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REVIEW PAPER

Aerial Delivery Systems and Technologies

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ABSTRACT

Aerial Delivery Research & Development Establishment (ADRDE) was started at Kanpur during latter part of 1950's consisting of two Aerial Delivery Sections primarily for the indigenisation of Parachutes and related equipment for Para-dropping of men and materials. Today, the charter of ADRDE includes design & development of parachutes, Aerostat Systems, Aircraft Arrester Barrier Systems and Heavy-Drop Systems for both military and civilian applications. The technological competence built in Aeronautical, Textile, Mechanical and Electronics engineering has imparted ADRDE, a unique combination of know-how and capabilities to evolve new solutions in these fields, with emphasis on quality assurance. This paper highlights the design and development of technologies developed by ADRDE to stengthen the India's aerial delivery system and its future plans.

Keywords: Parachute systems, emergency floating systems, controlled aerial delivery systems, heavy drop system, supply drop system, flexible aerodynamic decelator, aerostat

1. INTODUCTION

Aerial Delivery Research & Development Establishment (ADRDE) was started at Kanpur during latter part of 1950's consisting of two Aerial Delivery Sections primarily for the indigenization of Parachutes and related equipment for Para-dropping of men and materials. These two sections were moved to Agra during 1965, and a full-fledged establishment viz. Chief Inspectorate of Aerial Delivery Equipment (CIADE) was formed. This DGI Estt. came under the fold of DRDO in May 1968 and ADRDE was created in January 1969. In 1980 ADRDE was brought under Directorate of Aeronautics, during restructuring of DRDO.

In the last two decades ADRDE has executed projects on Man-carrying Parachutes, Cargo & Heavy Equipment Dropping Systems, Aircraft Brake Parachutes, Weapon Delivery Parachute Systems, Ammunitions Parachutes, Recovery Parachutes & related equipments, Arrester Barriers and Aerostats.

Today, the charter of ADRDE includes design & development of parachutes, Aerostat Systems, Aircraft Arrester Barrier Systems and Heavy-Drop Systems for both military and civilian applications. The technological competence built in Aeronautical, Textile, Mechanical and Electronics engineering has imparted ADRDE, a unique combination of know-how and capabilities to evolve new solutions in these fields, with emphasis on quality assurance. This establishment is also responsible for ensuring the transfer of technology of the matured and established technologies to the identified production agency. Subsequent to establishing source for bulk production, ADRDE continues to provide advice and assistance to the production agencies both within and outside MoD, during production, inspection and maintenance of stores.

Apart from stipulated R&D work, this establishment also carries out design modifications for extending the capabilities of existing stores/equipments of armed forces. Life extension studies are also undertaken depending upon needs of the users.

The ADRDE is one of the seven Aero-cluster labs. Though, it is small in size but it is not so in terms of technological feats and its commercial value. In the last five years, just one of the products of ADRDE i.e. Parachutes has fetched Ordnance Parachute Factory over Rs. 170 crores whereas the expenditure budget of ADRDE in salaries & projects was ~ Rs 30 crores during the same period. Similarly, indigeneous Arrester Barrier Nets of 20 ton class and Su-30 class have saved foreign exchange worth ~ Rs. 60 crores in the past ten years.

Each and every product developed by ADRDE is backed up by conformance to stringent quality standards. In its quest of delivering the most modern and up-to-date technological solutions, this lab is well equipped with state-of-the-art testing and measurement facilities. Over a period of time ADRDE has built strong bonds of partnership with industry, reputed institutes like IITs, CSIR labs, Ordnance factories, etc. Our sincere efforts in developing technologies and system development has helped us in graduating ADRDE from an indigenisation lab of parachutes to a system lab offering customized turnkey solutions to user requirements in a gamut of Aerial delivery systems.

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2. PARACHUTE SYSTEMS

ADRDE is the unique center in our country for design and development of flexible Aerodynamic decelerators commonly known as ‘Parachute’. Parachute is foldable large surface, which produces massive air resistance when deployed behind any moving body. Due to this, parachutes are also termed as aerodynamic decelerators. It covers a very wide range of applications including recovery from space. The decelerator may be a single parachute, sequence of parachutes, multiple ballistic parachutes, gliding parachute and many other combinations of these.

2.1 Categories

The various kinds of parachutes designed, developed and offered by ADRDE for a wide range of applications are:

2.1.1 Paratrooper Parachute

The capability of the parachute is to deploy the troops in remote area within very short span of time, from flying aircraft or hovering helicopter. The Aero-conical parachute is designed for such application.

Figure 1. Paratrooper parachute.

2.1.2 Seat Ejection Parachute System

The Flat circular slotted canopy parachute is designed for the purpose of recovery of aircrew, during any emergency, after the seat ejection from the aircraft. All the fighter variants of aircraft available in the IAF inventory are equipped with ADRDE parachutes.

2.1.3 Armament Parachute

The uni-cross parachute is used for deployment of weapons, from low level flying aircrafts, for safe operation,

Figure 2. Seat ejection parachute system.

Figure 3. Armament parachute.

before exploding: to provide stabilization and to provide a proper impact angle.

2.1.4 Torpedo and Sonobuoy Parachute

Air dropped torpedo and sonobuoy requires use of parachute to assure proper orientation of torpedo or sonobuoy while striking the water surface. Guide surface and uni-cross parachutes have been designed & developed for the deployment of various torpedo and sonobuoy respectively.

Figure 4. Torpedo and sonobuoy parachute.

2.1.5 Aircraft Brake Parachute

The uni-cross and conical ribbon parachutes have been developed and proven for very effective aircraft deceleration, to shorten the landing run. Brake parachutes for various aircraft viz. MiG series, SU-30, Jaguar, Mirage-2000 and LCA have been developed and successfully being used.

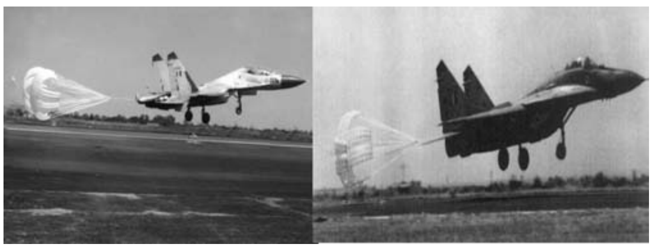


Figure 5. Aircraft brake parachute.

