Lockheed Martin Lighter-Than-Air Programs

Keck Institute for Space Studies
JPL / Caltech Airship Workshop
30 April – 3 May 2013

Aerostats

Hybrid Airships

Stratospheric Airships

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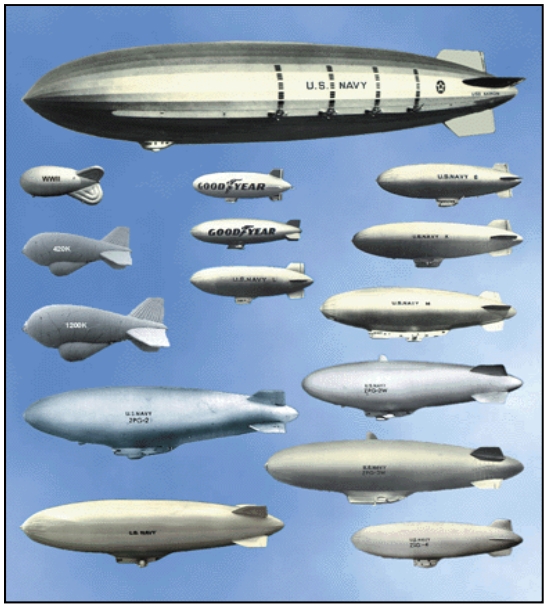
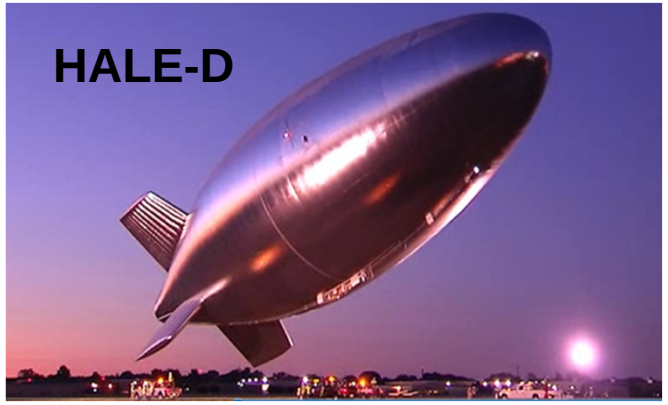
Lockheed Martin
Lighter-Than-Air Technologies

Program Role: Prime Contractor, System Developer and Integrator





Lighter-Than-Air Systems Center of Excellence

Designing and Building LTA Systems for more than 80 years

Lockheed Martin Aerostat Products

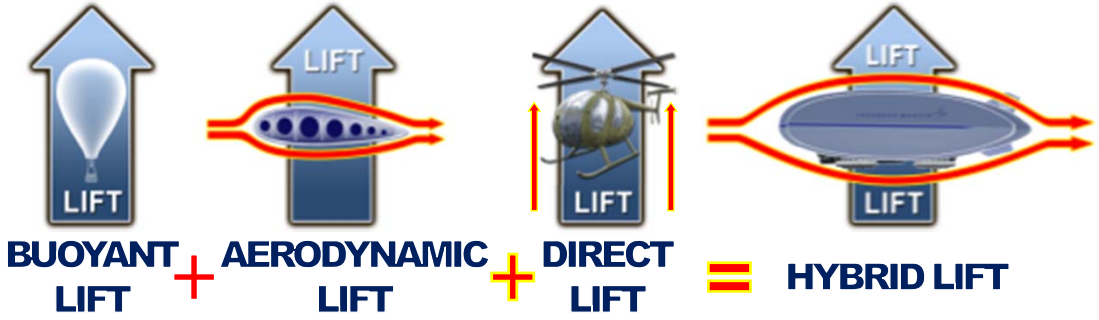
74K Aerostat System

- Customer: US Army
- 74,000 cubic feet volume
- Operating at 5,000 ft
- Endurance: > 30 days
- Payload capability: > 1,100 lbs
- Payload power: 5 kW
- Multiple 74K-based systems (Persistent Threat Detection Systems - PTDS) used in Iraq and Afghanistan

