Industrial and optimized auto-coding process for AOCS SW development in CD phase

Session 2 - Automated Code Generation for AOCS

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Auto-coding process for AOCS SW development

**Roadmap / context**

- **Two demonstrators** have been carried out with CNES and DLR, from April 2012 to March 2013

- Positive conclusion of the autocoding Go / No-Go review within Airbus Defence and Space declared the **“autocoding process” as the baseline for future projects** (2013)

- Positive feedback from technical directorates ESA (ESTEC and ESOC), CNES and DLR in the frame of autocoding process deployment into demonstration projects (2013-2014)

- AOCS Autocoding selected for **AS400 product line** - covering NGSAR and MetOp-SG - Merlin, JUICE, Quantum and Eurostar Neo product line
Auto-coding process for AOCS SW development

Model Based Design with respect to AOCS functional architecture

Common transnational architecture

- Easing communication with SW, OPS and FDIR engineers
- Harmonising new developments and supporting autocoding
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**AOCS model (MCL) perimeter within Central Software (CSW) Architecture**

**AOCS MCL Model**

around 15% of the CSW

- **Interface**
  - **AOCS (SUB)MODE MANAGEMENT**
  - **AOCS STATUS MONITORING & FDIR**
  - **ACTUATOR PROCESSING**
  - **GUIDANCE**
  - **CONTROL**
  - **COMMAND**
  - **SENSOR PROCESSING**
  - **STATE DETERMINATION**

**Interface (e.g. DATA POOL)**

- **SENSOR DATA + AVAILABILITY FLAG**
- **ACTUATORS COMMANDS**

**System S/W Spec (SSS)**

- **DATA ACQUISITION + ACQUISITION VALIDATION + COMMANDING**
  - **MIL BUS**
  - **RIU**
  - **STR**
  - **IMU**
  - **CSS**
  - **RW**
  - **CPS**

**AOCS equipment management interfaces here**

- **Well-defined interfaces between AOCS SW and rest of CSW**

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Process presentation

- AOCS design
- Models design
- AOCS Tuning
- AOCS closed-loop simulator development and validation
  - AOCS fct-models
  - AOCS MCL model
- If anomaly
  - AOCS functional validation and AOCS performances
    - FAME
  - AOCS MCL S/W Code Generation (autocoding)
- AOCS functional model integration for other benches
  - model/bench team
  - AOCS team
  - CSW team

CSW engineering & design
- AOCS MCL S/W integration into CSW
- AOCS Software validation
  - NSVF

FAME: Simulink™ simulator
NSVF: Real time simulator
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AOCS & GNC activities

AOCS/GNC team

System eng.

AOCS MCL SW development

MCL SW specification

Design and modelling

Model validation

Performance

System engineering

- AOCS/GNC analyses and trade-offs
  - Contribution to System requirements

MCL SW

- AOCS/GNC model architecture
- System requirement analysis
  - AOCS/GNC MCL SW Specifications (AMS & AMSW ICD)

Design and modelling

- AOCS/GNC detailed design
- AOCS/GNC MCL model development
  - AOCS/GNC MCL model
  - Algorithms Functional Description (AFD)

Model validation

- AOCS
  - Reference cases definition and execution in FAME
    - AOCS/GNC reference test cases description (RTCD)
    - Functional Validation MCL model
    - AOCS/GNC reference test cases report

- SW
  - Model Standard analysis
  - Model Complexity analysis
  - Model Peer review
  - Model coverage
    - AOCS/GNC MCL VCD & SQAR

- AOCS/GNC performance assessment and validation
  - AOCS/GNC performance report

Kick-off

MCL SW

SRR

PDR

MCL SW

CDR
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Summary of CSW - AOCS Interactions

- CSW Team
  - Applicable Standards, PA Plan, Planning SW/SW IRD (I/F + perfo) document
  - SW/SW ICD
  - AOCS MCL SW
  - Reference Tests Cases (RTC)
  - System Database
  - CSW data
  - RTC Results

- AOCS study Team
  - AOCS MCL S/W Development
  - AOCS MCL data
  - Development, Validation, Verification, Configuration and Quality Plans
  - Spec AOCS-MCL (AMS)
  - TM/TC ICD, SW-SW ICD
  - Validation spec (RTC)
  - AFD, code
  - VCD, SQAR, SVR, BR

