HiSentinel Stratospheric Airships

Peter Lobner, 21 December 2020

1. Introduction

HiSentinel was a science and technology development effort that was part of the Army's High Altitude Airship (HAA) program, which also included the HALE-D airship. The HAA program's long-term objective was to develop a solar-electric powered airship capable of carrying a 2,000 pound (907 kg) payload to 65,000 feet (19,812 m) and generating 15 kilowatts of power for airship systems and a payload for conducting persistent (24/7) on-station intelligence, surveillance, and reconnaissance (ISR) missions lasting more than 30 days.

HiSentinel was the first airship delivered under the HAA's Composite Hull High Altitude Powered Platform (CHHAPP) program, which had the goal of developing a series of increasingly more capable sub-scale solar-electric powered stratospheric airships to test technologies needed for conducting long endurance tactical missions at high altitude. The HiSentinel project was focused on demonstrating technologies for a low-cost, expendable (single use) stratospheric airship that could be deployed in the field.

The HiSentinel project was initiated in 2005 (FY2006). Southwest Research Institute (SwRI, https://www.swri.org) was the HiSentinel prime contractor and was responsible for the design of the airship and its telemetry, flight control, power, and propulsion systems. Aerostar International, Inc. (a subsidiary of Raven Aerostar, https://ravenaerostar.com) was the subcontractor responsible for fabricating the lightweight gas envelope (the airship's hull) and supporting integration and test flights. The Air Force Research Laboratory (AFRL) developed the unique launch system for the HiSentinel airships, provided facilities, and supported launch and recovery operations. The U.S. Army Space and Missile Defense Command (SMDC) sponsored this project.

For HiSentinel, the SwRI / Aerostar team built on its experience from three earlier, similarly designed Sounder high-altitude lighter-than-air vehicle engineering flights conducted between 1999 and 2003 for other sponsors.

2. The Hi-Sentinel patent

During this period, SwRI submitted patent application US6609680B2, “High altitude airships,” which described how the Sounder and later HiSentinel airships were designed and operated. This patent was submitted on 23 May 2001 and was granted on 26 August 2003.

As shown in patent Fig. 2, the lifting gas (28) only partially inflates the fixed volume airship hull (22) at launch. The airship ascends nose-first with the uninflated portion of the hull hanging loosely from the nose section. Airship controls and mission equipment are contained in the cargo block (30).

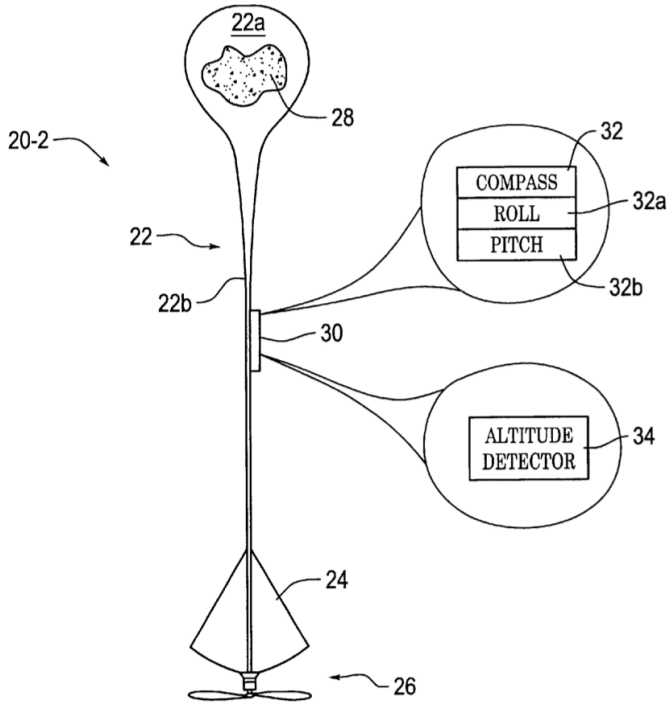


Fig. 2

As the airship ascends, the lifting gas expands as ambient air pressure decreases. The airship’s center of buoyancy (36) shifts aft as the bottom of the hull inflates, causing the airship’s pitch angle to

rotate from 90° (vertical) to a more horizontal attitude, as shown in patent Fig. 3. At maximum altitude, the fixed volume hull is fully inflated with a slight super pressure (a positive pressure with respect to atmospheric pressure) and the hull forms a stiff, rigid structure.

