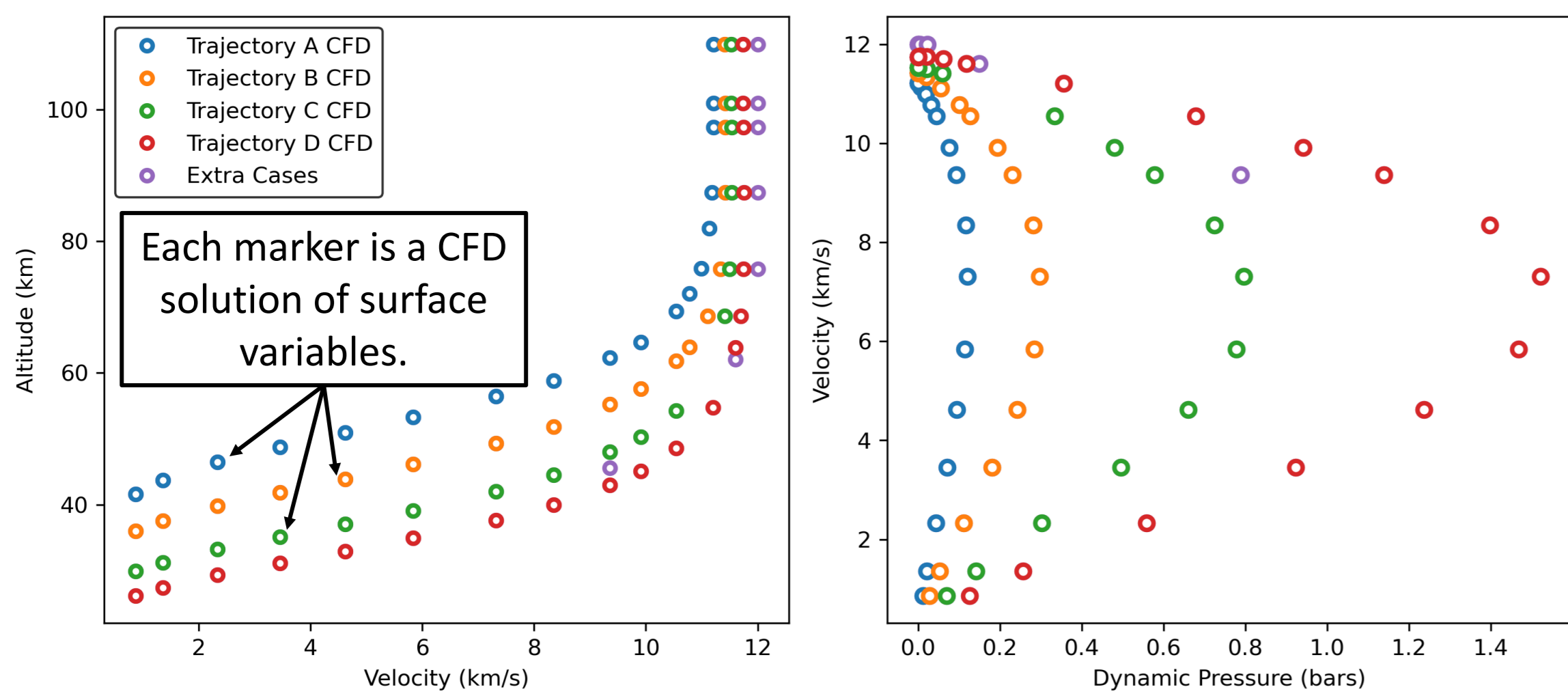


Background

- Lack of an integrated aerothermal database that runs in-the-loop with flight mechanics simulations
- Capability can allow for increased fidelity aerothermal results to be generated from simulations
- This poster will present the proof-of-concept development with numerical results for Earth Entry Vehicle (EEV)

