AOCS S/W Development Process for SWARM, Sentinel-2 and EarthCare

(contribution to NAVVA workshop)

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All the space you need

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Topics

- Introduction
- S/W Development & Specification
  - S/W Architecture
  - AOSE – AOCS Offline Simulator
  - Algorithm Development
  - Executable Specification
- Formal Verification
  - Reinjection of Flight Code

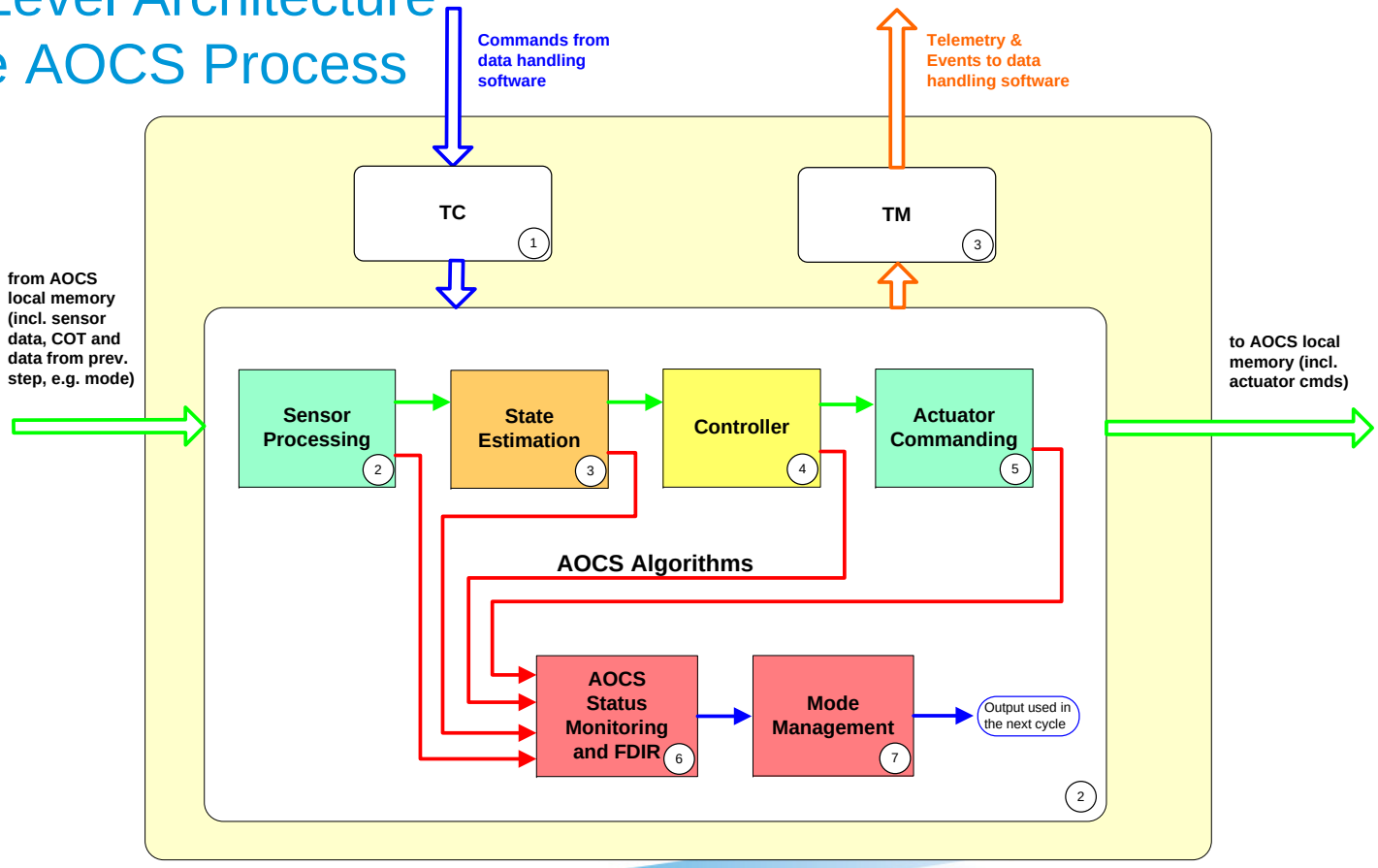
Introduction

- Abstract
  - Using the Matlab/Simulink environment and a dedicated AOCS offline simulator (AOSE) we are able to develop, define and test AOCS algorithms very early in the project