Kiev Public Aeronautics Design Bureau (OKBV)

Peter Lobner, 11 February 2022

1. Introduction

In the early 1960s, several “Voluntary Design Bureaus” were formed in the Soviet Union to promote the development of dirigibles as a means for solving important national economic problems in cargo transportation, agriculture and research, and for filling an industrial void that had existed since before WW II. The first such bureau appears to have been the Leningrad Volunteer Design Bureau of Dirigible Construction, which was formed in 1961. Others design bureaus were established during the early 1960s in Kiev, Novosibirsk and the Urals.

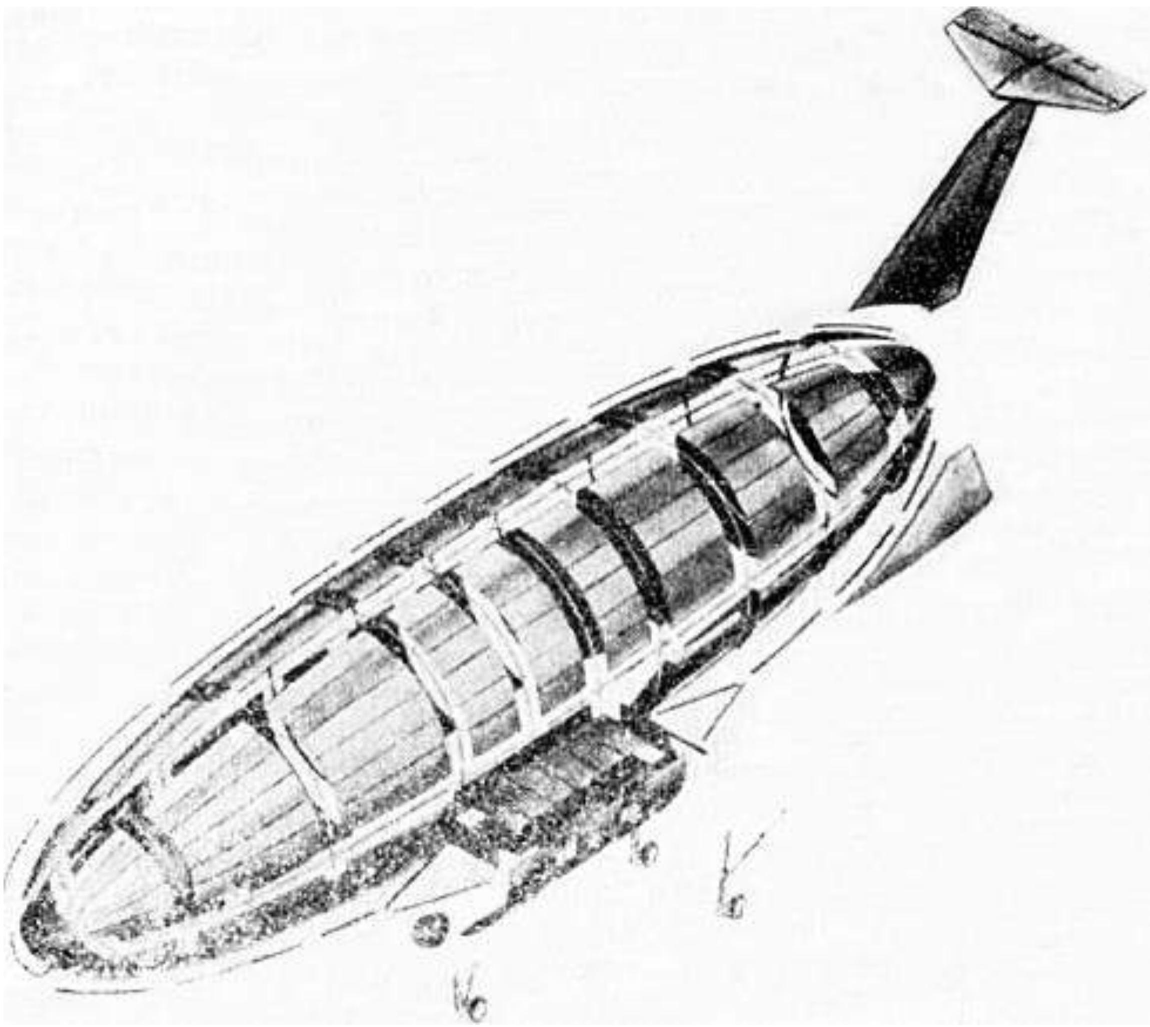
The Kiev Public Aeronautics Design Bureau (OKBV) was formed in 1961 by talented engineer Roman A. Gokhman. The OKBV united a large group of aviation engineers and scientists from the Academy of Sciences of the Ukrainian SSR. The OKBV received support from O.K. Antonov, head of the Antonov aircraft design bureau, and carried out research in a wind tunnel of various forms of airships.

