# Generic AOCS units simulation models

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# Summary

1. Motivation for the ESA ITT
2. Scope and choices of the Study
3. The Study team
4. Study results / Guidelines
5. Study results / 3 models for 6 units
6. Study results / Main simulation models features
7. Study results / Expected status at completion
8. Schedule
9. Distribution and Maintenance
10. Future steps
11. Meet us at ESTEC
12. Q&As

# Motivation for the ESA ITT

- SAVOIR / Building blocks logic in the frame of the AOCS V&V cycle

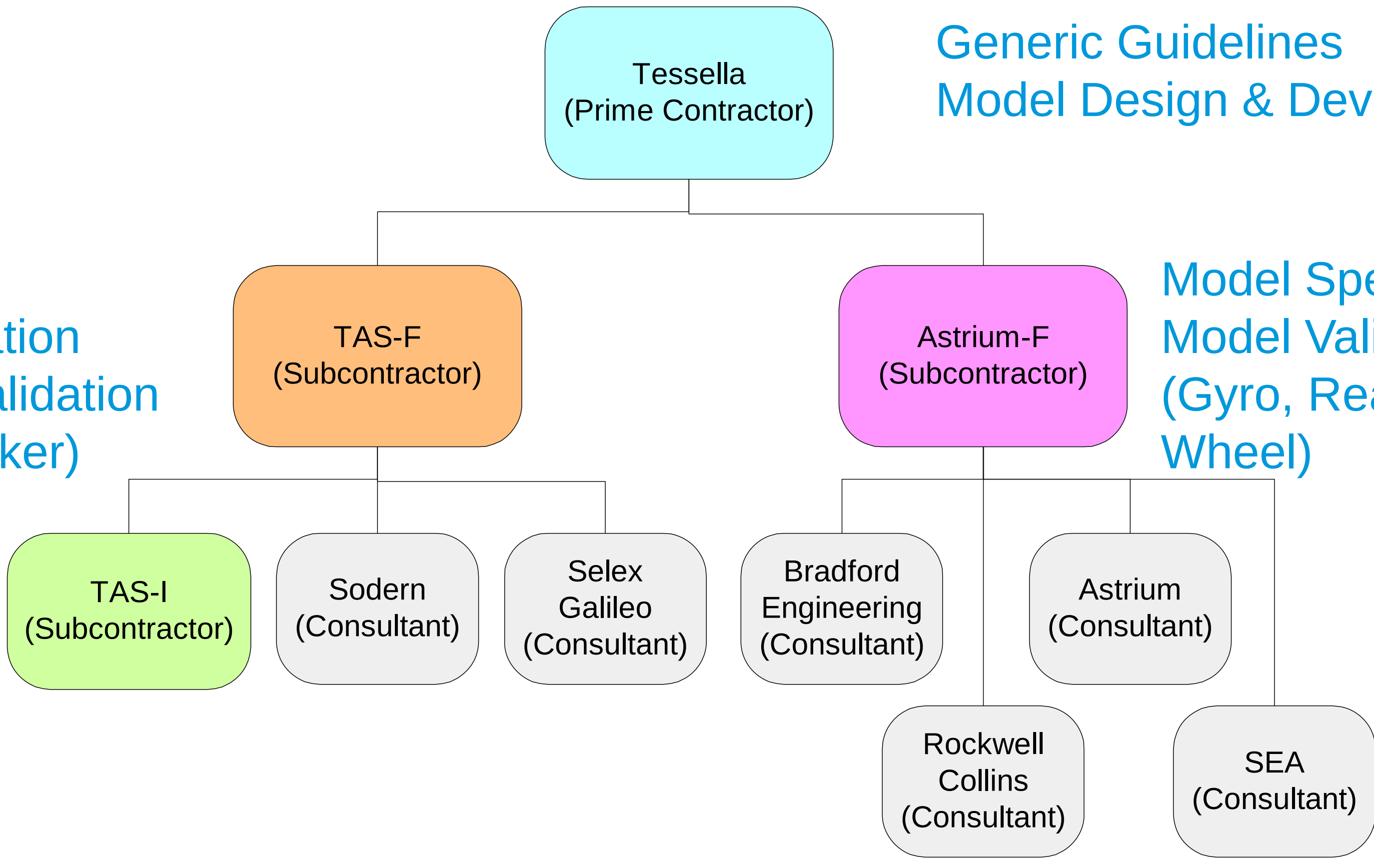
- AOCS HW simulation models
  - For all ESA-member states companies
  - Generic models ensured as far as possible (multi-unit, multi-benches, multi-users)
  - Direct use for Engineering & Functional AOCS simulators
  - Portable on SW and Avionics benches
  - Re-use to lower risk and cost and to allow shared and flexible use

