DEVELOPMENT OF INDIGENOUS HELICOPTERS IN INDIA -
HISTORICAL PERSPECTIVE, CHALLENGES AND
FUTURE POTENTIAL

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Abstract

In independent India, design and manufacturing of aircrafts is intricately linked to Government labs and Defence Public Sectors. In case of fixed wing aircrafts, there are more than one design agencies in addition to Hindustan Aeronautics Limited (HAL), such as ADA, DRDO and NAL. However, in case of rotary wing aircrafts, HAL is the only company involved in the design and development of helicopters. This paper is an attempt to chronicle the journey of HAL, from a licence producer of helicopters starting in 1964 to becoming a key player in design and production of indigenous helicopters. The journey had its ups and downs, trials and tribulations, leading to success. The paper addresses the Design and manufacturing challenges faced during the development.

That HAL rolled out its 300th production helicopter of Advanced Light Helicopter (ALH) in September 2020, bears testimony of its perseverance. Presently, HAL has come a long way and has emerged as a major company in India which is capable of design, development, testing, integration and certification of indigenous helicopters and augmented with capability in production, maintenance, repair and overhaul of helicopters. The experience reveals that indigenous design and development has its own share of uncertainties and risks and hence will suffer from time over run due to inexperience, design iterations, performance issues, lack of manufacturing capabilities and limitations in eco-system etc. while bringing out first product. However, things improve with consecutive products. The hard truth is that the only path left to the developing countries, is to start the design (if required with design consultancy from abroad), make sincere efforts to learn through mistakes, sweat it out and improve the product.

Keywords: Design, Development, Helicopters, ALH, LCH, LUH

Abbreviations

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<tr>
<th>Abbreviation</th>
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<tr>
<td>AFCS</td>
<td>Automatic Flight Control System</td>
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<td>ARIS</td>
<td>Anti Resonance Isolation System</td>
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<td>AVCS</td>
<td>Active Vibration Control System</td>
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<td>ALH</td>
<td>Advanced Light Helicopter</td>
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<td>CAG</td>
<td>Controller and Auditor General</td>
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<td>CEMILAC</td>
<td>Centre for Military Airworthiness and Certification</td>
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<td>DGAQA</td>
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<td>GoI</td>
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<td>GSQR</td>
<td>General Staff Qualitative Requirements</td>
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<td>HAL</td>
<td>Hindustan Aeronautics Limited</td>
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<td>HDB</td>
<td>Helicopter Design Bureau</td>
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<td>HPS</td>
<td>Helmet Pointing System</td>
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<td>IADS</td>
<td>Integrated Architecture Display System</td>
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<td>IAF</td>
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Introduction

As a consequence of the Sino-Indian conflict of 1962, the Government of India realised the need for cohesive long term planning of defence requirements and this resulted in the First National Defence Plan, formulated and announced in 1964, to be implemented over a period of five years. Tomar [1] gives details regarding Indian defence program in the period between 1964-78. Subsequently, in the study focussed on Indian self reliance and self sufficiency, Tomar [2] examines the experience of the Indian aircraft industry with special reference to Hindustan Aeronautics Limited over a 15 year period and the process should be accelerated through technical collaboration.

Government of India entered into a 10 year collaboration agreement in September 1970 with SNIAS of France for the design, development and production of an Armed Light Helicopter to meet the requirements of the Armed forces. As part of this Agreement, SNIAS would impart training to Indian technical personnel to the extent of 18 trainee years. In addition to the training imparted at the design offices and shops, the trainees sent by Government of India would also attend general courses at the French Aeronautical schools or with French Government Test Centres such as Centre de Essai en Vol (CEV).

Formation of Helicopter Design Bureau (HDB)

Based on the recommendations of the Subramanian Committee, in May 1971, HAL Board approved the formation of nucleus Helicopter Design Cell, and Mr. Raj Mahindra who was then General Manager, Helicopter Factory headed this new Core Group of Helicopter Design. Thus started the design of helicopters in India. The design and development project for a single engine Armed light helicopter was approved by Government of India in 1976, based on Indian Air Force requirement issued in 1971. HAL proceeded with the design of single engine helicopter, building test facilities, new hangars, full size mock up helicopters etc. Based on new data and emerging
scenarios around the world, Indian Air Force had a re-thinking on Single engine requirement and in 1977, IAF proposed a change over from Single engine to Twin engine configuration.

**Advanced Light Helicopter (ALH)**

Based on the fresh tender and subsequent intensive negotiations, an agreement was finally signed in 1984 between Government of India and MBB, Germany, for the design and development of Advanced Light Helicopter. A detailed account of the start of the project till 2007, together with people who contributed to the project, is well chronicled in the book by Dr. C.G.K. Nair, et al.[3].

