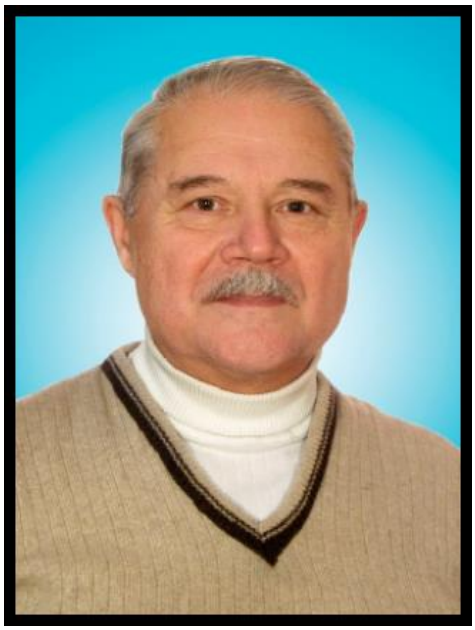
V.S. Shalaev and the Krylo Design Bureau

Peter Lobner, 11 February 2022

1. Introduction



In 1993, Vyacheslav Stepanovich Shalaev (Shalavyev) founded the Aviation Scientific and Technical Complex Krylo (ANTK Krylo, “Wing”), located in Omsk, Russia, in central Siberia. The state-run Bureau was situated at the Siberian State Automotive-Road Academy Innovation Centre (SibADI), where Shalaev served as Director and General Designer until his death on 24 October 2013.

Source: Shalaev bio

Little is known about Krylo’s airship design activities, except that the design bureau was primarily engaged in the design of very large cargo airships (known as RVKs) that could serve communities between the Baltic Sea and the Pacific and help these regions overcome their physical isolation from the rest of Russia. Shalaev devoted thirty years working on the designs of a series of very large, rigid cargo airships with “active regulation of their aerodynamic characteristics” (known as the “SHa” series).

As General Designer, Shalaev led an ambitious Krylo program that created a concept for an airship industry and transportation infrastructure based on super-large-capacity airships. This concept was presented in 2009 and 2013 at specialized international exhibitions in Russia. Extraordinary all-weather performance capabilities were described, with airship operating altitudes ranging from 2,000 to 12,000 meters (6,562 to 39,370 ft) and airspeeds from 150 to 450 kph (93 to 280 mph).

In 2013, Shalaev said that if this project were to receive adequate funding, it would have an unprecedented impact on the development of Russia between the Baltic Sea and the Pacific. The construction of infrastructure in this region for road, rail and airplanes would be unnecessary with the new airship infrastructure, allowing cheaper, quicker development of the remote areas of the country. While Russian authorities allocated some funds for building a test model of a Krylo cargo airship, no airships were built before Shalaev's death in October 2013.

More details on VS Shalaev's life are available in a biography at the following link:
https://lynceans.org/wp-content/uploads/2021/10/Vyacheslav-Stepanovich-Shalaev-biography.pdf

After his death, the entire Krylo Design Bureau team left their base in Omsk and joined the Kaliningrad commercial firm ABVERTA, which launched and provided the patronage for the Tretye Izmereniye (Third Dimension) project (http://ngsw.ru). This project was launched on 20 March 2014 to develop the concept for a "New Great Silk Road" cargo transportation route across Russia, spanning more than 9,000 km (5,600 miles) from Vladivostok to Moscow, using unmanned, autonomous super-large-capacity airships (RVKs) as the primary transport vehicles. The RVKs are based on the SHa-3500 rigid airship designed by Vyacheslav Shalaev.

2. Krylo airship designs

Krylo Design Bureau addressed what it saw as key limitations to the use of airships on long trans-Siberian transportation routes: low speeds, suitability of a textile shell (envelope), flammability (with hydrogen lift gas), and wind sensitivity. Krylo was granted more than 200 Russian patents for various aspects of airship design and operation.

Two particular patents granted in 1995 to Shalaev and other inventors at the Krylo Design Bureau, RU2034745C1 and RU2028962C1, address designs for variable buoyancy controls for hybrid thermal (Rozier-type) airships that generate aerostatic lift from a combination of lift gas and hot air. These patents are described in

the following section. It appears reasonable to believe that the Krylo-designed RVKs are Rozier-type, rigid, hybrid thermal airships that can make vertical takeoffs and landings (VTOL).