2.1.6 Air Delivery of Combat Material

For heavy drop a cluster of flat circular slotted canopies are used to drop various types of combat loads, using different types of aircrafts and platforms. India is now capable of dropping combat loads ranging from a few hundred kilograms upto 16 tons, using such cluster of parachutes, for drop from both, fixed wing and rotary wing aircraft.

Figure 6. Air delivery of combat material.

2.1.7 UAV Recovery

The Aero-conical parachutes have been applied to recover UAV's viz. Lakshya and Nishant, with an option of sea landing and ground landing capabilities.

2.1.8 Spin Recovery

The Conical Ribbon parachute for spin recovery of a fighter aircraft like LCA and IJT has been developed, with the capability to recover the aircraft, when it goes into an uncontrolled spin.

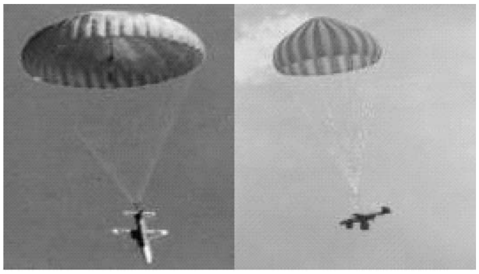


Figure 7. UAV recovery.

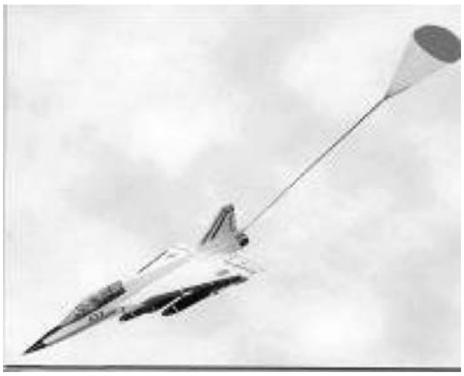


Figure 8. Spin recovery.

2.1.9 Gliding Parachute

The capability of the parachute is to descend as well as glide to reach the target location, also referred to as Ram Air Parachute. With Ram Air Parachutes, a L/D (Lift to drag) ratio of three or more can be obtained, depending on the type of aerofoil being used.

Figure 9. Gliding parachute.

2.1.10 Controlled Aerial Delivery System

The capability of the system is to deliver a payload to a predefined target location. The system is developed for the payload capacity up to 3000 kg. The Ram Air Parachute with onboard computer & sensors is used for control in the system.

Figure 10. Controlled aerial delivery system.

2.1.11 Space Recovery of Payload

ADRDE had designed and developed a recovery system for a space recovery experiment (SRE) of 590 kg payload which was successfully recovered in the year 2007. Three different parachutes were used in two-stage deceleration mode. The payload supported by flotation system was recovered in sea.

2.2 Future Plans for Parachutes Linked with Space Mission

2.2.1 Space Recovery of Payload

The next step toward the space recovery is to design

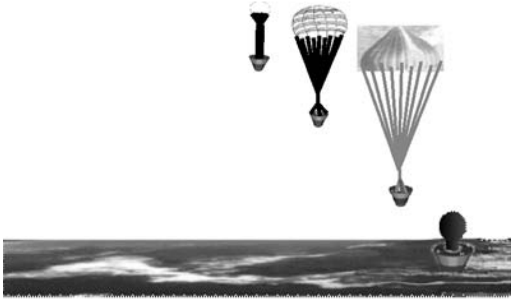


Figure 11. Space recovery of payload.

a recovery system for heavy payloads i.e., range up to 3000 kg.

2.2.2 Recovery System for Manned Spacecraft Terrestrial Landing

A space capsule with crew can be recovered by a parachute-based earth landing system.

2.2.3 Launch Vehicle Recovery

This is to recover the launch vehicle like solid rocket booster.

2.2.4 Planetary Spacecraft Descent

A parachute based system for interplanetary mission.

2.3 Future Plans for Parachutes Linked with other Applications

2.3.1 Powered Parachute

A gliding parachute with a propulsion system can cover a very large range to deliver the payload.

2.3.2 Smart Ammunition Delivery

Parachute can retard the ammunition speed to low subsonic speed for effective searching of the target.

2.3.3 Controlled Aerial Delivery Heavy System

The capability of the system is to deliver a heavy payload range up to 3000 kg to a predefined target.

2.3.4 Supersonic parachute

The parachute can recover a payload from the supersonic speed to a low subsonic speed.

2.3.5 Tandem Parachute System

Looking ahead there are projects like Tandem Combat Free Fall parachute system capable of two personnel jumping with single parachute. The passenger jumper can be a doctor/ anti personnel mine personnel etc., who may be required in the operational area and he himself need not be a jumper. similarly trained mine detector dogs or other search dogs can also be made to jump in this tandem system.

3. CADS

Airdrop technology is a vital capability for rapid deployment of payloads to predetermined location. To produce rapidly deployable units, there is a driving need to equip individual payload package with a parachute and guidance & control module so that each system can steer itself to a predetermined location after release from delivery aircraft. The delivery accuracy of non-steerable (e.g. round) parachute systems is primarily a function of deployment altitude and the wind conditions encountered during descent. Ram Air Parachutes (RAP) (parafoil) with their abilities of gliding and soft touch down are occupying the prominent place in airdrop technology as an alternative to round parachutes.

3.1 Description

Presently, the heavier payloads are being dropped using cluster of round canopy parachutes. For this, the deployment is done at around 380 m altitude and close to desired landing point. The system then lands with the prevailing wind conditions near the target. The aircraft needs to fly in the proximity of intended target point at low altitude for the successful and accurate delivery of payload. Wherein, the inherent advantage of (CADS) is safe and quite delivery without endangering of the aircraft. The CADS aims to deliver the useful payload, to the armed forces, in a place where delivery by other means is either not possible or inordinate delay would occur. The combat team assembly time, prior to the start of the mission, is crucial and needs to be minimum. Payload and the team is despatched together using RAPs. While the commandos steer themselves to the target, the load integrated with CADS gets directed towards the target. The para team and the load make a touch down near the target within a CEP (circular error probability) of 100 m. This results in quick assembly time which leads to an effective and fruitful mission.

