Lockheed Martin High Altitude Airship (HAA)

Peter Lobner, 21 December 2020

1. Introduction

The Army's High Altitude Airship (HAA) Advanced Concept Technology Demonstration (ACTD) program's original long-term objective was to develop and deploy very large solar-powered airships (HAA Operational Systems) capable of carrying a 2,000 pound (907 kg) payload to an altitude of 65,000 feet (12.3 miles, 19.8 km) while generating 15 kilowatts of power for a payload for conducting persistent (24/7) on-station intelligence, surveillance, and reconnaissance (ISR) missions lasting more than 30 days.

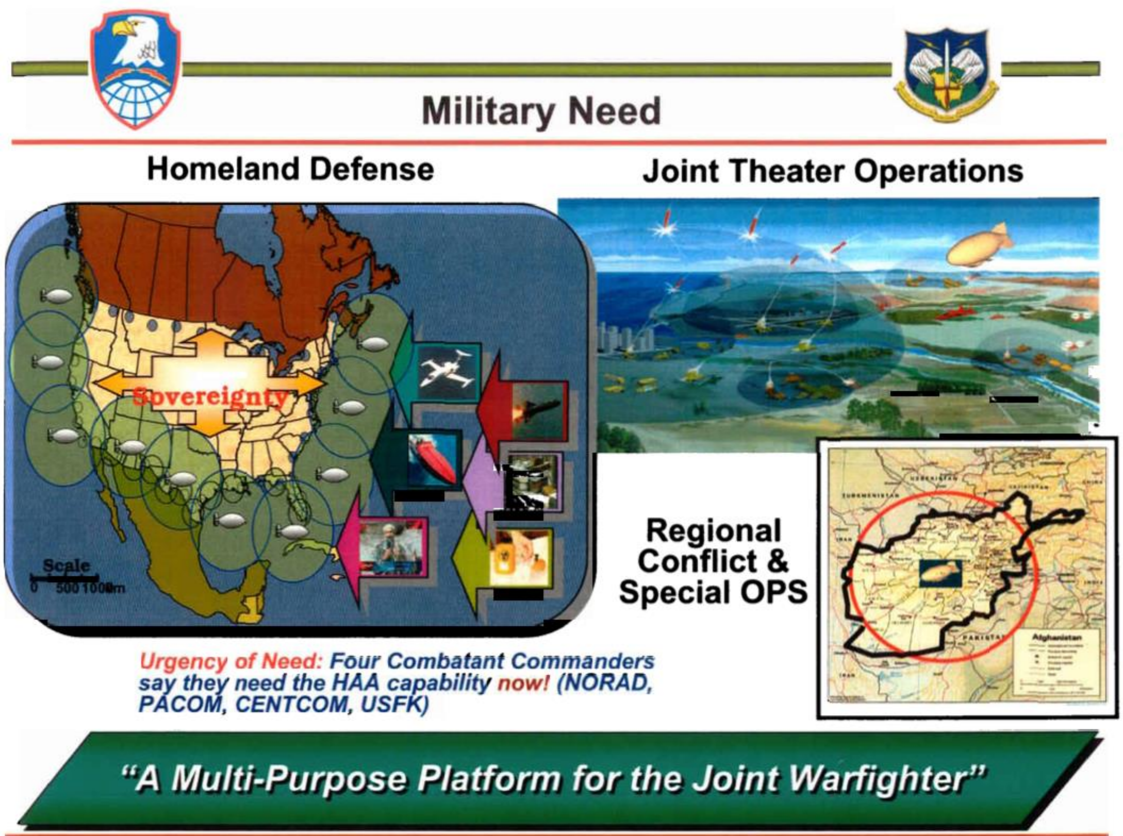
Development of the full-scale HAA stratospheric airship was conducted in parallel with science and technology development efforts being performed under separate programs with the sub-scale High-Altitude Long-Endurance Demonstrator (HALE-D) airship and the HiSentinel family of airships. These stratospheric airships are the subjects of separate articles.

