Project / study

Study of New architecture needs for AOCS / Avionics

Title

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The ESA "Study of New architecture needs for AOCS / Avionics" was performed in parallel to the study "Attitude estimation systems, Requirements on sensor suite" . Both studies have the common objective to derive a development plan for AOCS sensors and actuators. The present study concentrates on the architectural aspects. After a review of the previous roadmaps and the standards identifying the foreseen evolutions, a critical review of current AOCS/Avionics architectures has been performed on a set of three representative missions: an interplanetary mission (ROSETTA), a "middle class" LEO (THEOS) and a large LEO (SPOT 5). This review enables to identify the main sources of concern and complexity. Then after a review of future missions needs, the study provides recommendations for the architecture of future AOCS systems. Finally, based on the inputs from this study and the parallel study on the functional aspects, an AOCS unit roadmap and development plan is proposed.

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The ESA "Study of New architecture needs for AOCS / Avionics" was performed in parallel to the study "Attitude estimation systems, Requirements on sensor suite". Both studies have the common objective to derive a development plan for AOCS sensors and actuators. The present study concentrates on the architectural aspects while the parallel study concentrates on functional aspects.

The study has for objective:

- To make an inventory and analyse the emerging Technologies or Units developments (foreseen or currently in progress) that will be mature within the 2013-2015 timeframe, and that will contribute to evolution of current Avionics architecture solutions.
- To thoroughly examine and streamline all aspects of satellite development experiences, from initial design phases, unit procurement phases, to AIT and in flight operations. This will allow identifying possibilities for more efficient AOCS and Avionics architectures, given the expected benefits from the above inventory of emerging developments, and the trends into new mission requirements.
- To demonstrate clearly the expected benefits and possible limitations of such new architectures solutions. This shall be done from a system point of view in a top – down approach, where the overall optimisation, including End to End cost and development issues, supersedes local optimisations at a lower level.
- As a final step, to determine the architectural derived requirements applicable to future AOCS units, so as to derive the necessary developments and updates to be incorporated into the "Medium and Long Term AOCS Sensor and Actuator Development Roadmap" in preparation for the next round of harmonization

Emerging Technologies

In the frame of the European technology harmonisation activities lead by ESA, several documents define the foreseen evolution of AOCS and data handling systems. In addition, support is provided by ECSS and CCSDS standards.

The main following general technology goals are defined: Having at least one European ITAR free source for all sensors and actuators commonly used, Miniaturize units taking benefits for higher achievable integration level, increase radiation hardening with more usage of custom ASICs and large capacity FPGAs, Standardization of interfaces, Develop high processing power radiation hardened DSP, Develop high speed serial links, Develop new generation solid State Memories and high speed low power ADC and DAC.

Critical Review of current AOCS/Avionics Architecture

Three missions have been selected for an in depth review: An interplanetary Science institutional spacecraft: ROSETTA (D), A "middle class" LEO export market spacecraft: THEOS (F) and finally a "large" LEO institutional spacecraft: SPOT 5 (F).

Efficient Architecture Design and Justification

On Board Data Management Aspects: No stringent DHS issues have been identified during the critical review. The trend and recommendation is to merge DHS and AOCS computer, leading to simpler and efficient architectures. The decision of IO segregation has to be made function of the program context (Need for adaptation from program to program; geographical return constraint). The LEON processor imposes itself as the next processor. ITAR issues can be minimized by developments of Rad Hard ASICs. Concerning the Data bus, MIL-STD-1553B was a very satisfying solution but is now too costly and complex for new generation of sensors. No real replacement is currently available. It is proposed to keep the same protocol on top of a RS485 physical layer (1553-NG) allowing seamless integration of new units into legacy architectures.

Equipments Issues & Improvements: The trend is toward increasing the autonomy of the sensors. Autonomous Star tracker enabled lots of simplification of the avionics and AOCS; this will be also true with APS Sun sensors and coarse Earth sensors which will replace simpler but more constraining sensors (Sensitivity to thermal, straylight…). There is however a price to pay which is robustness. Star tracker robustness is not sufficient and shall be improved with the next generation (Solar flare, straylight, Moon…). FDIR being still a source of high complexity, MEMS gyros are expected to be a potential source of simplification, allowing dedicated low cost/mass safe mode rate detection. Wheels are still a major source of disturbances some concern like the friction torque stability (“Oil jog”) shall be handled at equipment level by improving the technology. Micro-vibrations are not expected to be reduced any more at equipment level (except by a technology break like magnetic bearing) and solutions shall be searched at isolation level (active/passive).

