DRDO / ADRDE - aerostats & unmanned airships

Peter Lobner, 19 June 2023

1. Introduction

In India, the Defense Research and Development Organization (DRDO) is the research and development (R&D) wing of the Ministry of Defense, Government of India, with a mission to empower India with cutting-edge defense technologies. Formed in 1958 with 10 laboratories, DRDO has grown to a network of more than 50 laboratories by the early 2020s. DRDO's broad R&D initiatives are part of a national "Make in India" drive.

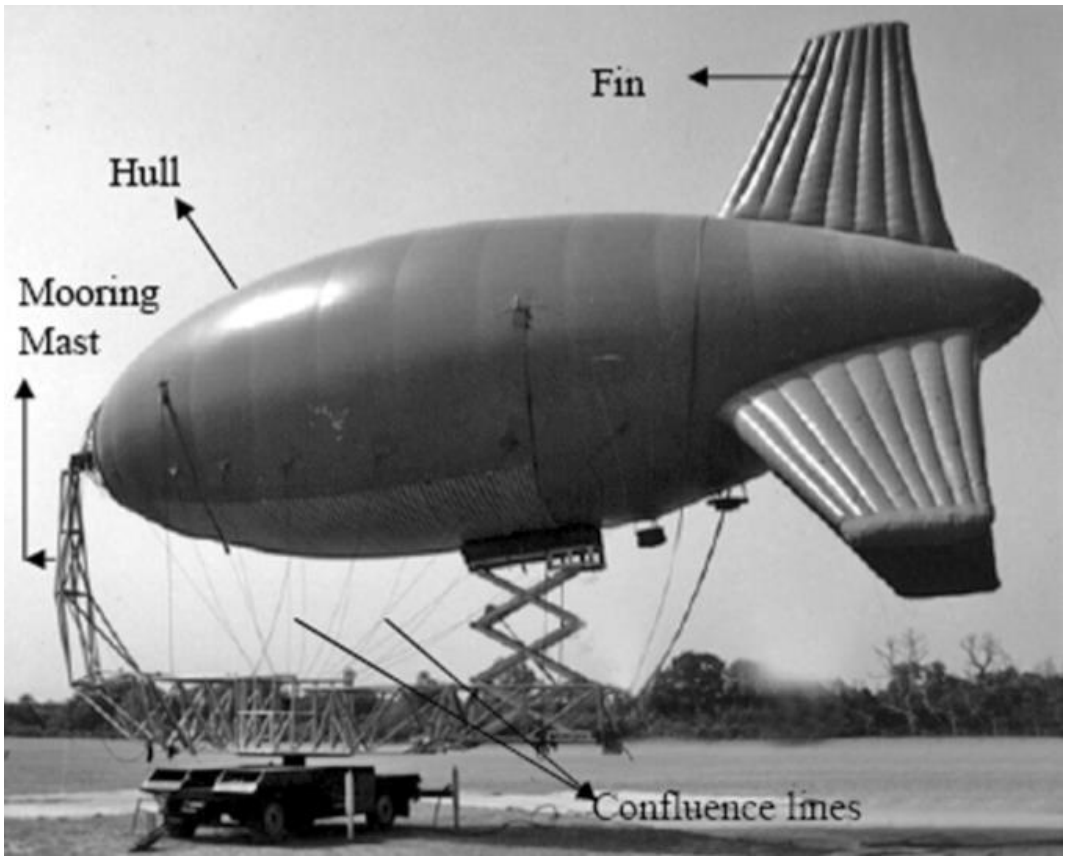
DRDO assigned responsibilities for the design and development of lighter-than-air (LTA) systems and aerospace textiles to the Aerial Delivery Research & Development Establishment (ADRDE), which is based in Agra. ADRDE's efforts related to the gas envelope are supported by another DRDO lab, the Defense Materials and Stores Research and Development Establishment (DMSRDE), which is located in Kanpur. Other DRDO labs support development of various aerostat systems, mission payloads, and ground support systems.

