VOLTITUDE

Unlocking the Stratosphere®

Enhancing HAPS Navigation and Operating Safety Margins During Remote Operations

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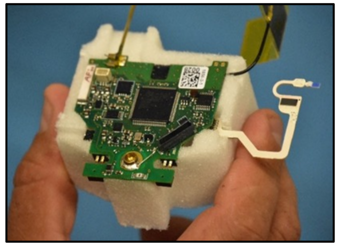
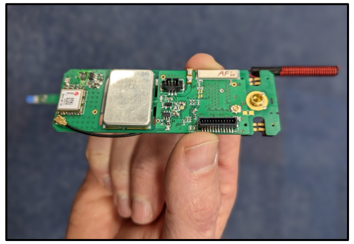
Company Introduction

Voltitude technology is **Unlocking the Stratosphere®** providing Remote Sensing, Earth Observation and Connectivity Services from High Altitude Platforms.

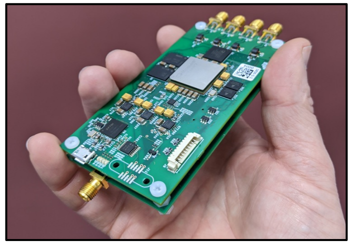
- Lighter-than-air and fixed-wing HAPS R&D and technology demonstration
- Payload development
- C2ISR services
- Near space T&E services



Dropsonde

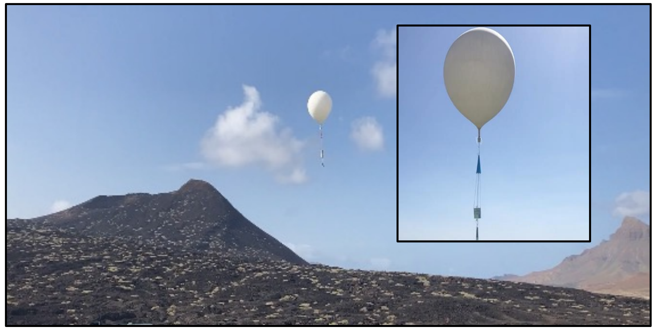


Nav-sonde



Ground mobile radio repeater payload

HAPS flight control research



Long endurance balloon operation

Corporate affiliate of

StratoSolutions

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Contents

"*Enhancing HAPS Navigation and Operating Safety Margins During Remote Operations*"

The challenges:

- Platform vulnerability
- Meteorological uncertainty

Solutions:

- Remote in-situ weather data observations
- Dynamic Mesoscale Models
- Operating Envelope Expansion

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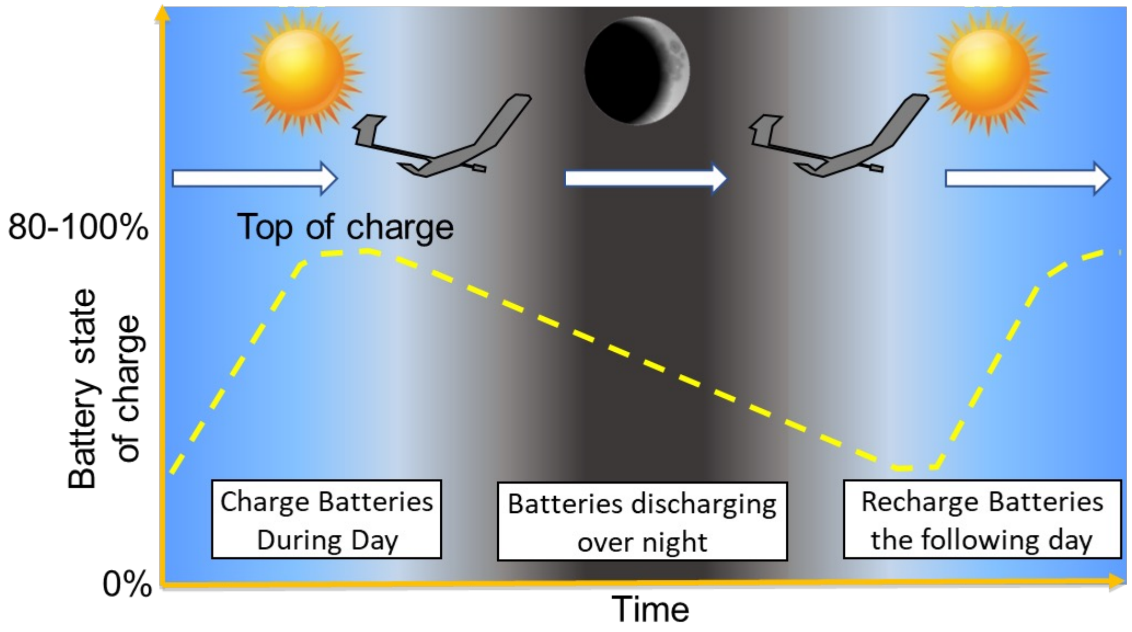
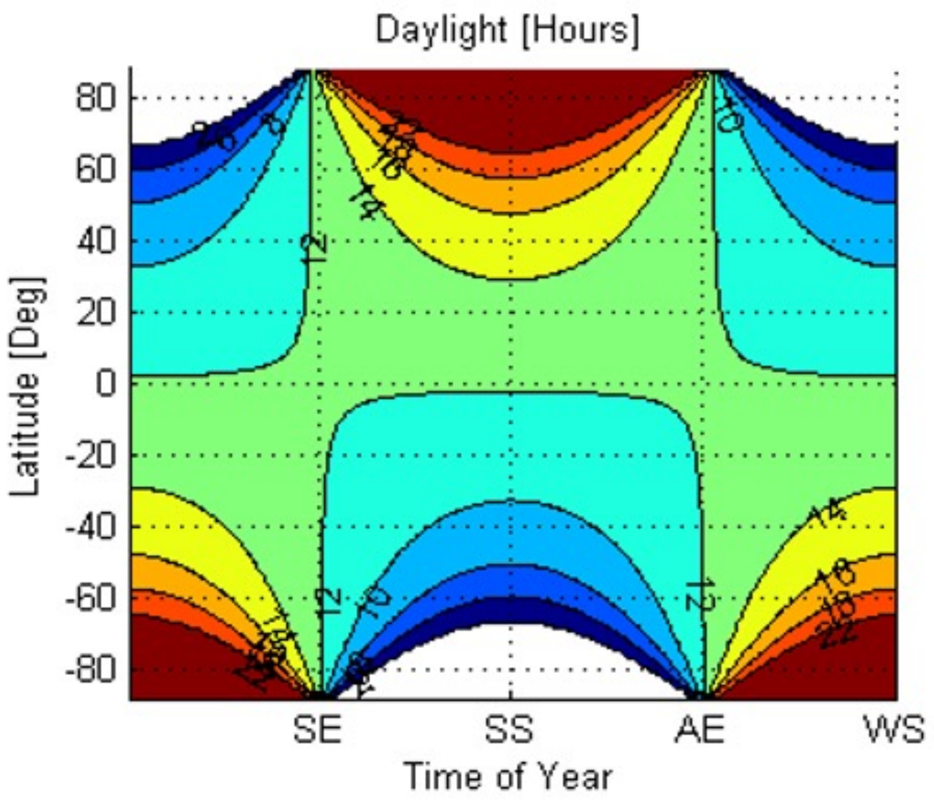
“Perpetual” Solar Powered Flight





Total energy collected and stored during the day	≥	Total energy consumed overnight

