ISL Aeronautical & Space Systems (formerly Bosch Aerospace Inc.) – UAV blimps and tethered aerostats

Peter Lobner, updated 27 October 2023

1. Introduction

James Boschma founded Bosch Aerospace Inc. in 1995 in Huntsville, AL. At about that time, the US Army contracted with Bosch Aerospace to develop a lighter-than-air (LTA) unmanned aerial vehicle (UAV) that became known as the SASS LITE (Small Airship Surveillance System, Low Intensity Target Exploitation), which could be configured for a wide variety of applications such as border surveillance, waterway surveillance, search and rescue, missile data collection, and radio relay. The first SASS LITE flew in 1996. Bosch Aerospace built six SASS LITE unmanned blimps, with envelope volumes up to 977 m^3 (34,500 ft^3).

In 1998, Naval Air Warfare Center - Aircraft Division, Patuxent River, Maryland awarded Bosch Aerospace a Phase I (six month) SBIR (Small Business Innovative Research) contract to build and test a full-scale prototype aircraft cycloidal propeller. In October 1998, Bosch Aerospace became the first company in more than 50 years to build and run an aircraft cycloidal propeller.

Information Systems Laboratory (ISL) Aeronautical & Space Systems acquired Bosch Aerospace in 2002, with Jim Boschma remaining as Vice President and head of the ISL Bosch Aerospace Division thru 2008. ISL built two more UAV blimps for defense applications.

- The first was the Airborne Communication Extender (ACE), with a volume of 2,067 m^3 (73,000 ft^3). It was delivered in 2004.
- The second was larger, with a volume of 3,709 m^3 (131,000 ft^3).

The even larger Advanced Unmanned Reconnaissance Airship (AURA), with a volume of 5,663 m^3 (200,000 ft^3), was in the planning stage circa 2013, but was not developed. Bosch Aerospace Inc. and ISL Bosch Aerospace Division delivered a total of eight UAV blimps.

From 2002 to 2011, James Boschma invented several aerostat deployment systems, including the Rapidly Elevated Aerostat Platform (REAP), which was developed by ISL Aerospace Division.

Today, ISL no longer is in the unmanned airship or aerostat business. Their current business is described on the company's website here: https://www.islinc.com

2. Bosch Aerospace SASS LITE (Small Airship Surveillance System, Low Intensity Target Exploitation)

The SASS LITE is a small UAV blimp that was built in single- and two-engine configurations in a range of gas envelope sizes from 340 m^3 (12,000 ft^3) to 977 m^3 (34,500 ft^3). The SASS LITE operates at speeds up to 72 kph (45 mph), with slower cruise speeds in the range from 40 to 56 kph (25 to 35 mph). These airships were designed to operate at maximum altitude of 1,524 to 1,829 m (5,000 to 6,000 ft) above ground level (AGL) with mission altitudes typically being at lower altitudes. The maximum AGL altitude was limited by the size of the pressure control air ballonet. Higher altitudes could be achieved with a proportionally larger air ballonet.

The SASS LITE initially was designed and tested with an air-cooled Volkswagen Beetle engine, and later was powered by a more dependable 60 kW (80 hp) Rotax engine. The twin engine versions have vectored thrust to enhance launch and recovery with small ground crews. Maximum ground crew size is 5 individuals.

Operating characteristics of the Bosch Aerospace SASS LITE UAV blimps (varies by design)

Parameter	SASS LITE UAV blimp
Payload, max	190 to 225 kg (419 to 496 lb)
Speed, max	72 kph (45 mph)
Speed, cruise	40 to 56 kph (25 to 35 mph)
Altitude, max	1,524 to 1,829 m (5,000 to 6,000 ft) AGL
Altitude, mission	762 to 1,067 m (2,500 to 3,500 ft) AGL
Endurance	12 to 24 hours

One novel application described by Bosch Aerospace in 2001 was for sea mine detection. For this mission, the unmanned blimp would be programmed to fly a grid pattern over the area of interest and use a laser scanner to search for mines. The blimp also could be used to drag the surface with a mine-detonating sled. In both cases, the SASS LITE unmanned blimp can reduce the risk of very hazardous mine detection / clearance activities.

Single engine Bosch Aerospace SASS LITE.
Source: PopMech Magazine, September 1996, p. 19

Source: PopSci Magazine, October 1996, p. 11

In 2013, Defence R&D Canada reported on an industry survey the Canadian government had sponsored to examine the use of UAVs as a means to enhance the Canadian Force's ability to conduct Communication, Command, Control, and Computers Intelligence Surveillance and Reconnaissance (C4ISR) in Canada's maritime and Arctic regions. The survey examined both COTS (commercial off-the-shelf) and MOTS (military off-the-shelf) heavier-than-air and lighter-than-air unmanned platforms.

One of the "classical airship" UAV platforms examined in the 2013 Canadian survey was the Bosch Aerospace SASS LITE. The survey reported the following:

> "It is equipped with a triple redundancy radio control system. Its primary control link is in the "L" band microwave frequencies. An auto-track dish antenna is used to provide direct control to 100 kilometers. Video downlink is also accomplished in this frequency range. The "L" band data links are backed-up with a function-matched "P" band data link system, which is equipped with Yaggi directional antennas. These systems are interfaced to a digital autopilot and GPS navigator, which facilitates autonomous navigation beyond radio line of sight. An independent, battery-powered, multi-function Flight Termination System (FTS) is carried on the nose ring of the airship. This FTS system allows for engine shutdown, ballast, and helium vent control, and includes a hot wire burn system. The shutdown and vent control features allow for "free balloon" operations to a desirable landing site, while the burn wire can be activated to destroy the ship in flight if mandated by military necessity. Electronics are jam resistant and the primary system is military hardened.
>
> An advanced digital switching and telemetry system allows the ground operators to control all airship functions and the payload. Three 9,600 baud digital links are embedded in the data link system to facilitate control of the airship. Automated control devices such as pressure control, vents, and auto-navigation can be overridden by the remote pilot.

