Trend for the use of simpler and cost-effective AOCS sensors

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Reasons for Change

- **Cost reduction and competitiveness**
  - **Fierce Competition against US primes on commercial (telecommunication and observation) market :**
    - **$ change, institutional market…**
  - **Chinese DFH4 platform soon to be operational and new countries are developing P/F (India, Brazil, Argentina, Turkey…)**

- **New Techno available**
  - **Larger CPU and memory is becoming available on PF computer**
  - **New sensor techno**

- **Add New Functionality with Return on Investment**
  - **For example Autonomous Orbit determination using GNSS receiver or other methods**
  - **Autonomous Station keeping**

Examples of the observed trend:

- **Low recurrent cost target for constellations (GB2, O3B, IRIDIUM NEXT) paving the way to find new cost effective solutions :**
  - **Merge within the PF computer, functions that are currently distributed**
  - **Large batches allowing more automated processes**

- **New sensors becoming available :**
  - **Sun Sensor on Chip : reduced accommodation constraints, light weight, no baffle, Insensitive to straylight**
  - **MEMs Gyros : AOCS can deal with Coarse Gyros**
  - **APS and Multi head STR : cost saving**

- **Reduction of the number of sensors**
  - **Done on Alphabus and Spacebus 4000 : no more IRES**
  - **GB2, IRIDIUM : no Gyro**

A Difficult Change

- **Commercial operators are very conservative**
  - **Some of them requires a minimum of 3 years of in orbit operations**
  - **Progressive Introduction, small step approach is usually preferred**
  - **Fly new products together with “old” design**

- **Changing operators mind requires time as shown by TAS experience for STR :**
  - **SB4000 avionics was designed and validated for IRES-less concept but it was a difficult to convince our customers in spite of outstanding in-orbit performance :**
  - **03-Feb-05 Star trackers for Yaw axis – Roll and Pitch provided by Earth Sensor**
  - **05-Jul-07   3-axis control provided by STR – Earth sensor kept ON for monitoring**
  - **31-Aug-09 3-axis control provided by STR – one earth sensor onboard but kept OFF**
  - **04-Aug-10 3-axis control provided by STR – no earth sensor onboard**

- **Promote early in-flight demonstration of prototypes :**
  - **Use current mission to validate new technologies**
  - **Partnership with operators in a win/win approach**
  - **Institutional funding is required to support in-flight demonstration**

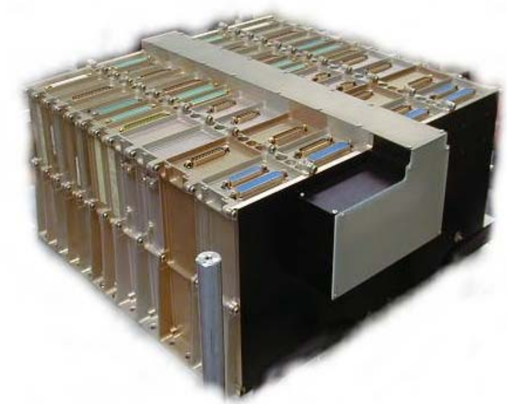
Focus on Low Cost Coarse Gyro

- **Some functions that required high performance Gyros are no more needed :**
  - **Antenna Mapping on Gyro**
    - STR allows large re-orientations and very precise pointing
  - **PMF or AMF with Gyro**
    - STR provides permanent 3 axis determination, no sun nor earth acquisition required before boost
  - **Precise control during sun search phases (safe mode)**
    - Low cost Sun Sensors on a Chip provides large FoV w/o straylight constrains
- **Low cost coarse gyros offer new functionalities :**
  - **MEMS Gyros can remain ON for 15 years**
  - **Permanent Gyro-Stellar control**
  - **Permanent Gyro calibration**
  - **STR forced tracking can be based on Gyro data**

- Such components are already used: TAS-I (TRIS on Integral, H/P…) and Surrey (On GIOVE) university have already used them to build one gyro unit. Unfortunately, they have not been able to take advantage of the extremely low cost of these components, because :
  - Their objective was still to deliver an "autonomous" gyro with medium to coarse performances, whereas coarse performances gyros are enough for telecom S/C with STR. This has induced additional electronics to correct constant bias and thermal bias using hardware.
  - The introduction of these components in one dedicated box still need qualification at unit level : the cost of vibrations, thermal vacuum is not reduced.
- The new concept shall be to :
  - Implement rate sensors components directly on RIU boards, PFC, …
    - Acceptance of gyro function will be part of the unit acceptance
  - Perform all the corrections using PFC S/W
    - No need of an autonomous gyro if everything can be handled by SW, in the same way than the CSS solar cells' output processing
    - Can be done with moderate use of computer time

