Light-powered flyers for the mesosphere

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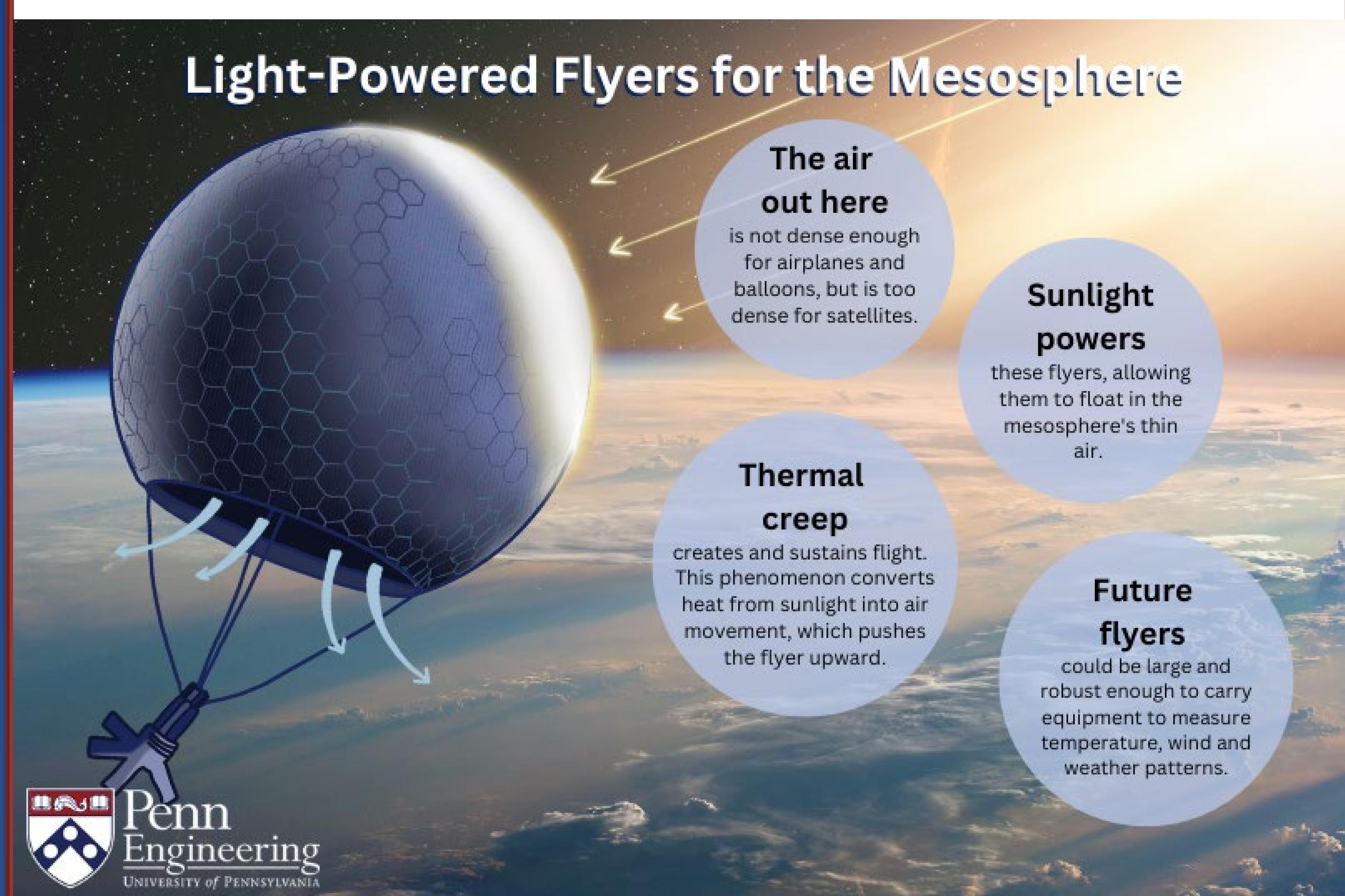
NASA Innovative Advanced Concepts

