Design and Performance Optimisation of Atmospheric Breathing Electric Propulsion (ABEP) Intakes

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1. INTRODUCTION

Spacecraft orbiting in Very Low Earth Orbit (VLEO) **benefit** from payload and platform advantages because of their proximity to Earth

ABEP systems **(Fig. 1)**, based on the ingestion of residual atmospheric particles as propellant, enable **numerous sustainable space applications** in VLEO

However, the design and optimisation processes are complex and involve many parameters

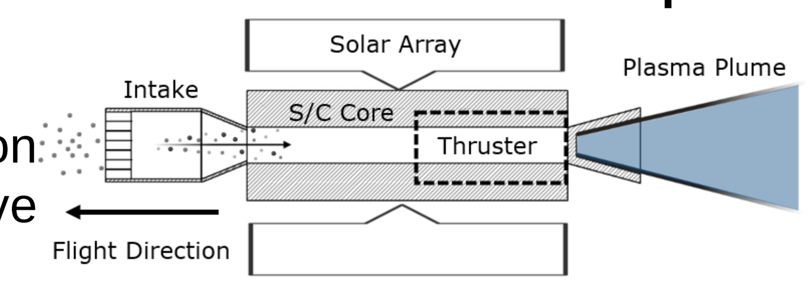
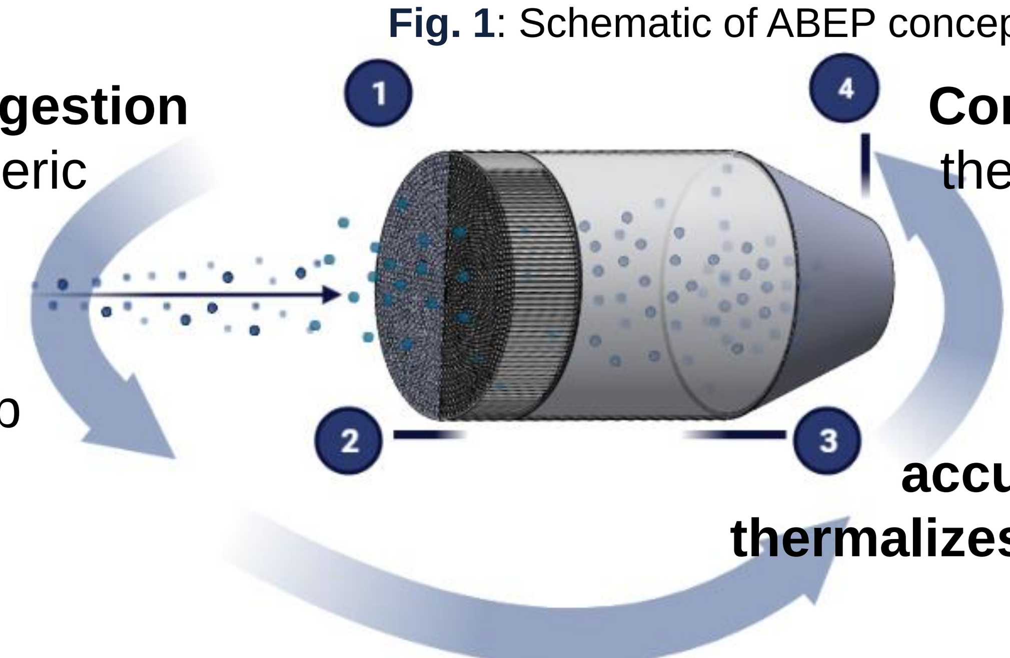


Fig. 1: Schematic of ABEP concept. Adapted from: [1]



Passive ingestion of atmospheric particles

Compression of the flow which is fed into the thruster

Honeycomb **reduces backflow**

Chamber **accumulates** and **thermalizes** the particles

BALANCING MODEL

- Analytical model to **evaluate** performance of ABEP intakes **(Fig. 2)**
- Requires **transmission probability** of individual components

