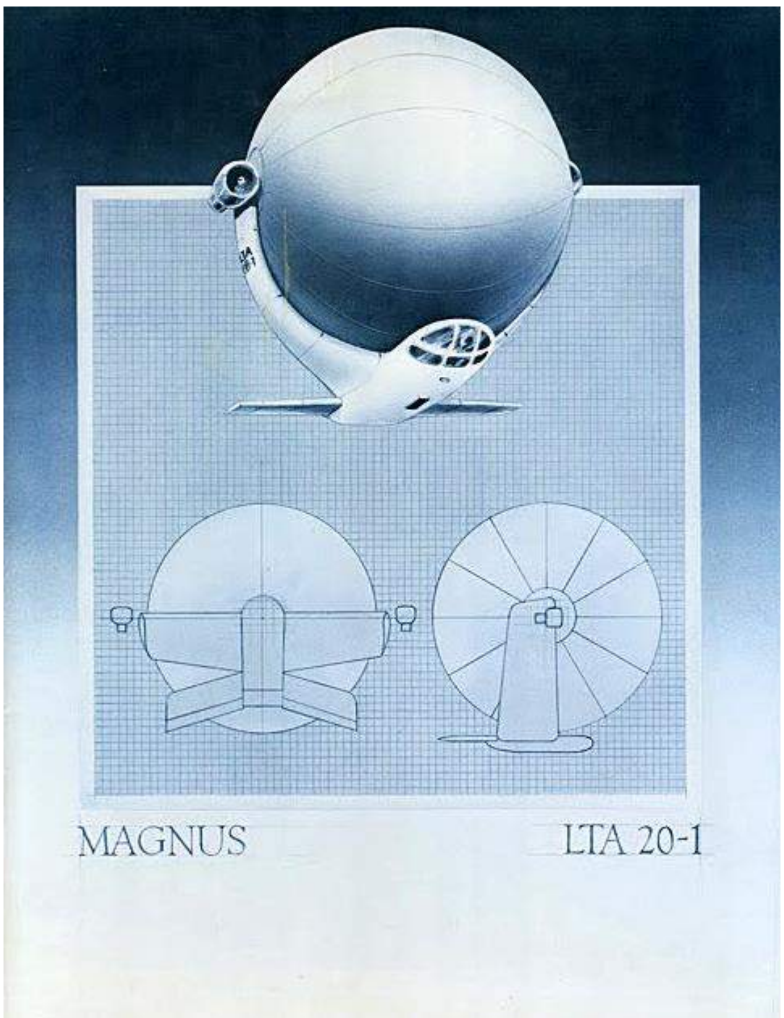
Magnus Aerospace Corp. - hybrid spherical airship

Peter Lobner, updated 9 March 2022

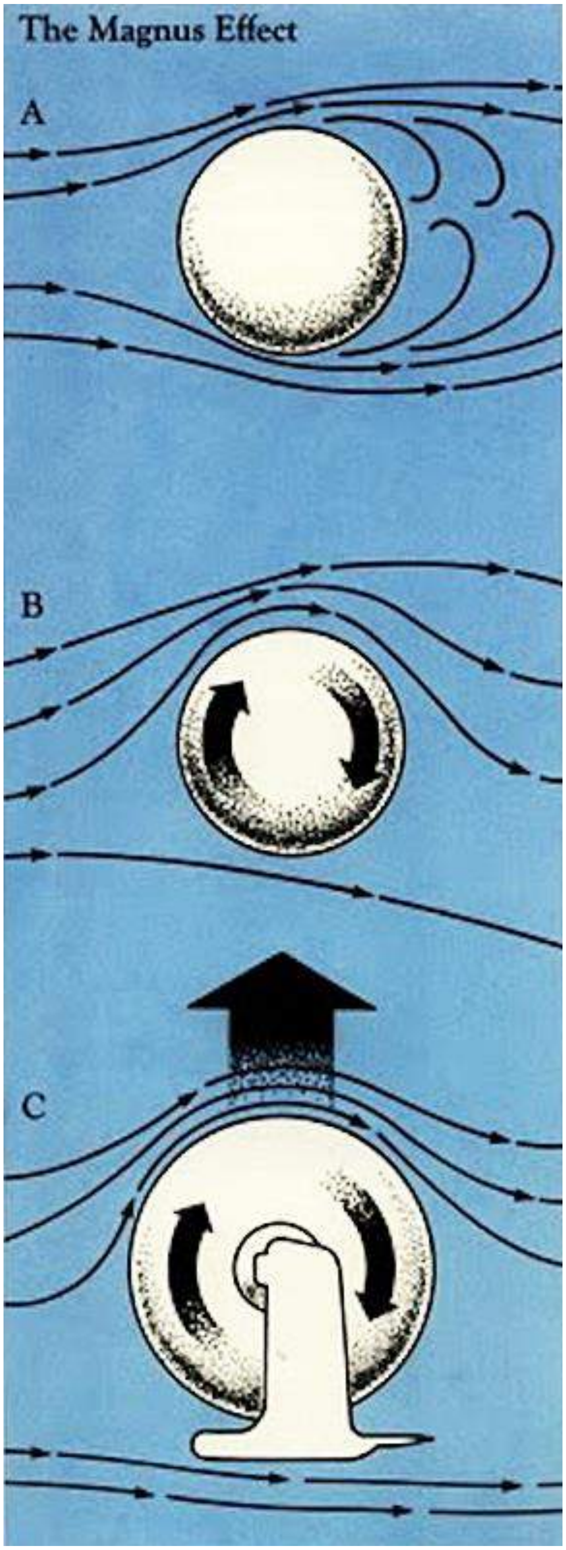
1. Introduction

The LTA 20-1 was a spherical, heavy-lift, hybrid airship designed in the early 1980s by Magnus Aerospace Corporation of Ottawa, Ontario, Canada. The LTA 20-1 combined three sources of lift: aerostatic lift from helium, dynamic lift from vectored thrust engines, and aerodynamic Magnus lift from the spherical hull rotating with a backspin. The craft's structural weight, including engines, gondola and sphere, were fully supported by the aerostatic lift.



Magnus Aerospace Corp. promotional brochure cover.
Source: J.D. Lowe, 30squaresofontario.blogspot

2. Magnus effect



Magnus Aerospace Corp used the accompanying diagrams to explain how their airship generates Magnus lift.

Figure A shows airflow around a non-rotating sphere. Airflow separates equally from the top and bottom, near the midpoint of the sphere. No lift is generated.

Figure B shows airflow around a sphere rotating with a backspin. The top of the sphere rotates away from the direction of travel. Flow remains attached longer to the top side, speeding up the airflow. Interference at the bottom causes earlier flow separation. The airflow velocity difference between top and bottom and the downward deflection of the wake produces Magnus lift.

Figure C shows the airflow around a rotating sphere with a gondola suspended by a yoke from the axis of rotation. The gondola masks the areas of interference between the sphere and the free stream air, smoothing out the air flow. Air remains attached to the top of the sphere as before. Stability is enhanced by controlled boundary layer shedding at the back of the gondola.

Source: Magnus Aerospace Corp. promotional brochure

The Magnus effect is a special case of the Bernoulli principle, applied to a rotating cylinder or sphere. The effect was first described by the German physicist Heinrich Magnus in 1852.

Magnus lift is generated during LTA 20-1 forward flight, when there is a relative wind over the spherical hull. In cruise flight, total lift is the sum of aerostatic lift and Magnus lift from the rotating sphere. The vectored thrust engines are not needed for lift during cruise flight and are positioned to produce thrust for forward flight.

