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# LESSONS LEARNT FROM THE INDIGENOUS DEVELOPMENT OF ADVANCED LIGHT HELICOPTER

**References** A: Indian Air Force Air Staff Requirement 2/79

B: Indian Navy Staff Requirement AO/4721/1978

C: CAG Report No.10 of 2010-11, Chapter-III (ALH)

## Introduction

1. The Advanced Light Helicopter (ALH), also called the Dhruv (Polestar) is an indigenous project and has been in series production since 2002. The origins of the ALH project was in the IAF-Army requirements specified in Air Staff Requirements (ASR) 2/79 which released in May 1979 and a related Navy Staff Requirement (NSR) AO/4721/1978, released in 1985 for the Navy variant. The genesis of these service requirements was the decision of the Government in the late Seventies to develop indigenously, a light helicopter that could take care of the needs of the three services. The project itself had gone through several iterations. Initially, in the early Seventies, a light single-engine helicopter was envisaged. That was changed to a larger twin-engine configuration in the Eighties for reasons of better survivability in the battlefield environment.

2. The ambitious requirements given in the ASR and NSR were for a common base platform capable of performing a sweeping range of roles at altitudes ranging from sea level to 6 km (19,500 ft) Pressure Altitude, at high temperatures. The roles for the Army-IAF variants included a contentious requirement for a high altitude landing at 6 km Pressure Altitude with payload of 200 kg plus a large fuel load. Other requirements were reconnaissance and armed roles with wide range of weapons and sensors including turreted 20 mm cannon, anti-armour missiles, air-to-air missiles, EW suite and advanced sighting and aiming systems. The agility and manoeuvrability requirements specified were also challenging. The Navy roles included anti-submarine and anti-surface warfare, SAR, troop carriage, weapons that included torpedoes, Exocet-class missiles and depth charges. Sensors included dipping sonar, surveillance radar, sonobuoys and MAD. The Navy also wanted capability to change roles in quick-time (capability to remove ASR equipment in three hours).

3. Against these very high benchmarks and somewhat sweeping and futuristic expectations, the Government set up a Negotiations Committee to explore the possibility of collaboration with Aerospatiale (France) or MBB (Germany). Thereafter, HAL was tasked in 1984 to develop the helicopter and Germany's Messerschmitt-

Bölkow-Blohm (MBB) was contracted in July 1984 to act as a design consultant and collaborative partner for the programme for a period of 10 years. The first prototype flew in August 1992. Whereas the testing for the Army-IAF variant progressed steadily albeit with delays, the Navy prototype which flew with US (Allied Signal) CTS-800 engines ran into severe delays. This was mainly when the US withdrew these engines in the sweeping embargo enforced following our nuclear tests in Pokhran, 1998.

4. The ALH (Dhruv) was designed against then futuristic benchmarks and its design and technology is indicative of this fact. At the time of inception in the early Eighties, there were several budding technological options in rotor blades, gearboxes and vibration control that promised large jumps in performance and other benefits. At that period of time, when these budding technological options were still in a state of flux, the Negotiations Committee took their considered decision to approve certain design options recommended by MBB to achieve the specified benchmarks.

**Lessons Learnt**

5. While its quite easy to be wise after the event and hindsight is always ‘6x6’, the indisputable fact is that the combination of spectrum-sweeping performance and role requirements that were demanded from a single platform and certain design options that were incorporated, caused extremely severe hurdles to practical implementation. Whereas today one is not aware of the imperatives that influenced the drafting of the staff requirements in the late Seventies, or the decision of the Negotiations Committee in accepting the recommendations of MBB in the early Eighties, the fact remains that some of the futuristic design options put forth by MBB were ***initially resounding failures***. The project that was supposed to have progressed smoothly under the tutelage of advanced German technology, instead stumbled badly to almost a point of no-return and required extreme effort by our indigenous teams to recover, re-develop from basic design stages and optimise for production. Each of the contributory factors therefore needs deeper scrutiny for better clarity.

6. Requirements for Spectrum-Sweeping Performance and Roles.

(a) To be only fair, the ALH owes its excellent performance to the then futuristic requirements that were specified by the Services. If the specified requirements had been moderate, then the product undoubtedly would have been mediocre. The demand for extreme excellence at specific performance points and in some roles is justified and even welcomed, as that is what makes the product unique. However, the problem creeps in when the requirements are at far too many points spread across the spectrum and are also beyond the range of contemporary technology for a single platform. Whereas the IAF-Army and Navy had issued separate ASRs, the fact remained that the base platform was common and the IAF-Army ASR also acknowledged the fact. Especially when seen together, some of the requirements were clearly contradictory and beyond the reach of contemporary technology for a single platform.