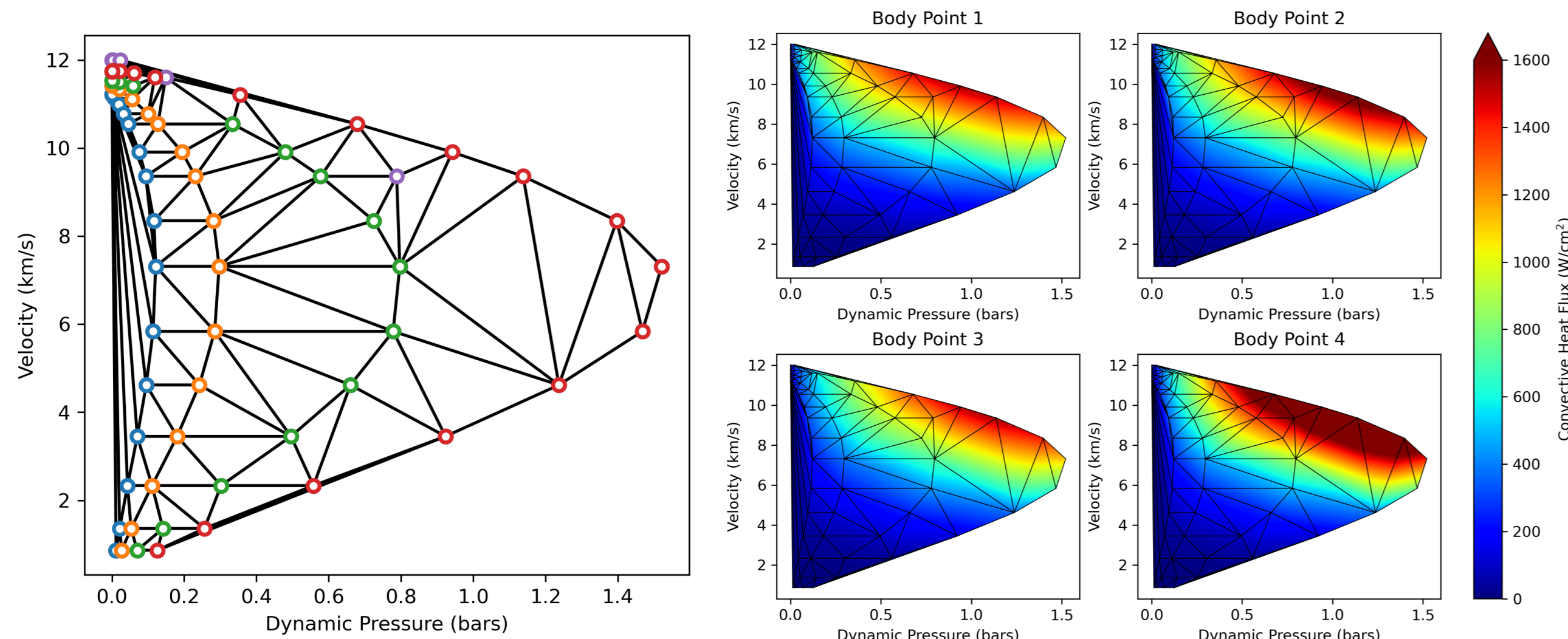
Formulation of Database

- Run high-fidelity CFD cases at freestream conditions to bound expected trajectories.
- EEV CFD cases were run at freestream conditions pulled from candidate trajectories (see figure below).



Aerothermal Database Freestream Conditions In (Left) Flight Domain and (Right) Interpolation Domain