With direction and funding from DRDO, ADRDE's first LTA project was to design and build a 95 m^3 (3,355 ft^3) tethered barrage balloon for the Air Force in the early 1990s.

ADRDE's first indigenous aerostat with a mission payload was a 160 m^3 (5,650 ft^3) tethered aerostat equipped with an electro-optical (EO) sensor, and capable of operating at an altitude of about 300 meters (1,000 ft) above sea level.

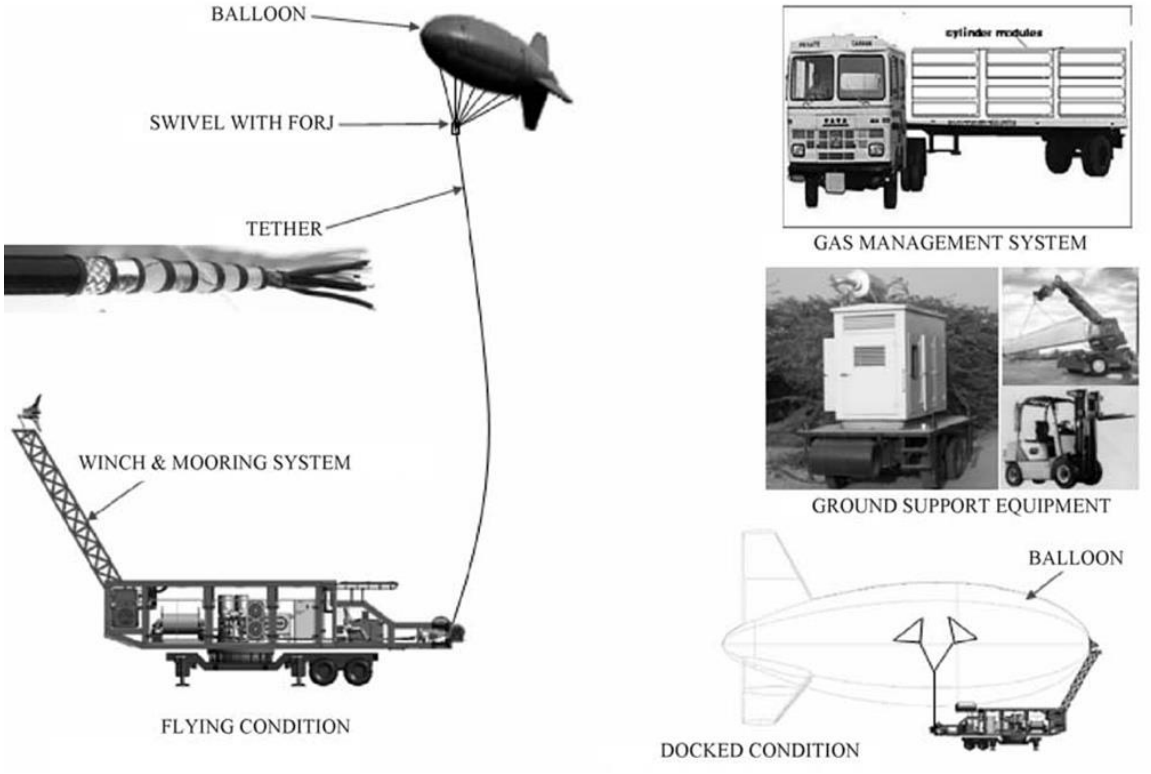
DRDO 160 m³ aerostat, circa mid-1990s. Source: B. Gupta (2010)

In the late 1990s, ADRDE designed and built a larger 250 m^3 (8,829 ft^3) tactical aerostat with a payload capacity of 55 kg (121 lb).