# Scope and choices of the Study

- Scope
  - prototype several AOCS units simulation models to be used for AOCS validation up to Avionics testbench
  - design according to users needs
  - validate against real HW behaviour and performance
  - maintain genericity as far as possible
- Choices
  - AOCS sensor/actuator: Star tracker, Gyro and Reaction Wheel
  - Number of real HW units per type of AOCS sensor/actuator: 2
  - Simulation models for direct use in Engineering/Functional AOCS simulators
  - Compatible with Real Time benches (SW and Avionics) –with extra layers to be introduced-

# The Study team

Generic Guidelines
Model Design & Development

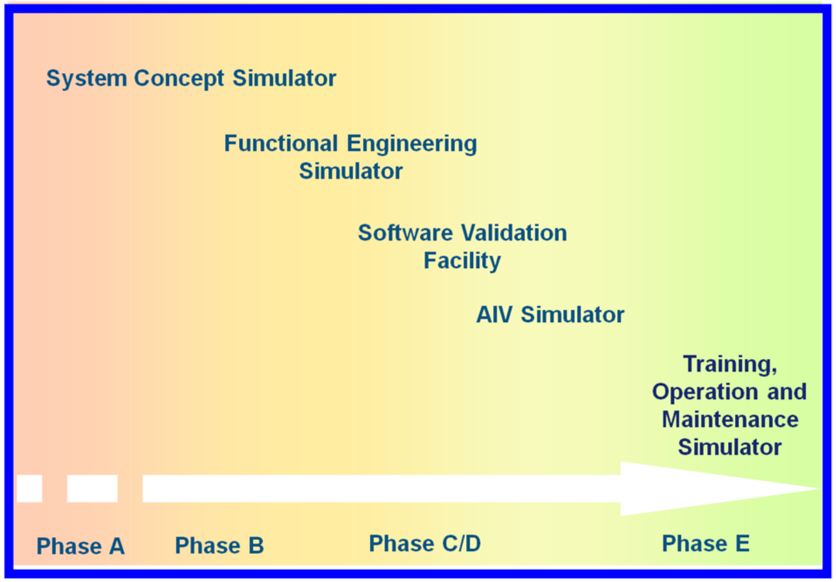



Model
Specification
Model Validation
(star tracker)

Model Specification
Model Validation
(Gyro, Reaction
Wheel)

# Study results / Guidelines

1. Targeted use of generic models – necessitated careful capture of guidelines for development

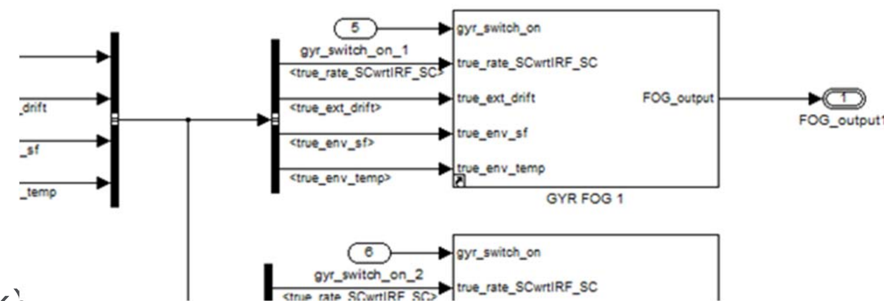



2. Key areas of focus driving guidelines:
   - Architecture
   - Re-usability
   - Tuneability
   - Configurability
   - Run time
   - Fidelity
   - Interface
   - Format & language
   - Validation
   - Model parameter handling

