Photophoretic thruster for trajectory control of large, high-altitude balloons

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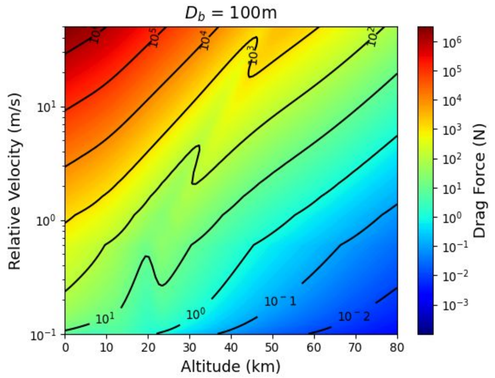
Motivation

- Large, high-altitude balloons have many uses
  - Atmospheric data collection
  - Surveillance (e.g. “Chinese spy balloon”)
- Fly along with prevailing winds, no control of path
- Want to slightly change flight track over time to steer balloons to preferred latitudes
  - Right path = longer missions = more data
- Existing types of control correct drift velocity by a few meters per second → dramatic improvements to the overall trajectory

What is “Photophoresis”?

- Light heats one side of a porous film
- Gas moves from the cold side to the hot side through holes in the film
- Thruster harnesses that gas movement to direct flow

Forces on the Balloon



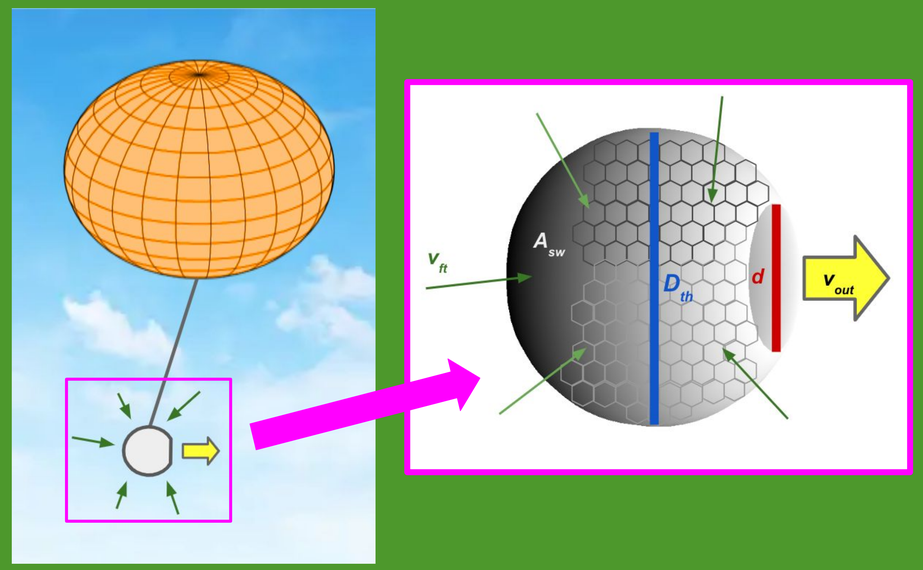
- Drag depends on many factors:
  - Altitude, temperature, pressure, air viscosity, air density, size of balloon, shape of balloon, relative wind velocity, etc.
- Model predicts the forces on the balloon including drag (above) and buoyancy

Furor Over Chinese Spy Balloon Leads to a Diplomatic Crisis

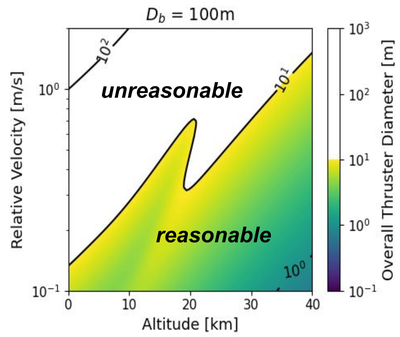
How a Chinese 'spy balloon' prompted the U.S. to scour the skies

New photos show the Navy recovering downed China spy balloon off U.S. coast

Weather Balloons Can Be Steered with Light

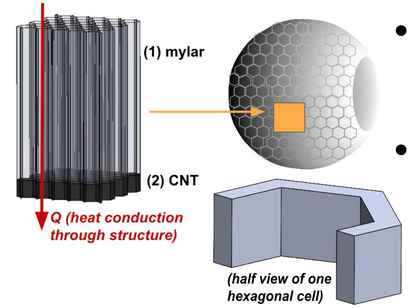


Feasibility of Thruster



- Main limiting factor: overall thruster diameter (D_{th})
  - Also impacted by drag/buoyancy
- Compensate for a few meters per second of wind velocity at ≤10 meters in overall diameter

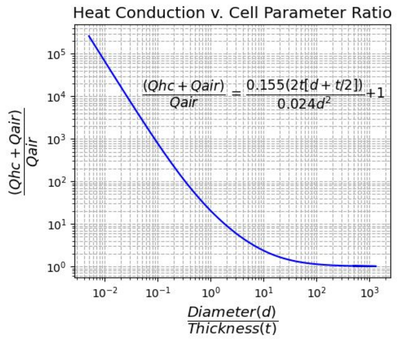
New Thruster Material



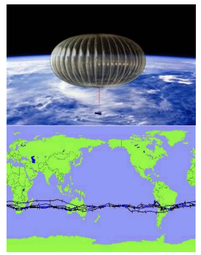
- Honeycomb-structure mylar coated with CNTs on the inner surface
- Unlike nanocardboard, would allow for 100% air flow through the channels

Ideal Dimensions of Material

- Temperature difference leads to heat conduction through walls and air
- At approx. $d/t \geq 10^1$, the heat conduction ratio is small enough to neglect heat conduction through solid walls



Further Study



1. Determine ideal thickness of material (expected ~10^{-2} m)
2. Adjust existing nanocardboard model to reflect new geometry
3. Test fabrication of honeycomb mylar and CNT material
4. Small scale experiments with thruster and balloon in controlled environment

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