

China's Shanghai Jiao Tong University - Zhiyuan-1 and Tianzhou-1 unmanned research airships

Peter Lobner, 10 September 2022

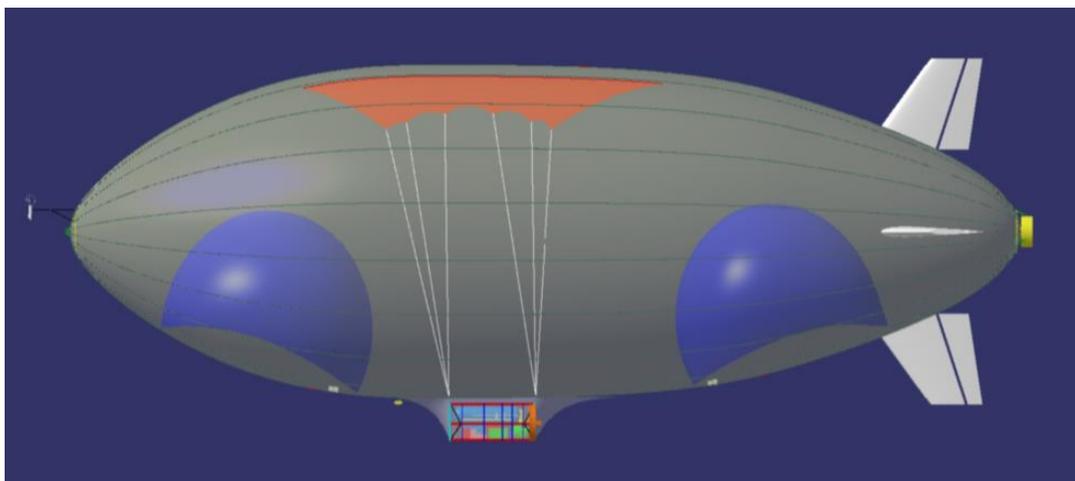
1. Introduction



Between 2007 and 2013, Shanghai Jiao Tong University (SJTU; Chinese: 上海交通大学), developed and flew two small, unmanned, low-altitude, non-rigid airships that were used primarily to develop flight controls and other systems for a future stratospheric airship. These airships, the Zhiyuan-1 (ZY-1) and Tianzhou-1, are described in this article.

2. Zhiyuan-1 (ZY-1) airship (2007 – 2009)

The Zhiyuan-1 (ZY-1) unmanned airship was designed, fabricated and flown during the period from 2007—2009 by Shanghai Jiaotong University as a technical demonstration platform for flight controls for a future stratospheric airship. This 25 m (82 ft) conventional blimp had cruciform fins with aerodynamic control surfaces, three propellers, ballonets and an external gondola suspended via internal catenaries.



Zhiyuan-1 airship general arrangement, showing two ballonets (blue), catenary curtain (ochre) supporting the gondola, and the tail-mounted propeller (yellow). Source: X. Ning, et al. (2021)

The all-electric power system is comprised of a hydrogen fuel cell and batteries for propulsion and a lower voltage battery for flight control and payload systems. A three propellers layout was adopted, with two thrust vectoring shrouded propellers cantilevered from the sides of the gondola, and one fixed shrouded propeller mounted at aft end of the envelope.

Flight control during cruise is provided by conventional rudder and elevator control surfaces on the cruciform tail fins. At low speed, when the aerodynamic control surfaces are ineffective, the thrust vectoring propellers provide control for maneuvering.

General characteristics of the Zhiyuan-1 airship

Parameter	Zhiyuan-1 (ZY-1)
Length	25 m (82 ft)
Diameter, max	7.5 m (24.6 ft)
Fineness ratio	3.3
Envelope volume	750 m ³ (26,486 ft ³)
Power system	Hybrid hydrogen fuel cell / battery system provides 300V for propulsion power: <ul style="list-style-type: none"> • 10 kW fuel cell with 140 L / 20 Mpa (40 gallon / 2,900 psi) gaseous hydrogen tank • 6.0 kW Li-ion battery 1.2 kW Li-ion battery provides 28V for flight control system and payload
Propulsion system	<ul style="list-style-type: none"> • 2 x thrust vectoring, 300V electric motor-driven shrouded propellers cantilevered from the gondola • 1 x fixed, 300V electric motor-driven shrouded propeller mounted at the aft end of the envelope • Total propulsion power: 8 kW (10.7 hp), split 1.0 : 1.1 between the gondola motors and the tail motor
Station keeping	± 100 m (328 ft) in autonomous flight control mode
Wind speed, max	8 m/s (29 kph / 18 mph) design, 10 m/s (36 kph / 22.4 mph) demonstrated
Altitude max	800 m (2,625 ft)
Endurance, max	4 hours (design), 80 minutes demonstrated

Flight control system included a manual remote controller and an autonomous control system, which could be engaged and disengaged in flight. An operator in a mobile ground station installed in a minibus could exercise full remote control or, during autonomous

flight, update course and waypoints. The ZY-1 flew a total of 12 test flights between September and December 2009. On these flights, manual control was used for takeoff and landing. Autonomous controls were demonstrated in flights lasting up to 80 minutes.