lifetime. The algorithms specification is taken directly from the AOSE. After SW coding by the SW supplier the AOCS part of the overall onboard software is reinjected into the AOSE for performance verification.
    This all assures a lean development process.

- Background Information
  - Activities for „Detailled“ Algorithms Specification Start in middle of Phase B
  - Big part of AOCS Offline Simulator (AOSE) already available from Phase A
  - The process has been applied on SWARM and is applied on Sentinel-2 and EarthCare

AOCS S/W Architecture

- Top Level Architecture of the AOCS Process



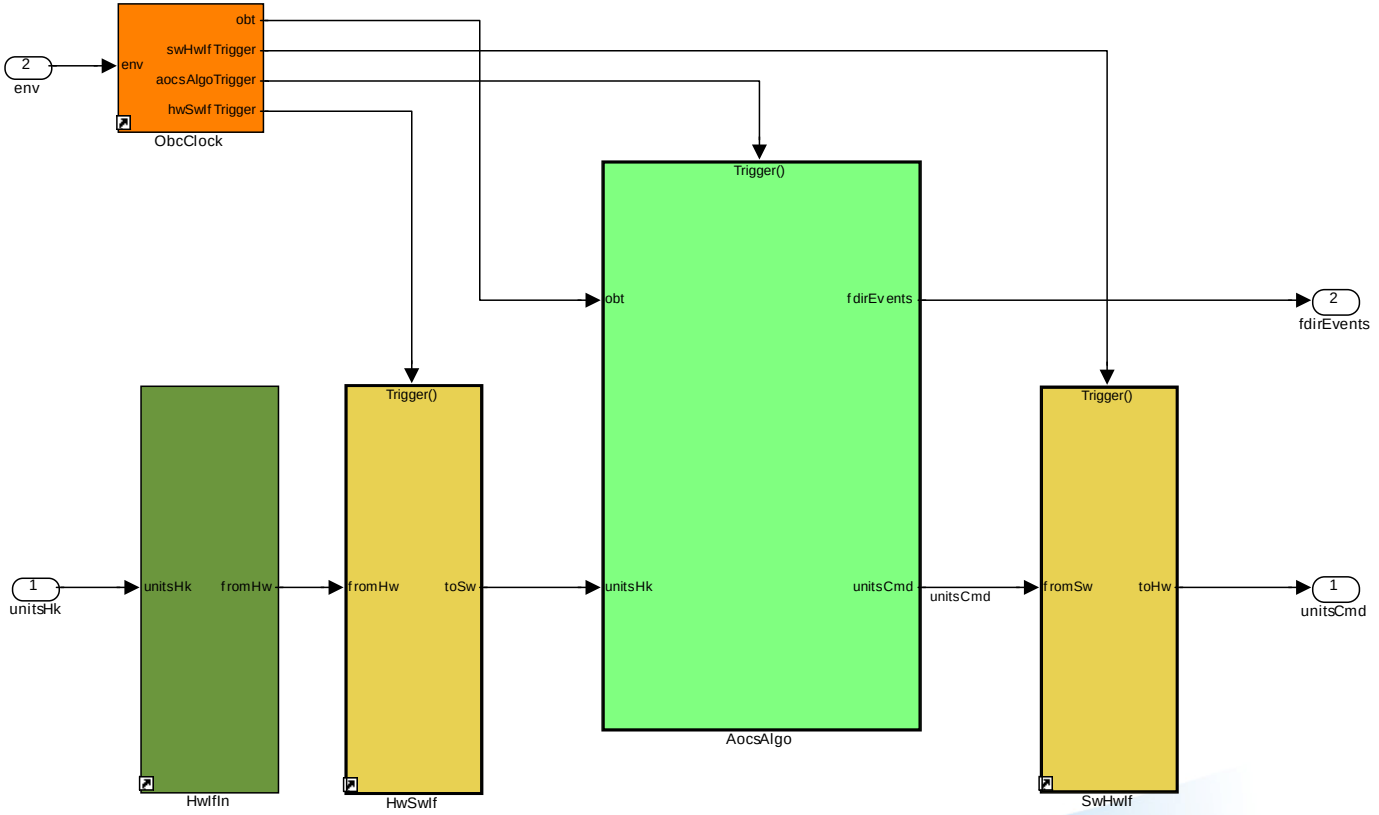
(In-house standard AOCS SW functional architecture)