# Study results / 3 Models for 6 Units

Tessella Technology & Consulting

1. Models developed for reaction wheel, gyroscope and star tracker
2. Detailed specifications for implementation prepared by TAS (STR), Astrium (RWL,GYR) with support from unit suppliers.
3. Models validated against 2 examples of each unit, and for real time operation on benches
4. Final product for the AOCS community:
   a. Simulink Models
      – Reaction wheel
      – Star Tracker
      – FOG gyro & MEMs gyro
   b. C Models (autocoded from Simulink)
   c. Parameter Files
   d. Validated tunings for two units for each model
   e. Acceptance Test Code
   f. Comprehensive documentation

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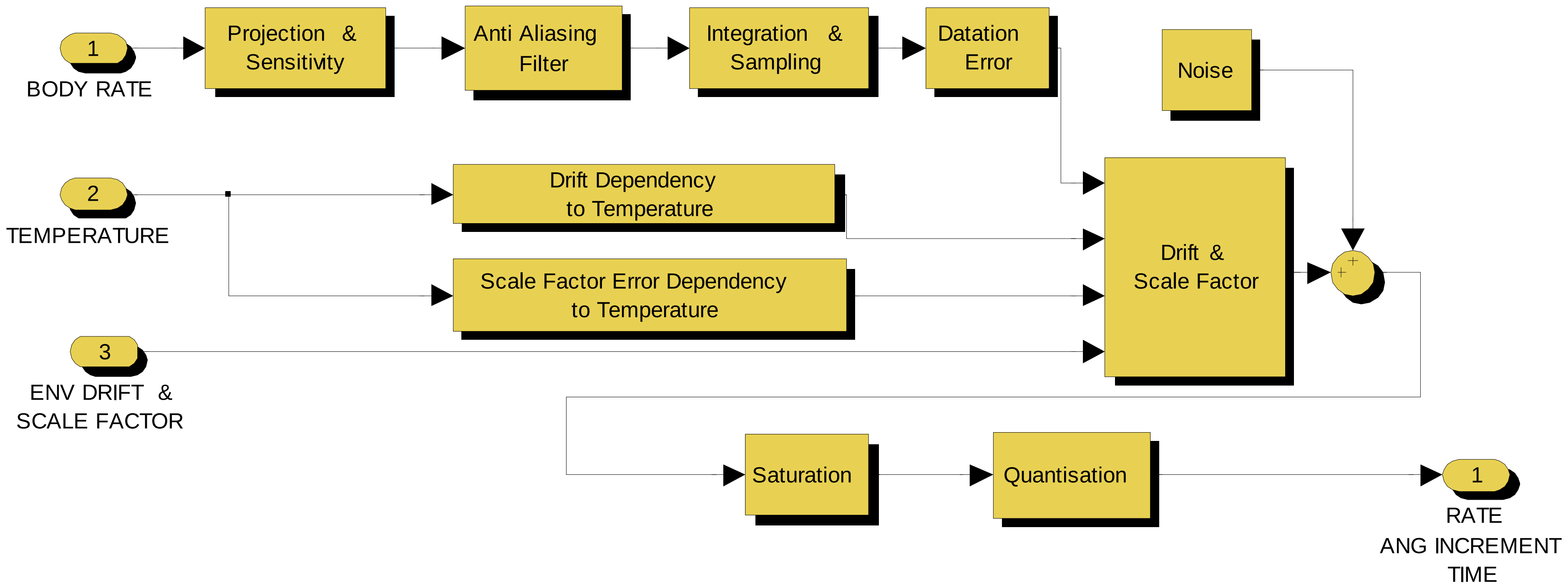
# Study results / Main Simulation Model Features - Gyro



