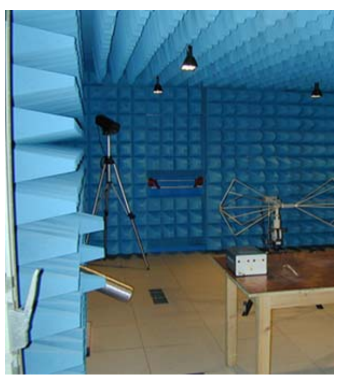
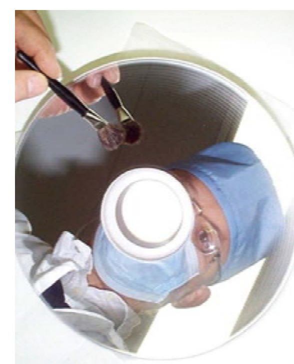
Leonardo Star Trackers - Flight Experiences and Introduction of SPACESTAR Product on GEO Platforms

11th ESA Workshop on Avionics, Data, Control and Software Systems

LEONARDO
AIRBORNE & SPACE SYSTEMS

- Leonardo Space LoB activities in space date back to the mid of the ’60 years, when Officine Galileo provided the attitude sensors to the first European programs promoted by the European Agencies ELDO (European Launcher Development Organisation) and ESRO (European Space Research Organisation).
- Today like then Leonardo is not a sensors’ integrator Company. We offer the advantage of starting from the raw materials and all the manufacturing process of our products is executed “under the same roof”.
- This allows us full control, and to our customers the confidence to be in good hands.

EVOLUTION OF LEONARDO STAR SENSORS

Conventional HR STR

Star position measurement

Mass 7.2 kg + baffle

Flying since 1995
(ISO, SAX, SOHO, Integral ...)

A-STR

CCD Autonomous STR

Attitude measurement (**autonomous**)

Mass 3.5 kg

Flying since 1997 (Cosmo, Stereo, Messenger, Radarsat, MRO, Pluto, Herschel/Planck, Phoenix, LRO, LCROSS, SDO, GAIA, Sentine-1l, Grail, GPM JWST…)

AA-STR

APS Autonomous STR

Attitude measurement (**autonomous**)

Mass 2.6 kg

Flying since 2009 (Proba 2, Alphabus, Bepi Colombo, Astro-G, SpaceBus 4000, ExoMars...)

SPACESTAR

APS Based Optical Head

Attitude measurement **Software is embedded in the Satellite On Board Computer**

Mass 1.4/1,6 kg (LEO/GEO)

Flying since January 2017. 90 units operating in flight

AA-STR 2.0

APS Autonomous STR

Attitude measurement (**autonomous**)

Under development.

Main drivers:

- High robustness
- Power, Mass, Volume and Cost efficiency
- Configurable to meet different mission requirements

HR-STR: we started from the highest accuracy

- in the 80ies Leonardo started to develop a high accuracy star tracker, suitable for being used in the ESA telescopes.
- **HR-STR is a high accuracy (better than 1 arcsec), narrow field star tracker** based on an optical system with cathadioptric objective built with radiation hardened glasses.
- In December 1995 the ESA telescopes ISO and SOHO were launched, bringing to space our High Resolution Star Trackers (HR-STR) for the first time.
- Many other Leonardo star trackers' launches have followed since then, **cumulating to the date more than 500 years of successful in flight operations**.

