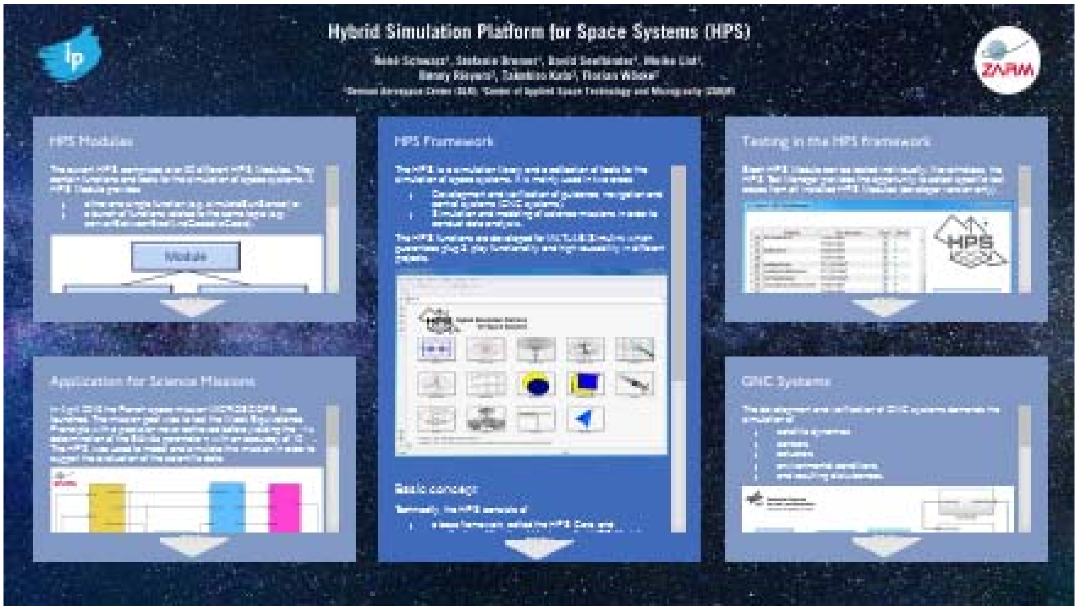
Hybrid Simulation Platform for Space Systems (HPS)



René Schwarz[1], Stefanie Bremer[1], David Seelbinder[1], Meike List[1], Benny Rievers[2], Takahiro Kato[2], Florian Wöske[2]

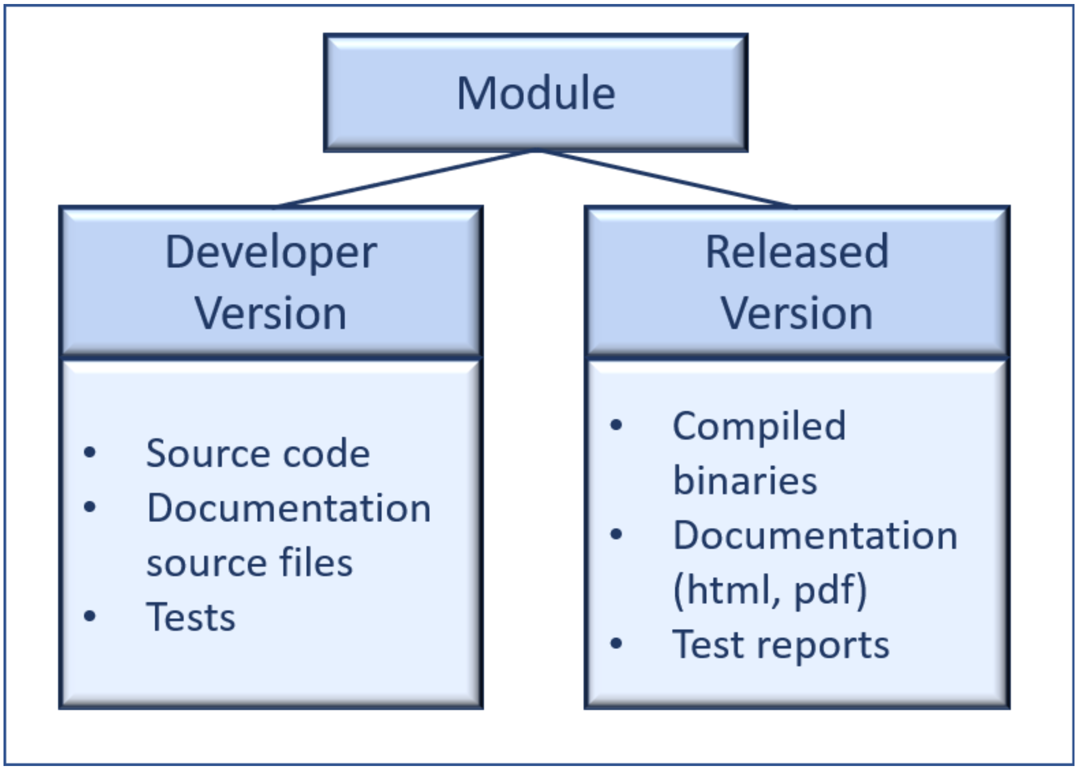
[1]German Aerospace Center (DLR); [2]Center of Applied Space Technology and Microgravity (ZARM)

