DARPA / Lockheed Martin - ISIS stratospheric airship

Peter Lobner, updated 16 June 2023

1. Introduction

ISIS (Integrated Sensor is Structure) was a joint Defense Advanced Research Projects Agency (DARPA) and Air Force Science and Technology (S&T) program that integrates advanced radars with tracking and moving target indication capabilities directly into the structure of a very large, solar-powered, stratosphere-roaming, non-rigid airship. DARPA initiated the program in 2004 with the following goals:

> "The joint DARPA/Air Force Integrated Sensor is Structure (ISIS) program is developing a sensor of unprecedented proportions to be fully integrated into a stratospheric airship. ISIS is designed to provide persistent wide-area surveillance, tracking, and engagement for hundreds of time-critical air and ground targets in deployed overseas urban and rural environments, without requiring in-theater support facilities or personnel. ISIS seeks radical sensor improvements by melding the next generation technologies for enormous lightweight antenna apertures and high-energy density components into a highly integrated, lightweight, multi-purpose airship structure, completely erasing the distinction between payload and platform."
>
> "The ISIS concept includes 99% on-station, 24/7/365 availability for simultaneous Airborne Moving Target Indicator (AMTI) (600 kilometers) and Ground-Based Moving Target Indicator (GMTI) (300 kilometers) operation; ten years of autonomous, unmanned flight; plus U.S.-based operation."

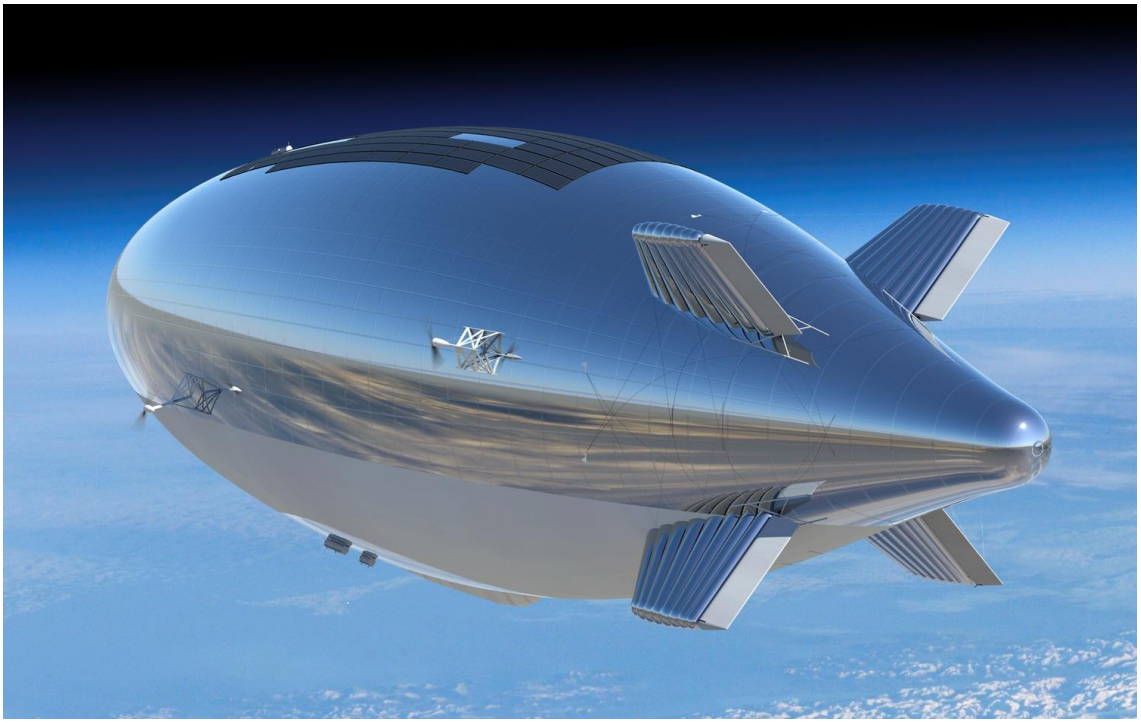
The original plan was for the USAF to take over the ISIS program after flight tests with a sub-scale "demonstration system" (DS) had been completed and the ISIS concept had been validated. The full-scale ISIS airship was known as the "objective system" (OS). In FY 2010, the USAF began contributing funds under a joint DARPA/Air Force initiative.