Artist's rendition of a Lockheed Martin HAA stratospheric airship in flight. Source: Lockheed Martin

You can watch a short (0:46 min) YouTube video**, "**Lockheed Martin High Altitude Airship" at the following link:
https://www.youtube.com/watch?v=V3ZIGULlP7Q

2. Military missions

The military user community for the HAA are identified in the following chart, circa 2003. One potential user, North American Aerospace Defense Command (NORAD), planned for a fleet of 11 high-altitude airships with 10 deployed to provide overlapping radar coverage of all maritime and southern border approaches to the continental U.S., and to also serve as an asset in Homeland Security efforts.



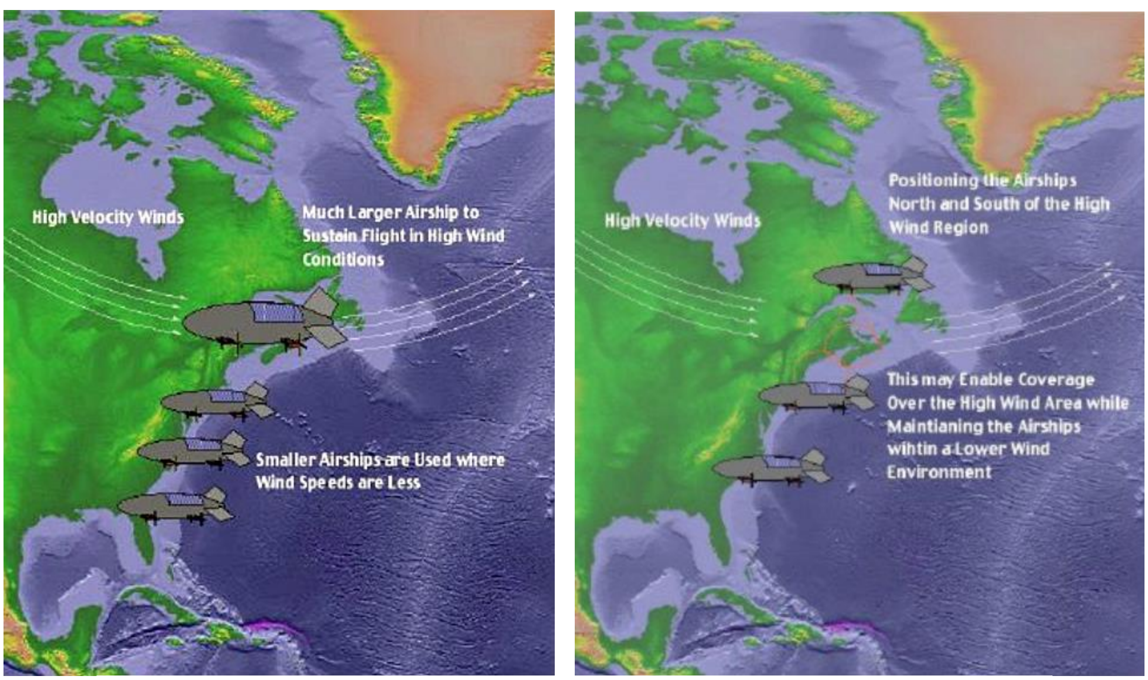
Source: Army MDA

It is well known that prevailing wind speeds above about 60,000 ft (18,288 m) are relatively lower than wind speeds at lower altitudes. This reduces the station keeping power required for geostationary airship operation above 60,000 ft. Specific in-theater conditions at high altitude need to be considered in HAA deployment.

For example, a NASA study published in 2005 reported that a stream of high altitude wind exists above 60,000 ft at higher latitudes, approximately over the eastern US / Canadian border. This means that NORAD HAAs providing radar coverage in that region will face stronger winds and may require greater station keeping power than the HAAs operating along the US southeast and southern coasts. To address this matter, the following strategies were identified:

- Deploy larger, more powerful HAAs to sustain flight in high wind conditions.
- Position the HAAs north and south of the high wind region (potentially leaving a gap in coverage).
- Change altitude to stay within a lower wind speed environment.
- Have the HAA fly a racetrack pattern where it gets blown downwind on one side of the racetrack and then returns to the starting point via a lower wind region on the other side of the racetrack.