> SASS LITE can carry a variety of sensors, radio relays, scientific instruments, or electronic warfare devices. Its payload attaching system facilitates fast change-out of payloads, and installation of a wide range of payload shapes, volumes, and weights. The current airship carries loads of approximately 400 lb (190 Kg) and it is capable of greater loads with reduced fuel loads. It has carried multiple IR and visible cameras on independent gimbals on a single mission, as well as a combination multi-spectral payload that included radar, IR, and visible light sensors interfaced via a software bridge. Power for payloads is provided by two onboard alternators delivering a total of 3,250 watts at 24 VDC."

At the time of the Defence R&D Canada survey (2013), Bosch Aerospace had built six SASS LITE UAV airships, with the general characteristics listed in the following table.

Physical characteristics of the Bosch Aerospace SASS LITE UAV blimps

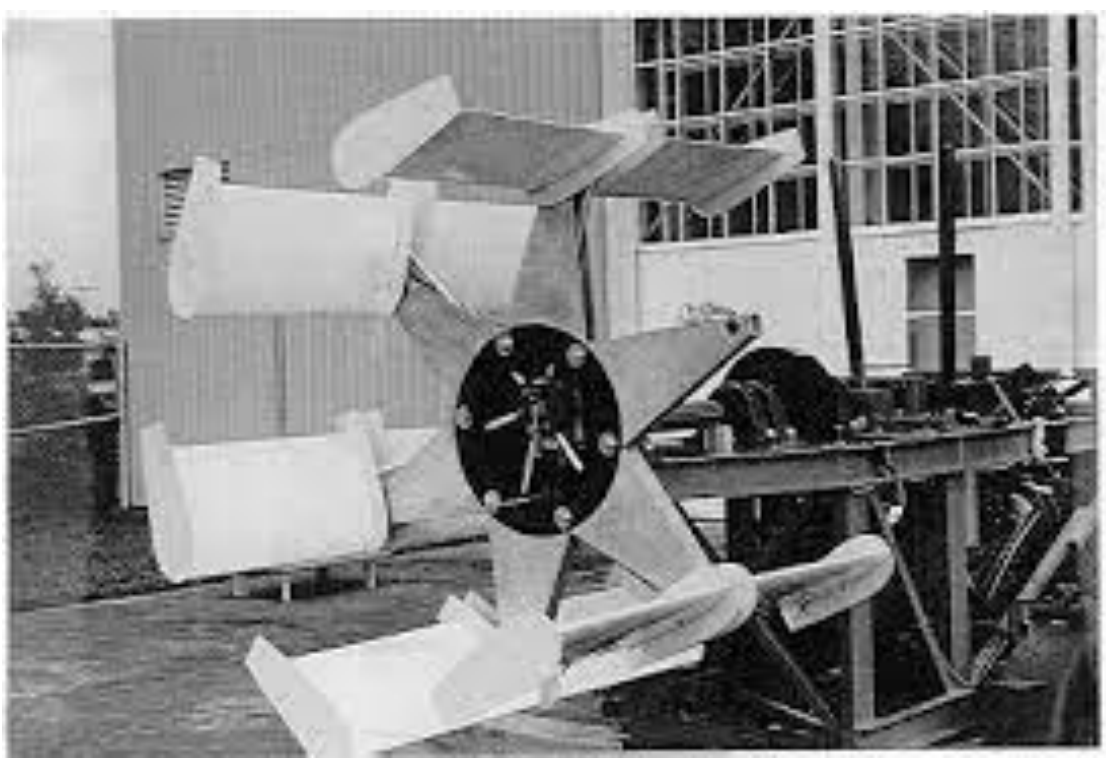
Ship	Envelope Volume	Dimensions	Engine
Ship No. 1 & 2	340 m^3 (12,000 ft^3)	18 x 6.1 m (60 x 20 ft)	Single 31.3 kW (42 shp) engine w/ fixed prop
Ship No. 3	481 m^3 (17,000 ft^3)	22 x 6.4 m (72 x 21 ft)	Same as above
Ship No. 4	623 m^3 (22,000 ft^3)	25 x 6.7 m (82 x 22 ft)	Same as above
Ship No. 5	850 m^3 (30,000 ft^3)	28 x 7.6 m (92 x 25 ft)	Two engines w/ thrust vectoring props
Ship No. 6	977 m^3 (34,500 ft^3)	30.5 x 7.6 m (100 x 25 ft)	Same as above


Bosch SAAS LITE. Source: Defence R&D Canada, March 2013

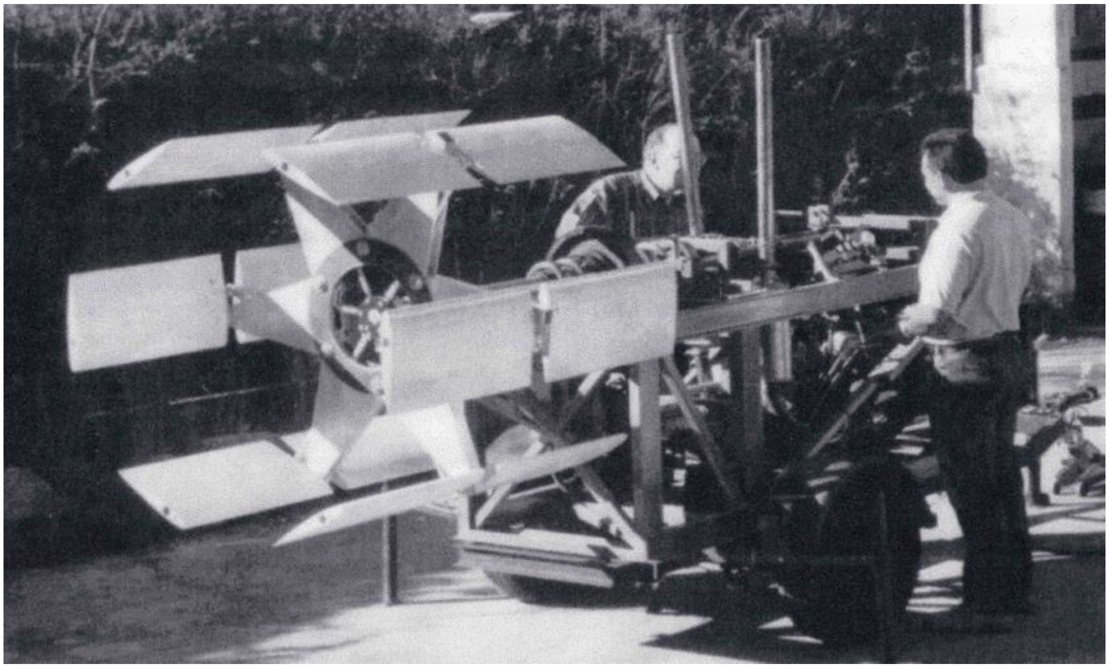
3. Aerial cycloidal propeller development at Bosch Aerospace (1997 – 1998)