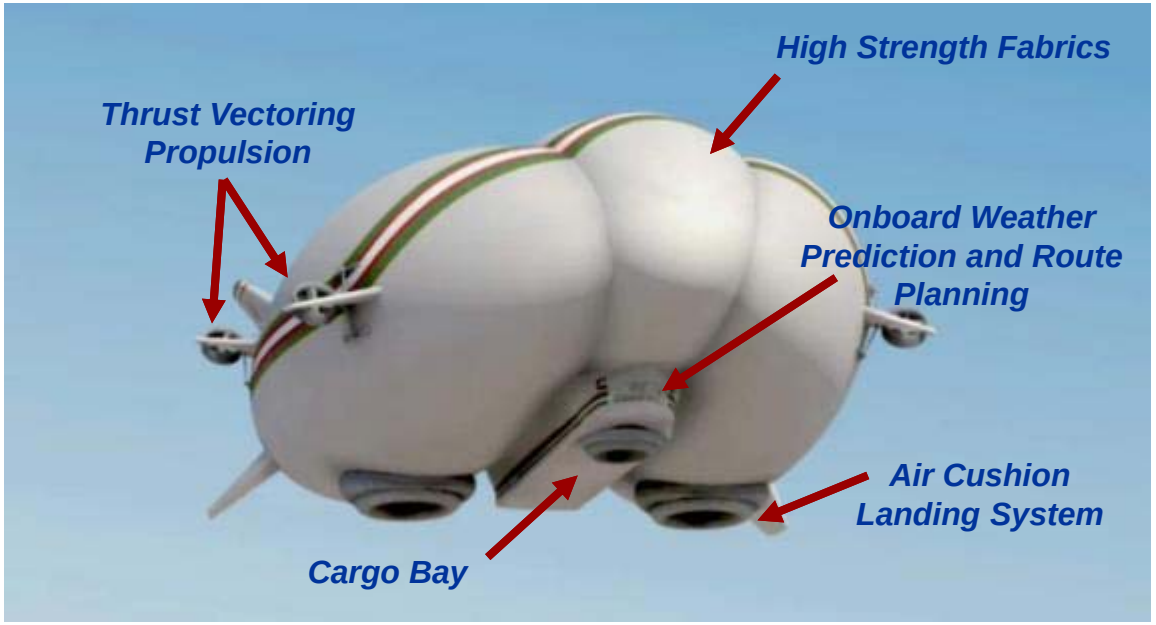
420K Aerostat System

- Customer: USAF
- 420,000 cubic feet volume
- Operating at 15,000 ft
- Endurance: > 30 days
- Payload capability: > 2,000 lbs
- Payload power: > 8 kW
- Multiple systems (Tethered Aerostat Radar Systems – TARS) used along the Southern border

Lockheed Martin Hybrid Airships
The Technology



- 80% Lift From Buoyancy
- 20% Lift From Aerodynamics or Direct Lift

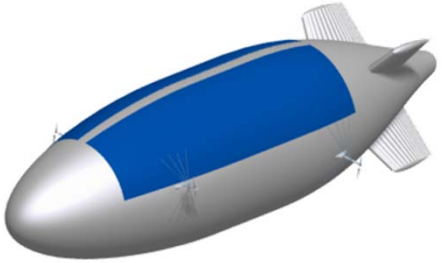


Benefits

- Large Payloads
- Large Cargo Volumes
- Takes Off and Lands On Unimproved Surfaces, Water
- Overflies Trouble Areas
- Decreased Fuel Consumption
- Little or No Forward Infrastructure
- Piloted (or Unmanned for Security and Sovereignty Operations)
- Remote Access With Connectivity to Modern Cargo Networks
- Humanitarian Operations

New and Efficient Hybrid Aircraft – Revolutionary Cargo Transport

Summary of Lockheed Martin Stratospheric Airship Programs

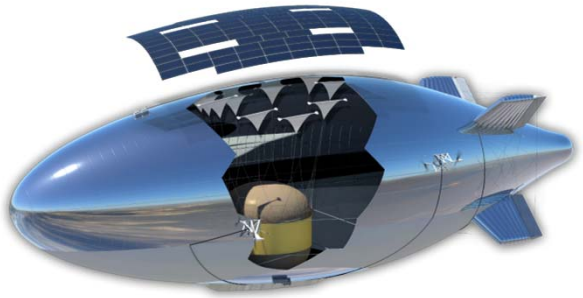


High Altitude Airship (HAA™)

- Customer: MDA / SMDC
- Stratospheric LTA Platform
- Operating at 65,000 ft
- Endurance: months
- Multi-payload, multi-mission platform
- Re-usable, re-taskable
- Solar-based regenerative power system

Demo System (HALE-D)

- Length: 240 ft; Diameter: 70 ft
- Volume: 500,000 ft^3
- Demo duration goal: 5 days
- 80 lb payload (comms & camera)
- Flight tested in July 2011



