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DEVELOPMENT OF A WORKFLOW IMPLEMENTATION TO CONDUCT AUTOMATED THERMAL ANALYSES OF SPACECRAFT FROM AN MBSE SYSTEM MODEL

Abstract

Model-based systems engineering (MBSE) is an emerging methodology not only in the field of spacecraft systems engineering. The key objective is to store the whole system design in one single source of truth system model. The continuously maintained and customizable open-source MBSE tool Virtual Satellite (VirSat) developed by the German Aerospace Center (DLR) offers a framework for storing such a system model. Since the open-source 3D CAD software FreeCAD has a dedicated VirSat workbench for importing the 3D model file generated by VirSat, it is possible to export the 3D model from VirSat, apply changes to it in FreeCAD, and afterwards reimport it in VirSat. This paper presents a workflow implementation to conduct automated steady-state and transient thermal analyses using the VirSat system model as a basis, utilizing the aforementioned features. Part of this effort was to extend VirSat by thermal modeling capabilities, such as material parameters, surface characteristics, thermal interfaces, boundary conditions and further relevant aspects. With custom Java applications, so-called "Apps", all aspects of the system model relevant for a thermal analysis are exported from VirSat and written to accordingly generated text files. Moreover, the before described 3D model export is used to export the model to FreeCAD. The FreeCAD Python console, in combination with the finite element method (FEM) workbench, is used to create a script that executes meshing, application of the boundary and initial conditions, as well as identification of contacts between parts and application of the specified contact conductance values. The obtained files form a complete thermal model and can be fed directly into the open-source FEM software CalculiX for executing the thermal analysis. Then, the result can be processed by an additional VirSat App. To account for the space thermal environment an additional feature was added to the FreeCAD script. The feature uses orbit information obtained from external mission analysis tools (e.g., STK) to calculate the approximate combined heat load from Sun, Earth infrared, and albedo radiation at each time point in the specified simulation time interval. This new workflow allows to execute quick thermal analyses at an early design stage and therefore opens new opportunities in the evaluation of different system designs, as early as in a concurrent engineering study. Configuration parameters are provided that also allow more sophisticated analyses in later development phases, such as custom mesh definition and local mesh refinement.