The first two strategies are shown in the following figures.



Two strategies for HAA deployment along the East Coast.
Source: NASA/TM-2005-213427 (2005)

3. HAA program risk assessment

RAND reported that the High Altitude Airship (HAA) Advanced Concept Technology Demonstration (ACTD) program documentation referred to the HAA as a “fast paced program” with “some technical risks” but “enormous potential benefits.” The RAND authors stated, “Against these statements, it is critical to note that the program is attempting to design and fly an unmanned airship that is orders of magnitude larger (in terms of volume) than any other previously attempted. There is substantial uncertainty surrounding all aspects of vehicle performance and control at this scale.” Their risk summary is shown in the following table.

Issues	Risk Management Approach
Envelope material (strength and weight)	Restrict ascent/descent conditions
Thermal control (superheat)	Incorporate reflective envelope
Helium leakage	Limit endurance; use hydrogen from fuel cells
Photovoltaic cells	Limit endurance
Fuel cells	Use Li-polymer batteries as fallback
Weatherability	Restrict ascent/descent conditions; improve weather prediction; provide emergency ballast dump; add sprint engine(s)
Survivability	Operate within own air defense envelope
Airspace access	Restrict ascent/descent locations and times
Launch/recovery	Mechanization; restrict ascent/descent locations/times

Source: RAND

You can read this RAND report, “High Altitude Airships for the Future Force Army,” at the following link: https://www.rand.org/content/dam/rand/pubs/technical_reports/2005/RAND_TR423.pdf

4. Full-scale HAA program timeline

The full-scale HAA program was initiated by the Army’s Missile Defense Agency (MDA) in October 1998 with the start of the concept feasibility phase. Lockheed Martin, Aeros and Boeing performed Phase 1 studies to develop concepts for an operational HAA.

After down-selecting to a single contractor, development of the full-scale HAA airship was to be performed in Phases 2, 3 and 4, which originally were defined as follows:

- Phase 2 - Risk reduction: Estimated total value of $40,000,000 with a period of performance from October 2003 to June 2004.
    - On 29 September 2003, Lockheed Martin Naval Electronics & Surveillance Systems, Akron, Ohio, was selected to perform Phase 2.
- Phase 3 - Prototype development, build & demonstration: Estimated total value of $50,000,000 with a period of performance from June 2004 to July 2006.
- Phase 4 - Extended User Evaluation Period: Estimated total value of $9,000,000 with a period of performance from August 2006 to July 2008.

In January 2006, Lockheed Martin Maritime Systems was selected as the single contractor to perform Phase 2 of the HAA project. Lockheed Martin described their HAA as follows: "…..an unmanned, untethered, lighter-than-air vehicle operating autonomously in the stratosphere for sustained, ultra-long endurance missions as a stable, geostationary platform suitable for intelligence, surveillance, and reconnaissance (ISR) and communications."

For Phase 2, Lockheed Martin received a $149.2 million cost-reimbursable contract to build and demonstrate the technical feasibility and military utility of the HAA. The Missile Defense Agency (MDA) issued this contract (HQ0006-06-C-0001), and eventually planned to deploy approximately 10 blimps to provide overlapping coverage of U.S. coastal regions.

FY2008 funding for Phase 3 was canceled because of budgetary constraints. Consequently, FY2007 activities (Oct 2006 – Sep 2007) focused on wrapping up many technical efforts and consolidating project records. Had Phase 3 proceeded as originally planned, the HAA vehicle would have been built in Lockheed Martin's Akron Airdock, which is 1,175 feet long, 325 feet wide and 211 feet high. Lockheed Martin would build the smaller HALE-D airship in this facility a few years later.