It also appears that Krylo favored the use of “stabilized” hydrogen, which was invented and patented in 1997 by V.V. Azatyan and others in Russian patent RU2081892C1, “Method for preventing of combustion and explosion of hydrogen-air mixtures.” Use of a small quantity of an “inhibitor” appears to make hydrogen a viable and much less costly lift gas substitute for helium.

Following are brief descriptions of three Krylo design concepts: SHa-10b, SHa-2000 and SHa-3500.

SHa-10b

Krylo’s model numbering scheme seems to incorporate the cargo tonnage, so the SHA-10b likely is a 10 metric ton (11 ton) hybrid airship. With this modest cargo capacity, it is likely intended for local / regional transportation from a cargo hub.

Krylo SHa-10b hybrid airship.
Source: Rossiyskaya Gazeta (2013)

SHa-2000

The SHa-2000 is an RVK designed to transport a 2,000 metric ton (2,200 ton) cargo between cargo hubs. This huge airship has a length of 660 m (2,165 ft), a width of 185 m (607 ft) and a hull volume of 5,300,000 m^3 (187,200,000 ft^3). That's more than 26 times the volume of the Hindenburg LZ-129 (200,000 m^3). The SHa-2000 was viewed as a prototype for the even larger SHa-3500.

Display model of the Krylo SHa-2000.
Source: Vitaly V. Kuzmin via Aerosmena

SHa-3500

The SHa-3500 is the massive RVK design adopted by the Third Dimension project as their primary, optionally-manned, cargo transport for the New Great Silk Road and subsidiary routes. In many routes, the SHa-3500 will fly autonomously between RVC ports and between ports and outlying destinations. Routes judged to be more difficult will be flown by manned SHa-3500s operating in a manual or semi-automatic flight mode.

The payload is carried internally in a detachable internal cargo platform that is designed for rapid unloading and loading. After making a vertical landing at an RVC port, the ground cargo handling system will enable the simultaneous disconnection of the incoming

cargo platform and replacement with another loaded cargo platform. The logistics timeline is for the airship to complete the load exchange and make a vertical takeoff two hours after it arrived. During the load exchange, the variable buoyancy control system will trim the airship for the appropriate buoyancy conditions for departure. Large unitary cargo that doesn't fit on a cargo platform can be carried externally as a suspended load. This would be a technically complex flight that likely requires an airborne load exchange.

General characteristics of the SHa-3500 airship

Parameter	**SHa-3500**
Envelope length	850 meters (2,789 ft, more than ½ mile)
Envelope height	150 meters (492 ft)
Envelope volume	about 9,000,000 m^3 (317,000,000 ft^3)
Payload	3,500 metric tons (3,850 tons)
Propulsion	• Primary: electric-powered fan-type propulsors. • Supplementary: turboprop or turbojet • Emergency: "fuel-free air-gravity technology"
Cruising speed	250 kph (155 mph)
Full load ceiling	8,000 m (26,247 ft)
Service life	30 years, minimum

In connection with its operation along the New Great Silk Road, the SHa-3500 is described as having the ability to fly during an emergency using "fuel-free air-gravity technology," which is described as "a flight technology in which the movement of the RVC in the air is carried out due to aerodynamics and the energy of the earth's gravitational field without the use of fuel propellers." This would be a form of variable-buoyancy propulsion, as first demonstrated in 1863 by Dr. Solomon Andrews and his Aereon 1 airship. In the case of the SHa-3500, this means of propulsion is enabled by its Rozier-type of buoyancy control and the high altitude capability of the airship.