2. D-1 rigid airship

The first airship design developed by the Kiev OKBV in the mid-1960s was the large, multi-purpose D-1 rigid airship with an ellipsoid, semi-monocoque hull. In 1967, the OKBV first announced some details of the D-1 dirigible. Construction and test flights were completed in 1969 and were reported as being successful.

The symmetrical ellipsoid hull has a fineness ratio (length / max. diameter) of 3.36. For comparison, the Hindenburg’s (LZ-129) fineness ratio was a more slender 5.95. The tall, swept-back T-tail placed the vertical and horizontal stabilizers above the zone of disturbed air flow behind the airship’s hull and increased the moment arms of the aerodynamic control surfaces.

The rigid hull was formed by four longitudinal stringers running the length of the hull and nine transverse frames that define the internal compartments containing 21 lifting gas cells made of polyethylene terephthalate film. The bottom stringer was enlarged and reinforced to serve as a narrow tunnel that allowed crew members to move between compartments located in the bow, center and stern of the ship, along the bottom of the hull. The structural frames and stringers supported rigid, three-layer fiberglass laminate panels that formed the smooth skin of the airship. The space between the inner and outer fiberglass layers was filled with expanded polystyrene foam. The rigid skin panels were impervious to rain and frost. A de-icing system permitted operation in cold weather.



D-1 airship cross-section showing two of the four longitudinal stringers (spars) and all nine of the transverse frames that define the hull shape and the size of the lifting gas compartments. The central cargo bay is also shown. Source: Arie, "Dirigibles" (1986)

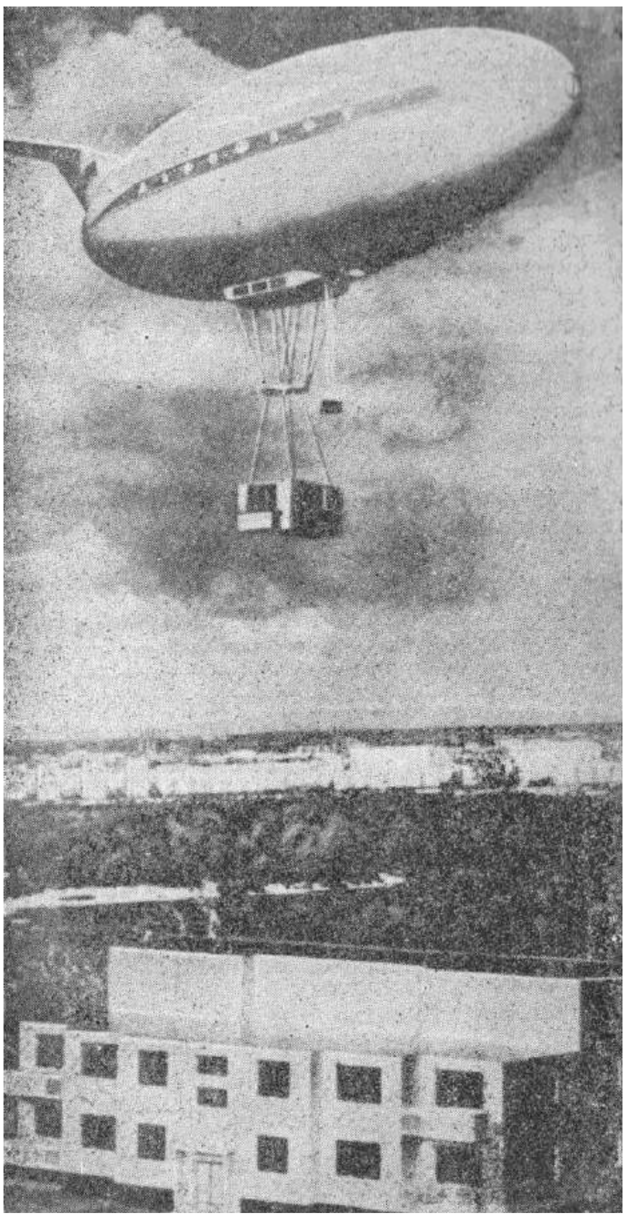
General characteristics of the D-1 airship