PRESENTED AT:

HPS MODULES

The current HPS comprises over 90 different HPS Modules. They contain functions and tools for the simulation of space systems. A HPS Module provides

- either one single function (e.g. simulateSunSensor) or
- a bunch of functions related to the same topic (e.g. convertBetweenEcefAndGeodeticCoord).



Each HPS Module is structured in the same way and incorperates an XML file which contains information on e.g.

- the author,
- provided functions,
- dependencies to other HPS Modules,
- compilation procedure.

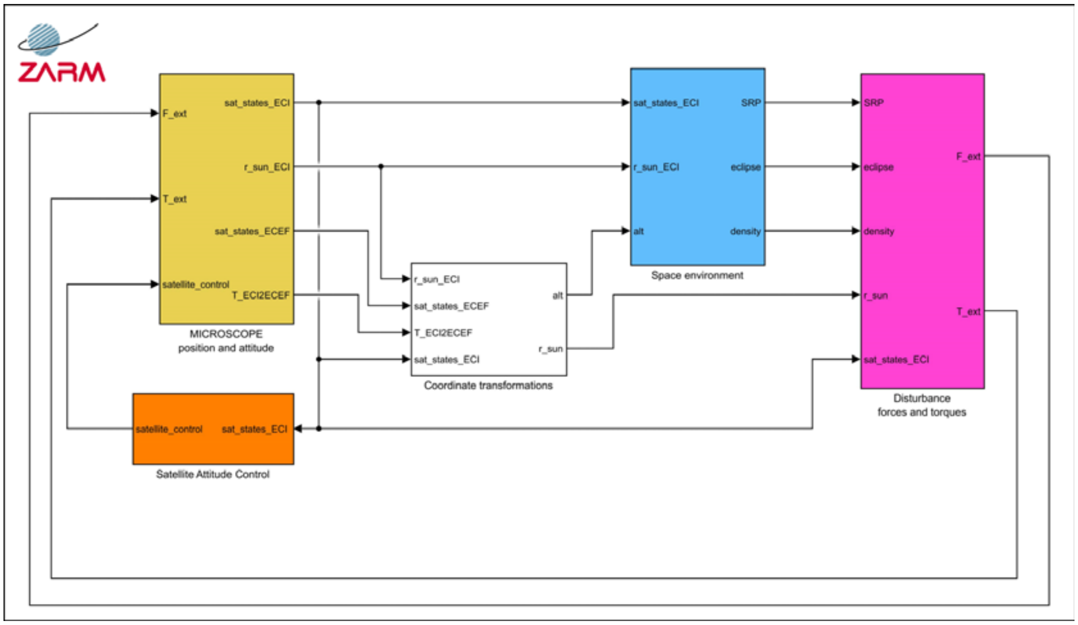
Thus every HPS Module can be released by an automated process via the HPS Core. In contrast to the developer version of the Module, its released version contains only compiled binaries and the full documentation including test reports for direct usage.

The modular design offers several advantages:

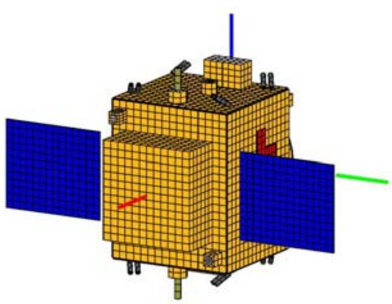
- The module development can be done independently from other parts of the software.
- Every Module is tested individually which eases the review process.
- Every user can select individually the combination of HPS Modules for his or her application (the dependency management ensures the installation of dependent Modules).

APPLICATION FOR SCIENCE MISSIONS

In April 2016 the French space mission MICROSCOPE was launched. The mission goal was to test the Weak Equivalence Pronciple with a precision never achieved before yielding the determination of the Eötvös parameter η with an accuracy of 10^{-15}. The HPS was used to model and simulate this mission in order to support the evaluation of the scientific data.