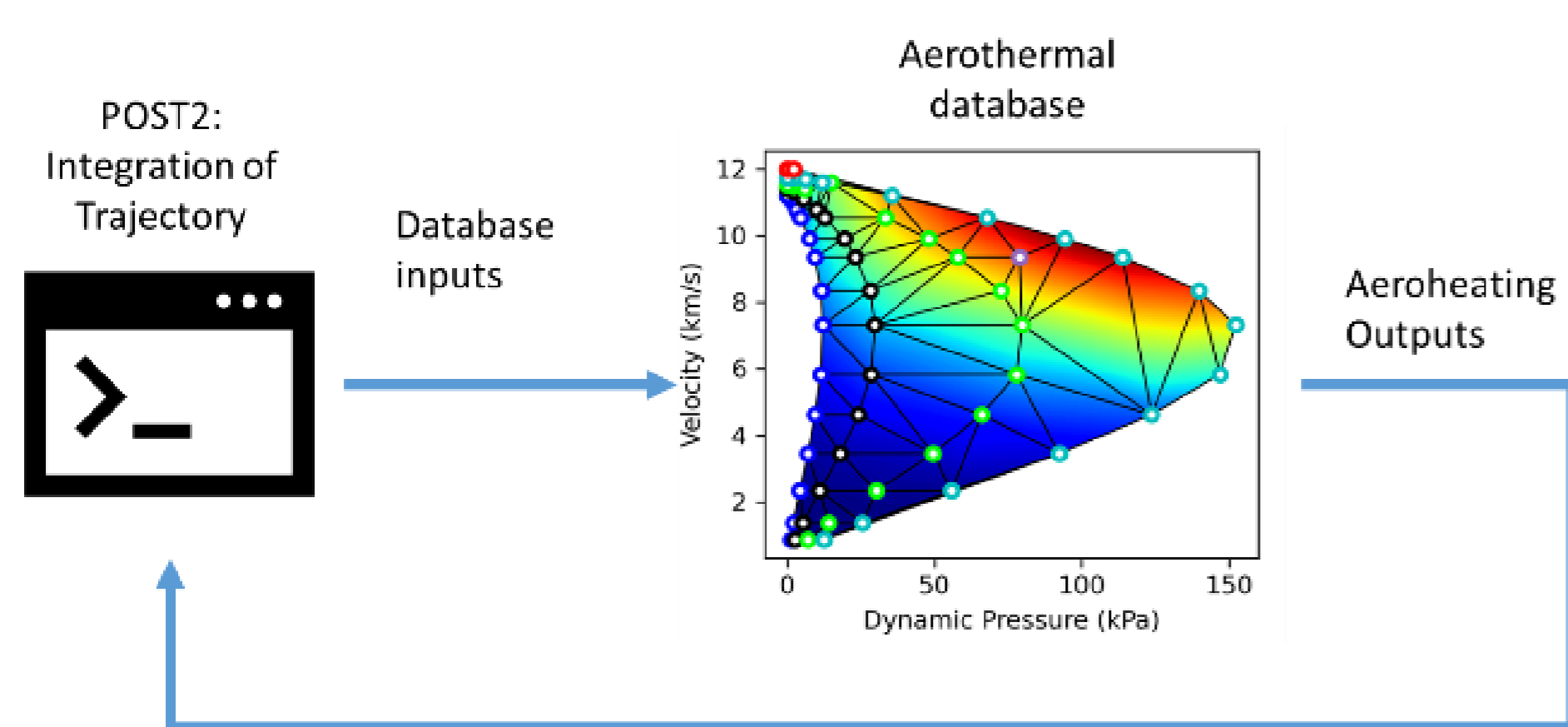
- CFD surface variables are linearly interpolated within a triangulated mesh (e.g., Delaunay triangulation).
- Each (variable, body point) combination has an independent interpolation space.



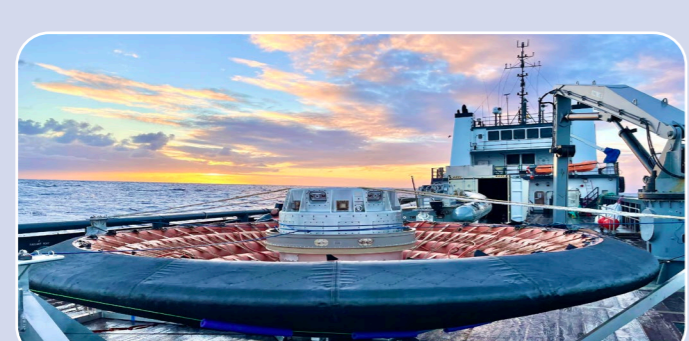
(Left) Database Triangulation and (Right) Convective Heat Flux Interpolation Spaces for Various Body Points.