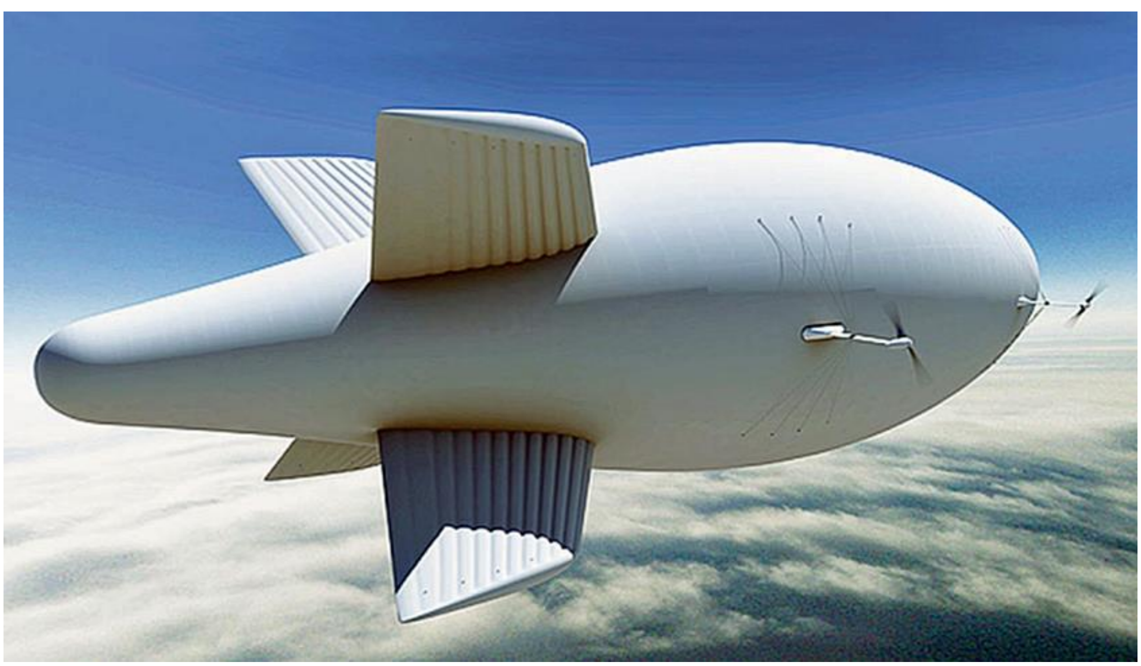
In April 2008, what remained of the HAA program was transferred from MDA to the Army's Space and Missile Defense Command (SMDC) in Huntsville, AL. After HAA Phase 3 cancellation, SMDC and Lockheed Martin continued HAA technology development under the HALE-D stratospheric airship program, which concluded in 2011.

Lockheed Martin also continued their involvement in stratospheric airship development on the DARPA and USAF-funded Integrated Sensor is Structure (ISIS) airship program, which continued until FY2015. ISIS is the subject of a separate article.