The technical collaboration with MBB was detailed such that major work is to be carried out by Indian engineers with the guidance of a small team of German domain experts and technicians who would be resident in India for short periods of time. This was augmented by deputing Indian engineers for in-plant training at MBB facilities in West Germany. The MBB team at HAL, Bangalore was headed by Mr. D. Bender. The ALH was conceived to be a helicopter with twin engines and with two different landing gear configurations skid landing gear for Airforce & Army and Wheel landing gear for Navy version. Based on global selection process, TM 333 2B2 engine made by Turbomeca, France was selected. The helicopter was also required to be weaponised later after proving the utility roles.

Based on qualitative requirements from IAF pertaining to stringent high altitude performance, ALH project included multiple new and modern concepts [4].

- The approved design had an Upper Control System (UCS) with main rotor pitch control rods routed inside the main rotor shaft, the configuration named as Integrated Dynamic System (IDS)
- A Main Gear Box (MGB) with only two-stage reduction, having large area-contact gears
- Composite four-bladed hinge-less main rotor, also called rigid rotor
- A three-axis passive vibration damper system called ARIS (Anti Resonant Vibration Isolation system) to isolate vibrations
- Tail Rotor with flex beam technology
- All composite fuselage
- Crashworthy design
- Ballistic survival features

All of these technologies were tried out first time in the country. Hence right from go-ahead, the project faced technical challenges.

Three main technology challenges, in terms of realisation and manufacturing, were composite technology (particularly blades), the gear box, and upper control system. Mr. Sachindran [3] says "The wipe test of gears was a big challenge. The set up for testing the gearbox was delayed and outsourcing was impossible. Another challenge was the collector gear-technology. As capability in India was limited, grinding and fixing of bearings was done abroad. Logistics was a problem and the companies abroad gave lower priority for Indian requirements. This kept the program on a bind. However constant follow up and dedication of HAL management was a great example of team effort and the company’s great ability in crisis management". Further, HAL management pooled up their best officers to manufacture ALH prototypes and also brought in quality specialists from other divisions of HAL.

The project went through all phases of, Feasibility studies, Preliminary Design Phase (PDP), Detailed Design Phase, Mock-up, Interface Functional Check Rig (IFCR), Component and System Testing, Ground Test Vehicle (GTV), Prototype Flight Testing and Certification.

The first flight ALH prototype (PT1) was carried out in August 1992 by Chief Test Pilot Gp. Capt. (Retd.) B. S. Chhoker, Test Pilot Wg. Cdr. (Retd.) C. D. Upadhyay and Flight Test Engineer, Gp. Capt. (Retd.) G. Murthy. The first flight was a red letter day in Indian Aviation. The first flight of second prototype (PT2) was carried out in April 1993, the third prototype (PTA) had maiden flight in May 1994. The fourth prototype meant for Navy (PTN) with wheel landing gear, flew for the first time in December 1995 with LHTEC-T-800 engines made in USA, as an alternate to TM 333 2B2. All initial test flights on PTN were carried out using LHTEC-T-800 engines and the same engine was selected for the ALH Civil variant. However, HAL had to revert to Turbomeca due to the sanctions/embargo imposed by USA soon after the Pokhran nuclear experiments by India in May 1998.

Certification flights were progressing on all four prototypes. Each flight data was analysed before going ahead. During the stages of certification flights, many minor /
major problems were encountered which needed to be tackled such as

- High temperatures encountered on the tail boom were resolved by reorienting the exhaust duct
- High temperature of lubricating oil of MGB
- Low life of the composite springs of the anti resonance isolation system required redesign of the springs
- ALH was overweight and considerable efforts were put to carry out weight reduction.

All these were addressed and remedial measures incorporated. However each such issue caused delays as the Design/flight test team was not only to investigate, find causes & solutions, but also to convince the Inspection / Certification agency to give go ahead for further flight tests. The technical consultancy with MBB ended, in 1995, and HAL team continued independently thereafter with design, development, certification and weaponisation activity.

The carbon prepeg ARIS spring supplied by M/s. Eurocopter, Germany had low life. HAL redesigned ARIS and developed a Composite ARIS spring using R-glass single tow winding, using filament winding machine and R-glass Unidirectional and prepegs. ARIS spring with much enhanced fatigue life was developed successfully[5]. The Design division had a sound technical footing in areas of Rotor dynamics and Aero-elasticity, Rotors, Flight controls etc. [6-12].