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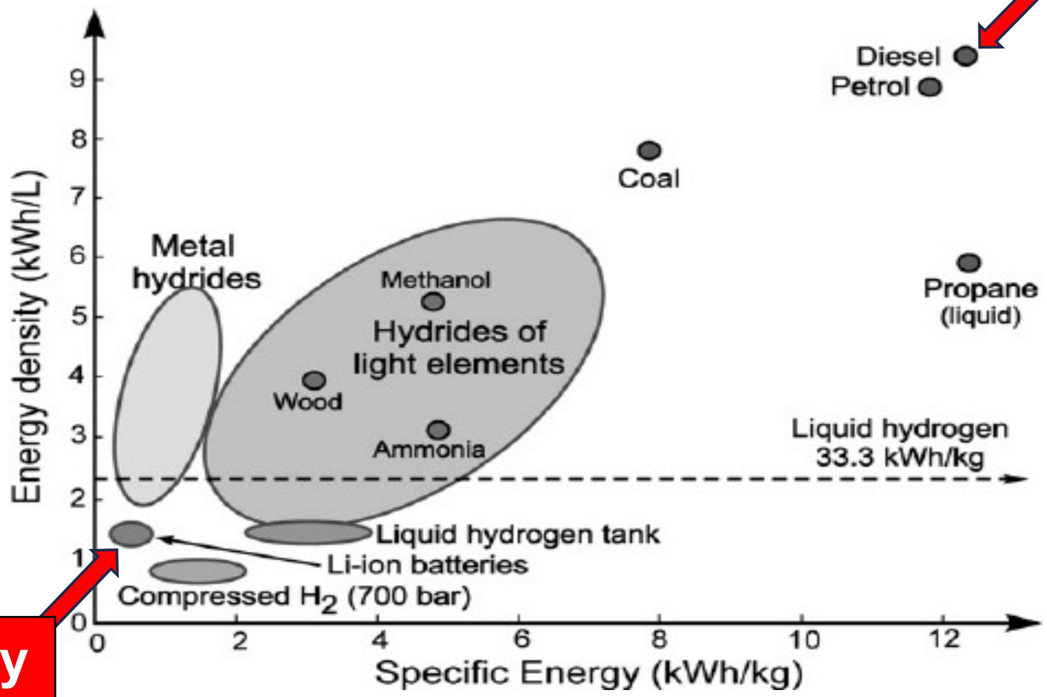
Low Energy Density Fuel

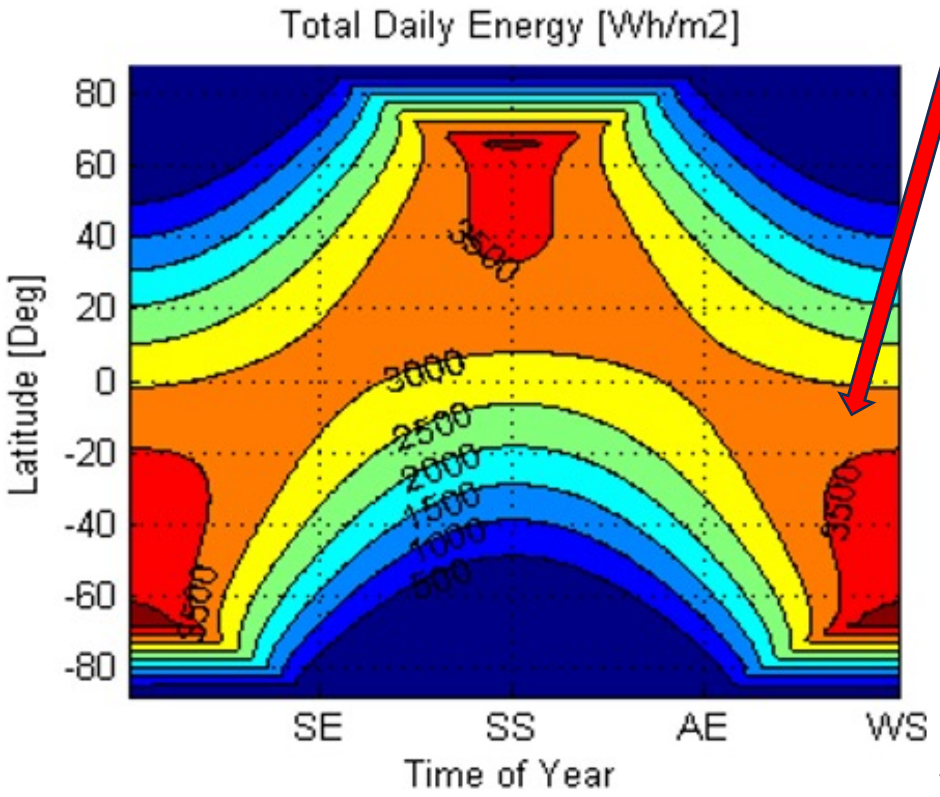


Aviation gas energy density 12kWhr/kg

Battery energy density

Battery energy density is at least 25 times lower than aviation gas

Every 1m² of solar array (30% eff.) is harvesting an amount of energy equivalent to <100ml of aviation gas per day



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The Solar Energy Challenge

How can we design a plane which flies for 14-16hrs between refuelling when limited to fuel which has 25 times lower specific energy density than aviation gas.

$Drag\ \alpha\ V^2$ $\quad$ $Power = D \times V$

$$Power\ \alpha\ V^3$$

Fly slowly to minimise drag and power

Lightweight with low wing loading

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The Great Flight Diagram

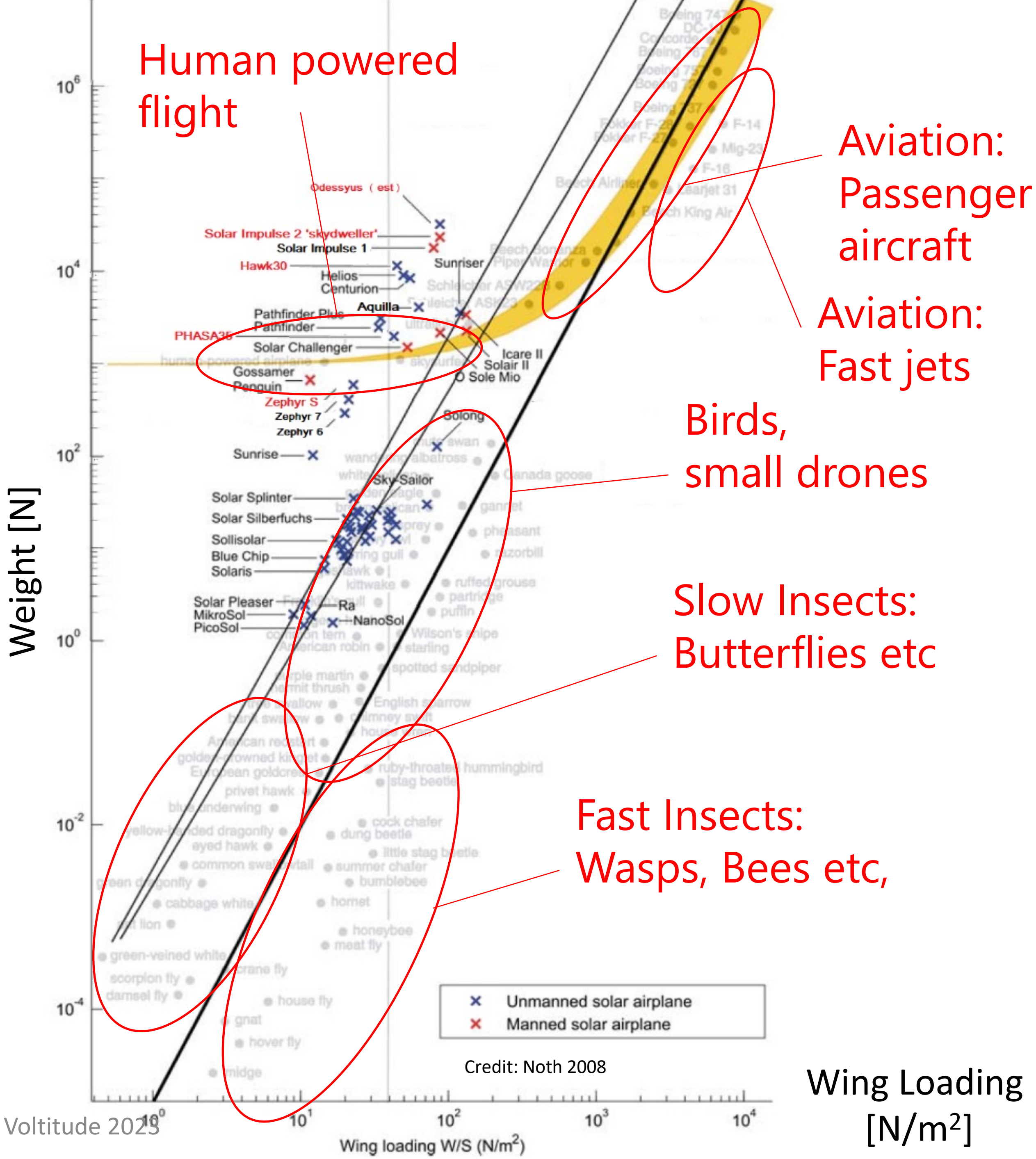
The great flight diagram is useful to understand **what is possible in the history of aviation**, including manned, unmanned and flying animals

