**Airship / Helicopter Hybrid Aircraft (Helistat)**

Peter Lobner, Updated 21 December 2020

1. **Introduction:**

There have been many different designs of airship / helicopter hybrid aircraft (a helistat) in which the airship part of the hybrid aircraft carries the empty weight of the aircraft itself and helicopter rotors deployed in some fashion around the airship work in concert to lift and propel the fully loaded aircraft without the need for an exchange of ballast.

In this section, we’ll take a look at one heavy-lift helistat that actually flew (the Piasecki PA-97-34J) and other heavy-lift helistats that have been described in patents and concepts designs.

- Piasecki Aircraft Corp. helistats (USA, 1955 – 1986)
- NASA heavy-lifter (USA, 1975)
- Aerocran (USA, 1975)
- Goodyear buoyant quad-rotor, heavy-lift Dynastat (USA, 1979)
- Rotor-aerostat composite aircraft patent (USA, 2000)
- Hybrid aircraft patent (Canada, 2002)
- Hybrid lift air vehicle patent (Canada, 2007)
- Boeing lighter than air vertical load lifting system (USA, 2007)
- Skyhook International improved hybrid lift air vehicle patent (Canada, 2009)

2. **Piasecki Aircraft Corp. helistats (USA, 1955 – 1980s)**

After engagements with earlier firms, including Piasecki Helicopter Corporation, Frank Piasecki founded the Piasecki Aircraft Corporation (PiAC) in 1955 in Essington, PA. The Piasecki Aircraft Corporation website is here: [https://www.piasecki.com](https://www.piasecki.com)

From the mid-1950s through the mid-1980s, Frank Piasecki was a major force in the development of helistat technology and flight testing in the US.
Piasecki Patent US 3,008,655, “Helicopter and Balloon Aircraft Unit” (1958)

Frank Piasecki filed a patent application for a “Helicopter and Balloon Aircraft Unit” on 17 March 1958 and received Patent US 3,008,655 on 14 November 1961. This patent described an early concept for a helistat with a large, spherical helium balloon coupled to a central load beam that was connected to two tandem-rotor helicopters by a rigid cross beam. The helicopters have an integrated control system that enables a single pilot to fly the helistat. This general configuration is shown in the following figure.

As described in the patent,

“The present invention relates in general to helicopters, and more particularly to an assembly of a plurality of interconnected helicopters and a balloon forming an aircraft unit particularly suitable for transporting heavy loads…… beyond the normal capability of helicopters.”

You can read Patent US 3,008,655 here: https://patents.google.com/patent/US3008665

On 12 October 1979 Frank Piasecki and Donald Meyers filed a patent application for a “Vectored thrust airship,” which was a more advanced design for a helistat, with a large blimp-shaped aerostat connected to four individual helicopters with an integrated control system flown by a single pilot. They received Patent US 4,591,112 A on 27 May 1986. This patent describes the basic design and operation of this helistat as follows:

“An airship with provisions for vectored thrust provided by a plurality of controllable pitch rotor thrust producing units attached to the elongated aerostat hull spaced from and on opposite sides of the center of overall mass of the airship. The pitch control systems for the rotors of all thrust units include collective and cyclic pitch controls of the main, horizontally rotating lifting rotors and the control systems are interconnected to be operable by a master control which establishes both similar and differential pitch settings of the rotors of selected thrust units in a manner to establish vectored thrust in directions which establish the required amounts of vertical lift, propulsion thrust, trim and control forces to control all flight aspects of the airship.”

You can read Patent US 4,591,112A here:


Frank Piasecki notes, “Semi-rigid pressure envelopes or rigid envelopes can be adapted to the Hell-Stat concept. The longitudinal and lateral support beam structure, which serves to attach the helicopters and support the payload, can be tied structurally to the structural frames of the rigid envelope. In the case of the semi-rigid (envelope), the helicopter attachment and load-support beams can be made integral with the fore-and-aft keel structure.”
The patent includes several helistat design concepts, including the following:

The helistat is comprised of a non-rigid lift gas envelope (10b) and four helicopters (22b, 23b, 24b & 25b) that are connected via cantilever arms (15b) to the rigid keel structure (40).