The CADS with its air-borne unit (ABU) steers its flight path towards predetermined target by operating two of its control lanyards based on cross-track error, i.e., heading error and altitude. The system uses global positioning system (GPS) to get the current co-ordinates, altitude, and magnetic heading sensor to get the current heading for its entire control operation. The system control can also be overtaken in manual mode by ground operator during the terminal phase of flight. The CADS development needs a suitable size parachute and a mathematical model of parafoil/payload system in terms of turn rate, glide ratio, and descent rate with respect to different brake conditions and a control law (CLAW).

3.2 Development Approach

For theoretical model, three approaches adopted:

(a) Wind tunnel testing on scale down model of RAP at IIT Kanpur;

(b) Theoretical 9 DOF model development at IIT mumbai; and

(c) Developmental flight trials of CADS in different configurations.

The feasibility study was carried at NWTF, IIT Kanpur to develop a suitable model and the wind tunnel experiments were conducted. In consultation with the ADRDE team, a semi rigid model of the 15 cell RAP was fabricated to generate wind tunnel data for various asymmetric and symmetric deflections of the control surfaces. It was felt necessary to have the model of CADS parafoil/payload and to simulate its behaviour in different conditions. This was attempted at IIT Mumbai. The developed model was validated using theoretical data set and simulation response was created. Wind tunnel data generated from the NWTF experimentation proved vital in validating the model. Model was also used at ADE, Bangalore to validate against the trial data. The model was also taken into account for refining the generic control law developed at ADE Bangalore. The CLAW developed was test flown in the CADS. The CADS for 300 Kg payload have been completed with 11 successful consecutive trials from altitude up to 7620 m and offset up to 25 km. In the last 2 trials which were from 6705 m, 22 km offset and 7620 m and 25 km offset, respectively, the system landed with CEP of 15 m and 17 m.

Two CADS are available for demonstrations. Interaction with army is underway to demonstrate the technology. Trials in high altitude area have been successfully carried out at Stakna DZ Leh on 1 April 2009, where two CADS were dropped at an altitude of 5000 ft AGL with offset of 2-3 km. Trials in jungle terrain are being planned as suggested by the INF-7.

Figure 12 (a). CADS 300 kg touch down at stakna drop zone, LEH on 1 April 09, and (b). CADS 300 kg in flight at stakna drop zone, LEH on 1 April 09.

3.3 Future Plans for CADS

After successful development of CADS for 300 kg payload jointly with ADE, Bangalore, the ADRDE is planning for the development of the similar kind of system for delivery of heavier payloads up to 3 ton within a CEP of 100 m.

The development is proposed to take place in 2 stages-

- Development of CADS 1 Ton and
- Development of CADS 3 Ton

The CADS 1 Ton will be able to deliver the payload ranging from 700 kg to 1000 kg AUW (all up weight) and CADS 3 Ton will be able to deliver payload from 1800 kg to 3000 kg (AUW). The useful payload to be delivered by CADS 1 Ton would range from 400 kg to 700 kg and for CADS 3 Ton it would range from 1300 kg to 2500 kg.

A newer concept is also emerging where the heavy load is released at a reasonable offset and altitude, well beyond the danger zone and is made to travel at faster rate of descent using CADS allied technology. Once the system reaches the vicinity of the intended landing area, the RAP opens the conventional round canopy to make the system touch down softly. This is also one of the future activities under plan at ADRDE.

4. HEAVY DROP TECHNOLOGY

There are numerous ways of transportation of military stores between static unit to the battlefield or to the training field or to the border areas and many other such combinations. One of the important means of transportation is para dropping of these stores.

ADRDE has been developing many such systems for the Indian armed forces for last four decades. These systems are called and supply drop systems (SDS). The SDS and HDS have been designed and developed by ADRDE for the para dropping of various types of military stores (supplies, eatables, consumables, etc.) and for para dropping of vehicles/boats/tanks, etc., required by the troops, respectively. The importance of these systems is realised when these target areas are inaccessible by roads.

4.1 Classification

These systems are broadly classified in following two categories:

4.1.1 Supply Drop System (SDS)

The SDS are primarily used for para dropping the supplies using skid boards for the payload up to 500 kg. At present, MI-17 helicopter and AN-32 aircraft are used for this purpose. ADRDE has also developed earlier systems, which were useful in packet aircraft (C-119) and AN-32 aircraft. Some salient features of the SDS are:

- Used for payloads up to 500 kg (ration and ammunition)
- Uses skid board for palletisation
- Use of static line for extraction
- Extraction is by gravity method
- Generally discarded after single drop

4.1.2 Heavy Drop Equipment System (HDE)

These are the systems, which are used for para-dropping of heavier loads. Some salient features of the HDE are:

- These are used for heavy payloads like jeep, tanks
- Extraction of payload from aircraft is done by extractor parachutes
- Special devices to lock and release the platform within aircraft
- Parachute disconnector and shock absorption system are used
- System has multi use capability

These systems can be further classified as follows:

4.1.2.1 HDE AN-32 Aircraft

These systems have been indigenously developed by ADRDE for the paradropping of military stores up to 3 tons weight class, suitable payloads of Indian Army/ Navy/ Air Force.

4.1.2.2 HDE IL-76 Aircraft

These are the systems for 7 ton and 16 ton weight class used for IL-76 aircraft. These systems are defined as P-7 and P-16 HDE. The heavy loads such as jeep, trolley, bigger vehicles, and tanks/BMPs are dropped with these systems.

4.2 Description

The HDS and SDS primarily consist of two main sub-systems as platform system and parachute system. Platform is generally a structure made of steel/aluminum alloy sections and sheets. Platform system is made strong enough to absorb the shock generated by the parachute opening and it protects the payload at the time of landing. Parachute systems are assembly of various types of parachutes used during various stages of descent. The main functions of parachutes are the extraction and retardation of touchdown speed, for safe delivery of payload near the intended target location.

4.3 SDS/HDS developed by the ADRDE

4.3.1 HDS

Name of HDES	Indigenous development by ADRDE
AN-32	Successfully developed, system under bulk production (159 nos.)
P-7	Successfully developed, undergoing user’s trial 10/13 completed)
P-16	Under development

4.3.2 Skid Boards

Name of skid board	Capacity (kg)	Indigenous development by ADRDE
AN-32	500	Already inducted into services
MI-17	500	Under bulk production
DORNIER	250	Successfully demonstrated
ALH	250	Prototype ready for trial

4.4 Other Useful Products in HDS

4.4.1 Underslung Nets

These are made of textile tapes and cordages primarily used for transportation by helicopters in underslung condition. Such nets for Chetak/Cheeta helicopters have been successfully designed and developed by ADRDE. These nets are also being used for transporting the electronic/sensitive equipments developed by one of other laboratories.