Right hand limit:

- the structure gets heavier, and no fuel exists with high enough specific energy to offer a useful endurance

Left hand limit:

- Flying system is too slow and fragile



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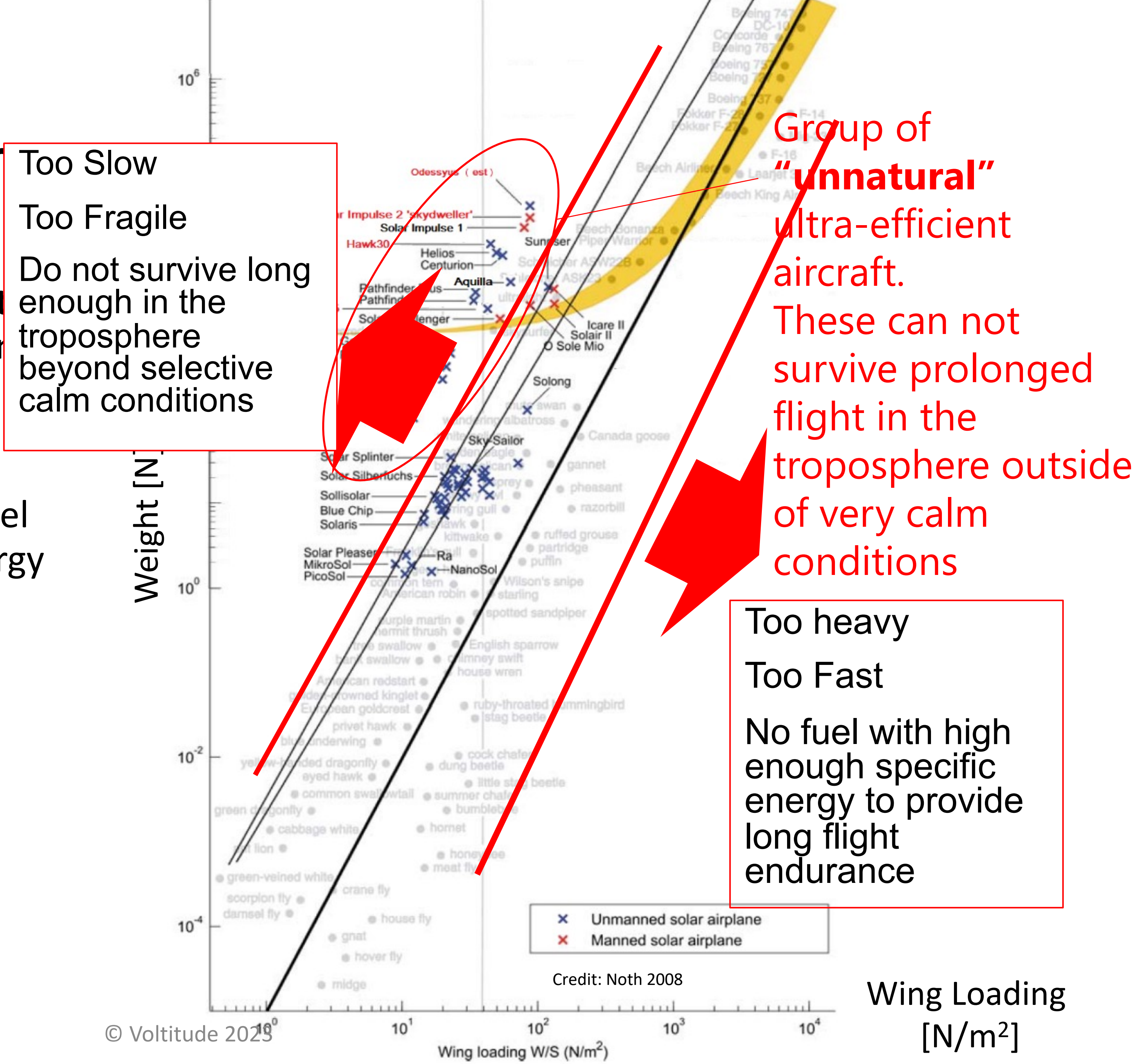

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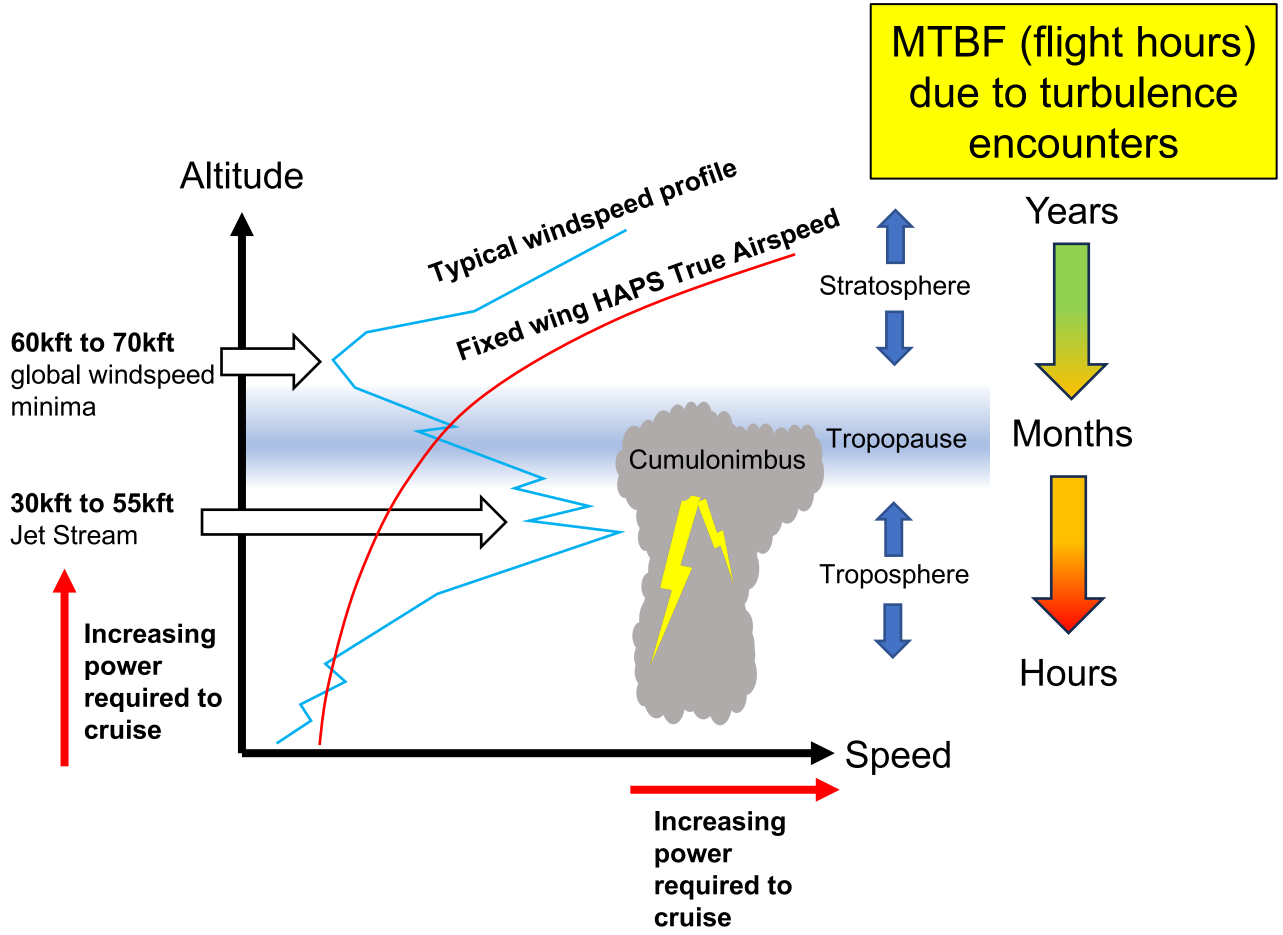
Fixed Wing HAPS Vulnerability



