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AI-Enhanced Computational Tools for Entry Systems Modeling

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Abstract

To advance the understanding of complex atmospheric entry phenomena, NASA's Entry Systems Modeling (ESM) team [1] has developed high-fidelity computational tools addressing multiscale challenges, from material microstructures to full-scale heatshield response. This abstract highlights a subset of ESM tools, focusing on AI integration to enhance workflows and predictive modeling.

- *PuMA* [2] computes effective material properties from high-resolution micro-CT scans, supporting TPS analysis for NASA missions.
- *TomoSAM* [3] automates 3D tomography dataset segmentation for *PuMA* using the Segment Anything Model, reducing manual effort and improving accuracy.
- *PATO* [4] models porous reactive materials under extreme conditions, with advancements such as unified solvers, mechanical erosion, and TPS coatings for NASA missions.
- *arcjetCV* [5] employs deep learning to analyze arc jet test footage, measuring recession rates, shape changes, and shock standoff distances, bridging simulations, and experiments to reveal TPS ablation behavior.
- *ARCHeS* [6] simulates arc heater plasma flows, modeling turbulence, radiation, and electromagnetic interactions to optimize arc heater performance, validate TPS under extreme conditions, and serve as a foundation for developing digital twins of arc heater facilities.
- *SPARTA* [7] simulates rarefied hypersonic flows and gas-surface interactions for planetary entry missions, leveraging GPU architectures for scalable and efficient aerothermal and ablation analyses.

AI-driven solutions, such as deep learning segmentation, have streamlined workflows in ESM tools and still hold significant potential to further accelerate processes and enhance automation in entry systems modeling.

[1] Haskins, J.B. (2023), [2] Ferguson, J.C. (2018), [3] Meurisse, J.B.E. (2018), [4] Semeraro, F. (2023), [5] Quintart, A. (2024) [6] Meurisse, J.B.E. (2022), [7] Plimpton, S.J. (2019)

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