Parameter	**D-1**
Type	Rigid, semi-monocoque hull construction
Length	84 m (275.6 ft)
Diameter, max	25 m (82 ft), circular cross-section
Lifting gas	Helium, in 21 polyethylene terephthalate cells
Volume	27,500 m^3 (971,100 ft^3)
Weight, max takeoff	27,500 kg (60,627 lb)
Weight, empty	13,200 kg (29,101 lb)
Weight, fuel	2,000 kg (4,409 lb)
Payload	14 metric tons (15.4 tons)
Cargo bay dimensions	15 L x 6.2 W x 3.3 H meters (49.2 x 20.3 x 10.8 ft)
Load platform lowering height (from hover)	60 m (197 ft)
Crew accommodations	6 persons in a separate, pressurized crew cabin (two 3-person crews for extended flights)
Passenger accommodations	Up to 80 passenger in two compartments installed on the cargo hold
Propulsion	1 x Ivchenko AI-24 turboprop engine rated @ 2,550 shp (1,900 kW), installed at the tail, driving a shrouded, variable pitch pusher propeller
Auxiliary gas turbine	1 x Ivchenko AI-25 gas turbine engine, installed in the nose section, serving as an auxiliary power unit (APU), driving an air compressor and generator: • supplies high-pressure air to the gas-dynamic system of air jets used for low speed maneuvering • supplies high-pressure air to the variable ballast control system, • provides electric power for the air conditioning system & other airship systems
Takeoff/landing modes	VTOL or STOL
Speed, cruise	170 kph (105.5 mph)
Speed, max,	200 kph (124.3 mph)
Altitude, design	Up to 6,000 m (19,685 ft)
Range	• 1,000 km (621 miles) with a payload of 11 metric tons (12.1 tons) • 1,700 km (1,056 miles) with a payload of 9 metric tons (9.9 tons)
Service life	30,000 hours (8 – 10 years)

Source: Arie & Polnker (1983)

The cargo bay was located along the bottom of the hull, between transverse frames #3 and #5. The bay measured 15.0 L x 6.2 W x 3.3 H meters (49.2 L x 20.3 W x 10.8 H feet). A cargo platform can be lowered from the cargo bay to facilitate rapid loading and unloading. With the airship hovering above its destination, the cargo platform can be lowered up to 60 m (197 ft).

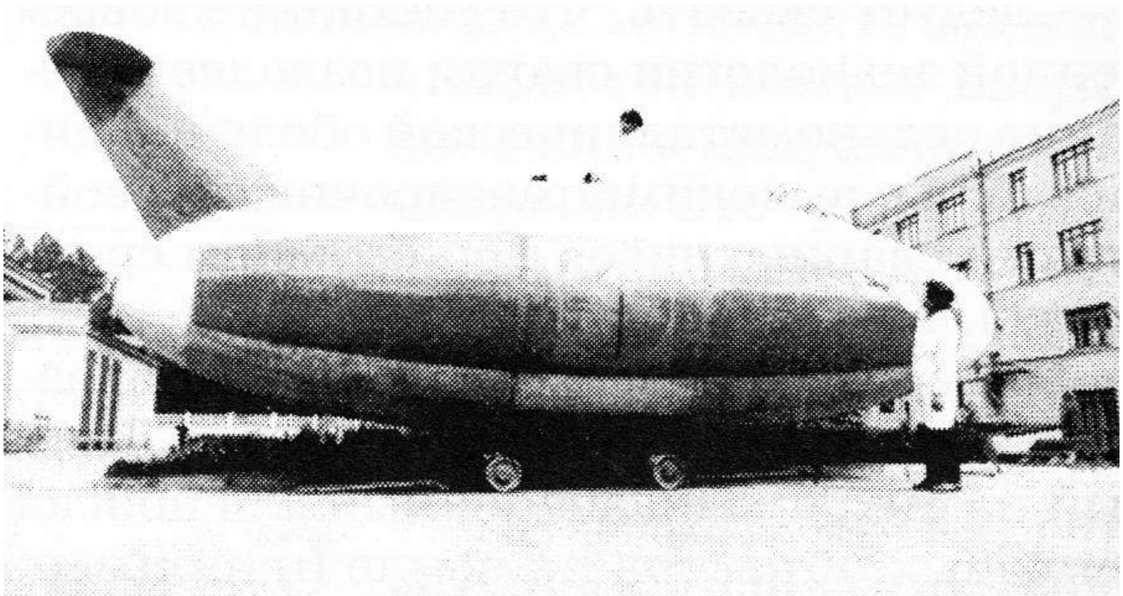
The cargo platform can be reconfigured for passenger service by installing two passenger compartments, each designed to accommodate 40 passengers. The separate crew compartment was located forward of the cargo bay.



The airship is designed for vertical takeoff and landing (VTOL) and short takeoff and landing (STOL) on its retractable 3-point landing gear. The ship can carry out a vertical landing on an area of 120 X 120 m (394 x 394 ft). At low speeds, where aerodynamic controls lose effectiveness, and during hover, the D-1 used a gas-dynamic control system with thrust vectoring high-pressure air jets to maintain control of the airship. A separate auxiliary gas turbine engine drives a compressor to supply the gas-dynamic control system, the variable ballast control system, and other airship systems.