In November 1997, the U.S. Department of Defense issued a Request for Proposal (RFP) for a novel propulsion unit for a remotely piloted aircraft that did not require rotors, tilt-rotors or vectored thrusters. James Boschma, of Bosch Aerospace in Huntsville, Alabama, submitted a proposal using a Curtate cycloidal propeller, which was selected because it provides the best hover performance and excellent flight performance up to speeds up to about 120 knots. In May 1998, the Naval Air Warfare Center - Aircraft Division, Patuxent River, Maryland awarded Bosch Aerospace a Phase I (six month) SBIR (Small Business Innovative Research) contract to build and test a full-scale prototype Curtate cycloidal propeller. Roy P. Gibbens served as a consultant to Bosch Aerospace on this project.

On 31 October 1998, Bosch Aerospace became the first company in more than 50 years to build and run an aircraft cycloidal propeller. Their 4-foot (1.2-m) diameter, six-bladed prototype cycloidal propeller is shown in the following photos.



Bosch Aerospace prototype six-bladed cycloidal propeller.
Source: Roy P. Gibbens



Bosch Aerospace prototype six-bladed cycloidal propeller.
Source: Roy P. Gibbens

Gibbens reported, “Following the first start in Huntsville, AL, the propeller was transported to the Raspet Flight Research Center at Mississippi State University (MSU) in Starkville, MS. Qualifying test were run and approved by the Navy and a follow-on SBIR (contract) was awarded for further testing. Under the new SBIR, the metal blades were replaced with composite blades. Extensive testing was accomplished under the direction of Mr. Boschma and the Raspet director, Dr. Bennett.”

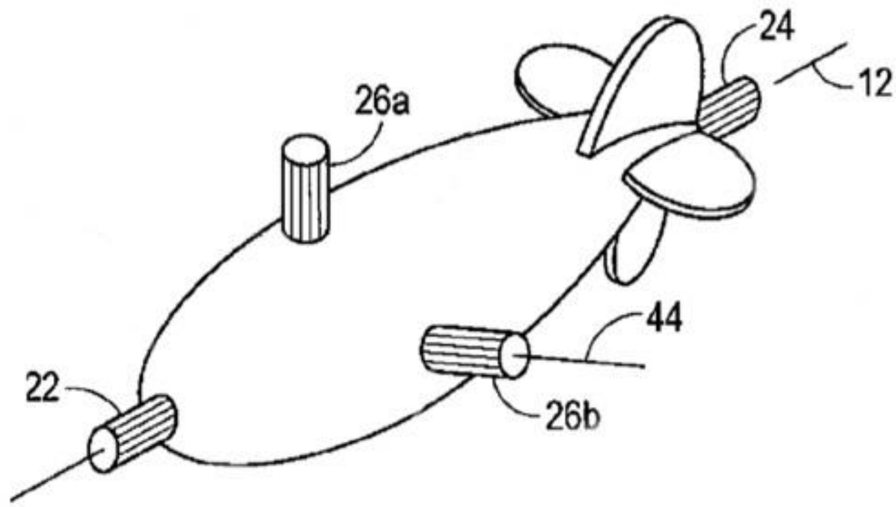
In their November 1998 Final Report, Bosch Aerospace provided the following summary of their test results:

> “The cycloidal propeller tests were designed to accomplish two major goals, to measure thrust, and to assess thrust vector capability…….”
>
> “Thrust measurements were taken at various RPMs in two orientations, 90° up, and then 90° down from horizontal. Vector assessment was made throughout the 360° arc. Downward thrust was approximately 20% below projections. Upward thrust in lower RPM ranges was 3% above projections. However, as RPM increased thrust decreased to the 20% below projections

> level. Reduced data showed that thrust varied from approximately 10.88 lb/Hp at low RPM, to 8.4 lb/Hp at high RPM."

Bosch Aerospace built a test airship with three cycloidal propellers, however, project funds were cut in 1998 and it never flew. Nonetheless, the project demonstrated the high thrust / horsepower and 360° thrust vectoring performance of the cycloidal propeller as well as its low noise characteristics and responsiveness to rapid control changes.

Years after its cycloidal propeller development program ended, Bosch Aerospace's parent, Information Systems Laboratories (ISL), was granted patent US7264202 B2 for a "tri-cycloidal airship," which used cycloidal propellers to provide propulsion and control on all three flight axes (pitch, roll, yaw). Callum Sullivan, the Bosch Aerospace design engineer, was listed as the inventor and the patent was assigned initially to ISL. In 2011, the patent was reassigned to Boschma Research Inc.