4.4.2 CSAR (Combat Search and Rescue) Basket

These are the metallic baskets made of light aluminum alloy pipes, which can carry the wounded soldiers from enemy areas to the friendly areas. Two persons on stretcher or four wounded soldiers can be accommodated in this.

Figure 13. Trials of Heli-Net conducted at Leh in Nov 2008.

This can also be also suitably utilised during the disaster management.

Figure 14. Combat search and rescue basket.

4.4.3 Duck Drop Systems

Marine commandos (MARCOS) operate in sea using their motorised boats (Zemini) after dismounting from the mothership towards the target. If these operations are to be conducted at distant places, the travel time has been drastically reduced with the advent of the duck drop system developed by ADRDE. These Zemini boats (02 nos on each system) can be paradropped from AN-32 aircraft whereas MARCOS can jump with steearable parachutes and land in the closed vicinity of the Zemini boats. They can board into the Zemini boats for the assault in a quicker time. The duck drop system for AN-32 aircraft has already been inducted in Indian Navy.

Figure 15. Duck drop system for AN-32.

4.5 Future Plans for HDS

The ADRDE is planning to extend the range of product by undertaking the following tasks for the armed forces.

4.5.1 P-7 Duck Drop system

This system has been successfully demonstrated in trials conducted by joint operation of Indian Navy and ADRDE. The system is going to be inducted shortly.

4.5.2 P-16 HDE

Development of the system is in the current five-year plan.

4.5.3 HDS for Hercules

Six new cargo aircraft C130 (Hercules) have been inducted into the Indian Air force. These aircraft would be used for the paradropping the stores. ADRDE is studying the aircraft features required for paradropping. Development of HDS for Hercules is in near future plan.

5. AIRCRAFT ARRESTER BARRIER SYSTEM

The purpose of aircraft arrester barrier system(AABS) is to engage a fighter aircraft to halt its forward momentum in the event of aborted takeoff or landing over run with minimal damage to aircraft or injury to the crew. The AABS basically consist of net (or pendant cable for hook type aircraft) deployed across the end of runway to envelope the aircraft. This net is connected to the energy-absorbing unit called energy absorber through purchase tape. Net is kept raised with two-pole type of structure called stanchion. Net is connected to stanchion with the help of engagement system support consisting of shear-off coupling, wire rope (suspension cable) and attaching hardware. Shear-off coupling consists of a shear pin which shears off during engagement to free the net from top. Net lower horizontals are anchored to the runway with the help of 12 nos. of net anchors. Net is connected to purchase tape with the help of mechanical link called tape connector. Roller assembly, called sheave assembly, which is wounded over the tape drum of energy absorber, guides travel of purchase tape. Energy absorber is a turbine type of system consisting of rotary and stationary blades.

5.1 Description

The multiple element net assembly is raised with the help of stanchion system on a command received from remote control located in the ATC tower, when emergency arresting of an aircraft is necessitated. As the net envelopes the aircraft, the pull exerted on the net releases the net-bottom from the net anchors and breaks the shear pins in the shear-off couplings, releasing the net-top from the suspension system. The purchase tapes attached to the net end loops are pulled through the fair-lead tubes and begin paving off the two energy absorber tape drums, thereby, turning the rotary hydraulic brakes. This action generates a uniform braking force, which smoothly decelerates the aircraft to a safe stop. After the aircraft has been safely arrested, the net is manually disconnected from the purchase tapes, removed from the aircraft and transported to the hanger for later inspection and repair. The purchase tapes are rewound onto the energy absorber tape drums by the tape retrieval systems. During tape retrieval, the pressure roller system ensures a tight wrap onto the tape drum. After the tapes are retrieved a new net is quickly installed across the runway, thus allowing the system to be ready for another emergency arrestment.

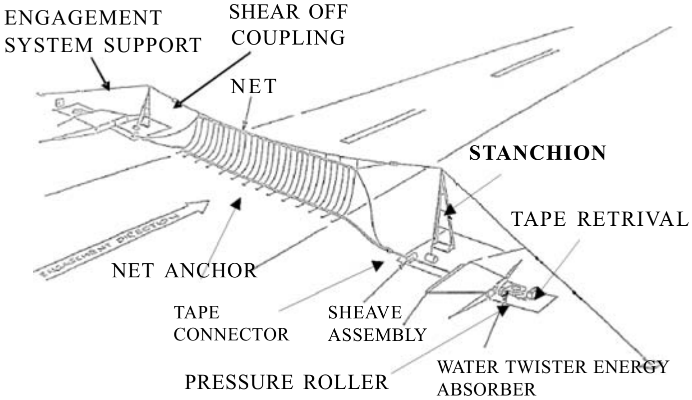
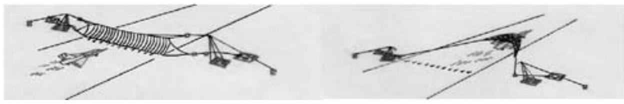


Figure 16. Aircraft Arrester Barrier System.



(a) (b)

Figure 17. (a) Configuration before engagement and (b) Configuration after engagement

5.2 Classification

Based on the mass of the aircraft desired to be saved the system is classified as:

5.2.1 20 Ton

ADRDE started the work on AABS developing multiple-element net for imported 20 ton friction brake type arrester barrier in 1989. Subsequently, ADRDE has developed net for 20 ton water twister type arrester barrier and soft top element net assembly for imported 10 ton arrester barrier. ADRDE has developed full AABS for 6 to 20.4 ton aircraft duly cleared (provisional) by CEMILAC for installation and use in 1997. Subsequently, 21 AABS have been installed at different air force stations based on the requirements of IAF.

5.2.2 40 Ton

Further, ADRDE has developed AABS for 20 to 40 ton aircraft duly cleared (provisional) by CEMILAC for installation in 2005. Now, ADRDE has received a requirement from IAF for supply and installation of Six 20-40 Ton arrester barrier at different Air Force stations. Installation of two arrester barriers has been completed and rest four is in progress. IAF require 21 more barriers for 20 Ton class of aircraft and four more barriers for 40 ton class of aircraft.

