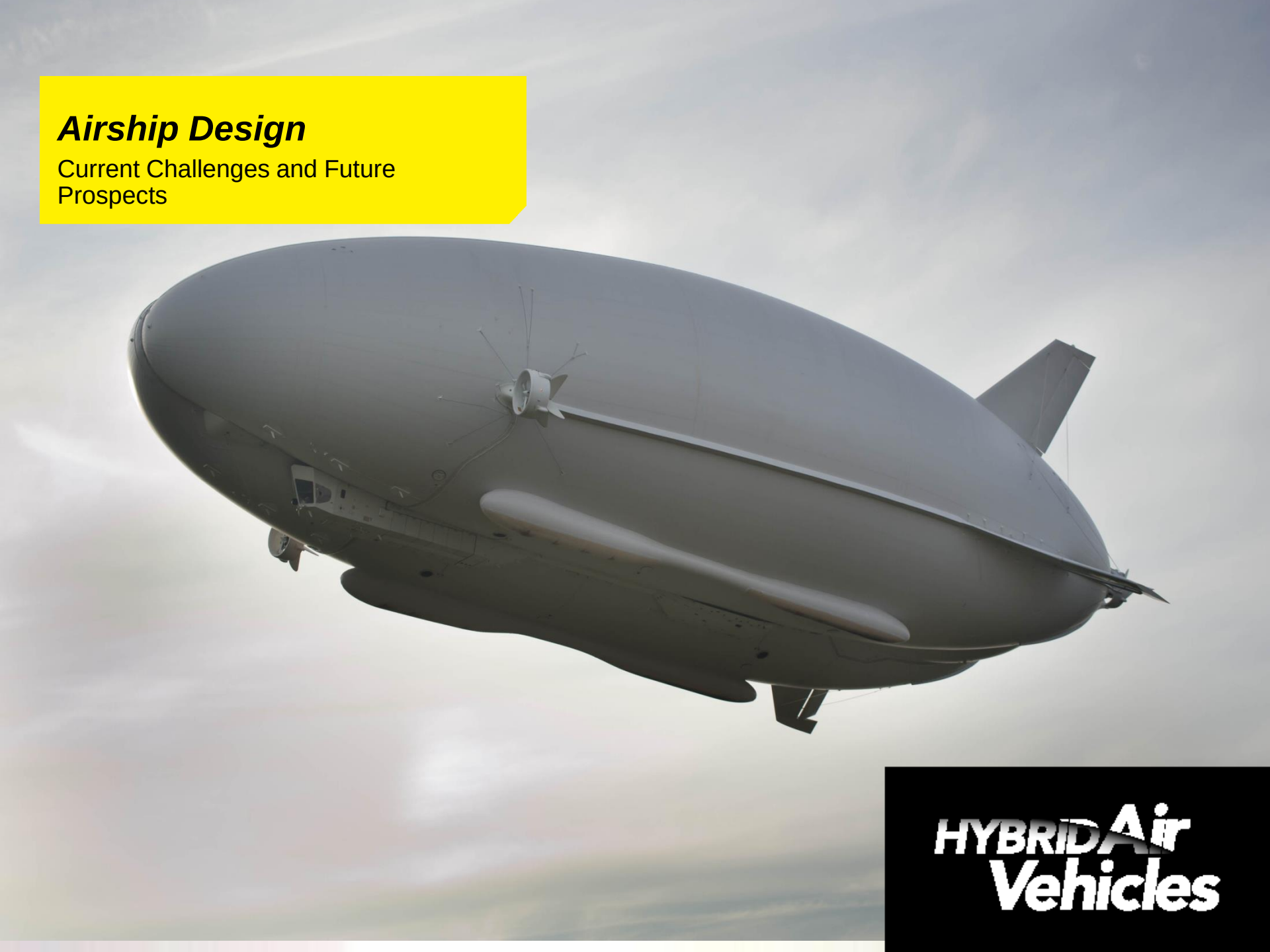
Airship Design

Current Challenges and Future Prospects



HYBRID Air Vehicles

Agenda

- Airship Basics
- Airships Through the Ages
- History of Hybrid Air Vehicles
- Development of the hybrid air vehicle concept
- Market Opportunities
- Design considerations of hybrid air vehicles
  - Aerodynamics
  - Stress
  - Propulsion
  - Avionics
  - Materials
  - Landing Systems
  - Ground Handling
- The LEMV Programme
- The Future