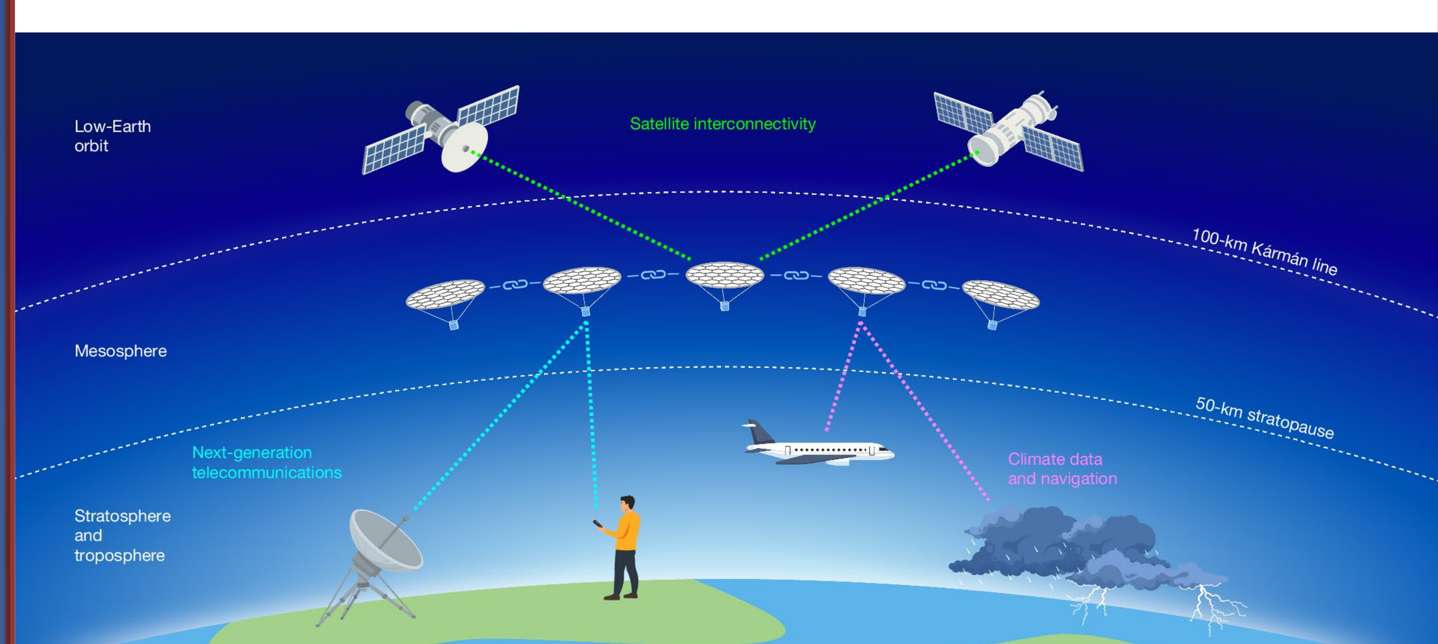
Introduction

We are developing a propulsion mechanism and aircraft designs capable of generating solar-powered lift without moving parts at altitudes of 50–80 km. The system relies on micro-perforated films that exploit photophoretic forces—the motion of gas molecules induced by light. Under natural sunlight, these forces are strong enough to lift lightweight structures, such as sensor payloads in environments where conventional flight is impossible, such as Earth's mesosphere or the thin atmosphere of Mars.



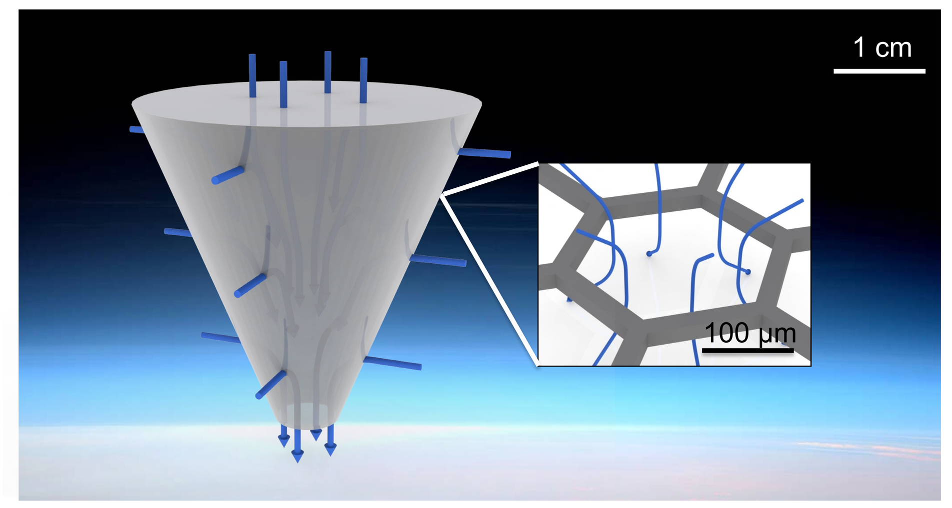
Applications include

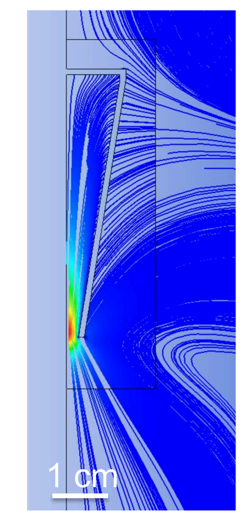
- atmospheric data sensing and tracking of wind patterns in the mesosphere (50-80 km) or on Mars (>10 km altitudes)
- Persistent surveillance