Figure 18. Successful engagement of aircraft in AABS at Sirsa, AF Station.

5.3 Achievements of AABS

Over a period of ten years, AABS has saved the country FE worth ~60 crores. Moreover, AABS installed at various AF stations has successfully engaged aircrafts without any serious injury to pilot and major damage to the aircraft, thus prevented two pilots and MiG-21s from damage.

5.4 Future Plan for AABS

In future, there is a need to develop technology for Six 40 Ton fixed and mobile arrester barrier for all aircrafts available in India. There is also a need to develop complimentary technologies for friction brake, Eddy current type energy absorbers, and computer-controlled systems. The work for development of mobile arrester barrier for 6-40 ton aircraft has already been started in another laboratory.

6. EMERGENCY FLOATATION SYSTEM

6.1 Background

ADRDE is working in the field of floatation system since Agni Recovery System. This was developed for Defence Research and Development Labouratory (DRDL).

ADRDE went ahead with the indigenisation of seaking floats for Indian Navy. The floats were designed and developed with indigenous materials. All the tests and trials were

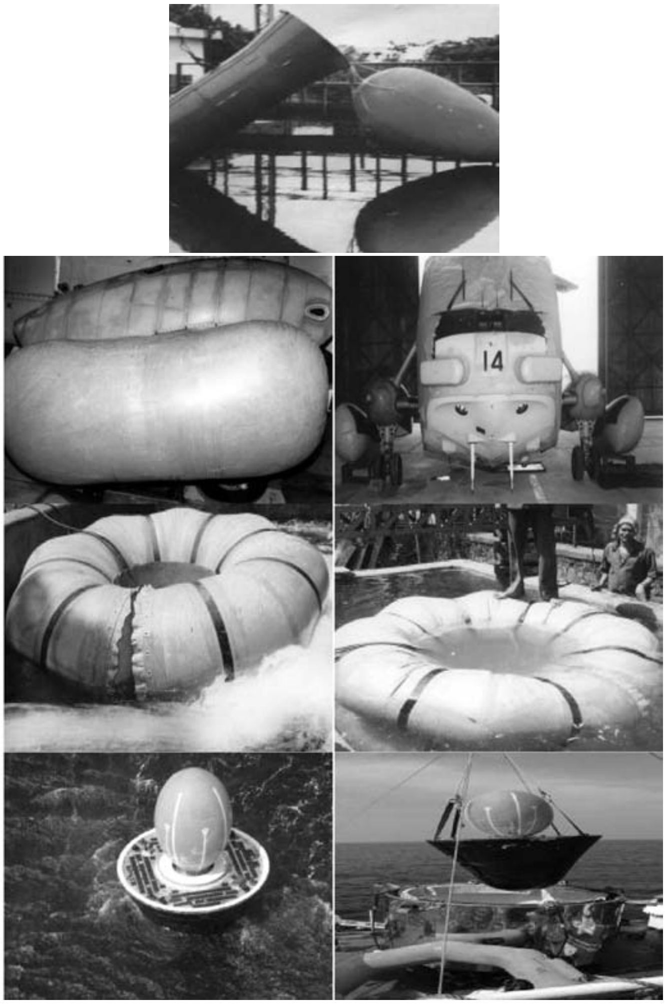


Figure 19. Floation systems developed.

conducted successfully. ADRDE has delivered eight seaking floats to Indian Navy.

ADRDE also designed and developed a float system for K-15 missile recovery system. The tests were carried out successfully by ADRDE and DRDL.

Figure 20. Floatation systems developed.

ADRDE has also designed and developed floatation system for SRE recovery system. This was required by ISRO, and a 500 kg payload was recovered in the first attempt in the country.

6.2 Status

ADRDE is at present involved in the design and development of emergency floatation system of ALH. The emergency floats are required to be deployed by helicopter during ditching. The float system has been developed. The electrical activation system has been designed, developed, and tested as per MIL specificat-ions. The pneumatic system and the polycarbonate float pack covers are under development.

6.3 Future Plan for Floatation Systems

ADRDE intends to undertake the design and development of floatation system for human space recovery. The system is under study with ISRO.

7. INFLATABLE RADOME

7.1 Background

Inflatable radome is used as a protective enclosure for radar antenna, or any other expensive equipment which may get damaged by exposure to harsh environmental conditions. This is fabricated from strong and flexible rubberised airtight material supported by air pressure. Since the structure material is relatively thin and uniform, it approximates to thin shell structural membrane that provides very low transmission loss of electrical signal. An inflatable radome is constructed of gore shaped fabric sections with seams in the vertical direction. This is kept inflated through air blowers. Reliable operation depends on the use of uninterruptible power supplies and redundant air blowers. These structures can be folded into small package, which makes it suitable for transportable radome requiring mobility and quick assembly and disassembly time.

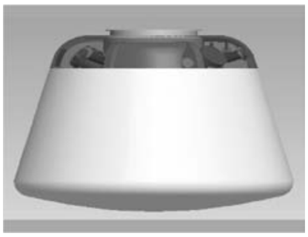


Figure 21. Floatation systems-future plan.

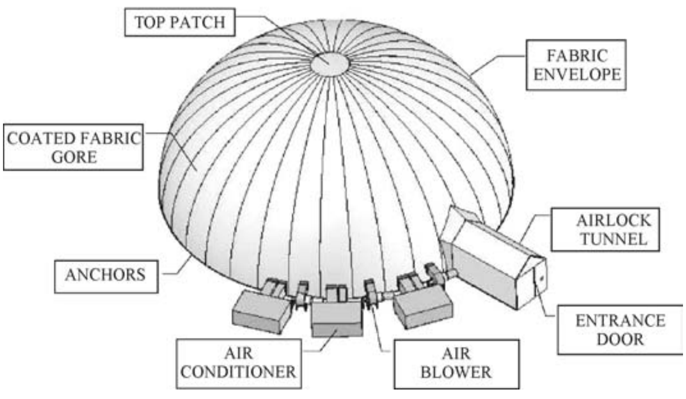


Figure 22. System configuration of inflatable radome.

