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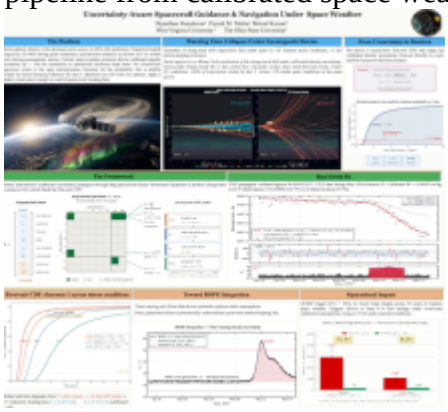
Poster
Thermospheric density is the dominant error source in low-Earth orbit prediction, yet density model uncertainties are seldom propagated through to the orbital quantities that drive operational decisions. Geomagnetic storms can enhance densities by factors of 2-5× within hours, and even during quiet times empirical models disagree by 20-40% but these uncertainties typically stop at the density level without reaching downstream orbital risk. The May 2024 G5 Gannon storm illustrates the consequence: KANOPUS-V 3 experienced 917 m of semi-major axis decay within days, exposing how quickly storm-driven density errors can cascade into collision avoidance challenges, premature reentry risk, and station-keeping violations.
We present a framework that bridges this gap by mapping any calibrated density uncertainty envelope into orbital impact. The approach propagates multiplicative density and ballistic coefficient uncertainties (??, ?B) through drag-specialized Gauss Variational Equations via an augmented state-covariance system, producing first-exit time distributions: the probability that along-track drift exceeds a prescribed tolerance as a function of time. This reframes the question from "how much will the orbit decay?" to "how much warning do I have?” a quantity directly relevant to maneuver planning. We demonstrate the framework on constellation station-keeping, where G5-level density uncertainty reduces median time-to-violation from days to hours.
The framework is density-model agnostic, currently baselined with NRLMSISE-2.0. Ongoing work will integrate the Reduced Order Probabilistic Emulator (ROPE), a data-driven thermospheric model developed at ASSIST Lab, West Virginia University that provides storm-resolved density distributions enabling a direct pipeline from calibrated space weather research to downstream orbital impact assessment.



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