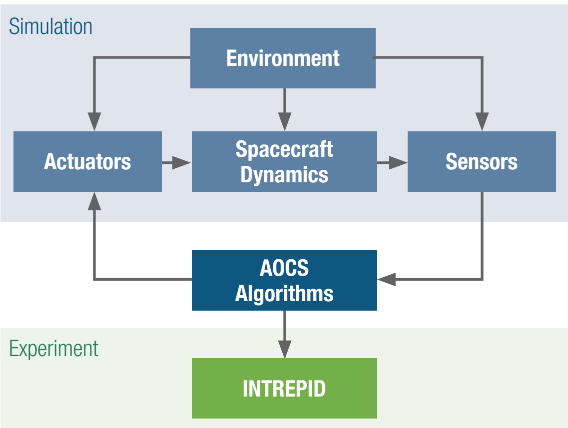
The on-board processing unit running under Matlab's xPC-Target real-time environment allows rapid prototyping and verification of the AOCS functional design. Thanks to autocoding capabilities of the simulation environment, the whole functional AOCS algorithms (architecture, operation modes, and low-level functional modules) used in the offline simulation environment can be directly transferred into the experimental environment without any modification. The AOCS algorithm design of a mission is thus well-proven when it is ported to the on-board computer of the satellite.



Testing of AOCS Algorithms with INTREPID in the Loop

The given setup allows for broad capabilities of rapid algorithm prototyping and experimental performance verification of the AOCS system, in particular:

- Determination of moment of inertia characteristics and structural flexibilities
- Identification of actuator dynamics
- Analysis of fuel sloshing dynamics
- Assessment of micro-vibration effects

The CMG hardware demonstrator is the main enabler to achieve these goals with a technology readiness level (TRL) of 5 to 6.

Specifications of INTREPID

Air Bearing Table	
Moments of inertia	[30,30,40] kgm²
Tilting capabilities	+/- 50 deg on lateral axes
Payload capacity	150 kg
Actuators	
Primary actuators	Configurable array of 4 single-gimbal CMGs: pyramid/roof configurations
CMG momentum capacity	4 Nms @ 5000rpm
Max. CMG gimbal rate	40 deg/s
Max. output torque	3 Nm
Sensors	
Inertial measurement system	3-axis MEMS
Absolute attitude determination system	Vision-based rms < 0.1deg
On-board processing unit	
On-board processor	PC-104
Interface cards	Various D/A boards, WiFi interface
Operation	
Autonomous operation using batteries	120 min
Data acquisition	Real-time acquisition of all AOCS algorithm variables

CONTACT

Dr. Jens Levenhagen, department head AOCS/GNC and Flight Dynamics, Airbus Defence and Space Friedrichshafen, Germany
Phone: +49 7545 8 2569
Email: jens.levenhagen@airbus.com

ACKNOWLEDGEMENTS

This work has been financially supported by the Space Agency of the German Aerospace Center (DLR, Deutsches Zentrum für Luft- und Raumfahrt e.V.) with means of the German Ministry of Economy and Technology under support numbers 50 RR 1301 and 50 RR 1302.

Supported by:

Federal Ministry for Economic Affairs and Energy

on the basis of a decision by the German Bundestag

In collaboration with

iFR

Institute of Flight Mechanics and Control
University of Stuttgart

AIRBUS DEFENCE & SPACE

1005. August, 2016.

HOREOS Agile

Technology Development for Advanced AOCS, GNC and Flight Dynamics

- Agile AOCS
- High Precision Pointing
- Dynamics and Control Laboratory

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INTRODUCING HOREOS AGILE

"HOREOS agile" stands for High Optical Resolution Earth Observation Satellite under agility conditions, and is a technology development program by Airbus Defence and Space in collaboration with the Institute of Flight Mechanics and Control (iFR) at the University of Stuttgart and supported by the German Aerospace Center (DLR) in Bonn. Its main purpose is the development of advanced attitude control strategies for highly demanding optical satellite missions for Earth observation and science.

A particular emphasis within HOREOS agile is put on mastering the domain of agile satellites, i.e. when the spacecraft performs fast rotations and follows some given attitude profile with high accuracy. Typical agile satellites are equipped with control momentum gyros (CMG), which allow generation of high internal reaction torques and hence performing attitude maneuvers with high angular rates.