POST2-ATDB In-The-Loop Concept of Operations

- ATDB written in C++ and compiled with POST2 C-code



- JSON file used to define aerothermal model



$$= k \left(\frac{\rho}{R_n} \right)^{\frac{1}{2}}$$

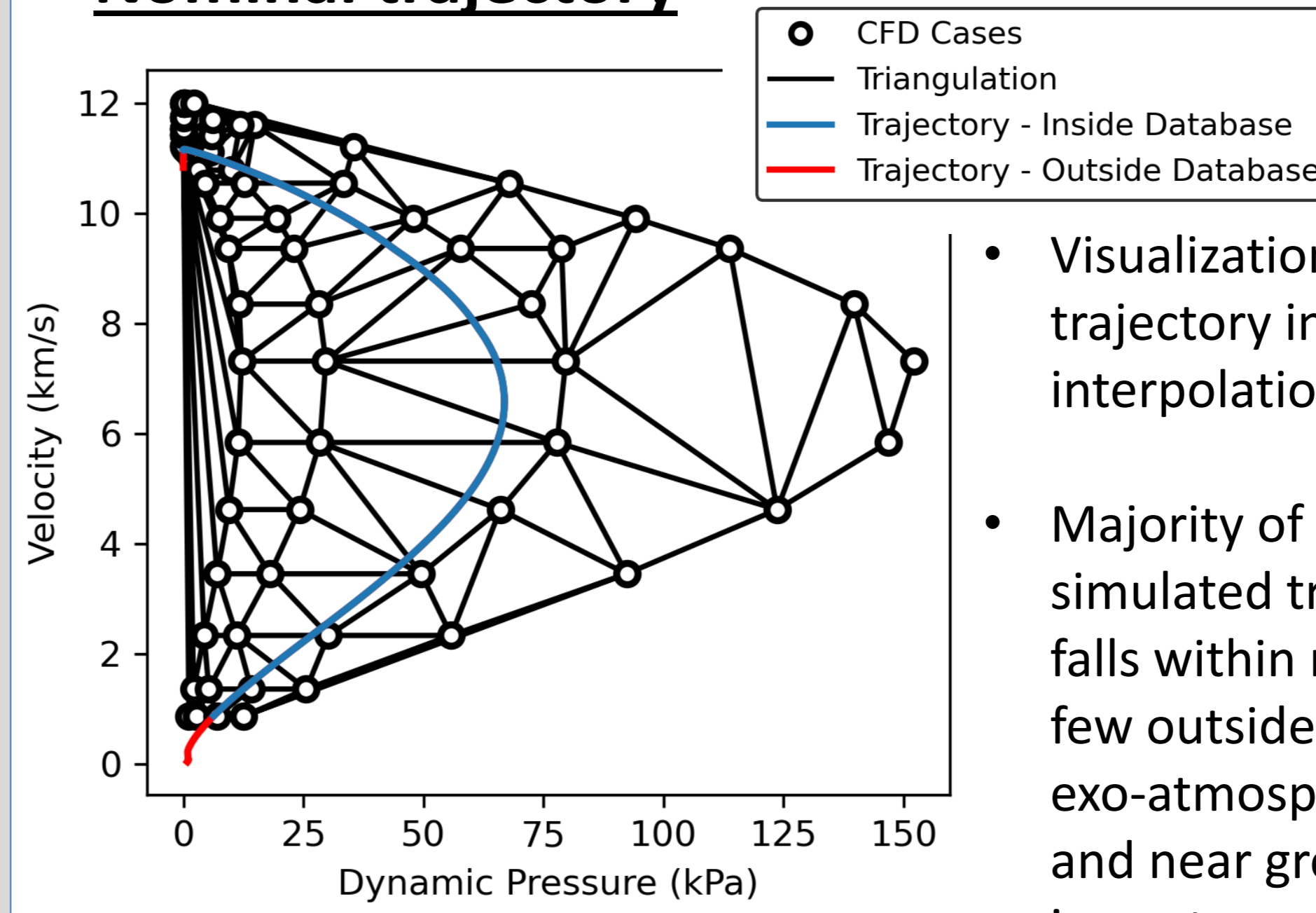
Interpolation
• EEV
• ARRIVAL

Indicator Models
• LOFTID
• Dragonfly