SOHO HR-STRs are still working nominally after almost 22 years of flight at L1 (launched 02-Dec-1995):

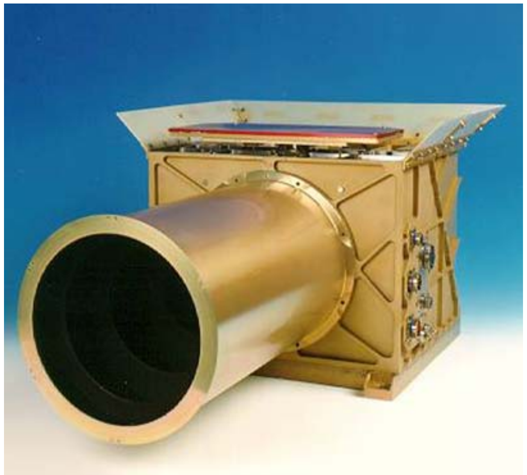
- SOHO was meant to operate until 1998, but it was so successful that ESA and NASA decided to prolong its life several times and endorsed several mission extensions.
- Scientific Operations will continue until the end of 2018.

CASSINI SRU: our first “autonomous” Star Tracker

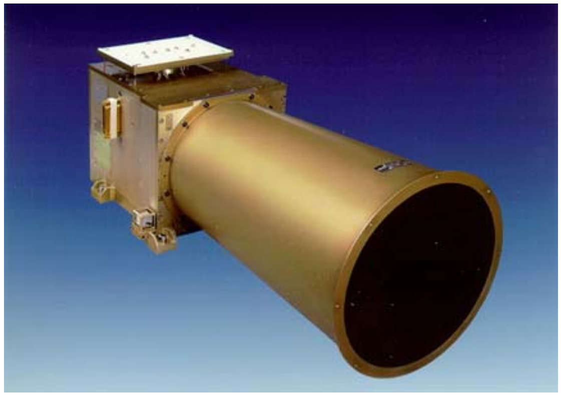
- The first large FOV Star Tracker of Leonardo was developed for the CASSINI satellite, launched in October 1997 and working nominally till the end of the mission (02-Dec-1995).

- Starting from this activity in participation with JPL (in charge of the Electronic Processing Unit), Leonardo developed a new product “series” which was used on Rosetta (where we also have the Navigation Camera), Mars Express, Venus Express.

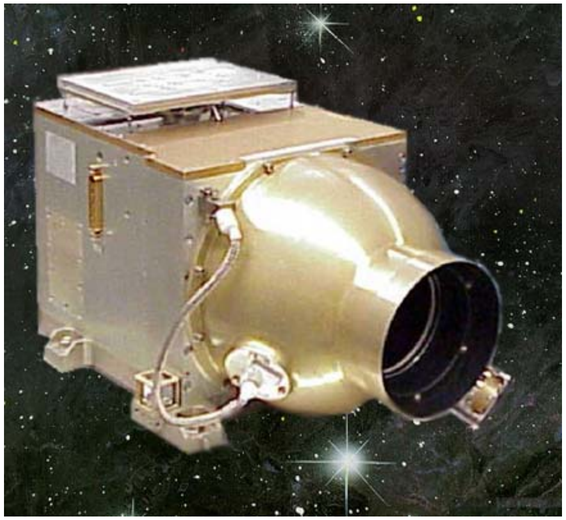
- The A-STR is actually the Commercial Commodity derived from the SRU heritage.



Cassini SRU



Rosetta, MEX & VEX STR



Rosetta Navigation Camera

A-STR: an example of products' flexibility

The modular design of the A-STR product allowed Leonardo to employ a common design for a broad range of missions.

- The ***Herschel and Planck*** programs of ESA are an example of the flexibility of the A-STR design
  - The A-STR is used both in the extremely accurate pointing Herschel Telescope (3 axis stabilized satellite) and in the slowly spinning (1 rpm) Planck spacecraft. This has been achieved by implementing in the standard A-STR product an "interlaced" tracking mode and a TDI (Time Delay Integration) mode respectively.
  - The TDI mode of the A-STR is also used in the New Horizons ***Pluto Kuiper Belt*** mission of JHU-APL, with S/C spinning at 10 rpm
- For the **JUNO Mission** of JPL Leonardo developed a derivative of the Pluto Kuiper Belt configuration, allowing to cope with both harsh radiation requirements and spinning satellite configuration.