AOSE – AOCS Offline Simulator

- The AOCS „Offline“ Simulator
  - Simulates
    - Physical environment around the S/C (Gravity, Magnetic Field, Eclipse, ...)
    - Unit models (all Sensors, Actuators, OBC and PCDU)
    - S/C itself (incl. geometry, mass properties, ...)
  - Development environment for
    - AOCS S/W Algorithms
    - Verification tasks
      AOCS S/W unit tests
      Open loop tests
      Closed loop tests
  - Supports mission analysis tasks (e.g. simulation of calibration manoeuvres)
  - Based on STAR (In-house library for Dynamics and Environment Models)

AOSE – AOCS Offline Simulator (cont'd)

- OBC



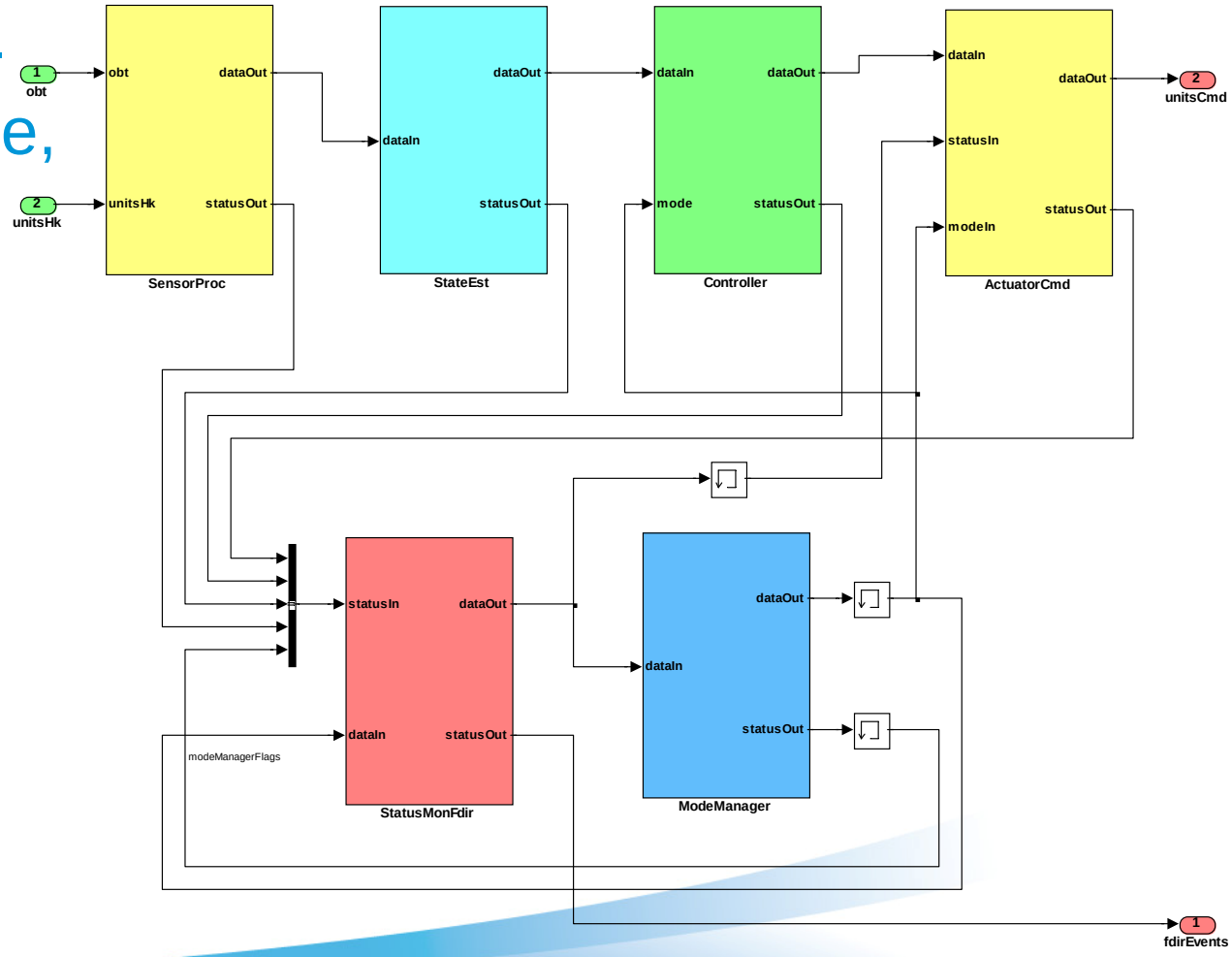
- Converts analog to digits
- selects the cold redundant units
- data corresponds to data pool
- OBT generation
- further proc. not included in AOCS Algo