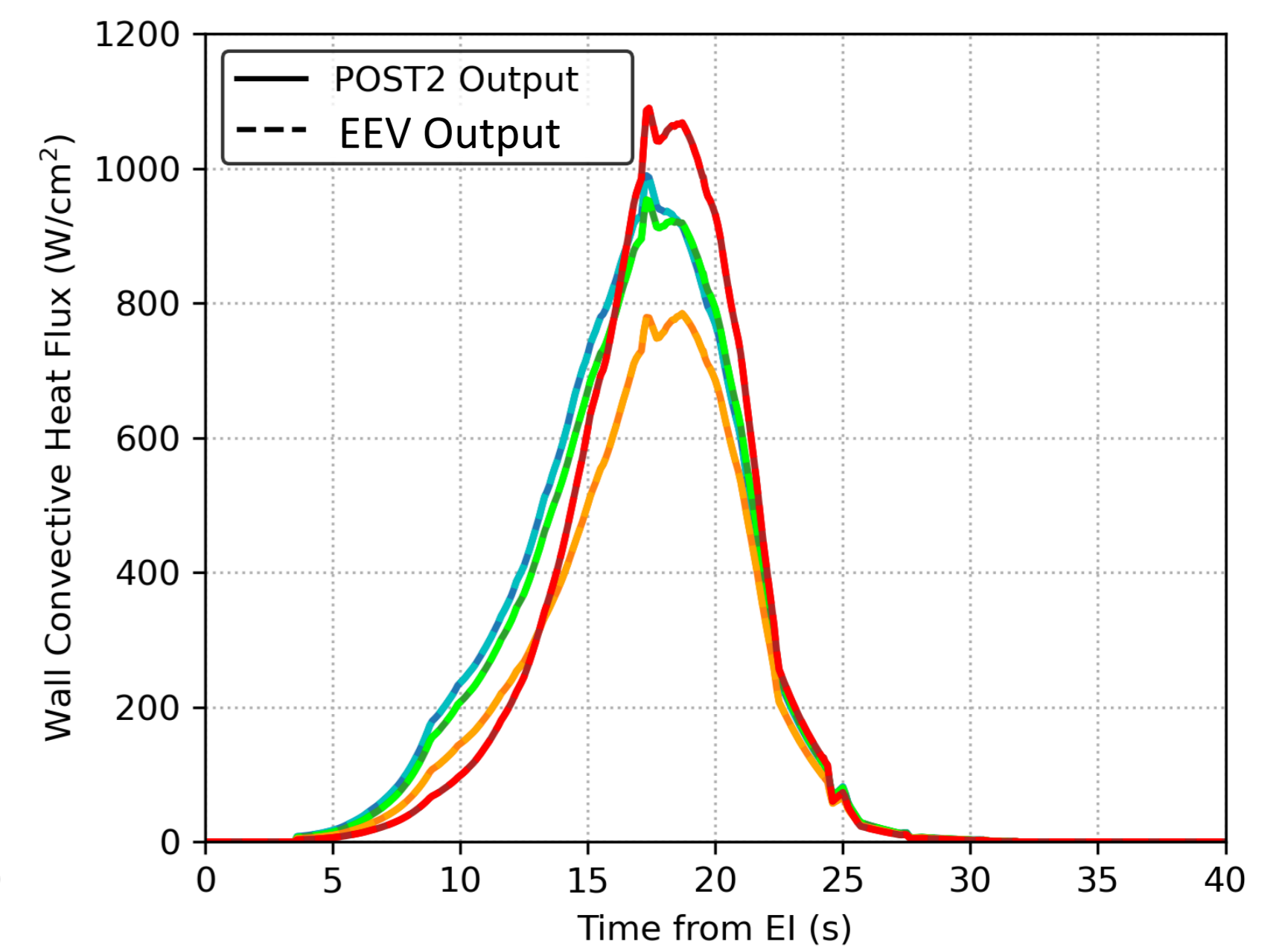
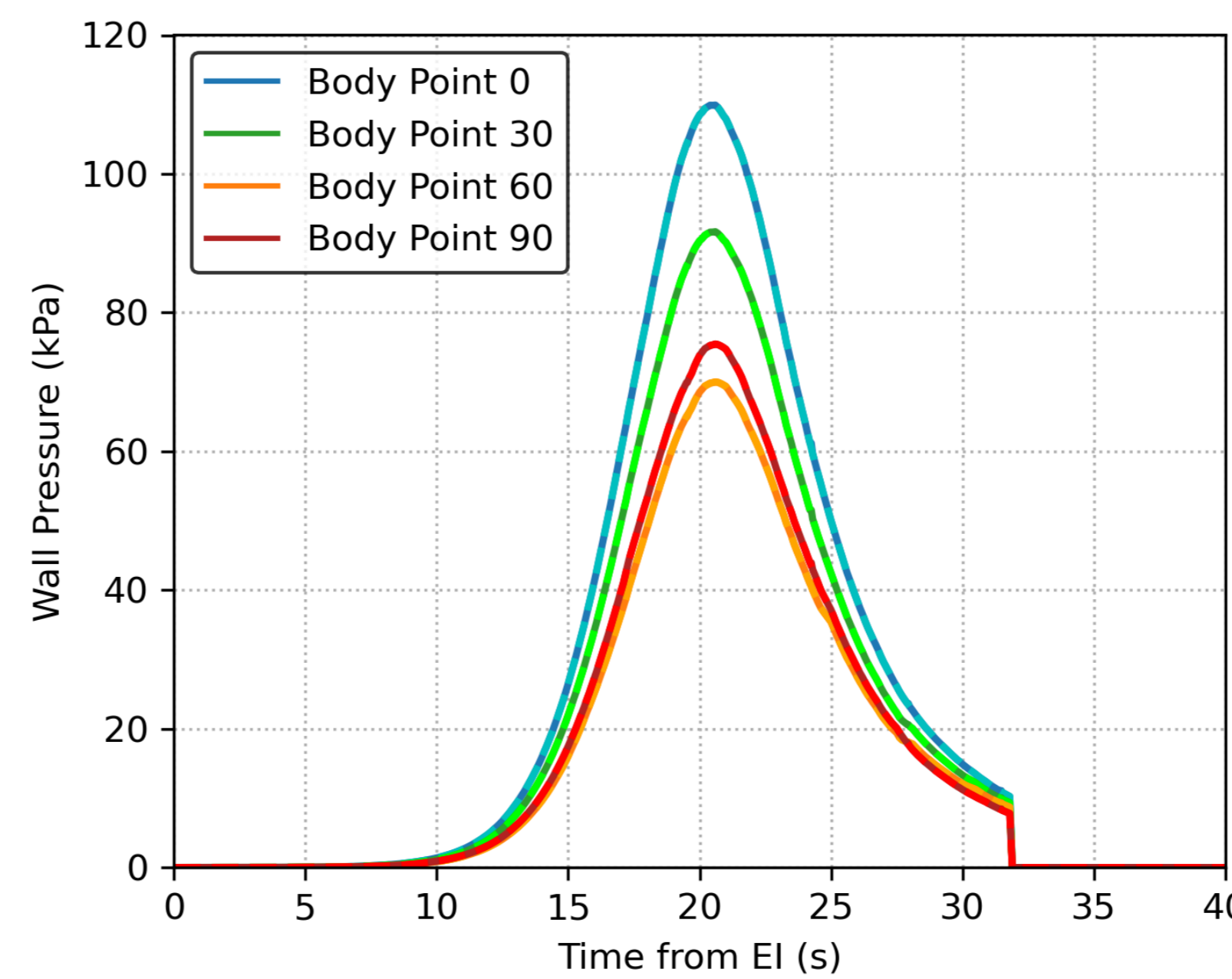
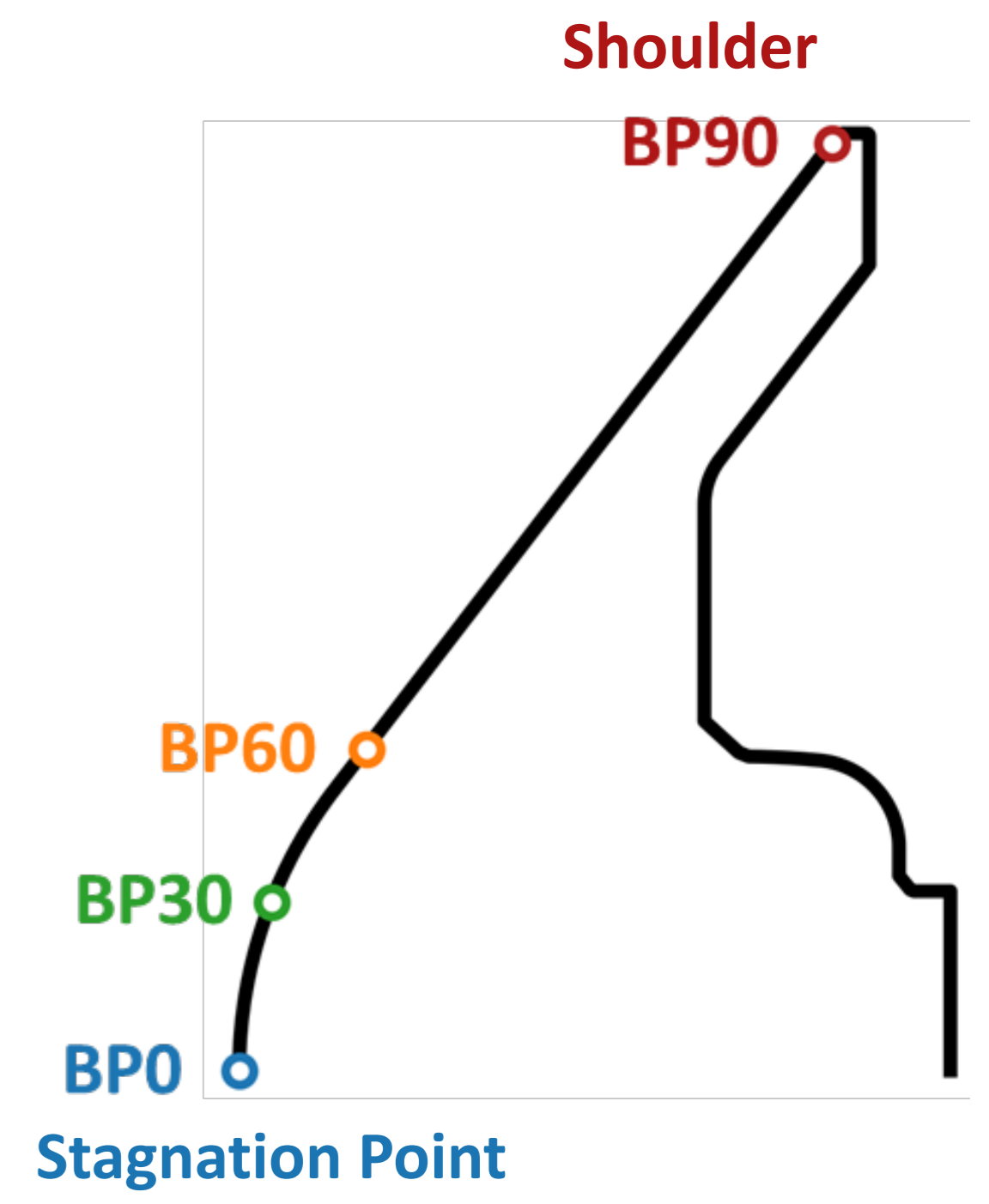
Engineering Correlations
• Sutton-Graves
• Tauber-Sutton

