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Space systems stakes and strategy for avionics in the context of constellation

10th Workshop on Avionics, Data, Control and Software Systems
ESTEC, Noordwijk, The Netherlands

E. Kervendal, O. Notebaert, Airbus Defence and Space

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New Space and Constellation

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"[…] $ 7,4 billion in satellite transactions are projected over the next 5 years, and over 200 startups are redefining the use cases and economics of space.
[…] space is becoming ever more affordable, thanks to reusable launch vehicles and cheap « of-the-shelf » components. Investor excitement and start-up valuation are growing."

Space 2.0 2017 (April- 25-27, 2017, Silicon Valley, CA), Introduction note,

"Almost 80% of Satellite Market is for LEO Orbit, increasing trend vs last year view
[…] Increasing trend as well for commercial satellites, almost 60% of the overall market.
[…] All those signals confirm the "new space" market trend coming from US :
[…] smaller satellites, big number of satellites, higher fault tolerance, lower costs and purely commercial"

Low Cost avionics presentation, CCT CNES on Small Platform, June, 14th, 2016, Toulouse

Content

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Components-of-the-shelf for avionics

- Benefits and cost-efficient design
- COTS components for avionics vs. quality and reliability

Fault, Detection, Identification and Recovery: strategy for COTS

- From unit level to cope with SEU sensitivity of COTS
- To system level

Possible impacts of constellation on avionics and strategies

Brief summary of discussion and questions

Benefits of COTS components for space avionics

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COTS components are very for design of space avionics

- High performance components (e.g. processors)
- Low power technology
- Highly integrated circuit: low mass and low volume
- Mass production
- Cost-efficiency

Use of COTS makes economic sense, but onboard avionics and DHS will never be 100% COTS-based

- Several key components are not developed by commercial market (RF for instance).
- Compliance to Space standard and robustness to radiations and space environment

COTS-based design does not mean poor design! Several approaches are possible to combine benefits and mitigate drawbacks.

Quality and reliability of COTS

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On one side, since dawn of space industry, design of space avionics relies on well-defined quality standard.

- ESCC, JAXA, MIL...
- 100% High Rel EEE parts are screened
- Highest level of quality and reliability is expected.

On the other side, COTS are designed w.r.t. the constraints of their key, commercial market

- They were not initially designed and qualified for space market
- Ruggedized version of COTS (COTS plus) however exists in Automotive for instance
  - More conservative design rules: AEC-Q[XXX]

Possible strategies for reliability of COTS-based unit

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Avionics is made up of « ruggedized » COTS

- Extra money is spent in the re-design and upscreen of products: not cost-efficient

Infant mortality of COTS for avionics can be significantly reduced

- « make them older» by tests
- Control and verification of manufacturing process, verification of dispersions
  - Good initial qualification, same wafer

Trade-off between qualification status, availability of reliability data and requirements:

- Qualified part (including automotive), vs. non qualified parts
- with satisfactory reliability data or without reliability data
- As a function of requirements defined by system/unit/mission design

FDIR approach at Unit Level

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SEU mitigation is key due to use of COTS in avionics!

FDIR design has to take into account an increase sensitivity to SEU (potential high level of SEU rates)

- SEU detection
- Fast recovery (to avoid increased mission outages)

Several strategies to get immune to transient at Unit level

- Mitigation techniques (within Unit)
  - Error detection and correction techniques (e.g. coherency checks, EDAC…)
  - Fault isolation and propagation avoidance
  - Redundancies and retries (memory accesses, processes, external I/O’s…)
- Retry bus/unit
- Reboot

Examples of mitigation to SEU with COTS

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Self mitigation architecture