The basic design of the later PA-97-34J helistat was very similar to the one shown in patent Figures 7 and 8.
The Piasecki 75 ton project X-97-0004 (1975)

This helistat design concept had a 75-ton (68 metric ton) payload capacity based on using four existing CH-53D heavy-lift helicopters and an aerostat with a gas envelope volume of 3,600,000 ft³ (102,000 m³). The gas envelope's overall length was 500 ft (152.4 m), with a diameter of 133 ft (40.5 m). The helistat had an overall height of 155 ft (47.2 m) and an overall width with rotors operating of 292 ft (89 m).

The 75 ton heilstat had the following general characteristics:

- Maximum gross weight: 345,940 lb (156,915 kg)
- Empty weight: 177,540 lb (80,531 kg)
- Useful load (payload, crew, fuel & oil): 168,400 lb (76,385 kg)
- Payload: 150,400 lb (68,220 kg)
- Cruise speed: 100 mph (161 kph)
- Operating altitude (ferry): 10,000 ft (3,048 m)
- Hover ceiling: 6,000 ft (1,829 m)
- Rate of climb: 500 fpm (vertical), 2,000 fpm (forward flight)
- Range (full load): 160 miles (257 km)
- Range (ferry): 2,000 miles (3,219 km)
The Piasecki 140 ton project X-97-0011 “Gargantua” (1975)

Project X-97-0011 "Gargantua" was a design concept for a huge helistat with a 140 ton (127 metric ton) payload capacity. This helistat was created from four Sikorsky CH-53E heavy-lift helicopters connected to a rigid (dirigible) airship with a gas envelope volume of 5,700,000 ft³ (161,400 m³). The aerostat had the streamlined shape of the Navy's 1930-vintage dirigible Macon, but with one less middle section in the hull. Gargantua had an overall length of 770 ft (234.7 m), a hull diameter of 133 ft (40.5 m) and an overall height of 125 ft (38.1 m). Overall width with the rotors operating was 292 ft (89 m).

The Gargantua was designed for transporting the National Aeronautics and Space Administration (NASA) Space Shuttle and other very large cargo items. There was a longitudinal recessed cargo bay under the hull that would have enabled the Space Shuttle to have been hoisted up and carried as a semi-submerged load, with only the wings and lower fuselage outside of the cargo bay.

The Piasecki project PA-97-212B helistat (1977)

The 1977 project PA-97-212B helistat was designed to use four Bell 212B (UH-1N) "Twin Huey" utility helicopters.

The project PA-97-212B helistat. 
Source: Piasecki Aircraft Corporation via US Forest Service

The Piasecki PA-97-34J helistat (1979 – 1986)

In the early 1970s, the US Forest Service initiated Project Falcon, which was a research and development program for advanced logging systems to “…provide more wood products for a growing population and, at the same time, accommodate an increasing concern over the natural environment.” In the late 1970s, Piasecki proposed a helistat to the Forest Service to demonstrate a heavy vertical airlifter for harvesting timber from inaccessible terrain. The Forest Service expected the helistat to carry 25 tons (one truckload, 22.7 metric tons) of timber for distances of up to 5 miles (8 km) over steep mountainous terrain.
The Forestry Service funded development and testing of the PA-97-34J in 1980 via a $10.7 million contract administered by the Naval Air Development Center. Total program cost was expected to be $25 million, with $11 million for helistat construction and flight testing and $14 million for a planned three-year demonstration phase in the Gifford Pinchot National Forest in Washington State. The Forest Service expected to recover most of the helistat project costs through timber sales during the demonstration phase, when the helistat was expected to harvest nearly $19.6 million worth of timber.