Rendering of D-1 carrying a modular housing unit as a sling load. Source: Arie & Poinker (1983)

Work on a 1/10th scale “technological” model of the D-1 began in 1967 and was completed in 1969.



The 1:10 scale D-1 airship technological model.
Source: Boyko (2001)

Successful test flights of the D-1 prototype were reported in 1969. However, the prototype must have had a short operating career and the D-1 did not enter production.

D-1M1

The D-1M1 model was designed without a vertical tail fin to enable two or more D-1 airships to be grouped vertically or horizontally to lift a heavy load that was beyond the lifting capacity of a single D-1. Using their combined lifting capacities, a D-1 and a D-1M1s could be stacked, one above the other, to lift a load weighing up to 25 metric tons (27.5 tons). Larger loads of 37.5 or 50 metric tons (41.25 and 55 tons) would require three or four airships, respectively. For long loads, the airships would be arranged in tandem over the load.

3. D-2, D-3 and D-4 rigid airships

The Kiev OKBV planned to develop a family of larger airships based on the design of the D-1. The next larger D-2 would have had a payload capacity of 30 metric tons (33 tons). The D-3 would have doubled that to deliver a 60 metric ton (66 tons) payload capacity and the D-4 would have (almost) doubled it again to carry 100 to 120 metric tons (110 to 132 tons).

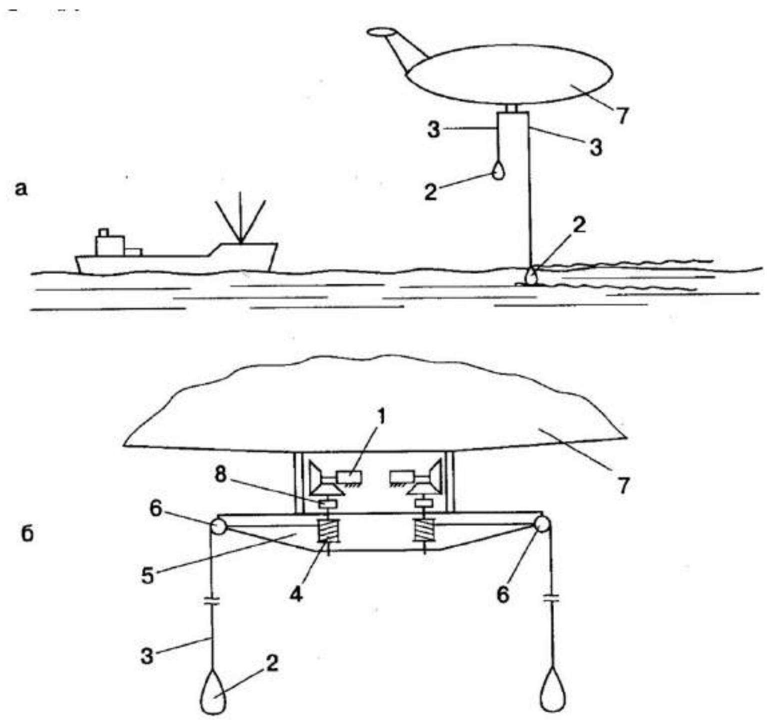
General characteristics of the D-4 airship

Parameter	**D-4**
Length	168 m (551 ft)
Diameter, max	50 m (164 ft)
Volume	220,000 m^3 (7,769,200 ft^3), about 20% larger than the LZ 129 Hindenburg
Weight, max takeoff	220,000 kg (485,017 lb)
Weight, empty	100,000 kg (220,426 lb)
Weight, fuel	20,000 kg (48,512 lb)
Payload	100,000 kg / 100 metric tons (220,426 lb / 110 tons)
Cargo bay dimensions	50 L x 16 W x 5 H m (164 L x 52.5 W x 16.4 H ft)
Load platform lowering height	60 m (197 ft)
Crew	5 crew members
Passenger accommodations	Up to 1,000 passengers
Propulsion	2 x turboshaft engines rated @ 3,300 kW (4,425 shp) each
Auxiliary gas turbine	Not identified, but functionally similar to D-1 system
Speed, max	200 kph (124.3 mph)
Speed, cruise	170 kph (105.5 mph)
Altitude, max.	Up to 6,000 m (19,685 ft)
Range	• 5,000 km (3,107 miles) with a payload of 80 metric tons (88 tons) • 15,000 km (9,321 miles) max range
Service life	30,000 hours (8 – 10 years)

Sources: Arie & Polnker (1983) & Boyko (2001)

The D-4 gas envelope had 20% greater volume than the LZ 129 Hindenburg in a rigid hull that was considerably shorter (168 m vs. 245 m), and broader (50 m vs. 41.2 m).