AOSE– AOCS Offline Simulator (cont'd)

- AocsAlgo
  - Block contains all S/W algorithms for AOCS
  - Interfaces to outer world are minimised
  - S/W architecture is split into levels 1-3
    - Level 1 – Top Level Architecture (project independant)
    - Level 2 – „Unit" Level Architecture
    - Level 3 – „Function" Level Architecture, connects „Building Blocks"
    - Architecture always implemented in Simulink
  - „Buildings Blocks" contain the algorithms
    - Big reuse of In-House verified „Building Blocks" library, collected into „AOCS Functions"
    - Implemented in Embedded Matlab (EM)
  - „Support Functions"
    - Support „Building Blocks" with basic functionality
    - E.g. math library, filter, integrator, signal handling, ...

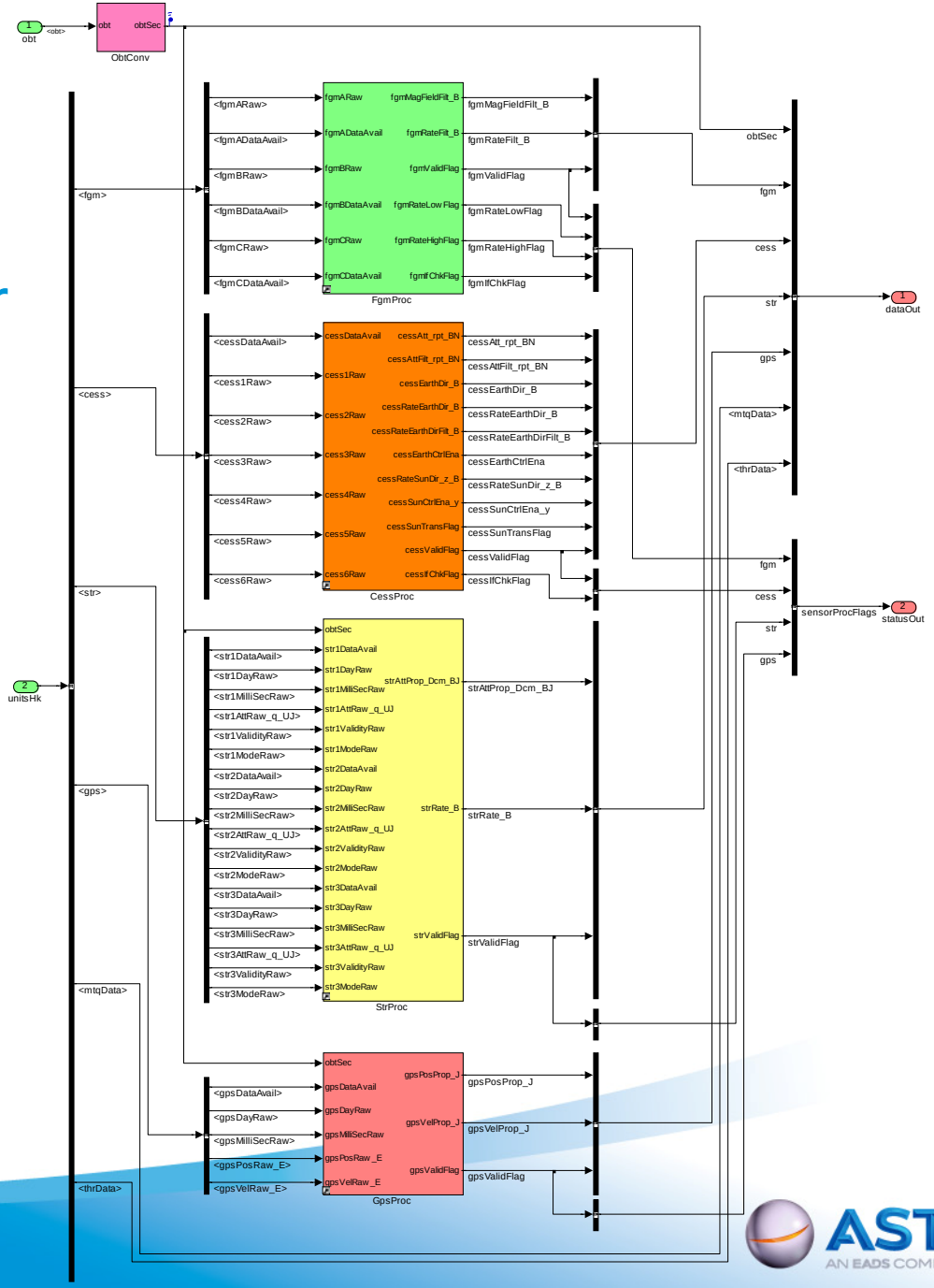
AOSE – AOCS Offline Simulator (cont'd)

- AocsAlgo - Architecture, Level 1



AOSE – AOCS Offline Simulator (cont'd)