Schafer, B.C., Kim, Jh., Sharipov, F. et al. Photophoretic flight of perforated structures in near-space conditions. Nature 644, 362–369 (2025). https://doi.org/10.1038/s41586-025-09281-8

3D Aircraft Geometries

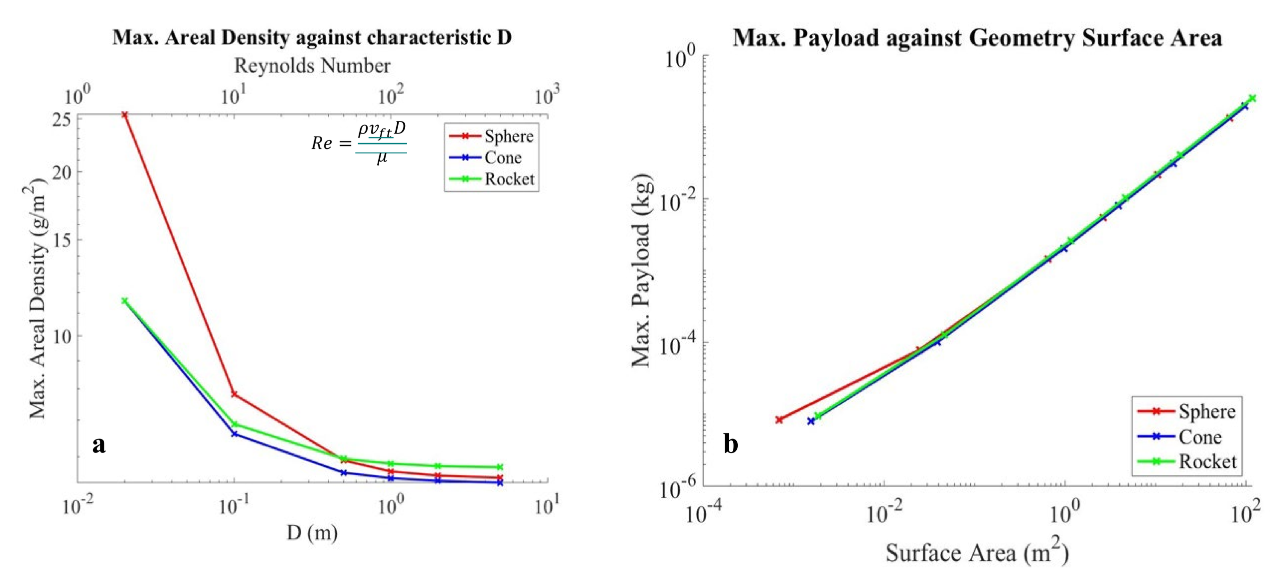




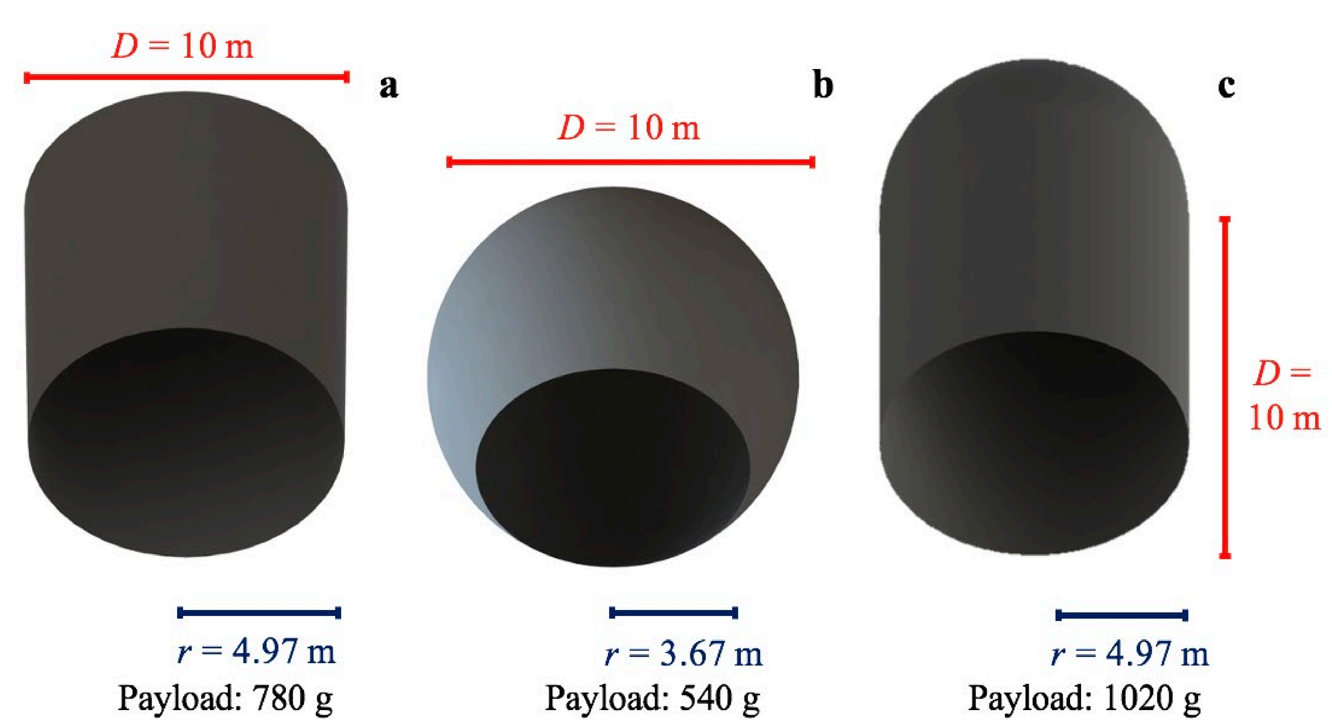
- 3D geometries with porous side walls and a nozzle for jet velocities can increase lift force
- Air flows into hollow inner cavity and out a jet through the same Knudsen pumping