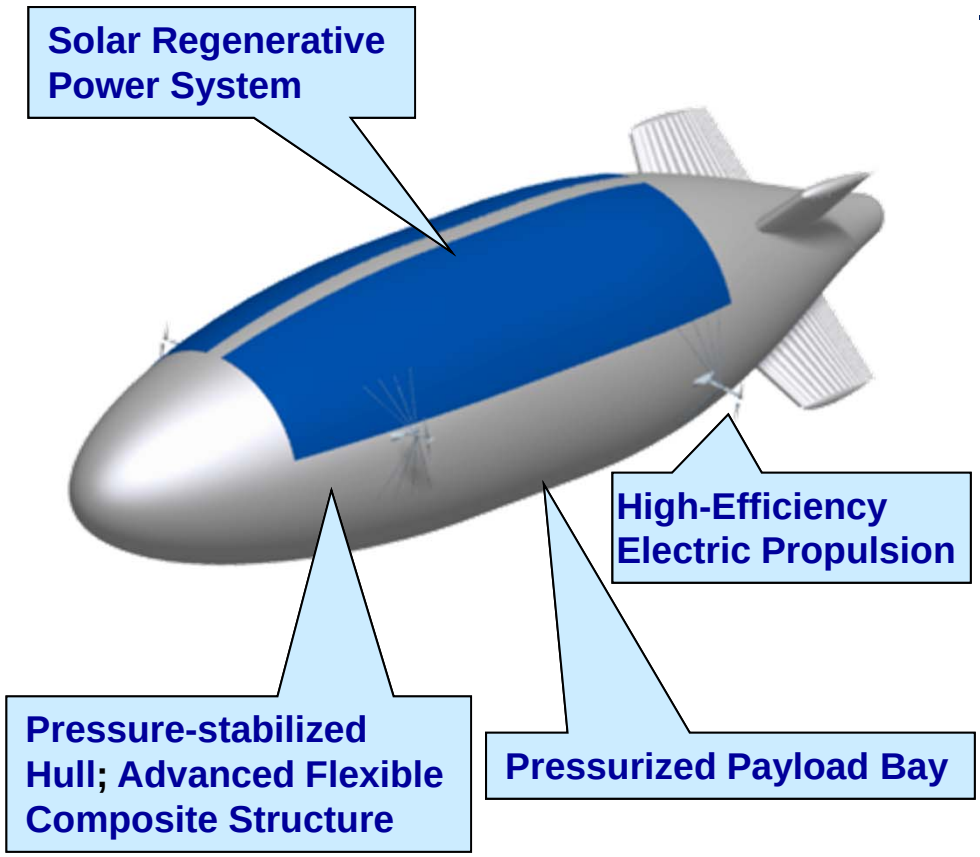
ISIS Operational System

- Customer: DARPA & USAF
- Dual-Band (UHF-/X-Band) MTI radar, 2600 kg payload
- Operating at 65,000 ft
- Operational system duration: up to 10 yrs
- One-launch concept / no recovery
- Solar & regenerative fuel cell power

ISIS Demo System Characteristics

- Length: 510 ft; Diameter: 160 ft
- Volume: 5,800,000 ft^3
- Demo duration goal: 1 year
- 1200 kg payload (radar)
- In development

High Altitude Airship (HAA™)