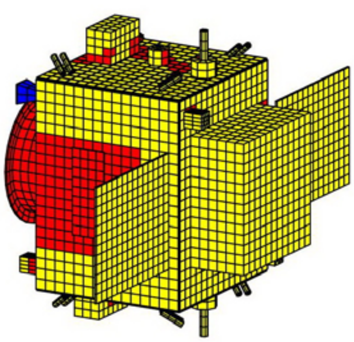


Within the MICROSCOPE project, the HPS was not used for GNC systems design, but for the accurate modeling of disturbance forces that act on the surface of the satellite.



The figure on the left shows a simplified Finite Element (FE) model of the MICROSCOPE satellite. The colors indicate different surface materials. Depending on the material properties, each surface element interacts in a different way with the space environment resulting in a non-uniform distribution of disturbance forces.

One of the main contributors to the disturbance budget for MICROSCOPE is the force due to solar radiation pressure (SRP). Here the illumination conditions of the satllite are of special interest as only areas in sunlight contribute to the overall disturbance force. The HPS overs a Module that computes this SRP disturbance force depending on the incident sun angle taking into account shadow effects (red elements) and not illuminated regions (blue elements). Look-up tables with resulting SRP disturbance forces are provided for a chosen range of incident sun angles. These tables are incorporated into orbit simulations yielding realistic disturbance effects on the satellite.

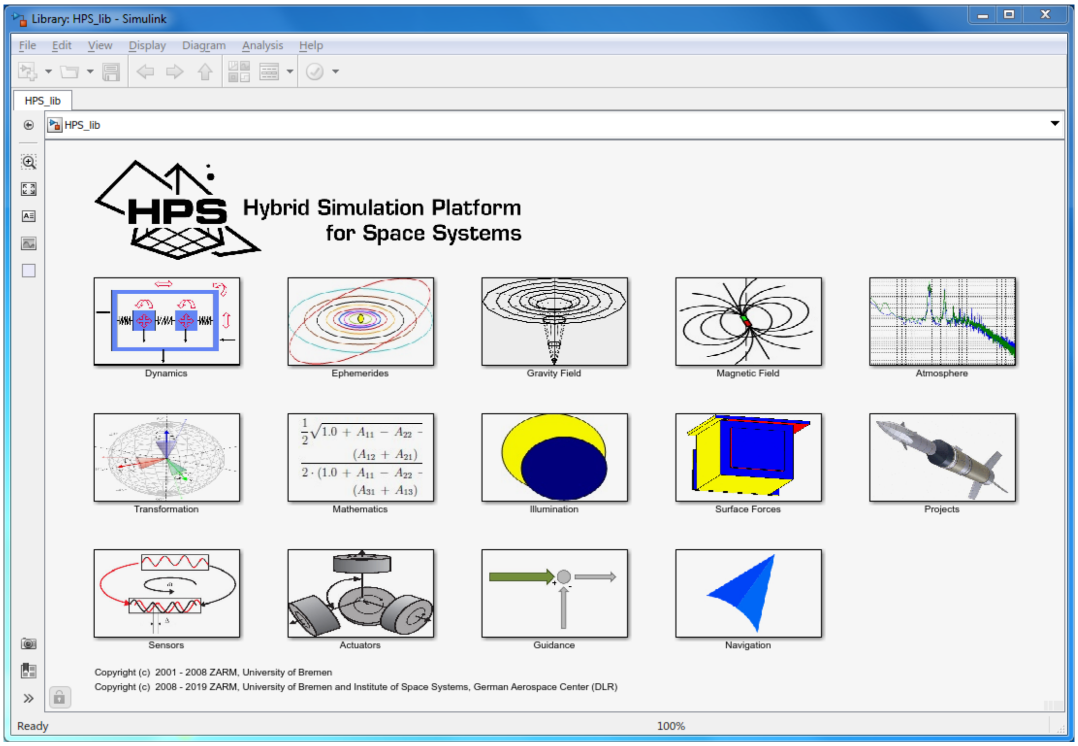


HPS FRAMEWORK

The HPS is a simulation library and a collection of tools for the simulation of space systems. It is mainly used in two areas:

- Development and verification of guidance, navigation and control systems (GNC systems).
- Simulation and modeling of science missions in order to conduct data analysis.

The HPS functions are developed for MATLAB/Simulink which guarantees plug & play functionality and high reusability in different projects.



Basic concept

Technically, the HPS consists of

- a base framework, called the HPS Core, and
- a collection of functional blocks, called HPS Modules.

