DESIGNING BIOLOGICAL EXPERIMENTATION SYSTEMS FOR HIGH ALTITUDE BALLOONING

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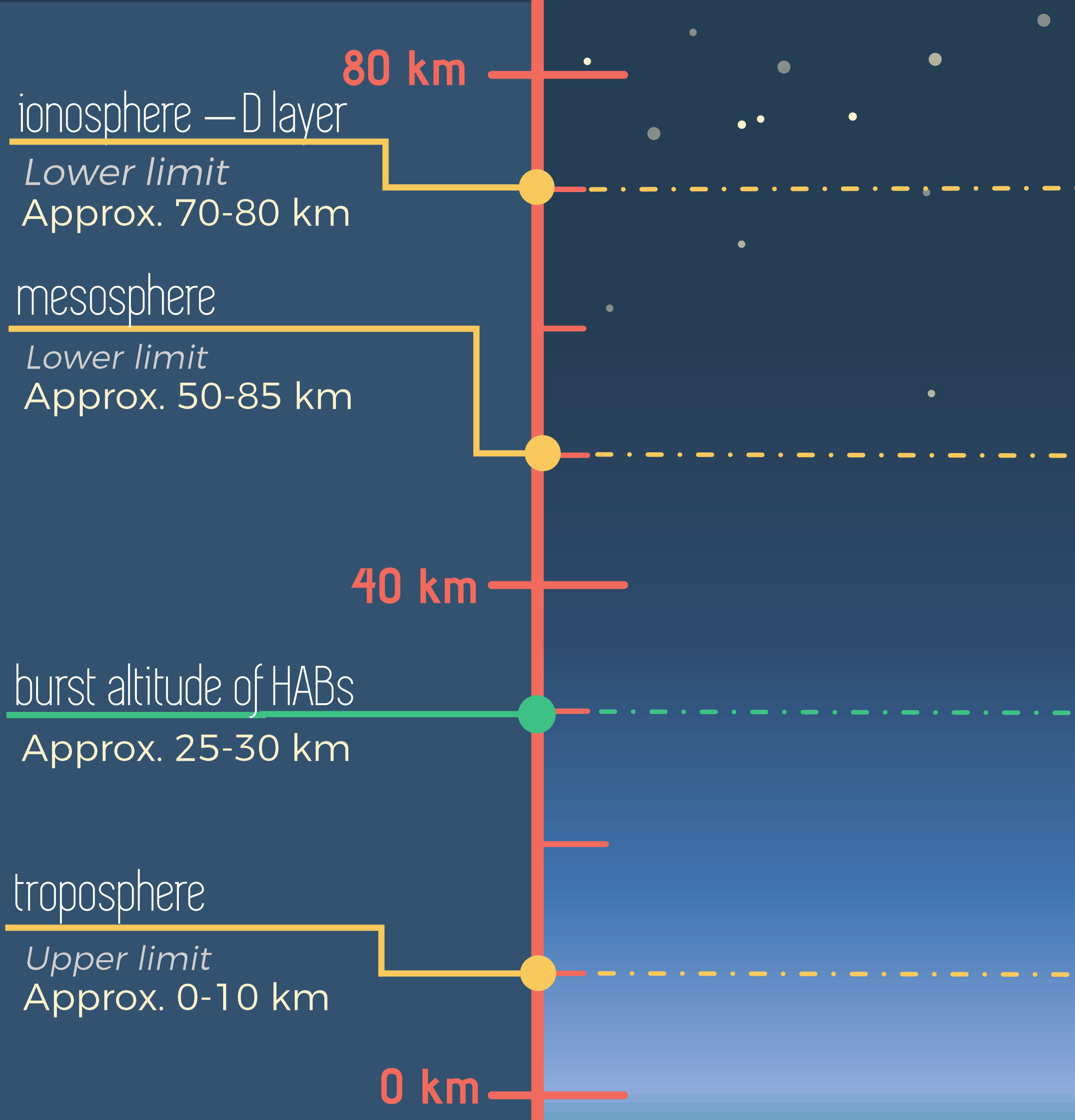
INTRODUCTION

- Atmosphere viewed as a conduit for biological life rather as thriving biome

- Aerial microbiome closely related to underlying biosphere
  - Cells can remain in atmosphere for 1 week on average
  - Can replicate and form permanent aerial colonies