In 2009, the team of Lockheed Martin and Raytheon beat a Northrop Grumman team for a $400 million contract to design, build and fly the sub-scale (approximately 1/3 scale) DS airship.

The original timeline called for the technology demonstrator airship (the DS airship) to make its first flight in late 2013 from the Lockheed Martin airship manufacturing site in Akron, Ohio. While the USAF had not yet committed funding, the full-scale ISIS airship (the OS airship) was expected to fly in about 2020.

2. Overview of the ISIS airship

ISIS is a very large, solar-powered, stratosphere-roaming, non-rigid airship (blimp) designed to be launched from a base in the continental U.S. to self-deploy and conduct very long duration ISR and communications missions anywhere in the world. During the mission, all ISIS data is transmitted to a continental U.S. center for process and distribution. No in-theater data processing facilities are required. After the mission, the ISIS airship would fly back and be recovered at its base in the continental U.S.



ISIS airship concept drawing, rear quarter view. Note the metallized, non-rigid gas envelope and the inflated X-tail fins with aerodynamic control surfaces. Source: Lockheed Martin

ISIS concept drawing showing top-mounted solar photovoltaic array and flank-mounted propellers attached directly by the non-rigid gas envelope.

ISIS airship exploded view showing the location of the ASEA radar within the hull, and the solar photovoltaic array on the top of the hull. Source, both graphics: Lockheed Martin

The 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.

General characteristics of the Lockheed Martin ISIS airship

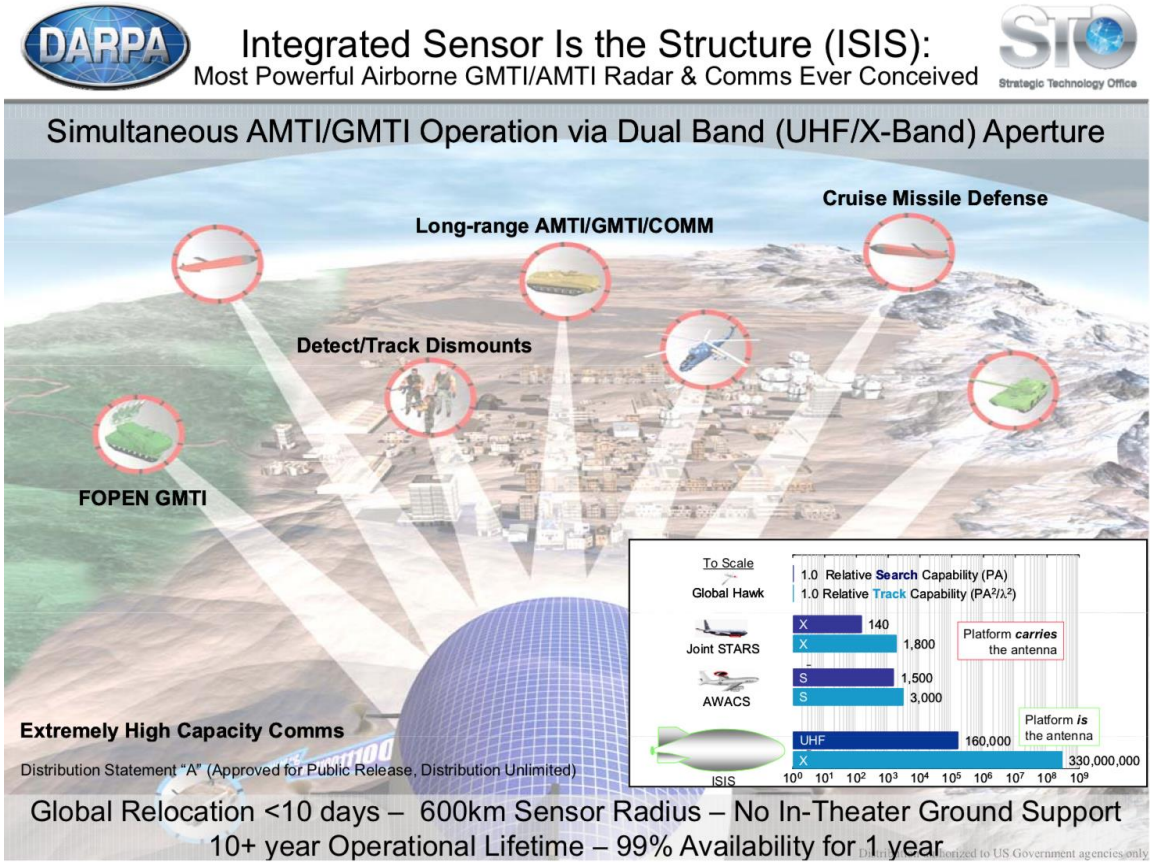
Parameter	ISIS Demonstration & Objective Systems (DS & OS)
Length	DS - 492 feet (150 m); OS - 984 feet (300 m)
Diameter	DS - 164 ft (50 m) at its widest point; OS - 328 m (100 m)
Volume	OS - 5.2 million ft^3 (147,248 m^3)
Hull material	Metallized, flexible, fabric laminate hull material with an extremely high strength-to-weight ratio • 4X reduction in fabric mass over current state of the art. • Will last 10X longer than conventional blimp hull material.
Operating altitude	DS – 65,600 ft (12.4 miles, 20 km); OS – 70,000 ft (13.3 miles, 21.3 km)
Line of sight from operating altitude	OS - About 373 miles (600 km) to the horizon
Electric power system	A solar photovoltaic array on the top surface of the airship is paired with regenerative hydrogen fuel cells to deliver 24/7 power for the mission package and for propulsion. • During the day, solar cells generate electricity & provide power for electrolysis of water to produce hydrogen & oxygen for the fuel cell. • At night, hydrogen & oxygen are recombined in the fuel cell, which generates electricity and produces water.
Propulsion	Four electric motor-driven vectorable propellers are mounted directly on the flanks of the non-rigid hull.
Speed	60 knots sustained, 100 knots maximum
Control	Autonomous or remote control
Payload	• Dual-band (UHF and X-band) active electronically scanned array (ASEA) radar system with a shared aperture with backend digital beam forming. • Communications data link to transmit all radar data back to a processing center in the continental U.S.
Payload mass	The radar sensor itself will account for about 30% of the total mass of the airship • DS radar - 6,600 pounds (2,994 kg)
Mission duration	DS – Three months OS – Up to 10 years