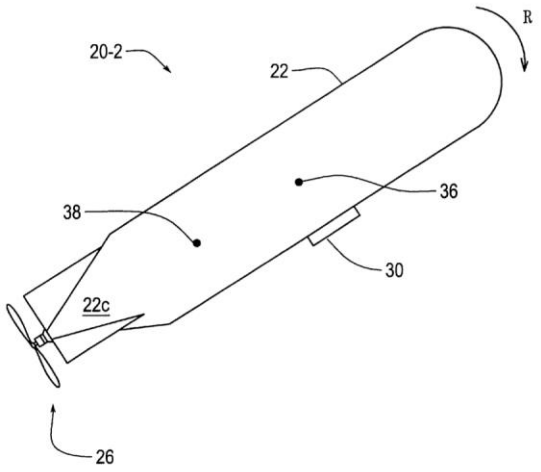


Fig. 3

A horizontal (0°) pitch angle is established by the ballast assembly (40), which moves a ballast fluid (48) between an aft reservoir (44) and a forward reservoir (42) until the center of buoyancy (36) and the center of mass (38) are aligned.

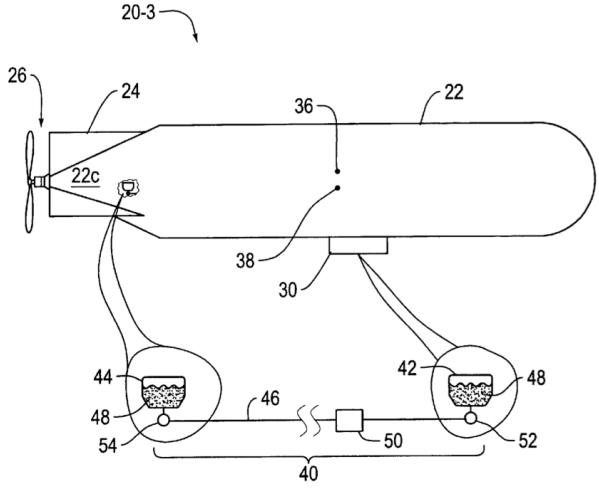


Fig. 4

You can read this patent here:
https://patents.google.com/patent/US6609680B2/en

3. The HiSentinel missions

Three HiSentinel demonstration airships were developed and flown between 2005 and 2010: HiSentinel 20, HiSentinel 50 and HiSentinel 80. The number denotes the approximate payload weight in pounds. All of these unusual hybrid LTA craft implemented the basic design described in patent US6609680B2: non-rigid, fixed volume hull with a single lifting gas chamber and no ballonets.

The HiSentinel airships did not require a large hangar or special ground facilities. These airships were designed to be launched partially inflated, looking like a tall vertical balloon at launch, and taking the shape of a conventional, horizontal, cylindrical airship as the helium lift gas expanded at higher altitudes.

Partially-inflated HiSentinel 80 launch sequence.
Source: Steve Smith Conference paper: DOI: 10.2514/6.2007-7748