(b) For example, the cabin size required to accommodate all the weaponry and sensors for the Navy variant would require a larger and heavier airframe, with larger rotors and engines that in turn makes it beyond reach the specified performance and payload required for 6 km altitude for the IAF-Army utility role. Similarly, it is doubtful whether the IAF-Army specified first-line capability for change-over between all roles including day-attack, would not have impacted basic aircraft weight and thereby affected high altitude performance. Thus a lesson learnt is that the requirements need to be consolidated, prioritised and the focus needs to be on only few clearly defined prime areas.

7. First-time Project and Multiple New Concepts. The approved design configuration included several innovative concepts that included the following:-

- Upper Control System (UCS) with main rotor pitch control rods routed inside the main rotor shaft.
- A Main Gear Box (MGB) with only two-stage reduction, having large area-contact gears that is quite a radical design, even in the present context.
- Then futuristic composite four-blade hinge-less Fibre Elastomer Lager (FEL) main rotor consisting of only few parts with a composite hub and titanium centre-piece.
- A three-axis passive vibration damper system called ARIS to isolate vibrations at the MGB itself.
- A very light-weight yet powerful four-blade ‘stiff in-plane’ tail rotor that essentially comprises just two composite cross-piece blades bolted together at the centre.

8. Each system, when seen in isolation appeared to be the way forward to meet the challenging requirements that were specified in terms of manoeuvrability, low basic weight, high altitude performance and ballistic tolerance. However, implementing some of these concepts caused severe delays and proved extremely challenging. Whatever the reasons were then for opting for the configuration, the fact remained that for a first-time project, there were too many new concepts being tried out. It would also appear that MBB had either over-estimated their capabilities or perhaps had even attempted to experiment the feasibility of some of these concepts at the cost of our project.

9. Abrupt Departure of MBB. During 1994-95, MBB’s involvement in design consultancy of the project abruptly ceased as their contract had expired and was not renewed for any further period. This period was crucial, as flights of the first prototypes were well underway and all the design related problems were showing up on test-benches, Ground Test Vehicle (GTV) and on the prototypes. Issues pertaining to repeated and early failures of the MGB, failures of the ARIS, weight increase, etc had very clearly manifested during this period. Whatever the imperatives of that decision were, the fact remains that this abrupt and untimely departure of MBB resulted in a whole lot of very problematic design issues relating to various complicated systems suddenly being tackled solely by designers of HAL. This was compounded by the fact that our designers did not have any previous experience. All this resulted in an iterative

approach in attempting several design alternatives for rectification that sometimes did not work, usually required repetitious testing and almost always contributed to delays.

10. Main Gear Box(MGB).

(a) The MGB is designed to be compact, light-weight, yet capable of handling the high power output of the two turboshaft engines. It comprises only a two-stage reduction, with a large diameter central collective gear that has a titanium stub-shaft directly bolted onto it. The large diameter was mostly dictated by the need to run the control rods inside the rotor shaft. The stub-shaft in turn is attached to the titanium centre-piece that has the main rotor blades attached to it. The compact, squat and light-weight MGB frees up huge amounts of cabin space below, which is essentially the secret to the ALH's excellent cabin volume. The project to develop the MGB was sub-contracted by MBB to ZF (Zahnradfabrik Friedrichshafen), Germany, a drive-train specialist that had previous aviation experience limited to developing and building gear boxes for the smaller MBB's BK-117 and Bo-105 helicopters.

(b) Although ZF's BK-117 MGB also uses a two-stage reduction, it has important differences in layout and geometry of the bevel and collective gears. Also, it handles only about half of the power of the ALH MGB. The first series of ALH MGBs were spectacular failures – these would not even last one hour of ground run on the Ground Test Vehicle (GTV). After every ground run, shed gear material would be found on the magnetic plugs indicating commencement of gear teeth failures. Initially ZF's MGBs stubbornly refused to improve despite various efforts and this threatened to bring the whole project literally and figuratively to a grinding halt. After MBB (and ZF) left, it took our dedicated in-house transmission team many years of sweat and hard work, to recover the situation by going back to the drawing board, experiment with several remedial measures and introduce numerous modifications, so as to gradually bring the MGB to production standard. Obviously, this caused severe delays in the project.

