Lockheed Martin - HALE-D

Peter Lobner, updated 16 June 2023

1. Introduction

The High-Altitude Long-Endurance Demonstrator (HALE-D) was a science and technology development effort that was part of the Army's High Altitude Airship (HAA) Advanced Concept Technology Demonstration (ACTD) program, which also included the HiSentinel family of airships. The long-term goal of the HAA program was to develop the full-scale HAA.

The ACTD program was focused on the developing the following key technologies for a high-altitude airship:

- Material suitability, primarily high-strength, light-weight fabrics for hull construction
- Fabrication methods
- Power systems, including thin-film solar arrays and a regenerative power supply (batteries)
- Aerodynamics
- Propulsion, focusing on lightweight units for station-keeping at high altitude
- Flight controls, including a remote piloting data link
- Thermal management over widely varying day / night environmental conditions at high altitude
- Gas pressure management
- Systems integration

HALE-D was initiated in FY2003 by the Missile Defense Agency (MDA) with plans to build a prototype and a subsequent full-scale airship. In FY2005, the program scope was reduced to develop just a single prototype. The Army's Space and Missile Defense Command (SMDC) took over funding in FY2008. Lockheed Martin was the prime contractor.

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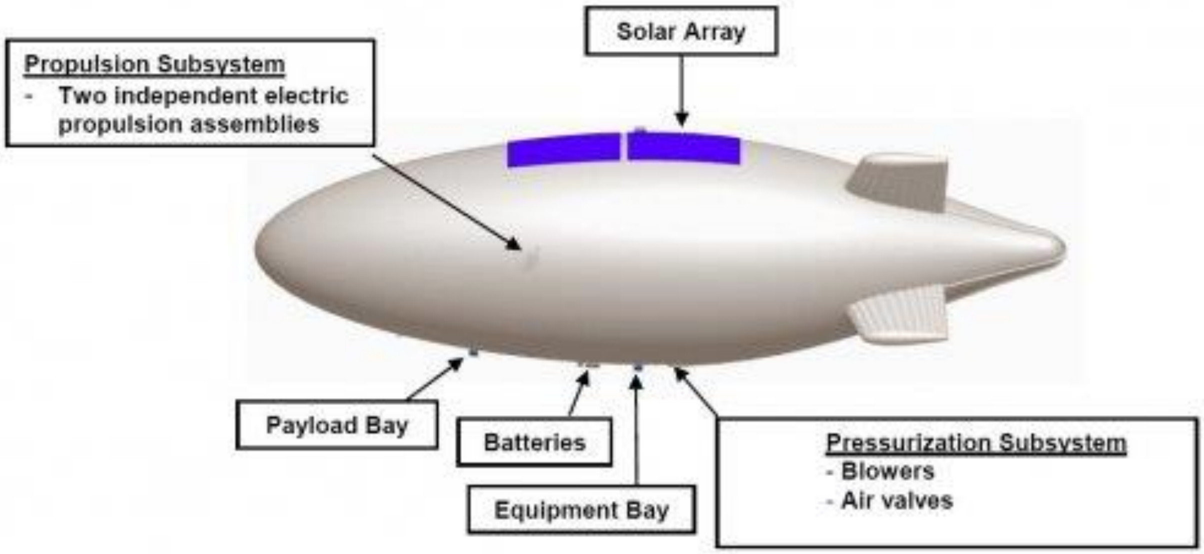
2. The HALE-D airship