Legend: *Cycloidal propulsive units (22, 24 & 26), longitudinal axis (12), transverse horizontal axis (44), Transverse vertical axis not shown.*

Bosch Aerospace cycloidal propeller airship concept.
Source: Adapted from Patent US 7264202 B2 Fig 1

4. ISL Bosch Aerospace unmanned Airborne Communication Extender (ACE) airship

In 2003, a joint program sponsored by the Army Research, Development, and Engineering Command (RDECOM), Aviation and Missile Command (AMCOM), and the Naval Air Warfare Center established requirements for an unmanned airship that could provide improved communications coverage for military units in the field of combat, including the ability to keep up with moving convoys.

In January 2004, ISL Bosch Aerospace was awarded an approximately $1.2 million contract to deliver a unmanned airship that could support various payloads for reconnaissance, surveillance, target acquisition and communications missions and provide "exceptional endurance."

The resulting product was the ACE UAV blimp, which was about twice the size of the largest SASS LITE blimp. ACE originally was named "Shirley," after Shirley Duffie. an analyst working on the project

The general arrangement of ACE blimp was similar to the design shown in Patent US7163177, Figs. 1, with a single ballonet, cruciform tail surfaces, suspended engine (12) and shrouded propeller (16).

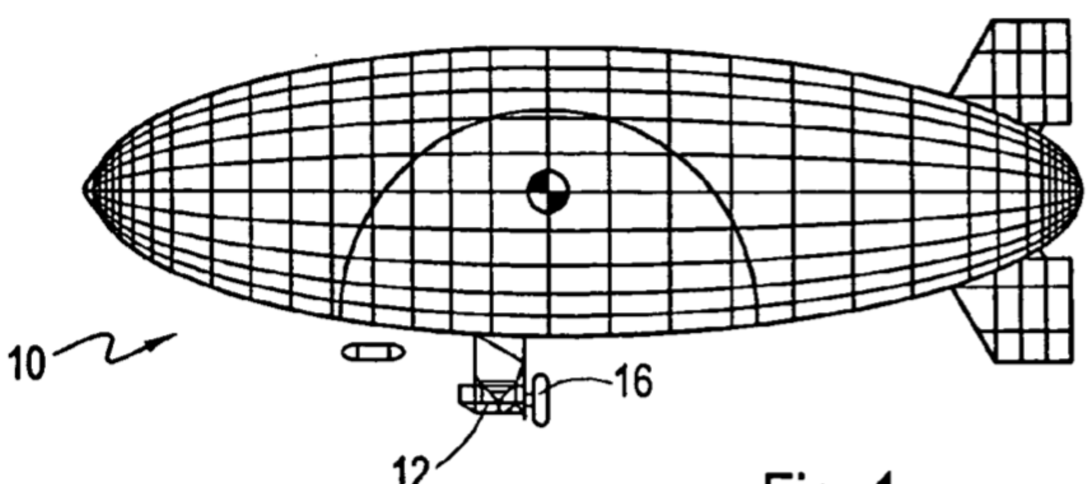


Fig. 1

Blimp general arrangement. Source: US7163177, Figs. 1

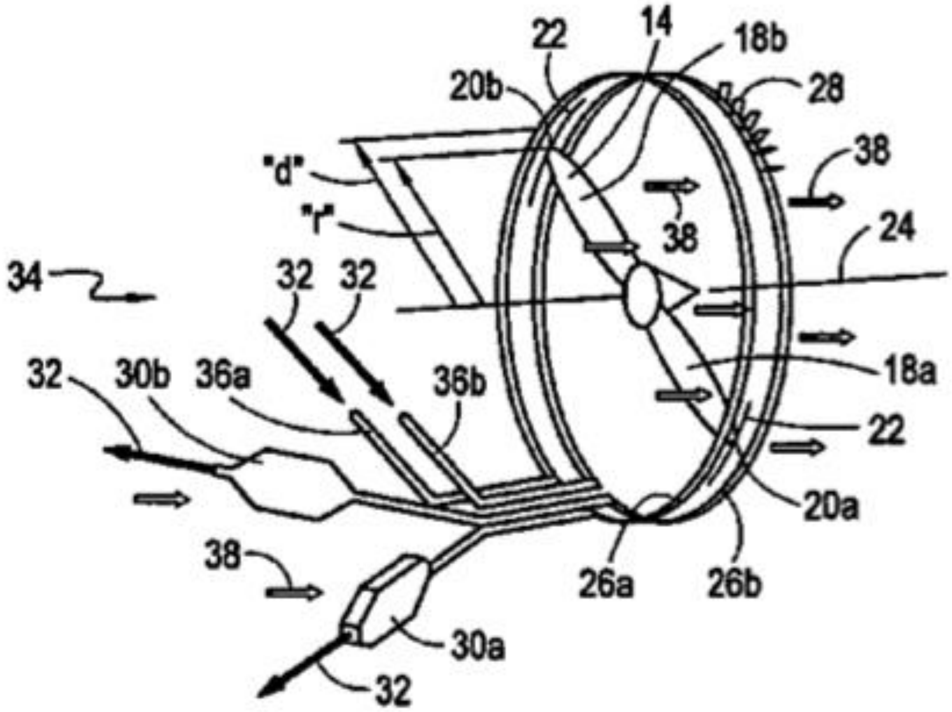
General characteristics of the ISL Bosch ACE UAV blimp