HAPS frequently have close spatial and temporal proximity to dangerous or fatally hazardous gusts or turbulence due to:

- **Low Operating Speed and Rate of Climb:** often unable to evade hazardous weather resulting from changes in forecasted conditions.
- **Low Performance Margin**: While the stratosphere is generally a calm region for aviation, the troposphere is rarely a safe place for HAPS.
- **Stratospheric Gusts and Turbulence:** Low but non-zero probability of encountering hazardous turbulence in the benign environment of the stratosphere, i.e. mean time between failure due to turbulence.

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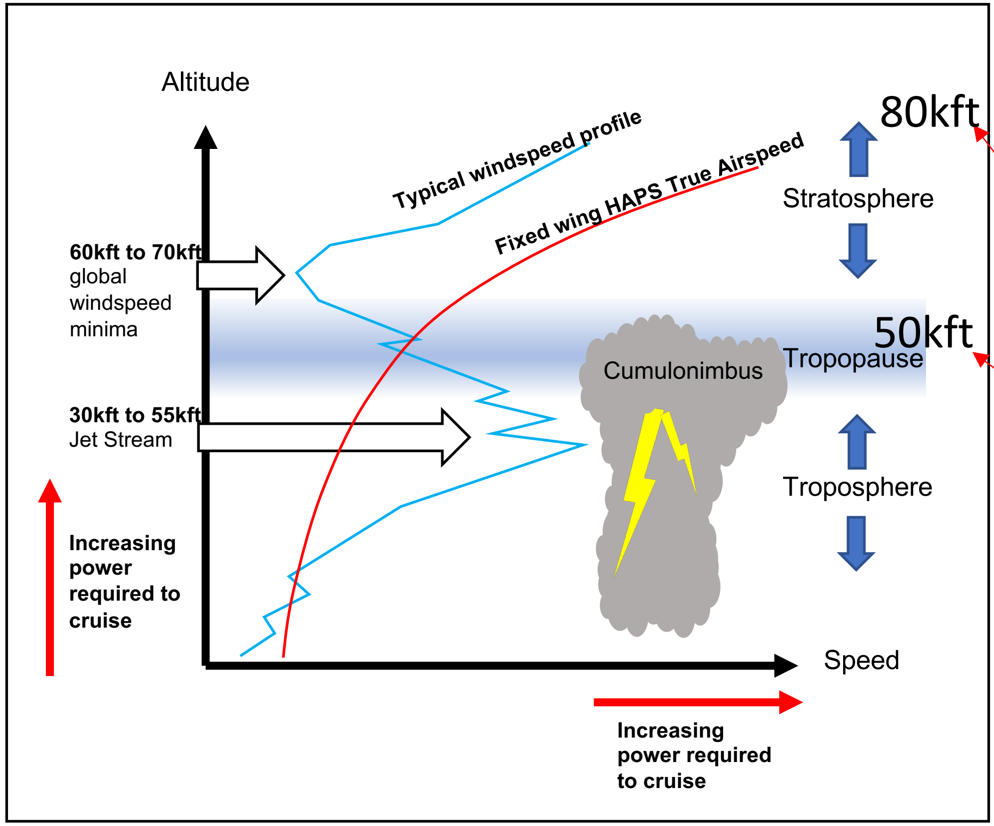
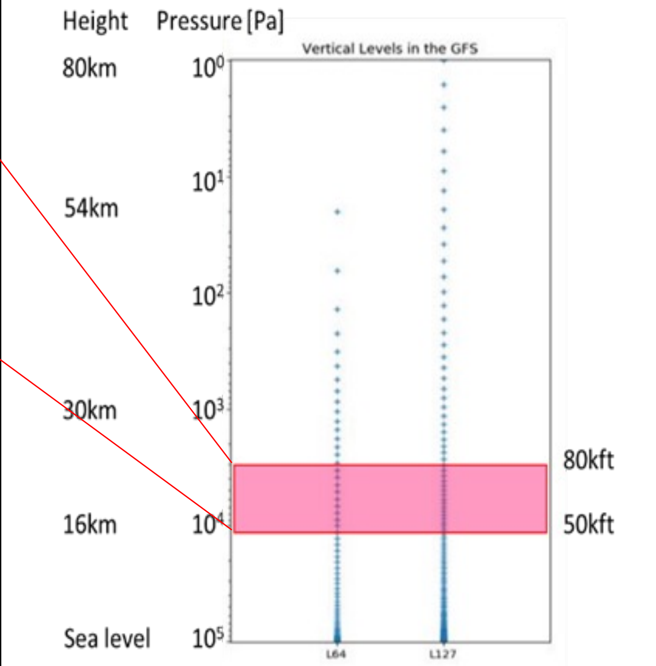
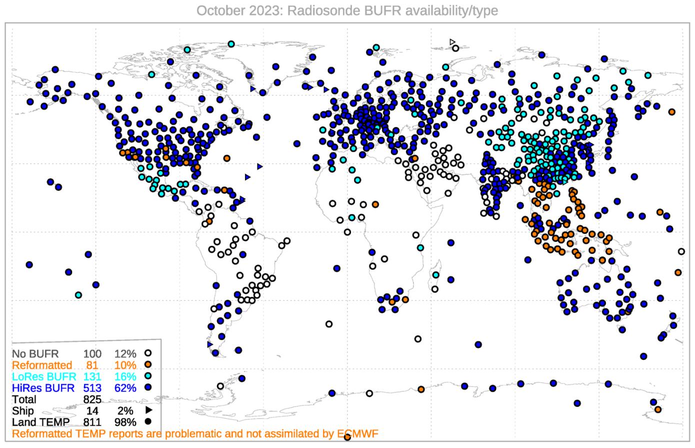
Meteorology – Forecast Resolution and Accuracy Challenges