Proof-of-Concept Results : EEV

Nominal trajectory



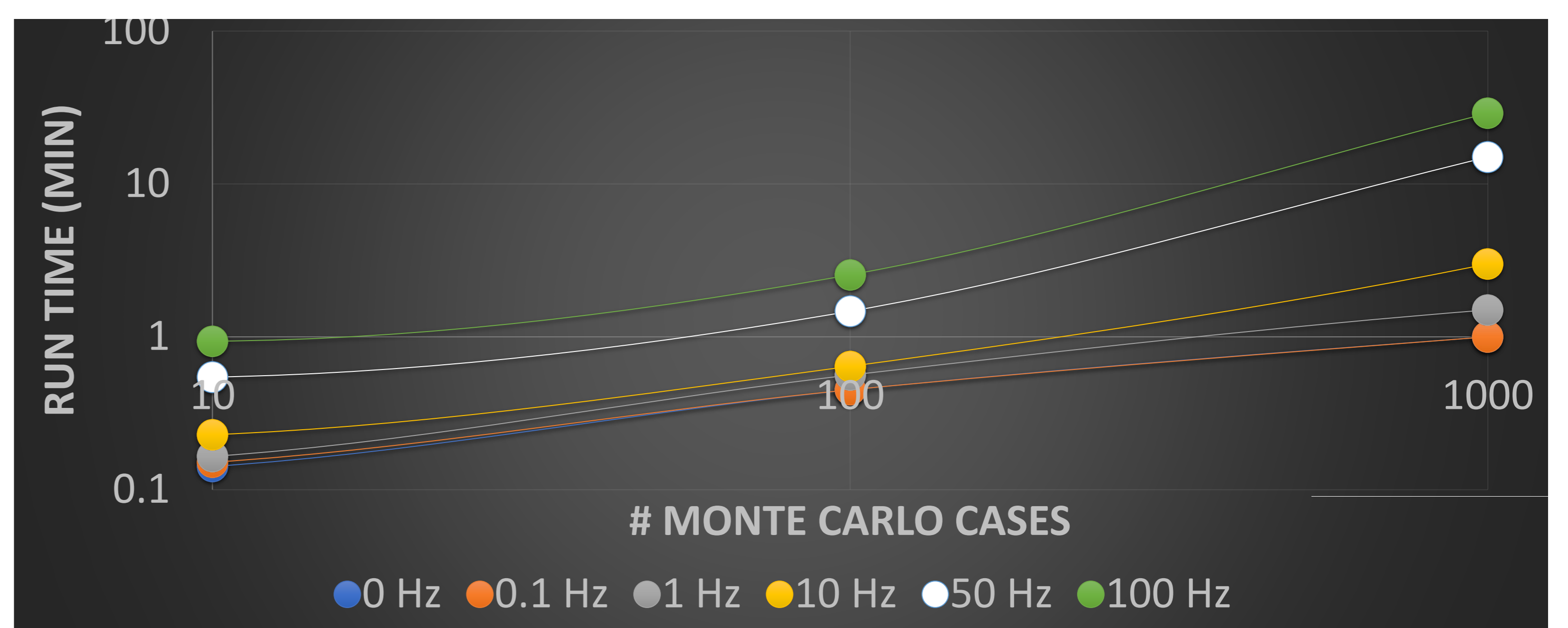
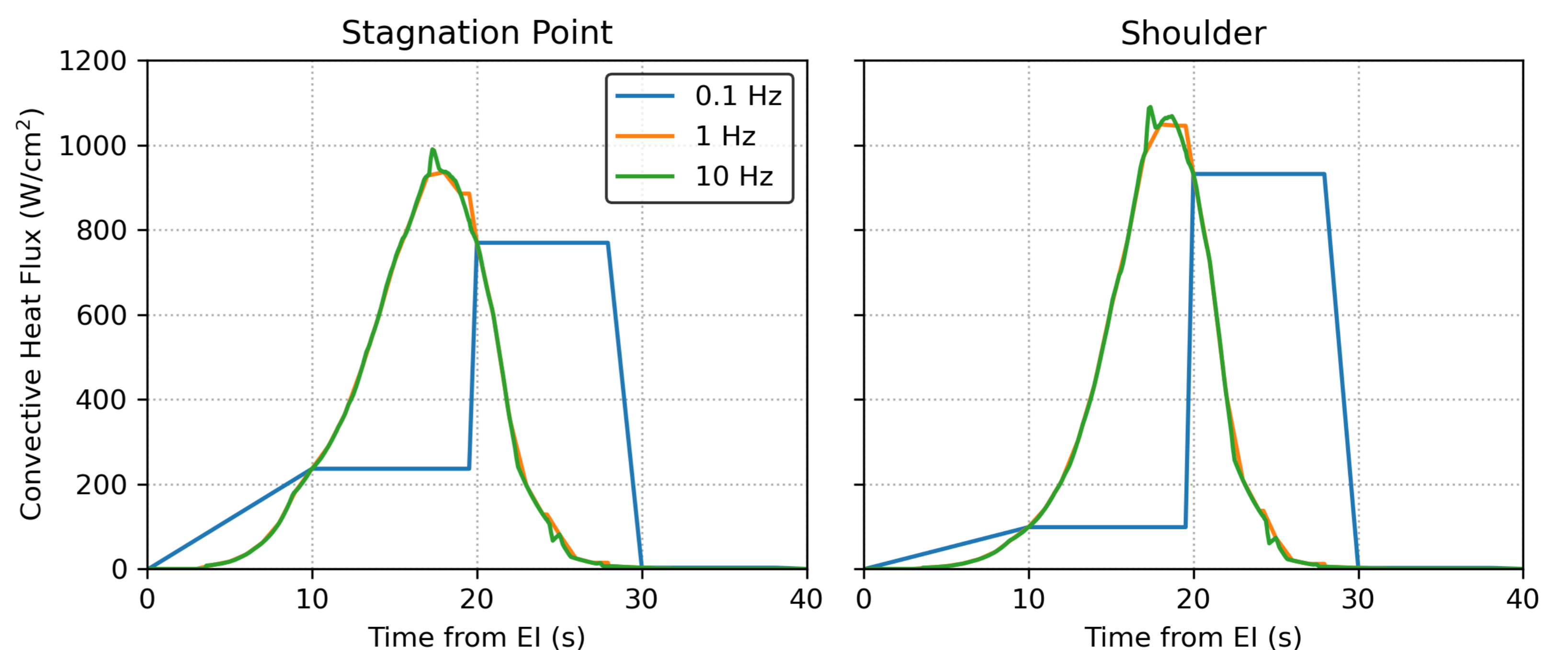
- Visualization of the trajectory in the q-V interpolation region
- Majority of the simulated trajectory falls within region, with few outside occurring exo-atmospherically and near ground impact