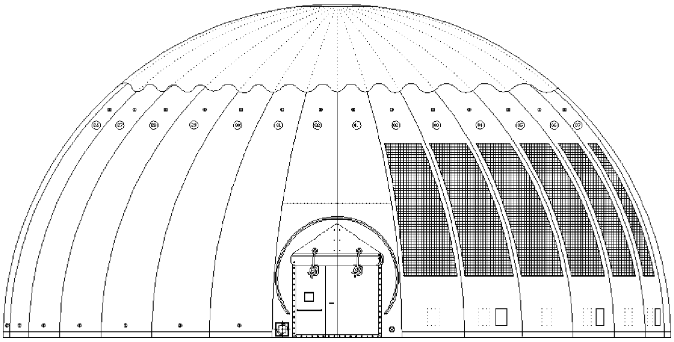


Figure 23. Sectional view of inflatable radome.

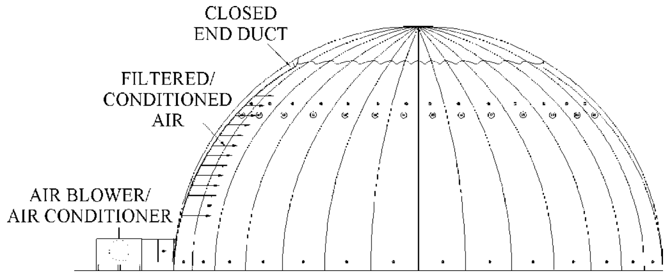


Figure 24. Flow of filtered/conditioned air into inflatable radome.

7.2 Status

ADRDE has designed an 80 ft diameter inflatable radome (design wind speed 120 km/h) for Electronics Research & Development Establishment. The development work has been initiated at ADRDE. The industrial partners have been identified. The technical specification of the subsystems along with test plan has been prepared. The fabrication drawings have been completed. The system would be developed in next 3-4 years.

7.3 Description

The inflatable radome consists of following subsystems:

- Structural envelope
- Air blowers
- Air conditioners
- Control system
- Emergency generator

Structural envelope would be fabricated from high strength PVC-coated polyester fabric gores. There would be an airlock tunnel for the entry inside the radome without any significant loss of inside pressure. Dimension of airlock tunnel would be 3 m x 3 m x 6 m. It would have two airlock doors having transparent depressurisation window. Fabric envelope and airlock tunnel would be anchored with concrete base through angles and bolts.

Three air blowers would be used for the inflation of envelope and to maintain the required inside gauge pressure. Air blowers would be attached with the hemispherical envelope through metal and fabric ducts. Filtered air would pass through these ducts and pockets created by the outer and inner-coated fabric layers. Finally air would enter inside the hemispherical envelope through PVC-coated polyester fabric meshes, which are attached in the inner coated fabric layer. High gauge pressure would be required at the time of high wind velocity or snowfall. Inside gauge pressure would be controlled through blower governor mechanism, pressure sensor and electrical control system.

Air conditioners would be used to control the temperature and humidity inside the radome envelope. The air blowers would supply fresh air. To control the activity of all subsystems, programmable logic control-based electrical control system would be utilised. This will maintain the parameters at the set points

An emergency generator would provide the rated power supply to the emergency blower to maintain the required pressure inside the inflatable radome in any condition for 24 h. Speed of the blower would be controlled with the help of variable frequency drive. There would be arrangement of lightening arrestor at the top of inflatable radome for the safety of overall system. Lightening arrestor rod, wind sensor and strobe light would be mounted at the top plate of inflatable radome.

7.4 Future Plan for Inflatable Radome

In long term, ADRDE plans to design and develop still bigger size inflatable radomes for extreme wind conditions as per user requirement. Army and other service units may also use some advanced variants of this system as an on-field operation theatre. There are numerous cost effective civil applications of different shape and size inflatable domes. These can be used as disaster relief domes, multi-sport/recreational activity domes, and bulk storage domes, etc.

8. AEROSTAT SYSTEMS

8.1 Background

ADRDE started its work towards the lighter-than-air (LTA) technology with the development of balloon barrage system using 95 cum balloon and supplied to Air Force. After maturing on this technology, ADRDE started working on payload carrying aerostat system.

Aerostats are tethered balloons that are manufactured from advanced composite materials, which can withstand severe weather conditions. These systems are based on lighter than air technology, wherein helium gas is used to develop the positive lift, which pulls up the aerostats to desired altitudes. It is an extremely reliable system with high endurance. Aerostats can be equipped with payload like It consists of COMINT (communication intelligence – jamming and detection of enemy communications), ELINT (electronics intelligence–jamming and detection enemy radar), electro optical sensors and BFSR (battle field surveillance radar), etc. as per the user requirement. Aerostats have both military as well as civil applications. Towards the military side, it is primarily used as a platform for surveillance, detection of low altitude flying targets, tracking etc. Towards the civil side, it is used for radio and television broadcasting and environmental monitoring. Proposal for an aerostat-based surveillance system for the Taj Mahal is under consideration. The primary adjective of the aerostat is its easy maintenance and support. Although high performance aircraft radar systems provide excellent long-range detection of low-flying aircrafts and other targets but the limited on-station time and requirement of multiple aircraft and operating crew to provide round-the-clock coverage results in high acquisition and operation cost. These parameters make aerostats more demanding. Apart from these parameters

Figure 25. 160 cum aerostat developed by ADRDE.

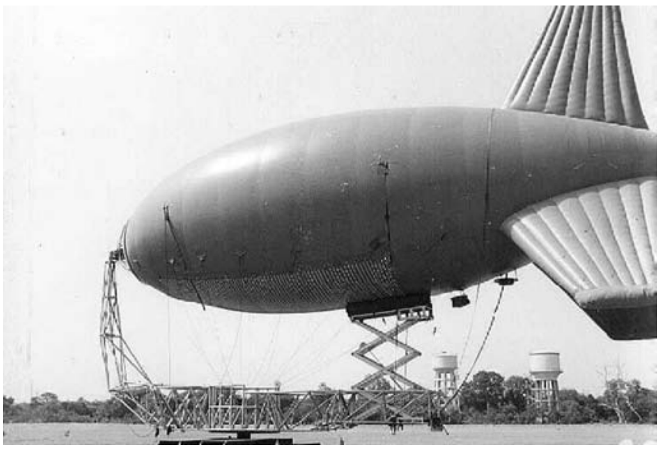


Figure 26. 250 cum aerostat developed by ADRDE.

aerostats have also advantages in terms of adaptability, transportability, and look down capability.