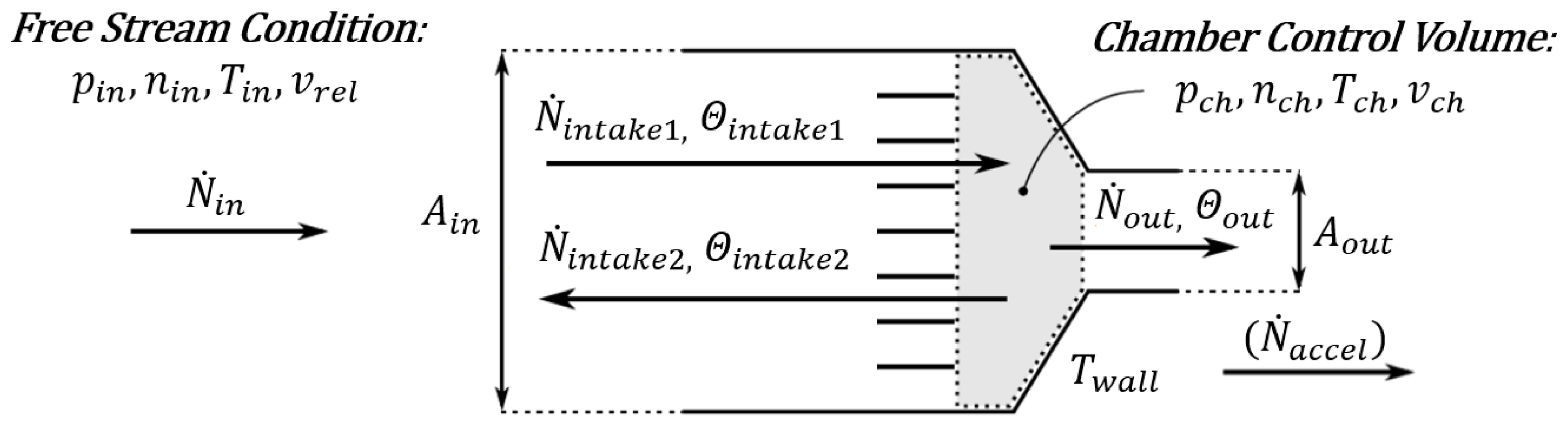
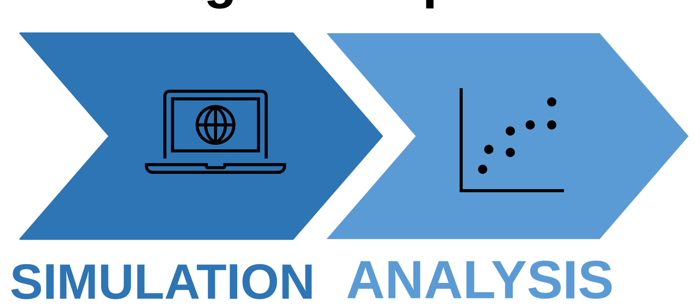


Fig. 2: Balancing Model Scheme. Adapted from: [2,3]

2. RESEARCH AIM

To **design** and **optimise** the performance of **passive ABEP intakes**



- **Model** and **Simulate** geometries to obtain transmission probability
- **Compute** and **Maximise** the intake collection efficiency

3. DIRECT SIMULATION MONTE CARLO (DSMC)

- Based on direct measurements coupled with physical time
- Inherently **stochastic** method
- **dsmcFoam+** solver within *OpenFOAM* toolbox; **OF-v1706** version and *hyStrath* repository

1. PRE-PROCESSING

- Import geometry as STL file
- Meshing
- **Boundary Conditions (Fig. 3)**
- Time-step selection
- **Surface interactions**
- Binary **intermolecular collisions**