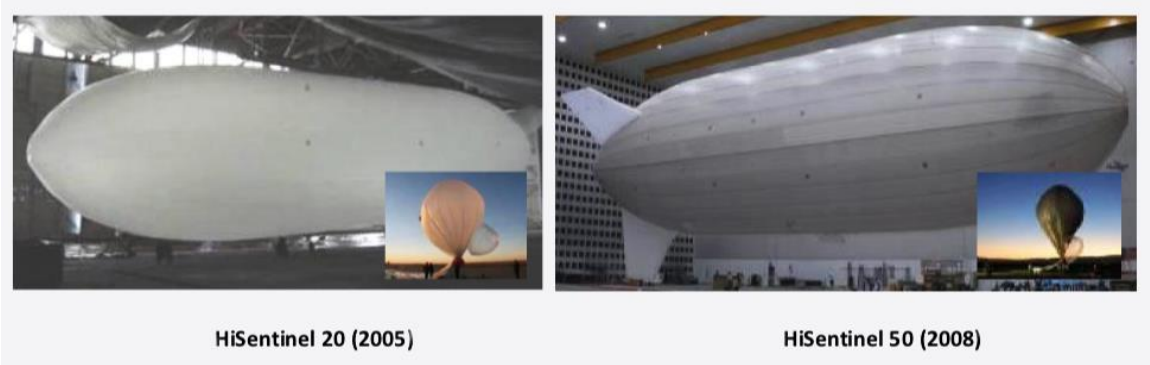
A helium super pressure within the gas envelope provides enough rigidity to prevent the lightweight inflated horizontal hull from buckling. A fluid ballast system trims the airship once it is at “float altitude,” which is established by the initial charge of helium lifting gas prior to launch. Mission duration may be limited by the helium leak rate from the inflated hull.

When an adequate super pressure can no longer be maintained, the single chamber hull will buckle and control of the airship will be lost. At the end of the mission, the equipment pod is released and parachutes back to the ground for recovery and refurbishment for a future mission. The expendable lightweight gas envelope is not intended to be recovered.

HiSentinel 20

On 4 December 2005, the 146 foot (44.5 m) long HiSentinel 20 airship carried a 60 pound (27.2 kg) equipment pod with a 20 pound (9.1 kg) payload to an altitude of 74,000 feet (22,555 m) and successfully demonstrated powered airship flight in the stratosphere, becoming only the second airship to do so. For this five hour flight, power was provided by batteries alone.

The first powered airship flight in the stratosphere was accomplished in 1969 by the High Platform II airship, which flew at 70,000 feet (21,336 m) for two hours with a 5 pound (2.3 kg) telemetry and propulsion payload. High Platform II was built by Raven Aerostar.



Source: DoD (2012)

HiSentinel 50

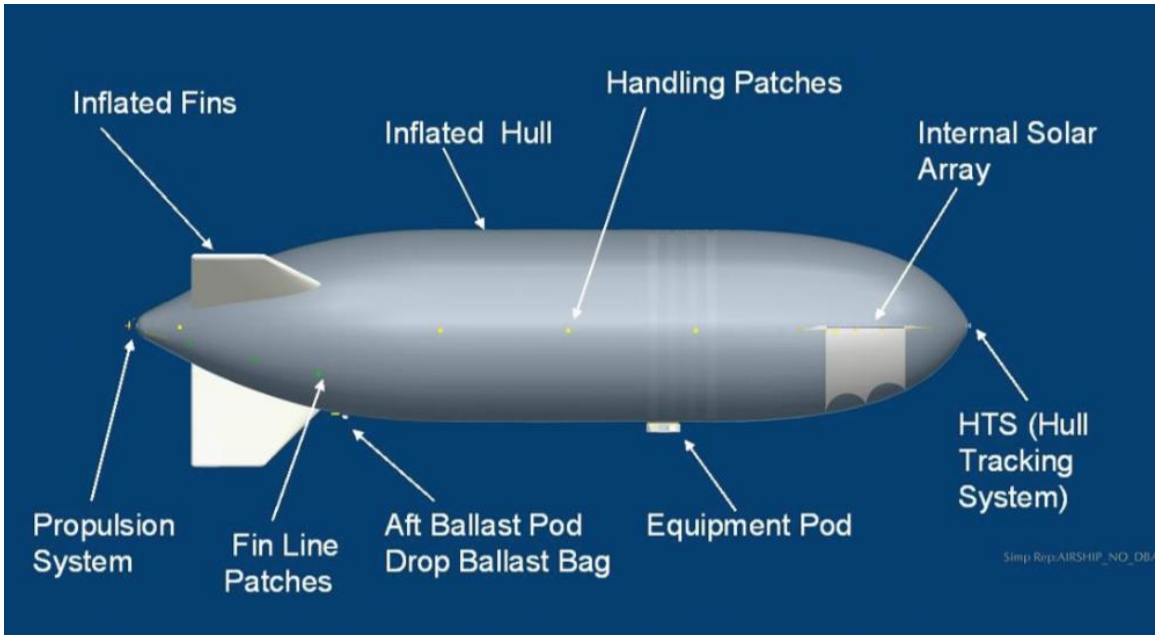
In June 2008, the 178.7 foot (54.5 m) long, 39.7 foot (12.1 m) diameter HiSentinel 50 airship flew to an altitude of 66,400 feet (20,239 m) with a 50 pound (22.7 kg) payload consisting of a General Dynamics communications relay and an ITT high-resolution camera system. This was the first HiSentinel airship to carry a photovoltaic array within the gas envelope to supplement the battery and deliver 50 watts of continuous power.