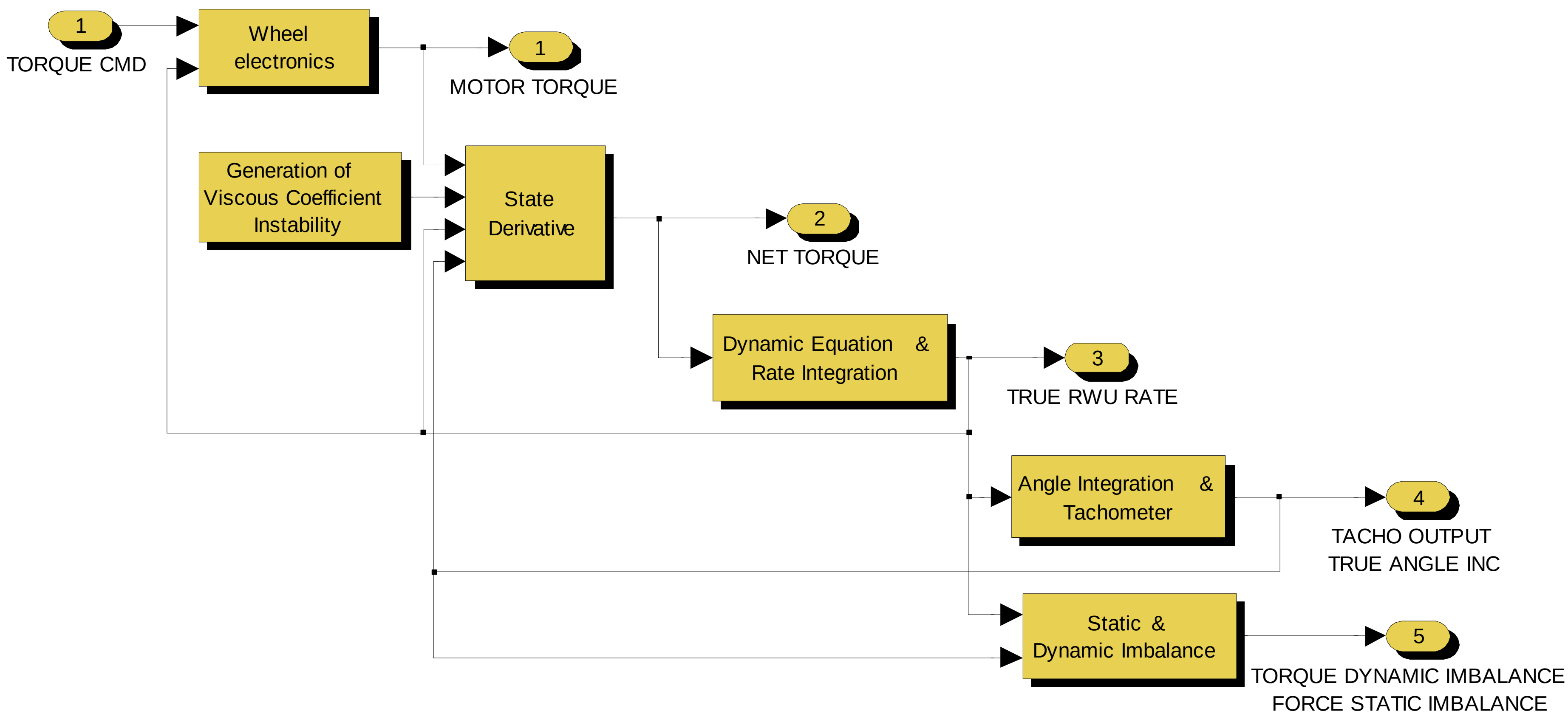

Single axis FOG Architecture

# Study results / Main Simulation Model Features - Gyro

| 1.1.1.2 Module | Key Elements & Description |
| --- | --- |
| Projection & Sensibility | Projects the spacecraft rate onto the axis measured by the gyro and then models the range of rate that can be seen by the gyro. It contains the following elements: • Misalignment computation • Projection of spacecraft rate onto gyro axis • Rate blind zone: (small angular rates below a threshold are not be detected by the gyro) |
| Anti-Aliasing Filter | Implements a second order low-pass anti-aliasing filter. |
| Integration & Sampling | Models the integration of the rate into angle increment and samples the outputs following an external signal. |
| Datation Error | Models the measurement time jitter by extrapolation of the measured data at the real sample time date. It is not a delay of the output. |
| Drift Dependency to Temperature | Implements a polynomial dependency between the Temperature and the Drift. |
| Scale Factor Dependency to Temperature | Implements a polynomial dependency between the Temperature and the scale factor. |
| Drift & Scale Factor | Models the gyro scale factor and drift and implements the possibility to inject external scale factor and drift due to environment. |
| Noise | Simulates the following elements: Angle White Noise, Angle Random Walk, Flicker Rate Noise, Rate Random Walk |
| Saturation | Implements the Rate saturation. Indeed, if the angular rate is too high (above a saturation level) the gyro saturates |
| Quantization | Models the quantization of the output signal (both increment angle and time). |