DRDO 250 m³ aerostat, circa late-1990s. Source: A. Rajani, et al. (2010)

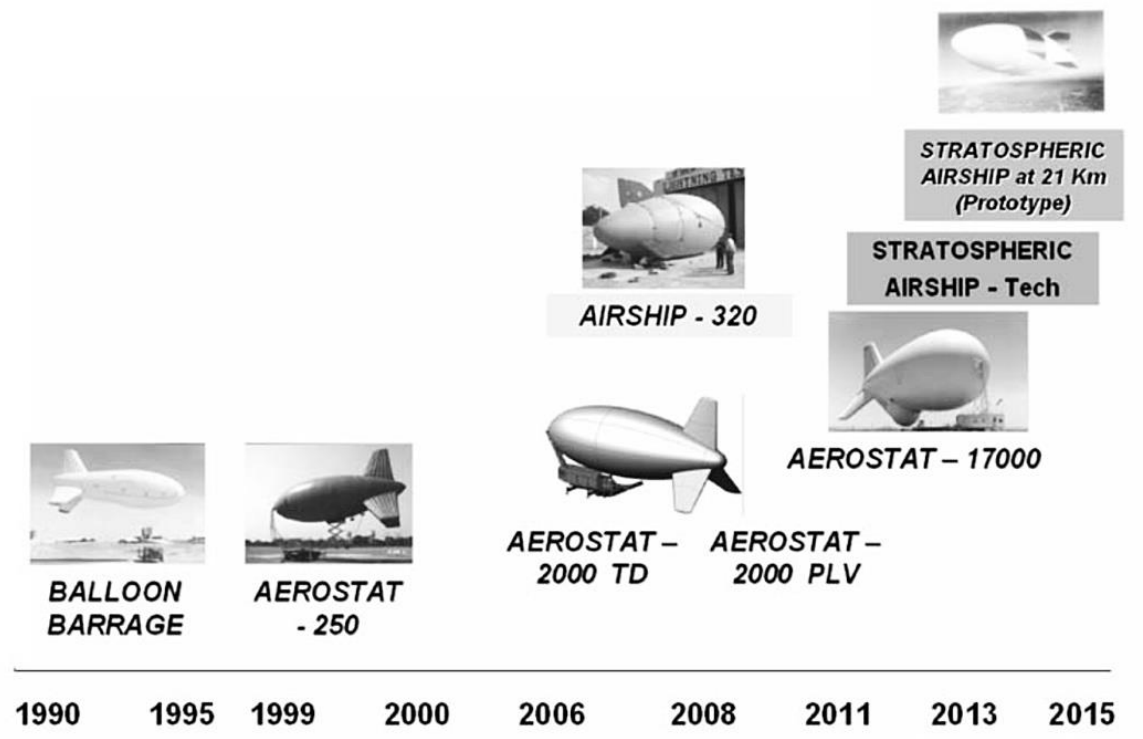
In a 2010 paper, Balraj Gupta reported: “The tether used for this system was power conducting with 80 g/m of linear mass. The winch and mooring system for this aerostat was trailer mounted and could be easily transported from one place to another. The mooring structure was fabricated with aluminum alloy and the winch system was hydraulic type. The system was designed for 60 knots of wind speed for operational condition and 90 knots for survival under the moored condition.”



Elements of the aerostat system. Source: B. Gupta (2010)

To meet the increasing demands of the Indian military, DRDO proposed an aggressive program for near-term development of a family of larger and more capable tethered aerostats and longer-term development of a free-flying stratospheric airship.

Under this DRDO program plan, the next tethered aerostat development effort was for a larger, medium-sized (operational-class) aerostat system under the project named “Akashdeep.”



DRDO program plan for LTA vehicle development, circa 2010.
Source: B. Gupta (2010)

In December 2010, India's first indigenously-developed, medium-size aerostat, Akashdeep, was successfully launched. This aerostat was designed as a testbed to demonstrate basic aerostat capabilities (i.e., payload lift to altitude, stability & handling) and prototype communications / signal intelligence (COMINT / SIGINT) mission payload integration and testing.

Lessons learned from Akashdeep were important inputs to the development of a larger tethered aerostat known as Nakshatra, which was flight tested in 2016, but did not lead to series production. Instead, the program was shut down in January 2017 after the Indian military did not accept the aerostat system.

ADRDE also built and tested other small LTA vehicles, including a tactical tethered aerostat and a free-flying, sub-scale Unmanned Small Airship System (USAS) demonstrator.