Validation Check Between the "In-The-Loop" Interpolator and the Original EEV Post-Processing Script

Monte Carlo Results

- (Control): Sim Hz = 0 -> No ATDB-in-the-loop
- Exponential increase in run-time with increasing Sim Hz and Monte Carlo Run Size
- 1 Hz provide balance between run-time and interpolation accuracy



	Nominal Run-Time (sec)	Monte Carlo Run-Time (sec)	Post-Processing Run-Time (sec)	Post-Processing Disk Space Cost (GB)
No ATDB-in-the-loop	8.293	7 min, 19.225 sec	12 min 21.919 sec	9.3
ATDB-in-the-loop	9.565	8 min, 30.017 sec	0.00 sec	0

- Overall, integrated ATDB-in-the-loop with POST2 shows promising results

References:

C. Naughton et al., Improved Aerothermal Reliability Analysis Enabled By The Mars Sample Return Earth Entry System Aerothermal Database, (2023) IPPW 2023
 R. Deshmukh et al., Flight Mechanics of Mars Sample Return Earth Entry System, (2024) NASA TM-20240007323
 C. Naughton et al., Aerothermal Analysis of the Dragonfly Titan Entry, (2024) IPPW 2024
 R. McDaniel et al., Orion Aerosciences: Aerothermal Database Development (2022) Advanced Modeling and Simulation Seminar Series
 B. Hollis et al., Aerothermodynamic Analyses for the LOFTID Technology Demonstration Mission (2024) AIAA SciTech Forum