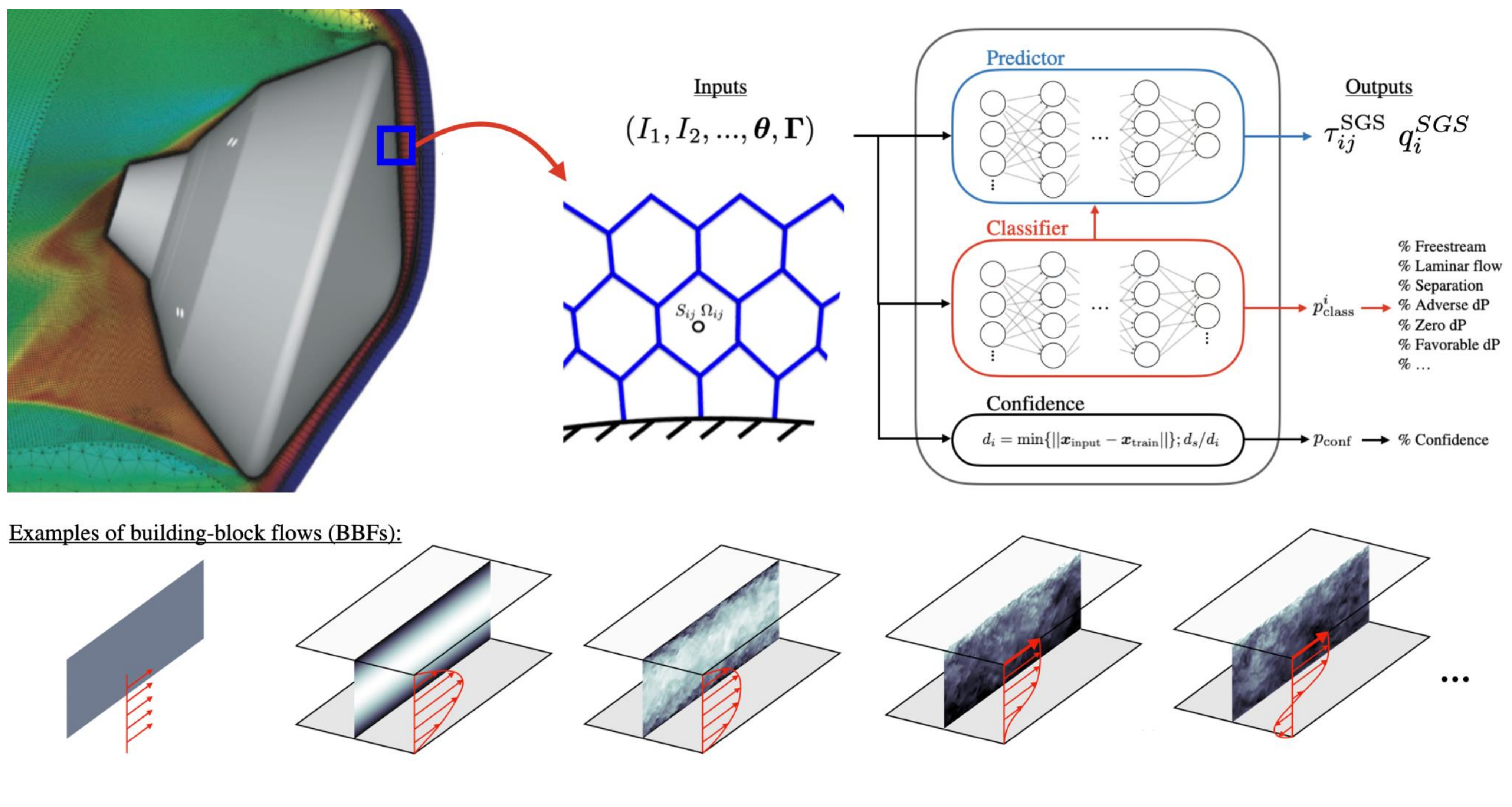
Machine-learning building-block-flow model for large-eddy simulation of high-speed flows with strong heat transfer and wall roughness

- Prof. Adrian Lozano-Duran
- Department of Aeronautics & Astronautics
- Massachusetts Institute of Technology

Research Objectives

- We lack a Computational Fluid Dynamics (CFD) approach providing accurate predictions across all physics phenomena of interest for NASA.
- The goal of this project is to devise a unified closure model for CFD of hypersonic flows accounting for multiple flow phenomena (e.g., flow separation, mean pressure gradients,...) and enhanced skin-friction and wall heat transfer due to surface roughness.
- Applications are focused on Entry, Descent, and Landing (EDL) Vehicle configurations with ablated thermal protection systems.
- The approach has been demonstrated for low-speed flows and will be portable to NASA solvers (from TLR1 to TLR2)



(Top-left) Example of application to Entry, Descent, Landing Vehicles. (Top-right) Model architecture with predictor, classifier, and confidence score estimator. (Bottom) Examples of representative building-block flows used for training the model.

Approach

- Main modeling assumption: there is a collection of simple cases that contain the essential flow physics to model more complex scenarios.
- The closure model is developed for wall-modeled large-eddy simulation.
- The model is implemented using artificial neural networks trained in simple flows and it comprises two components: one classifier and one predictor.
- The model provides a confidence score in the prediction used for uncertainty quantification and automatic grid refinement.

Potential Impact

- The improved modeling capabilities will facilitate the development of EDL applications for future NASA missions to Mars, Titan, and Gas Giant planets.
- The closure model could enable high-fidelity CFD of other complex flows relevant to NASA's mission due to its scalability to account for additional physics.