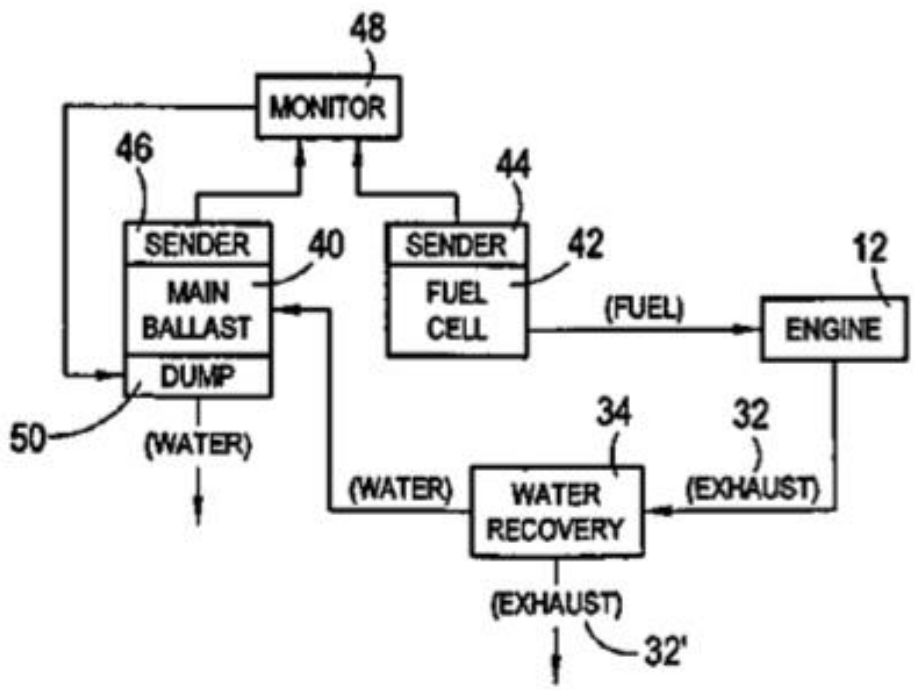
Parameter	ACE UAV blimp
Length	38.1 m (125 ft)
Diameter	10.7 m (35 ft)
Volume	2,067 m^3 (73,000 ft^3) with a single ballonet
Height, overall	15.2 m (50 ft)
Propulsion system	1 x diesel or gas aircraft engine rated @ 164 kW (220 shp), with exhaust water recovery system and reversible pitch propeller
Payload power system	4 kW @ 28 V
Payload, max	204 kg (450 lb)
Speed, max	83.7 kph (52 mph)
Speed, cruise	40 to 72 kph (25 to 45 mph)
Windspeed, max to launch	24 kph (15 mph)
Altitude, max	3,048 m (10,000 ft) AGL
Altitude, mission	152 to 2,286 m (500 to 7,500 ft) AGL
Endurance	24 to 30 hours (sources vary)

ACE is equipped with communications equipment and a flightTEK™ mission computer from Geneva Aerospace Inc. The flightTEK™ mission computer enables the blimp to fly a pre-programmed mission autonomously from launch to recovery. When needed, a remote operator at a ground control station can update the mission plan in flight or take control and pilot the blimp remotely.

The onboard power system can provide up to 4 kW of power, enough to simultaneously support communications data link and surveillance systems.

The engine is equipped with an exhaust water recovery system, which is described in Patent US7163177. As shown in the following patent diagrams, engine exhaust gas (32) enters the system (36a, 36b) and is directed to cooling tubes (26a, 26b) arranged in the plane of the propeller and outside the tip path. Exhaust gas cooling continues in the intercoolers (30a, 30b) before the dry exhaust gas (32) is discharged to the atmosphere. Water condensed from the cooled exhaust is collected and pumped to a ballast tank (40). The mass of water collected partially balances the mass of fuel consumed by the engine, thereby reducing the rate at which overall buoyancy (or static heaviness) changes during engine operation.





Exhaust water recovery system schematic and process flow diagrams.
Source: US7163177, Figs. 2 & 3

ACE was delivered to the US Army in 2004 and was tested by RDECOM at the Navy's former blimp facility at Lakehurst, NJ.

Inside the ACE UAV blimp's non-rigid gas envelope.
There are no internal catenary curtains.

ACE UAV blimp in Hangar #6 at Lakehurst.
Source, both images: Screenshots from ISL Bosch video (2006)

Attaching a payload module to mounting rails along the bottom of the gas envelope.

ACE UAV blimp rollout from Lakehurst Hangar #6.
Source, both images: Screenshots from ISL Bosch video (2006)

ACE UAV blimp rollout on the mobile mooring tower (above & below).
Source, both images: Screenshots from ISL Bosch video (2006)

ACE UAV blimp on the mobile mooring tower prior to launch with Lakehurst Hangars #5 and #6 in the background

Closeup of the suspended engine gondola and smaller mission pod. Source, both images: Screenshots from ISL Bosch video (2006)

ACE UAV blimp in flight at Lakehurst.

ACE on approach to landing at Lakehurst.
Source, both images: Screenshots from ISL Bosch video (2006)

This photo from the ISL website appears to be the ACE airship on its mobile mooring. Source: ISL

5. ISL Bosch Aerospace Advanced Unmanned Reconnaissance Airship (AURA)

The 2013 Defence R&D Canada survey reported that ISL Bosch had developed a design for a substantially larger UAV airship known as AURA.

This large UAV airship was designed to carry 1,363 kg (3,000 pounds) of radar and optical payloads to a medium altitude of 3,048 m (10,000 feet) for mission durations of up to 36 hours. Mission control would use the same radio frequency control links as used for SASS LITE. An additional direct satellite communications link would support a continuous, real-time data link beyond radio line-of-sight.

It appears that AURA was not developed.

General characteristics of the ISL Bosch Aerospace AURA UAV blimp

Parameter	AURA UAV blimp
Length	48.8 m (160 ft)
Volume	5,663 m^3 (200,000 ft^3)
Propulsion	Twin engines with thrust vector control, derived from SASS Lite design
Payload, max	1,361 kg (3,000 lb / 1.5 tons)
Speed, max	88.5 kph (55 mph)
Speed, cruise	64.4 kph (40 mph)
Altitude, max	3,048 m (10,000 ft) AGL
Range, max	Trans-oceanic flight when equipped with auxiliary fuel tanks
Endurance	36 hours

6. ISL Bosch Aerospace's last UAV blimp

Little is known about ISL's last UAV blimp except that it likely was one of two blimps developed while Jim Boschma was the head of the ISL Bosch Aerospace Division (thru 2008). On their website, ISL reported that their largest unmanned blimp had an envelope volume of 3,709 m^3 (131,000 ft^3), which is almost twice the volume of ACE, but significantly smaller than AURA.