While one part of development is to carry out detail design on the drawing board, the more complex part is to carry out testing of components, sub-assemblies and assemblies, before parts go into the flying machine. HAL has established elaborate ground testing and flight testing facilities and infrastructure including test set up such as whirl tower and advanced telemetry. The testing infrastructure and results of ground testing and flight testing are elaborated by Balakrishna, et al. [13] and Venugopalan et al. [14, 15], Mathen [16] and Rao [17]. Various features of Autopilot and challenges faced in tuning of Autopilot gains are detailed by Sampo, et al. [18] and Vijaya Kumar et al. [19]. A review of Reliability Growth Management during Prototype Development is provided by Kumaraswamy [20]. Details of Hydraulic System is provided by Viswanth [21]. Survivability of Composite Main Rotor Blade due to Ballistic damage study was made [22]. Further, studies on Rotor system modelling was done by Prashanth [23], Subramanian [24], Lokeshwara Rao [25] and modelling of helicopter Flight Dynamics by Gagandeep [26].

**Evolution of ALH Mk-I to Mk-IV (2002-2015)**

The initial batch of Limited Series Production ALH, christened as "Dhruv" was delivered to Airforce, Army, Navy and Coast Guard during March 2002. These set of helicopters was termed as Mk-I which had conventional cockpit instruments equipped with analog indicators and are operated by IAF (Fig.3), Army, Navy and Coast Guard. Since its induction to Services in 2002, the ALH has evolved incorporating advanced features and systems to make it contemporary with other modern helicopters in the world. The analog instruments in the cockpit were found to have reliability issues as well as were becoming obsolete. Hence, these instruments were replaced by Multi Function Displays (MFD). This configuration of using MFDs for cockpit display is called as Glass Cockpit or the Integrated Architecture Display System (IADS). The ALH fitted with TM 333 2B2 engine and Glass Cockpit was termed as ALH Mk-II which is operated only by Indian Army.

Further, in order to meet the payload capability at high altitudes, a need was felt for a higher powered engine. A higher powered engine co-developed by HAL and Turbomeca (presently SAFRAN) termed as Ardiden 1H1 (in France) and Shakti (in India) has been integrated and certified on ALH Mk-III and Mk-IV. Based on the feedback of Mk-I and Mk-II Helicopters, Vibration reduction and monitoring systems were implemented through the integration of Active Vibration Control System (AVCS) and Vibration Monitoring System (VMS). The ALH was integrated with Mission Sensors and Systems such as Helmet Pointing System (HPS), EO Pod, FCD, SSDVR and EW Suite, along with other systems such as IR Suppressor, OBIGGS, AVCS and VMS. Extensive testing was carried out on Prototype Helicopters for integration and certification. The ALH fitted with Shakti engine, IADS and Mission Sensors and Systems is termed as ALH Mk-III which are presently operated by IAF and Army. The ALH Mk-III Skid variant (Fig.4) was accorded Initial Operational Clearance (IOC) by the Centre for Military Airworthiness and Certification (CEMILAC) in October 2010.

The Mk-III version was integrated with Weapons such as 20 mm Turret Gun, 70mm Rockets and Air-to-Air Missiles. After extensive flight testing and firing trials,
Initial Operational Clearance (IOC) for ALH Mk-IV (called Rudra, Fig. 5) was accorded by the CEMILAC in 2013 for Army variant and in 2015 for IAF variant.

Manufacturing Improvements on ALH

Since its induction of ALH to Services in 2002, HAL has continuously improved manufacturing process, in terms of consistency, interchangeability, quality, volumes, aesthetics etc. Sadagopan [27] describes all lessons learnt from manufacturing of Dhruv, some of which are highlighted below.

To overcome the problems noticed with E-Glass wet layup process, Flex beam were fabricated with R-Glass Prepeg material. Tooling for bonding fixtures were improved and better monitoring and recording of process parameters were adopted. Coupon level and component level tests were carried out to establish inter-laminar shear strength and flexural properties. Static and fatigue tests were carried out to establish structural integrity, strength capability and fatigue/technical life of blades. Helicopter level tests were carried out to confirm performance.

In terms of improvement of manufacturing of gears, for example, there are 33 steps in getting a collector gear from forged blank to final part. A series of measures were taken to improve reliability of MGB.

• Collector gear teeth tip radiusing was improved
• Gear teeth tip radiusing was carried out on special purpose machine
• Introduced additional inspection checks for case depth confirmation

Heat treatment process was improved through various measures including installation of an industrial robot for collector gear quenching within 20 secs. HAL introduced multi-axis machine and High speed machining, to improve throughput of MGB.

Technology, Performance, Stability and Safety of ALH

ALH has emerged as technologically state-of-the-art helicopter with technologies mentioned above.

To quote Gp. Capt. (Retd.) Hari Nair [28], who has flown ALH in high altitude, "The ALH Mk-III with Shakti engines has exceptional high altitude performance. It exceeds the original ASR high-altitude payload-cum-landing requirement at 6 km altitude at high temperatures and is perhaps the only helicopter in existence worldwide in this AUW class category that can fulfill the requirement. In terms of performance at high altitude, it has achieved better than QR of IAF".