- AocsAlgo – SensorProc, Level 2



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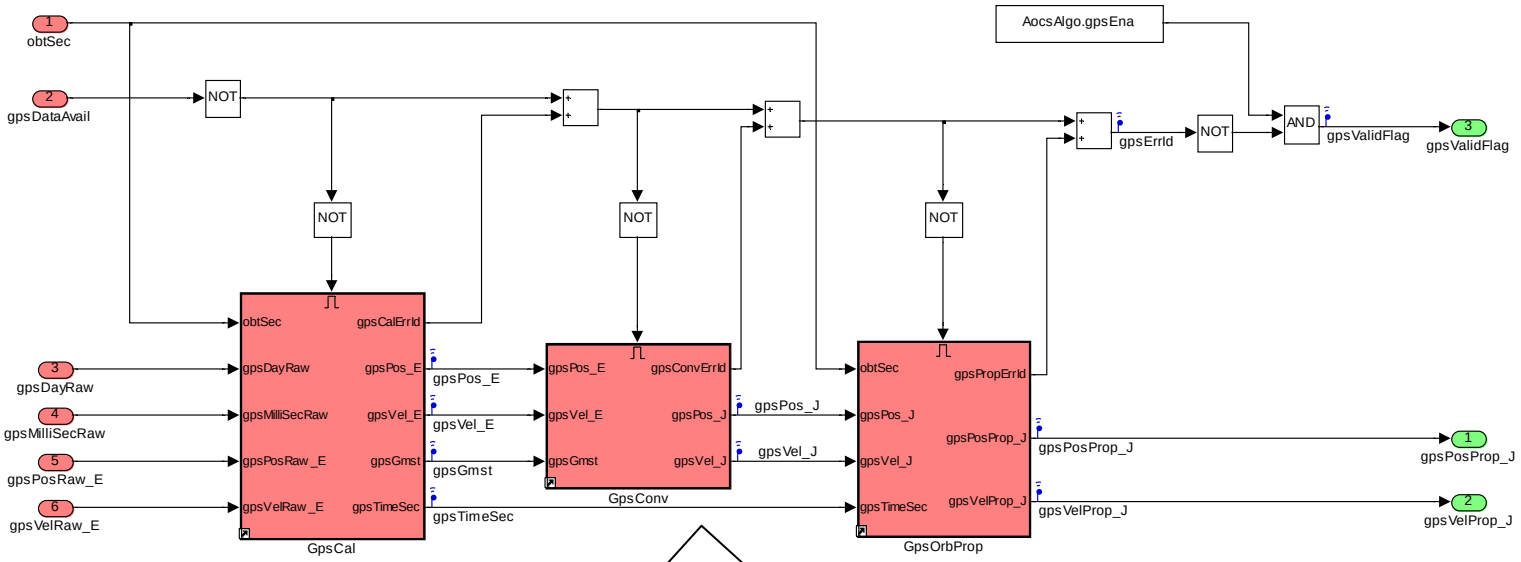
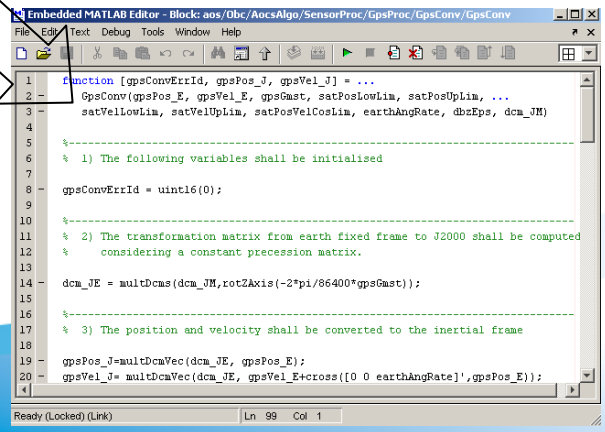
Algorithm Development





Level 3 + Building Block

Example: GPS data processing

