation of the new device in severe radiation environment. Several samples have been submitted to radiation tests up to 80 Krads without measuring any modification of the main parameters. This unique experience has been fully transferred to the new A-STR product.

The test facilities and test procedures developed and refined in the frame of the qualification program of ROSETTA STR constituted the basis for the qualification of the new tracker. In particular an electrical checkout equipment, capable of stimulating the processing electronics with images representative of sky scenes as imaged onto the CCD detector, (not only static scenes but also moving ones), has been designed in this program to verify the robustness of the pattern recognition and attitude estimation algorithms.

A-STR MAIN FEATURES (Flexible design adaptable to different mission requirements):

- ✓ **High performance (as for scientific missions-ROSETTA)**
  - high boresight stability in temperature
  - Autonomous Attitude Determination w.r.t J2000 inertial reference frame with full coverage of the celestial sphere and without any a-priori attitude knowledge. 10Hz Attitude data update.
- ✓ **Reduced volume and mass:**
  - main structure by micro-casting
  - volume optimisation
  - Single package sensor (baffle, focal plane, proximity electronics, processing electronics and power supply)
  - high integration of electronics and opto-mechanical parts



A-STR main structure

- ✓ **Designed for severe vibration environment (>26 g rms)**
  - extremely rigid structure (first frequency > 840 Hz)
- ✓ **Designed to withstand the radiation environment of 15 years GEO applications**
  - possibility to adapt the radiation resistance level to the mission requirements without design changes: EEE parts can be purchased with different quality and radiation resistance level allowing cost savings
- ✓ **CCD maintained at the operative temperature by a two stages ThermoElectricCooler**
  - adequate for use in GEO application at 20°C operating temperature.
- ✓ **Low power consumption**
  - high electronic integration (ASIC, careful parts choice)
- ✓ **Low recurring cost**
  - reduced number of parts
  - assembly flow optimised for cost reduction

- extensive test automation

SUMARY OF TECHNICAL DATA:

Characteristic	Value
· Field of View	16.4° x 16.4°
· Dynamic range	1.5 to 5.5 Mi
· Number of trackable stars	up to 10
· Attitude accuracy (3σ)	
- BIAS:	<13 arcsec about three axis
- ORBITAL AND LOW FREQUENCY:	
- Pitch/Yaw :	7 arcsec
- Roll	30 arcsec
- RANDOM	
- Full accuracy (up to 0.5 deg/sec)	
- Pitch/Yaw :	15 arcsec
- Roll:	135 arcsec
- Reduced accuracy (up to 1 deg/sec)	
- Pitch/Yaw :	20 arcsec
- Roll:	210 arcsec
· Track mode updating rate	10 Hz
· Attitude acquisition time:	> 99% up to 1 °/sec. within 10 sec.
· Attitude output data format	Quaternion in the inertial reference frame J2000, Raw star data, Housekeeping data
· Exclusion angle (with standard baffle):	
- Sun:	45 deg
- Earth:	30 deg
· Data I/F to AOCS	MIL -STD-1553 B (or RS422)
· Operating Voltage:	22V to 50 V.
· Power consumption (with MIL 1553 i/f)	8.5W @ 20°C 10.5W @ 50°C
· Mass:	
· Sensor without baffle	2.4 Kg.
· Baffle (standard)	0.45 Kg
· Dimensions (mm) :	
· Without baffle	160(H) x 146(W) x 158(L)
· Baffle (standard)	250(L), 190 (upper diameter)
· Total	355(H) x 146(W) x 158(L)
· Operating temperature	-25°C to 60°C