The HPS Core

- provides the run-time environment for all HPS Modules (MATLAB/Simulink integration, testing framework, link to version control),
- does not contain any scientific functionality itself,
- includes tools for HPS developer, and
- is platform independet, currently used on Windows and Linux systems.

HPS Management

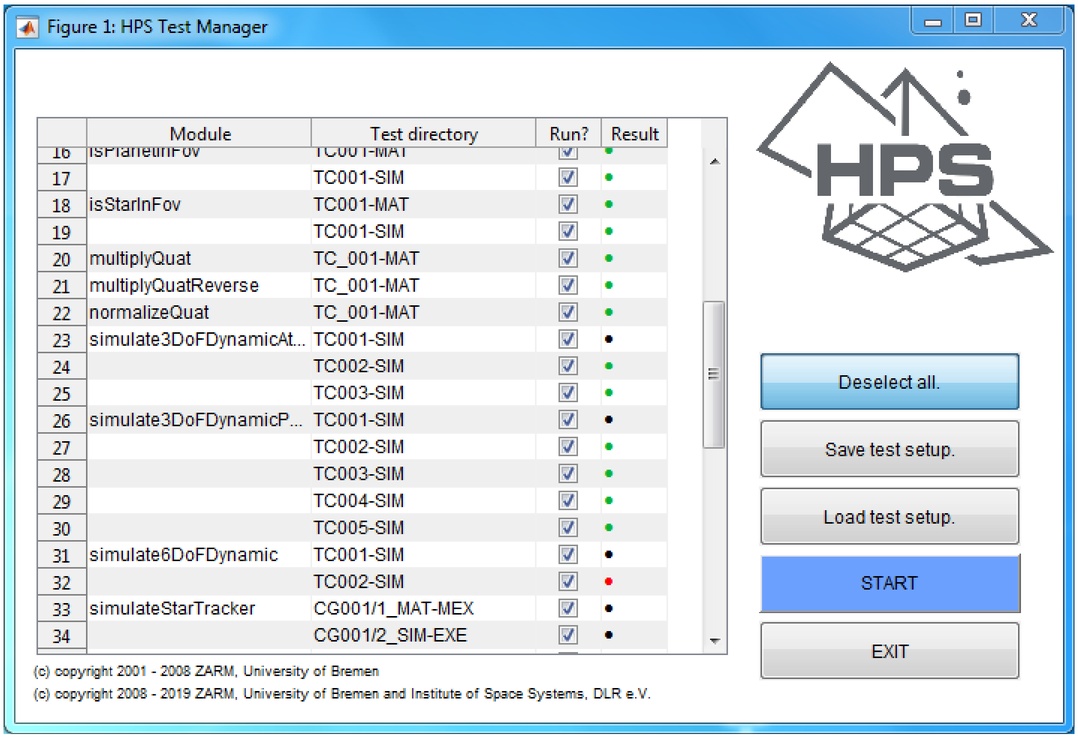
The HPS is a joint project of the Department of Guidance, Navigation and Control Systems of the DLR Institute of Space Systems and the Center of Applied Space Technology and Microgravity (ZARM) at the University of Bremen. The Technical Management Board (TMB) with members of both institutions is responsible for the development of the HPS, i.e. the TMB

- decides on the development roadmap,

- accepts new HPS Modules,
- defines the testing framework
- decides on the issue handling including, and
- organises workshops.

TESTING IN THE HPS FRAMEWORK

Each HPS Module can be tested individually. Nevertheless, the HPS Test Manager provides the opportunity to select specific test cases from all installed HPS Modules (developer version only).



The developer receives direct feedback on the test results:

- green: Test run without errors.
- red: Test was executed but with unexpected results.
- black: Test could not be executed (e.g. due to missing files).

The creation of tests for HPS modules follows a set of guidelines including amongst others

- variation of each input parameter,
- validation of each output,
- testing of all run-time environments (e.g. MATLAB and Simulink),
- code coverage,
- input and reference data must be documented and reproducible.