The main sub-systems of an aerostat can be categorised into mainly three groups:

8.1.1 Platform

It mainly includes balloon that is used to lift the payload; tether, which is the only connecting link between aerostat and the ground platform; Aerostat health monitoring system used to maintain the shape of balloon. Winch and mooring system is used for controlled deployment, retrieval, keeping the balloon at a fixed altitude, and mooring it effectively. to do maintenance as well as attachment of payloads safely.

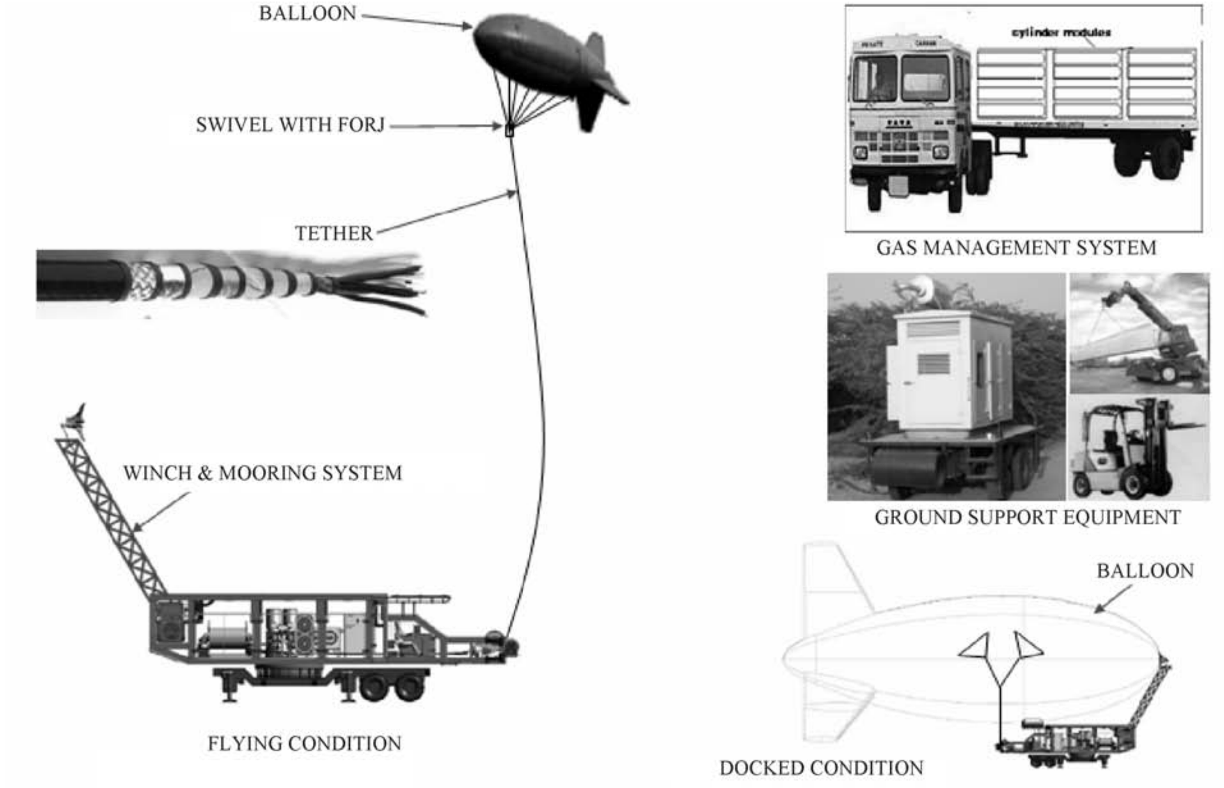


Figure 27. Different sub-systems of aerostat showing both flying and docked condition.

8.1.2 Ground Support System

It includes the gas management system (GMS), used for purification of filling gas as well as controlled filling of gas inside the balloon; DG set which is the primary source to provide power to the system for proper functioning of electrical and electronic sub-systems and aerial access platform; and hydraulic scissor lift, fork lifter, etc. which are primarily used for maintenance or repairing of balloon at heights which are beyond the reach of man standing on ground.

8.1.3 Payload

It consists of COMINT (communication intelligence–jamming and detection of enemy communications), ELINT (electronics intelligence – jamming and detection enemy radar), electro optical sensors and BFSR (battle field surveillance radar), etc.

8.2 Status

The first aerostat developed by ADRDE was of 160 cum volume. The payload lifting capacity of this system was less and could lift it up to 300 m (AGL) of height. The payload was EO sensor. 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.

After this ADRDE developed another aerostat of 250 cum volume, which was similar to 160 cum in many the aspects but could lift payload of 55 kg. The power-conducting tether had linear mass density of 100 g/m. Fig. 26 shows the actual photo of 250 cum aerostat in moored condition with dummy payload.

The requirement of lifting heavier payload up to high altitude motivated ADRDE to develop a medium size aerostat. Presently, it is involved in developing 2000 cum aerostat. The objective behind this is to design and develop a 2000 cum aerostat platform with payload capacity of 300 kg and flying at an altitude of 1.0 km AGL. The main components of this system are:

- 2000 cum balloon
- Aerostat health monitoring system

Figure 28. 2000 cum aerostat developed by ADRDE.

- Tether with FORJ
- Winch and mooring system
- Ground support system
- Gas management system
- Trailer-mounted silent DG set, etc.

Various sub-systems of this aerostat are ready and trials are planned shortly. The present system being developed would be cost-effective, requiring less maintenance, and can function round-the-clock.

8.3 Future Plans for Aerostat

In the near term, ADRDE plans to establish the 2000cum aerostat with respect to reliability and usage under different terrains. This will be followed by development of large size aerostats, which are needed by Air Force. To establish capability of designing aerostat system for continuous operation (long endurance), higher altitudes, advanced payloads, and higher reliability will specially call for development of highly reliable fabric material for ultra low helium permeability, incorporating redundancy, use of high quality and reliable components in critical areas. As per the trend in technology advancement, the next mission will be 17000 cum (78 m length) aerostat capable to lift 2000 kg payload up to 5 km. Some sub-systems developed for this project will be available directly for large size aerostat. The stable shape of the balloon is under consideration and will be available for review only after rigorous simulation.