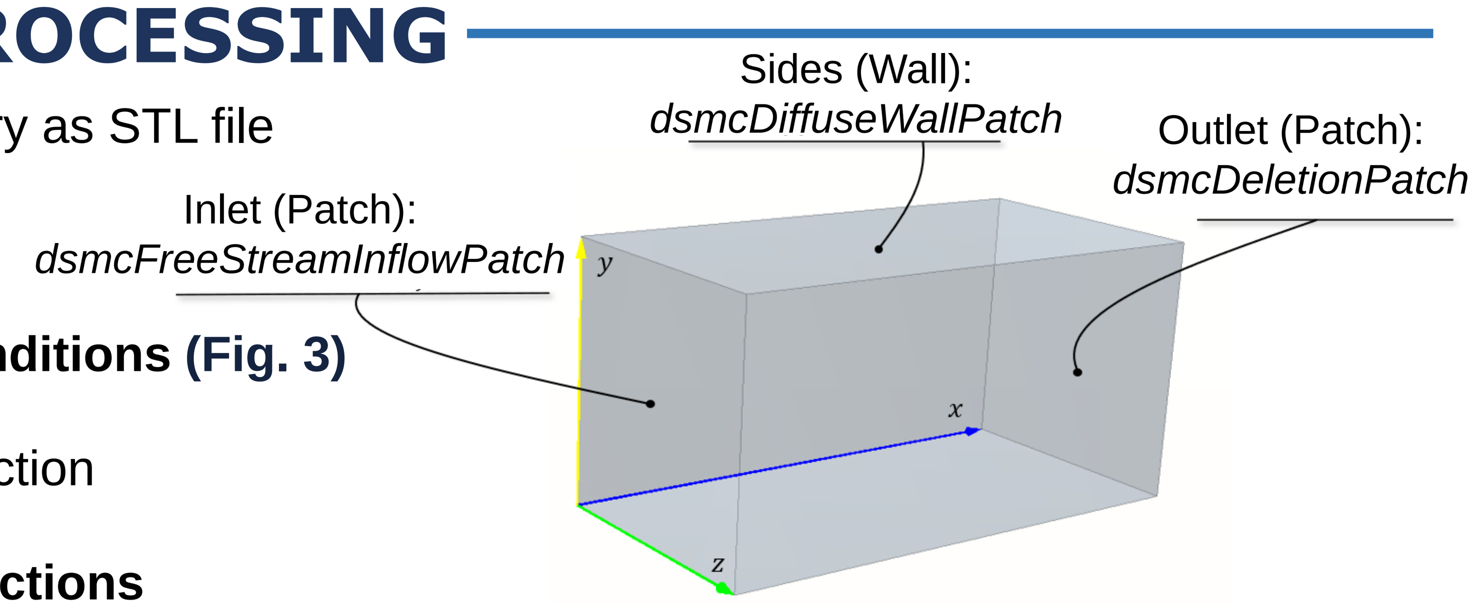


Fig. 3: Computational domain and boundary conditions set-up

2. PROCESSING

- 2,500 time-steps to reach **convergence**
- 17,500 useful data points are **sampled** for each simulation
- A **Gaussian distribution** is observed **(Fig. 4)**