In addition to forest management, Piasecki saw applications for their helistat for patrolling sea areas, transporting military equipment, unloading cargo ships, building power lines, oil rigs, residential and office buildings.
Piasecki PA-97-34J was a very large semi-buoyant hybrid airship comprised of a retired Navy ZPG-2W blimp gas envelope, which formed the helium-filled aerostat, and four Sikorsky H-34J helicopters without their tail sections, connected beneath the blimp via a rigid framework. The basic design parameters for this helistat were:

- Overall length: 343 foot (105 m)
- Overall height: 113 ft (34.4 m)
- Maximum width (rotors turning): 188 ft (60.6 m)
- Aerostat gas volume: 1,000,000 ft³ (28,317 m³)
- Gross weight: 107,051 lb (48,558 kg)
- Empty weight: 54,885 lb (24,895 kg)
- Aerostatic lift: 55,851 lb (25,334 kg)
- Dynamic lift: 51,200 lb (23,223 kg)
- Useful load (payload, crew, fuel & oil): 52,166 lb
- Cruise speed: 60 knots
- Working range (with reserves): 143 miles (230 km)
- Rate of climb: 100 fpm (vertical), 950 fpm (forward flight)
- Ceiling: 8,000 ft (2,438 m)
- Hover ceiling: 3,000 ft (914 m)

In June 1981, the General Accounting Office (GAO) reviewed the Forest Service’s helistat demonstration program and recommended that program objectives and progress be reevaluated. At issue were the lack of end user input to the operational requirements for helistat logging and a concern that the PA-97-34J may not actually be suited for demonstrating the economics of aerial logging.

*Rigid framework for PA-97-34J. Source: Flight Int’nl 18 Feb 1984*
The first static tests of the helistat’s structure were carried out in 1983. The first tethered flights occurred in October 1985 at Lakehurst Naval Air Engineering Station. The PA-97-34J first flew on 26 April 1986.
Piasecki PA-97-34J helistat in flight.
Source: US Navy via Planes in Polish Aviation

PA-97-34J in flight with US Forest Service markings.
Source: Piasecki Aircraft Corporation via Planes in Polish Aviation
After 15 test flights, the PA-97 was destroyed during a flight test at Lakehurst on 1 July 1986, after a vibration-induced structural failure resulted in the starboard-aft helicopter breaking free from its mounting and its rotors cutting the aerostat’s gas envelope. The other three helicopters also separated from their supporting framework during the crash, which killed one pilot. Development of the PA-97-34J was discontinued after the crash.

You can watch a short (4:58 minute) video, “Piasecki PA-97 Helistat | The craziest aircraft you have never heard of,” at the following link:

https://www.youtube.com/watch?v=qaUhdDLv8Qk

**Piasecki advanced helistats**

The Piasecki PA-97-34J was the first, and only, US helistat to fly. Piasecki had expected that this helistat would be the precursor to much larger helistats. The Vertical Flight Society reports that “Helistat payload capacities of up to 280 tons have been designed, but no upper limit has been set on the combined helicopter and airship lift capacity.”

*Example of a Piasecki advanced helistat design. Source: Piasecki via Vertical Lift Society*
In the mid-1970s the National Aeronautics and Space Administration (NASA) had a program to develop concepts for heavy-lift lighter-than-air (LTA) vehicles for possible civil and military use. One concept, called the “heavy lifter,” was a semi-buoyant hybrid vehicle with four helicopter rotor systems supported from a large rigid airship (dirigible) hull. At sea level, the gas envelope volume of 75,000 m$^3$ (2.5 million ft$^3$) would provide 83,550 kg (184,196 lb) of aerostatic lift. When loaded with cargo, a helistat is only semi-buoyant (it is heavier-than-air), thereby greatly simplifying ground handling requirements. The helicopter rotor systems provide the dynamic lift to carry heavy loads without also having to lift the whole weight of the vehicle. In addition, the helicopter system enables the helistat to precisely hover above a destination for in-flight cargo pickup or delivery.