INTRODUCTION

- Airborne bacteria discovered at 8 -15+ km
  - May exist as permanently established populations at high altitudes.
- Evidence of microbial life at 70-80km



AETHEROPHILE

(n.) A micro-organism capable of surviving and thriving at high altitudes. *

Derived from the Latin root aether *('upper air') and* -philus *('liking').*

**This term was coined by the author.*

SIGNIFICANCE

- Aetherophiles are active agents of meterological change
  - Nucleation sites for clouds
  - Determine cloud type
  - Chemical composition of atmosphere
- Biological implications of near-space conditions
  - Juxtaposition against terrestrial counterparts

HIGH ALTITUDE BALLOON FLIGHTS

- Accessible due to low cost (~ $1000)
- Passive transport limits disturbances of atmospheric biome
  - Subject to air currents that affect aetherophiles
- Can travel 72 km downrange of launch site on avg.
  - Allows for cross-biome sampling
- Ascent (5 m/s) provides sufficient airflow for sample collection

CHALLENGES AND CONSTRAINTS

- ❖ Weight and dimensions
  - ❖ Degradable material (e.g. foam core) not compatible with repeated use of liquid sterilizers
  - ❖ Aluminum alloy increases fabrication time for payload
- ❖ Liquid-based collection impractical
- ❖ Gamut of environmental conditions
  - ❖ Pressure equalization vs need for sterile environment
- ❖ High velocity winds and impact velocity
- ❖ Financial burden of premade biological equipment

CASE STUDIES

IN BIOLOGICAL PAYLOAD DESIGN

PHANTOM

Probe for High Altitude Numeration and Tracking of Micro-organisms

University of Maryland, College Park

p.h.a.n.t.o.m.

Near-space Program

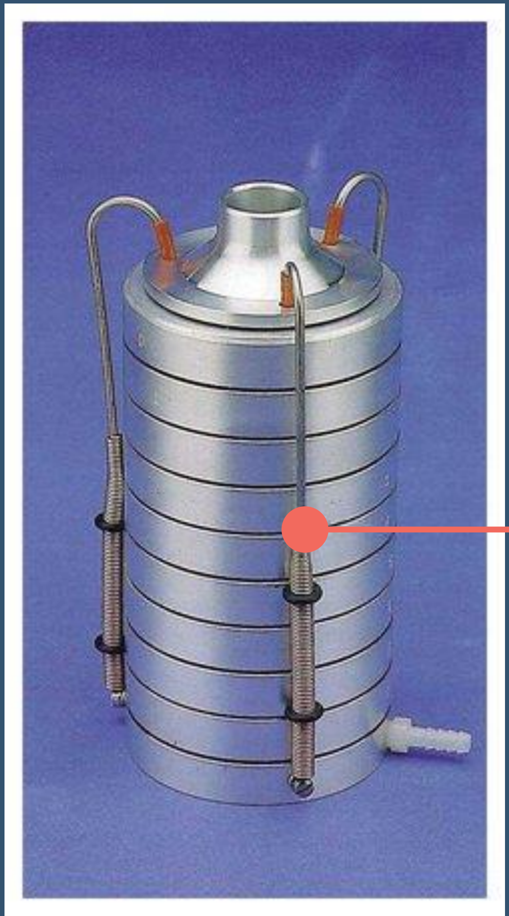
OBJECTIVES: PHANTOM

- Facilitate the reconnaissance and identification of micro-organismal species across various altitudes
  - Collect longitudinal data and map density of aetherophilic species across various altitudes

- Future goals
  - Self-contained telemetry/telecommand system for real-time user controlled sampling

RATIONALE

- Active sampling (drawing particulates over collection surface) superior to passive collection
- Preferred method in hospital safety testing: impacting