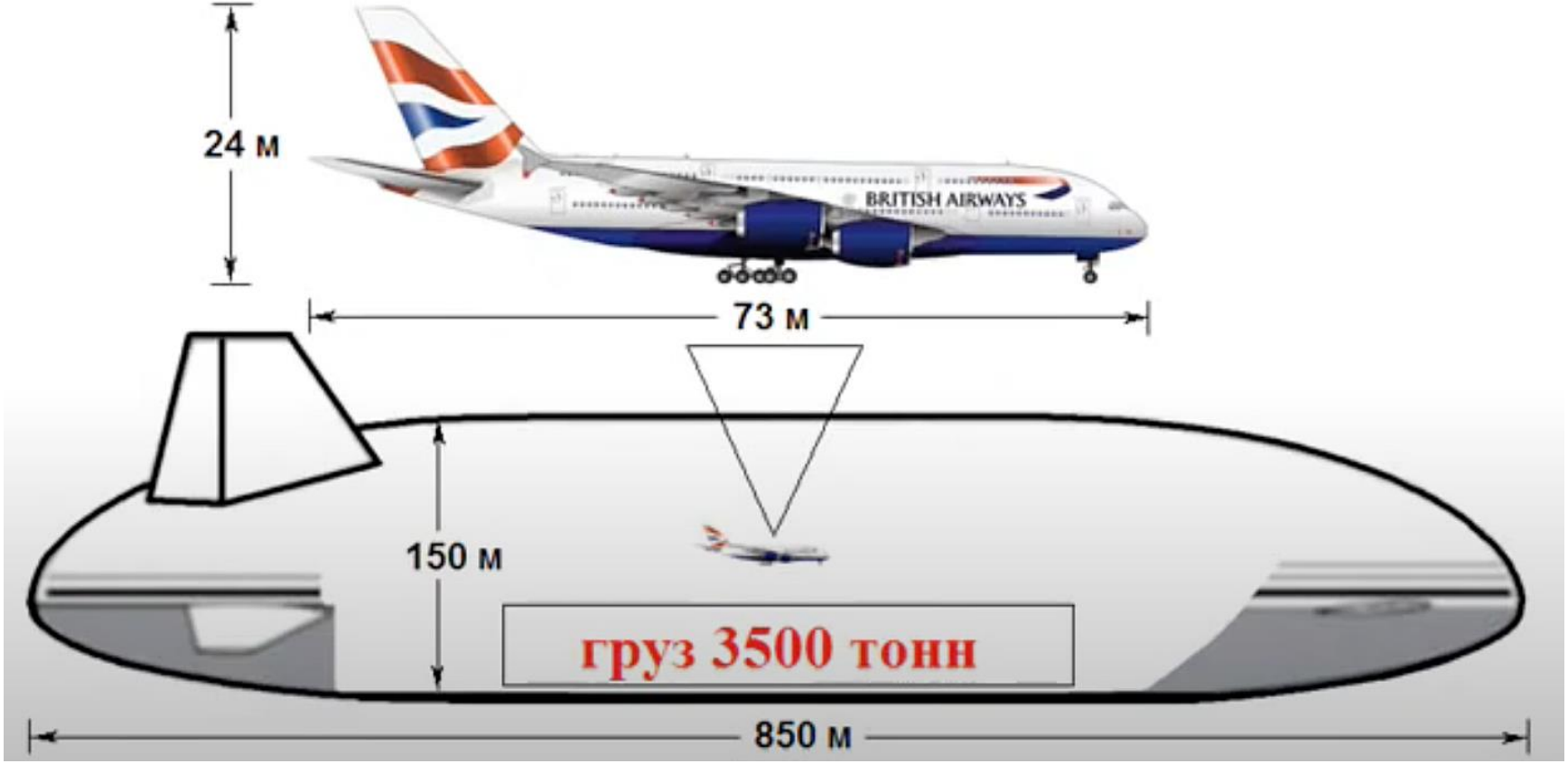
- **For gravity-powered descent:** The buoyancy control system establishes negative buoyancy, making the airship heavier than air. The semi-buoyant airship can be trimmed to fly like a giant lifting body as it gradually descends with significant forward speed. Flying at maximum lift/drag ratio may yield best range before making a decision to land or continue flying.

- **For a porpoising flight profile:** A descent can be terminated by using the buoyancy control system to re-establish positive buoyancy, enabling the airship to continue flying in a desired direction as it ascends to a new, higher altitude. The repetitive cycling between a higher altitude and a lower altitude enables the airship to exploit the forces of aerostatic lift and gravity for propulsion.

As configured for the Third Dimension project, the SHa-3500 airship has provisions for operating vertical takeoff and landing (VTOL) aircraft from a landing pads on top of the envelope and housing a similar aircraft in a stern hangar. The VTOL aircraft depicted in the following diagram are semi-buoyant manned aircraft and a semi-buoyant UAV designed by Siberian firm Tumencotrans.