Kiev OKBV developed a scheme for using a large D-class rigid airship as an icebreaker that dropped and retrieved a pair of heavy weights (“ice breaking bodies”) to crack the ice along the intended direction of travel by a surface ship. This scheme is shown in the following diagrams. The two “ice breaking bodies” would alternate striking the ice and then be winched up for the next strike.



Legend:
1 - cargo winches; 2 - ice-breaking bodies; 3 - ropes; 4 – rope drums; 5 – platform on the bottom of the airship; 6 – blocks; 7 – airship; 8 - clutch

Icebreaking gear carried by an airship. Source: Boyko (2001)

4. Aerostatic fuel transportation system (SATT)

The SATT concept, developed in 1975, employed airships to transport large quantities of gaseous and liquid fuel over long distances, with the lowest energy transportation costs, relatively low capital investments, and the possibility for rapid deployment. The SATT concept appeared to offer significant cost savings in comparison to building oil and gas pipelines, particularly in difficult terrain.

In the SATT concept, two D-1 airships would be used to tow an aerostatic fuel train (ATP) composed of several un-powered, un-manned, fuel-carrying aerostats (BATs) that were connected in tandem and trimmed for neutral buoyancy. One D-1 would be at the head of the ATP and serve as the “locomotive.” The second D-1 would be the last airship and would help stabilize the ATP. Arie & Polnker (1983) explain how the SATT cargo carriers would operate:

> “Natural gas is pumped into separate fuel-carrying balloons, which receive an aerostatic lift that exceeds the weight of the structure. The excess lift is compensated by loading liquid fuel, such as oil, into the balloons. Loaded fuel balloons are connected to each other in a train and towed by airships of the D-1 type. Several variants of such trains have been developed.”

Arie (1986) provides the following additional details on the design of the BATs:

> “For balancing BAT, they are provided with tanks for pumping liquid fuel. The BAT also has a ballonet system for regulating aerostatic lift and a neutral gas system. Under the outer shell of the BAT, at some distance from it, the inner shell is located, and the space between them is filled with a neutral gas - nitrogen. The presence of this layer of gas, covering the transported fuel, minimizes the fire hazard during operation of the vehicle.”

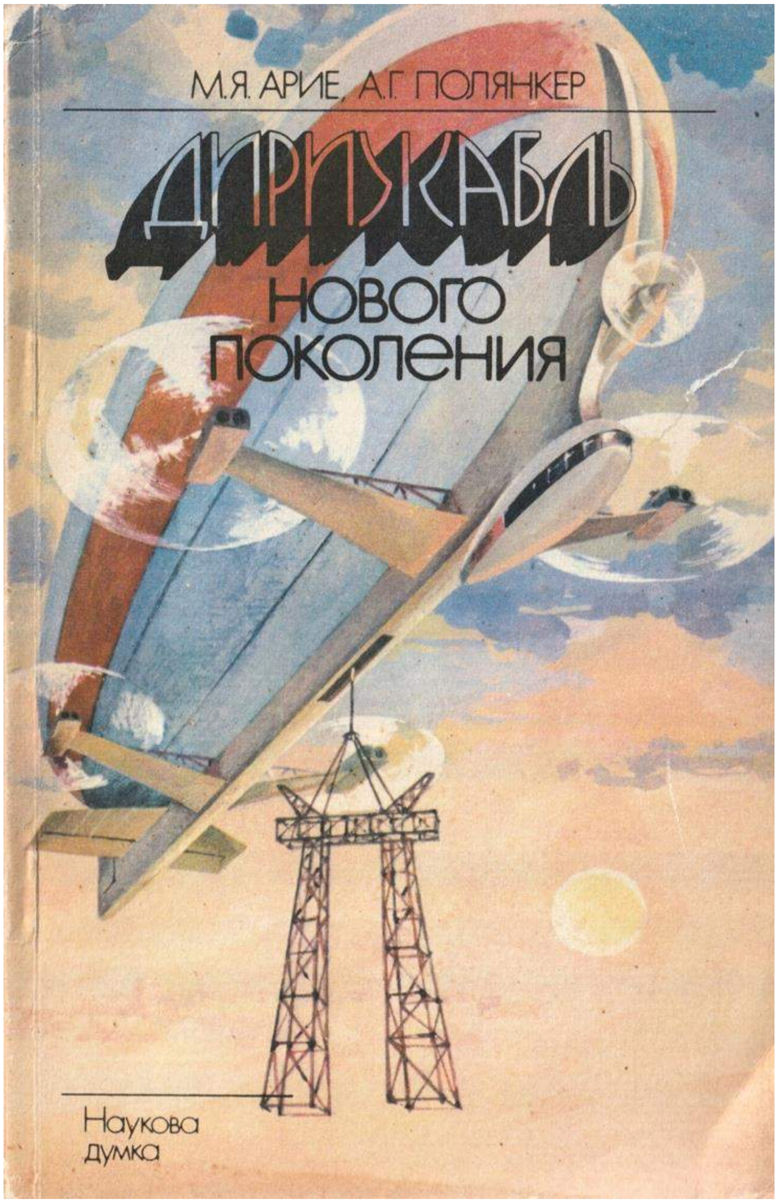
General characteristics of the ATP “train” and BAT aerostats