This short-haul heavy lifter concept could provide the lifting capacity needed to deliver heavy power generating equipment of other industrial equipment, particularly when its destination is a remote area not served by other heavy transportation systems.
4. Aerocrane (USA, 1975)

The Aerocrane is an unusual concept, even for a helistat, because the large, rotating spherical aerostat also is the “hull” of the helicopter component of the helistat. During operation, the four large rotors (or wings) rotate at about 11 rpm to generate a controllable amount of lift and a controllable thrust vector for propulsion and positioning the Aerocrane during a load exchange. A sling load is supported below a stabilized control cab that does not rotate.

An empty Aerocrane is a lighter-than-air (LTA) vehicle with an operating empty weight between 31 – 35% of design gross weight. In comparison, the empty weight of a heavy lift helicopter is between 57 – 72% of design gross weight, leaving much less margin for carrying cargo.

Aerostatic lift supports two-thirds of the Aerocrane’s design gross takeoff weight, including payload. This means that the aerostat supports the full structural weight of the hybrid vehicle and up to 50% of the design sling load, while aerodynamic lift from the rotors only need to support the remaining 50% of the sling load.
In their 1975 paper, authors R. G. Perkins & D. B. Doolittle reported:

- The primary advantages of the Aerocrane are:
  - VTOL load capacity greatly exceeds heavy-lift helicopter capacity and eliminates the common airship problem of ballast transfer during a load exchange
  - The rotor provides 360° vectorable thrust to supply a relatively large force component for mitigating gust loads
  - Symmetrical shape reduces the mooring problem of airships

- The primary penalties of the Aerocrane are:
  - Larger and more cumbersome than a helicopter
  - Reduced forward speed envelope; a 40 knot design cruise speed seems to be practical

- Principal areas of uncertainty to be addressed in a development program are:
  - Aircraft stability and control characteristics
  - Practical modes of operation considering its airship-size bulk, speed envelope, and potential gust sensitivity

- The Aerocrane is best suited for short range, high load/unload cycle missions where loads are in excess of helicopter capabilities

- The Aerocrane does not compete directly with helicopters because the concept does not scale down to helicopter load size. The Aerocrane also does not compete with airships because it cannot offer efficient long range service comparable to an airship.

You can read their complete paper here:

5. Goodyear Aerospace Corp. quad-rotor, heavy-lift Dynastat (USA, 1979)

In the 1960s and 1970s, Goodyear developed several design concepts for a class of semi-buoyant hybrid airships they called “Dynastats.” In a Dynastat, the aerostatic lift of the airship carries most or all of the deadweight of the airship while vectored thrust propulsion and aerodynamic lift share the weight of the cargo throughout the flight envelope, from vertical takeoff and landing (VTOL) to level cruise flight.

Goodyear Aerospace airship development continued through the 1970s. In 1979, it was reported that the corporate R&D funded airship program was focused on heavy-lift airships and maritime patrol applications. One example of Goodyear’s work during this period is the quad-rotor, heavy-lift Dynastat shown below. In spite of its Dynastat name, this hybrid craft was a helistat. This basic configuration has a cylindrical airship hull with a rigid framework supporting the quad-rotor modules. Auxiliary horizontal-thrusting propellers are shaft-driven from the associated main rotors. These Dynastat propulsion modules were optimized for high reliability and low maintenance and would be de-rated relative to comparable, lighter weight, higher performance helicopter propulsion systems.