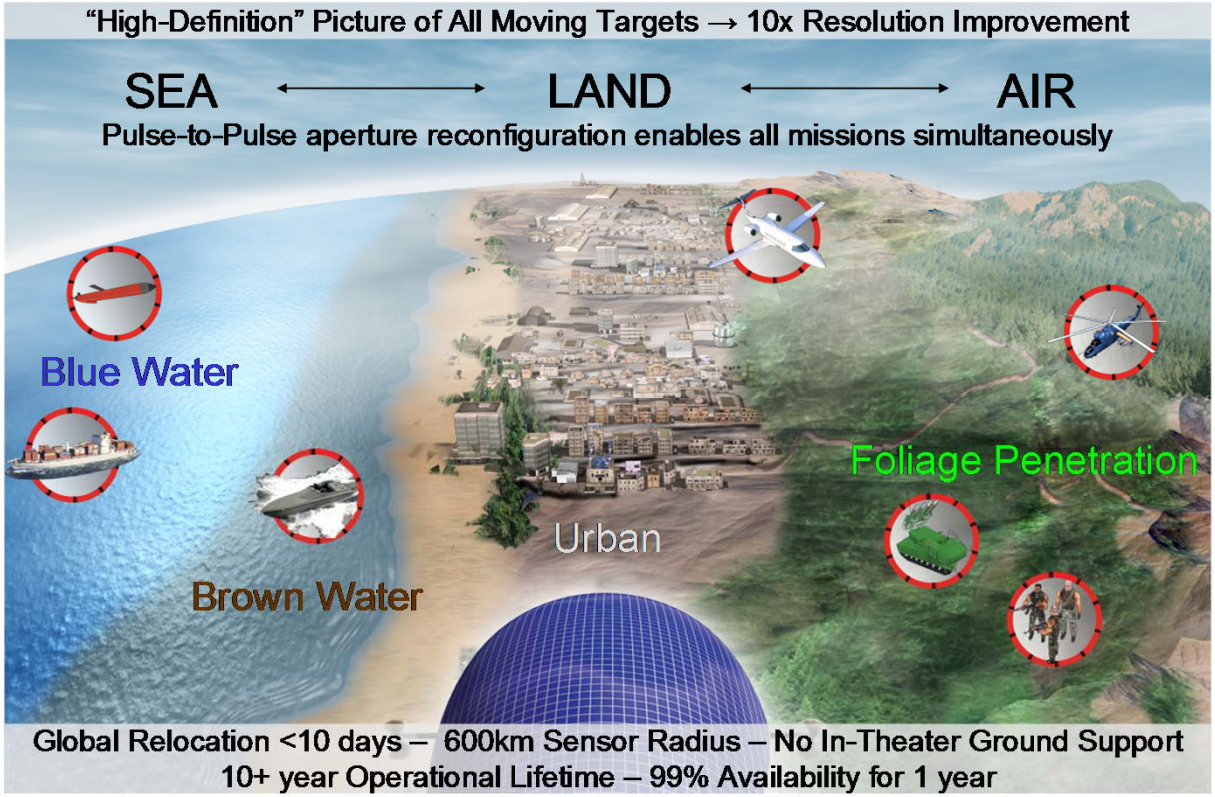


HAA™ OPERATIONAL SYSTEM

- *Extremely long endurance (months) at 65 kft altitude*
- *Multi-payload / Multi-mission*
  - *2000+ lbs payload weight*
  - *10+ kW payload power*
- *Global Operations*
- *Recoverable / Re-taskable*
- *No in-theater logistics*
- *Lowest lifetime cost for long-endurance missions*
- *Easy payload integration*
- *Can host payloads in multiple locations*

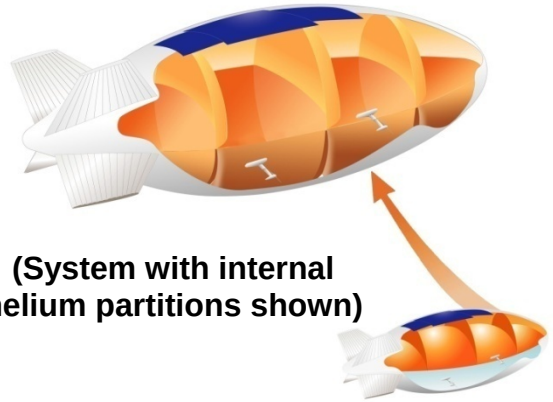
VERSATILE, AFFORDABLE PERSISTENCE IN LOWER STRATOSPHERE

ISIS Redefines Persistent Surveillance

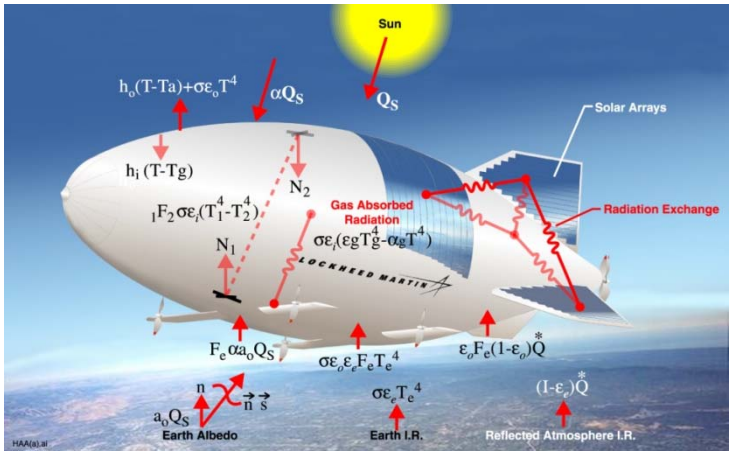


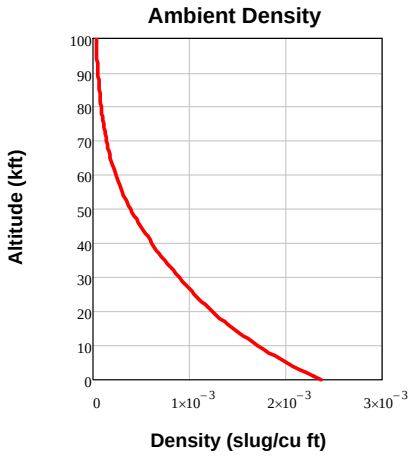
- 100% Solar & Regenerative Power
- Materials Technology Enables Up to 10 Years of Airborne Operations
- No Forward Logistical Footprint; Dramatically Reduced O&S Costs
- Transformational UHF- / X-Band Single Aperture Radar

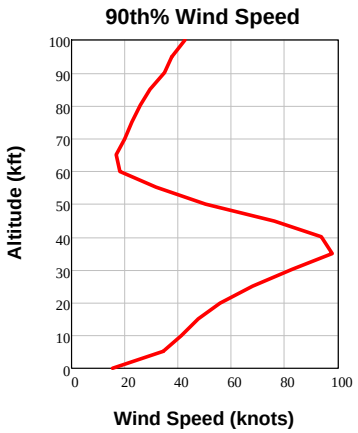
Stratospheric Airship Basics

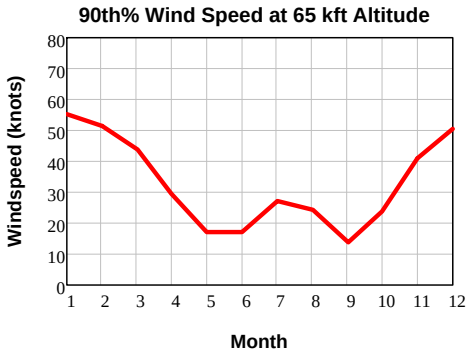


(System with internal helium partitions shown)