Architecture and data flow implemented using Simulink. Detailed algorithms implemented in Embedded Matlab (EM) function blocks.

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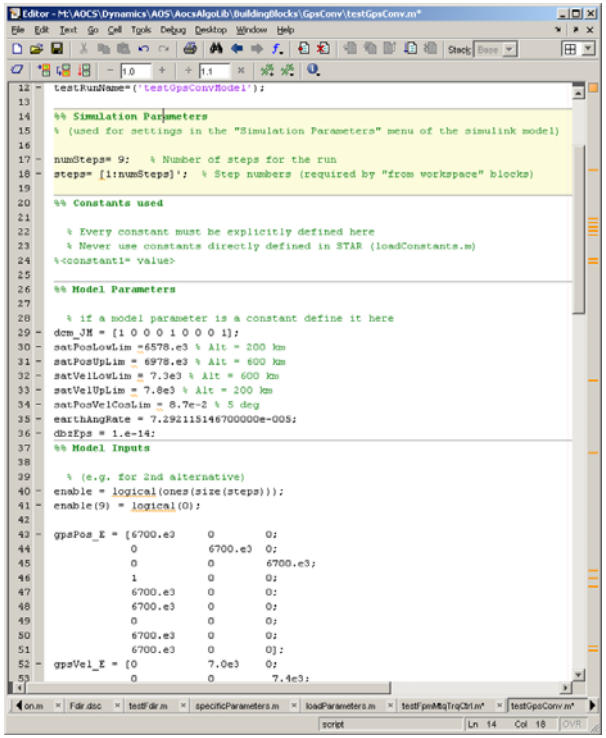
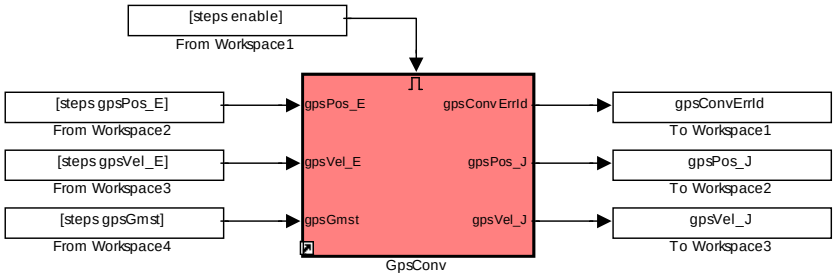
Algorithm Development (cont'd)

