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# FORCE AND TORQUE DISTURBANCE MODELING DUE TO GENERAL THRUSTER PLUME IMPINGEMENTS

**Abstract**

Thruster plumes can intercept neighboring surfaces on the host spacecraft, leading to unwanted effects. The placement and direction of the thrusters relative to surfaces of concern, such as solar arrays, is often done intuitively or with simple analysis. This paper presents an automated objective measure for their placement. The methodology presented gives forces, torques, and heat transfer from thruster plume impingement on spacecraft surfaces. This becomes a modular tool for spacecraft design, but also for real-time attitude and navigation simulations. This plume impingement study therefore allows for objective thruster placement, and higher fidelity simulations in support of future attitude control designs, allowing for more stringent pointing requirements.

This paper applies, for the first time, a general mathematical derivation of conical intersections to the plume impingement problem. The simulations presented allow for the study of any number of thrusters with a surface of arbitrary orientation. Using the derived conical functions to bound the region where the plume is acting, the pressure profile is integrated yielding forces and torques. In order to maintain a modular, reusable code, the pressure function from the thruster can be entered independently instead of being modeled analytically. This new and different approach allows to get precise effects for different thruster specifications, and different spacecraft designs. Results are compared to pressure profiles in the literature in order to validate the accuracy of the computation. Compared to more traditional high fidelity computational fluid dynamics, this method allows for applications in real-time simulations, with an adjustable balance between speed and accuracy.

This implemented study is also run within the Basilisk astrodynamics software framework, which incorporates other high fidelity dynamic effects such as fuel slosh, jitter, and hinged rigid body effects. The plume impingement forces and torques are then computed and compared to these other dynamic perturbations. This adds to the fidelity of the dynamics, but also helps with thruster placement on a simulated spacecraft. The heat transfer from the plume also contributes to better surface temperature estimates, which can be critical for already warm surfaces such as solar arrays.