Success of a project depends on the resolve of the manufacturer and the users to iron out the deficiencies noticed. Wg. Cdr. (Retd) Unni Pillai, who is Chief Test pilot at HAL, says [29] "This resolve is apparent from the fact that, there is a change in the present day production of ALH Mk-III compared to the first LSP Dhruv, 12 years ago. There are changes in quality, reliability, maintainability, vibrations, aesthetics and any other issues pointed out by the users".

The high degree of redundancy provided for primary and critical systems, crashworthy features (in bottom structure, landing gear, crew seat, fuel tanks), survivability features (ballistic tolerant rotor blades, IDS concept, warning/alert systems) have enhanced the safety levels of ALH. In many incidents of hard landing/crash landing, the crew have walked out unhurt due to the above crashworthy design features.

Usage of ALH in Disaster Relief and in Rescue Operations

An offshoot of ALH’s utility has been its excellent deployment for disaster relief in India and adjacent countries. The helicopter could be effectively deployed under inclement weather and to reach inaccessible terrains under extreme conditions to rescue thousands of people in distress. ALH took part in rescue operations in different parts of the country. When Uttarakhand tragedy struck, Government deployed 44 helicopters in June and July 2013, out of which 28 were Dhruv. The operation "Rahat" was one of the largest rescue operations of its kind anywhere in the world. ALH helicopters flew for nearly 630 hours and made 2,380 sorties over difficult terrain and in hostile weather conditions. In recognition of exemplary service by helicopters during Operation Rahat, American Helicopter Society International presented an award to HAL in May 2014.

Some rescue missions undertaken by the Guardians (ALH squadron of Navy) are, Boat tragedy in Thekkady, fire cracker explosion at Putttingal Temple, airlift of critical patients from Lakshadweep Islands, Cyclone Ockhi
(Operation Sahayam) and Rescue of two Indonesians, in adverse weather conditions with excessive wind speed.

**Recognition for the Work on ALH**

Design projects receive more brickbats, good news however also trickled in, albeit slowly. It was a good news when Services placed a contract for 159 ALH helicopters. This is now followed up with further order of 41 ALH for Army. HAL carried out critical updates, as requested by Coast guard, after Mumbai attacks. Coast guard and Navy returned, after a gap of about 15 years, to place orders for ALH Mk III with specific customisation involving integration of 19 new systems. The American Helicopter society brought out a special issue of Vertiflite in 2011, titled "India in Ascendance" [30].

The squadron commissioned as INAS 322 (Guardians) in 2013 operates ALH Mark I, from "INS Garuda" in Kochi. To quote a media report in July 2018, as per a Navy officer involved in ALH operations, since inception of the new squadron INAS 322 (Guardians) in 2013, "the squadron has enhanced ALH roles including NVG (Night Vision Goggles) operations, special operations for commandos tasks (MARCOS), SAR (search and rescue) by day and night, embarked missions on helicopter capable platforms, casualty evacuation, anti-piracy operations (armed) and logistics/communications duties among others". An Indian Navy official says "From a flying machine with many issues, she (ALH) has matured by miles. The enormous potential of the platform has been harnessed after the fitment of new equipment. From the role of helicopter training of our pilots, the ALH has definitely progressed in the last five years".

To quote further from the same report, "Night flying over sea is considered the Holy Grail of helicopter flying over the sea as it is often fraught with risks and one that requires exceptional skills and courage. Today, India is among the few nations around the world having the ability to undertake SAR by night". The Navy has cleared the Guardians for undertaking night SAR missions after formulating a series of procedures. The Guardians are univocal in their view that the wait for a helicopter capable of handling the punishing and difficult operating environment at sea is finally over with the coming of age of the ALH.

ALH received many awards from various institutions and organisations. The best award was when an Army Colonel told this author, after just then completing his Leh-Ladak tenure, "When troops positioned in Siachen Glacier, at great Himalayan Heights and biting cold, hears the noise of arrival of ALH, their faces gleam with hope and I have carried many times 5 troops, at one go in ALH". And this is the ultimate test ALH has passed. Having produced 300th helicopter, ALH is on the roll, leaving behind fair or unfair criticisms. There are many people associated with these projects, too numerous to be named and the book [3] provides a good account of people involved in the initial stages of ALH project.

**Light Combat Helicopter (LCH)**

The need for a dedicated Combat Helicopter which can operate effectively at high altitudes with considerable payload in terms of Weapons and ammunition was an immediate fall out of Kargil War in 1999. Subsequently, the requirement for a dedicated combat helicopter, the Light Combat Helicopter (LCH) was provided by the IAF in August 2003. The project was sanctioned by MoD in October 2006. The LCH is a twin engine dedicated combat helicopter in the 5.5 tonne class.