This article provides an overview of Akashdeep, Nakshatra, the tactical tethered aerostat and the USAS.

2. Akashdeep aerostat system

ADRDE developed the Akashdeep aerostat system for the Indian military as a ground surveillance and COMINT / SIGINT platform capable of carrying a 300 kg (661 lb) payload to an altitude of 1,000 m (3,281 ft). The aerostat system included a medium-sized aerostat, a powered tether with a fiber optic data link, and all associated ground equipment [i.e., winch and mooring system, gas management system, power management system, Aerostat Health Monitoring System (AHMS), data transfer system and a ground control station].

Elements of the Akashdeep aerostat system. Source: DRDO

Model of DRDO's Akashdeep aerostat during wind tunnel testing. Source: DRDO via Strategic Frontier

Akashdeep made its first flight in December 2010 and was on display at the Aero India 2011 air show in February 2011. Akashdeep was configured with a prototype mission payload consisting of a gyro-stabilized, electro-optical day/night (thermal) camera turret providing 360º coverage, and COMINT / SIGINT antennas. This payload was designed to provide anti-terror and security surveillance to a range of about 20 km (12.4 miles). Longer distances would be possible with a more advanced camera system.

*Akashdeep moored. Source: **Strategic Frontier***

The stabilized EO payload (front) and COMINT / SIGINT antenna complex (rear position) installed on Akashdeep. Source: Defense Update (Jan 2011)

General characteristics of the Akashdeep tethered aerostat

Parameter	Akashdeep aerostat
Length	35 meters (114.8 ft)
Envelope volume	About 2,000 m^3 (70,629 ft^3)
Envelope material & life	• Polyurethane (PU)-coated nylon envelope • Envelope life of 18 months
Lifting gas	• Helium
Payload weight, max	300 kg (661 lb) [Note: Some sources report 200 kg (441 lb)]
Payload	• Initially, EO (electro-optical) & COMINT / SIGINT (communications / signal intelligence). • Other payloads such as ELINT (electronic intelligence), electronic jamming, communications relay, and surveillance radar also could be integrated.
Tether	Textile cable with electric power & fiber optic data cables
Winching & mooring drive	Electro-hydraulic
Raising & lowering time	30 minutes
Operating altitude, max	1,000 m (1 km / 3,281 ft) AMSL (above mean sea level) at STP (standard temp & pressure)
Wind speed limits	• 50 kts (operational) • 70 knots (survival)
Endurance	5 days

The Akashdeep project successfully demonstrated the prototype medium-sized aerostat, mission payload and the related ground systems. In addition, the project provided valuable lessons learned regarding aerodynamics shape optimization, fabrication technology and integration of payload and systems. However, one significant operational issue was the relatively poor helium leakage performance and operational life of the polyurethane (PU)-coated nylon envelope.

When work on Akashdeep ended, ADRDE shifted their attention to the larger, more advanced Nakshatra aerostat system, which had been on a parallel development path since 2011.

Akashdeep tethered aerostat, moored (left) and being deployed (right).
Source: A. Kumar, et al., IJMET (2013)

3. Nakshatra aerostat system

In July 2011, India's Ministry of Defense authorized ADRDE to conduct the technology demonstration project 'Nakshatra' and deliver an aerostat system with a larger 38-meter class aerostat, with a powered tether and ground-based systems similar to Akashdeep. The former Aerostat Health Monitoring System (AHMS) now became the Active Pressure Control & Health Monitoring System (APC&HMS).