- ANSYS Fluent simulations performed for nozzle, cone, sphere, rocket-like shape for estimation of this theory
- Theory based on Stoke's drag and momentum equation with interpolated fitting parameters:

$$F = C_1 16 \mu R v_{in} + C_2 \rho A v_{jet}^2$$

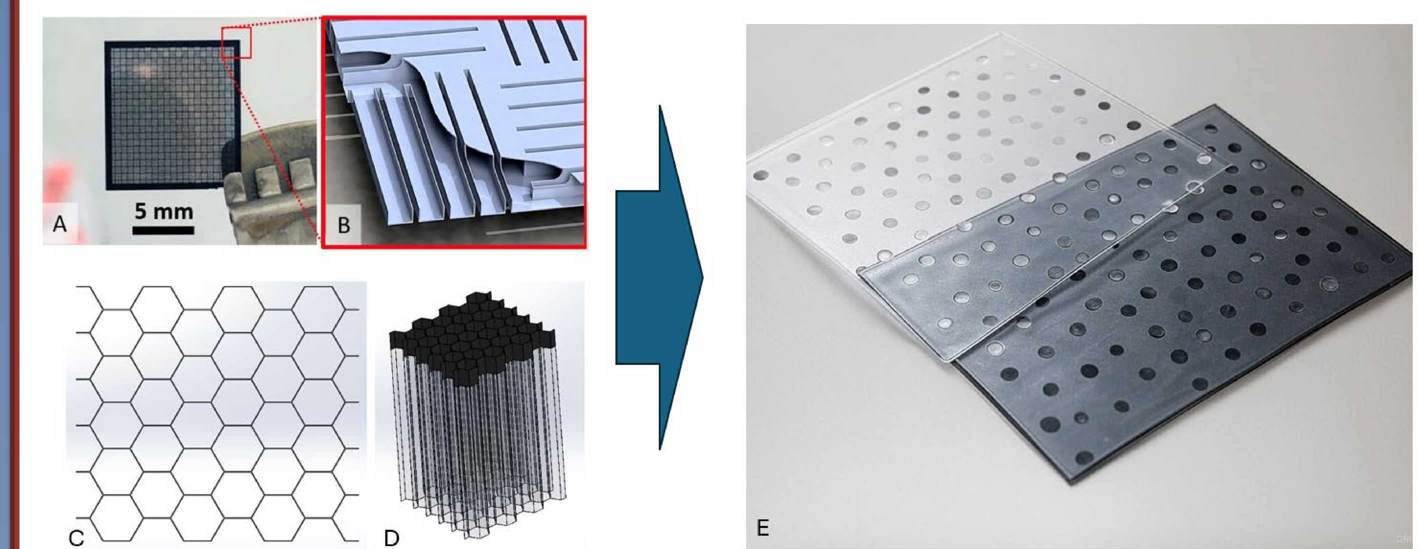
Simulation Results



- The mesosphere devices must be made from lightweight films (a micron thick or a few grams per square meter)
- The payloads can reach kilograms for sizes of > 10 meters