General arrangement of the SHa-3500 configured to operate along the New Great Silk Road, showing the locations of the internally-carried detachable cargo platform, the landing pad on top of the gas envelope, and the internal aircraft hangar at the stern.
Source: Russian Aeronautical Transport Company

The initial models of the SHa-3500 would be exclusively used as cargo carriers. As operational experience developed, passenger service could be considered later.



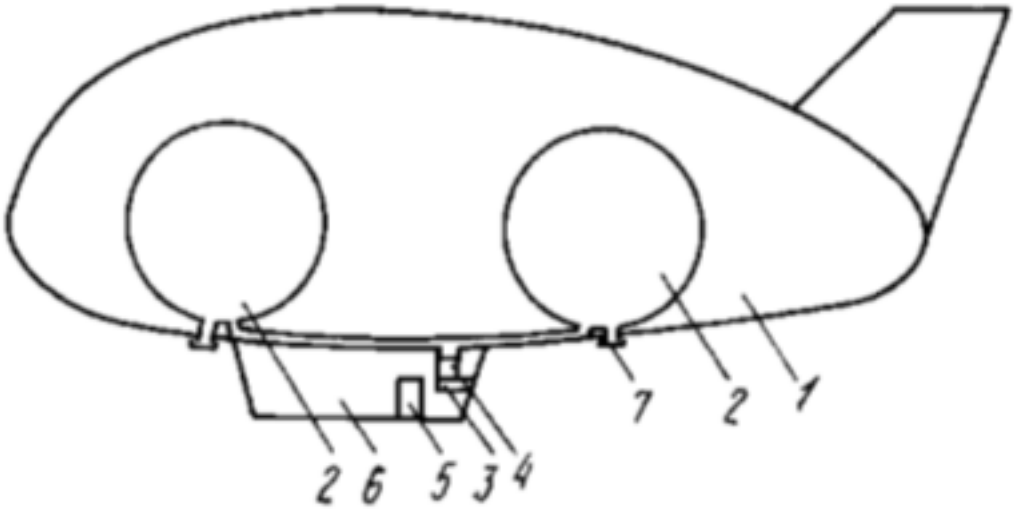
Relative scale of a Krylo SHa-3500 very heavy lift airship and an Airbus A380 airliner.
Source: Screenshot from Third Dimension Project video.

3. Krylo hybrid thermal (Rozier-type) airship patents

Two particular Krylo patents address the design and operation of hybrid thermal variable buoyancy control systems for a Rozier-type airship that derives its aerostatic lift from both a lift gas (helium or stabilized hydrogen) and hot air. These patents may provide useful insights to the type of variable buoyancy control system used on Krylo RVK very heavy lift airships.

Patent RU2034745C1, "Airship"

- Inventors: F.S. Sobachkin, V.S. Shalaev, V.I. Sheronkin
- Application filed: 15 July 1992 by Aviation Scientific and Technical Complex Krylo ("Wing")
- Patent granted: 10 May 1995.
- Patent available here: https://patents.google.com/patent/RU2034745C1/en?oq=RU2034745C1



This patent describes an airship with a non-rigid lift gas envelope (1) propelled by an engine (5) mounted in a nacelle or gondola (6). The envelope (1) encloses two ballonets (2) containing heated air to maintain the non-rigid envelope shape, regardless of flight altitude, environmental parameters and other conditions. The roles of

ballonets are to maintain the required pressure of the lift gas, control the magnitude of the lifting force of the airship, and control trim. The ballonets (2) are made of heat-resistant material and are located inside the lift gas envelope (1), but without direct contact in order to limit unwanted heat exchange. Each ballonet (2) has an exhaust valve (7) that discharges directly to the atmosphere.

Ambient air temperature during the year can vary from -50 to +45º C (-58 to 113º F). The heater (4) can heat the air in the ballonets to an average temperature of 100º C (212º F), likely limited by the ballonet material. At this ballonet temperature, average helium temperature would be about 30° C (86º F).