Forecast model vertical resolution



Weather balloon launch locations

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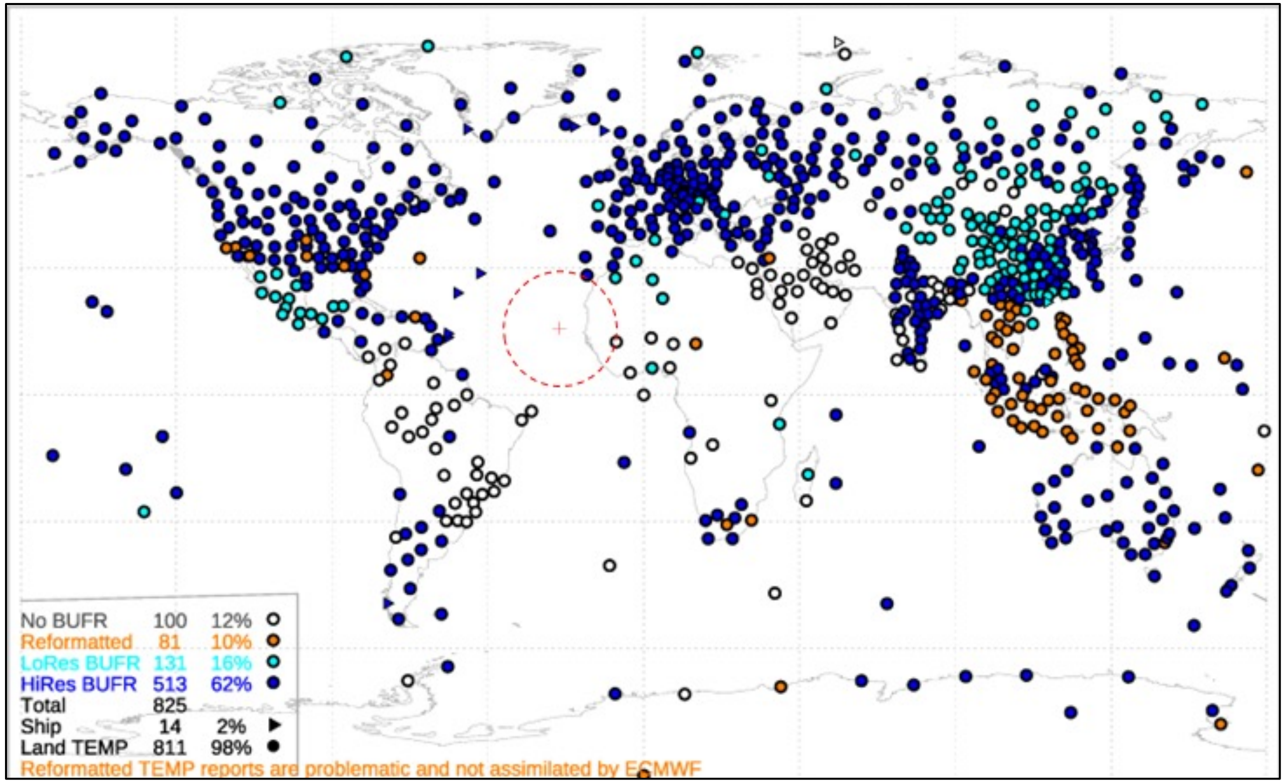
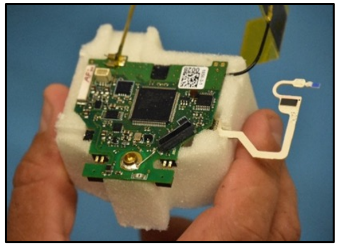
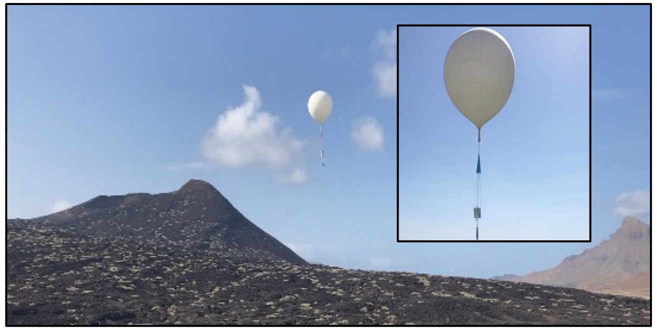
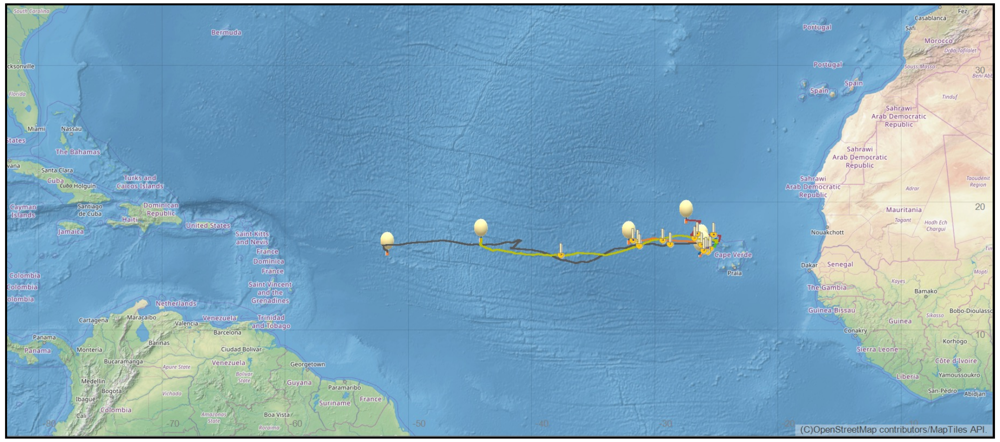
Met Study – Cabo Verde Trial



In September 2023, from Cabo Verde the nearest observations were over 1,500 km away as indicated by the red dotted circle







Dropsonde data had not been made available to global weather models.

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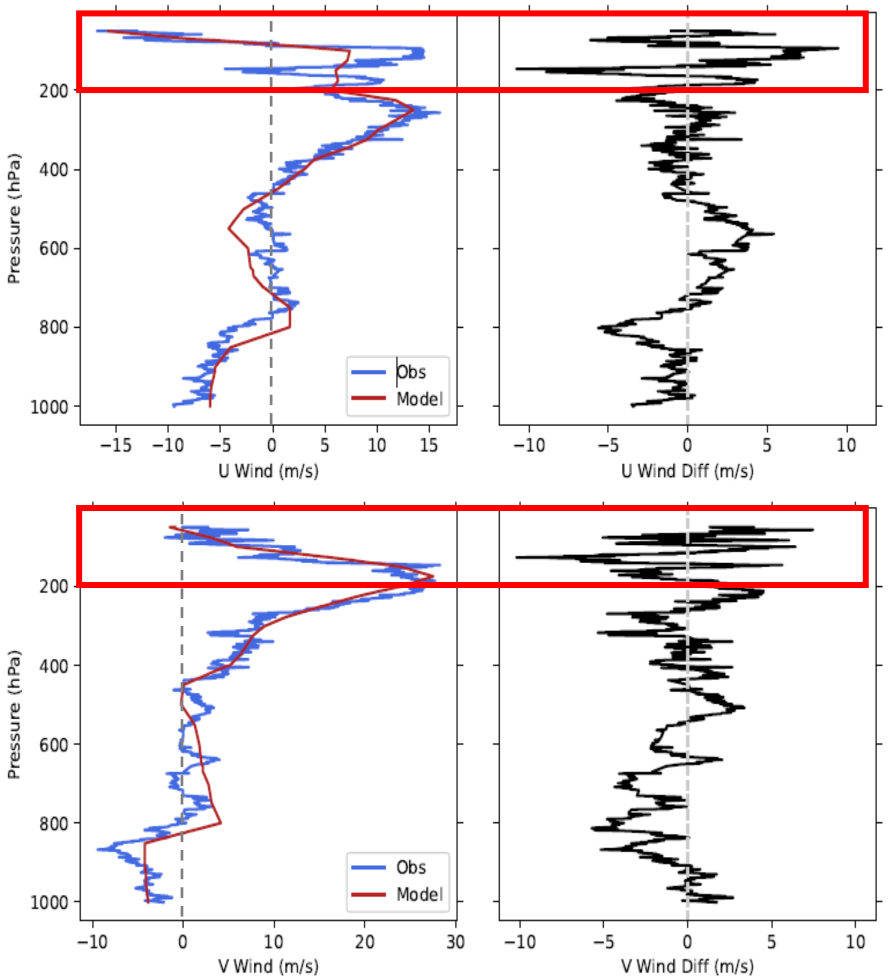
Met Study – Quantifying Disparity