Parameters	**ATP “train” & BAT aerostat**
BAT Length	202 m (662.7 ft)
BAT Diameter, max	60 m (196.8 ft)
BAT Volume	380,000 m^3 (13,400,000 ft^3)
Number of BATs in an ATP “train”	7
ATP “train” length, with 2 x D-1s	> 1,582 m (> 5,190 ft), about a mile
ATP total volume of loaded gas fuel	1,900,000 m^3 (67,100,000 ft^3)
ATP total weight of loaded liquid fuel	1,029 metric tons (1,159 tons)
ATP speed	100 kph (62 mph)

With the support of the Academy of Sciences of the Ukrainian SSR, the Kiev OKBV submitted a SATT proposal to the State Expert Commission of the USSR State Planning Committee. While they received support "to begin extensive research work in the field of aerostatic trains and airships, to begin the development of projects for the first experimental trains and ships,” no operational tests of this transportation concept were conducted.

5. Helistats

In a typical helistat, a large aerostat is connected to one or more rotor systems in a manner that allows the hybrid vehicle to lift a heavy payload using both aerostatic lift and the dynamic lift from the rotor systems. The aerostat typically carries almost all the empty weight of the hybrid vehicle, while the rotor systems carry the weight of the payload and may also provide propulsion. For stability on the ground, the empty hybrid vehicle is negatively buoyant (heavier-than-air).



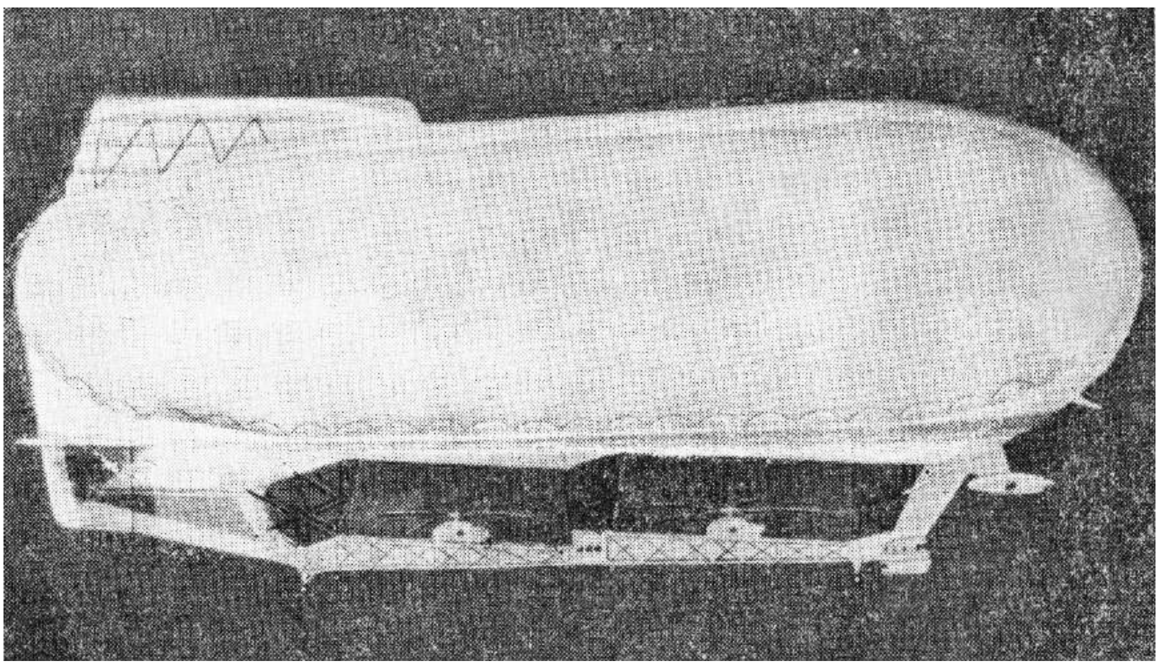
A Ukrainian helistat concept drawing. Source: Book cover illustration, Arie & Poinker (1983)

ELAS-1 helistat

Arie & Polnker (1983) reported that the All-Union Institute "Orgenergostroy" was developing various vehicles for use in the energy construction industry, including for the transportation and installation of power transmission line towers and large equipment for nuclear power plants. One of their proposed solutions was a helistat that combined the aerostatic lift of a non-rigid aerostat and the dynamic lift of multiple large diameter helicopter-style rotors. Their flying model, known as the ELAS-1, was designed with a carrying capacity of up to 8 metric tons (8.8 tons).