It was proposed that the LCH would have maximum commonality with ALH-WSI, especially on systems such as Rotors, Transmission, Shakti engine, Hydraulics and LRU of Electrical and Avionics. Also, the Weapons and Mission Sensors were planned to be the same as that of ALH-Rudra. Systems specific to LCH included Airframe, Flight controls, Tail rotor control using push-pull cables, Landing gear, Fuel system, IR suppressor and Particle separator. By this time, HAL had improved technology base and all drawing were made in 3-dimension drawings using a 3D software package and management of drawings were in electronic form. Printing of drawings in hard copy was discontinued.

The first inaugural flight of the first prototype of LCH called TD1(Technology Demonstrator 1) was carried out in May 2010. HAL built three more prototypes TD2, TD3 and TD4. From the beginning, the LCH project was steered by IAF. It was during December 2014, that Army expressed interest and got involved in the project. After initial flights, there were design challenges noticed. A few examples are

- Weight of the helicopter was more than envisaged
- Shortfall in forward speed
- Higher vibrations noticed near gunner cockpit
- Increased vibration levels in front cockpit
• Handling qualities
• Airspeed measurement issues

Each problem was addressed and resolved. Shortening of cockpit length, drag reduction actions, repositioning of Pitot static tubes, reinforcement of structural beams are some of the remedies implemented. While commonalities with ALH were conceived as a measure to reduce design cycle time, it turned out that during the course of the project, various hardware and software adaptations suiting to LCH configuration took considerable efforts and iterations leading to time and cost over runs.

LCH successfully completed flight testing at sea level, Hot weather trials, Cold weather trials, High altitude trials, Hot weather and High altitude trials, weapon system integration (Gun, Rockets and ATAM), firing trials and certification tests. LCH is perhaps the only attack helicopter which is capable of functioning at altitudes above 10,000 feet (Fig.6).

Initial Operational Clearance (IOC) of LCH-LSP accorded by CEMILAC in August 2017 for Air Force version and in February 2019 for Army version.

Detailed studies on ground testing and impact of bird hit testing are published Halejol [31] and Vijayakumar [32]. Studies on estimation of control system gains and Development of Optimisation Tools for Helicopter Design are published [33-34]. Study on Analysis of Vibration Signals from a failed component in a Helicopter Gearbox was published [35].

In the service life of a helicopter, it becomes necessary to carry out improvement and updates on two major systems, namely Glass cockpit and Autopilot. In order to become self-reliant and to be able to carry out these hardware and software updates, these two systems are being developed indigenously by HALs R and D Centres. This will also increase the Indigenous Content (IC) of LCH.

Light Utility Helicopter (LUH)

Indian Army and Indian Air Force together are operating about 400 Cheetah and Chetak Helicopters supplied by HAL starting from 1960s. The ageing fleet in the Services needs to be replaced in a phased manner with a more efficient and state-of-the-art helicopter with improved performance and payload capability.

In the year 2008, Indian Army and Indian Air Force finalized the requirement of a Reconnaissance and Surveillance Helicopter to succeed Cheetah and Chetak and issued a GSQR. The total projected quantity required by Armed Forces is 384 helicopters, of which, 197 helicopters are earmarked for direct global purchase and remaining 187 helicopters are classified under ‘Make’ category to be indigenously manufactured by HAL. The Government of India accorded approval in February 2009 to go-ahead with design and development of Light Utility Helicopter (LUH). The LUH is a single engine, 3 tonne class utility helicopter designed to meet operational requirements of Indian Army and IAF. The LUH project design is fully an ab-initio effort by RWRDC without any technical collaboration. The challenge was in designing and realizing the Rotor System and Transmission System in particular which are totally different from that of ALH, on which RWRDC Designers had gained confidence of Design and Development since 1984. The Key technologies that need to be developed ab-initio for LUH are Transmission System based on sun-planetary main gear box and a matching tail gear box, Main Rotor System having composite blades with two segments, Smart Cockpit Display System (SCDS) based on state-of-the-art hardware with software developed indigenously by HAL.

The project faced challenges in the selection of suitable engine. After prolonged techno-commercial process, Ardiden 1U from M/s SAFRAN HE, France was selected and the selection process took nearly 33 months. The first Ground Test Vehicle (GTV) run (helicopter strapped to ground) with SAFRAN TM333 2B2 engine was carried out in December 2014. GTV runs resumed in December 2015 with SAFRAN Ardiden 1U engine. Three prototypes of LUH were made. It should be noted that before first flight, all major parts undergo testing and all dynamic components will have completed millions of cycles in various testing. First flight of LUH PT-1 was carried out in September 2016, and two more prototypes PT-2 and PT-3 were built subsequently for carrying out flight testing. Initial teething problems were all diligently addressed, resolved and project was progressed towards certification (Fig.7).

For the first time, HAL selected an agency NLR in Netherlands, through a competitive bidding process, who carried out complete design review of the indigenously designed rotor system of LUH project. Studies on the experience of ab-initio design of Main Gear Box and its testing are detailed [36-37]. Initial operational clearance
was accorded in February 2020 for IAF version. IOC for Army version is in progress.