- DSC-File (DSC: Descriptor)
  - used for description, interfaces, masking, test setup, ... (see later)

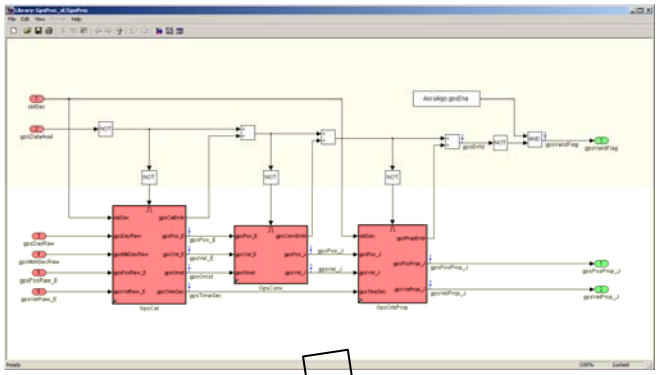


- Testing
  - Each algorithmic BB is formally tested

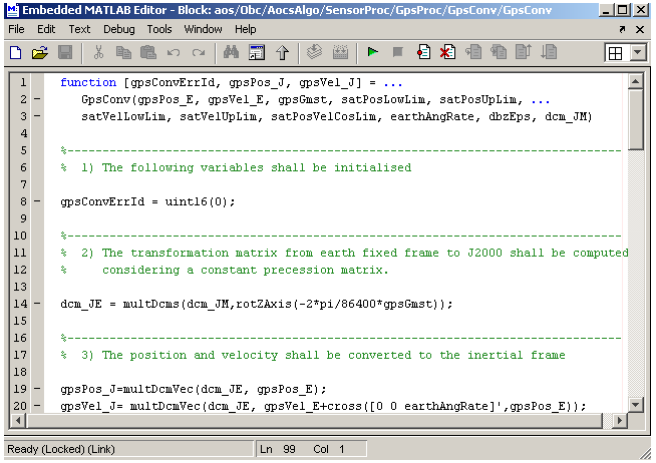


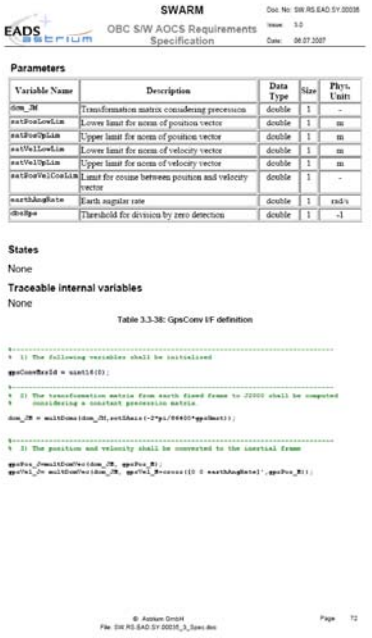
  - Tests consists of one Simulink model and one or many test m-files
  - Time series (not constant) for inputs
  - Time series of simulated output is checked against time series of expected output with specified evaluation criteria
    => Test passed or failed

“Executable” Specification



- sum of all Dsc-files
  + all Simulink architecture models
  + all Embedded Matlab code
  = AOCS S/W Requirements Specification





Embedded Matlab code is directly used
in the written AOCS S/W specification.

