WELCOME STEPS TOWARDS AN INDIGENOUSLY EQUIPPED INDIAN AIR FORCE

VIVEK KAPUR

INTRODUCTION

The Indian Air Force (IAF) was formed on October 8, 1932 with the first flight of its No. 1 Squadron realised on the ground in April 1933 at Drigh Road Airfield, Karachi with four Westland Wapiti-II biplanes.[1] India was a colony ruled by the British, and it was only to be expected that the IAF would utilise imported British equipment. This was what happened. In later years, whenever equipment of British origin was unavailable or could not be obtained, aircraft, such as the DC-3/C-47 'Dakota', were sourced from Britain's former colony and close ally, the USA. This situation of utilising imported British or American equipment continued until India gained independence in 1947. For a variety of reasons that span the full gamut from policy decisions at the highest levels to the more technical and technological, IAF has continued (even after 1947) to be equipped primarily with imported equipment, albeit sourced from a wider selection of suppliers than was possible prior to 1947.

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1. Indian Air Force, "History of IAF", at https://indianairforce.nic.in/content/history-iaf-0. Accessed on March 8, 2021.

Today, after a long time, there are unmistakable trends that point towards a future IAF equipped with cutting-edge equipment spanning from aerial platforms, sensors and advanced weapons designed, developed and manufactured in India. Several tests of equipment under development, and mature equipment undergoing pre-induction trials by the armed forces that are reported in the media, lead to this optimism.

It should be clear to all strategically minded readers that at the end of the day when the chips are down one can depend only on what strength one *actually possesses*. Therefore, it is important for a country to own the technology and all aspects of the equipment that a country's armed forces need to utilise.

Today, after a long time, there are unmistakable trends that point towards a future IAF equipped with cutting-edge equipment spanning from aerial platforms, sensors and advanced weapons designed, developed and manufactured in India. Several tests of equipment under development, and mature equipment undergoing pre-induction trials by the armed forces that are reported in the media, lead to this optimism. Several weapon systems under induction, or in late-stage development by the country's scientific and industrial agencies, are comparable with similar equipment available from foreign vendors. There are other weapons, such as the Brahmos supersonic cruise missile in its surface, air and sea-launched variants,[2] that are superior to most equivalent foreign weapons. This bodes well for the overall power of the country and the effectiveness of the IAF in carrying out its assigned tasks well.

DESIGN, DEVELOP AND BUILD Vs BUY/IMPORT

Importing equipment from foreign vendors has advantages as well as risks. These are discussed below:

2. "India successfully tests air and land-based variants of the BrahMos missile", PTI, December 17, 2019, at https://www.theweek.in/news/india/2019/12/17/india-successfully-tests-air-and-land-based-variants-of-the-brahmos-missile.html. Accessed on March 12, 2021.

Advantages of Importing

Ready and Relatively Quick

Through import, a country gets to induct ready weapons systems that have already gone through design, development, testing, evaluation, and manufacture processes in the country of origin and could already, in most cases, be in military service. This greatly reduces the risk for the buyer country in inducting a proven product that will work as expected. In contrast, indigenously developed equipment requires a lot of painstaking work in design and development of the sub-parts and systems that would make up the final product. In this process, it is quite likely that several avenues of research may lead to dead ends, which necessitate the exploring of alternative methods to develop the required technology. This is likely to result in cost and time overruns. If the development teams are unable to resolve, or work around an issue, the entire project may get stuck with no final weapon system emerging, or a weapon system being offered for production and induction that does not meet all requirements. For instance, the Indian HF-24 "Marut" fighter, designed at HAL by a team led by Professor Kurt Tank (the German designer and test pilot who designed the famous and very successful Luftwaffe combat aircraft, the Focke Wulf Fw-190 fighter, of World War II[3]), was planned to be powered by two British Orpheus 12 afterburner equipped jet engines, each delivering a thrust of 3,705 kilograms static thrust (kgst).[4] Due to the engine not being developed by Britain, for its own reasons, the HF-24 team was forced to use the one

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3. John Zukowsky, "Kurt Tank German aircraft designer and test pilot", February 20, 2021, at https://www.britannica.com/biography/Kurt-Tank. Accessed on March 14, 2021.
4. V. Narayan, "Indian Aviation—HF-24 Marut, first Indian designed jet fighter", 2014, at http://www.teambhp.com/forum/commercial-vehicles-india/159928-indian-aviation-hal-hf-24-marut-firstindian-jet-fighter.html. Accessed on March 12, 2021.

available in India through the earlier Gnat programme. This was the non-afterburning Orpheus 703 engine that delivered only 2,200 kgst, which left the HF-24 with a total thrust deficiency of 3,010 kgst (deficiency in thrust from planned figures of 1,505 kgst per engine for the twin-engine fighter). With the reduced thrust the HF-24 was unable to meet all the performance parameters desired by the IAF. Thus, there is great benefit in reduced risk and potentially quicker availability of importing weapons systems and allied equipment from countries that have already developed and manufactured them.