Gyro model modules

# Study results / Main Simulation Model Features - Reaction Wheel

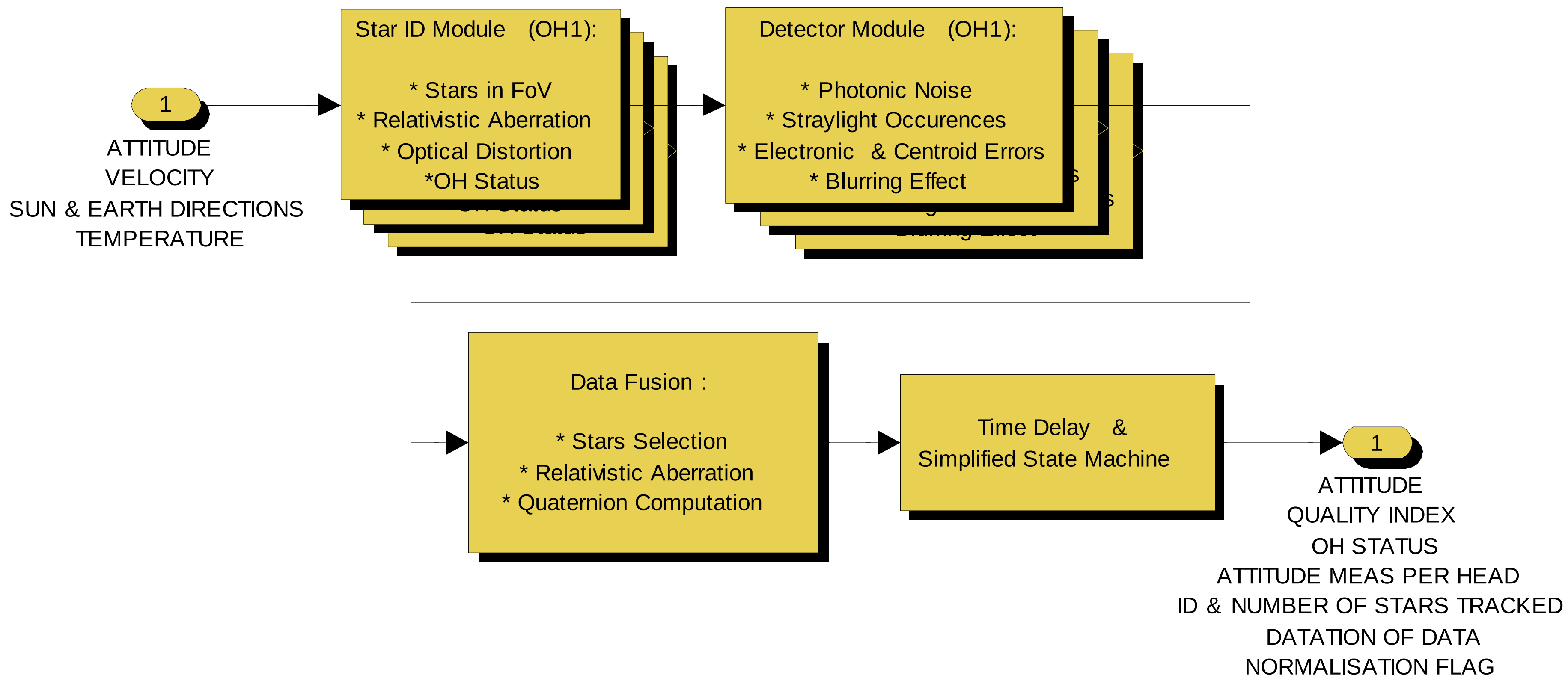


# Study results / Main Simulation Model Features - Reaction Wheel

| 1.1.1.1 Module | Key elements |
|---|---|
| Wheel Electronics | • The commutation delay which depends on whether the torque direction has changed<br>• The torque command limiter<br>• A bias and scale factor error |
| State Derivative | • Striction<br>• Coulomb friction<br>• Viscous friction<br>• Spikes<br>• Motor torque ripple |
| Generation of Viscous Coefficient Instability | • Generation of a random instability at a given sampling time. This sampling time is a housekeeping parameter only used to generate a random signal. |
| Dynamic Equation and Rate Integration | • Generation of wheel acceleration from wheel torque<br>• Integration of the wheel acceleration into a wheel rate<br>• Note that this block can be replaced by an interface to the overall spacecraft dynamical block (including the wheel dynamics) |
| Angle Integration & Tachometer | • Integration of the wheel rate into a wheel angle and a number of revolution<br>• Integration of the absolute value of the wheel rate to generate the number of tacho pulses<br>• Evaluate the measure of the wheel sign |
| Static and Dynamic Imbalance | • The Torque Dynamic Imbalance computation<br>• The Force Static Imbalance computation |

Reaction Wheel model modules

# Study results / Main Simulation Model Features - Star Tracker



# Study results / Main Simulation Model Features - Star Tracker

| 1.1.1.3 Module | Description & Key Elements |
|---|---|
| Star Identification Module | Simulates both the "environment" and the optical part of the sensor. It enables the identification of the visible stars in the STR field-of-view, on the basis of the input quaternion and of the main STR features (focal length, size of the CCD/APS matrix). This module also:<br>• Applies relativistic aberration error<br>• Simulates the effect of the optical distortion that occurs mainly on the edge of the field-of-view.<br>• Determines validity of delivered quaternion wrt to Sun blinding and Earth occultation.<br>• Simulates the impact of the straylight level on the star selection process. |
| Detector Module | Simulates the behaviour of the APS/CCD detector, in a simplified way (i.e. no pixel-level transformation of the vault image). This module also includes the following functions:<br>• Detector noise simulation<br>• Detector electronics and centroid errors simulations<br>• Blurring effect simulation<br>• Failure effect simulation |