The propulsion system is comprised of four flank-mounted, electric motor-driven propellers attached directly to 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.

3. The ISIS dual-band (UHF and X-band) radar

The ISIS radar system had the following key functional capabilities for engaging hundreds of time-critical targets:

- Simultaneous Airborne Moving Target Indicator (AMTI) at 373 miles (600 km) and Ground-Based Moving Target Indicator (GMTI) at 186 miles (300 km) with the X-band aperture
- Tracking human-sized targets or vehicles hidden under foliage or camouflage nets at 186 miles (300 km) with the UHF aperture



Concept of operations for employing the ISIS radar
Source: Tim Clark / "DARPA Investment in Large Apertures"

Unlike conventional radars, the ISIS radar performance is based on array (aperture) size rather than power. As aperture size increases, the tracking performance increases exponentially.

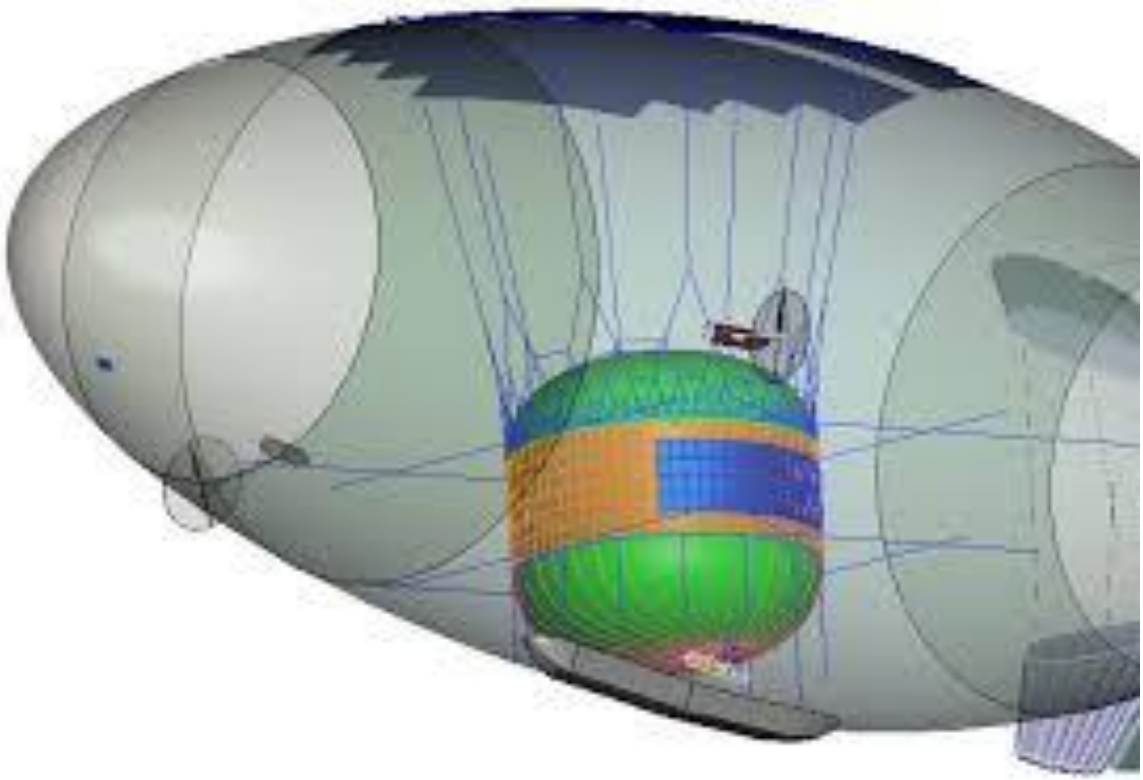
The very large ISIS radar aperture is built up from a very large number of small, low-power transmit / receive modules that are based on low-cost cell phone technology. By employing low-power electronics, there was no need for an electronics