11. ARIS Vibration Dampers.

(a) Based on MBB's recommendations, it had been decided to introduce a new high-tech three-axis vibration damping system to attenuate main rotor vibrations. There are four ARIS (Anti Resonance Isolation System) dampers and the MGB is mounted on these to isolate vibrations developed by the main rotor from the fuselage. Like the MGB, the initial ARIS design by MBB was another spectacular failure. All four ARIS failed halfway through the first flight itself and on return, all the four ARIS's composite diaphragms were found cracked. Like the MGB, the ARIS proved to be another extremely difficult design failure to correct. Despite initial modifications, the ARIS springs used to routinely fail within 10 hours of flight. Again after MBB left, it was another herculean task again taken on by our in-house vibration analyses group to re-design, experiment and gradually bring the ARIS to a standard suited for production aircraft.

(b) Subsequently, it was learnt that MBB had worked in parallel on another version of vibration isolators and had installed a simpler two-axis SARIB vibration dampers on their Tiger attack helicopter, which uses a main rotor similar to the ALH. During an informal interaction many years later with MBB's then chief designer for ALH in India, he candidly indicated to this author that the ARIS in his opinion was not an easy concept to implement and should not have been used for a first-time project like the ALH. Here it would appear that there was an attempt by MBB to experiment with an uncertain high-risk design option on our project.

12. Weight Reduction. As with most aviation projects, the initial prototypes had overshot the budgeted basic weight; therefore a detailed weight reduction programme was launched and pursued aggressively. Whereas the weight reduction programme was inevitable, had yielded good results and the basic weight was reduced by about 150 kg, there were cases when we had to undo the modification for weight reduction after the reduced weight components were found deficient in life or strength. The prime driver for the weight reduction programme was the 6 km high altitude requirement. In the end, the Mk-III ALH demonstrated its 6 km altitude capability well in excess of the requirement and this was partly due to the successful weight reduction. However, the aggressive weight reduction exercise itself could have perhaps been moderated and balanced to avoid the cases that required back-tracking on modifications due to reasons such as increased vibrations or reduced structural strength.

13. No Time Gaps Between LSPs and Production ALHs. Ten Limited Series Production (LSP) ALHs rolled out during 2001-03. The decision to go in for the LSPs was good in itself, as this enabled the dedicated use of 10 ALHs by the operators solely in their respective op environment. Whereas the prototypes are used in a strictly regulated flight testing regime in a protected factory environment, the use of the 10 LSPs in the field by the operators revealed different issues that required remedial action. Even in hindsight it is very obvious these issues may not have come to light in its entirety in the prototypes and the decision for having LSP aircraft was sound. However, instead of having a deliberate pause after the LSPs to fix the issues revealed by the LSPs usage, the regular production line itself was commenced in 2002-03. The imperatives of this decision (which included acquiescence of the Services and approval of MoD) are not known. This decision caused the various niggles found in the LSPs to be passed on the first batches of production aircraft also, which then had to be subsequently retro-modified to correct the problems.

14. No Facilities for Large Scale Powered Model Testing.

(a) The ALH being the first rotary wing project in the country is obviously being used as a base to spawn off other projects. Certain amount of wind-tunnel testing was done on the ALH fuselage using scale models, however given the fact that the project was initiated in the late Eighties, the wind-tunnel testing was limited to static scale models (without rotating rotors). Helicopter aerodynamics is complex and predicting the airflow interaction of the rotor wake with the fuselage and empennages without advanced wind-tunnel facilities, are at best limited to approximations that need to be proven and checked out during flight testing. Also, this invariably requires various combinations of fairings, empennage settings to be actually flight-tested before identifying the optimum combination.

(b) To resolve these vexing issues, recent helicopter projects such as the NH-90 have used more than 1900 hours of wind tunnel testing that has included large 1:3.88 scale models with powered rotating main rotors (model rotor diameter 4.2 m) in the Large Low speed Facility (LLF) of the German Dutch Wind-tunnel (DNW). Wind tunnel testing was used to refine the design of the engine intakes, exhausts, IR suppressors, horizontal stabiliser setting and even rotor performance and helicopter stability characteristics. Using data from such tests, the design of the prototypes itself can be refined to such an extent that it would reduce flight testing, developmental efforts and time. In fact it has been acknowledged that the extensive tests with powered models in wind-tunnels had contributed substantially towards the NH-90 project.

(c) In sharp contrast, we are yet to establish such facilities in the country. The option of using facilities abroad for such extensive testing is not easy, given the inevitable bureaucratic delays in approvals and uncertainties of free time slots available at those wind-tunnels during our required time periods.