- Good overall agreement between models and dropsonde observation data.
- Focusing on the upper air data:
  - Large (often 100%) wind speed magnitude and heading errors seen in all datasets
  - Mainly in the “light and variable” wind layer immediately above the tropopause in the lower stratosphere



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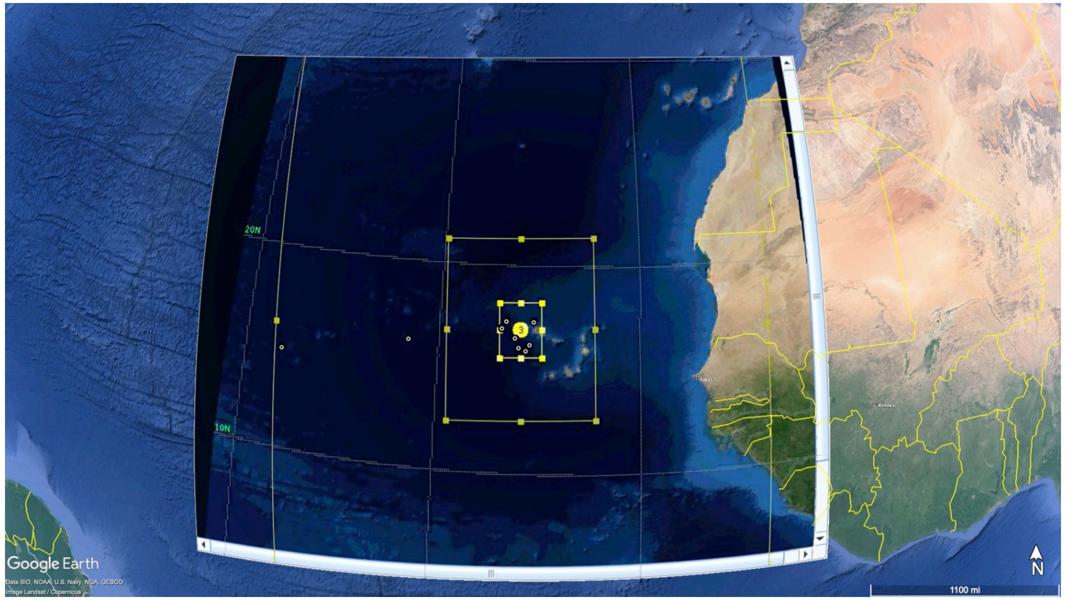
Met Study – High Resolution Modelling

- Voltitude sub-contracted WeatherExtreme Ltd, a private weather forecast company based in the USA for consultation and numerical weather prediction modelling services
- The Weather Research and Forecasting Model (WRF) was used for this study
- The initial conditions for WRF simulations were provided by ECMWF global model re-analysis data (ERA-5), although some runs were performed using GFS data for comparison.



- Nested WRF model domains shown overlaid in Google Earth for perspective.
- The largest having a horizontal resolution of 27km, the middle domain having a resolution of 9 km, and the innermost domain a resolution of 3 km

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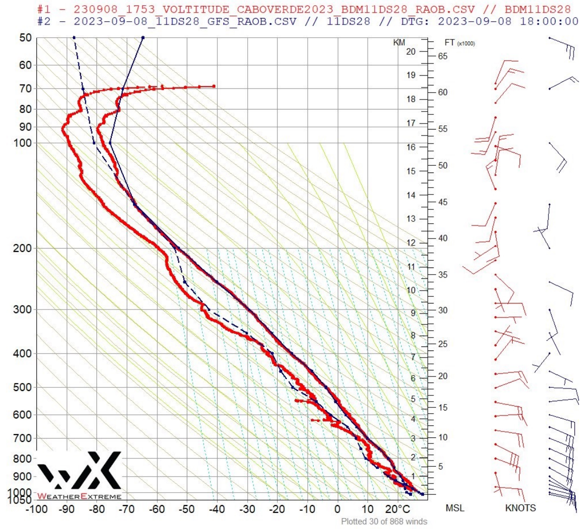
Met Study – Data Ingestion

- Test runs performed with comparisons with ERA-5 data to establish model stability and agreement with re-analysis data over each nested domain.
- Two complete WRF model runs were then performed
  1. Control run
  2. Experimental run – included ingestion of some dropsondes to allow forecasting improvement to be compared with non-ingested dropsonde data.



Ingested	Time Gap	Comparison	Distance
BDM11DS28 *(#1)*	—~2hr—>	**BDM11DS29** *(#2)*	24.51 mi (39.44 km)
BDM13DS02 *(#5)*	—~4hr—>	**BDM13DS03** *(#6)*	91.58 mi (147.38 km)
BDM17DS09 *(#8)*	—~13hr—>	**BDM17DS14** *(#9)*	435.49 mi (700.85 km)

Improvements in accuracy seen in all meteorological variables, at most levels, between the control and experimental runs, most notably in wind speed and direction in the stratosphere

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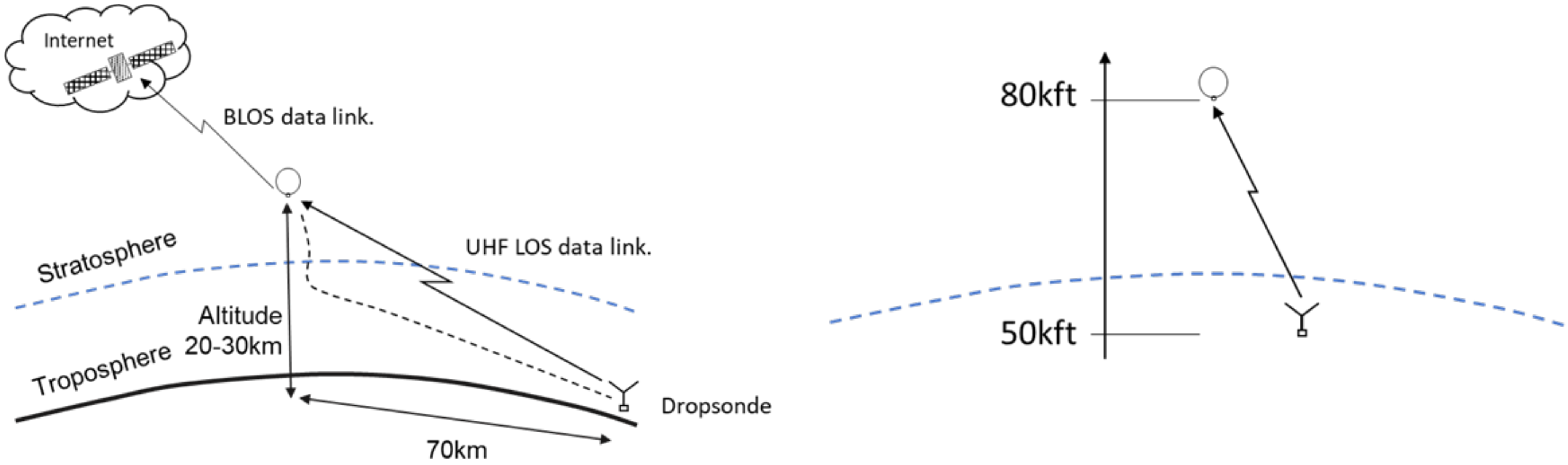
Met Study – Nav-Sonde HAB Use Case



Data link performance geometry for the standard full profiling micro-dropsonde (left) and the stratospheric platform navigation dropsonde (right).