7. Airship Shelter

As described in Patent US2008/0110105A1, Jim Boschma and an ISL team developed a design and method for building a protective airship hangar in the field, as follows:

> "A storage facility for an airship (22) includes a wall that is made from a plurality of box-like ISO containers (24, 26). The wall surrounds an area on the ground (18), and a semi-cylindrical member (16, a roof) is affixed to the top of the wall (12, 14). This creates an enclosed volume over the area (18) for the storage and protection of the airship. Buttresses for supporting the wall can be made from additional containers, and restraints can be used to secure the containers of the facility to each other."

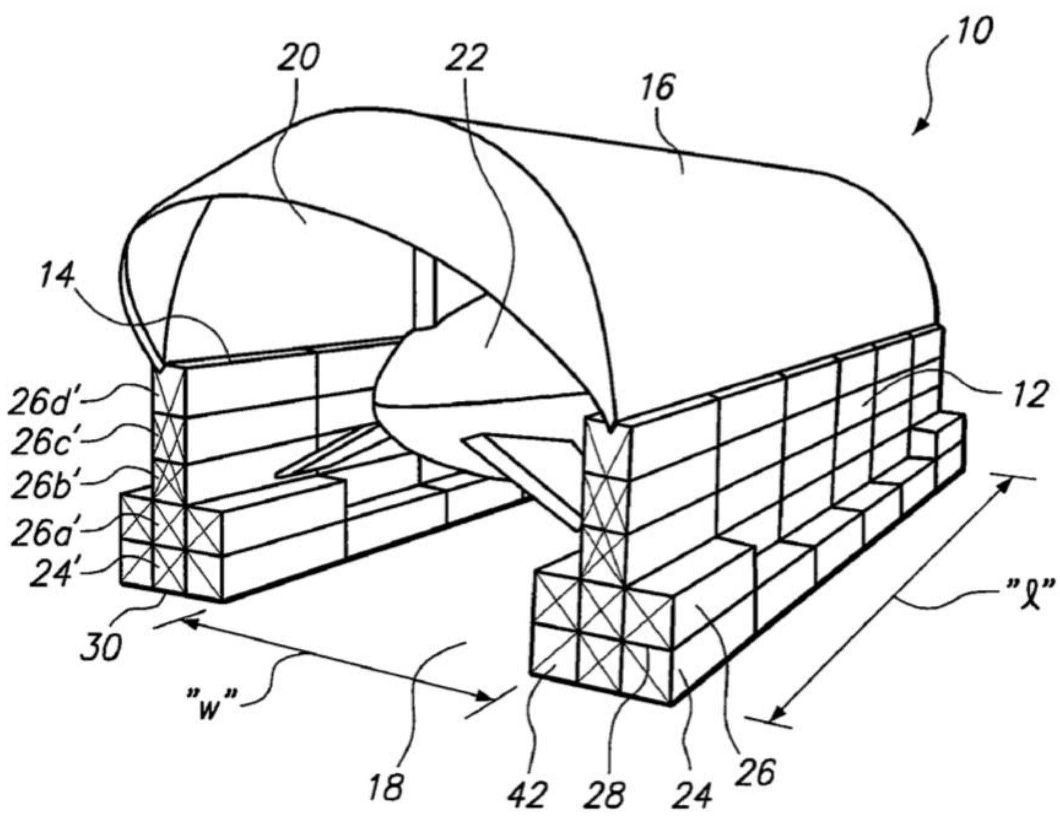


FIG. 1

Airship shelter. Source: US2008/0110105A1 (2008)

8. ISL Bosch Rapid Deployment Elevating Platform (REAP) aerostat

ISL Bosch has manufactured and operated aerostats ranging in volume from 74 to 2,690 m^3 (2,600 to 95,000 ft^3). The firm offered customized, fast-deploying REAP mobile aerostat systems invented by Jim Boschma. The REAP aerostat was launched from an Integrated Mooring System (IMS) and could self-deploy in as little as 3 minutes, even in relatively high winds. Typical payloads include electro-optical / infrared (EO/IR), signal intelligence (SIGINT), or radio-frequency (RF) relay. The design and operation of the REAP system is described in Patent US2012/0181380A1.

ISL integrated customer specified sensor and communications systems with fiber optic and/or radio frequency (RF) data links. ISL manufactured payload support systems and ground control stations (GCS) ranging from brief case size to an S-250 / S-280 type tactical aluminum insulated shelter designed for extreme climates. This type of shelter can be truck-mounted. Aerostat customers have included the US and UAE military, law enforcement, and commercial customers

In June 2012, the Government Accountability Office (GAO) reported that the US military had acquired and deployed three REAP XL-B aerostats. The Army provided $4.7 million in FY11 funding and used the aerostat to demonstrate their ability to provide persistent surveillance while operating at more than 305 m (1,000 ft) AGL. Two REAP-XL B prototype aerostats were deployed and tested in Afghanistan. The Army systems could be launched from the back of a High Mobility Multipurpose Wheeled Vehicle (Humvee) by two people in 10 minutes. The Navy provided $668,000 in FY10 funding and used one unit as an extended communications relay system operating from a shore base and flying at altitudes up to 305 m (1,000 ft) AGL. Total REAP-XL B program funding was $5.3 million.