This variable buoyancy control system operates as follows:

> **Before the flight:** With the hot air system turned off, the airship is heavier-than-air. Heater (4) is turned on and fan (3) drives hot air into the ballonets (2). With the exhaust valve (7) open, cold air is discharged from the ballonets as hot air enters. The lift gas is heated through the shell of the ballonets (2), and expands, slightly compressing the ballonets and displacing some air from the ballonets (2). The aerostatic lifting force of the airship increases, and when it reaches a value exceeding the loaded mass of the airship, the airship begins to rise. When the airship ascends to a desired height, engine (5) is engaged and the airship begins horizontal flight. The heater (4) can be turned off. The patent does not describe the source of power for the heater (4) and it does not discuss using the airship's propulsion engine as a heat source for the ballonet air.
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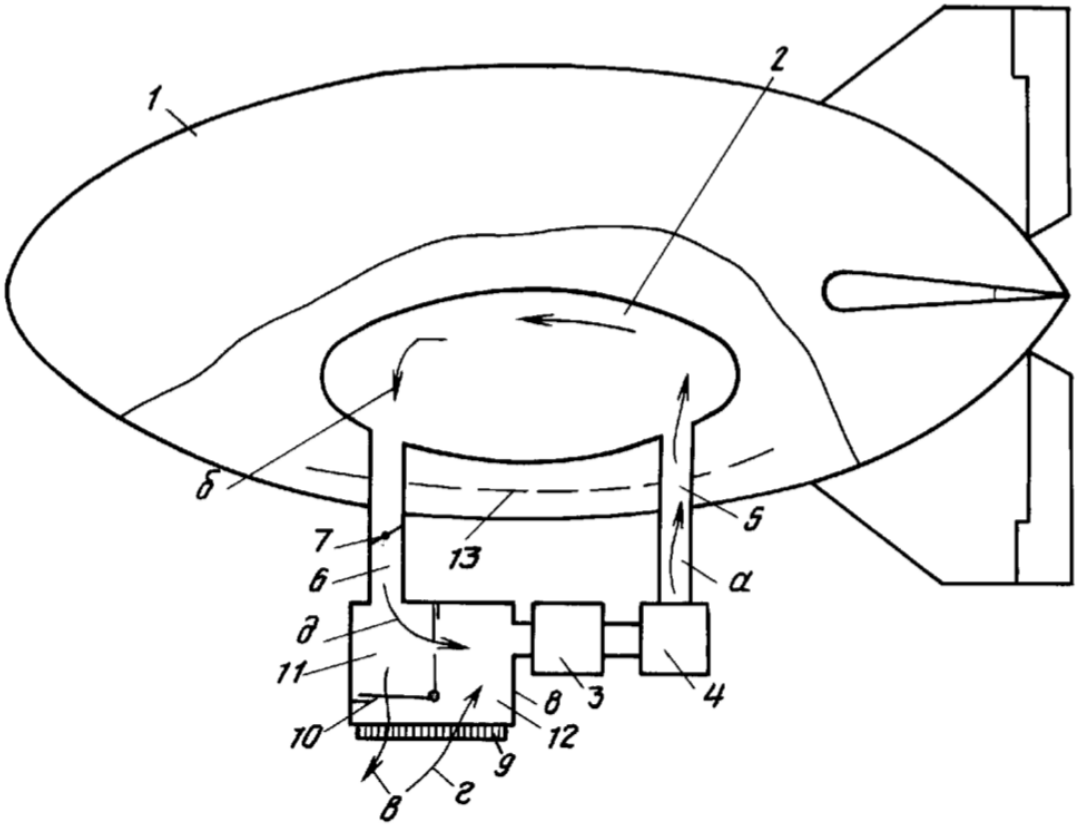
> **To reduce buoyancy:** With fan (3) on and heater (4) off, cold ambient air can be pumped into the ballonets (2). The lift gas in contact with the ballonets (2) is cooled, causing the aerostatic lift of the airship decrease. Ballonet discharge valve (7) is opened, and, upon reaching the desired overall buoyancy, is closed again.