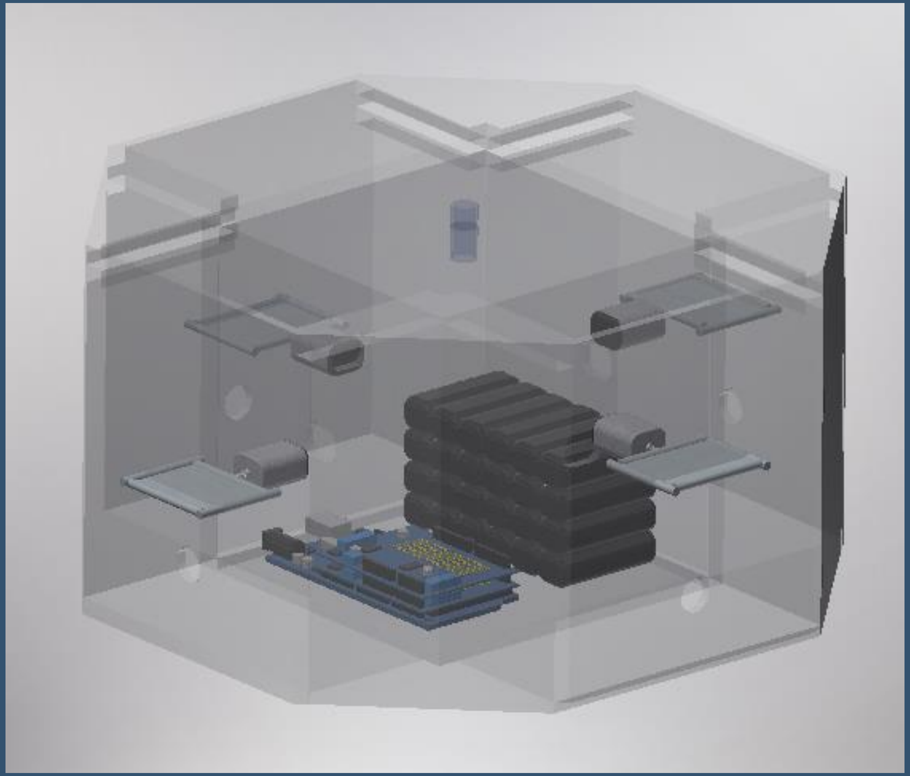


Anderson 6 –stage impactor

Weight: 3.6 kg
Cost: > $300
Image credit: ThermoFisher Scientific

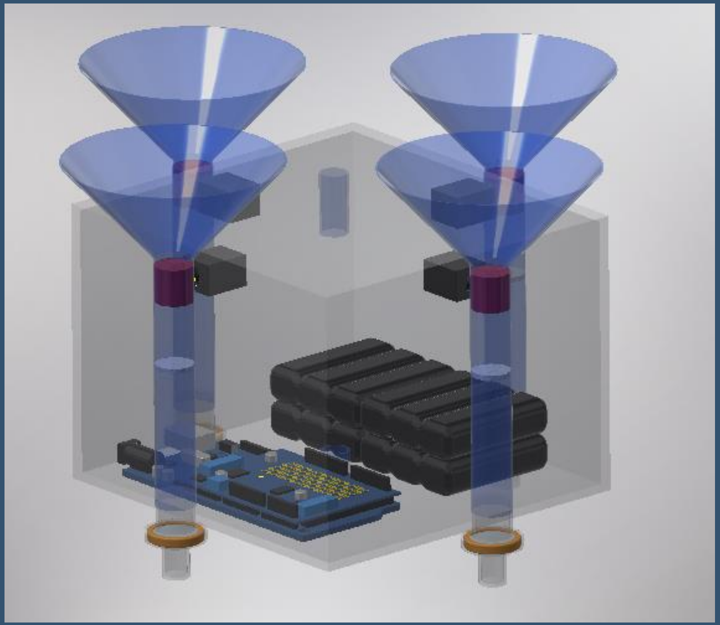
DESIGN EVOLUTION: PHANTOM v. 0.1

- v. 0.1
  - Considered linearly actuated doors and filter paper-based collectors
  - Foamcore box
  - Altitude measurements read from BME280 + Arduino Mega
  - Cost and weight were prohibitive



DESIGN EVOLUTION: PHANTOM v. 1.0

- ❖ Controlled by Arduino/BMP280
- ❖ Foamcore box
- ❖ Takes advantage of airflow from wind
  1. Air forced through funnel
  2. Valve opens at altitude for 10 s
  3. Airflow pushes sample onto syringe filter
- ❖ Ran on 1200 mAh 12V LiPo w/ LVC