During LTA 20-1 vertical takeoff and landing (VTOL) or hover, there will be little or no relative wind and no lift is generated by the Magnus effect. In this case, total lift is the sum of aerostatic lift and dynamic lift from the vectored thrust engines.

As airship size increases, aerostatic lift increases with the cube of balloon diameter, whereas Magnus lift varies with the square of balloon diameter. As airship size increases, the relative contribution of Magnus lift decreases. At an envelope diameter of 160 ft (48.8 meters), Magnus lift is able to generate about half of the "net disposable static lift." In even larger airships, Magnus lift will be useful if it can produce about 30% of the net disposable static lift.

3. Magnus effect spherical airship patent

Magnus Aerospace Corp. filed several patents that describe the design and operation of their Magnus effect spherical airship. In this section, we'll take a look at US Patent US4366936A, "Aircraft having buoyant gas balloon."

- Inventor: Frederick Ferguson
- Filed: 4 November 1981
- Granted: 4 January 1983
- Assigned to: Magnus Aerospace Corp., Ottawa, Ontario, Canada
- Available here: https://patents.google.com/patent/US4366936A/en?q=magnus+airship&oq=magnus+airship

With reference to patent Fig. 5, the non-rigid, non-elastic, spherical gas envelope is designed as a superpressure balloon, operating at greater than atmospheric pressure (up to 0.14 psig), with stable dimensions that are not substantially affected by atmospheric pressure and temperature. The envelope is connected to endplates (114) that secure the envelope and ballonet (124) fabric and connect to an axle (116). The patent described a continuous axle. Later analysis showed that the stiffness of the inflated envelope allowed the use of exterior end axles that resembled the nose mooring device for a blimp. The endplates include ports for filling helium and overpressure protection devices to vent helium. The axles of the rotating envelope connect to the load support yoke (132) via bearings at the tops of the yoke arms. The yoke carries the weight of the gondola (136), with the crew cabin (136b) and payload bay (136a), and the thrust vectoring main propulsors (140), and transfers that load via the endplates into the fabric envelope.

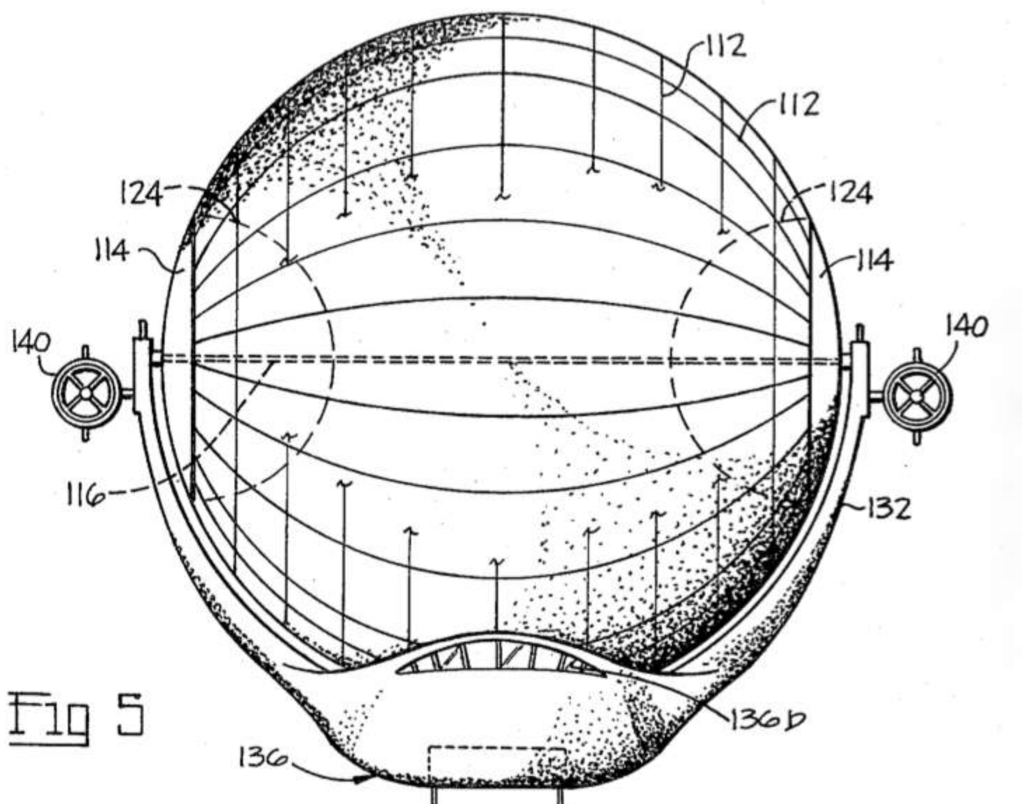


Fig 5

Electric motors for rotating the spherical gas envelope are installed in the fixed yoke. The rate of rotation is adjusted to the forward speed to maximize the Magnus lift. At 60 mph, the rate of rotation is 3.5 rpm.

Magnus lift can be increased by the use of a non-smooth surface (i.e., a dimpled golf ball). Dimpling of the airship's gas envelope can be achieved with an arrangement of longitudinal and transverse reinforcing cables (112), with pillowing of the envelope fabric in the square spaces between the cable intersections.

Aerostatic buoyancy and trim are controlled by the two air ballonets (124). When fully expanded, the ballonets have the shape of hemispheres as shown in Fig. 5. The ballonets provide the sole means for regulating the altitude of the airship. The maximum altitude for unloaded flight was 15,000 ft.