Proposed Development plan

From the analysis performed in both study (“Attitude Estimation Systems Optimized Requirements on Sensor Suite» and “Study of New architecture needs for AOCS / Avionics”) we can derive the followings trends:

- Standardization of solutions and architectures
- Miniaturization of sensors
- Performance improvements.

Concerning sensors, the trend is toward miniaturisation of sensors. We shall however distinguish two types of sensors: The sensors which can be downsized with low penalty on the performances (Magnetometers, Accelerometers, GNSS receivers, Sun sensors, Earth sensors…) and the sensors which cannot due to the limits imposed by physics (Star trackers and gyrometers).

For the sensors which can be miniaturized, the penalty of standard interfaces (1553 bus and unregulated power supply) becomes more and more dominant leading to select new interfaces. For those types of sensors, standardization of lightweight interfaces is considered a mandatory preliminary step. New generation 1553 bus has been proposed as Astrium preferred solution, minimizing software impact, reusing the quality of the well known 1553 protocol for platform control purposes and allowing low cost minimum footprint of the HW implementation. The power interface of such sensors should also be redefined having in mind to minimize overall system cost while satisfying necessary interface design rules to ensure failure tolerance on redounded avionics and not only on single string µsat avionics. Another trend could be to group several functions into the same housing (e.g. MEMS gyros in STR). This is considered to be a good idea if the function of the hosting sensor takes benefit of this combination. If not the preferred option would be to minimize interface overhead as stated previously and keep the flexibility to choose the most appropriate sensor combination for a given system design.

Among the sensors which can be miniaturized, GNSS receivers are the ones which will require most innovative developments. First the Galileo European GNSS constellation deployment will enable new perspectives for European space missions and allow achieving new level of accuracies. New level of integration with the AGGA4 will enable small size highly integrated receiver design and open the door to new markets like launchers and GEO missions.

For the sensors which cannot be miniaturized further without loss of performances (Star tracker and gyrometers) the trend is to minimize the requirements on them (Gyroless or coarse gyro AOCS). Star trackers are a special case as they becomes the reference sensor for any medium to high performance AOCS. The trend is to pursue the improvement of performances through more sophisticated algorithms (e.g. autocalibration), more integration of electronics (fewer parts) and improve robustness.

Concerning actuators, the trend is more on performance improvement: minimization of disturbances and higher agility. Concerning angular momentum transfer actuators (wheels and CMGs) we shall distinguish high agility and medium agility missions. CMG are the actuator of choice for high agility missions but may be too costly for low end class of missions where agility is desirable but do not justify the cost and complexity induced by CMG technology. For these classes of missions (especially mini/µsat range) availability of high torque/high efficiency wheels is desirable. Obviously this will be at the cost of mass penalty but will keep cost and complexity low. Minimization of induced disturbances is the next subject of concern. Continuous improvement of wheel performances (lower µvibs and removal of fast variation of friction torques) shall therefore be followed while efficient methods of cancellation of residual disturbances shall be developed (passive/active isolation).

EADS astrium

Mission type	STR			SUN	Coarse Earth	GNSS Rx		Wheels		CMG		Gyro	Accelero	MAG
	High perfo	Robust./ autonomy	On-chip	Digital coarse (On chip ?)	New product	2 freq.	Additional long term filtering	High torque small wheel	µ-vibration & friction spikes reduction	"mini-CMG"	"µCMG"	Coarse/ mini (MEMS)		Mini (AMR)
LEO agile					(1)							(1)		
Non agile LEO					(1)							(1)		
Obs GEO														
µ-sat					(1)							(1)		
Science/interplanetary												(2)	(3)	
Science/observatory												(2)		

	No interest for the mission
	Might be interesting for the mission class
	Medium interest for the mission class
	High interest for the mission class

(1) Assuming a Safe mode using Coarse earth sensor and coarse gyros
(2) For FDIR purpose
(3) ITAR free

Figure 1: Missions needs versus sensors and actuators expected evolutions

An attempt has been made to prioritize identified developments, although in an ideal world we would recommend to develop simultaneously all identified new equipments! The priority being given to development for which no current alternative exist:

- High precision LEO GNSS receiver (<1m)
- Coarse gyro and accelerometer IMU (MEMS based)
- Sun sensor on the chip (APS based)
- Low Cost Coarse Earth Sensor