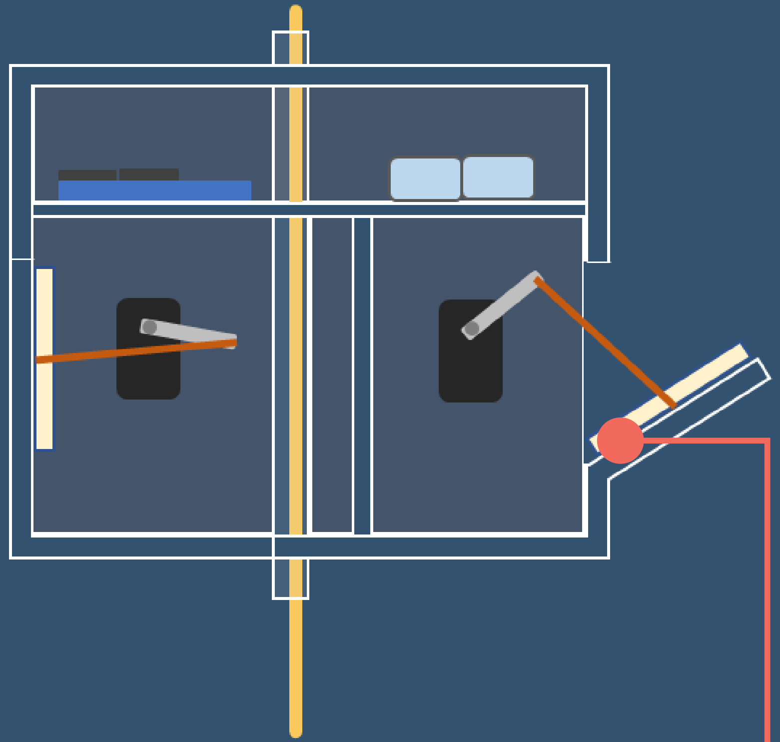
DESIGN EVOLUTION: PHANTOM v. 2.0

- Problem: insufficient airflow from valves, syringe filters dislocated during impact

- Solution: rotary-style collector array
  - Driven by stepper motor, rotor made from CD
  - Samples collected on 3 cm diameter filter paper

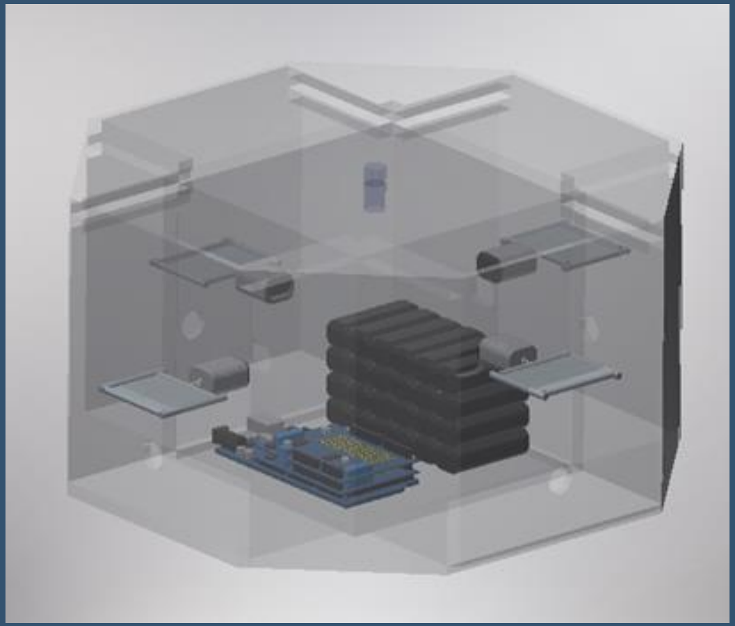
DESIGN EVOLUTION: PHANTOM v. 3.0

- Results from v. 2.0:
  - Negative control from flight did not show growth
  - *E. coli* outcompeted aetherophiles in experimental samples
  - Vulnerability to contamination: rotor and lid must be flush
- Reconfigured to collect samples on agar gel (nutrient media)
  - Located on interior of drawbridge-style door, powered by servo
  - 4 separate sealed compartments, powered by Arduino (in 5th compartment)