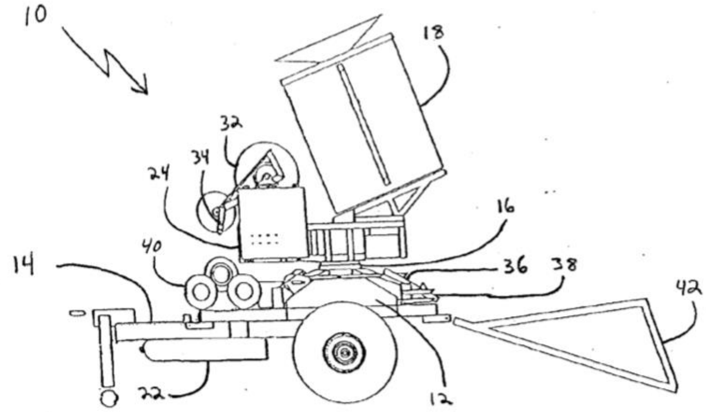


Fig. 1

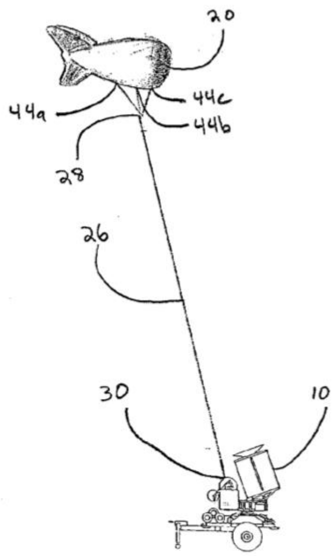


Fig. 2

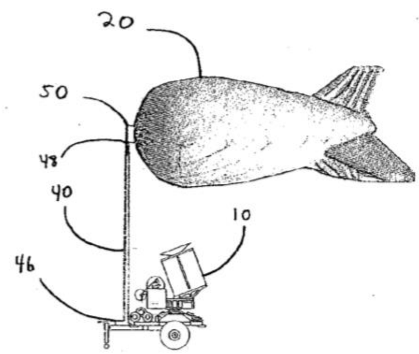
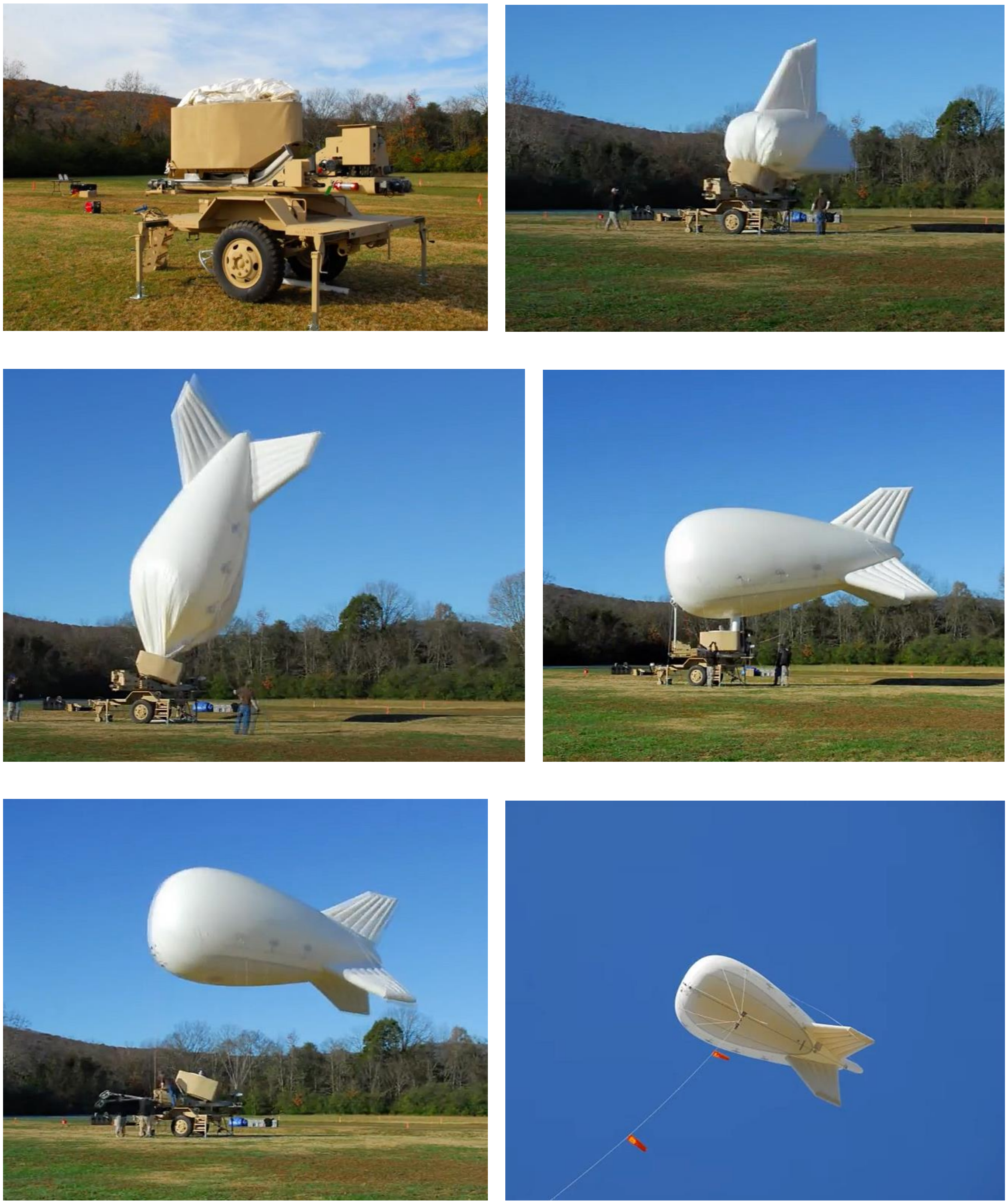


Fig. 3

The REAP IMS (10) and aerostat (20).
Source: US2012/0181380A1 (2012)

General characteristics of an ISL Bosch REAP aerostat

Parameter	REAP aerostat
Length	9.5 m (31 ft)
Volume	74 m^3 (2,600 ft^3)
Payload, max	16 kg (35 lb)
Altitude, max	305 m (1,000 ft) AGL
Endurance	10 days