**Development of Civil Versions**

HAL made its foray into Civil helicopter market by developing a dedicated ALH civil version which was certified by Indian DGCA in October 2003 (Fig. 8). Towards International certification, the EASA certification of ALH is in progress. In order to fulfil the national mission on UDAN scheme, HAL has upgraded the existing configuration of Civil ALH and would be shortly offering ALH Mk III Civil version to Indian civil operators. HAL has also launched the development of civil version of LUH.

**Development of Manufacturing Infrastructure/ Capabilities**

As ALH production started, Helicopter Division was continuously augmented by adding new machines, acquiring new technology, additional man power. ALH structure is composite material intensive and to cater to the manufacturing of composite parts not only for ALH Project, but also for other Projects such as LCA, a dedicated division for manufacturing Composite parts, "Composite Manufacturing Division" was formed in 2007. As more and more ALHs were delivered, necessity of having a dedicated MRO division was felt and a dedicated Division called "Helicopter MRO Division" under the control of Helicopter Complex was formed and is operational since December 2006. Keeping in view the increasing numbers of ALH under manufacturing and future manufacturing requirements of LCH and LUH which are again in huge numbers, a need was felt to expand the helicopter factory. Government of Karnataka has allotted land of about 600 acres, near Tumakuru, a city 100 km from Helicopter Division. The foundation stone of new Helicopter factory was laid by Honourable Prime Minister Shri Narendra Modi on 3rd January 2016. It is proposed to manufacture LUH and other helicopters in this factory.

There has been a paradigm shift in the manufacturing policy post liberalisation, whereby the manufacturing of components/subsystems and assembly of systems and airframe are now being envisaged to be extensively subcontracted, instead of HAL carrying out all the activities under a single roof. HAL has been encouraging partnerships with the private industries in the areas manufacturing and tooling. HAL has further plans to subcontract many of the non-core activities, to Tier-1, Tier-2 and Tier-3 supplier base [38]. This strategic change in HAL policy is driven by the necessity for HAL to become an assembler / lead integrator of the flying platform to achieve economic advantage and focus on core activities viz. final assembly of helicopter, system Integration, acceptance, flight testing and delivery of all the helicopters by HAL. HAL has been subcontracting indigenous development of LRUs/Systems for its helicopter platforms [38]. HAL, in all, has about 1000 Private Industries and MSMEs, whereas Helicopter complex has about 500 of them, a great leap compared to 23 ancillary units in 1982 [2].

**Design and Infrastructure Augmentation**

HAL has constantly augmented Ground testing and Flight testing infrastructure, procured new software packages to assist design of Helicopter modelling, rotor system and transmission system, additional licences of CAD/CAM etc. HAL continued constant interaction with IITs, IISc and DRDO Labs. Regarding improving the design capabilities of engineers, many initiatives have been taken time to time.

**Transfer of Technology (ToT), Funding of Design Projects and Monitoring Mechanisms**

HAL has good experience in ToT for manufacturing, wherein some technologies (other than critical technologies), tooling, drawings, methodisation are transferred by OEM. However, OEMs insist that, key technologies of rotor and transmission design, are retained by them, thus ensuring hold on the product. HAL is not allowed to carry out any modifications on the product without consent by the OEM and this may be compared with the fact that there are at least 7 versions of ALH already. As regards Transfer of Design "know how" and "Know why", it is a well known fact and experience that Transfer of Technology (ToT) of Design, is a myth and ToT from foreign OEMs often become an exercise in withholding of critical information. The hard truth is that the only path left to the developing countries, is to start the design (if required with design consultancy from abroad), make sincere efforts to learn through mistakes and get the first product out. Thereafter, subsequent products will come out easily with less cycle time. In this context, it is pertinent to mention that there are not many countries in the world, may be six countries, who can design and develop helicopters - rotor system, helicopter blades, transmission systems etc.

World over, new military development projects, be it developed by a Government owned or private company, is often funded by the Government agencies, like DARPA, defence services in USA and Europe or directly by the
ruling governments. This is often the practice, as the futuristic defence projects have uncertainty in design and development, leading to cost and time overruns, therefore fail to get support from shareholders of the companies. The delays in two development projects by Boeing and a Civil Helicopter by Bell Helicopters serve as recent instances. It is to be noted that in the area of Technology development, Defence Systems are developed continuously and the concerned organisations are nurtured, to keep ahead and make improvements, by the Government in most of the countries.

In India also, the helicopter projects ALH, LCH and LUH have been funded and monitored by Government of India. This is aptly summarised by Mr A. K. Baweja [3], regarding ALH project, "Working together as team between HAL, private industries, and customers, and certifying agencies was another important learning achievement. Steering committees chaired by the secretary Department of Defence Production and Supplies and representatives of customers and Certifying agencies monitored the project at Government level. The leadership and support given by successive Secretary Defence Production and Joint secretaries to solve complex management and customer issues was a significant factor in the success of ALH project".

