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SimuPy Flight Vehicle Toolkit

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Software

- Review
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Summary

Vehicle flight simulation is an important part of the innovation of aerospace vehicle technology. The NASA Engineering Safety Center (NESC) has identified and addressed the need to verify flight vehicle simulations through their work on the flight simulation test cases (Murri et al., 2015). In that work, the NESC established flight vehicle simulation test cases to compare and validate a suite of simulation tools, several from within NASA and one external, open-source tool. The SimuPy Flight Vehicle Toolkit provides a modular framework for the rapid implementation of simulations for novel flight vehicle concepts, similar to the simulation tools used to develop the test cases. The open source repository of the source code includes implementations for the sixteen atmospheric test cases defined by the NESC, which serve as validation of the simulation framework and examples of its usage. One author has used a precursor to this software package to simulate control system performance for a novel mechancially deployed hypersonic entry vehicle (D'Souza et al., 2019, 2021; B. Margolis et al., 2021; B. W. Margolis, Okolo, Nikaido, et al., 2019; B. W. Margolis, Okolo, & D'Souza, 2019; B. W. Margolis et al., 2020; Okolo et al., 2020).

The SimuPy Flight Vehicle Toolkit leverages open source scientific computing tools to implement an efficient simulation framework for flight vehicles in Python. Equations of motion are composed in blocks using the SimuPy library (B. W. Margolis, 2017), an open source Python alternative to Simulink. The resulting differential equations are solved using SciPy's wrappers for standard Fortran implementations (Jones et al., 2001–). Equations of motion for the inertial state of a rigid-body model of the vehicle representing the position, orientation, and their corresponding rates for integration are developed using the SymPy symbolic library (Meurer et al., 2017) and implemented using code generation. Kinematics equations are implemented through symbolic definition and code generation. Open-source scientific libraries are leveraged where possible, such as solving the inverse geodesy problem (Kerkwijk et al., 2020) and implementing a standard atmosphere model (Bell, 2016 – 2021). The library also provides a parser for the American Institute of Aeronautics and Astronautics's (AIAA) simulation description mark-up language standard (Jackson & Hildreth, 2002) using code generation. Aerodynamic data table interpolation is implemented using ndsplines (B. W. Margolis & Lyons, 2019).

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