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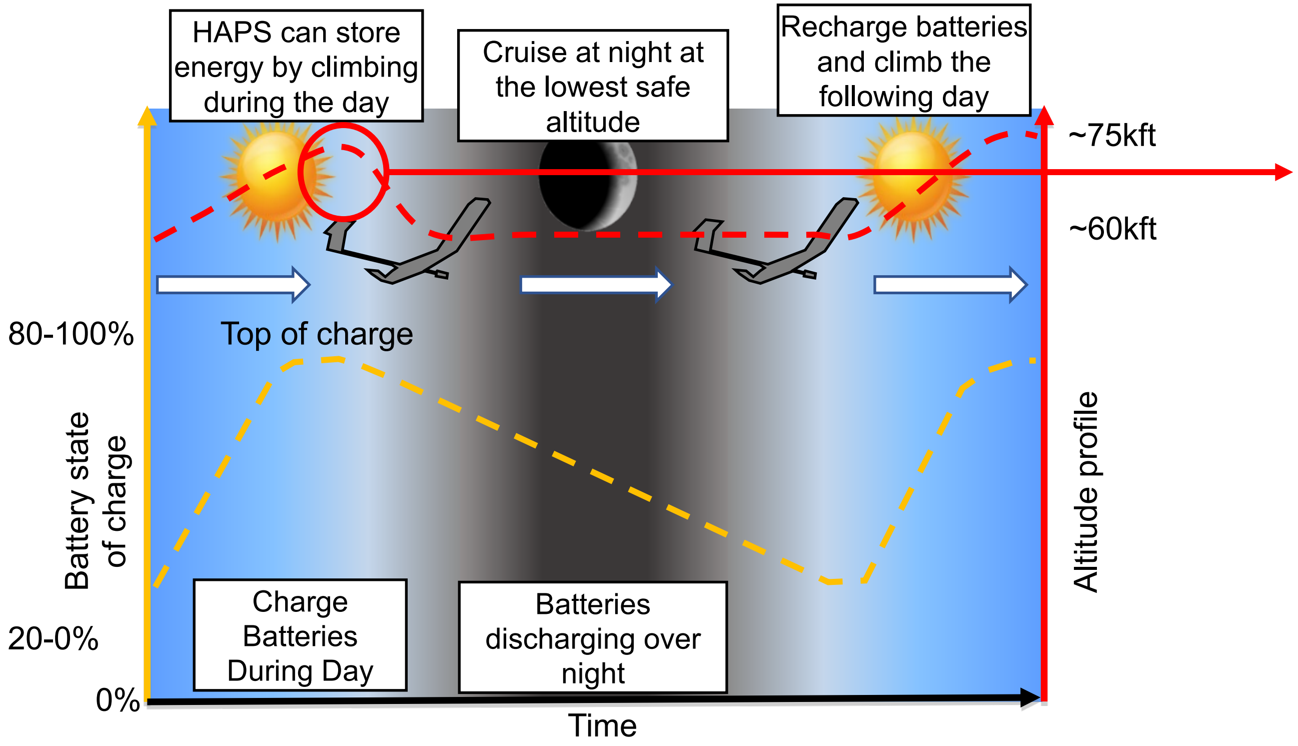
Met Study – Nav-Sonde HAPS Use Case



- Identify potential hazards below, while the HAPS is still “high” and has options
- Better understand proximity to danger
- Better understand optimal cruise altitudes for overnight flight

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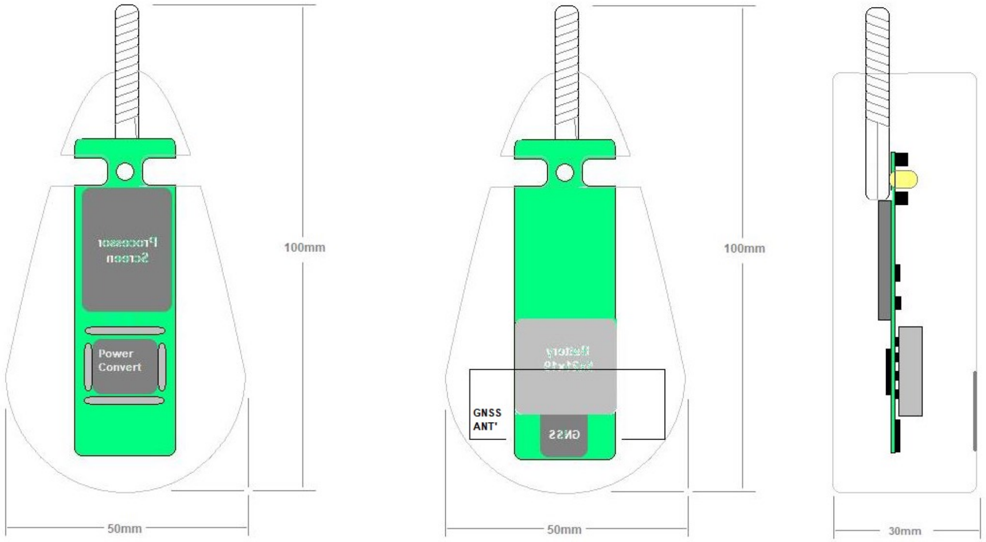
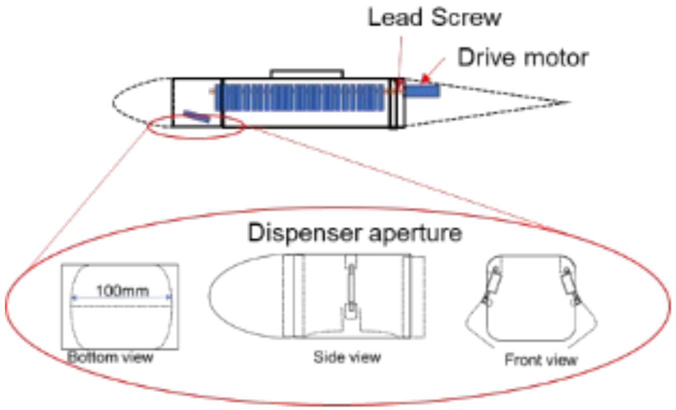
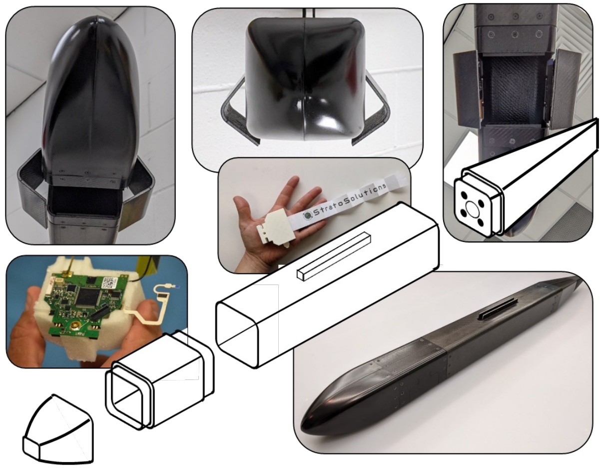
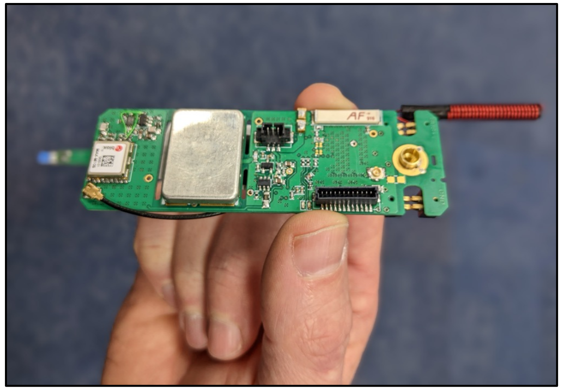
Met Study – Nav-Sonde

- Prototyping has demonstrated that a reduction in micro-dropsonde mass is possible
- The reduction in packing volume will enable ~32 Nav-Sondes to be stored in a screw-drive mechanism which is less than 1m in length and <1kg.