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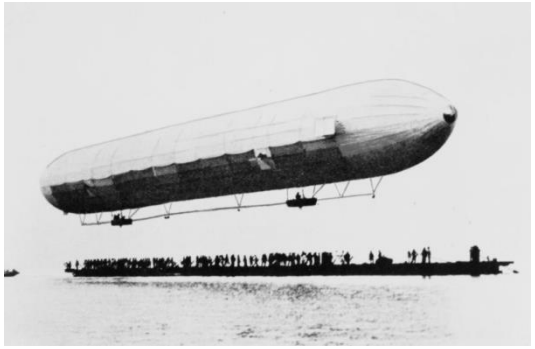
HYBRID Air Vehicles

Airship Basics

- Heaviness = Total Mass (Including Gas Mass) – Displaced Mass
- If Total Mass > Displaced Mass then the vehicle is ‘Heavy’
- If Total Mass < Displaced Mass then the vehicle is ‘Light’
- If Total Mass = Displaced Mass then the vehicle is at equilibrium, or ‘EQ’

- Airships can be rigid, semi-rigid, or non-rigid
- Non-rigid airships are pressure stabilised and use air filled bags called ballonets to maintain a constant hull pressure
- As the airship ascends, the helium expands and forces the air out maintaining pressure and likewise as the airship descends, the helium contracts and air is forced into the ballonets
- Once the ballonet is empty the airship has reached the pressure ceiling and to go any higher would require helium to be vented to prevent over-pressurising the hull
- Semi-rigids contain some structure but are pressure stabilised
- Rigids have a metal framework that makes up the hull and the lifting gas is contained in large gas bags

Airships Through the Ages



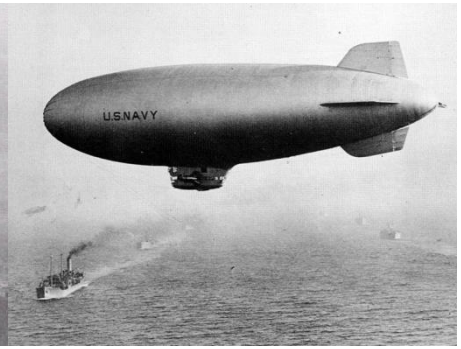
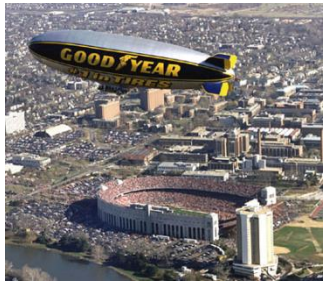


Photo # 80-G-441983 USS Macon recovering two F9C aircraft



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Hybrid Air Vehicles History

HAV are the world leaders in lighter-than-air (LTA) technology

- Over 30 years experience working on a number of programmes
  - Skyship series of airships (as seen in James Bond!!)
  - S1000 airship for the US Navy
  - AT-10 airship
  - Consultants to Lockheed Martin on Aerocraft programme
  - Partnered Boeing on Stratsat programme
  - Designed Skycat 20 vehicle (first hybrid air vehicle)
  - Partnered Northrop Grumman on LEMV programme
  - Currently designing the Airlander series of vehicles

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Development of the hybrid air vehicle

Experience and design iterations has led to the development of the hybrid air vehicle

- Hybrid air vehicles combine aerostatic lift (buoyancy) with a lifting body shape to produce aerodynamic lift
- This allows the vehicle to take-off and fly heavier than conventional airships
- Vectored thrust allows the hybrid air vehicle to fly and land lighter than conventional airships
- This results in longer endurance, economic and ‘green’ transportation and greater safety
- Vectored thrust allows precision hover and V/STOL
- Ducted propellers improve efficiency at low speed and the rear engines operate in the wake of the vehicle increasing the thrust and efficiency

Circa $500m has been invested in the technology and HAV has complete IP ownership

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HYBRID Air Vehicles

Market Opportunities

What are the capabilities of airships and hybrid air vehicles?

- **Long endurance**
- **Long range**
- **Ability to operate in areas with little or no infrastructure**
- **Low speed**
- **Stable**
- **The bigger the better**

What markets would benefit?