15. <u>Local Vendor Facilities for Complete Systems</u>. There has been concerted efforts to increase the levels of indigenisation in the project. However, despite all the progress made, we have not been very successful so far in developing local vendor facilities for complete systems. As a theoretical example, this project could have had the beneficial spin-off in terms of developing local vendors for complete systems such as the MGB. The vendor could then have used their capability with this technology to take on work for manufacturing or overhauling complete MGBs for other foreign and Indian helicopter projects also. Unfortunately, this has not happened. A main reason for inability to nurture indigenous vendors for such specialised and complex systems is our cast-iron Government dictated procurement procedures that require re-tendering after procurement of a batch of items. There is also the officially dictated aversion to a ‘single-vendor’ situation, whereas in the world of aerospace industry, niche specialisation is the norm and that effectively gives rise to ‘single-vendors’ for complex or specialised systems, processes or materials.

16. <u>User’s Project Monitoring</u>. The Services have on-site project monitoring teams that have been associated since the early days of the project (except for the Army, which set up their independent monitoring after the Army Aviation was separated from IAF operational control). Whereas project monitoring had been stringent during the early prototype phase, there were certain ‘blank’ phases that need highlighting as under:-

(a) During the crucial period of transition from prototypes to LSP, there was little or no monitoring by IAF as the project group itself was not manned. It would appear at that point in time, priorities were disproportionately skewed towards certain other high-visibility fixed-wing projects.

(b) There was a similar situation in the Navy during the same period when there were no specialists (test pilots or flight test engineers) posted to the project team.

17. The Positive Aspects. Criticism of the ALH project in the media, think-tanks and even official ones such as the CAG report sometimes have extreme negative undertones. Such criticisms that only harp on all things negative often leaves one with a feeling of self-flagellation that does little good and more harm to our collective psyche. 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 country's 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:-

(a) 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 fulfil the requirement.

(b) The ALH rotors have good control power that translate into good manoeuvrability and has added benefits of excellent handling at high altitudes. Its manoeuvrability, handling and high altitude performance is ***better*** than any other helicopter in current Service inventory, ***including*** Attack Helicopters.

(c) The Mk III especially has excellent power-to-weight ratio that along with its good control power lends to ***easy handling***.

(c) It has among the best in-class cabin volume with seating for 14 fully equipped troops. In fact, the cabin space is comparable with even the 9-tonne AUW class Black Hawk.

(d) The ALH has a very rugged airframe, mainly due due to its crashworthy design. This has been proven during a couple of instances of mishandling. In one instance involving the civil wheeled variant ALH, the crew mis-handled and entered a state of vortex ring during a routine maintenance sortie. The aircraft impacted the ground with a vertical acceleration well in excess of 14.5 G, yet the crew and passengers survived with relatively minor injuries. There was negligible compression of the cabin and cockpit area, which were largely intact and the heavy masses atop (engines and MGB) did not penetrate the cabin. The civil certification authority (DGCA) investigator remarked on the ruggedness of the

ALH and said that had it instead been any another civil type, the outcome for the crew and passengers would have been very different.

(e) It is cleared for IFR, because of its well integrated autopilot, good avionics fit and redundancy in critical systems.

(f) Its tail rotor has excellent control power, a broad operating envelope and complements the main rotor in manoeuvrability. An infamous issue that afflicts some other current generation helicopter types in military and civil use in our country is LTE (Loss of Tail rotor Effectiveness), which is actually a design deficiency couched in technical jargon. The ALH tail rotor does not have any such issues throughout its operating envelope, as its performance is tailored to meet the ASR specification of generating and controlling 60°/s rate spot turns in hover.

**Conclusion**

18. The ALH (or Dhruv) is an ambitious first-time project to design and build a common helicopter platform catering to all the requirements of the Army, Navy and IAF. The roles it was envisaged to fulfil in different variants were extremely varied, ranging from landing at 6 km altitude to armed, night attack, Anti-Submarine, Anti-Surface Warfare, SAR, troop carriage and utility roles. The wide range of envisaged sensors and weapons included 20 mm cannon, anti-armour missiles, torpedoes, Exocet-class missiles and depth charges. The Army-IAF variant was to have EW suite and advanced sighting and aiming systems and the Navy variant was to have dipping sonar, surveillance radar, sonobuoys and MAD. The Navy also wanted capability to change roles in quick-time (capability to remove ASR equipment in three hours). The agility and manoeuvrability requirements specified were challenging. These spectrum-sweeping requirements were attempts to achieve exceptional performances in all roles through variants derived from a single base platform.