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Met Study – Conclusions

1. **Disparity:** 100% error in forecasted wind speeds over layers exceeding 3-kft is typical in the lower stratosphere.
2. **Improvement:** Fine resolution mesoscale model with additional observation data ingestion. Forecast accuracy enhancement is most visible in the upper levels and particularly on wind shear. It significantly improves following the assimilation of dropsonde data.
3. **Nav-Sonde:** optimisation study of a new variant of micro-dropsonde, even lower-cost lighter-weight, designed to target 30kft below HAB/HAPS platform.

For example: Balloons cannot station keep according to forecast data.

Study achieved proof of concept benefit through assimilation of dropsonde data, quantity and intensity of dropsondes insufficient to fully characterise potential of this technology in this study alone.

Having data available “organically” to HAB and HAPS will provide:

- more efficient navigation
- greater operating safety margins
- lower operation costs
- higher service availability

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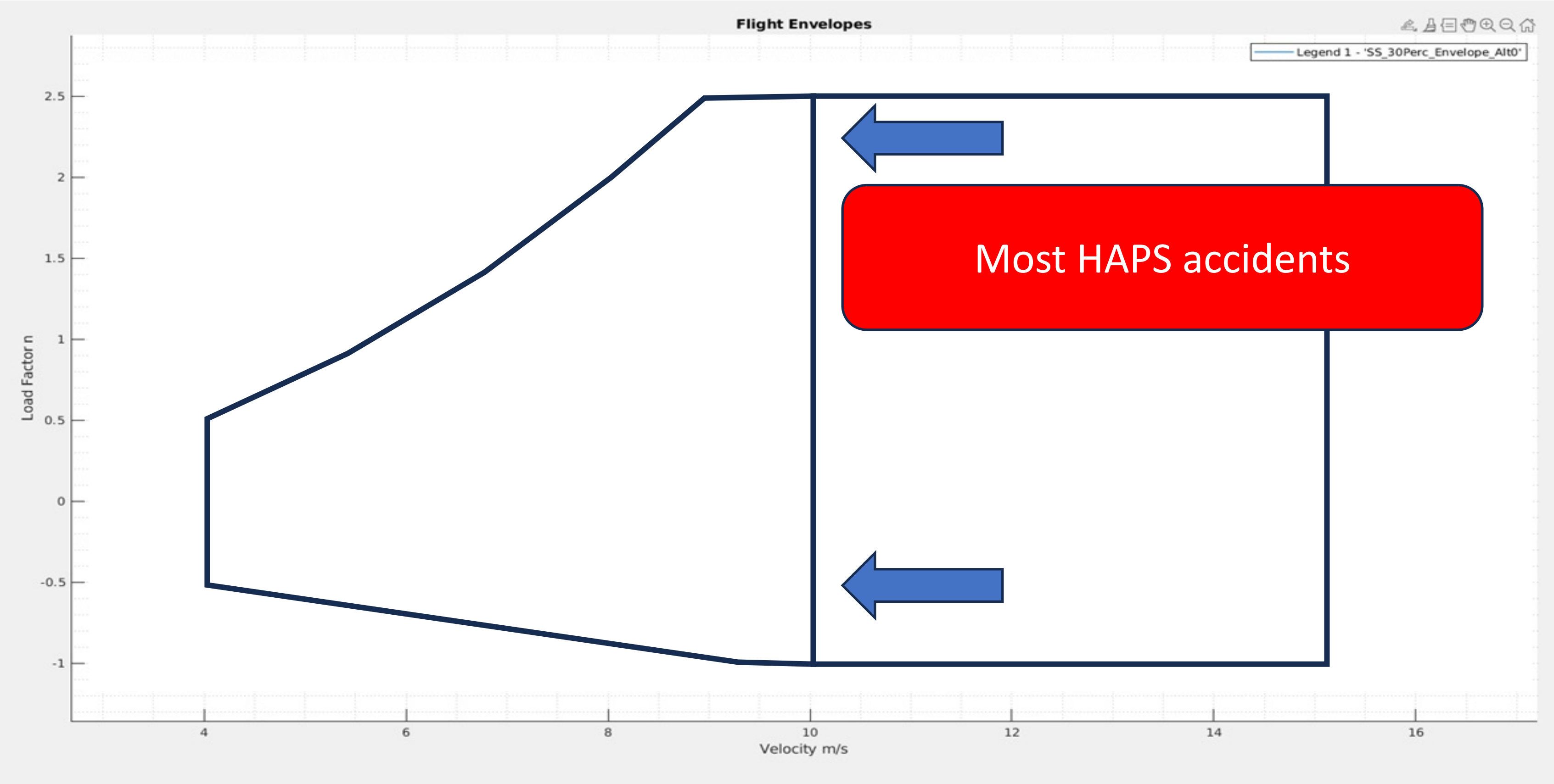
Operating Envelope Expansion



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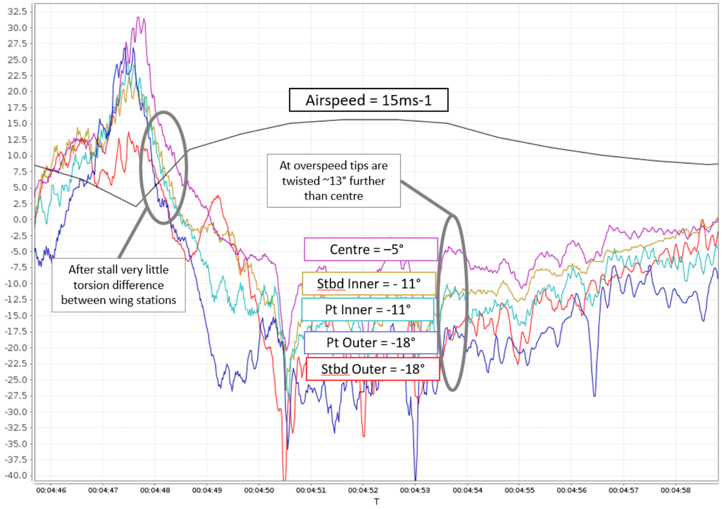
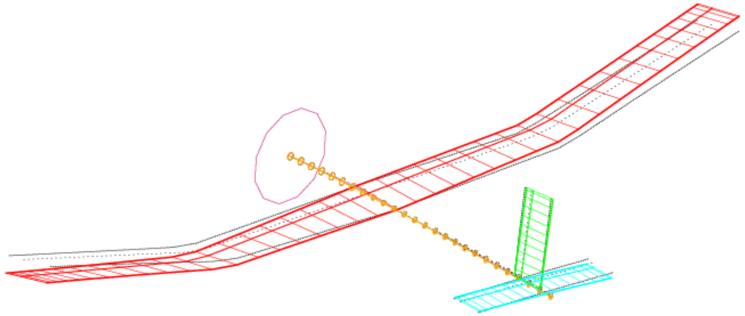
Operating Envelope Expansion – Validation





t = 0.596 s frame 201

- Cannot re-create gusts in flight
- Can use controlled excursion such as flutter to validate torsional and bending response

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Unlocking the Stratosphere®

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