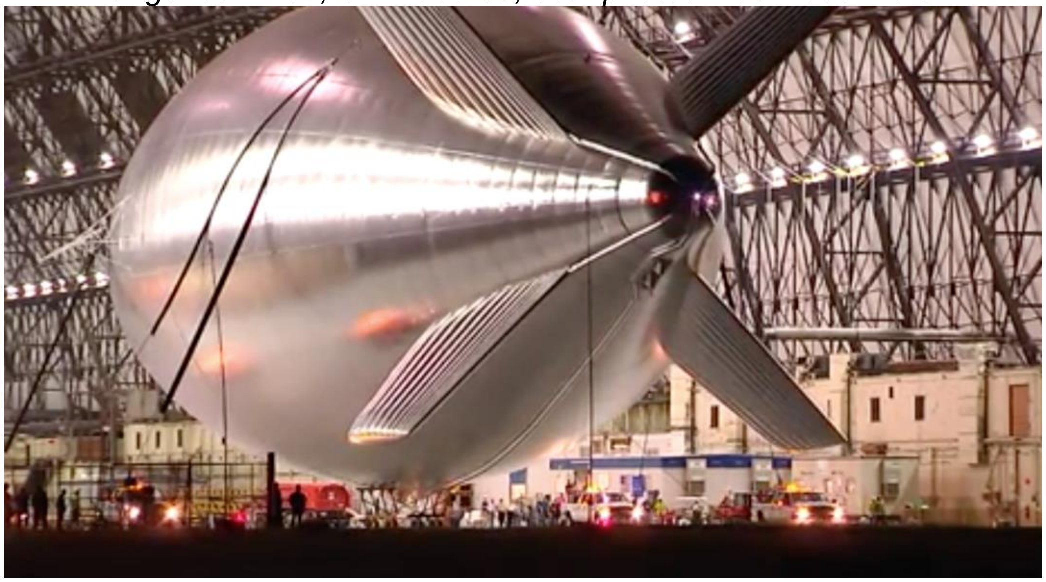
HALE-D airship general arrangement. Source: Lockheed Martin

General characteristics of the HALE-D airship

Parameter	**HALE-D**
Length	240 feet (73.1 m)
Diameter	70 feet (21.3 m) at the widest point
Volume	500,000 ft^3 (14,158 m^3)
Hull material	Metallized, flexible, fabric laminate hull material with an extremely high strength-to-weight ratio
Airship mass	3,800 lb (1,724 kg)
Maximum altitude	60,0000 feet (11.4 miles, 18.3 km)
Electric power system	• 40 kW-hr, 270 volt lithium ion batteries supplemented by a 15 kW lightweight, thin-film, amorphous silicon photovoltaic array on the top of the gas envelope • First airborne use of flexible substrate solar cells
Propulsion	Two flank-mounted electric motor-driven propellers attached directly to the non-rigid gas envelope, 2 kW propulsion power
Speed	18 knots cruise; 26 knots maximum
Control	Autonomous or remote control
Payload	High-resolution camera system & communications equipment
Payload weight	About 80 lbs (36 kg)
Payload power	150 watts, continuous
Mission duration	2 to 3 weeks

The non-rigid, pressure-stabilized hull was made of metallized, flexible, fabric laminate material. This reflective skin reduced solar energy absorption, thereby enhancing the thermal management of the airship. This type of hull material is addressed in Lockheed Martin patent US2009/0042037A1, "Metalized flexible laminate material for lighter-than-air vehicles," which was filed on 20 September 2006 and granted on 3 September 2013.

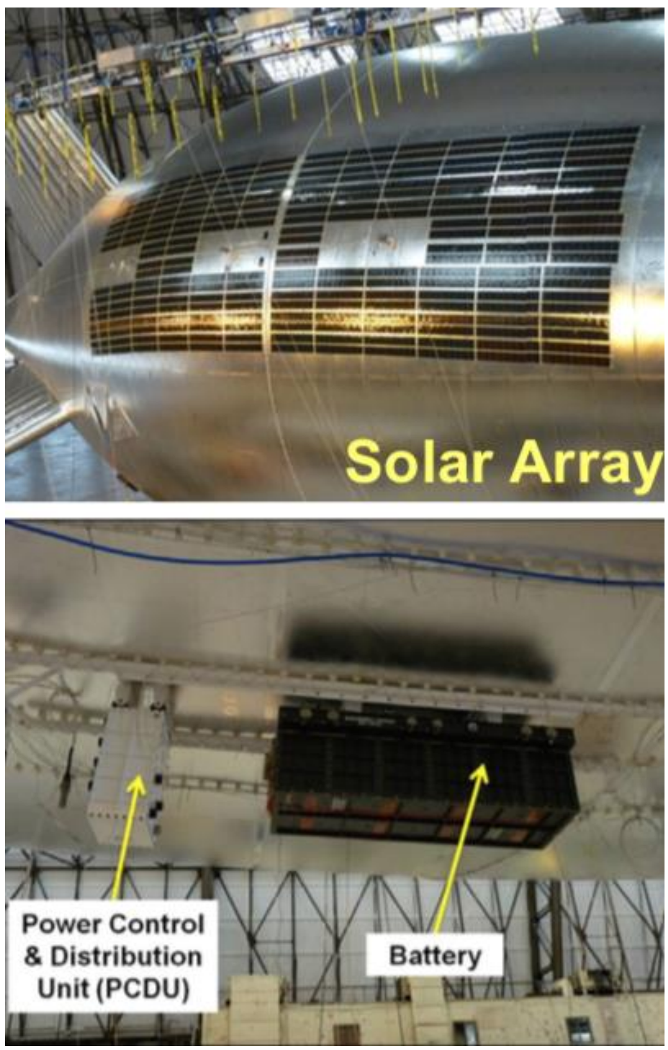
Bow view of the HALE-D in the Lockheed Martin Airdock hanger at Akron, OH. Source, both photos: Lockheed Martin