cooling system, which is common in high-power radar systems. The combined effect of low-power electronics and no electronics cooling system greatly decreased the electric power required to operate the ISIS sensor system, thereby enabling the airship to run on solar power.

As the ISIS (Integrated Sensor is Structure) name implies, lightweight flexible array panels are bonded onto airship structures to create a large, cylindrical radar antenna within the hull of the airship. These lightweight array panels have an average mass density of only 0.4 pounds/ft^2 (2 kg/m^2).

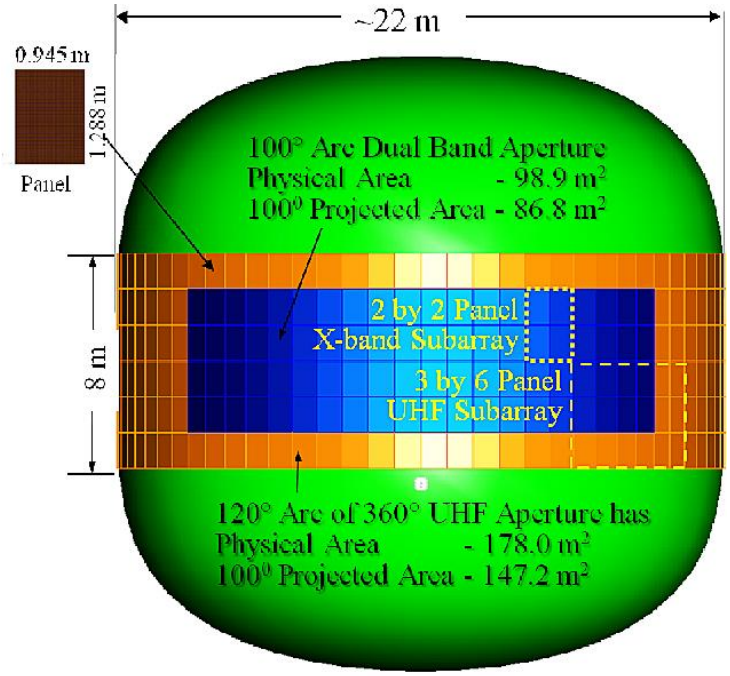
The relative scale of the DS and OS airships and their respective dual-band radars is summarized in the following table.

	DS	OS
Altitude	20 km	21.3 km
Airship Length	150 m	300 m
Airship Diameter	50 m	100 m
Antenna Height	8 m	36 m
Antenna Diameter	22 m	50.5 m
UHF Aperture Area	530 m^2	5725 m^2
UHF Elements	3,922	42,365
X-Band Aperture Area	98 m^2	5725 m^2
X-Band Elements	347,500	20,300,000
First Launch	2013	2020

Source: Tim Clark,
DOI: 10.1109/ARRAY.2010.5613396



Location and suspension of the dual-band ASEA radar within the ISIS technology demonstrator (DS) airship hull.