- **Surveillance**
  - Geo surveying
  - ISR (Intelligence, Surveillance and Reconnaissance)
- **Cargo transport**
  - Equipment
  - Mining support
  - Oil and gas support
  - Humanitarian aid
- **Search and rescue**
- **Coastal Patrol**
- **Advertising and filming**

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HYBRID Air Vehicles

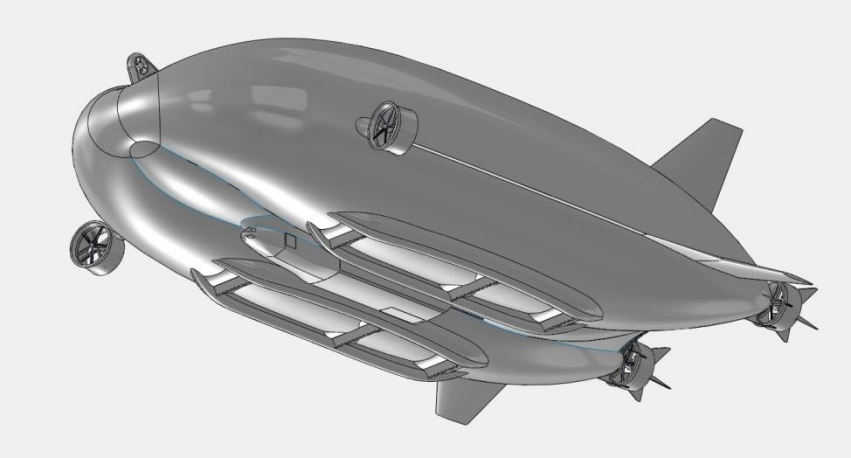
Hybrid Air Vehicles Portfolio

HAV currently offer two vehicle types:

The long endurance surveillance HAV304

Length: 93m
Volume: 38,500m³
Speed: 80kt
Payload: 1,000kg

The heavy lift (50 tonnes payload) Airlander 50



Length: 120m
Volume: 103,000m³
Speed: 105kt
Payload: 50,000kg

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Aerodynamics

Hybrid air vehicles utilise a cambered hull to generate aerodynamic lift

- Result of a number of wind tunnel tests and sub-scale flying

Bi-lobe or tri-lobe hull design

- Helps improve induced drag characteristics and improves stability

Aerodynamic devices

- Devices such as the Leading-Edge Root Extension (LERX) and the strakes help reduce induced drag

Wake Effect

- The rear engines sit in the wake of the main hull and this been shown to increase the thrust and therefore improve efficiency

Loads Estimation

- A combination of theory, wind tunnel and flight tests allow prediction of aerodynamic loads to be provided to the Stress Department

Stress

Finite Element Analysis is conducted on all major components

Load Cases

- Working internal pressure loading
- External aerodynamic loading
- Flight manoeuvre cases
- Flight gust cases

Structural Response to engine vibration

- Obtain data from accelerometers and strain gauges positioned around engine test rig
- Post-process data to predict vibration transmissibility and identify items that are vibration sensitive
- Ensure there is sufficient margin on resonant frequencies

Flutter and Aeroelastic Stability

- The fundamental resonant frequency of a rigid control surface is calculated using the surface's mass and hinge moment data

Propulsion

Thrust vectoring

- Due to aerostatic lift, hybrid air vehicles can fly very slowly
- Conventional control surfaces only work at airspeeds above 25kts
- Either vectoring the propeller itself or the thrust it produces allows low speed control

Vectored thrust also allows the hybrid air vehicle to land light

- The vehicle can be powered down onto the ground before ballast is added

Ducted or open propeller

- A ducted propeller provides efficiency improvements at lower speed, however at higher speeds the drag of the duct outweighs the efficiency improvements

Bow Thruster

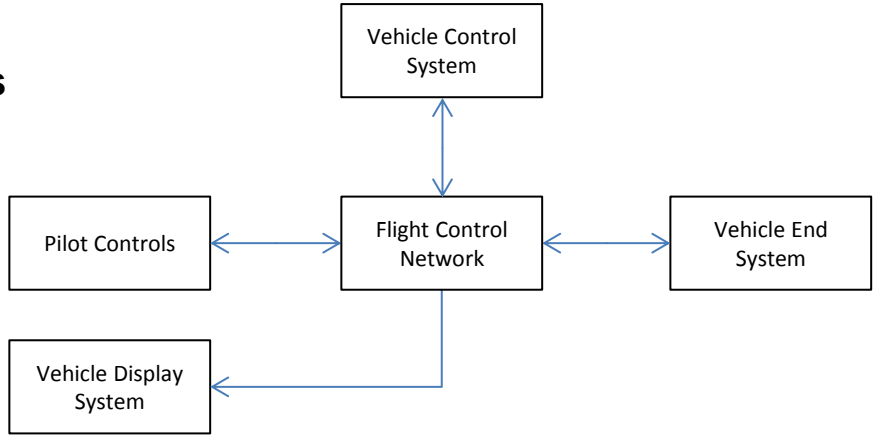
- A Fenestron style fan for yawing the vehicle during low speed flight or ground taxi operations