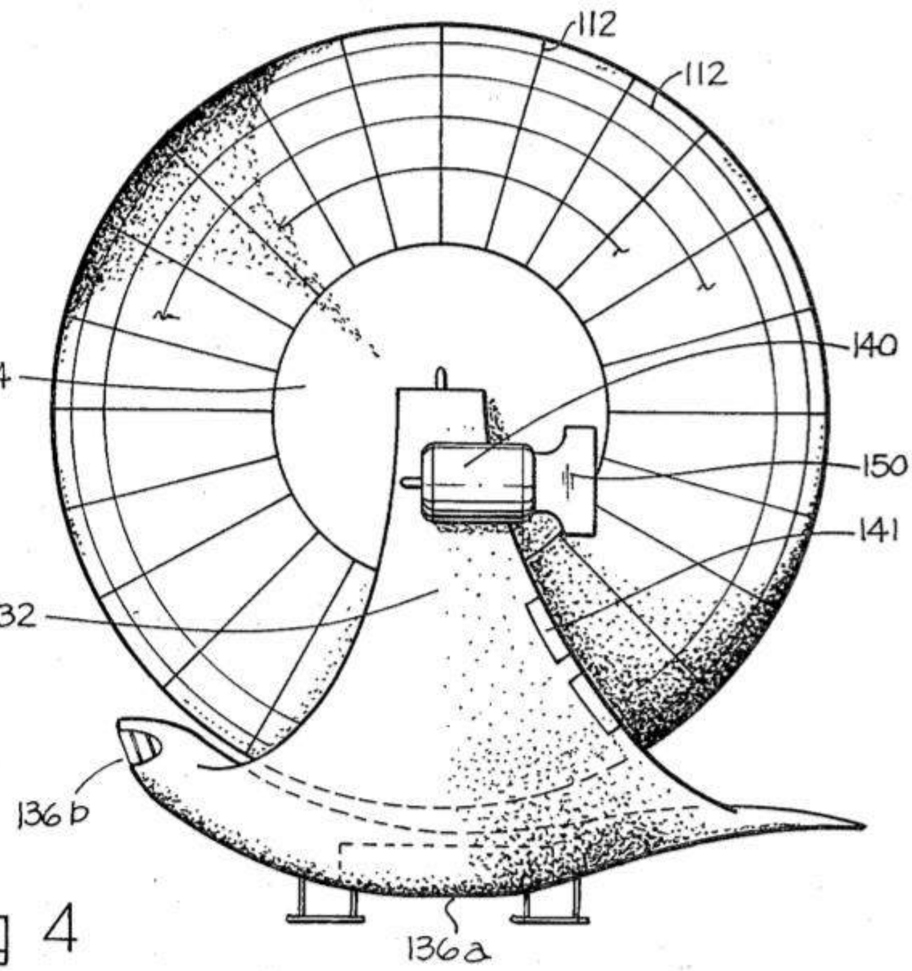


Fig 4

With reference to Figs. 4 and 5, note that the shape of the yoke interior surfaces and the gondola upper surface conforms closely to the adjacent surfaces of the gas envelope. At its closest point, the gap between these surfaces is less than 2% of the balloon radius (gap less than 12 inches). This is done to limit airflow between the yoke / gondola and the envelope and reduce aerodynamic drag by smoothly deflecting airflow around the sides and under the gondola.

The main thrusters (140) are shown in their position for cruise flight. Thrust deflectors in the exhaust slipstream (150) also can be used for yaw control. The main thrusters are shown as ducted fans, which would have variable pitch propellers and thrust reversing capabilities. The main thrusters rotate in a vertical plane through 200° to give the ability to move the airship up or down, forwards or backwards and rotate about the airship's vertical axis.

Transitioning between forward flight and VTOL is accomplished by rotating the thrust vectoring engines (140) thru about 90° and controlling engine power as Magnus lift decreases as airspeed decreases. The airship has dedicated side thrusters for direct lateral control during precise VTOL and hover maneuvers.

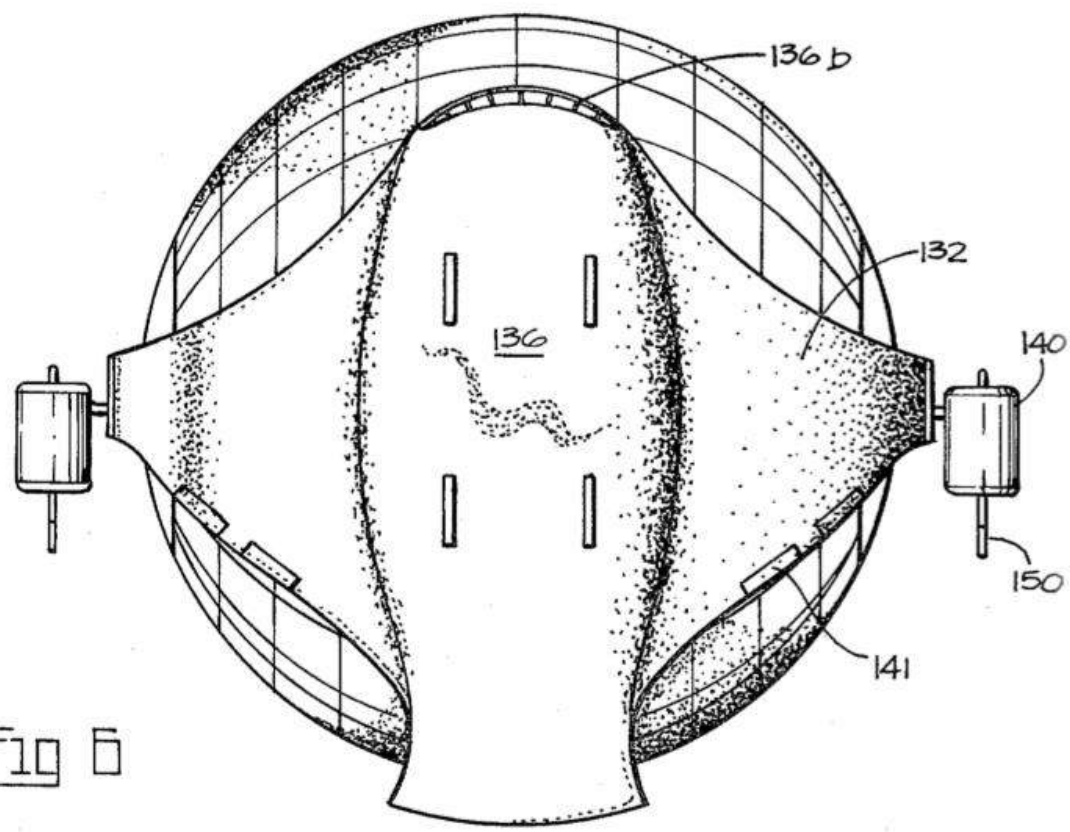


Fig 6

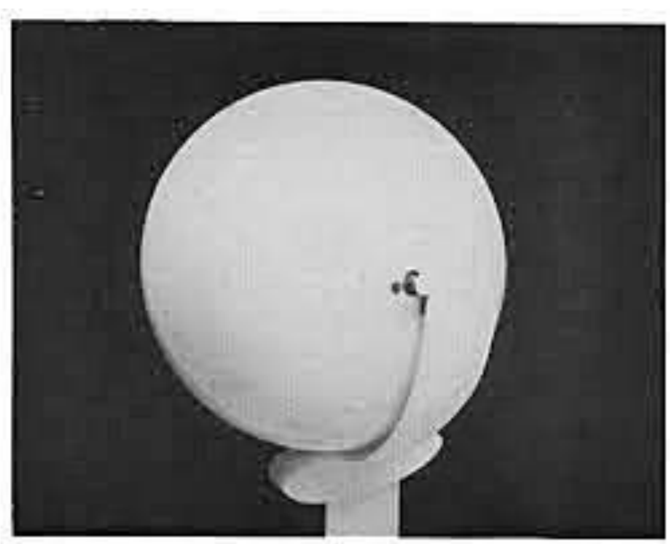
Fig. 6 is a view from beneath the airship. The landing skids on the gondola (136) can be fitted with pontoons for landing on water.

The patent provides the following basic specifications for two airship models, designated 72P and 160P.

LTA VEHICLE 20-1 DESIGN SPECIFICATIONS		
Model designation	72P	160P
Sphere diameter (ft)	72	160
Total sphere volume (cu ft)	195,500	2,144,500
Total static lift (lb)	12,900	140,600
Net weight (lb) (without fuel)	7,000	45,600
Net static lift (lb)	5,900	95,000
Max. Magnus lift (lb)	6,000	30,000
Fuel load (lb)	2,400	40,000
Net disposable static lift (lb)	3,500	55,000
Net maximum disposable lift (lb)	9,500	85,000
Max. airspeed (mph)	70	70

4. The sub-scale Magnus model airships

In the early 1980s, Magnus Aerospace contracted with the University of Toronto's Institute for Aerospace Studies (UTIAS) subsonic aerodynamics group to study the aerodynamics of the LTA-20-1. Over the span of several years, UTIAS tested more than 100 model configurations in their wind tunnel. In addition, they built and tested several small free flying models.