Kiev OKBV helistat

In the early 1980s, the Kiev OKBV developed their own large, semi-rigid helistat design concept for transporting oversized cargo weighing up to 30 metric tons (33 tons) on an external sling and installing some large items (i.e., electrical transmission towers) while hovering. A model of the helistat was displayed in 1984.



Model of the Kiev OKBV helistat, profile view.
Source: Arie, "Dirigibles" (1986)

This helistat had a large, non-rigid gas envelope that was attached along its underside to a rigid keel truss frame that maintained the shape of the envelope. The envelope is fastened to the keel truss by means of cables and catenaries similar to the type used in Goodyear non-rigid blimps.

At the front, the keel truss was connected to a bow reinforcement that absorbed aerodynamic loads during forward flight. The aft end of the keel truss carried the attachment points for the lower vertical stabilizer / rudder and the horizontal stabilizers / elevators. The fixed upper vertical stabilizer was a soft structure that attached directly to the envelope.

Three vertical trusses connect the keel truss along the bottom of the envelope to a "sub-engine frame," which was an open truss structure that carried two large-diameter helicopter rotor systems, the "load master's" control station, the payload attachment points and handling systems, and the four-post landing gear. The cockpit / crew compartment and the main propulsion engine were at the front end of the "sub-engine frame," and attachment points for the lower vertical stabilizer / rudder and an enclosed elevator were at the rear. In order to provide adequate airflow, the two rotor systems installed on the "sub-engine frame" had 7 meters (23 feet) of clearance to the bottom of the envelope.

Michael Arie (1986) described the helistat's truss structures as follows, "Longitudinal belts and transverse struts are made in the form of trusses from tubular elements. The cages of the keel truss are reinforced with cable braces. The upper part of the keel truss in the area of the propellers has the shape of an inverted trapezoid in cross-section, which in the bow and stern parts is transformed into an equilateral triangle facing downward. The sub-engine truss has a rectangular shape in cross-section."

Arie (1986) described the helistat's gas envelope as follows, "The shell is made of a material with low helium gas permeability (0.2 liter / (m^2-day)). By means of a soft longitudinal diaphragm located in the lower part of the shell, the latter is divided into a gas space and an air ballonet. The gas container and the ballonet are divided by seven transverse diaphragms into eight compartments. The air for filling the ballonets is taken from the compressors of the main engines. The envelope is provided with an automatic pressure regulation system."

During cruise flight, the helistat used its aerodynamic control surfaces to maneuver the hybrid vehicle. At low speeds and during hovering, aerodynamic controls were ineffective and helicopter cyclic controls were used to precisely maneuver the helistat and control dynamic lift.

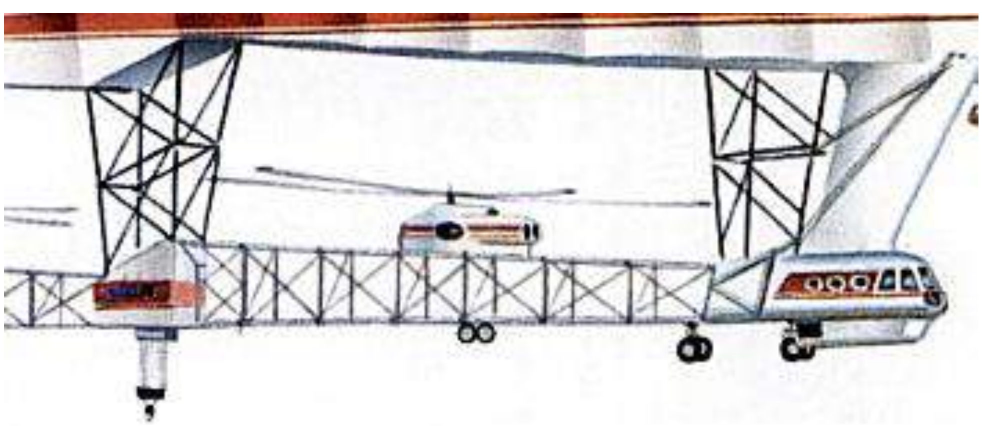
Kiev OKBV helistat, circa 1991.
Source: Illustration by Paul Dimare, Popular Mechanics, p. 33, Aug 1991