AA-STR - APS based STR

- The AA-STR takes advantage of the CMOS Active Pixel Sensor (APS) technology and, when compared to CCD based star trackers belonging to the same "class", features robust and accurate three axis attitude determination within two-thirds the size, weight, power and cost, combined with a significant burst in tolerance to harsh radiation environment.

The AA-STR's characteristics make it suitable for a broad range of missions, including:

- Communications satellites GEO;
- Earth observation satellites;
- Scientific satellites;
- and for interplanetary missions/probes.

TRL-9 achieved in Nov, 2009.
More than 40 years cumulated in-flight operations

SPACESTAR STARTRACKER

SPACESTAR was originally developed to provide a cost-effective solution for large commercial constellation programs.

- HW limited to Optical Heads, each hosting the optics, the detector and the small portion of digital electronics needed to operate the detector and perform communication with the spacecraft computer.
- SW, hosted in the spacecraft AOCS computer, able to elaborate "compressed sky images" coming from the OHs and output quaternions.
- SW optimized to match CPU time allocation (sharing resources with all the other satellite AOCS activities), without penalizing the system robustness and reliability, through simultaneous management of up to three OHs per satellite.

Iridium NEXT: 81 S/C each using 3 STRs and NO Gyros

SPACESTAR STARTRACKER STATUS

- Over 200 Iridium NEXT SPACESTAR FMs have already been delivered at a rate of 9 FMs per month,
- The product achieved TRL-9 on January 14, 2017 when a SpaceX Falcon 9 rocket blasted off from Vandenberg Air Force Base and successfully delivered the first batch of ten Iridium NEXT Communications satellites.
- Other two Iridium NEXT launches occurred in June and October.
- All the 90 SPACESTAR FMs on board Iridium NEXT are performing nominally.

- As just described, in a matter of years, Star Trackers have become smaller, lighter, smarter, more energy and cost efficient.
- Their ubiquitous use means that their optimization in terms of cost, size, weight and power translates into tangible technical and financial benefits throughout the industry; this is especially true for large constellations and for recurrent platforms.
- From the SPACESTAR configuration tailored to the Iridium NEXT constellation, Leonardo is deriving star tracker solutions that raise the bar and set a new standard in term of the aforementioned optimizations.

SPACESTAR STARTRACKER

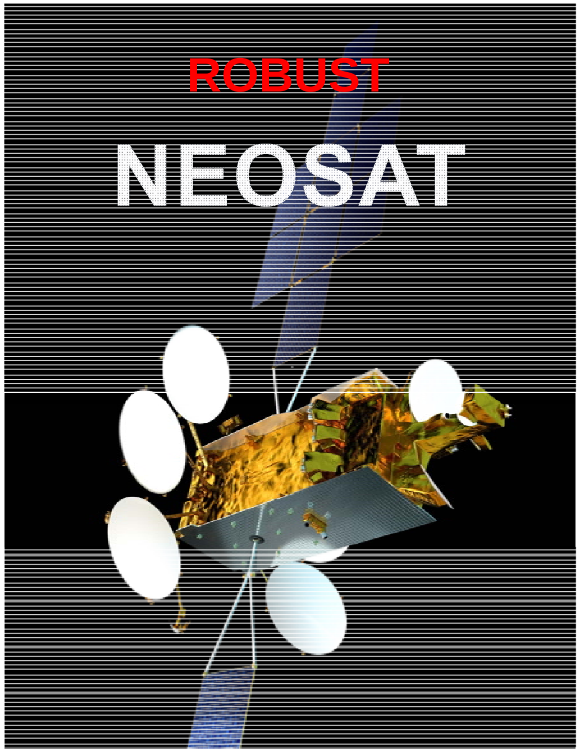
CONFIGURATIONS

LARGE CONSTELLATION

SPACESTAR STARTRACKER LC

EARTH OBSERVATION & SCIENCE

SPACESTAR STARTRACKER EOS



GEO TELECOMMUNICATION

SPACESTAR STARTRACKER TLC

SPACESTAR STARTRACKER CONFIGURATIONS

SPACESTAR STARTRACKER LC

MAIN FEATURES

- Optical Heads: 2/3
- EEE Parts: ≤ Level 2
- OH: 1400g
- Robust (suitable for gyroless)