HiSentinel 80

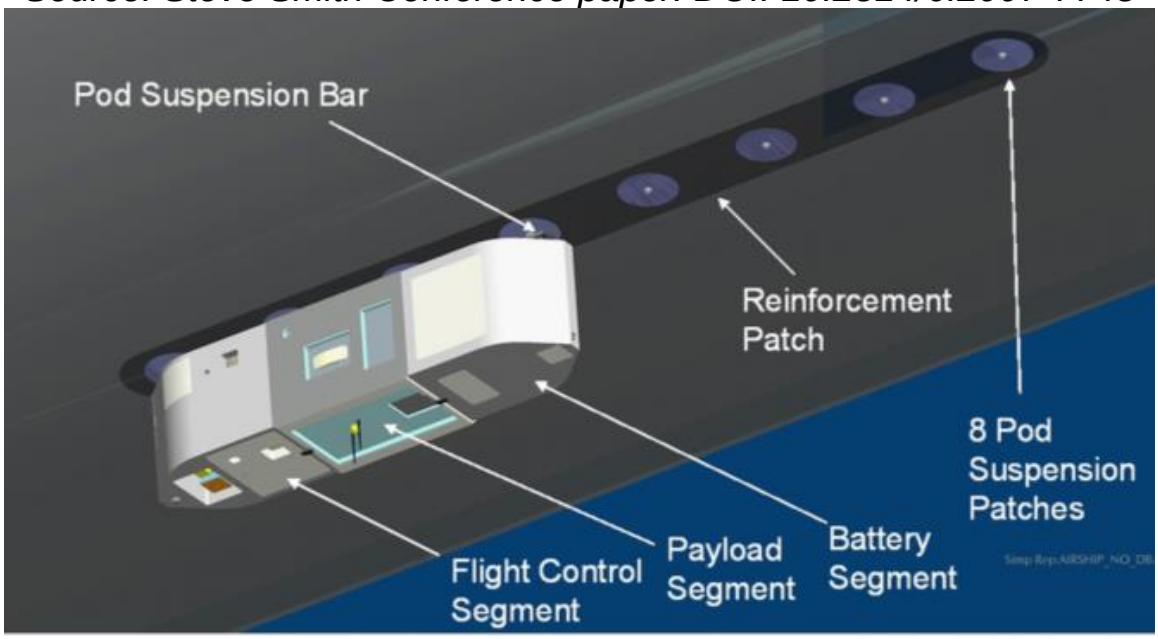
Basic characteristics of the larger HiSentinel 80 unmanned sensor platform are outlined below:

- Type: Single-use, non-rigid, fixed volume, single chamber, Vectran / nylon gas envelope (nylon is the gas barrier) with inflatable tail fins and a recoverable equipment pod.
- Length: 199 feet (60.6 m)
- Diameter: 45 feet (13.7 m)
- Gas volume: 241,765 ft^3 (6,846 m^3)
- Airship mass: About 1,102 lb (500 kg)
- Payload: About 80 lbs (36 kg)
- Sensor types: High-resolution camera system and communications equipment
- Mission duration: Up to 1 day
- Maximum altitude: Designed for 65,0000 feet (19,812 m)
- Power source: Batteries supplemented by a 1.2 kW thin-film, flexible photovoltaic array inside the gas envelope (~70% light transmission), delivering 50 watts continuous power.
- Propulsion: One tail-mounted electric motor-driven propeller
- Speed: 18 knots average cruise speed

HiSentinel 80 inflation test in the Alamodome in San Antonio, TX. Source: Steve Smith Conference paper: DOI: 10.2514/6.2007-7748



HiSentinel 80 general arrangement.
Source: Steve Smith Conference paper: DOI: 10.2514/6.2007-7748



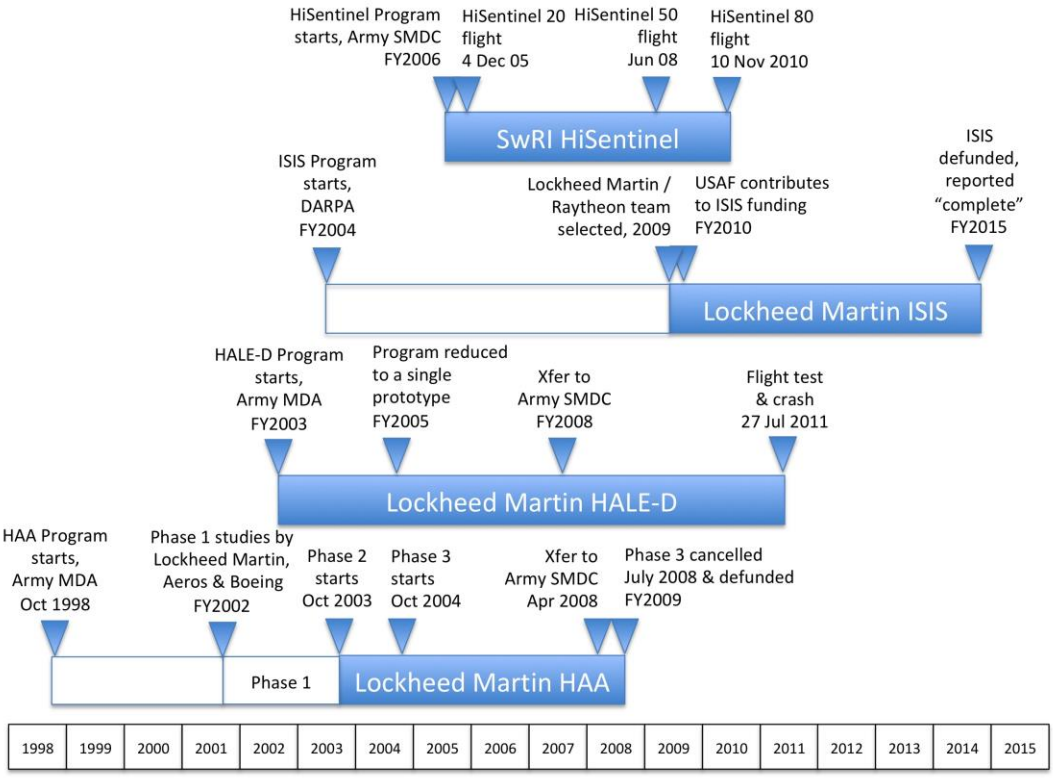
HiSentinel 80 equipment pod general arrangement.
Source: Steve Smith Conference paper: DOI: 10.2514/6.2007-7748

HiSentinel 80 was equipped with the same payload package as used on SMDC's other HAA program, HALE-D. 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).