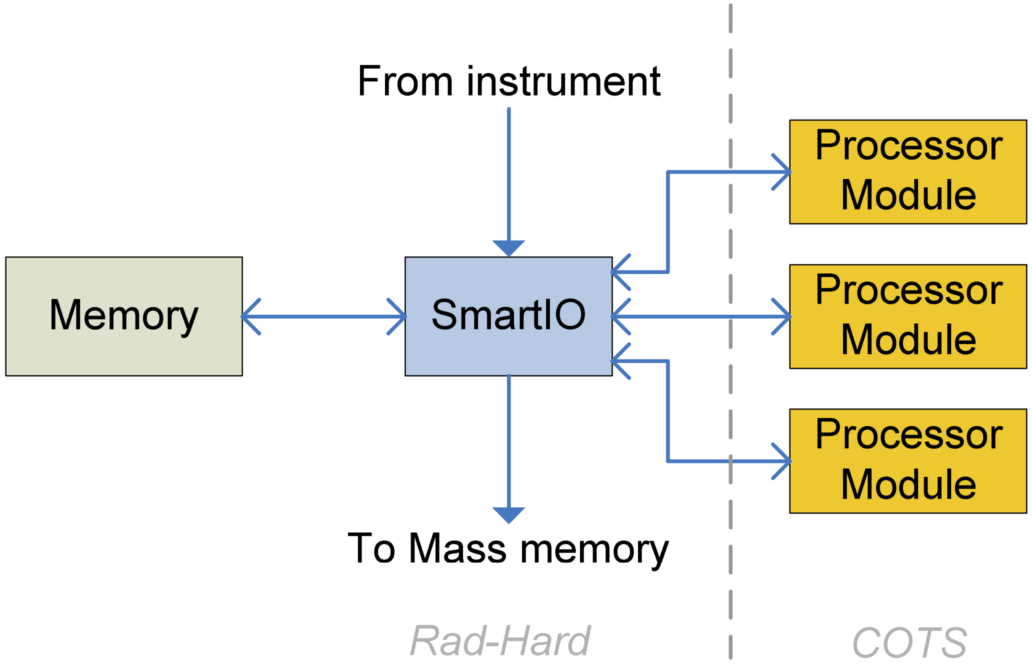
- Use redundancies internal to the COTS components to detect and correct errors

Micro-mitigation at instruction level

- Make use of a tightly coupled rad-hard mitigation unit

Smart I/O architecture

- COTS components are managed by the Smart I/O
- Loosely coupled and configurable depending on mission requirements



FDIR approach at System Level

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COTS-based design for avionics result from a trade-off between requirements, reliability and cost.

- Depending on requirement on mission availability w.r.t. (transient) loss of function
  - Bottom-up design: use of COTS with proper FDIR design
- At satellite level, a possibility is to promote « distributed » intelligence
  - For fast recovery during nominal mission
- At constellation level, a spare satellite can replace a defect satellite

Nevertheless, for mission critical phase, maximum redundancy should be considered.

- E.g. at satellite level, full redundancy for de-orbitation

Possible consequences of constellation on avionics

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When designing, validating and then operating large constellations, some issues might arise due to large number of satellites.

- During AIT, several satellites might be built at the same time
  - From a Satellite Reference Data Base (SRDB), there are a very large number of data to be handled
  - Satellites should be quasi-identical but with slight differences: it should be considered at DB and SW factory

- Regarding operations of constellation:
  - LEOP, IOT, and de-orbitation of several satellites might require large workload
  - Large mission plan should be updated/uploaded on regular basis, including collision avoidance
  - Status of each satellite should be monitored

Automation and autonomy as possible strategies

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A possible solution to mitigate these issues are a certain level of autonomy

Regarding the database,

- Dealing with each satellite via an automatic BD
- Only some data/parameters are different/key to mission performance
  - an in-flight auto-calibration of satellites to manage critical parameters and thresholds

Regarding the operations, workload in control center can be minimized

- automated tasks
  - Common operations core to manage the constellation
- Autonomous avionics can be considered
  - Autonomous check done by ground and/or onboard avionics
  - Autonomous Flight Dynamic System to perform mission maneuvers (in-orbit raising)

Summary

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Components-of-the-shelf for avionics in constellations

- Many benefits from using COTS
- Careful selection of COTS vs. quality and reliability data: COTS-based design does not mean poor design!
- Trade-off between reliability, cost and mission requirements

COTS impact on FDIR design

- from unit level: SEU mitigation is key due to use of COTS in avionics!
- To system level, with maximal redundancy for mission-critical phase.

Impacts of constellation on avionics design:

- Extra costs on DB (and SW factory) or operations
- Can be minimized with careful design of avionics/system, using various levels of autonomy