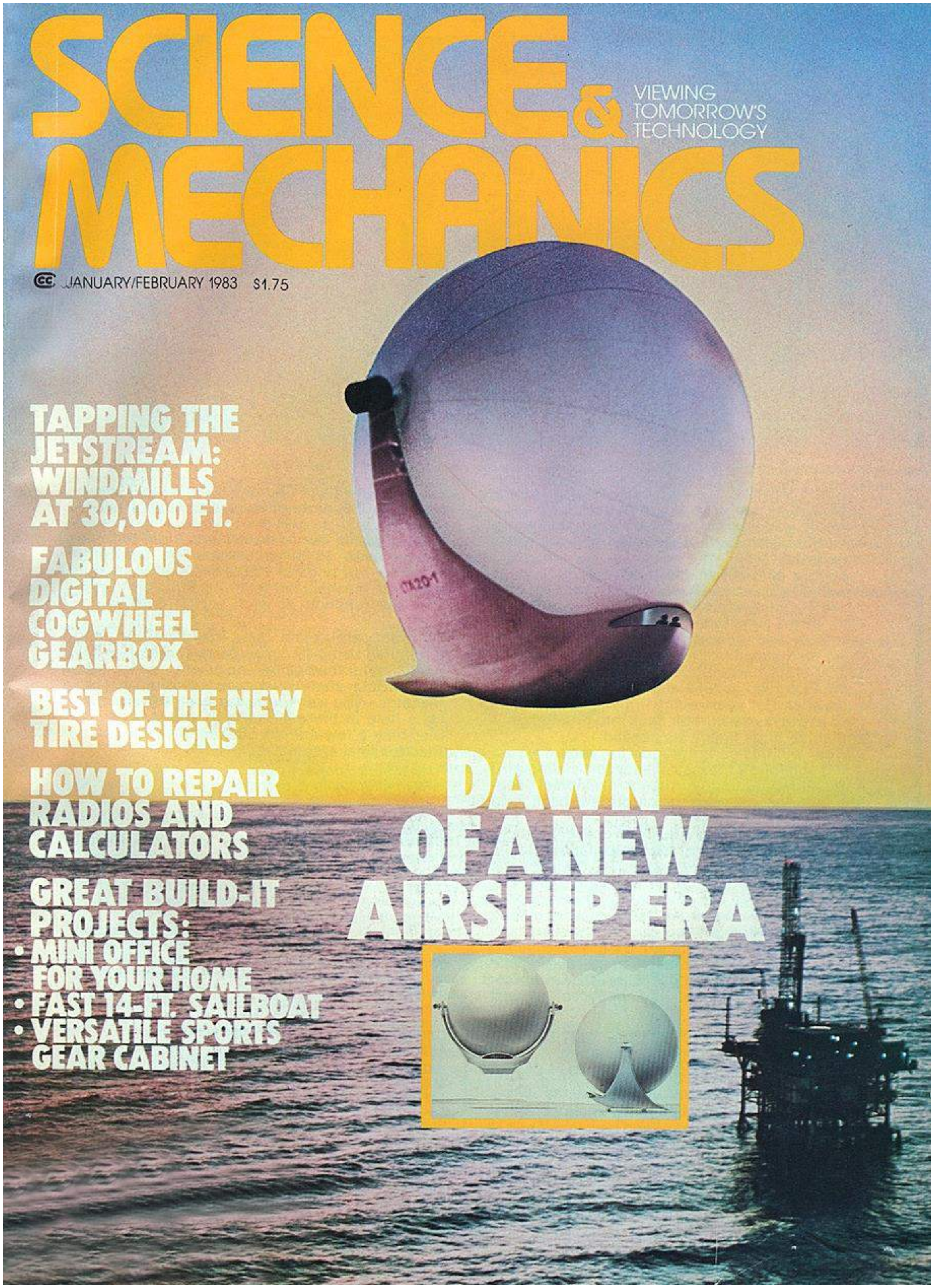
One of many wind tunnel models built and tested in the UTIAS wind tunnel. Source: J. Delaurier, et al., 1983

In the same time period, Magnus Aerospace also contracted with a team at Carleton University in Ottawa to build and test fly the 19-foot (5.8-meter) diameter model shown in the following photos. In test flights, the model demonstrated that it could generate Magnus lift. Later, it was used at Magnus Aerospace promotional events.

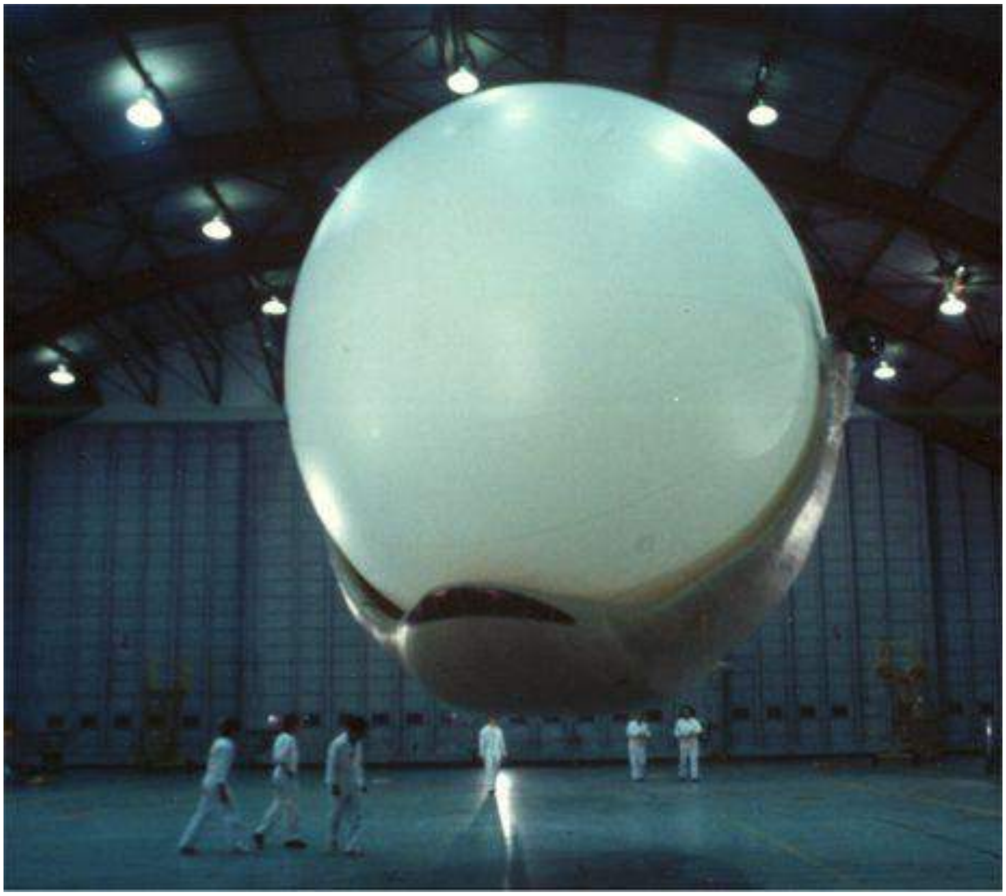
Subscale Carleton University model of the LTA 20-1.
Source: imgur.com

Subscale Carleton University model test flight.

Sources: (above) imgur.com.
(below) Magnus Aerospace Corp. promotional brochure



Science & Mechanics magazine cover, Jan/Feb 1983, showing an LTA 20-1 based on the design of the Carleton subscale model.


Carleton subscale model looking large in forced perspective.
Source: Pinterest

5. LTA 20-1 business applications

Magnus Aerospace Corp. designed the LTA 20-1 to carry much heavier payloads than helicopters over longer ranges and at much lower operating cost per unit of lift ($/ton-mile). The LTA 20-1 design could be scaled up to at least 100 tons of net payload.