Details of the dual-band ASEA radar array for the DS airship. Source, both graphics: Tim Clark, DOI: 10.1109/ARRAY.2010.5613396

4. The ISIS demonstration system (DS)

The ISIS demonstration system (DS) is an approximately 1/3-scale prototype of the full-scale ISIS objective system (OS). In its own right, the DS is a very large airship, with an overall length of 492 feet (150 m) and a diameter of 164 feet (50 m). The contract for developing the DS was awarded in 2009 to the team of Lockheed Martin (for the airship) and Raytheon (for the radar).

The AESA radar for the DS airship is comprised of two arrays of lightweight, digital transmitter/receivers bonded to a cylindrical structure measuring 26.2 feet (8 m) high and 72.2 feet (22 m) in diameter. DARPA reported, “these sizes will be large enough to validate manufacturing and calibration for the objective system and will provide an early glimpse of the air and ground target tracking performance possible with an operational system.” The DS radar system had a total mass is about 6,600 pounds (2,994 kg).

Lockheed Martin was developing a 200 kW solar array for the DS.

The original plan was for a one-year DS flight test program that culminated in a three-month on-station flight demonstration in FY 2013.

In October 2012, the General Accountancy Office (GAO) reported:

> “ISIS has experienced technical challenges stemming from subsystem development and radar antenna panel manufacturing. Consequently, earlier this year DARPA temporarily delayed airframe development activities, and instead will mainly focus on radar risk reduction activities. During this time period, the ISIS team will develop an airship risk reduction plan and conduct limited airship activities. Based on the radar and airship risk reduction studies, DARPA will reassess the future plan for ISIS with the Air Force.”

The USAF RDT&E budget for FY 2016 reported that the ISIS program was “complete in FY 2015.” A total of $471 million had been spent on the program from 2007 through 2012 with $15.2 million of additional USAF funding in FY 2013 and 2014. No airship was built.

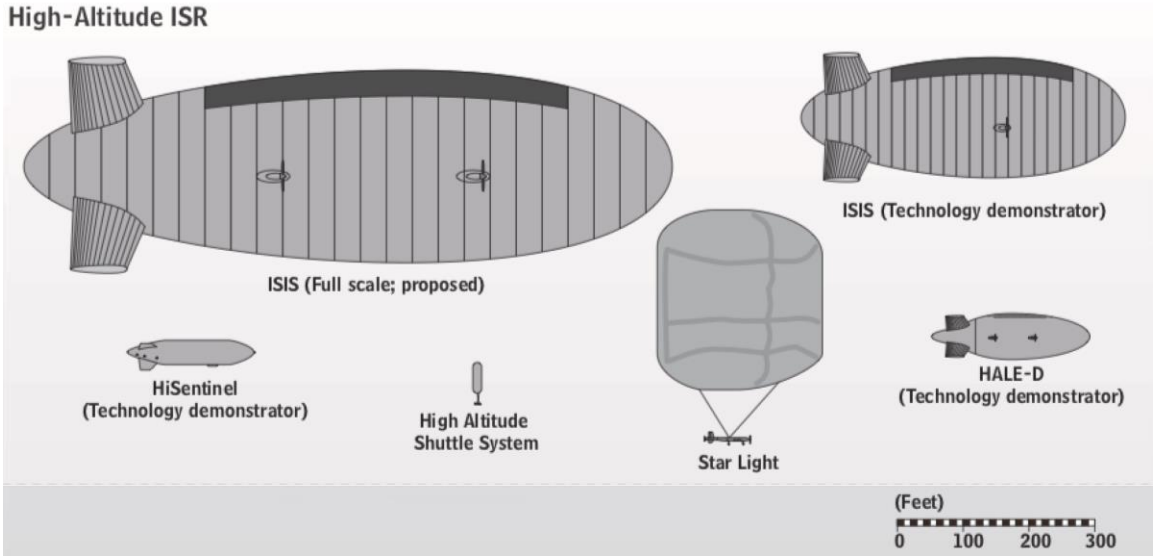
5. The full-scale ISIS objective system (OS)

The full-scale ISIS airship would have been huge, with an overall length of 984 feet (300 m) and a diameter of 328 feet (100 m). In comparison, the Hindenburg Zeppelin had a length of 803.8 feet (245 m) and a diameter of 135.1 feet (41.4 meters).

The massive cylindrical radar antenna inside the hull would have provided 360° azimuth coverage with an array measuring 118 feet (36 m) in height and 166 feet (50.5 m) in diameter.