5. The Lockheed Martin HAA airship

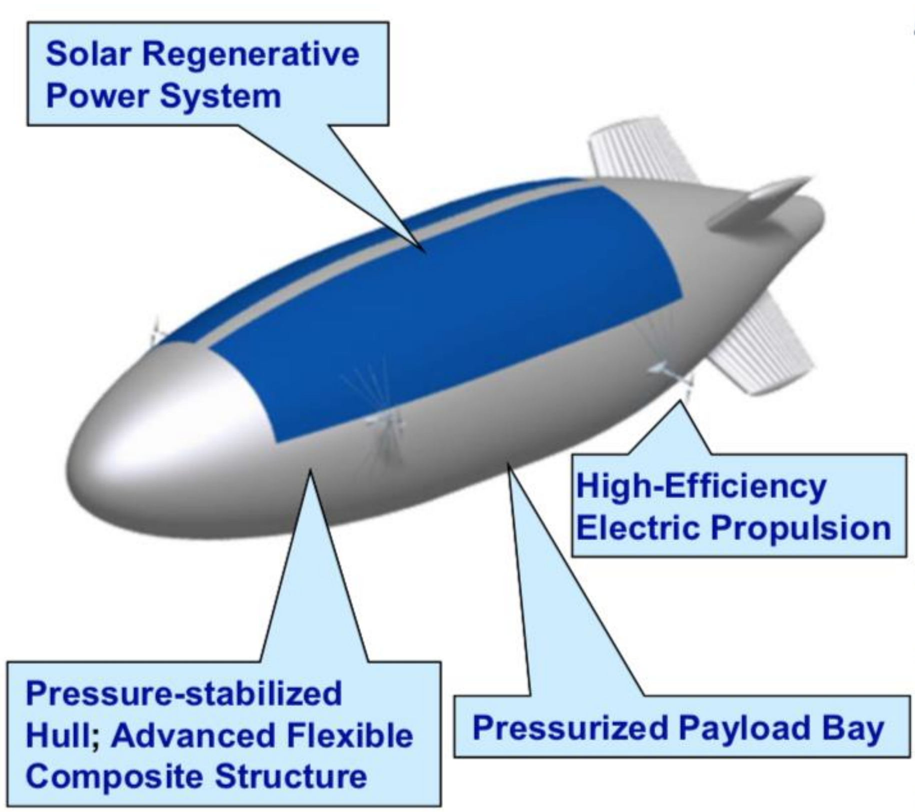
The HAA was designed for global operations without the need for in-theater logistics support. The HAA would fly from its main base in the US and self-deploy to an assigned geo-location and remain on station for up to six months. At the conclusion of that assignment, the HAA would return to base for maintenance and future tasking.

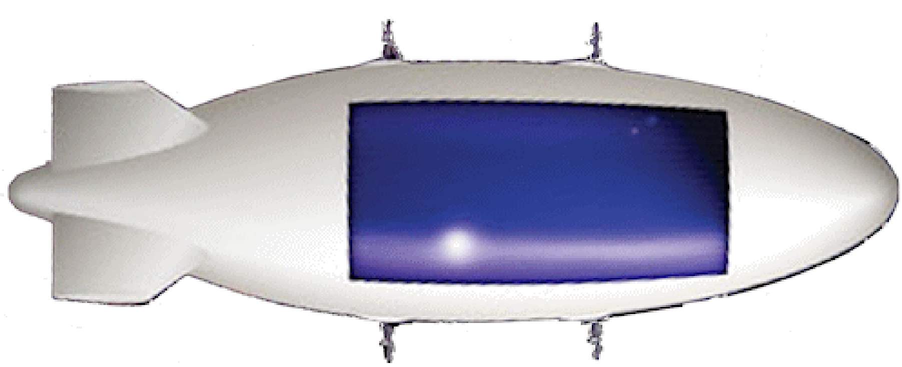
HAA was optimized for stratospheric conditions where air density is low, the air is relatively calm and the average wind speed is low. For these conditions, the optimized airship has a low power propulsion system installed on a lightweight and potentially fragile hull.



HAA general arrangement. Source: Lockheed Martin

Key features of the HAA are shown in the following diagrams.





Source, three graphics: Lockheed Martin

Basic characteristics of the Lockheed Martin HAA Operational System (OS) are outlined below:

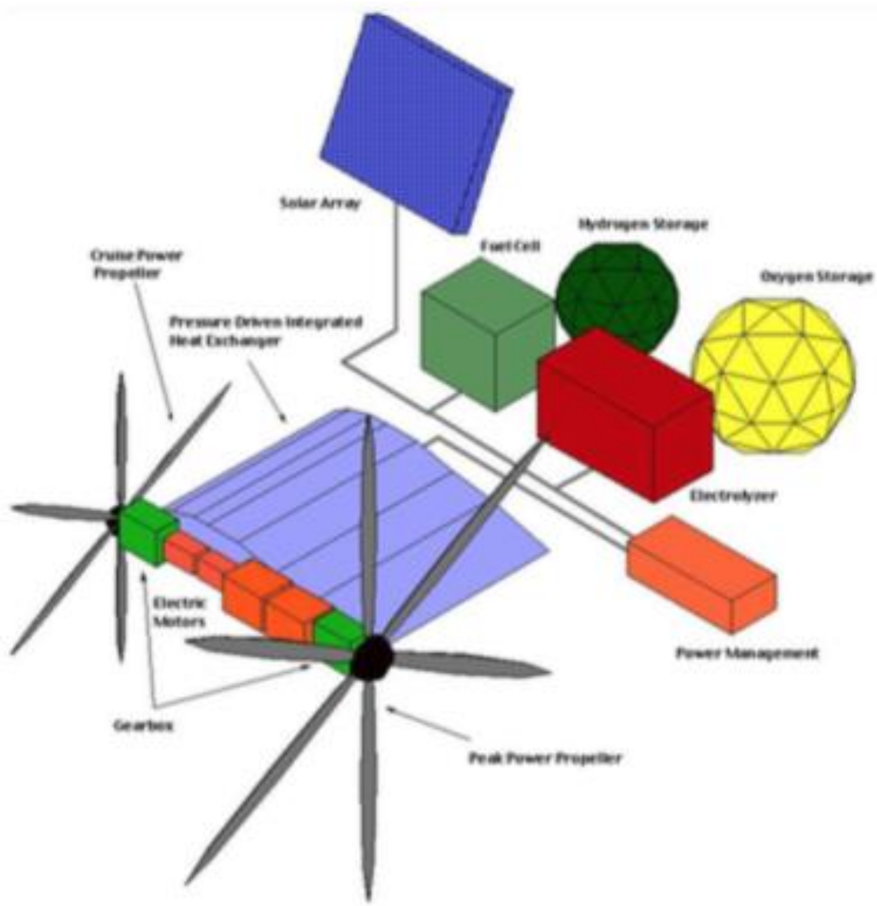
- Length: 480 feet (146.3 m)
- Diameter: 150 feet (46 m) at its widest girth
- Volume: 5.2 million cubic feet (147,248 cubic meters)
- Operating altitude: 65,000 feet (12.3 miles, 19.8 km)
- Line of sight from operating altitude: 314 nautical miles (582 km)
- Electric power system: thin-film photovoltaic solar cells on the hull supply loads during the day and charge batteries or fuel cells to support operation at night
- Propulsion: 4 x electric motor driven, 25 foot (7.6 m) diameter, variable pitch propellers.
    - Differential thrust control is used to maintain position at high altitude
- Speed: about 30 knots (for station keeping, dictated by the average wind speed at the operating altitude)
- Station keeping parameters: < 2 km for 50% of the time and < 150 km for 95% of the time
- Control: Autonomous or remote control
- Minimum payload: 4,000 pounds (1,814 kg) payload in an internal, pressure and temperature controlled bay
    - Payload interface is designed for simple integration and reconfiguration
- Payload continuous power requirement: at least 75 kilowatts
- Mission duration: six months to one year

The first unit (the full-scale prototype) would be slightly smaller than the OS and have reduced requirements in the following areas:

- Length: 430 feet (131 m)
- Diameter: 140 feet (42.6 m) at its widest girth
- Volume: 3.7 million cubic feet (84,951 cubic meters)
- Operating altitude: 60,000 ft (18.3 km)
- Payload continuous power requirement: 15 kilowatts
- Mission duration: one month