Stern view of the HALE-D in the Airdock hanger.

The propulsion system is comprised of two flank-mounted, electric motor-driven propellers attached directly by the non-rigid hull. This type of propulsion system installation is addressed in Lockheed Martin patent US7448572B2, "Direct mounted propulsion for non-rigid airships," which was filed on 5 October 2005 and granted on 11 November 2008.

HALE-D carried the same payload package as used on SMDC's other HAA program, the HiSentinel 80. This payload package included an ITT high-resolution electro-optical camera system, a Thales Multichannel, Multiband Airborne Radio (MMAR) prototype, and an L3 Communications Mini-Common Data Link (MCDL).



HALE-D solar array, battery & PCDU installations.
Note the equipment mounting rail installed along the
bottom centerline of the airship. Source: Lockheed Martin

HALE-D launched before dawn on its first, and only, flight on 27 July 2011 from the Lockheed Martin airship facility in Akron, Ohio.

HALE-D first flight, 27 July 2011.
Source, both photos: Lockheed Martin

This test flight originally was targeted to reach an altitude of 60,000 feet (18,288 meters), but was terminated after reaching 32,600 feet (9,936 meters) due to technical issues and subsequently crash landed at a heavily wooded site in Ohio, south of Pittsburgh.

HALE-D non-rigid gas envelope in the trees after crash landing on 27 July 2011. Source: Channel 4 WTAE Pittsburgh

The sequence of events leading up to the crash have been described in the 2016 document, “High-Altitude Platforms — Present Situation and Technology Trends” (see link below):

> “It was noticed a decrease in the rate of climb, which could take the airship to leave the restricted area defined by the American air traffic control agency (Federal Aviation Administration - FAA). It was decided to command an emergency recovery, with release of the helium gas. The aircraft descended on trees, after 2 hours and 40 minutes of flight. During the recovery operation, after removal of most of the equipment, a short circuit in solar panels caused a fire, destroying the aircraft. No person was injured due to the accident. After the accident analysis, it was verified that the rate of climb decrease was caused by freezing in the air valve.”

Lockheed Martin claimed the following success from this flight:

> “We demonstrated a variety of advanced technologies, including launch and control of the airship, communications links, unique propulsion system, solar array electricity generation, remote piloting communications and control capability, in-flight operations, and controlled vehicle recovery to a remote unpopulated area."

The last claim of a “controlled vehicle recovery”, seems to be a bit of an overstatement. The HALE-D airship was not rebuilt.