Basic features of the OKBV Kiev helistat include:

- Aerostatic lift was provided by 2.3 million cubic ft (65,128 cubic meters) of helium. At STP (standard temperature & pressure) conditions, this quantity of helium provides about 152,000 lb (69,000 kg) of lift.
- Vertical dynamic lift was provided by two Mil Mi-8 helicopter rotor systems attached to the helistat's "sub-engine frame". The maximum gross takeoff weight of a Mi-8 is about 12,000 kg (26,455 lb). That would be the maximum load that a single Mi-8 rotor system could support.

Mil Mi-8 helicopter. Two of these rotor systems were to be used on the Albatross helistat.
Source: Igor Dvurekov via Wikipedia

- Payload weight is carried entirely by the vertical dynamic lift from the two rotor systems installed on the "sub-engine frame" (the open truss structure) under the keel truss attached along the centerline of the gas envelope. Payload weight would be about 24 metric tons (26.4 tons / 52,910 lb).



Sub-engine frame with the cockpit at right, load master control station at left, and one rotor system. Source: Popular Mechanics

- Helistat propulsion is provided by a single, podded Ivchenko AI-24 turboprop mounted under the nose of the gas envelope and by the horizontal component of the rotor thrust vectors.
- The pilot's cockpit is at the front of the "sub-engine frame". The load lifting station is at the middle of the "sub-engine frame."

General characteristics of the Kiev OKBV helistat

Parameter	**Kiev OKBV helistat**
Length	115 m (377.3 ft)
Lift gas envelope volume	65,000 m^3 (2,295,000 ft^3)
Empty weight	about 55,000 kg / 55 metric tons (121,254 lb / 60.5 tons)
Rotor systems	• 2 x Mil Mi-8 rotor system arranged in tandem, each powered by two Kilmov TV2-117A turboshaft engines rated at 1,500 – 1,800 shp (1,118 – 1,342 kW) each. • Total rotor system engine power: 6,000 – 7,200 shp (4,472 – 5,368 kW)
Propulsion	• 1 x commercial Ivchenko AI-24 turboprop engine rated at 2,400 shp (1,790 kW) driving a tractor propeller located under the nose of the vehicle. • Also, the horizontal component of the rotor thrust vectors
Payload	Up to 30 metric tons (33 tons)
Speed	100 kph (62 mph)
Operating altitude	2,000 m (6,562 ft)
Range	1,000 km with 20 metric ton (22 ton) payload

Source: Arie, "Dirigibles," (1986)

OKBV Kiev sought development partners for their helistat, and it appears that one potential partner was the Antonov Design Bureau, which also was headquartered in Kiev, Ukraine.

The Antonov Design Bureau (originally OKB-153, founded by Oleg Antonov) was the largest aerospace manufacturer of fixed-wing cargo aircraft in the Soviet Union, including the giant, fixed-wing An-225 Mriya transport aircraft that first flew in 1988. Before the breakup of the Soviet Union in December 1991, and in approximately the same time frame as their work on the An-225, the Antonov Design Bureau formed a new lighter-than-air (LTA) division under the leadership of aeronautical engineer Michael Arie. One of their LTA projects appears to have been further development of the OKBV Kiev helistat. An August 1991 article in Popular Mechanics actually attributed this helistat, with the name “Albatross,” to the Antonov Design Bureau, with no mention of OKBV Kiev.

In the end, development of the Albatross helistat did not progress beyond preliminary wind tunnel tests.

6. For more information

- M. Ya. Arie & A.G. Polnker, “Dirigibles of a New Generation” (in Russian), Publishing House "Naukova Dumka", Kiev, Ukraine, 1983
- M. Ya. Arie, “Dirigibles” (in Russian), Publishing House "Naukova Dumka", Kiev, Ukraine, 1986
- William Garvey, “Rebirth of the blimp,” Popular Mechanics, p. 33, August 1991: https://books.google.com/books?id=JuQDAAAAMBAJ&printsec=frontcover&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false
- Yu.S. Boyko, “Aeronautics: Tethered, Free, Managed” (in Russian), ISBN 5.8122-0233-8, Publishing house MGUP, Moscow, Russia, 2001
- Alastair Reid, ”Russian Airships – An Illustrated History in English,” 2016, self-published and available thru Lulu: https://www.lulu.com/it/it/shop/alastair-reid/russian-airships/paperback/product-1km4n9zw.html?page=1&pageSize=4

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/