A test flight on 10 November 2010 was intended to achieve the design altitude, speed and mission duration targets and demonstrate a station-keeping capability. The flight achieved an average altitude of 66,200 feet (20,178 m). However, a failure in the propulsion motor controller rendered the propulsion system inoperable. As HiSentinel 80 drifted with the wind, the mission payload remained operational and SwRI reported that all functionally was tested successfully. The hull buckled due to helium leakage about 6-1/2 hours after launch. About 30 minutes later, the equipment pod was released. Both the pod and the hull were later recovered on the ground.

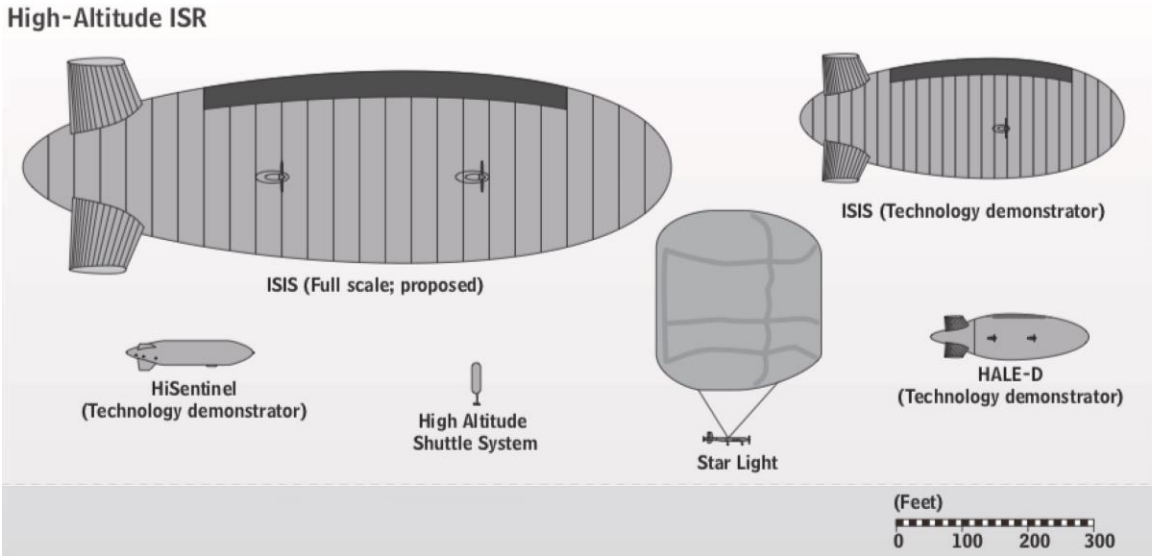
Funding for HiSentinel expired in FY2010. Total project cost from FY2006 to FY2010 was $11.2 million.

4. Timelines for US military high altitude airship programs



Timelines for the US Military High Altitude Airship Programs

As shown in the following chart, the HiSentinel airships were quite small in comparison to other contemporary high altitude ISR airships (ISIS and HALE-D) and one of the two DoD two-component maneuverable balloon systems (StarLight).



Source: Congressional Budget Office, Nov. 2011

5. For more information:

- Mike Hanlon, "Stratospheric airship reaches near-space altitude during demonstration flight," New Atlas, 4 December 2005: https://newatlas.com/stratospheric-airship-reaches-near-space-altitude-during-demonstration-flight/4901/
- Steve Smith, et al., "HiSentinel80: Flight of a High Altitude Airship," Conference Paper, September 2007, DOI: 10.2514/6.2007-7748: https://www.researchgate.net/publication/268571750_The_HiSentinel_Airship#fullTextFileContent
- 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
- Steve Smith, "HiSentinel & Stratospheric Airship Design Sensitivity," Southwest Research Institute presentation, 2013: https://kiss.caltech.edu/workshops/airships/presentations/smith.pdf