It is capable of operating with only common ground infrastructure.

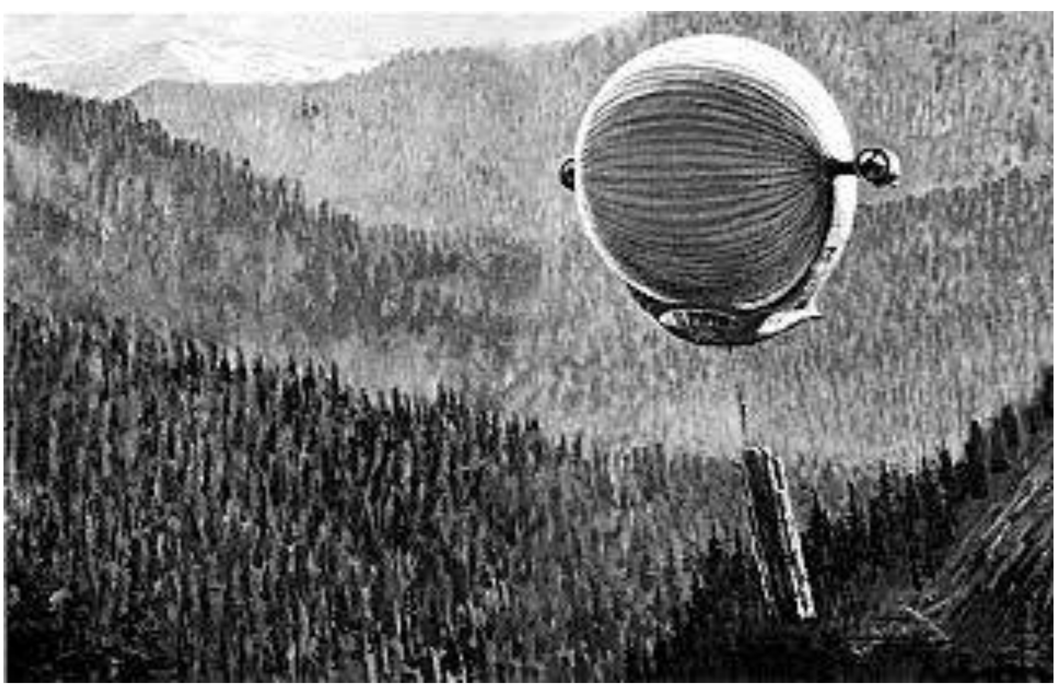
- A central mooring point under the gondola secures the airship to the ground.
- The spherical gas envelope can be rotated on the ground, greatly simplifying inspection and maintenance.
- The airship is easy to assemble and disassemble.
- Once disassembled, it can be stored and maintained in conventional structures.

With its ability to hover, control lift, and transport heavy loads, the LTA 20-1 appeared suitable for the following business applications:

- Logging
- Transport heavy loads for any industry (construction equipment, marine salvage, remote installations)
- Support resource development in remote areas by oil, gas and mining industries
- Support offshore exploration activities
- Support emergency response efforts
- Transfer cargo to/from ships at sea to avoid port congestion
- Transport military hardware and supplies

Logging

The LTA 20-1 gives the logging industry the ability to operate in steep terrain without the need to develop access roads through environmentally sensitive areas to get to the area being logged. The airship also gives the industry the ability to target their operations toward a specific variety and grade of lumber that matches current market demand.



Rendering of an LTA 20-1 conducting logging operations.
Source: Magnus Aerospace Corp. promotional brochure

The Magnus Aerospace promotional brochure includes the following general specification for a logging version of the LTA 20-1 with a 28 meter (99 feet) gas envelope.

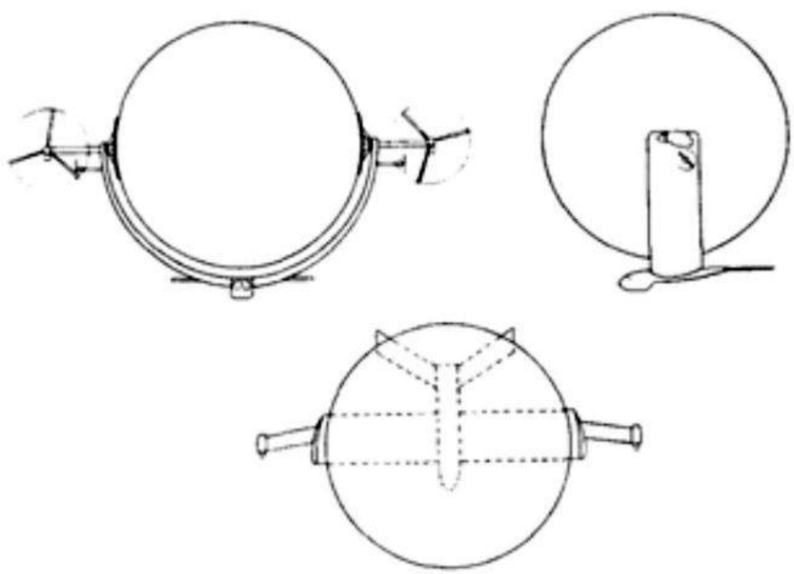
LTA 20-1 General Specifications

Logging Version

SPECIFICATIONS:

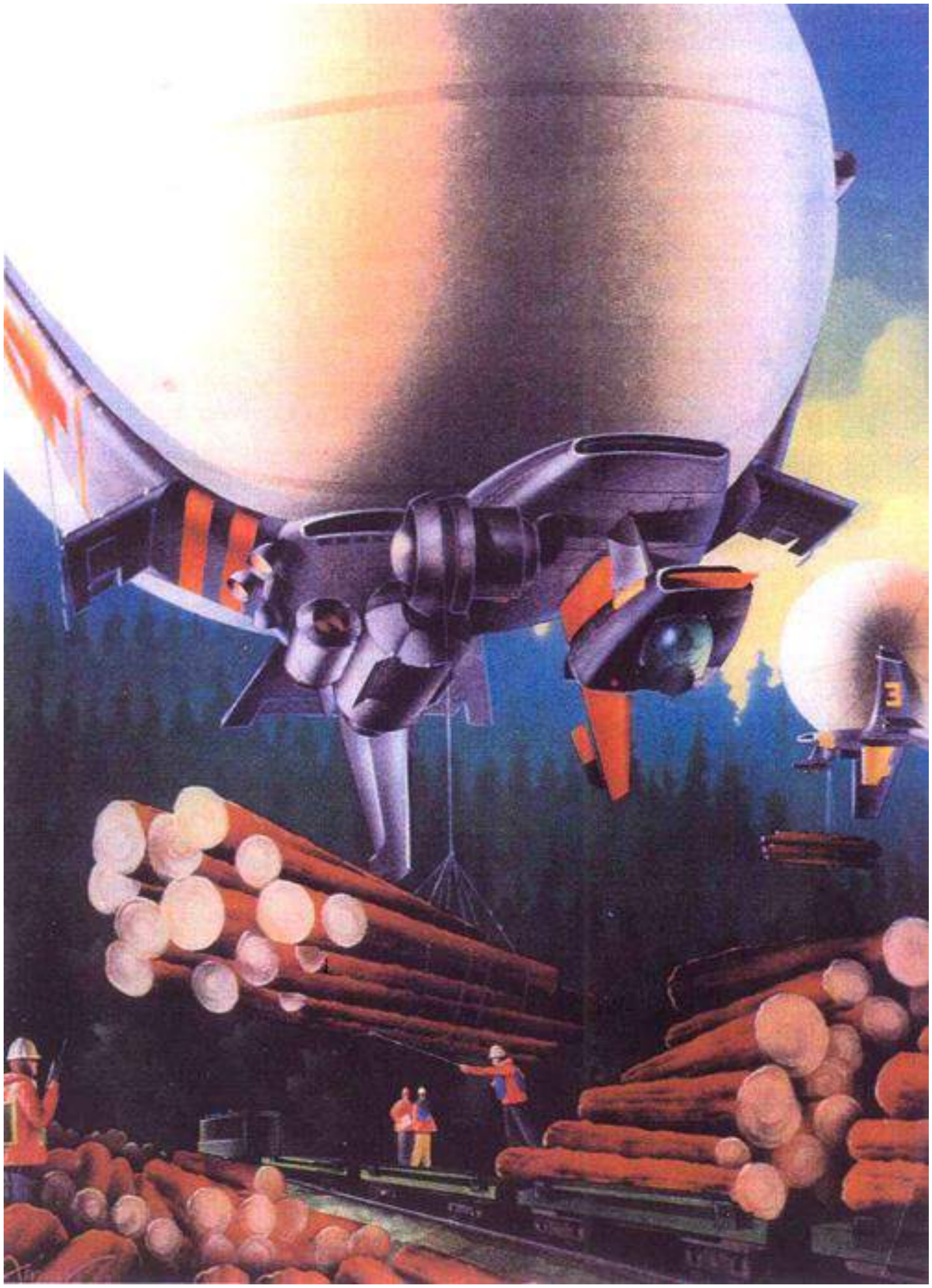
Main Envelope	: Spherical 28 m. diameter Gross Volume 11494 cu. m.	
Performance	: Maximum Speed 120 Kph. Range/Duration 520 Km./6.5 hr. (50 Kph., 20 min. reserve) Typical Duration In Yarding Operation 2.5 hr. (4 min. cycle time)	
Operators	: Pilot, Co-Pilot	
Takeoff/Landing	: VTOL	
Vehicle Weights	: Empty weight	8,453 Kg.
	Max Fuel	3,300 Kg.
	Payload (at zero fuel)	16,000 Kg
Lift	: Buoyant lift	9,453 Kg.
	Engine thrust	17,000 Kg.
	Manoeuvering thrust and losses	2,000 Kg.
	MGTOW	24,453 Kg.

Source: Magnus Aerospace Corp. promotional brochure



Three view drawing of a turboprop-powered LTA 20-1 in logging configuration. The tailplane primarily provides pitch damping. Source: J. Delaurier, et al., 1985

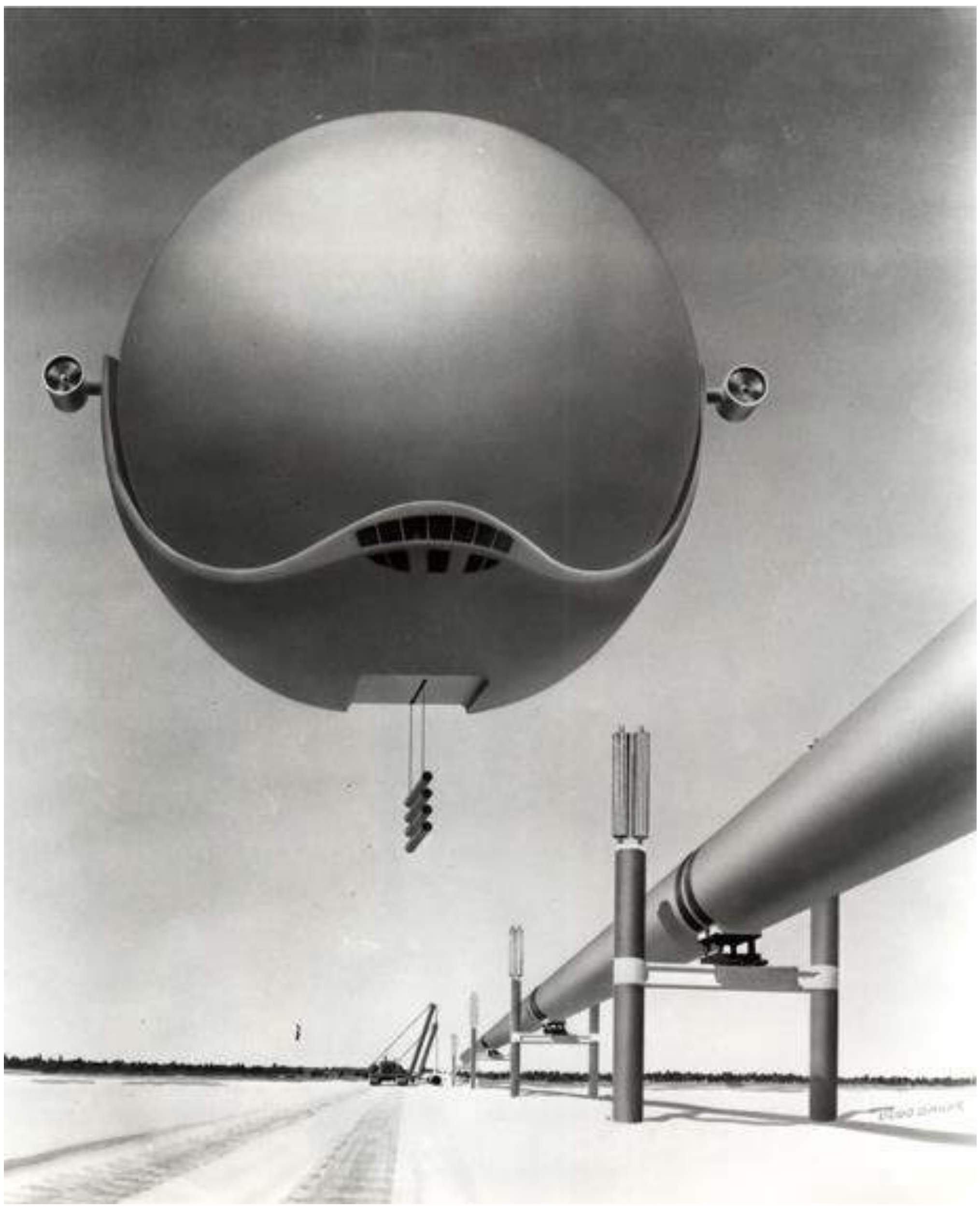
In 1985 Magnus Aerospace analyzed the dynamics of handling a heavy suspended load in turbulent air during logging and concluded that "…translational velocity disturbances to the vehicle's state can easily be corrected with small displacements of the control surfaces."



Rendering of a Magnus-type spherical airship conducting logging operations. Source: imgur.com

Pipeline construction support

As with logging, the LTA 20-1 can carry pipeline heavy equipment and pipe sections as suspended loads and deliver directly to the construction site, which may be in a remote location that does not have a transportation link by other means. The LTA 20-1 enables the work to be performed without having to build access roads through environmentally sensitive areas.