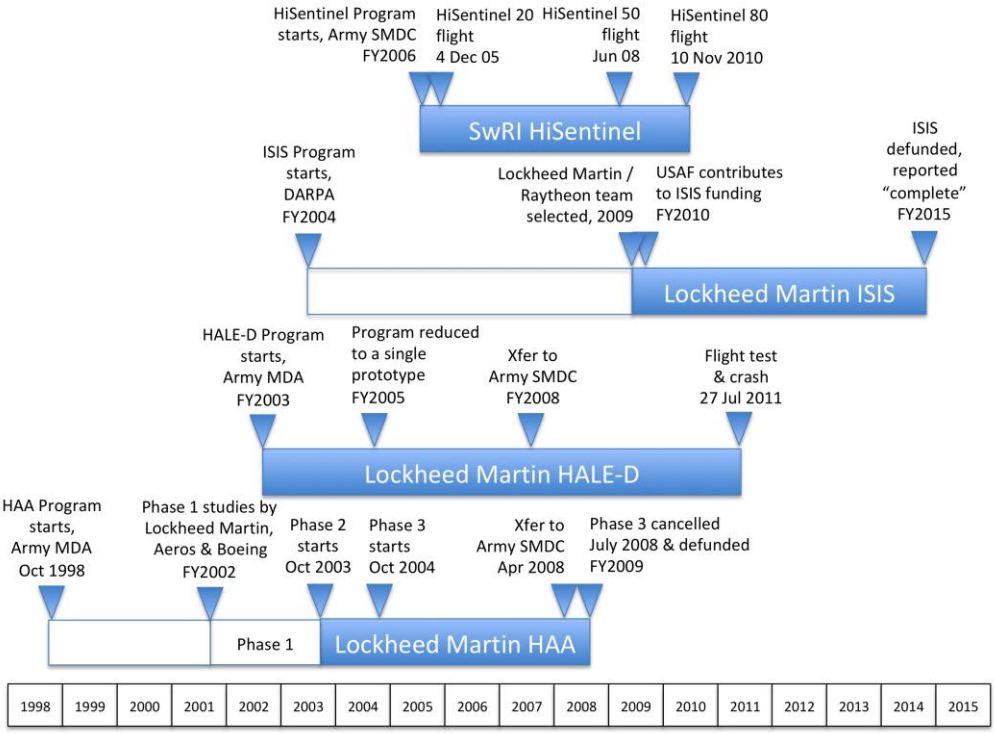
The solar-powered ISIS OS was designed to operate for up to 10 years as a “pseudo-satellite” without having to land for maintenance or refueling, while demonstrating a 99% average annual availability of mission systems. The airship would have been launched and recovered at a base in the continental U.S. and would not have required any in-theater support facilities.

No ISIS OS airship was built.



Relative scale of ISIS DS and OS airships and other U.S. ISR airships and two-component balloons. Source: Congressional Budget Office, Nov. 2011

6. Timelines for US military high altitude airship programs



Timelines for the US Military High Altitude Airship Programs

7. For more information

- DARPA's ISIS webpage is here: https://www.darpa.mil/program/integrated-sensor-is-structure
- Tim Clark, "DARPA Investment in Large Apertures," DARPA Strategic Technology Office: https://kiss.caltech.edu/workshops/apertures/presentations/clark.pdf
- "DARPA Contracts Lockheed Martin to Build High Altitude, Long Endurance Airship," Defense Update, 28 April 2009: https://defense-update.com/20090428_isis-hale.html
- Tim Clark and Esko Jaska, "Million element ISIS array," 2010 IEEE International Symposium on Phased Array Systems and Technology, Waltham, MA, 2010, pp. 29-36, DOI: 10.1109/ARRAY.2010.5613396: https://www.semanticscholar.org/paper/Million-element-ISIS-array-Clark-Jaska/efeac6e9981aedbd08d06d0a5e35b55d2daa5bcc

- “12 Miles High: An Integrated Airship – Radar on the Horizon,” MITRE, March 2010: https://www.mitre.org/publications/project-stories/12-miles-high-an-integrated-airshipradar-is-on-the-horizon
- “Recent Development Efforts for Military Airships,” Congressional Budget Office, November 2011: https://www.cbo.gov/sites/default/files/112th-congress-2011-2012/reports/11-01-Airships.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

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
    - Lockheed Martin – HALE-D
- *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/