6. Rotor-Aerostat Composite Aircraft patent (USA, 2000)

US Patent 6142414A; “Rotor-Aerostat Composite Aircraft”; published 7 November 2000; applicant: Donald B. Doolittle; assignee: All American Industries, Inc., Wilmington, DL; available here:


Abstract: “A composite aircraft comprising an aerostat containing a lighter than air gas, and a rotor assembly mounted to and below the aerostat, via an axle. The aerostat provides buoyancy to lift the weight of the aircraft plus a significant portion of the payload connected to the aircraft. The rotor assembly statically connects to the aerostat in all aspects except rotationally about the axle, and provides the remaining lift and propulsion to the aircraft and payload.”
7. Hybrid aircraft patent (Canada, 2002)


Abstract: “A hybrid aircraft having VTOL R-VTOL and S-STOL capabilities having a lifting body hull (1) and four wing sections (20) arranged in tandem which are pivotally moveable about their neutral axis. Each wing section has mounted thereon a pivotal propeller.rotor (21) assembly for providing thrust substantially in a range between horizontal and vertical. The wings and propellers are integrated to the hull by an outrigger designed to be very stiff and to distribute forces from the wings and propellers from the hull. The hull is shaped to provide aerodynamic lift in an airstream and to facilitate construction by minimizing the number of panels of differing curvature required. The hull is formed of a pressure-tensioned frame covered with semi-rigid panels, a lower cladding frame and bow and stem cladding nose cones. …… A turbo-electric drive system can be used to drive the aircraft.”

FIG. 6a
8. Hybrid Lift Air Vehicle patent (Canada, 2007)

US Patent 8167236 B2; “Hybrid Lift Air Vehicle”; filed 27 August 2007; published 6 March 2008; patent granted 1 May 2012; inventor: Peter Jess, Calgary, Canada; assignee: Shell Technology Ventures Fund; available here:


Abstract: “A hybrid lift air vehicle for lifting and transporting a payload to a delivery location, which comprises a helium or other lighter-than-air gas filled envelope mounted on an airframe. Variable and reversible vertical thrusters are positioned on the airframe, and at least two variable and reversible lateral thrusters are mounted on the envelope or mounted on truss arms attached and extending out from the airframe, Wherein, when the vehicle is connected to the payload for transport, the helium or other lighter-than-air gas supports or substantially supports the weight of the vehicle and the vertical thrusters are then continuously engaged to support the weight of the payload and to provide lift to the payload, Wherein the lateral thrusters are then engaged to effect lateral movement of the vehicle to the delivery location, Whereby, once at the delivery location, the lift provided by the variable and reversible vertical thrusters is reduced or reversed so as to allow the air vehicle to descend and the payload to again engage the ground surface, and where necessary, the variable and reversible vertical thrusters may be reversed to facilitate the unloading of the payload from the vehicle, the vehicle continuing to be kept aloft, once unloaded, by the helium or other lighter than air gas. In this manner, the vehicle utilizes the helium or lighter than air gas to offset or substantially offset the weight of the vehicle, the vertical thrusters providing the power to lift the payload.”

The counterpart international patent is WO2008/025139A1, which is available here:

9. Boeing lighter than air vertical load lifting system (USA, 2007)

Patent US8141814B2; “Lighter-than-air vertical load lifting system;” filed 26 November 2007; patent granted 27 March 2012; inventor: Richard Kulesha; assignee: Boeing; available here:


Summary: “The present disclosure provides an aerial load lifting system that overcomes …… disadvantages of the prior art by providing a neutral buoyancy or lighter-than-air aircraft comprising non-rigid or blimp-type lighter-than-air envelope surrounded at least in part by a structural shell. The structural shell contains the lighter-than-air envelope, and supports the cargo load, the engine(s), fuel tank(s), rotors, and transmission system(s) that power the lift and vectoring of the aircraft. The structural shell is designed to transfer the weight of the load essentially directly to the location of the rotors, thus avoiding unnecessary stress on the envelope. Utilizing a structural shell instead of utilizing a conventional frame or truss structure, large booms or hanging the apparatus from either a cable or from multiple cables from the balloon as in the prior art provides significant advantages, since we make a shell lighter than a “frame”. The system is designed so that the envelope provides essentially neutral buoyancy for the structure including the structural shell, engines, fuel tanks, rotors and transmissions, leaving essentially only the cargo weight to be lifted by the rotors. Preferably, but not necessarily the rotor controls are similar to standard helicopter rotor controls. Thus, the present disclosure provides a relatively compact and simple design for an aerial lifting system that is capable of transporting very heavy loads to remote locations.”