- Project Team
  - AOCS Requirements
  - Co-engineering

- AOCS Requirements
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  - CSW Team
  - System Database
  - RTC Results

- Co-engineering
  - AOCS study Team
  - Project Team

- Internal Review
  - CSW data
  - AOCS MCL data

- Project Review
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A multi-disciplines process

This AOCS SW development process defines different roles and responsibilities leading to the following challenges:

- Development coordination between disciplines (deliveries and reviews phasing)
- Common understanding of the disciplines needs and constraints (ECSS applicability, quality rules)
- Sharing or delegation of activities (SW performances budget estimation)

To face those challenges, Airbus Defence and Space organization has been adapted by creating the Functional Avionics entity, gathering a multi-disciplines perimeter (AOCS, SW, Simulator team, Database, FDIR, Operation and Functional Validation), coordinated by the functional avionics lead.
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Auto-coded AOCS SW properties

Auto-coded AOCS SW properties are driven by the **application of modeling standard** on the MATLAB™ source code. This modeling standard has been developed based on in-house know-how and in coordination with Mathworks™ and space agencies (ESA, CNES and DLR).

Among the different requirements, main features are:

- Limitation of allowed Simulink™ blocks (limited to data flow management and architecture)
- Architectural Conventions
- Mastering of elementary function complexity

As a consequence, **auto-coded AOCS SW properties are mastered at model level**
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Verification & Validation (V&V) Principles

- Main principle is to realize all the MCL S/W V&V activities at the MATLAB™ source code level
- Another important principle is that the generated code is never modified

Verification

- Quality metrics measured on MATLAB™ source code.
- Unit tests defined and performed on MATLAB™ source code based on complexity criteria.
  - These tests will derisk and complete the functional validation
- Decision coverage reached on MATLAB™ source code (mainly based on RTC) (target: 100 %)

Validation

- AMS functional requirements coverage reached by test on FAME (Reference Test Cases-RTCs) (target: 100 %)
- RTCs also executed on the Real Time Simulator (NSVF) on full CSW Image after integration of the MCL S/W executable
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Benefits for Verification & Validation cost and planning

For a development process where AOCS SW and AOCS simulator are developed by a team external to the AOCS one:

The delay between end of coding and first functional validation reaches some months (even if activity is prioritized to reduce this delay) whereas the risk of specification misinterpretation is present. In such context, iterations leads to over cost and delays.

For a development process where AOCS MCL and AOCS simulator are developed by a single AOCS team under a common Simulink™ environment (FAME):

The delay between end of coding and first functional validation is reduced to some days. Indeed, unit tests and early functional tests are ready quite synchronously. This means that iteration on the MATLAB™ units can be performed, taking into account both unit test and functional validation test results.

MATLAB™ unit tests and MATLAB™ code functional validation tests can be performed very efficiently with a lot of synergy, integrated in an iterative design short loop, leading to reduce strongly the risk of design and development errors and the development planning.
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Conclusions

- 6 projects currently in development
- Process reviewed and agreed by agencies
- A multi-disciplines process coordinate at Functional Avionic level
- V&V applied at MATLAB™ code level for cost and planning efficiency
- Auto-coded SW properties mastered by applying modelling standard at MATLAB™ code level
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Process industrialization: Documentation list

- 3 AOCS MCL SW dedicated internal standards:
  - Design standard: modelling Standard for autocoding
  - Specification standard: explains how to write the AOCS MCL SW Technical Specification
  - Verification and Validation standard: explains how to verify and validate the AOCS MCL SW Technical Specification, in particular how to design the reference test cases

- 3 AOCS MCL SW plans covering the 5 CSW plans perimeter (same topics as required by ECSS)
  - AMSDP: development plan, configuration management plan and verification plan
  - AMSVP: validation plan
  - AMSQAP: quality assurance plan

- AOCS MCL SW specifications
  - AMSW Specification (AMS)
  - AMSW Interface Control Document (ICD)
  - AMSW TM/TC Interface Control Document (TMTC ICD)
  - AMSW Configuration Item Data List (CIDL)
  - AOCS MCL Specification Requirements Traceability
  - AMSW Interface Requirement Document

- AOCS MCL SW quality
  - Status of Compliance Matrix with AMSW PA Requirements
  - AM Software Quality Assessments Report (AMSQAR)