Avionics

Smaller airships still tend to use wires and pulleys to affect control surfaces and trim of the vehicle

Most larger and modern airships and hybrid air vehicles use fly by wire or light controls

A generic system schematic could look like this



- The Flight Control Network (FCN) passes information around the vehicle
- The Vehicle Control System (VCS) houses the control algorithms (intelligence)
  - Allows the vehicle to operate in direct link, augmentation or auto-pilot modes
- Vehicle Display System (VDS) displays relevant vehicle status to the pilots
- Pilot Controls require careful consideration to prevent excessive pilot workload

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HYBRID Air Vehicles

Materials

Weight is critical to airships – probably more so than fixed-wing aircraft

- Selection of lightweight materials is critical
- The majority of the structure is carbon fibre

Non-rigid airship hulls are made from strips of material that are joined together

- The material and seams must be gas tight, weatherproof and provide the hoop and longitudinal tensions required

Modern hull fabrics are made from layers of different fabrics

- Vectran for strength
- Mylar for gas impermeability
- Tedlar for weatherproofing

Fins often have fabric skins covering a composite structure

Landing Systems

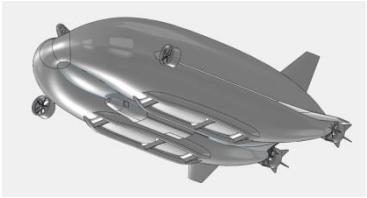
One of the benefits of hybrid air vehicles is that they can land heavy* and therefore need some form of landing system

The appropriate landing system should be selected for the mission

Two examples can be seen on the HAV304 and Airlander 50 vehicles:

- The HAV304 has a skid system which is relatively simple and cost effective
  - The HAV304 is designed as a long endurance surveillance vehicle, it is only intended to be on the ground once every few weeks and will be operating from prepared ground
- The Airlander 50 has a hover skirt system which is more expensive but also more versatile
  - The Airlander 50 is designed as a heavy lift cargo vehicle flying multiple segments every day
  - The Airlander 50 is designed to operate in austere environments with little infrastructure
  - The hover skirt system allows the Airlander 50 to operate just like a hovercraft over land, snow, ice and water water

*For definition of ‘heavy’, see slide 3



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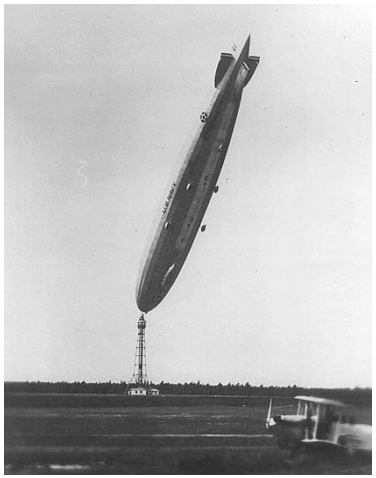
HYBRID Air Vehicles

Ground Handling



Traditional airships require large numbers of ground crew

Hybrid air vehicles require far less ground crew

- They land like conventional aircraft when heavy
- They can power themselves onto the ground when light

Consideration needs to be paid to ground support equipment

How will the vehicle be moored?

- High mast — Permanent Mast — Emergency Mast
- Low mast — Mobile Mast — Ballast Carriage

How is cargo to be loaded and unloaded?

- Winches — How to secure the vehicle
- Ramps

Although both traditional and hybrid air vehicles spend most of their lives outside, large hangars are needed for construction and maintenance

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HYBRID Air Vehicles

The Future

HAV has purchased the HAV304 used in the LEMV programme and is returning the vehicle to the UK to complete the flight test campaign.

There are two main areas where hybrid air vehicles can perform like no others:

- Long endurance high-resolution surveillance
- Cargo transport to areas with little or no infrastructure

HAV has developed the HAV304 and Airlander 50 vehicles to meet these needs.

HAV has successfully flown the first full-scale hybrid air vehicle.

The Airlander 50 will carry 50 tonnes of equipment with minimal environmental impact and significantly lower running costs than any other equivalent form of transport. Some of the leading mining companies globally have scoped out specific projects and indicated likely future budgets and order books. The development of this aircraft will springboard HAV to develop a 200 tonne aircraft type.

HAV passionately believe that these new aircraft provide a revolutionary sustainable air transport solution.

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