KEY DEVELOPMENTS

- Process definition, implementation, and validation for agile spacecraft AOCS simulation and analysis
- AOCS detailed design and verification for agile spacecraft with high pointing accuracy and precision
- Systematic Hardware-in-the-Loop (HIL) verification with INTREPID, the AOCS testbed for agile spacecraft

CHALLENGES

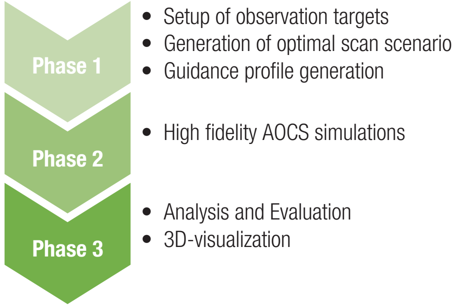
The ability of a spacecraft to rotate at high angular rates on the one hand and the necessity to achieve highly accurate pointing on the other hand gives rise to non-trivial challenges from multidisciplinary areas. The challenges related to attitude dynamics and control are:

- Guidance scenario generation with maximal observation coverage under given system boundaries
- Precise attitude determination under agile conditions
- Accurate knowledge of the spacecraft component dynamics involved in attitude control
- Sophisticated attitude control algorithms that incorporate the ability to follow reference profiles during the spacecraft rotation phase, highly accurate attitude control during the imaging phase, and optimized transitions between the slewing and imaging phases
- Advanced steering logic for CMG actuators to maximize output torque and angular momentum capability whilst minimizing occurrence of the actuator limitations (e.g. singularities)

A systematic treatment of the aforementioned challenges in a design process with innovative and cost-effective technological solutions is the focus of the HOREOS agile program.

AGILE S/C AOCS SIMULATION AND ANALYSIS PROCESS

The HOREOS agile team has acquired a broad know-how in modelling, simulation, control design and analysis of agile missions. The initial effort in designing the functional algorithms for agile missions was put into establishing a simulation and analysis process as illustrated below.

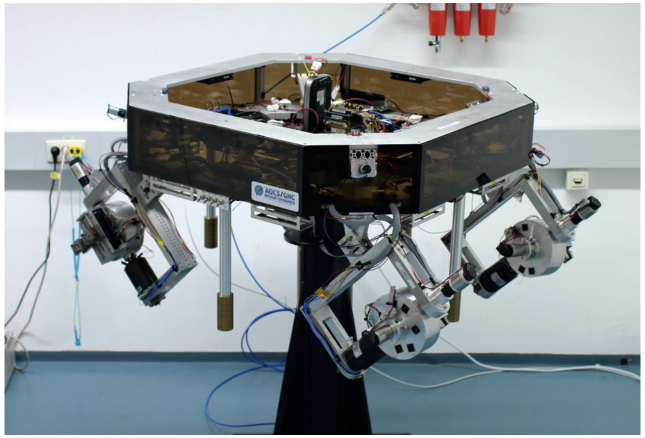


Along with common simulation packages such as Matlab/Simulink™, the simulation and analysis environment makes use of the following in-house developed tools for planning, optimization, simulation and visualization purposes:

- Agile Satellites Scenario Evaluation Tool
- AOCS Offline Simulation Environment
- Orbit Visualization Environment

INTREPID – AOCS TESTBED FOR AGILE S/C

"One kilogram of experiments is worth thousand kilograms of simulations." With this justification, an experimental environment involving HIL infrastructure has been established at Airbus Defence and Space facilities in Friedrichshafen. This setup consists of an air-bearing table with three rotational degrees of freedom: tilting around two lateral axes and rotation around the vertical axis. The relevant equipment modules located on the air-bearing test platform are the CMG actuators, on-board processing unit as well as attitude and rate sensors. To achieve a high similarity with spacecraft in-orbit dynamics, the center of mass location is aligned with the center of pivot by means of a dedicated mass balancing system. The air-bearing table can be powered either by using an external power source or a battery pack mounted on the platform. In the latter case, the platform motion is fully decoupled from any external disturbance sources.



INTREPID - AOCS Testbed for Agile Spacecraft