Planned space missions often depend on autonomous formation flying, in which one spacecraft approaches or flies alongside another. The Prisma project, led by OHB AG (OHB) in collaboration with the French and German space agencies and the Technical University of Denmark, tests and validates guidance, navigation, and control (GNC) strategies for advanced autonomous formation flying.

OHB engineers used Model-Based Design to develop GNC algorithms, run system-level real-time closed-loop simulations, and generate flight code for Prisma’s two satellites, Mango and Tango. They got a jump-start on the project by reusing MATLAB® and Simulink® models previously developed for the SMART-1 satellite.

“We evaluated different GNC algorithm concepts in MATLAB and then rapidly moved to Simulink models for simulation,” says Ron Noteborn, lead engineer at OHB. “Those models evolved into full flight models, which we verified in closed-loop simulation. From there, generated flight code was just a click away.”

The Challenge
Develop low-cost satellite GNC systems to enable autonomous formation flying, rendezvous, and close-proximity operations with a small team

The Solution
Use MathWorks tools for Model-Based Design to model GNC algorithms, perform real-time simulations, and generate production flight code

The Results
- Development time cut by 50%
- Early verification and test reuse enabled
- Interagency collaboration simplified

“The team ran closed-loop simulations in Simulink to verify GNC algorithms. These simulations tested individual components of the plant model as well as integrated systems comprising multiple subsystems that were contributed by the collaborating agencies. Using Simulink Coder™ and Embedded Coder®, OHB engineers generated code from

“With a limited amount of propellant on board, we needed to verify that our systems would work well before we started experiments in space,” says Robin Larsson, attitude orbit control system engineer at OHB.

OHB engineers needed to collaborate with engineers working in France and Germany and to integrate their Simulink models and C code into the complete GNC system.
their GNC models and plant model. They deployed the plant code to Simulink Real-Time®, and compiled the GNC code for the onboard target LEON2 processor. OHB then ran hardware-in-the-loop (HIL) tests of the combined Simulink Real-Time system and LEON2 controller to verify the real-time operation of the algorithms.

As satellite hardware became available, the team replaced parts of the plant model with real sensors and actuators and reran their simulations. This resulted in a test setup with a maximum amount of flight HIL, including the onboard computer and GPS receiver stimulated by RF signals. To rehearse actual mission flight operations and verify flight command sequences, OHB ran simulations against the plant model on Simulink Real-Time.

OHB engineers used MATLAB Compiler™ to build standalone applications for displaying and analyzing satellite flight data. OHB staff can use these applications to prepare for satellite operations even if they do not have MATLAB installed.

OHB engineers are reusing Prisma models for yet a third program: Small GEO, a general-purpose geostationary satellite platform.

The Results

**Development time cut by 50%.** “Using Model-Based Design to develop and verify our algorithms is 50% faster than hand-coding,” says Noteborn. “And by reusing 70% of the SMART-1 attitude control models, we eliminated development time for those parts almost completely.”

**Early verification and test reuse enabled.** “We have four levels of verification, ranging from desktop simulations in Simulink to HIL tests using Simulink Real-Time and flight command sequences on our target hardware,” says Larsson. “We ran tests very early on and then reused those same tests throughout development. This approach ensured consistency and repeatability.”

**Interagency collaboration simplified.** “We incorporate C code from other agencies into our Simulink simulations as S-functions so that we can verify them within the complete system,” says Noteborn. “We also exchange Simulink models with colleagues in other agencies. It’s much easier to understand how another engineer’s design works from Simulink block diagrams than from C code.”

Industry

- Aerospace and defense

Application Areas

- Embedded systems
- Control systems

Capabilities

- Data analysis
- Mathematical modeling
- Algorithm development
- Desktop and web deployment
- System design and simulation
- Embedded code generation
- Verification, validation, and test

Products Used

- MATLAB
- Simulink
- Embedded Coder
- MATLAB Compiler
- Simulink Coder
- Simulink Real-Time
- Stateflow

Learn More About OHB AG

www.ohb.de

Learn More About the Prisma Satellite Mission

www.prismasatellites.se/?sid=9028