General characteristics of the Nakshatra tethered aerostat

Parameter	Nakshatra aerostat
Length	38-meter class
Envelope volume	About 3,500 m^3 (123,600 ft^3)
Envelope material & life	• As built and flown: polyurethane (PU) coated nylon (similar to Akashdeep) with envelope life of 18 months. • Originally planned, but not flown: Multi-layer, imported laminated fabric with envelope life of 4 to 5 years.
Lifting gas	Helium
Payload weight, max	300 kg (661 lb)
Payload	• Initially COMINT (communications intelligence). • Other payloads such as EO (electro-optical), ELINT (electronic intelligence), and surveillance radar also could be integrated.
Tether	Textile cable with fiber optic data cable
Winching & mooring drive	Electro-hydraulic
Raising & lowering time	30 minutes
Operating altitude, max	1 km AMSL (above mean sea level) at STP (standard temp & pressure)
Wind speed limits	• 50 kts (operational) • 70 knots (survival)
Temperature limits	-10ºC to +55ºC (14ºF to 131ºF)
Endurance	• 5 – 7 days (PU coated nylon envelope) • 12 - 14 days (multi-layer laminated envelope)

Source: DRDO via Defence Forum India (26 Aug 2017)

The Nakshatra envelope

DRDO had been funding research and development toward improving mission endurance and balloon life of medium sized aerostats using domestically-produced PU-coated nylon fabric. DRDO also supported research into replacing the PU-coated nylon fabric with multi-layer laminated fabric.

For Nakshatra, ADRDE originally planned to use imported laminated fabric, which was expected to more than double the aerostat's mission duration from five days to two weeks and increase the life of the envelope from 18 months to 4 to 5 years. ADRDE actually imported the laminated fabric at the cost of Rs 6.20 crore (about $1.55 million USD). However, ADRDE manufactured the first Nakshatra envelope using domestic PU coated nylon fabric. A second envelope was manufactured with the laminated fabric, but that envelope was never flown. ADRDE officials later would claim that the balloon made of laminated fabric was kept as a spare and would have been used if any damage occurred to the PU coated nylon fabric balloon.

Nakshatra aerostat moored. Source: The Times of India (2016)

The Nakshatra mission payload

The Nakshatra aerostat carried an integrated COMINT payload designed to intercept and measure the direction of arrival of fixed frequency and frequency hopping signals even in a dense signal environment. The system consisted of a GSM (Global System for Mobile Communications) cellular phone communications interception system, a multichannel VHF/UHF radio signal monitoring system, a microwave receiver, and a DF (direction finder) processing unit. This integrated COMINT payload was developed by the Indian Defense Electronics Research Laboratory (DLRL) and the Electronics and Communication Systems (ECS).

Nakshatra aerostat moored. Source: ARDRE

Operational testing, project cancellation and audit

In 2016, ADRDE conducted abbreviated User Associated Technical Trials (UATT) of the Nakshatra aerostat with the Army's COMINT payload. Speaking to The Times of India (TOI), an ADRDE public relations officer reported:

> "The project was a complete success. We tested the technology of ADRDE at Gurdaspur, Punjab, close to the India-Pakistan border in 2016. Further, the Army demanded that the trials be extended for two more years at various locations close to international borders, but they didn't give us more funds to conduct the trials. So the operational feasibility of the system was never tested and the project was shut down."

A 2017 Defense Services audit report provided a different perspective on the UATT and project cancellation. Here are excerpts summarizing the key audit findings.

> "Interestingly, the imported laminated fabric was never used and the DRDO lab used only PU coated nylon fabric for the (Nakshatra) balloon."
>
> "The ADRDE stated (January 2017) that the integrated aerostat (PU coated fabric balloon) surveillance system was successfully demonstrated during user associated technical trials (UATT) (May/June 2016) and the project was closed. ADRDE also stated that the other balloon (i.e., balloon made of laminated fabric) was kept as spare and would have been utilized in case of any damage that might have occurred in unforeseen circumstances."
>
> "However, the Army replied (February 2017) to an Audit query by stating that the UATT for the system could only be carried out for three days and as such the effectiveness of the COMINT system could not be ascertained. It further mentioned that ADRDE has been requested to deploy the aerostat with the COMINT payload for three months for UATT as it is a pre-requisite to ascertain efficacy before taking over the system for extended trials."
>
> "Thus, the very purpose of import of a balloon made of laminated fabric was to attain the project's objective of a medium size aerostat without the constraints of endurance and shelf life experienced in PU-coated fabric. However, non-utilization of the imported balloon by the lab for purposes of the project militates against the project's objective as consequently neither the aerostat was deployed nor COMINT payload tested for the duration desired by the user."
>
> "…the project was shut down in January 2017, as the Army did not accept the product, incurring a loss of Rs 49.50 crore (about $12.4 million USD) to the exchequer."