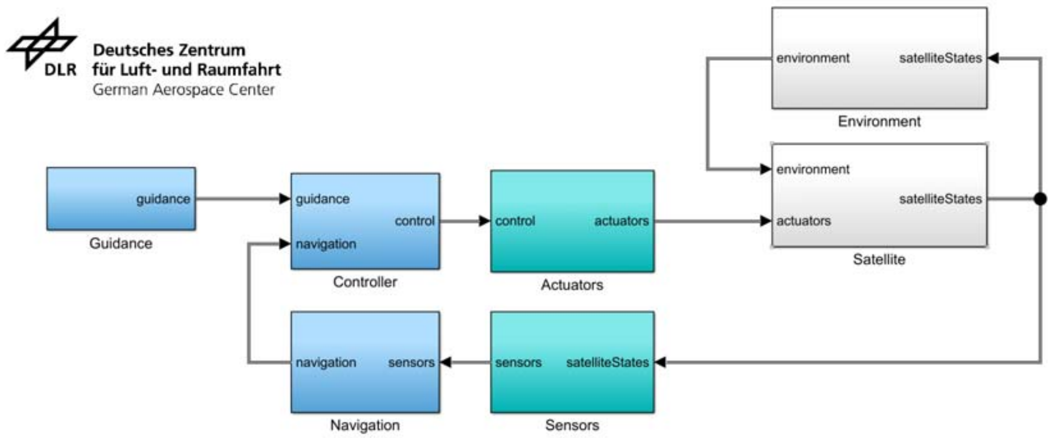
Only HPS Modules, that were successfully tested according to the guidelines are candidates for an open source release.

In addition, single HPS Modules are validated with real flight data.

GNC SYSTEMS

The development and verification of GNC systems demands the simulation of

- satellite dynamics,
- sensors,
- actuators,
- environmental conditions,
- and resulting disturbances.



The HPS offers functions and tools for all these domains. Due to its modular design, the HPS is constantly improved and extended with every new project. Thus the HPS is a key factor for time- and cost-effective project handling in the complex field of GNC systems design. The essential characteristics are

- Resuability
- Reliablity
- Conservation of expert knowledge

Additionally, some of the HPS Modules enable testing with Hardware-in-the-Loop simulations, which is a crucial capability in the validation process of GNC systems.

Projects

Since December 2018, the life science satellite Eu:CROPIS is orbiting the Earth at 600 km altitude. The satellite is rotating at constant speed in order to generate artificial gravity for the biological experiment on-board. The attitude control system for this mission was developed at the DLR GNC Systems Department by means of the HPS.

Another application of the HPS is the Reusability Flight Experiment (ReFEx) of DLR. The GNC Systems Deparment contributes to the ReFEx mission with the development of a hybrid navigation system (HNS) and the flight guidance.

Sorry but time is up!

AUTHOR INFORMATION

Corresponding authors:

M.Eng. René Schwarz for German Aerospace Center (DLR), Institute of Space Systems, Navigation and Control Systems, Bremen.

rene.schwarz@dlr.de

www.dlr.de/gnc

Dr.-Ing. Benny Rievers for Center of Applied Space Technology and Microgravity (ZARM), University of Bremen, Bremen.

benny.rievers@zarm.uni-bremen.de

www.zarm.uni-bremen.de

ABSTRACT

The development and verification of Guidance, Navigation, and Control (GNC) systems demands the simulation of the system dynamics of space vehicles, their sensors and actuators as well as the prevalent environmental conditions and disturbances. The development and validation of such simulations can require a significant effort because of the technical and emergent complexity. Sustainable, reusable, and reliable simulation software is a key factor for time- and cost-effective project handling and for the conservation of expert knowledge.

The Department of Guidance, Navigation and Control Systems of the DLR Institute of Space Systems and the Center of Applied Space Technology and Microgravity (ZARM) at the University of Bremen are jointly developing the Hybrid Simulation Platform for Space Systems (HPS). The HPS is a MATLAB/Simulink-based library of simulation models and tools for the simulation of space GNC systems and consists of more than 90 interconnected modules, which are steadily used and improved throughout the DLR and ZARM projects. One major application focus of these modules is science missions with a high demand for measurement and control accuracy. It has recently been used for modeling and simulation of MICROSCOPE, a satellite mission for testing the Equivalence Principle in space, and the development of the attitude control system for the life science satellite Eu:CROPIS.

Most parts of the HPS are planned to be released as open source software to the scientific community in the near future. The development of HPS modules is subject to a quality assurance process, which also comprises comprehensive module documentation, the verification of modules with unit tests as well as their validation with real flight data, as far as possible. Selected modules are already prepared to be used in hardware-in-the-loop applications and automatic code generation scenarios, whereas enabling these capabilities for all other modules is envisaged. The HPS is not simply a collection of simulation models, it also provides a framework for an automated, platform-independent, modular build, execution, test, and verification environment for space simulation models that seamlessly integrates into MATLAB/Simulink.

This framework has also been developed to support plug & play functionality, which enables interchange-ability of technically complex simulation scenarios.