Zhiyuan-1 airship flight, showing the darker outlines of the ballonets inside the envelope. Note that the shrouded propellers on the gondola are vectored horizontally to provide lift.

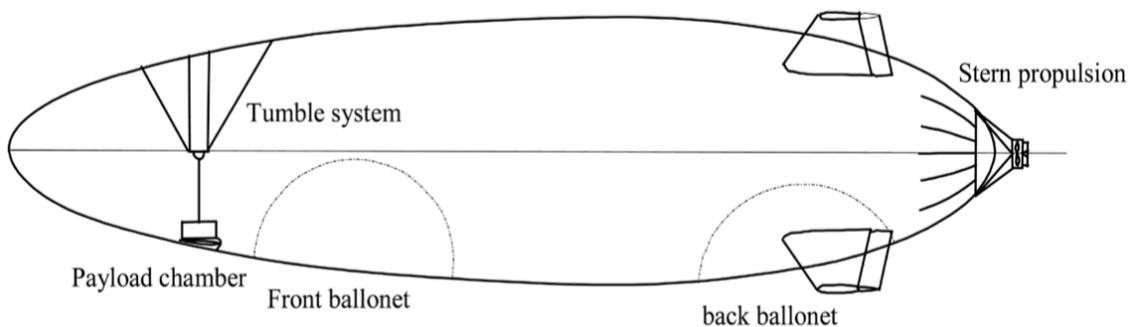
Source: X. Ning, et al. (2021)



Zhiyuan-1 airship moored. Source: X.L. Wang, et al. (2010)

3. Tianzhou-1 airship (2013)

Tianzhou-1 is a very streamlined airship with an X-tail, a single thrust-vectoring propulsor mounted at the aft end of the envelope, and an internal equipment bay.



Tianzhou-1 airship general arrangement.

Source: X. Ning, et al. (2021)

This general arrangement is reminiscent of the StratSat stratospheric communications airship that was being developed between 2001 – 2006 by the British firm ATG.

General characteristics of the Tianzhou-1 airship

Parameter	Tianzhou-1
Length	20 m (65.6 ft)
Diameter, max	5.3 m (17.5 ft)
Fineness ratio	3.75
Envelope volume	300 m ³ (10,594 ft ³)
Power system	Li-ion battery delivering 3.3 kW/300V to the propulsion system and 435 W/28V power to flight control and payload systems
Propulsion system	1 x DC motor (3.3 kW/300V) (4 hp) driving a single, tail-mounted, ducted propeller with 4 x flow deflectors in the slipstream to provide thrust vectoring
Station keeping	±100 m (328 ft) in autonomous flight control mode
Wind speed, max	10 m/s (36 kph / 22.4 mph, design)
Altitude max	500 m (1,640 ft)
Endurance, max.	1 hour (design)

Like the ZY-1, the flight control system included a manual remote controller and an autonomous control system, which could be engaged and disengaged in flight.

Flight tests of the Tianzhou-1 airship were conducted from January to December 2013. The main goals of these tests were to verify flight performance and stability of an airship with a single thrust-vectoring propeller at the stern. During these tests, the airship typically flew at altitudes between 300 to 500 m (984 to 1,640 ft).



Tianzhou-1 airship in tethered flight. Source: X. Ning, et al. (2021)

4. For more information

- X.L. Wang, G. Fu, D.P. Duan and X.X. Shan, “Experimental Investigations on Aerodynamic Characteristics of the ZHIYUAN-1 Airship,” *Journal of Aircraft*, Vol 47. No. 4, July – August 2010: <https://arc.aiaa.org/doi/abs/10.2514/1.C000243>
- L. Ping, G. Fu, L. Zhu & X.L. Wang, “Aerodynamic characteristics of airship Zhiyuan-1,” *Journal of Shanghai Jiaotong University (Science)*, Vol. 18(6), pp. 679-687, December 2013: https://www.researchgate.net/publication/271742334_Aerodynamic_characteristics_of_airship_Zhiyuan-1
- X. Ning, P. Liu & Z. Pan, “The Mechanical Characteristics and Experimental Study of the Stratospheric Airship,” *Journal of Applied Mathematics and Physics*, Vol. 9, pp. 183-196, 2021: https://www.scirp.org/pdf/jamp_2021012814484899.pdf

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