- **Comparison between TRIS from TAS-I and our concept to explain the cost reduction, made possible by reduced needs in performances :**
  - **2 separate boxes (containing 3 QRS11 each)**
  - **Power Converter**
  - **Voltage re-scale to reduce the covered range (+/- 100°/s to 10°/s)**
  - **Digitalization (A/D converter) of the data for the AOCS (serial interface)**
  - **Constant term correction using data stored in one EEPROM**
  - **Thermal drift correction using thermistor & Logic controller.**

- **What we propose :**
  - **Implementation of these cores on the RIU Board (no specific environmental tests)**
  - **No need of converter (already present),**
  - **Only HW to be added : to re-scale the QRS output and use of analog sensors & A/D converter.**
  - **All the correction handled by AOCS SW (no HW logic and no addition of EEPROM).**



The objective is to find one component, with this major requirement :

- **« If an angular velocity is present around the sensing axis, an output proportional to this velocity shall be delivered. »**

- **Several components available or to be available :**

  - **SYSTRON DONNER QRS11**
    - **Qualified, Space Heritage, No radiation sensitiveness**
    - **Used on GIOVE (MEO orbit), Herschel/Planck, SMART 1**
    - **3k$ per unit**

  - **IAS/SEA/SG detector and proximity board**
    - **Mixed ASIC to be developed**
    - **Detector and mixed ASIC or proximity boards to be provided as “Parts” for integration on existing units**

  - **TAS-Avionics MEMS**
    - **Used on commercial aircrafts or guided bombs**
    - **To be space qualified**

Focus on Star Trackers

- **Miniaturization and segregation between electronics and optical heads will ease the accommodation and drastically reduce the cost.**

- **Need for lower cost STR for telecom mission and some Earth observation missions (micro/mini satellites) that do not require the same precision and stability as science missions**
  - **Simplified manufacturing process**
  - **Reduced calibration tests**

- **Multi-Head Star Trackers with S/W in PFC assets :**
  - **Low mass, low dissipation : Suppression of the over-sized radiators**
  - **In flight Measurement of thermo-elastic effect**
  - **FDIR strategy simplified for STR (single failure of one head has no impact)**
  - **STR software embarked on PFC makes dedicated processing unit useless, thus reducing costs**

- **Multi-Head Star Trackers with S/W in PFC has been baselined for IRIDIUM NEXT**

- **Challenges for implementing STR Software in PFC :**
  - **Autonomous Star Trackers require large CPU and memory**
  - **Acquisition requires a lot of processing**
  - **Lots of data to be exchanged between optical head and PFC**
  - **Validation responsibilities to be defined between Prime and S/W supplier**

- **Possibilities to ease S/W implementation on PFC :**
  - **Maximize processing on Optical Head side (ASIC or FPGA)**
  - **Spacewire link between OH and PFC for high speed data rate**
  - **Increase PFC CPU by using LEON 2 or LEON 3 processor to keep 10Hz quaternion refreshing rate**
  - **Reduce STR measurement rate to 1 or 2 Hz**
    - **Most of AOCS modes do not require 10Hz sampling**
    - **For demanding performance (Normal Mode or Orbit Raising Mode) :**
      - **10Hz Gyro-stellar control that uses Low cost coarse gyro than remains ON 15 years**

Focus on GNSS Receivers

- GNSS receivers are used on all Constellations and LEO S/C (GB, GB2, O3B,…)
  - Reduced need for ranging
  - no need for complex on ground OD S/W whose operation requires large teams
  - New revenues : scientific data collection (radio-occultation)

- GNSS benefits for GEO Application :
  - Ground Hardware savings : One ranging station per 3 satellites
  - Manpower savings : 1p. Full time every 2 to 3 satellites
  - Autonomy for Military applications
  - Suitable solution when Ground stations are not well positioned wrt operated orbital slot

- Need for a GNSS receiver in-flight demonstration on GEO
  - Institutional support required as neither Primes nor Operators can support alone the cost of the demonstration

- Cost of future GNSS receivers shall be minimized
  - Build GNSS receiver standard RF boards to be embedded within PFC or RIU
  - Remove processor from receiver and run S/W on PFC

- **Before Sensors on a chip are available, the only major H/W cost reduction possibility is to shift memory and processing capability from sensors to PFC**

- **At least for commercial applications, sensors shall not be seen as independent external boxes with their own Housing, Power supply, CPU and memory but as far as possible as functions to be centralized and hosted by the PFC**

- **Sensors on a chip (Sun Sensors on a Chip, Star Trackers on a Chip), MEMS Gyros seen as “parts” will eventually drastically reduce the cost of the AOCS subsystem**

- **Change of usage is difficult and requires very early in-flight demonstration and long flight REX to convince end customers**