A REAP aerostat deploys from an Integrated Mooring System.
Source: Screenshots from ISL Bosch video (2011)

8. For more information

- "TV blimp flies as baggage," Popular Mechanics, September 1996, p. 19: https://books.google.com/books?id=RGYEAAAAMBAJ&printsec=frontcover&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false
- "Portable airship," Popular Science, October 1996, p. 11: https://books.google.com/books?id=B1r9RiyD6HgC&printsec=frontcover#v=onepage&q&f=false
- "Final Report – Cycloidal Propulsion for UAV VTOL Applications," Bosch Aerospace, 15 November 1998: https://apps.dtic.mil/sti/pdfs/ADA370541.pdf
- Roy P. Gibbens, James Boschma & Callum Sullivan, "Construction and testing of a new aircraft cycloidal propeller," paper AIAA No. 99-3906, presented at the 13th Lighter-Than-Air Systems Technology Conference, 28 June – 1 July 1999: https://arc.aiaa.org/doi/abs/10.2514/6.1999-3906
- James Boschma, "Unmanned airship development and remote sensing applications," Proceedings of the SPIE, Volume 4571, Sensor Fusion and Decentralized Control in Robotic Systems IV, pp. 45-49, October 2001: https://doi.org/10.1117/12.444168
- "Shirley the Spy," Inside the Army, 23 August 2004: (originally www.Inside Defense.com), now available at: https://www.jstor.org/stable/24821817?read-now=1&refreqid=excelsior%3A48259e924872cb6dfa01623a707cd45e&seq=3
- Trevor Monk, "New Technology from Geneva Aerospace Transforms Blimps into Satellite-Quality Communications Links for Army Units; flightTEK System Makes the ACE Airship Autonomous," Announcements: 2000-2005, 1 December 2004: https://spot.colorado.edu/~dziadeck/airship/announcements2000.htm
- Ian Glenn, et al., "Survey of COTS-MOTS Lighter Than Air Platforms and Communications Relays," Section 3.2.5, "BOSCH Aerospace Small Airship Surveillance System (SASS)," pp. 24 – 25, Defence R&D Canada, March 2013: https://zbook.org/read/d154_s-of-cots-mots-li-than-air-p.html

- "Unmanned Aircraft Systems – Reference Section," DocPlayer: https://docplayer.net/54527320-Unmanned-aircraft-systems.html
- "Future Aerostat and Airship Investment Decisions Drive Oversight and Coordination Needs," Government Accountability Office (GAO), Report GAO-13-81, October 2012: https://www.gao.gov/assets/gao-13-81.pdf
- "S-280 C/G SHELTER," AAR: https://www.aarcorp.com/50375-xxx-s-280-c/g-shelter/

Videos

- "ACE Army Airship Blimp Dirigible UAV RC," (3:03 minutes), ISL Bosch Aerospace video posted by pilotcoolbiz, 20 August 2006: https://www.youtube.com/watch?v=udQoRFIYiMk
- "REAP XL-B Teaser.mpg," (1:35 min), aerostat launch, posted by peterkvs, 6 December 2011: https://www.youtube.com/watch?v=g1L5rxareVA

Patents

- US7264202 B2, Tri-cycloidal airship," Inventor: Callum Sullivan, Filed: 1 November 2005, Granted 4 September 2007, Assignee: Boschma Research Inc.: https://patents.google.com/patent/US7264202B2/en

Jim Boschma is listed as the inventor or co-inventor on all of the following patents, which are assigned to ISL Inc.

- US2012/0181380A1, "System for providing Rapidly Elevated Aerostat Platform," Filed 29 November 2011, Granted 15 January 2013, Assignee: ISL Inc.: https://patents.google.com/patent/US20120181380A1/en?oq=20120181380
- US7503277B2, "Aerostat inflator," Filed 5 October 2006, Granted 17 March 2009, Assignee: ISL Inc.: https://patents.google.com/patent/US7503277B2/en?oq=7503277

- US2008/0110105A1, "System and method for establishing a protected work and storage space," Filed 10 November 2006, Published 15 May 2008: https://patents.google.com/patent/US20080110105A1/en?oq=•US2008%2f0110105
- US2008/0083848A1, "Aerostat inflator," Filed 5 October 2006, Published 10 April 2008: https://patents.google.com/patent/US20080083848A1/en?oq=•US2008%2f0083848
- US7275714B2, "Airship docking mechanism," Filed 1 November 2005, Granted 2 October 2007, Assignee: ISL Inc.: https://patents.google.com/patent/US7275714B2/en?oq=US7275714
- US7163177B1, "Airship ballast system," Filed 23 February 2005, Granted 16 January 2007, Assignee: ISL Inc.: https://patents.google.com/patent/US7163177B1/en?oq=•US7163177
- US6883749B2, "Aerostat deployment apparatus," Filed 16 December 2003, Granted 26 April 2005, Assignee: ISL Inc.: https://patents.google.com/patent/US6883749B2/en?oq=•US6883749
- US2004/0217233A1, "Aerostat deployment apparatus," Filed 16 December 2003, Published 4 November 2004: https://patents.google.com/patent/US20040217233/en
- US6715712B2, "Aerostat deployment apparatus," Filed 17 May 2002, Granted 6 April 2004, Assignee: ISL Inc.: https://patents.google.com/patent/US6715712B2/en?oq=•US6715712
- US2002/0171006A1, "Aerostat deployment apparatus," Filed 17 May 2002, Published 21 November 2002: https://patents.google.com/patent/US20020171006A1/en?oq=•US2002%2f0171006

Other *Modern Airships* articles

- *Modern Airships - Part 1*: https://lynceans.org/all-posts/modern-airships-part-1/
- *Modern Airships - Part 2*: https://lynceans.org/all-posts/modern-airships-part-2/

    - Roy P. Gibbens – AirLighter and cycloidal propellers
- *Modern Airships - Part 3*: https://lynceans.org/all-posts/modern-airships-part-3/