A 2018 paper by the DSDO laboratory Defense Materials and Stores Research and Development Establishment (DMSRDE) reinforced the need for additional research and development on high strength laminated fabric enveloped for medium-to-large sized aerostats. The authors, B. Dasaradhan, et al., concluded:

> "India's defense research system (DRDO) has made significant achievements in development of small-to-medium sized aerostats using the polyurethane coated nylon fabric. However, the medium-to-large sized aerostats need to be fabricated with high strength laminated fabric to meet the requirements with offering very good service life. The research on developing such inflatable laminated fabric is under progress with activities running at very high pace. The criticality associated with the study is to develop (domestically-produced) laminated fabric with shelf life of minimum 8-10 years."

4. Tactical Aerostat System

In response to an Army requirement of a small, transportable aerostat system capable of operating at an altitude of 3,658+ meters (12,000+ ft) with a VHF/UHF payload, ADRDE designed the Tactical Aerostat System and built a prototype unit for demonstration purposes. The complete aerostat system, which includes Gas Management and Ground Control units, is transportable in hilly terrains on two 2.5T vehicles. The Tactical Aerostat successfully completed a trial demonstration in forward regions (near the Pakistani border) of the country. The Tactical Aerostat System has not entered series production.

Tactical Aerostat System. Source: DRDO

This DRDO-sponsored Tactical Aerostat System is similar to the Israeli Mistral-RT1000, which was demonstrated in 2015 to India's National Security Guard (NSG) and Border Security Force (BSF) by Mistral Solutions.

5. Free-Flying Unmanned Small Airship System (USAS)

DRDO reports: "ADRDE is developing an Unmanned Small Airship System (USAS), which is a non-rigid, aerodynamically shaped autonomous guided and controlled platform. The airship is made up of advanced PU-coated fabric having a very high helium retention capability making it useful for longer operational profile. It is equipped with flight control computer with necessary sensor suite for autonomous GNC (Guidance, Navigation, Control), with (an Obstacle Avoidance & Warning System and) a manual override capability. A fuel-based, independent vector controlled propulsion system provides a greater degree of control and fulfills the thrust requirement of the system."

"The lab (ADRDE) has already developed and demonstrated a scaled-down flying autonomous airship and now realization of a USAS of required capability is under process. USAS equipped with appropriate sensor payloads could be used for various applications such as coastal/border area surveillance and monitoring, relay of communication signals, high resolution photography, etc."

USAS sub-scale prototype with a small gondola amidships. Source: DRDO

USAS sub-scale prototype. Note the two thrust-vectoring propellers (vectored up) cantilevered from the small midships gondola. Source: India Defence Forum (Jan 2019)

USAS sub-scale prototype. Note the red rudder and elevator control surfaces on the cruciform tail fins. Source: Defense India Twitter (24 Jun 2018)

6. For more information

- Samia Miraj, “List of DRDO Laboratories in India 2021,” EntriBlog, 25 June 2021: https://entri.app/blog/list-of-drdo-laboratories-in-india/
- YouTube slideshow, “Aerial Delivery Research and Development Establishment Top # 5 Facts,” posted by Nayana Shrimali, 1 November 2015: https://www.youtube.com/watch?v=eEVJ5XfmCFc
- Balraj Gupta, “Aerial Delivery Systems and Technologies,” ADRDE paper published in Defence Science Journal, Vol. 60, No. 2, pp. 124-136, March 2010: https://publications.drdo.gov.in/ojs/index.php/dsj/article/view/326
- A. Rajani, R.S. Pant & K. Sudhakar, “Dynamic Stability Analysis of a Tethered Aerostat,” Journal of Aircraft, Vol. 47, No. 5, pp. 1531 to 1538, September–October 2010: http://edge.rit.edu/edge/P14462/public/Working%20Documents/Research/P14462%20-%20Tether%20Profile%20Estimate.pdf
- B. Dasaradhan, et al., “A Brief Review of Technology and Materials for Aerostat Application,” Defence Materials and Stores Research and Development Establishment (DMSRDE), published in Asian Journal of Textile, 2018: https://docsdrive.com/pdfs/ansinet/ajt/2018/1-12.pdf