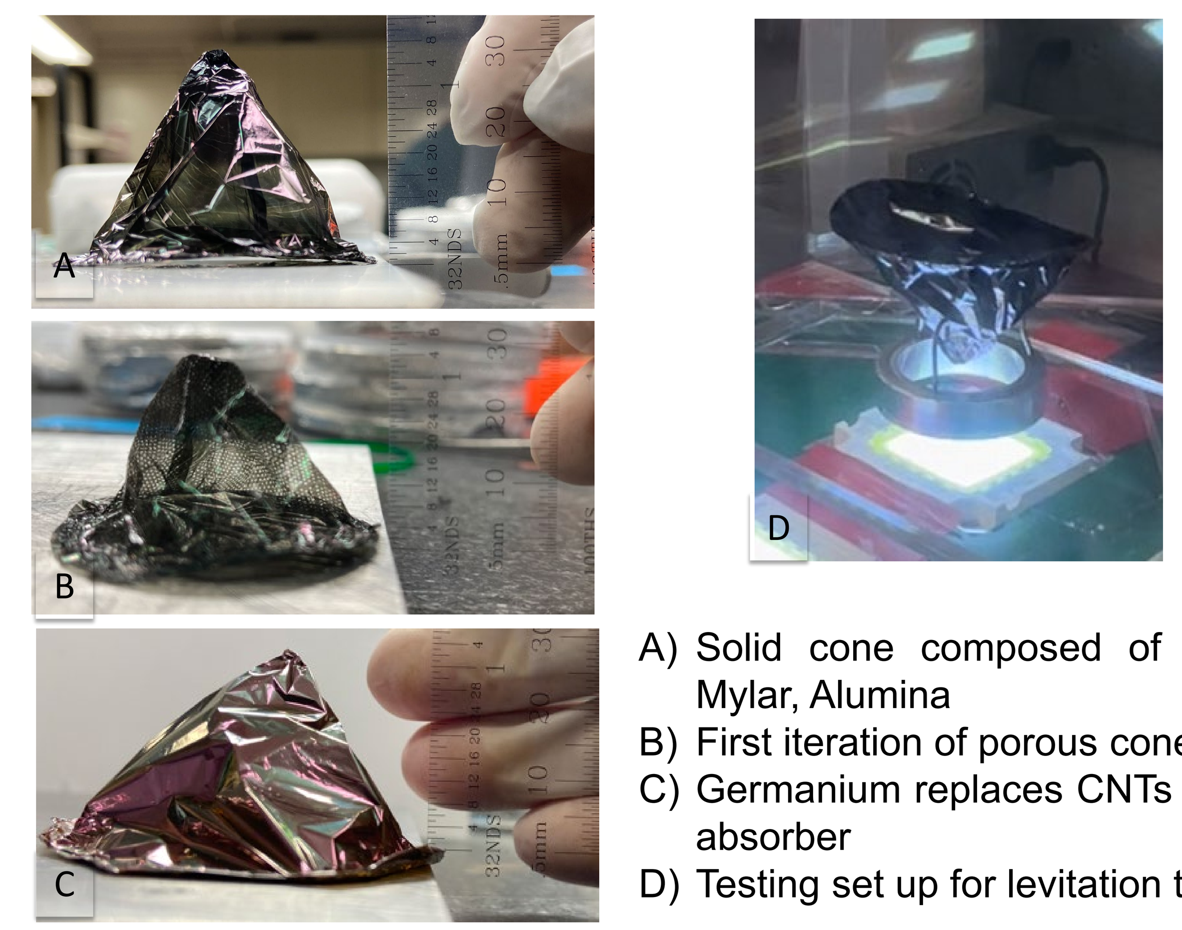


Concept progression from nanocardboard to scalable microporous film



The new paper from Joost Vlassak's group and collaborators shows we can use microperforated films offset from each other, a much more manufacturable approach than nanocardboard considered in Phase I NIAC

We have made and tested similar polymer films already:



A) Solid cone composed of CNTs, Mylar, Alumina
B) First iteration of porous cone
C) Germanium replaces CNTs as the absorber
D) Testing set up for levitation test

Technical approach

1. Demonstrate methods to fabricate square meters of porous film for high-speed Knudsen pumping
2. Develop payload attachment techniques (small sensors and antennas)
3. Model, design, and fabricate lab-scale prototypes of photophoretic aircraft and thrusters
4. Develop balloon-based missions that integrate photophoretic thrusters and flyers

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