Rendering of an LTA 20-1 assisting with pipeline construction.
Source: Magnus Aerospace Corp. promotional brochure

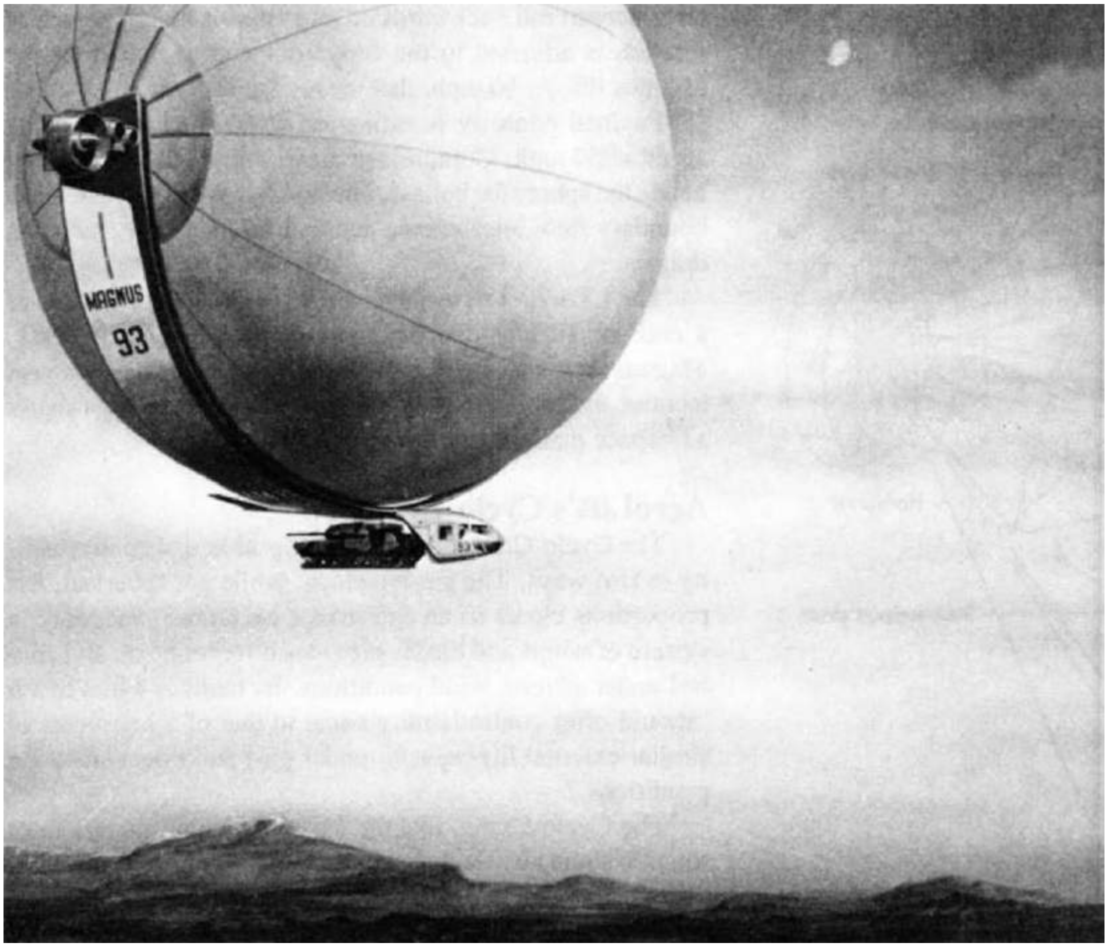
Emergency response

The LTA 20-1 can carry relief supplies directly to the point of need, which may be in a remote area that lacks access to other modes of transportation. In the case of a train derailment, the airship can operate as a flying crane to recover heavy rail cars and facilitate restoration of rail service.

Rendering of an LTA 20-1 assisting with recovery from a train derailment. Source: Magnus Aerospace Corp. promotional brochure

Heavy cargo transport

The LTA 20-1 can be developed to carry heavy unitary cargo, such as an armored military vehicle or large construction equipment, in a cargo bay rather than as a suspended load.



Rendering of an LTA 20-1 transporting a military armored vehicle on a cargo “shelf” behind the crew cabin.
Source: EIR Science & Technology, 1986

6. The end of the LTA 20-1, or was it?

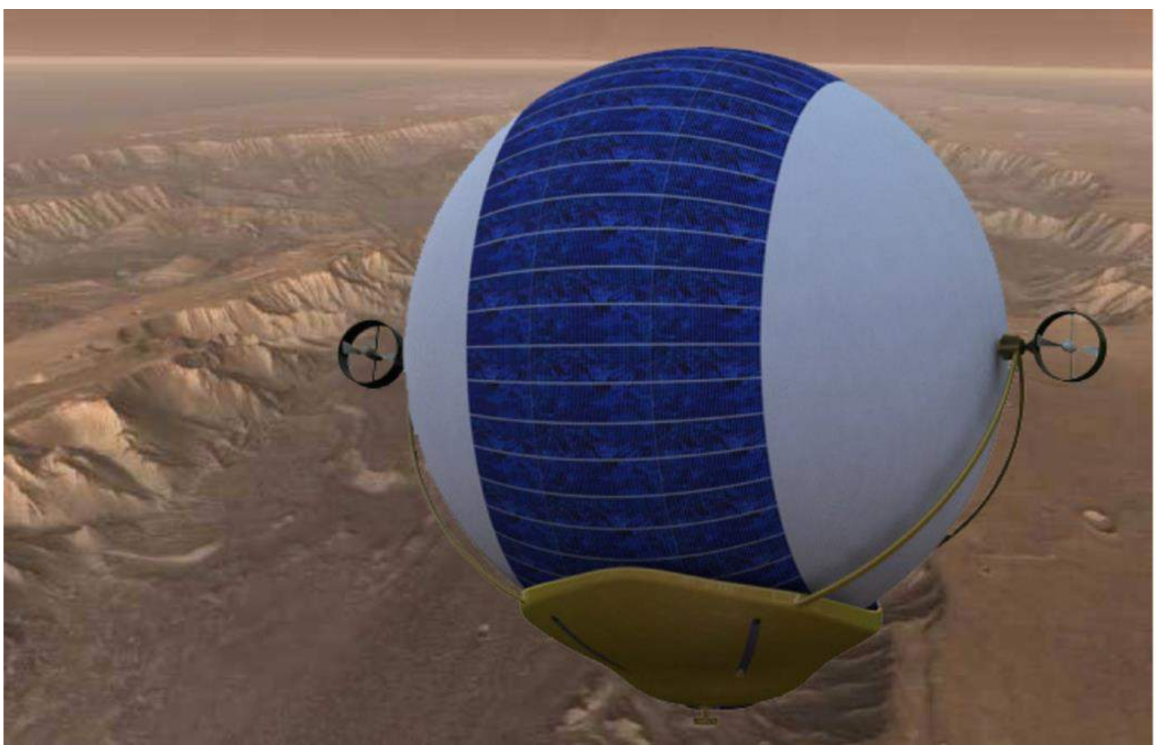
In 1986, Magnus Aerospace planned to issue stock in Canada to raise the money to scale up, and was looking to affiliate with a major aerospace manufacturer. Several foreign countries had expressed interest in the LTA 20-1 heavy-lift technology. Japanese companies C-Itoh and Nissho Iwai were interested in representing Magnus Aerospace in the Pacific Rim.

In spite of these prospects in 1986, a full size LTA 20-1 never was built. Magnus Aerospace Corp. is no longer in business.