(Generated through DOORS)

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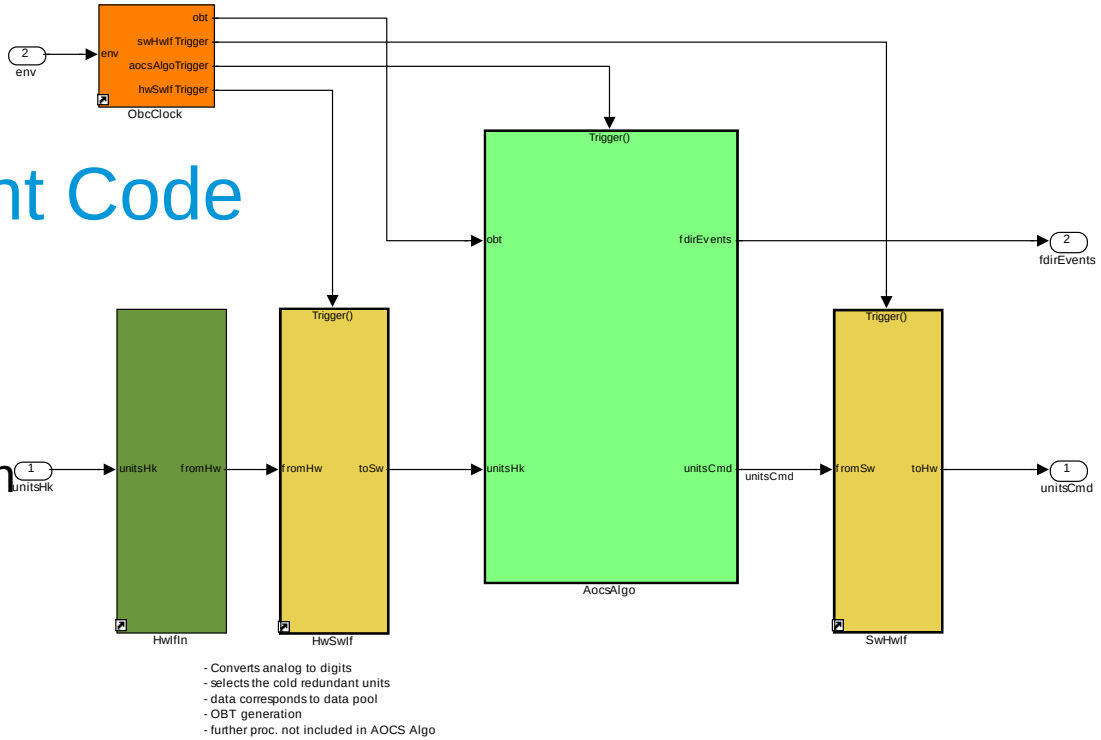
“Executable” Specification (cont‘d)

- Delivery to code supplier
  - Specification Document
  - Simulink and Embedded Matlab models (informal)
  - Unit test files for regression tests on BB level with
    - Input time series
    - Expected output time series
    - Evaluation criteria
    - Test Models in Simulink and Matlab (informal)

Reinjection of Flight Code

- In principal
  1. Take AOSE
  2. Replace AocsAlgo with S-function incl. supplier Ada-code
  3. That‘s all



- Required to / with code supplier
  - Clear interfaces for I/O, parameters, states, logging (TM), commanding (TC)
  - Clear scheduling of AOCS S/W items
  - Easy cut-out of AOCS S/W part from overall OBSW Ada code
  - No direct packet handling and no direct PUS-services in AOCS S/W part
  - Naming conventions wrt. Parameter (Variables) to be reused identically in SDB (TM/TC)

Reinjection of Flight Code (cont‘d)

- Advantages to have AOSE as precursor
  - Environment, Dynamics and Satellite Modelling are ready and verified
  - Equipment Models are ready and verified
  - During development of AOSE
    - Single mode tests
    - Multi mode tests
    - FDIR tests

    are debugged and executed
  - Big part of these tests can be reused for formal
    - Open Loop testing on supplier premises
    - Closed Loop testing with FVB
  - Test scripts including plotting and evaluation can be reused without modifications
  - New tests can easily be created by change of parameterisation files