Patent Figure 1A is a profile view of the Boeing helistat. The non-rigid (blimp) gas envelope (10) is partially enclosed by a rigid structural shell (50) that supports the engines (100), tandem rotors (200), cockpit (52) and retractable landing gear (54). The propulsion train consists of tandem rotors (200), two engines (200), two transmissions (120) and drive shaft (140) to deliver power to the front transmission and rotor.
The cargo (20) is carried as an external sling load suspended by cables (32) from four cargo hooks (30) on the rigid structural shell.

**FIG. 1A**

Patent Figure 1b is a cross-section view of the Boeing helistat. The gas envelope (10) is shown inside the rigid structural shell (50). The twin engines (100) flank the rear rotor (200). The cargo (20) is suspended by cables from four cargo hooks (30).

The gas envelope was expected to have an operating life of about 10 years with only minor maintenance.
10. Skyhook International Improved Hybrid Lift Air Vehicle patent (Canada, 2009)


Abstract: “A hybrid lift air vehicle for carrying and transporting a load, comprising an envelope (2) having a generally ellipsoidal shape adapted to receive a volume of lighter-than-air gas, at least two variable thrust vertical thrusters (28) in secure engagement with the envelope and at least two variable thrust lateral thrusters (30) in secure engagement with the envelope, means for temporarily securely engaging the load (12) to the envelope wherein the volume of lighter-than-air gas has a buoyancy that offsets at least 25% of the weight of the air vehicle when unloaded, wherein the thrust from the
at least two vertical thrusters may be varied to raise and lower the air vehicle and the load when engaged, and wherein the thrust from the at least two lateral thrusters may be varied to maneuver and transport the raised air vehicle and the load when engaged.”

The SkyHook JHL-40 (JHL = “Jess Heavy Lifter”) is the commercial incarnation of the patented heavy lift helistat designed by Peter Jess and assigned to the Canadian firm SkyHook International, as described in WIPO International Publication Number WO 2009/152604 Al. In July 2008, Boeing announced that it would team with SkyHook International to build the SkyHook JHL-40.
For the SkyHook application, the helium-filled gas envelope makes the empty aircraft neutrally buoyant. The rotor system will generate the lift needed to carry heavy loads. Lateral thrusters will provide cruise propulsion and precise positioning during load transfers.

The SkyHook JHL-40 was 302 feet (92 m) long, slightly shorter than the 1980s-vintage Piasecki PA-97-34J. The SkyHook was designed to carry an external sling load of 40 tons (80,000 lb; 36,287 kg) at a speed of 70 knots over a range of 230 miles (370 km) without refueling. Without cargo, the SkyHook was expected to have a ferry range of 800 miles (1,287 km).

Load exchange was accomplished with the SkyHook hovering precisely over its destination with the coordinated rotor system managing the increase in lift needed during load pickup and the decrease in lift needed during load delivery. No exchange of ballast was needed during a load exchange.

*Source: Boeing, SkyHook International*
The business case for a SkyHook JHL-40 operating in the Canadian high-North was based on the avoided cost and environmental benefits of not building roads or rails for ground transportation into these sensitive Arctic regions.
The JHL-40 was to be certified by Transport Canada and the U.S. Federal Aviation Administration, with the first aircraft expected to fly in the 2012 – 2014 time frame. However, the development program was cancelled in 2010 before the detailed design phase was completed.

Since the demise of the SkyHook program, there has not been another heavy-lift helistat program.

12. For more information:

**Piasecki**

- “ASN Wikibase Occurrence # 40405” (PA-97 crash 1 July 1986), Aviation Safety Network: [https://aviation-safety.net/wikibase/40405](https://aviation-safety.net/wikibase/40405)
Skyhook