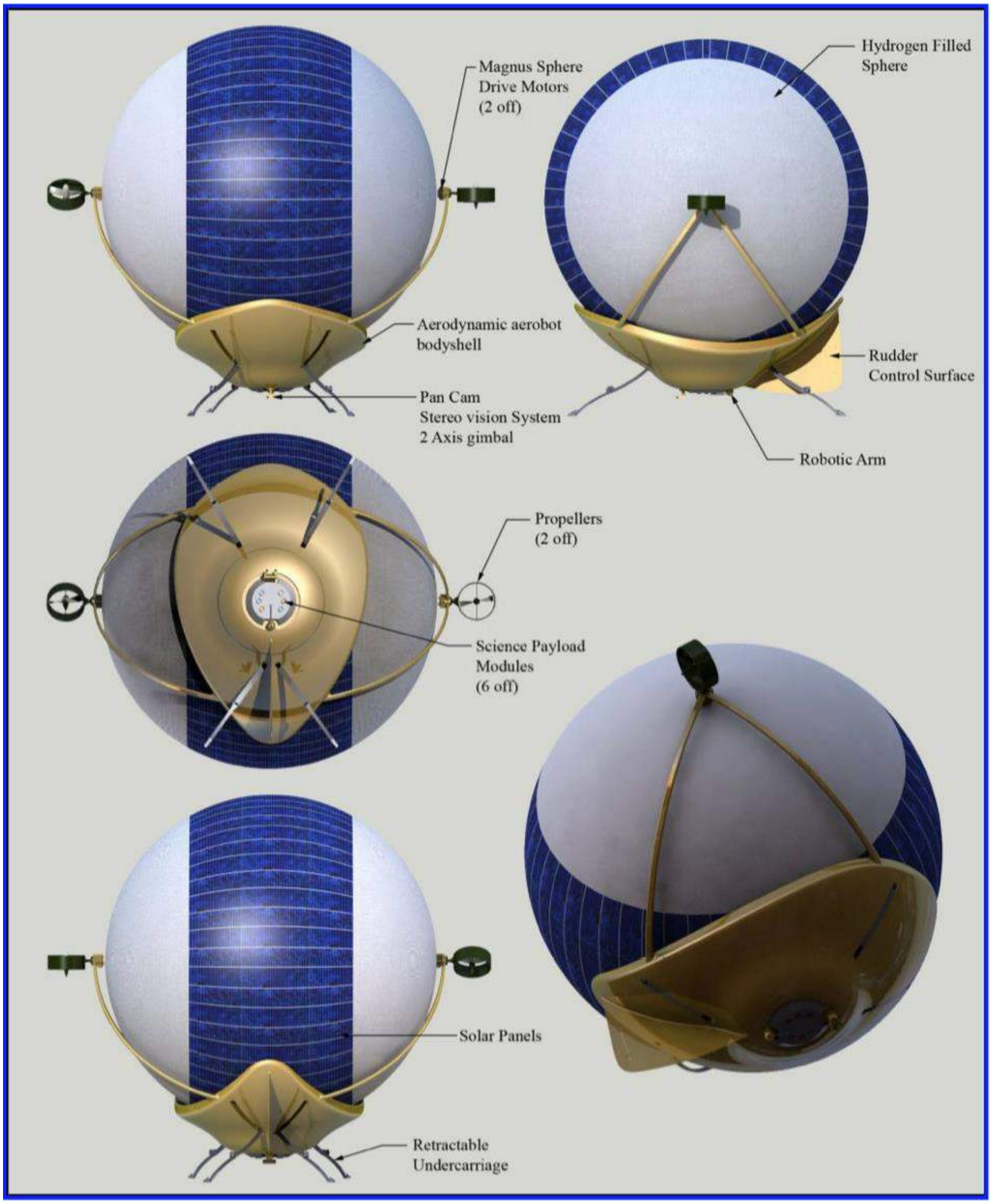
Thanks to former consulting flight dynamicist to Magnus Aerospace, James Lowe, for preserving a copy of the LTA 20-1 promotional brochure on his blog site: https://30squaresofontario.blogspot.com/2014/02/400-posts-1-about-blimps.html

7. Mars Magnus Aerobot (2010)

In a 2010 study at the Space Research Centre in the School of Engineering at Cranfield University, Bedford, UK, a "Magnus Lift Aerobot" that looked very much like an LTA 20-1 was proposed as a flying craft to operate in the rarefied atmosphere of Mars. Hydrogen was to be the lifting gas. The study found, "Such a craft would require a continuous power supply, undoubtedly requiring more energy than the solar panels could supply, resulting in a flight profile of short duration airborne periods with frequent landings for battery charging. A 10 m (32.8 ft) diameter aerobot could produce a net lift of 14.9 N (1.5 kg) in this way, ideal for a light weight science payload."



The Mars Magnus Aerobot. Source: S. Ravindran, et.al, 2010



You can read the Mars Magnus Aerobot paper here:

- S. Ravindran, S. Hobbs & J. Jennings, "Mars Magnus Aerobot Preliminary Design," conference paper SpaceOps 2010, Huntsville, AL, 25 – 30 April 2010: https://arc.aiaa.org/doi/pdf/10.2514/6.2010-2184

8. For more information

- J. Delaurier, “Preliminary report on the engineering development of the Magnus Aerospace Corp. LTA 20-1 heavy-lift aircraft,” The Aeronautical Journal , Volume 87 , Issue 864 , pp. 119 – 131, April 1983: https://www.cambridge.org/core/journals/aeronautical-journal/article/abs/preliminary-report-on-the-engineering-development-of-the-magnus-aerospace-corp-lta-201-heavylift-aircraft/B40B38A30E97F715904F8EBC47B26F7B
- H. Scholaert, “Dynamic analysis of the Magnus Aerospace Corporation LTA 20-1 heavy-lift aircraft,” Conference paper, AIAA 5th LTA Conference, Anaheim, CA, July 1983, published online 17 August 2012: https://arc.aiaa.org/doi/10.2514/6.1983-1977
- J. Delaurier, W. McKinney, W. Kung, G. Green & H. Scholaert, “Development of the Magnus Aerospace Corporation's rotating-sphere airship,” Conference paper, AIAA 5th LTA Conference, Anaheim, CA, July 1983, published online 17 August 2012: https://arc.aiaa.org/doi/10.2514/6.1983-2003
- J. Delaurier, W. McKinney, J. Lowe, D. Uffen & A. King, “Progress Report on the Engineering Development of the Magnus Aerospace LTA 20-1 Airship,” American Institute of Aeronautics and Astronautics, paper 85-0876,1985: https://arc.aiaa.org/doi/10.2514/6.1985-876
- J.D. Lowe, “An investigation into the hovering behavior of the LTA 20-1 airship in calm and turbulent air,” American Institute of Aeronautics and Astronautics, paper 85-0878,1985: https://arc.aiaa.org/doi/pdf/10.2514/6.1985-878
- David Cherry, “The Heavy Lift Vehicle That’s Lighter Than Air,” EIR Science & Technology, Vol. 13, No. 23, 6 June 1986: https://larouchepub.com/eiw/public/1986/eirv13n23-19860606/eirv13n23-19860606_020-the_heavy_lift_vehicle_thats_lig.pdf
- J.D. Lowe, “400 posts; 1 about blimps,” (this post includes a copy of the Magnus Aerospace Corp. LTA 20-1 promotional brochure), 5 February 2014: https://30squaresofontario.blogspot.com/2014/02/400-posts-1-about-blimps.html

- “LTA-20/Magnus Spherical Airship,” 17 January 2020: https://imgur.com/gallery/dNUNz9W

Other Magnus Aerospace Corp. patents

- European patent application EP0078713A2, “Aircraft Having Buoyant Gas Balloon,” filed 3 November 1982, published: 11 May 1983: https://data.epo.org/publication-server/document?iDocId=114658&iFormat=0

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/
- *Modern Airships - Part 3*: https://lynceans.org/all-posts/modern-airships-part-3/