Akashdeep

- “Akashdeep Medium-class Aerostat,” DRDO: https://www.drdo.gov.in/akashdeep-medium-class-aerostat
- “India's first aerostat radar launched,” India-Asian News Services via NDTV, 28 December 2010: https://www.ndtv.com/india-news/indias-first-aerostat-radar-launched-443262
- YouTube video: “Aerostat-mounted radar system developed by India's DRDO [NDTV Report],” (1:16 min,, Indian language), posted by Luptonga, 29 December 2010: https://www.youtube.com/watch?v=uPpIl2KZUJo
- “Indian Labs Demonstrate Mission-Ready Akashdeep Aerostat at Aero-India 2011,” Defense Update, 23 January 2011:

https://defense-update.com/20110123_akashdeep_aerostat_aero-india2011.html
- A. Kumar, et al., “Design Modifications and Enhancement of Adaptability of Mooring Structure for Medium Size Aerostat,” International Journal of Mechanical Engineering and Technology (IJMET), Vol. 4, Issue 6, pp. 161 – 170, Nov. – Dec. 2013: http://iaeme.com/MasterAdmin/Journal_uploads/IJMET/VOLUME_4_ISSUE_6/IJMET_04_06_017.pdf
- “India's DRDO to complete development of airship for surveillance by end of 2014,” Defence Forum India, 15 January 2014: https://defenceforumindia.com/threads/indias-drdo-to-complete-development-of-airship-for-surveillance.57572/
- A. Kumar, S.C. Sati & A.K. Ghosh, “Design, Testing, and Realisation of a Medium Size Aerostat Envelope,” Defence Science Journal, Vol. 66, No. 2, pp. 93-99, March 2016: https://publications.drdo.gov.in/ojs/index.php/dsj/article/view/9291

Nakshatra

- “Nakshatra,” DRDO: https://www.drdo.gov.in/nakshatra-0
- Arvind Chauhan, “Advanced Indigenous Aerial Surveillance System To Be Deployed Along Pak Border,” The Times of India, 12 May 2016: https://timesofindia.indiatimes.com/city/agra/advanced-indigenous-aerial-surveillance-system-to-be-deployed-along-pak-border/articleshow/52238174.cms
- “Report No. 15 of 2017 (Defence Services),” Section 6.1, “Development of an Integrated Aerostat Surveillance System,” pp. 81-82, 2017: https://cag.gov.in/uploads/download_audit_report/2017/Chapter_6_-_DEFENCE_RESEARCH_AND_DEVELOPMENT_ORGANISATION_of_Report_No.15_of_2017_-_Compliance_audit_Union_Government_Army_and_Ordnance_Factories_Reports_of_Defence_Services.pdf

- Arvind Chauhan, “DRDO’s Agra lab spends Rs 49.50 cr, 6 yrs, in developing surveillance system which fails Army standards,” Corruption in DRDO, 29 July 2017: https://corruptionindrdo.com/drdos-agra-lab-spends-rs-49-50-cr-6-yrs-in-developing-surveillance-system-which-fails-army-standards/
- Bharathi Dasaradhan, et al., “A Brief Review of Technology and Materials for Aerostat Applications,” Asian Journal of Textile, pp. 9 – 10, January 2018: https://www.researchgate.net/publication/328557689_A_Brief_Review_of_Technology_and_Materials_for_Aerostat_Application

Tactical Aerostat System

- “Tactical Aerostat,” DRDO: https://www.drdo.gov.in/tactical-aerostat

Unmanned Small Airship System (USAS)

- “Unmanned Small Airship System (USAS),” DRDO: https://www.drdo.gov.in/unmanned-small-airship-system-usas

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/