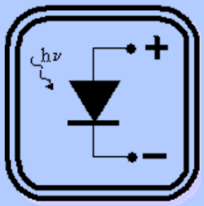




- **Stratospheric airships do not need to spend any energy to float at their design altitude; they only need to counter the prevailing winds**
- **60-70 kft altitude is the “sweet spot” for stratospheric airships**

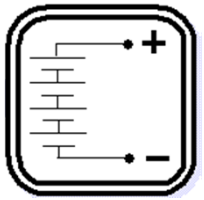
Stratospheric Airship Technology Enablers

- Airship materials (“fabrics”) and the power system account for ~80% of the weight of the airship system
- Advances in materials and power system technologies result in smaller, more capable stratospheric airships



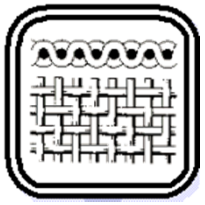
Solar Cells

Develop low-cost, high-efficiency, low-weight solar cell technology suitable for the stratospheric environment.



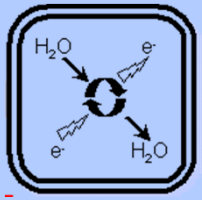
Rechargeable Batteries

2x increase in specific energy (Wh/kg) over current state-of-the-art rechargeable battery technology.



Hull Materials

Develop higher strength-to-weight materials with improved thermal properties, tolerant of long-term operation in the stratospheric environment.



Regenerative Fuel Cells

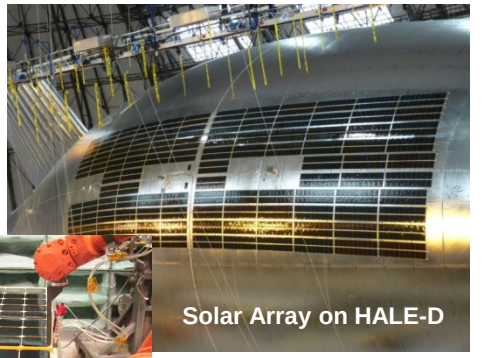
Develop highly efficient closed-loop regenerative fuel cell systems suitable for long-term operation and very high specific energy.

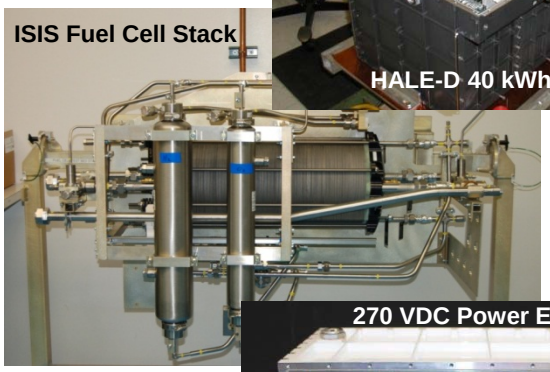
Lockheed Martin Power Systems for Stratospheric Airships

Lockheed Martin's extensive experience in the design, development and operation of Spacecraft power systems enabled the design of reliable power systems for long endurance/high altitude airships with emphasis on maximum watt-hour/kg

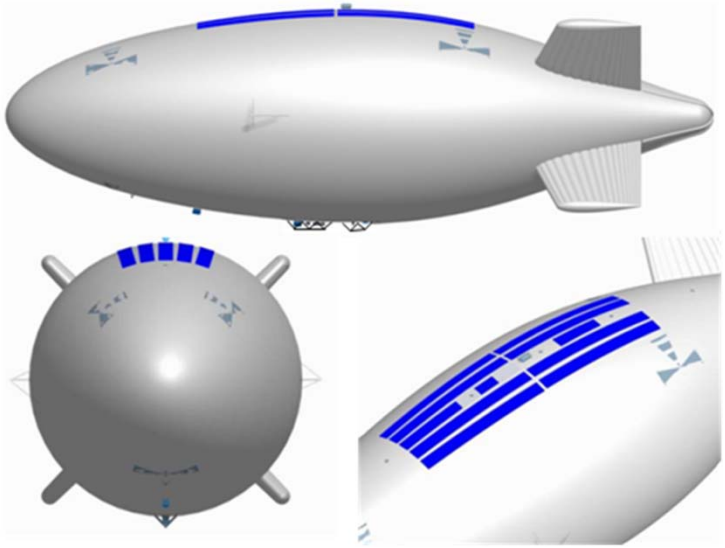
Key technologies completed and demonstrated include:

- **Power Generation**
  - Thin Film Amorphous Silicon Cell Solar Array developed and flown on HALE-D airship. 15 kW Growth to 100's kW
  - 200 kW solar currently in build for ISIS airship. High-efficiency crystalline silicon solar array
- **Energy Storage**
  - Developed and flew a very large 40 kWhr lithium ion battery
  - Developed a high-power closed-loop regenerative fuel cell/electrolyzer power system
- **Power Electronics**
  - Developed 270 V high-efficiency electronics to control solar array, power distribution, battery and fuel cell system





High Altitude Long Endurance Demonstrator (HALE-D)



- **Subscale HAA™ Demonstrator**
- **Performance Parameters**
  - **Station-keeping altitude: 60,000 ft**
  - **Payload weight: 80 lbs**
  - **Payload power: 150 Watts**

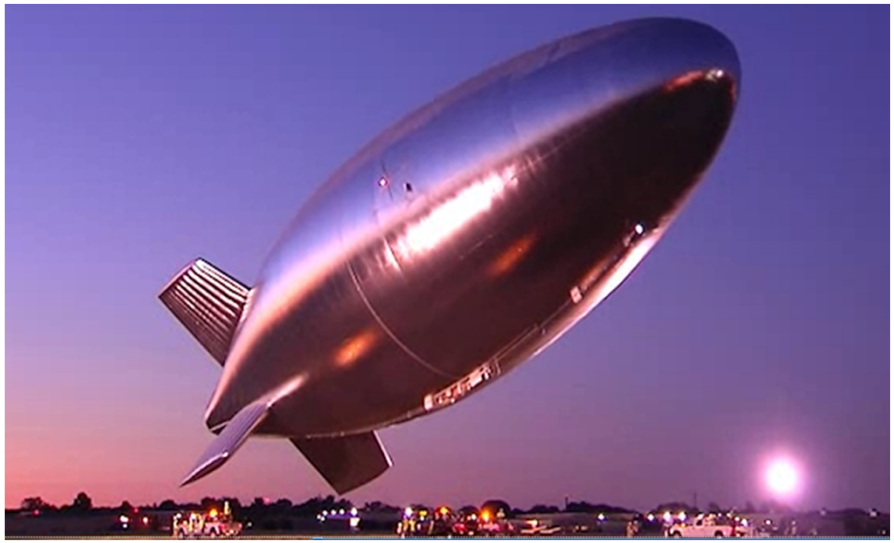
Hull Volume	**500,000 ft³**
Length	**240 ft**
Diameter	**70 ft**
Sea Level Gross Weight	**3000 lbs**
Propulsion Motors	**2 kW Electric**
Energy Storage	**40 kWhr Li-Ion Battery**
Solar Array	**15 kW thin film**
Cruise Speed	**20 ktas @ 60 kft**

HALE-D
Integration and Ground-Level Testing

HALE-D Project and Flight Demo Summary

- **Background**
  - Focus on overall system integration
  - Balanced system capabilities and redundancies with constrained funding

- **Flight Demo Highlights**
  - Flawless launch on 27 July 2011
  - 2.7 hour flight; Max altitude: 32,600 ft
  - C2 and flight termination systems successful in managing descent to remote area
  - Root cause of stalled ascent well understood and fixable



- **Accomplishments**
  - Demonstrated several key technologies
    - Advanced hull materials
    - Solar-based regenerative power system
    - Unique trim system
    - Operational models
  - Demonstrated safe operations of LTA UAS in National Airspace System (NAS)

HAA™ as a Science Platform

HAA™: Benefits as Science Platform

- Persistent, autonomous observations from LTA vehicle in near space (18-20 km altitude – above 90% of atmosphere)
- Multi-mission capabilities for single airship (polar ice, coastal ocean color, trace gas, heliophysics, astrophysics, etc.)
  - Top and bottom instruments for simultaneous Earth/Space viewing
- Fully recoverable, re-taskable asset (airship, payload, comms, etc.)
- Facilitates regionally focused, process-oriented science
- Capable of geostationary observations - high temporal data refresh rate
- Stable, benign-environment in lower stratosphere
- Enables observations with very high spatial resolution (sub-meter)

Low Cost, Reusable, and Accessible Platform for Research, Exploration, and Monitoring of Earth and Space

HAA™ and Earth Science

- Reusable asset enables low-cost geo-like/targeted observations for multiple PI-led missions (e.g. Venture Class)
- Benign launch and operations environment for instrument development and testing (e.g. IIP TRL demonstrations)
- Under fly LEO/GEO spacecraft for validation campaigns
- Over fly ground campaigns providing coincident high temporal and spatial resolution observations for geophysical process studies
- Quick turn-around and launch for multiple missions and payloads
- High spatial resolution with smaller apertures (lower-cost instrument packages)

Stable Geostationary-like Platform Enables Low Cost and Repeatable Access to Critical Earth Observations

HAA™ and Stellar Observations

- **Provide Arc-sec(s) Pointing and Stability for Stellar Instrument Pointing with Existing OTS Components**
  - **Platform Mounted on top of HAA™ vehicle**
  - **Platform Consists of Instrument/Telescope and Associated Attitude Determination and Control Components for Pointing**
    - **Inertial Measurement Unit (IMU)**
    - **Star Tracker**
    - **2-axis or 3-axis gimbals to point instrument**

