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Bridging the Gap between Systems Engineering and Detail Studies

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In early mission phases, simulation can greatly reduce cost and construction efforts, by reducing uncertainties on new, yet to be built space systems such as satellites or planetary rovers. At the DLR institute of system dynamics and control, simulation methods are researched to accurately simulate complex multi-physics systems, utilizing the Modelica modelling language and self-developed tools. The focus of the development is to bridge the gap between the early phase systems engineering, where only rough insight in the systems behavior is available, and the later phases detail studies, where already existing or to be developed hardware is simulated in detail and mostly isolated. The multi-physics approach of Modelica allows interconnecting different domains like electronics, (flexible) multi-body dynamics, propulsion systems, terra-mechanics or algorithms (e.g. path-planning). This allows the user to get a better grasp on the coupled system behavior and to optimize single components in the context of the complete space system.

New methods for multi-body simulations support for example the simulation of flexible satellite solar panels or robot manipulators, the inversion of their system behavior and the design of control laws based on this model inversion.

The same multibody methods are also used in the newly developed Rover Simulation Toolkit, where complex kinematics, terra-mechanic models, manipulator dynamics and path-planning algorithms are utilized to simulate different aspects of rover missions, e.g. locomotion or manipulation. The integrated multi-body simulation allows studying the impact of dynamic elements e.g. robotic manipulators on the rover dynamics, as well as analyzing the motion envelope, dynamics or manipulability of those robot arm payloads.

For such simulations in planetary exploration, soil- and terramechanics are playing an important role in order to understand the mutual influences on the dynamic behaviour of the instrument and the soil. Therefore several different tiers of soil interaction models have been developed for terrestrial analog cite studies and recent planetary exploration missions (i.e. InSight, Hayabusa II). Dependent on the mission phase and the needed level of detail those model apply from earliest system engineering up to the very detailed subsystem design. These models range from simple but real-time capable analytical models based on Rankines soil pressure theory, or Bekkers equation to very detailed particle based models using the Framework DEMETRIA. These different tiers of models thus enable the support of early systems engineering phases, over subsystem optimization up to mission planning.Another focus of the Rover Simulation toolkit is the optimization of parameters, like for example controller parameters, energy consumption, mechanical dimensions, utilizing the institutes Optimization toolbox for Modelica and the framework MOPS. Furthermore, an integrated visualization system has been developed to generate direct and reusable visualizations of complex mechanical systems.

The presented methods are already successfully utilized in projects as the demo mission within ROBEX, a cooperation with the JPL (terra mechanics) and current space missions as MASCOT or InSight.