Hyperloop Rarefied Anaylsis

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Outline

- Rarefaction analysis at provided conditions.
- Overview of DSMC technique
- DSMC results

Free-Stream Rarefaction Analysis

- Based on free-stream conditions and tunnel diameter (3.6576m), Knudsen numbers (Kn = mfp/D) listed below.
- Kn < 1.0×10^{-3} considered continuum (CFD), although local regions of rarefaction may exist.

Pressure (Pa)	Number Density ($1/m^3$)	Mean Free Path (m)	Knudsen Number based on Diameter
100	2.4143×10^{22}	5.8462×10^{-5}	1.5984×10^{-5}
50	1.2072×10^{22}	1.1692×10^{-4}	3.1966×10^{-5}
10	2.4143×10^{21}	5.8462×10^{-4}	1.5984×10^{-4}
5	1.2072×10^{21}	1.1692×10^{-3}	3.1966×10^{-4}
1	2.4143×10^{20}	5.8462×10^{-3}	1.5984×10^{-3}
0.5	1.2072×10^{20}	1.1692×10^{-2}	3.1966×10^{-3}
0.1	2.4143×10^{19}	5.8462×10^{-2}	1.5984×10^{-2}

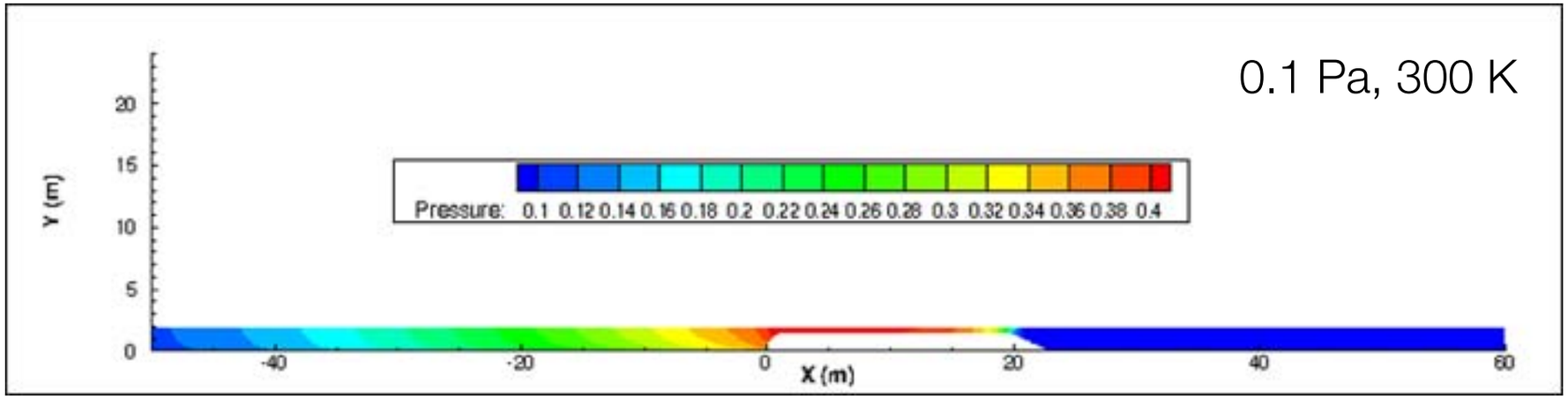
CFD | Crossover | DSMC

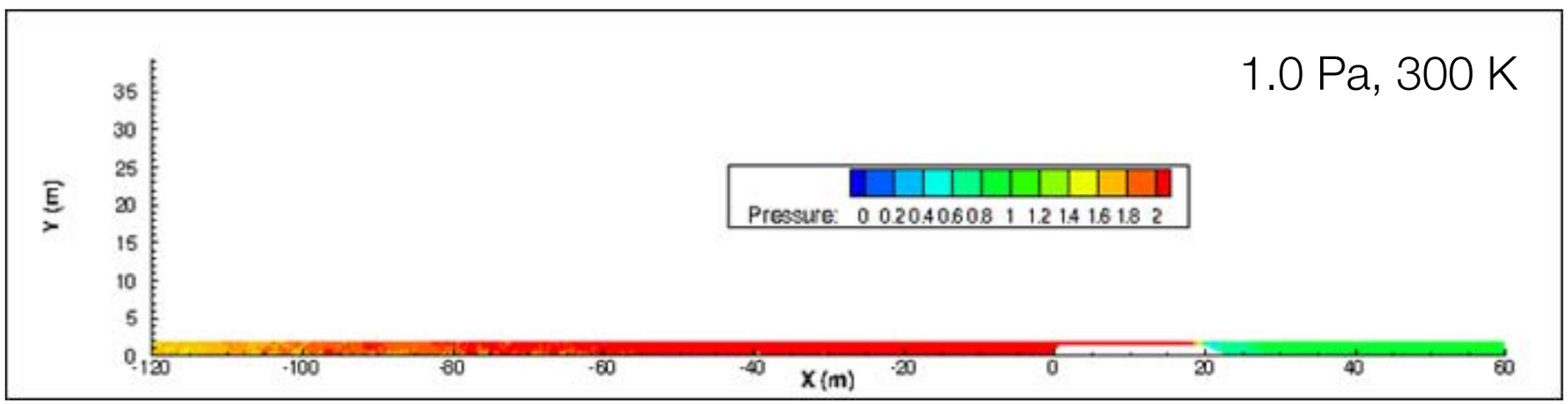
DSMC Technique Overview

- DSMC method is widely used for modeling gas flows by the computation of the motion and collisions of representative molecules.
  - CFD not appropriate in rarefied regimes because mean free path is not negligible
- The software MAP was used for this study
  - Morton Octree used for flow field with uncoupled triangulated surface grid.
  - VSS molecular model was used with parameters tuned to most closely match viscosity, diffusion, and conductivity of LAURA/Fun3d/DPLR.
  - Several new boundary conditions were required for the implementation of a subsonic object moving through a tunnel.

DSMC Results

- Good results at 0.1 Pa, but still trying to find acceptable location for inlet for 1.0 Pa.
- This indicates that the grid resolution requirements will be rather large for pressures of interest (10 Pa). However, CFD should be valid at these pressures.





Conclusion

- Rarefied analysis was performed for simplified Hyperloop configuration.
  - Pressures above 1.0 Pa should be sufficiently defined by CFD.