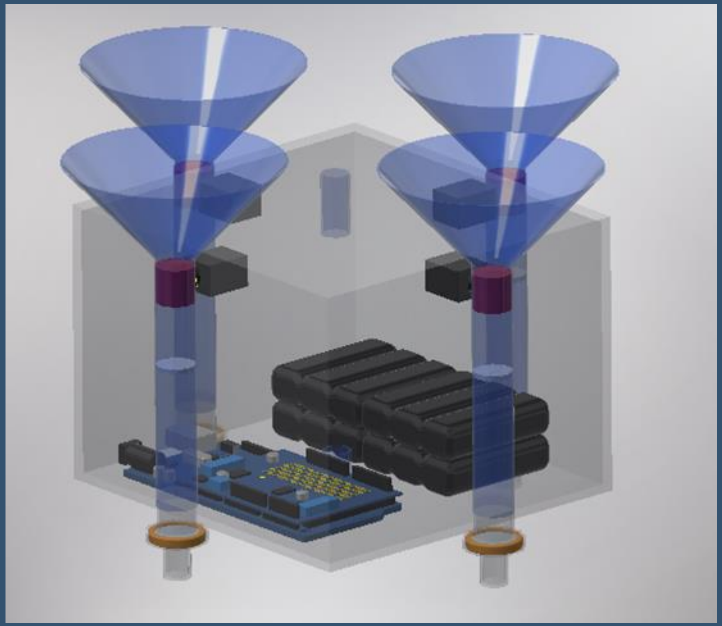


40% glycerol agar collects sample

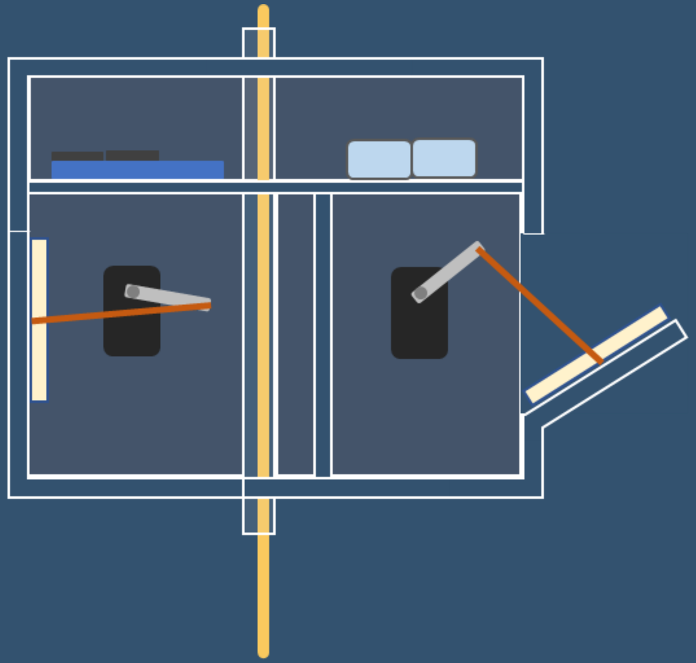
DESIGN EVOLUTION



PHANTOM v. 0.1



PHANTOM v. 1



PHANTOM v. 3

ATOMIC

Atmospheric Thindown Originating Mutagenesis Investigational Capsule

ATOMIC: OBJECTIVE

- Lower ionosphere altitude associated with a drop in temperature (e.g. during a solar eclipse)
- Investigating the effect naturally occurring doses of ionizing radiation on the mutation rates of common bacterial species
  - Involved sending bacterial culture on a HAB flight

DESIGN PROCESS

- Bacterial selection
  - *E. coli* and *B. subtilis* chosen for ubiquity, resilience, safety
- Growth media selection
  - Tested in thermal chamber and vacuum chamber
  - Pressure changes caused bubble expansion
  - Extreme cold caused syneresis of agar
- Prevention of syneresis
  - 40% glycerol, 2.5% LB agar gel used
  - Slowed bacterial growth but prevented syneresis
- Successfully launched during solar eclipse,

SIGNIFICANCE

- Biological experimentation has a very involved, interdisciplinary design process
- Results have applications in a variety of fields:

Meteorology
and
environmental science

Aerospace
engineering

Microbiology
and
public health

National security

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QUESTIONS?

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