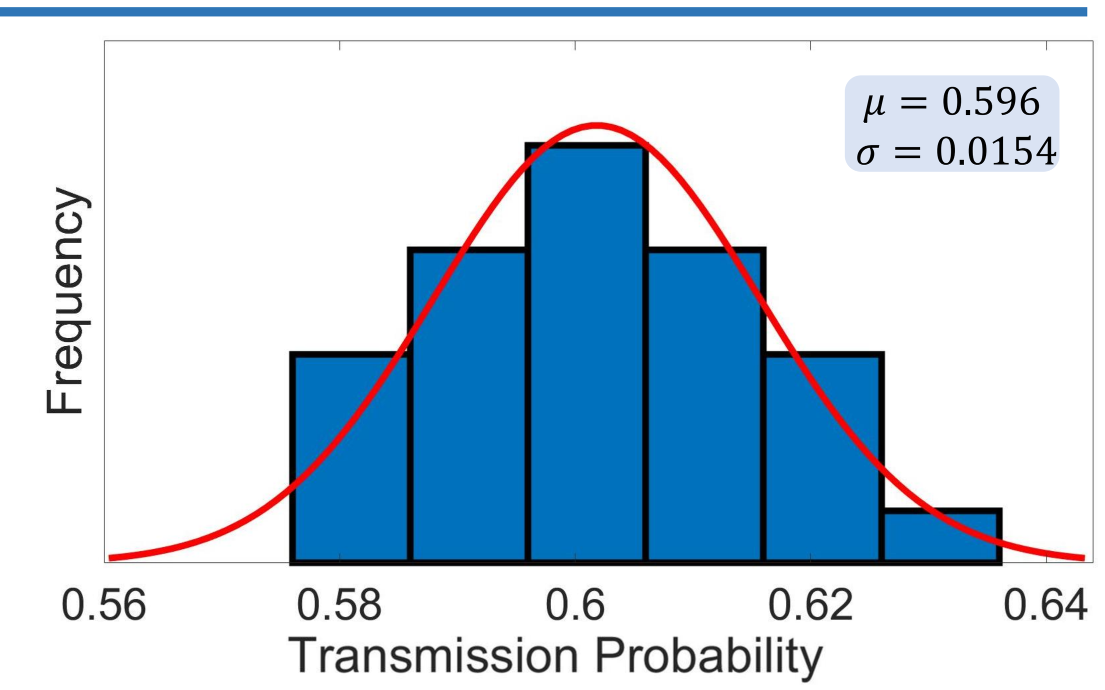


Fig. 4: Histogram and Gaussian distribution for transmittance of cylinder (L/R=1.4 and S=0)

3. POST-PROCESSING

- Inlet flow rate calculated analytically from boundary conditions [3]
- Outlet flow rate measured on *ParaVIEW* utility **(Fig. 5)**

Fig. 5: Velocity surface plot of cylinder (L/R=10)

- Repeated for varying aspect ratios (L/R) and speed ratios (S)

4. RESULTS

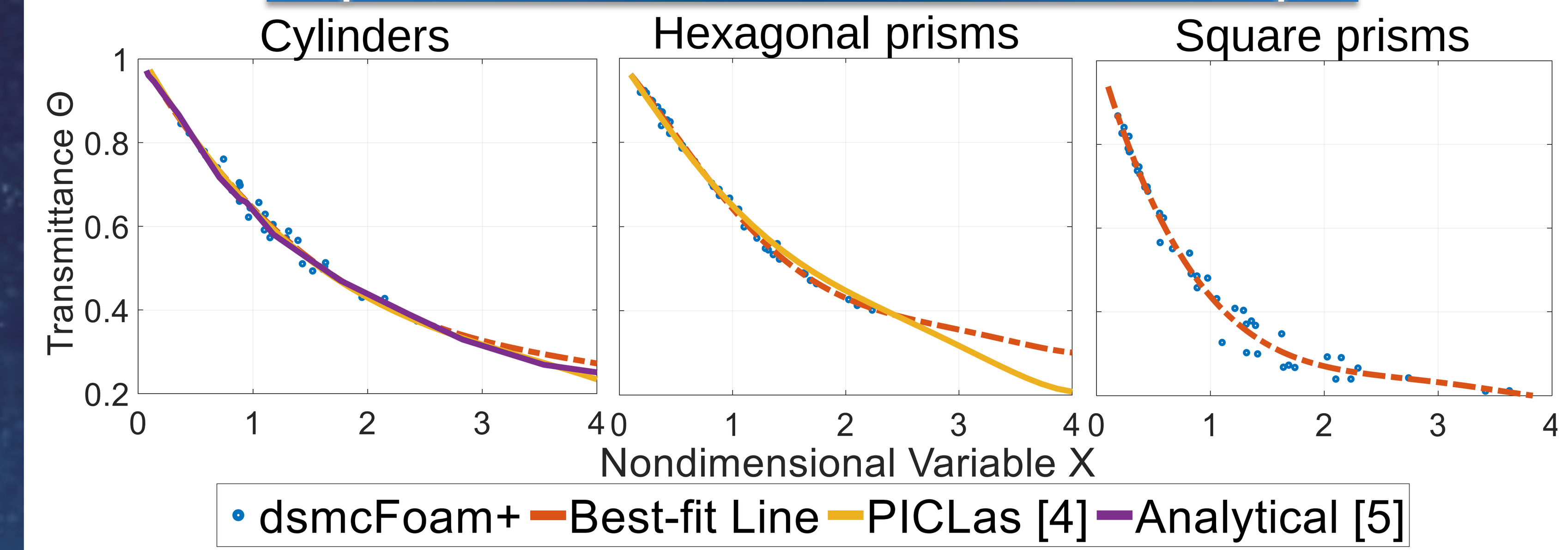


Fig. 6: Transmittance of cylinders (left), hexagonal prisms (centre) and square prisms (right)