Patent RU2028962C1, “Airship”

- Inventors: F.S. Sobachkin, V.S. Shalaev, V.I. Sheronkin, S.B. Stetsenko, Yu.A. Kotelnikov
- Application filed: 18 September 1992 by Aviation Scientific and Technical Complex Krylo ("Wing")
- Patent granted: 20 February 1995.
- Patent available here: https://patents.google.com/patent/RU2028962C1/en?oq=RU-2028962-C1#



The drawing shows the airship in a schematic representation with a system for managing buoyancy by supplying, recirculating and/or discharging heated or ambient air from an air volume (a ballonet) inside the lift gas volume. When this system is not in operation, all aerostatic lift is provided by the lift gas (helium or stabilized hydrogen) and the airship is heavier-than-air. When the system is in operation, the added buoyancy from hot air enables the airship to fly with heavy loads.

The airship contains a lift gas envelope (1), an interior ballonet (2), a supply fan (3), a heater (4), a conduit (5) for supplying heated air to the ballonet, another conduit (6) with a throttle valve (7) for discharging air from the ballonet (2) into a chamber (8), which has a movable shutter (10) for directing airflow for recirculation or discharge to the atmosphere, and an air intake / exhaust portal (9) to the atmosphere.

The hot air in the ballonet (2) provides aerostatic lift and also heats the lift gas in the envelope (1) primarily by convection. A metallized polyamide screen (13) is installed in the narrow space between the bottom of the ballonet and the envelope to reduce heat loss by radiation to the envelope and then to the atmosphere.

This variable buoyancy control system operates as follows:

> **Before lifting the airship**: The throttle valve (7) opens, the shutter (10) in the volume (11) is moved to the horizontal position to create a closed air recirculation path directly into volume (8), and fan (3) and heater (4) are turned on. With this flow path established, warm air flows through conduit (5) and enters ballonet (2), raising the average air temperature and increasing aerostatic buoyancy. Air flow from the ballonet (2) continues into conduit (6), flows through open throttle valve (7), enters volume (11) and is directed on a recirculation path to fan (3) and heater (4). Raising the average air temperature in the ballonet continues until the desired aerostatic buoyancy has been achieved. Then, the heater (4) can be cycled and/or the throttle valve (7) can be adjusted to maintain the desired aerostatic buoyancy.
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> **When landing**: The ballonet (2) must be purged with cold air. To do this, heater (4) is turned off, shutter (10) is moved to the vertical position, opening a flow path for air from the ballonet to be discharged to the ambient atmosphere. Fan (3) is turned on, drawing cold ambient air through volume (12) and into the conduit (5) to the ballonet (2). This creates an overpressure that circulates air from the ballonet through conduit (6) and the open throttle valve (7), through volume (11) and thence through the open portal (9) to the ambient atmosphere.

4. For more information

- Russian patent RU2081892C1, “Method for preventing of combustion and explosion of hydrogen-air mixtures;” Inventors: V.V. Azatyan, R. G. Ayvazyan, V.I. Kalachev and A.G. Merzhanov; Filed 16 may 1994; Granted: 20 June 1997: https://patents.google.com/patent/RU2081892C1/en?oq=RU2081892C1
- “Omsk engineers have developed a draft of a new generation of cargo airship,” 3 March 2013: https://survincity.com/2013/03/omsk-engineers-have-developed-a-draft-of-a-new/
- Svetlana Sibina, “Modern zeppelins may help develop Russia’s regions,” Rossiyskaya Gazeta, 2 July 2013: https://www.rbth.com/science_and_tech/2013/07/02/modern_zeppelins_may_help_develop_russias_regions_27671.html
- “Airship. The reality of dreams and the absurdity of reality,” WeapoNews.com, 23 January 2018: https://weaponews.com/opinions/22138-airship-the-reality-of-dreams-and-the-absurdity-of-reality.html
- Mikhail Shmelkov, “Средство осуществления проекта,” (“Project tools” in Russian), Third Dimension Project, 2014: http://ngsw.ru/index.php/sredstvo-osushchestvleniya#rvk

Other *Modern Airships* articles

- *Modern Airships - Part 1*: https://lynceans.org/all-posts/modern-airships-part-1/
    - Tumencotrans – BARS & Bella-1
- *Modern Airships - Part 2*: https://lynceans.org/all-posts/modern-airships-part-2/
    - The Third Dimension Project
    - Solomon Andrews - Aereon I and Aereon II
- *Modern Airships - Part 3*: https://lynceans.org/all-posts/modern-airships-part-3/