- **Enhanced Sub-Arcsec Pointing and Stability with Additional Hardware and Interfaces**
  - **Optical Bench Isolated From Disturbances Using Tuneable D-Struts**
  - **More Precise DC-Gimbal Drives for Pointing and Stability**
  - **GPS Receiver for Position and Rate Determination**
  - **Feedback of Stellar Data From Instrument for Sub-ArcsecPointing**
  - **Use of IMU Data to Drive Fine Steering Mirror in Instrument**

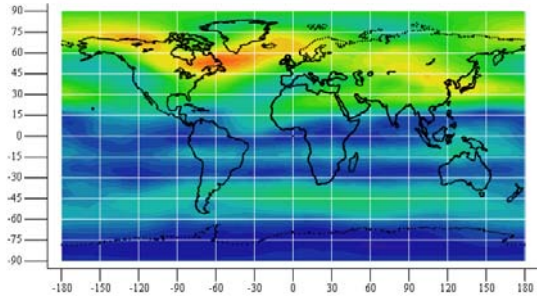
Summary

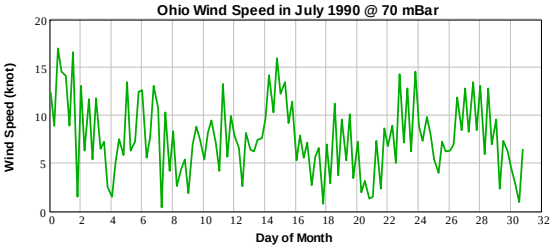
Lockheed Martin LTA systems and relevant experience can enable scientific exploration and experimentation via high altitude platforms

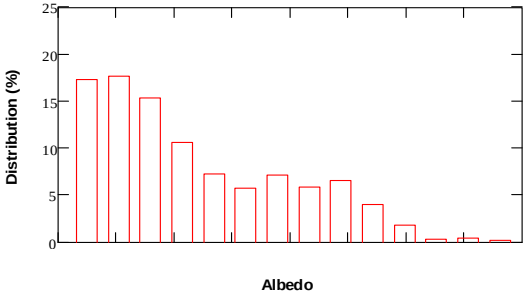
- Enabling technologies already developed and demonstrated on HALE-D and ISIS
- Enables regionally-focused process-oriented Earth science
- Enables Helio- and astrophysical observations above 90% of the atmosphere (no blurring)
- Multi-mission and re-taskable asset

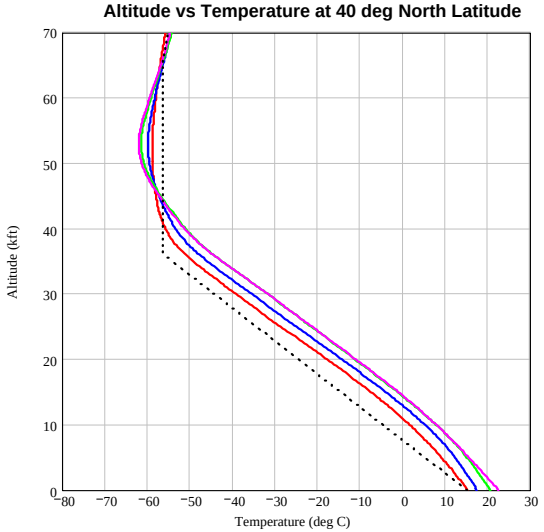

Questions?