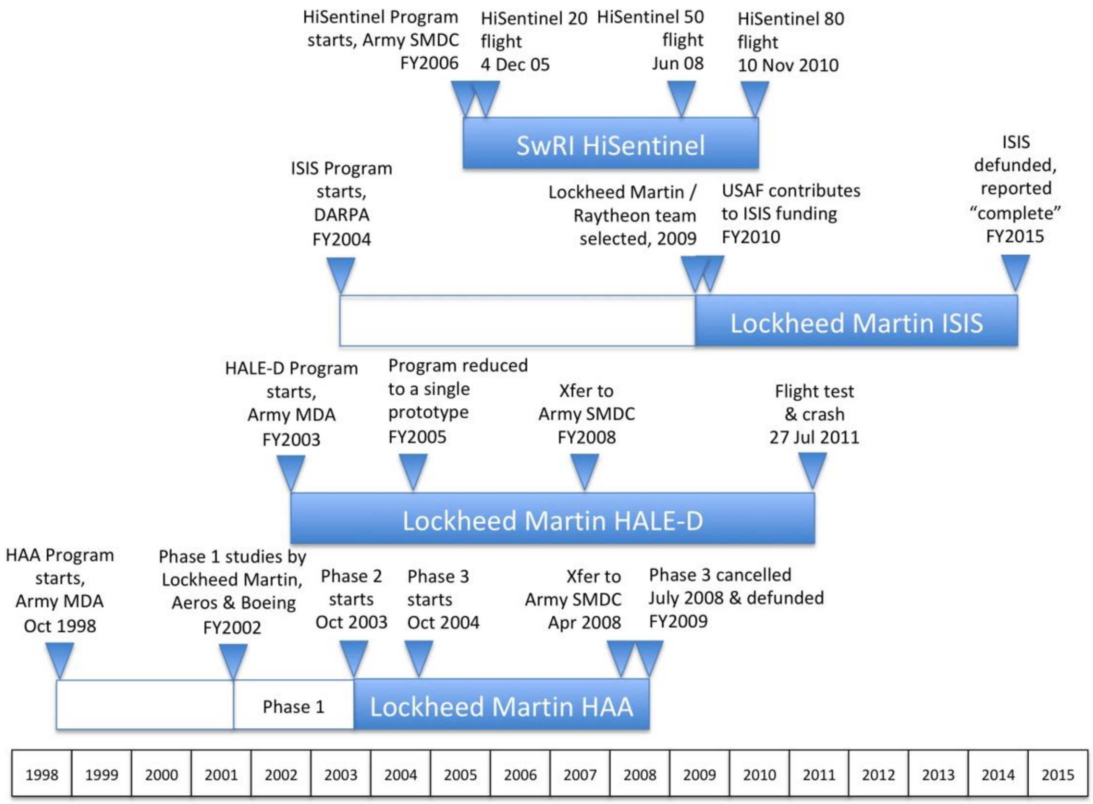
The unmanned airship was designed be controllable from a remote ground station, provide a payload environment suitable for electronic equipment with a maximum unobstructed viewing line-of-sight around the airship, and generate sufficient power to operate all airship subsystems and electronic payloads (with appropriate design margins and duty cycles) for continuous operations.

A representative photovoltaic (PV) / regenerative fuel cell (RFC) power system is shown in the following diagram. During the day, the PV system supplies airship loads, including propulsion, and the mission payload. The PV system also provides the power needed to electrolyze the water produced by the fuel cell into oxygen and hydrogen. When the fuel cell is required to support airship loads and the mission payload, the oxygen and hydrogen are recombined in the fuel cell and produce electric power and water. This closed-loop process is repeated day after day.



Example of a photovoltaic solar / fuel cell regenerative power system.
Source: NASA/TM-2005-213427 (2005)

6. Timelines for US military high altitude airship programs



Timelines for the US Military High Altitude Airship Programs

7. For more information:

- "Lockheed gets grant to develop high-altitude airship," Cleveland 19 News, 30 September 2003: https://www.cleveland19.com/story/1463350/lockheed-gets-grant-to-develop-high-altitude-airship/
- James Dolce & Anthony Colozza, "High-Altitude, Long-Endurance Airships for Coastal Surveillance," NASA/TM—2005-213427, National Aeronautics & Space Administration, February 2005: https://www.researchgate.net/publication/24329654_High-Altitude_Long-Endurance_Airships_for_Coastal_Surveillance
- L. Jamison, G. Sommer & I. Porche III, "High Altitude Airships for the Future Force Army," Technical Report TR-423, ISBN 0-8330-375905, pp. 8 – 11, RAND Corporation, 2005:

https://www.rand.org/content/dam/rand/pubs/technical_reports/2005/RAND_TR423.pdf

- "High Altitude Airship (HAA) FY03 ACTD," US Army, 2002: https://www.hsdl.org/?view&did=454710
- "High Altitude Airship (HAA)," Global Security: https://www.globalsecurity.org/intell/systems/haa.htm