- The dsmcFoam+ transmittance results **(Fig. 6)** show high accuracy when compared to values retrieved from literature $\overline{\delta}$~2% **(Table 1)**

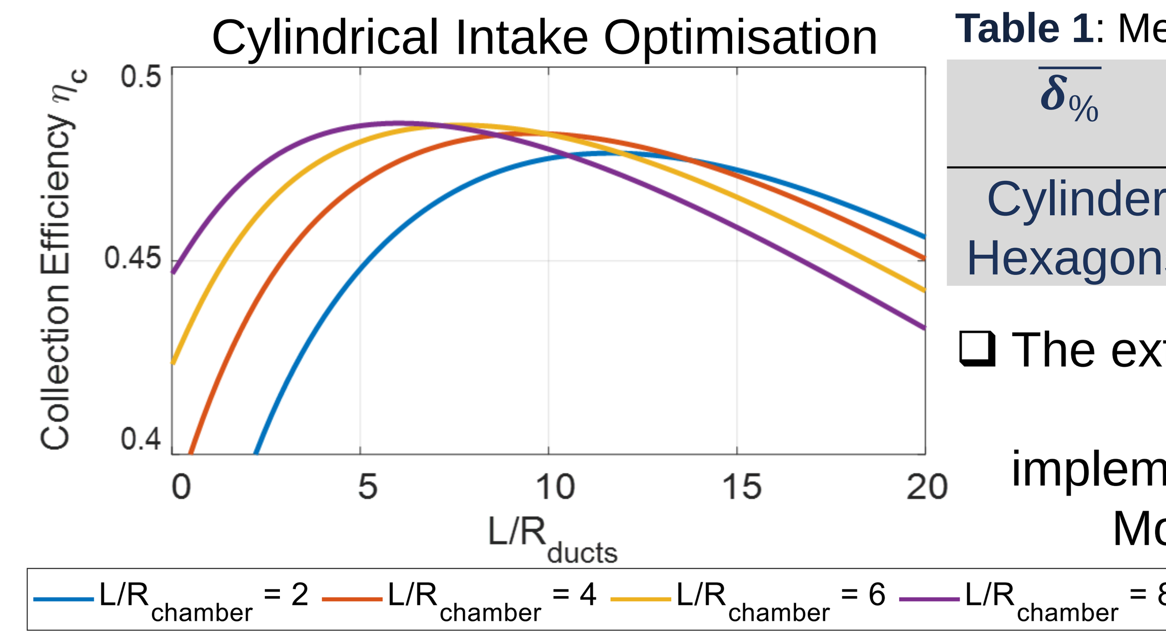


Table 1: Mean percentage error results

$\delta_{\%}$	PICLas	Analytical
Cylinder	2.24%	1.83%
Hexagons	2.12%	-

- The extrapolated expressions of transmittance are implemented in the Balancing Model to **optimise** ABEP intakes **(Fig. 7)**

Fig. 7: Collection efficiency of cylindrical chamber with cylindrical ducts (S=15)

5. CONCLUSION

- dsmcFoam+ has **high modelling capabilities** and shown to be **accurate** but **computationally expensive**
- Data gathered may be implemented to optimise ABEP intakes as Balancing Model requires transmission probability expressions

REFERENCES

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[5] Pond, H., 1962. The Effect of Entrance Velocity on the Flow of a Rarefied Gas Through a Tube. *Journal of the Aerospace Sciences*, 29(8), pp. 917-921.