In addition, the Army and IAF have positioned project monitoring teams (including Test pilots and Flight test engineers) which were co-located and these project teams have been largely helpful by providing operational insights and enable designers to incorporate necessary design features for ease of operation and maintenance. Various levels of review mechanisms such as Steering Committee as Apex body headed by Secretary Defence Production, Joint Project monitoring Group at Service HQ level and local reviews by Project Monitoring Teams have enabled understanding development issues by all stakeholders and timely decision making.

The development projects, ALH, ALH-WSI, LCH and LUH, had cost and time over runs. Notwithstanding, cost of design and development by HAL is lower when compared to similar development cost outside India. The time gap between the approval of the project to start of production was 17 years for ALH, 10-11 years LCH, 10-11 years for LUH. However, the time gap between first prototype flight and start of production is reducing, it is 9 years for ALH, 7 years for LCH and 4 years for LUH. If all stakeholders are serious about indigenous design and development, then these time and cost over runs, have to be monitored, understood and genuine reasons considered for granting extensions. To its credit, MoD has been considerate on the indigenous helicopter development projects and has sanctioned approvals for time and cost over runs after meticulously examining the proposals from HAL.

**Contributions of Stake Holders**

Such a journey would not have been possible without active support and participation of all stake holders, Government of India, Defence Services (Indian Air Force, Army, Navy and Coast guard), Certification authorities - CEMILAC, DGAQA and DGCA. It is to the credit of all these stakeholders, that all have grown and matured in knowledge, experience and confidence, since the project launch in 1984.

Any design and development of aircraft is dwelling into unknown, fraught with risks, has its own uncertainties. Mr. K. S. Sudheendra, who was heading RWRDC for long years, says [3], "ALH project development was no bed of roses. There were plenty of tense moments. Take for instance the day I was standing near the tarmac with a pounding heart at the time of maiden flight of ALH". This is true of all design and development projects.

It is important that all stake holders react in a mature manner to incidents/accidents during prototype flight testing. Every one is aware from past history that Aviation has its own risks, be it for designers, prototype flight pilots/flight engineers, Certifying agencies or for defence services it has its own risks. If all stake holders including decision makers in Government and Think tanks do not realise it, as a society, a developing country like ours, is bound to be at loss. This author has experienced these risks and tense movements, when he was flying on board ALH prototypes as a designer for tuning of Autopilot or when he was heading RWRDC for six years (2011-2017) or on the day of maiden flight of LUH. Designers get more often brickbats, and once in a great while, a bouquet. It is relevant to mention with profound gratitude, that highest risks are taken by test pilots and test engineers who carry out test flying of prototype helicopters.

Further, the customers who take initial deliveries of the helicopters face teething problems and their feedback is of paramount importance to improve the product. The constant feedback of customers and the co-located team of the representatives has been a plus and these teams have contributed immensely during prototype design and testing phase, by participating in prototype flight testing.
Certification authorities bring in the necessary strength in design and quality by overseeing the entire design and development process and are empowered with the authority to approve the design and quality assurance. To facilitate this aspect, the teams of CEMILAC and DGAQA are co-located so that they are part of the complete development of the indigenous helicopters. This arrangement gives confidence to Certification authorities when HAL approaches for initial and final certification and also for continued airworthiness, post-delivery to customers.

**Project Schedule and Criticisms**

The ALH project launched in 1984 had its own share of time and cost overrun. Debates are on whether too many technologies were tried on ALH for the first time or Qualitative Requirements (QR) was rather demanding [28-29] [39]. It is good to remember that in late 70s and in 80s, knowledge level in India was limited, QRs were sketchy, owing to obvious inexperience in design and development in all stake holders, HAL, GoI, Defence services and Certification agencies.

The other question is whether too many new technologies were attempted at one go as recommended by the consultant MBB. This obviously resulted in delay, but the plus side is that ALH turned out to be a world-class, state-of-the-art helicopter even to this day. The challenges in the ALH project are primarily due to design issues that required iterations that consumed considerable time, manufacturing challenges in a society which lacked an eco-system and to a less degree due to Program management /supply chain challenges. These challenges are not unexpected when design and development are tried for the first time. It is accepted as industry standard, a general norm that a new helicopter takes about 10 years to mature after first production helicopter delivery. During the development and initial production stage, criticism of the ALH project in the media, think-tanks and CAG report have been severe and with extreme negative undertones, displaying our societies immense capability for self-flagellation. “It is not out of place to note that the decibel pitch of media and think-tank criticisms are curiously lowered and often muted especially when accidents or incidents involve imported helicopter types. We perhaps need to look at our foreign counterparts and emulate their sense of balanced criticism of their countries projects, especially in the aftermath of unfortunate accidents or incidents. A balanced view requires taking in the positive aspects too and without resorting to blowing the proverbial trumpet, a simple ‘list’ is as under” [28].