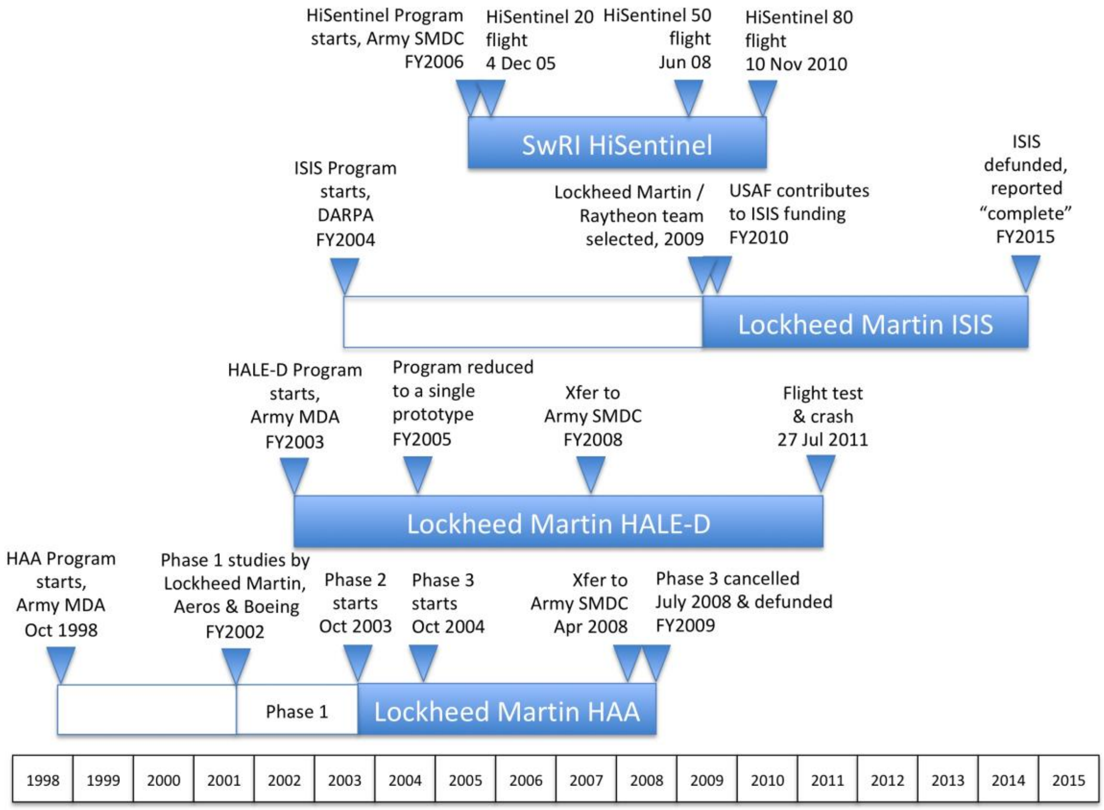
The GAO reported that $36.3 million had been spent on the HALE-D program between FY 2008 and FY 2011.

3. HALE-D Postmortem

Several key technologies incorporated into the HALE-D airship and briefly tested during its one and only flight also were intended for use on larger, operational stratospheric airship systems. Lockheed Martin noted that airship hull materials and the power system account for about 80% of the weight of an airship. They identified the following technologies as being key enablers for smaller, more capable stratospheric airships:

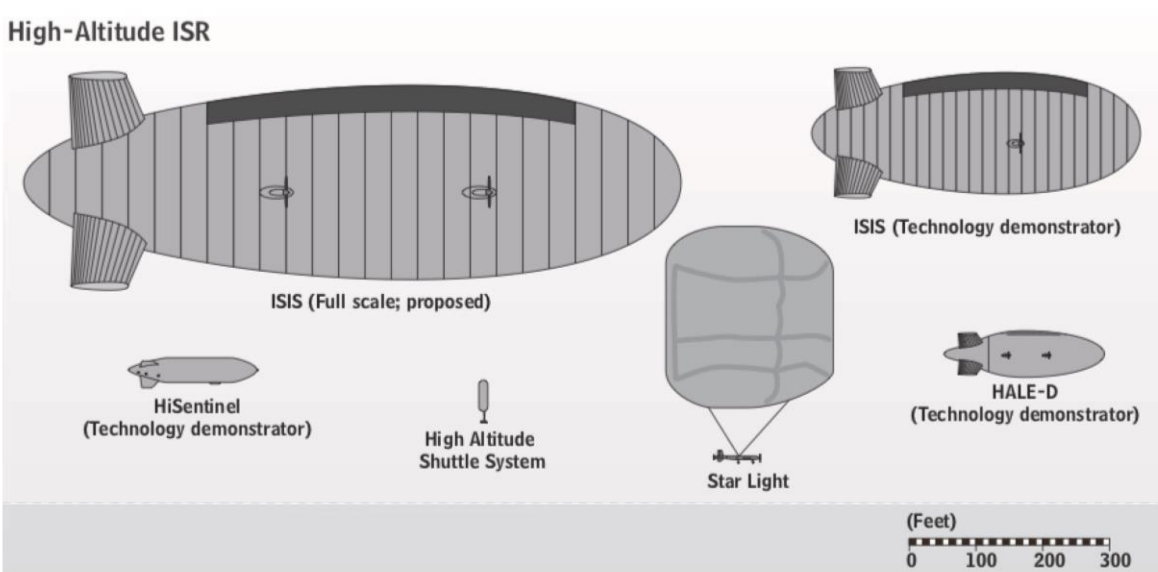
- Higher strength-to-weight hull materials (laminated fabrics) with improved thermal properties, tolerant of long-term operation in the stratosphere.
- Advanced power system technologies:
    - High-efficiency, low-weight, flexible solar photovoltaic (PV) arrays.
        - The HALE-D flexible PV array was rated at 15 kW.
        - Lockheed Martin was developing a 200 kW array for the ISIS Demonstration System (DS) airship.
    - 2X higher specific energy (watt-hours/kg) rechargeable batteries.
        - HALE-D used a 40 kW-hr lithium ion battery
    - High-efficiency, high-power regenerative fuel cells (not used on HALE-D).
    - Advanced power electronics.