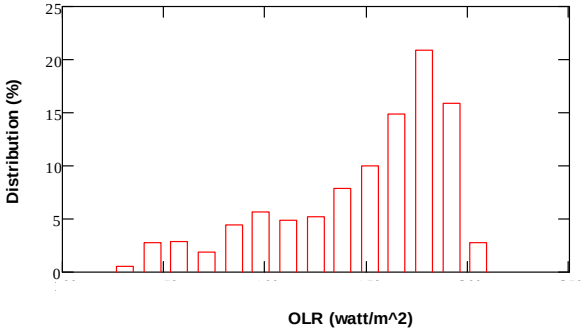
Very Demanding Environment

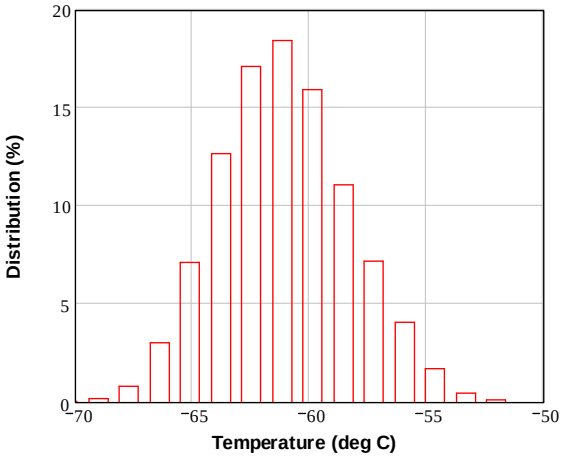


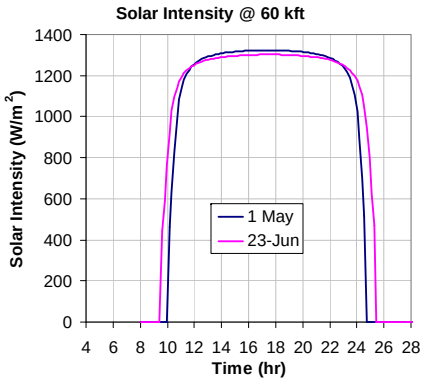








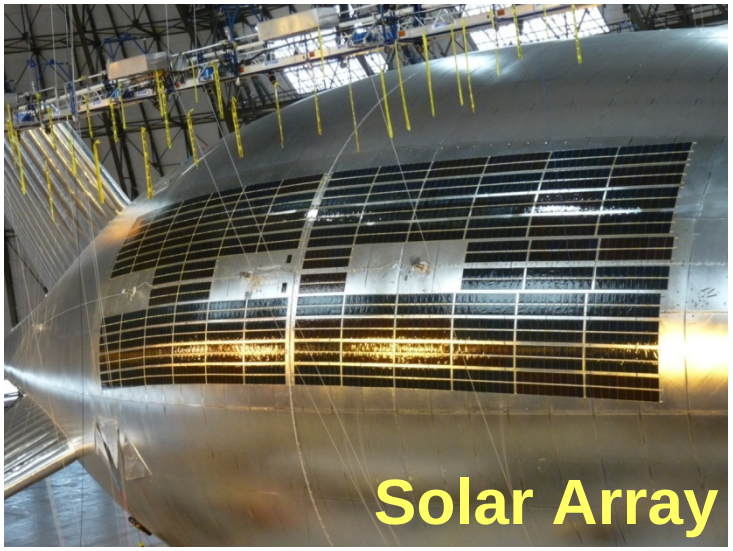




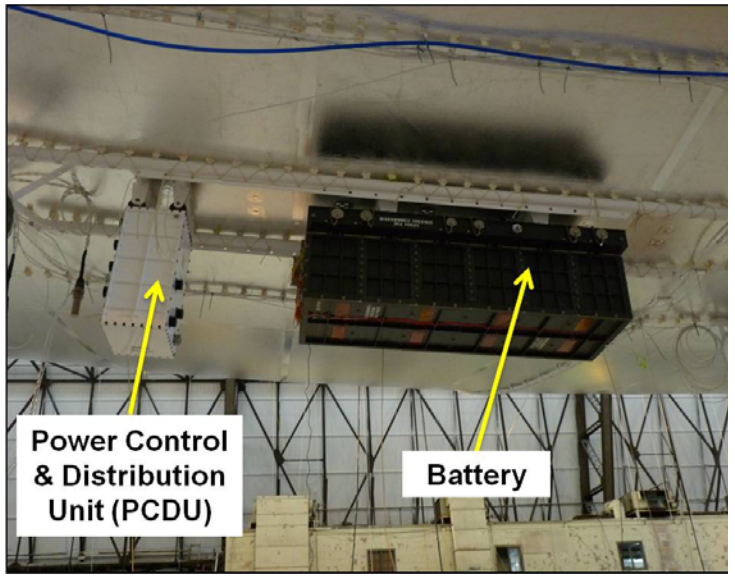
Environmental parameters such as winds, turbulence, atmospheric temperature, ozone, neutron flux, UV radiation, outgoing long-wave radiation, albedo, atmospheric electrodynamics, etc., need to be understood and accounted for in the design of a high altitude lighter-than-air platform

HALE-D Power System

- Lightweight / thin-film amorphous silicon photovoltaic (PV) cells
  - Twice the power density of conventional satellite solar arrays
  - First airborne use of flexible substrate cells



- Largest single Lithium Ion battery (270 V) on an aerial platform
  - Hundreds of cells integrated into one housing
  - State of the art energy density is ~30% higher than previous lithium ion cells



HAA™ Can Augment NASA Near-Space Programs

Platform	Duration	Payload Accommodation	Station Keeping	Altitude
Sounding Rockets	5 – 20 minutes	1,000 lbs	N/A	280 km
Aircraft (ER-2)	6 hours	2,600 lbs	N/A	65 kft
UAV (Global Hawk)	31 hours	1,500 lbs	N/A	65 kft
Balloons	•1-2 days (conventional) •3 weeks (long-duration) •100 days (ultra-long duration)	Up to 8,000 lbs	N/A	100 kft
HAA™	• >30 days (Prototype) • > 6 months (Operational)	500+ lbs (Prototype) 2,000+ lbs (Operational)	< 2km Radius	65 kft

HAA™ Enhances Suborbital Fleet with Long Duration, Station Keeping, and Multi-Mission Capabilities