19. Need to Keep Requirements Realistic and Focussed. It is undoubtedly a foregone conclusion that any helicopter mainly built to ASR 2/79 is bound to have exceptional performance and the ALH owes a lot to the guiding framework that it was designed and built under. However, the fact remains that in hindsight, the total expectations raised by the NSR and ASR are not achievable even today, by a single platform. Even certain sub-clauses in the ASR, which were subsequently moderated, are also not achievable by a single platform. Given the above, there is a need for dialogue with industry experts on current and short-term technology levels. A realistic and formal assessment of what contemporary technology is capable of and what technological advancements in the short-term may achieve, is necessary to temper the specified requirements that are put forth. There is also the need to focus on specific key areas of importance, rather than put forth requirements for all envisaged roles and performance points.

20. Limit New Concepts in First-Time Projects. The ALH design incorporated several innovative concepts that were being implemented for the first-time. When each is viewed in isolation, it appears a logical new-tech choice for a modern helicopter to meet the specified requirement. However, for a first-time project being attempted, there were too many new concepts being tried out. Also, MBB either over-estimated their capabilities to implement all of these or had perhaps also attempted to experiment on some of these concepts at the cost of the ALH project. The fact is that there were severe delays to the project mainly attributable to severe problems in some of the new concepts being implemented and at certain points in time, the nature of some of the failures had even threatened to derail the project altogether. The lesson is thus quite clear – even with good design consultancy, limit the number of new concepts being implemented, especially for a first-time project.

21. Accountability of Design Consultant. The abrupt departure of MBB during 1994-95 was due to non-renewal of contract and this was at the time when flight testing had picked up and all the problems related to some of the new concepts being implemented, especially the MGB, ARIS and increase in Empty Weight had clearly manifested. HAL designers, with no previous experience were now suddenly required to tackle these issues, which led to further delays. Ideally, MBB should have been held accountable and asked to stay on to rectify these difficult design deficiencies. They could have been contracted to stay on, until the design was successfully transferred to the regular production line. The extension contract document could have been structured to include these aspects and also progressively reduce their involvement as the project matured towards production.

22. Initial Failures of MGB & ARIS. The initial failures of the MGB and ARIS and subsequent delays it caused the project were directly linked to the decision to let the design consultant go away without accountability for their these major failures. Both designs required extensive re-work by our in-house design teams without previous experience in such systems. There is also the need to independently analyse and audit to the extent possible before any project go-ahead, the risks and feasibility of implementing each new concept and whether the design consultant is attempting to experiment at our cost on critical systems, especially if they are known to be working on a similar class of aircraft in parallel.

23. Need for Balanced Action on Weight Reduction. Almost any aviation project undergoes a struggle in the design-to-prototype phases to keep weights down. This requires definitive action to control and correct. The case of the ALH project is perhaps no different. Ultimately, the ALH Mk-III has outperformed the dreaded ‘corner point’ 6 km altitude specification of the ASR. What however needs to be learnt is the need to maintain a balanced and moderated action on weight savings versus structural modifications, so as to avoid the cases in the ALH when certain weight-saving modifications were subsequently required to be undone because these caused other problems of vibrations, etc.

24. Time Gap Required Between LSPs and Production Aircraft. Handing over a small fleet of Limited Series Production (LSP) to the three Services was a good decision as the problems with operating the helicopter in their respective operational environment came to light. However, the lesson learnt here is that it is prudent to have an appropriate pause in the production line between the LSPs and production aircraft to enable incorporation of the appropriate remedial measures on the production units.

25. Large Scale Powered Model Testing. Helicopter design is turning to use of large-scale, powered (rotating rotors) models complete with scale replicas of fuselage, horizontal stabiliser, etc, in wind tunnels to study and optimise the design of various components of the design. This reduces developmental and especially flight testing effort to identify the optimum configuration. To move with the times, we also need to think seriously and move towards establishing such facilities locally for future designs, since attempting to use such facilities abroad for continued periods of testing for future projects is not an easy option.

26. Nurturing Local Vendors for Long Term. We need to seriously take action for nurturing local vendor facilities for complete systems, including complex systems such as the MGB. Our rules and regulations need to be appropriately tuned to the real-world scenario in aviation, where niche speciality is the norm and long-term relationships are the rule with specialist and mostly ‘single-vendors’.

27. User Project Monitoring. User project monitoring has been stringent and detailed. However, there needs to be consistency in monitoring, especially during critical transition phases and monitoring needs to be maintained throughout the duration of the project till production has stabilised.

28. Need for Balanced Criticism. Instead of embarking on only negative and fault-finding missions, there is the need for a systematic, objective and impartial analyses of any indigenous project. Whereas failures definitely need to be highlighted along with reasons, it is equally important to impartially list out the achievements that also need to be duly acknowledged.

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