4. Timelines for US military high altitude airship programs



Timelines for the US Military High Altitude Airship Programs

As shown in the following chart, HALE-D was quite small in comparison to the planned ISIS airships and one of the two DoD two-component maneuverable balloon systems (StarLight)



Source: Congressional Budget Office, Nov. 2011

5. For more information

- Tamir Eshel, "HALE-D High Altitude Airship Crashed in Ohio," Defense Update, 29 July 2011: https://defense-update.com/20110729_hale-d-high-altitude-airship-crashed-in-ohio.html
- GAO-13-81, "Defense Acquisitions - Future Aerostat and Airship Investment Decisions Drive Oversight and Coordination Needs," Government Accountability Office, October 2012: https://www.gao.gov/assets/650/649661.pdf
- Report to Congress, "Summary Report of DoD Funded Lighter-Than-Air-Vehicles," DoD Office of the Assistant Secretary of Defense for Research and Engineering, 1 November 2012: https://www.hsdl.org/?view&did=728733
- "Lockheed Martin Lighter-Than-Air Programs," JPL / Caltech Airship Workshop, 30 April – 3 May 2013: https://kiss.caltech.edu/workshops/airships/presentations/horvarter.pdf
- Flavio Araripe d'Oliveira, et al., "High-Altitude Platforms — Present Situation and Technology Trends," J. Aerospace Technology and Management, Vol. 8 No. 3, São José dos Campos, Brazil, July/Sept. 2016: https://www.scielo.br/scielo.php?pid=S2175-91462016000300249&script=sci_arttext&tlng=en#B23

Video

- YouTube video, "US-Army unmanned untethered 60,000 ft Altitude Helium Airship, Hale-D takes off at sunrise in Akron" (1:48 minutes), 17 May 2013: https://www.youtube.com/watch?v=Qu7HOTYurqM

Patents

- US7448572B2, "Direct mounted propulsion for non-rigid airships," Filed 5 October 2005, Granted 11 November 2008: https://patents.google.com/patent/US7448572
- US2009/0042037A1, "Metalized flexible laminate material for lighter-than-air vehicles," Filed 20 September 2006, Granted 3

September 2013: https://patents.google.com/patent/US20090042037A1/en
- European patent EP1926591B1, "Metalized flexible laminate material for lighter-than-air vehicles," Filed 20 September 2006, Granted 13 April 2011: https://patents.google.com/patent/EP1926591B1/en?oq=EP1926591B1

Other *Modern Airships* articles

- *Modern Airships - Part 1*: https://lynceans.org/all-posts/modern-airships-part-1/
  - Lockheed Martin - HAA
  - DARPA / Lockheed Martin - ISIS
- *Modern Airships - Part 2*: https://lynceans.org/all-posts/modern-airships-part-2/
- *Modern Airships - Part 3*: https://lynceans.org/all-posts/modern-airships-part-3/