| Data Fusion | Simulates the post-processing of the vault images delivered by the optical heads; it includes the following sub-modules:<br>• Stars selection.<br>• Relativistic aberration correction.<br>• QUEST algorithm: performing the computation of the optimal J2000>STR quaternion. |
| Time Delay & State Machine | Simulates the delay that occurs during STR processing and the management of the states of the sensor; it includes the 2 following sub-modules:<br>• Time delay<br>• State machine: the purpose of this sub-module is to model both the acquisition and the tracking modes of the sensor, in a simplified way |

Star tracker model modules

# Study results / Expected status at completion

1. Guidelines completed for development to meet generic need

2. All models verified against specifications

3. Validated tunings for 2 examples of GYR, STR and RWL, against real unit or hi-fidelity simulated data

4. Models validated for use on real-time benches

5. Availability of models and associated collateral to the AOCS community

# Schedule

- Model Acceptance Review (study team + ESA)

  November 2012

- Final presentation and Final report (ESTEC – open meeting)

  December 2012

- Models maintenance and gathering of improvements & suggestions

  until June 2013

# Distribution and maintenance

- AOCS community (ESA member states): AOCS primes, AOCS HW suppliers, Avionics benches suppliers,…
- User license to be granted by ESA (free)
- Six-month maintenance period (exp. Until June 2012)
- Feedback from users are very welcome
- User workshop at the end of the six-month maintenance period (TBC)

# Future steps

- Improvement/enhancement of existing prototype models
- Enlarge the unit selection in the library
  - other gyros / star trackers / reaction wheels units
  - other types of units: GPS, sun sensors, magnetometers, magnetotorquers,...
- Design of the extra layers for use on Avionics benches
- Distribution

**Meet us at ESTEC**

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# Demos and Q&As on the AOCS Unit Simulation Models

Wednesday 24th Oct. from 8:30 until lunchtime

with Tim Pattenden (Tessella Ltd)

Bernard Polle (Astrium SAS)

Bénédicte Girouart (ESA/ESTEC)

## Open meeting in Meeting Room Df006

(ESTEC main building, main corridor ground floor)

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# THANK YOU FOR YOUR ATTENTION

Any (other) question, please send us an e-mail:

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