COST EFFICIENT

- Simplified Testing
- High Volume MAIT

SAVINGS

Compared to other APS Autonomous STRs

SPACESTAR STARTRACKER EOS

MAIN FEATURES

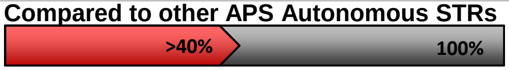
- Optical Heads: 2/3
- EEE Parts: Level 1 or Level 2
- OH: 1450g

HIGHEST ACCURACY

- Alignment mirrors
- Data Fusion
- Maintains tracking @ rates ≤5deg/sec.

SAVINGS

Compared to other APS Autonomous STRs



SPACESTAR STARTRACKER TLC

MAIN FEATURES

- Optical Heads: 2/3
- EEE Parts: Level 1
- OH: 1600g. Increased thickness for greater tolerance to radiation of the electronic components

ROBUST

- Performance in EOR
  - > SW modifications for SEU management
  - > Acquisition 8,000 p/cm2/sec
- 18y GEO orbit radiation shielding
- High Angular Rate Mode

SAVINGS

Compared to other APS Autonomous STRs

SPACESTAR STARTRACKER Earth Observation and Science (EOS) Configuration

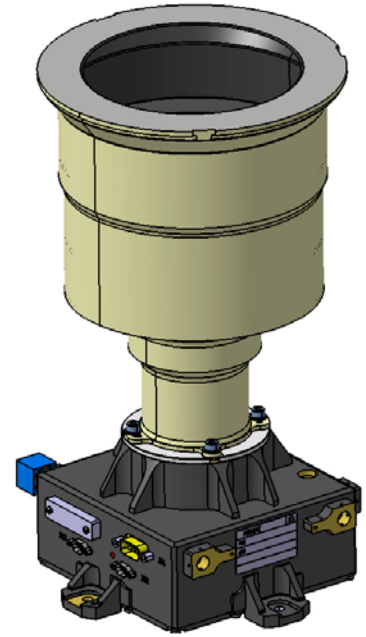
- An alignment cube is included, minimizing bias error due to alignment measurements

- EOS configuration employs “Data fusion” SW algorithms (at quaternion level) to improve quaternion accuracy and compensate thermo-elastic misalignments among optical heads.

- In the frame of an Italian Space Agency program for an agile and small E/O satellite, Leonardo is working to develop a data fusion mode “at star level”, where the different FOVs (from either 2 or 3 OHs) are “merged” into a single sky image. This feature will increase the capability to perform acquisitions from Lost-in-Space at high spacecraft rates.

SPACESTAR STARTRACKER GEO TLC Configuration

- SPACESTAR is suited for those mission in which proton and heavy ions are the dominating radiation sources. It was designed to be robust to natural environments at LEO and GEO orbits (18 years in GEO), for typical commercial and telecommunication satellites.
  - The proposed structure implements an increased thickness improving tolerance to radiation of the electronic components
  - Few EEE components (i.e. SpaceWire line driver/receiver,) are replaced with form, fit and function components having higher resistance to radiation
  - EEE components are upgraded to “Grade 1”
  - An alignment cube is included, simplifying alignment on spacecraft



- Leonardo is also completing SW modifications for SEU management in order to allow the OH to withstand in-orbit missions, constituted in worst case by an Electrical Orbit Raising (EOR) transfer period of hundreds of days, plus a minimum mission duration in geosynchronous orbit of 18 years.

Thank you for your attention.
For any question please contact:

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