The future in LTA as shown in roadmap holds the development of stratospheric airship (SA). The SA will operate in a quasi-stationary position at an altitude between 17 and 22 km in stratosphere. The reason for this height is that the wind velocity profile follows the minima at this altitude and hence power requirement for maintaining the airship at the desired location is minimum. Number of payloads can be attached on the stratospheric platform. Broadly, the technologies involved are:

- Envelope material, aerodynamic design and fabrication
- Gas management system
- Mooring system
- Propeller and propulsion system
- Modelling and simulations
- Guidance, control, and navigation
- Solar array for onboard power generation and storage system

9. TEXTILE TECHNOLOGY

9.1 Background

All the systems being developed at ADRDE involve large usage of textile materials. Hence, continuous development in technology in textiles is of prime importance and that has been given due consideration at ADRDE. Textile materials, viz., fabrics, tapes, cordages, sewing threads, coated and laminated fabrics, etc., have got wide area of application in parachutes, AABS and Inflatables structures (viz., aerostats, emergency floatation systems for helicopters and radome). since these systems are used for strategic aerospace applications for the Armed Forces and space applications, there is hardly any scope for failures. Further, these materials are required to be engineered resulting into textile materials with light weight and high strength. It is also required to be highly protective to prolonged exposure of environmental factors, i.e., temperature, water, moisture, sunlight, etc. ADRDE has got excellent in-house design and testing capability. For synergic benefit, ADRDE has associations with industrial partners, and academic institutions like IIT, Delhi and Textile Research Associations viz., ATIRA, Ahmedabad; BTRA, Mumbai; SASMIRA, Mumbai; NITRA, Ghaziabad etc. As a result, ARDE is able to develop all the required textile components in the country matching global standards and have also filed patents in this field.

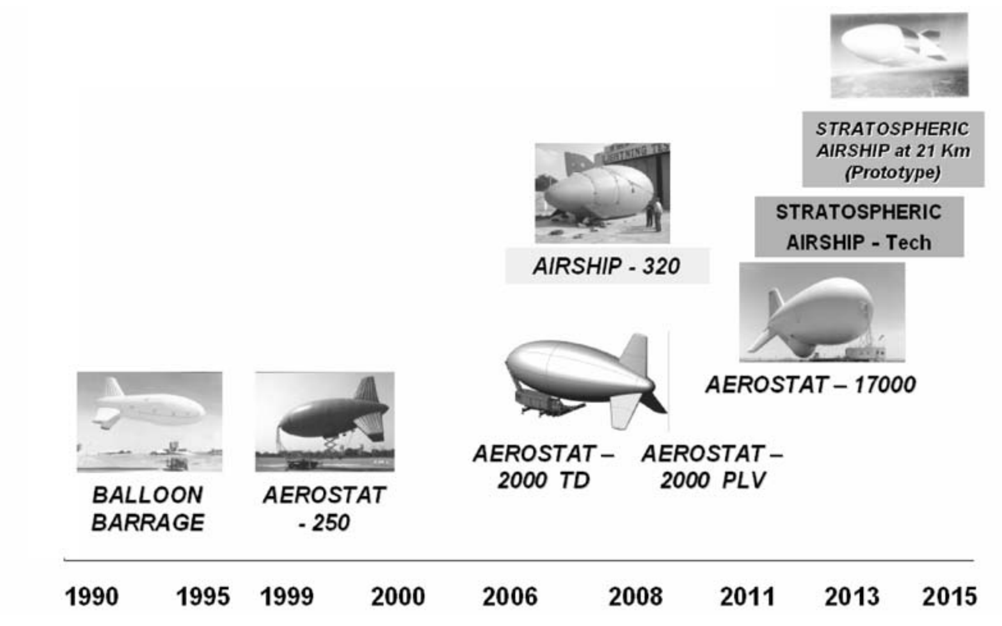


Figure 29. Road map of LTA technology development.

9.2 Design Perspectives

The aim is always to achieve the high ratio of strength to mass. Other characteristics like permeability, sewability and sealing characteristics, flexibility, wear resistance, and the effects of environmental exposure are also considered in the selection. The targeted product life is a vital design input for material and process selection. There is also probability that some of the primary physical properties of the subject textile items have got a close trade-offs amongst them. For example, the three significant properties of a canopy fabric, viz., strength, mass, and porosity are interrelated in such a manner that a change in any one of these is prone to throw others out of balance. A design is successfully completed when a reasonable compromise is made between these properties to achieve the desired performance.

9.2.1 Critical Products Developed

The following are the critical textile products developed for systems at ADRDE:

(a) Fabrics–Very light weight and low porosity canopy fabrics for RAPs.
(b) Narrow fabrics–High strength to mass ratio tapes and webbings with improved UV resistance, water repellency, abrasion resistance, etc. Base materials such as nylon, polyester, cotton and high performance fibres such as para-aramid, vectran, spectra, dyneema have also been used.
(c) Cordages–High strength to mass ratio tapes and webbings with improved UV resistance, water repellency, abrasion resistance, etc.
(d) High elastic recovery narrow fabrics and cordages–Special heat setting process and machine has been developed to improve the elastic recovery of materials that in turn leads to life enhancement of materials.
(e) Coated fabrics–A wide range of coated fabrics for specific application such as polyurethane (PU), poly vinyl chloride, neoprene, bromo-butyl.
(f) Finishes–materials with flame retardency, water repellency, UV resistance, siliconising and heat setting.

9.3 Future Plans for Textiles

ADRDE is constantly working towards development of new and improved textile assemblies by exploiting latest materials, processes, and technologies. The technology to focus for the next five years include:

(a) Nanotechnology for high performance coating,
(b) High performance laminated fabrics,
(c) Nano finishes,
(d) High strain rate testing, and
(e) Weight reduction through use of high performance materials.

10. CONCLUSIONS

ADRDE made a humble beginning as a small aeronautical laboratory to test the parachute fabrics. Since then it has come a long way, graduating to higher echelons like flexible aerodynamic decelerators, inflatables and aerostat. But there are still many more miles to go and many more feets to be achieved. It is aptly said that, 'Minds are like parachutes–they function best when open'.