It is quite easy to be wise after the event and pass judgements on pioneers. This would not serve well for a society and nation, if India as a nation or emerging power, would like to engage with adversaries, using indigenous aircrafts, artillerys and armaments, etc.

As with any new development, LCH and LUH had their share of challenges both technical and commercial which led to time over run as against initial estimates of project schedule. However these issues have been overcome and the helicopters have achieved the major operational objectives as seen in their recent deployment at Leh.

**Future Projects**

Based on the knowledge, expertise and operational experience gained over the last three decades, the Rotary Wing Research and Design Centre has ample confidence to move ahead further exploring new product design and to enhance the product range.

HAL signed a MoU with Indian Institute of Technology (IIT) Kanpur in February 2013, to collaborate on the development of a 10 Kg Rotary UAV, as a Technology Demonstrator. Based on that experience, HAL is working on Rotary UAV of 200 Kg (Fig.9).

Although preliminary work was going on at HAL regarding design and development of Indian Multi Role Helicopter (IMRH) of 10-12 Tonne class since 2007, HAL made it intentions to go at it alone, in February 2017. HAL after carrying out preliminary design, displayed a full scale mock up in Aero India 2017 (Fig.10). HAL has launched initial design of IMRH with internal funding.

HAL is working on Civil versions of ALH and LUH as well. HAL will have to work on getting full motion simulators (Level D or equivalent) for ALH, LCH and LUH.

**Lessons Learnt**

It is important to note that HAL entered into a technical collaboration with German specialists (MBB) for design of ALH. A small team of MBB specialists guiding a large team of HAL designers, on-site at HAL premises, has worked to the advantage of HAL. The efficacy of replicating such model elsewhere requires examination. Another lesson worth mentioning is that a complex machine such as helicopter does not come right at first attempt and
continuous efforts will have to be expended to bring out newer and improved versions.

Lessons are that customers (Indian defence forces) who showed a lot of patience in initial years (while importing their immediate requirements as "inescapable necessity") and persist with designers and manufacturing agencies, with regular interaction and participation, benefit with improved products.

Developing countries should stop believing that complex technology products such as Aircraft, Aircraft Engine etc., can be indigenously designed by Transfer Technology and that is a myth. There is no substitute for hard work and learning on our own.

New design and development projects will suffer from extension of timelines which have to be seen on their merit on a case to case basis. The training of the manpower available in terms well designed courses, sending officers for post graduation in premier institutes in India and abroad will help. It is imperative that HAL as OEM will have to resort to massive subcontracting, to improve productivity and volumes, contributing towards building eco-system for manufacture, design and MRO.

It is observed that project time overruns will reduce with experience. Taking customer feedback seriously and resolving them in a time bound manner, will improve the product. HAL needs to strengthen support system for exploiting the Civil helicopter market.

Summary

The journey of HAL on indigenous helicopter development and manufacturing is chronicled in this paper highlighting the various challenges faced during such bold initiatives as well as the associated topics involved. Support from GoI and synergy between HAL and Users are the prime movers in ALH being a success story today. The investment in terms of time, cost, confidence and perseverance on ALH project, in spite of time over run, has paid immensely in developing a strong knowledge base and an eco-system for helicopters in India which in turn has spin-offs in subsequent indigenous development and success of LCH and LUH.

It should be remembered that HAL designed/produced helicopters Cheetah, Chetak, Cheetal, ALH Dhruv, ALH Rudra (ALH Mark IV weaponised version) are rendering commendable service to our warriors in Himalayan border now. LCH and LUH helicopters are set to join them.

Today 300 ALHs have been manufactured and operationalised and orders for nearly 200 LCHs and 200 LUHs are expected from Armed Forces. With aggressive marketing initiatives, huge orders are possible for Civil applications of ALH and LUH. Export orders in future are not ruled out. HAL, which is in elite company of few countries in the world in helicopter sector, thus is poised to enhance product range so that HAL will be the one-stop solution provider for all helicopter needs of both Military and Civil customers in the times to come, thereby not only benefiting HAL but also numerous MSMEs and private players. This ultimately is what "Atmanirbhar Bharat" aims at, in defence design and production.

In summary, having assiduously built such a capability for indigenous design and development of helicopters, it is prudent that all stakeholders - Government, Users and concerned authorities, nurture this sector with HAL being the prime contractor and supported by all agencies, be it public or private, to achieve global leadership in Helicopter market.

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References


Fig. 7 Light Utility Helicopter

Fig. 8 ALH Civil Version

Fig. 9 Rotary UAV (200 Kg Class) - Mock-up

Fig. 10 Indian Multi Role Helicopter - Mock-up