Disadvantages of Importing

Limitations in Availability of High-Technology Platforms and Weapons

No country is usually willing to export its very best equipment to other countries, irrespective of how close their ties might be. One reason for this is that nation states realise that it is quite possible for today's friends to become tomorrow's foes. In such a case, one would have exposed one's best equipment to a potential foe. In the fluid world of global geopolitics, it can never be certain that today's ally will not become an enemy in later years. For instance, the two large communist countries, the People's Republic of China (PRC) and the Union of Soviet Socialist Republics (USSR) were close allies based upon their shared communist ideology, with the USSR providing extensive assistance on favourable terms to the vastly less advanced PRC in the fields of industry, agriculture, military operational techniques and military hardware manufacturing from the time that the PRC was formed in 1949.[5] There was a split between these close allies that lasted from 1960 till 1989. During this period, in March 1969, the two countries clashed militarily near the Damanski island on the Ussuri river, resulting in tens of casualties, and raising the prospect of an all-out Sino-Soviet war, or even a Soviet nuclear attack on China.[6] Today, after the dismantlement of the USSR in

5. "Establishment of the People's Republic", Britannica.com, at https://www.britannica.com/place/China/Establishment-of-the-Peoples-Republic. Accessed on March 10, 2021.
6. "The Sino-Soviet Border Conflict,1969: US Reactions and Diplomatic Maneuvers", National Security Archive Electronic Briefing Book No. 49, edited by William Burr, June 12, 2001, at https://nsarchive2.gwu.edu/NSAEBB/NSAEBB49/index2.html. Accessed on March 10, 2021.

1991,[7] the PRC and Russia are again close allies.[8] This shows the extreme uncertainty about who will be friends and foes in the real world over a period of time.

Reluctance to Export

The other possible cause for reluctance to export the best equipment could be the need to protect intellectual property (IP), developed with great effort and cost, from being copied by potential competitors and inadvertently leaked to enemies. The US has not exported its nuclear-powered super aircraft carriers, strategic bombers, such as the B-52, B-1, and B-2, or nuclear-powered submarines to any country, and is yet to permit export of its Lockheed F-22 "Raptor" Fifth-Generation fighter to even its closest allies. The Obey Amendment[9] to the 1998 Department of Defense Appropriations Act specifically prohibits the sale of the F-22 and its technology to even the closest of US' allies, such as Israel, Japan, and the UK, let alone any other countries. The Research and Development cost of US$ 62 billion of the F-22 programme led to its being the costliest fighter programme ever, until it was overtaken by the F-35 "Lightning-II" programme,[10] and ultimately the high cost of the F-22 led to the F-22 "Raptor" programme being terminated prematurely. On May 3, 2012 Lockheed delivered the 195th F-22, the last aircraft of the truncated contract, against the originally planned 750 aircraft procurement, to the USAF, and commenced mothballing the production facilities.[11] Despite the cost limitations due to a relatively small production run, the US Government has not lifted the Obey Amendment out of fears

7. Adam Janos, "Was the Soviet Union's Collapse Inevitable?", April 17, 2018, at https://www.history.com/news/why-did-soviet-union-fall. Accessed on March 13, 2021.
8. Melinda Liu, "Xi Jinping Has Embraced Vladimir Putin—for Now", October 3, 2019, at https://foreignpolicy.com/2019/10/03/xi-jinping-has-embraced-vladimir-putin-for-now/. Accessed on March 13, 2021.
9. Blake Stilwell, "This is why the US never exported the deadly F-22", May 22, 2020, at https://www.wearethemighty.com/mighty-tactical/why-f-22-never-exported/. Accessed on March 7, 2021.
10. Sébastien Roblin, "The Air Force admits the F-35 fighter jet costs too much. So it wants to spend even more.", March 7, 2021, at https://www.nbcnews.com/think/opinion/air-force-admits-f-35-fighter-jet-costs-too-much-ncna1259781. Accessed on March 10, 2021.
11. Jeremiah Gertler, "Air Force F-22 Fighter Program", July 11, 2013, at https://fas.org/sgp/crs/weapons/RL31673.pdf, pp. 2-10. Accessed on March 10, 2021.

that the very high technology developed for and used in the F-22 could leak to countries such as People's Republic of China (PRC) and Russia.

Possible Difficulties in Procurement of Supplies of Spares

Another important drawback of reliance on aircraft and equipment imported from another country is the possibility of it becoming unusable in case the regular supply of spare parts, etc., is disrupted for any reason. Imperial Russia, under the Tsars in the first few years of the 20th century, though a great power of the time, lagged behind other European countries in technological prowess. Tsar Nickolas II earmarked one million roubles to add an aviation arm to the Russian military in 1909. However, due to lack of advanced aircraft availability in Russia, the aircraft were imported from France and Britain. By mid-1914 the Imperial Russian Military could boast of the largest military air arm in Europe, after France. The aircraft of the Russian air arm, however, were either direct imports or licence-built foreign designs.

During World War I German blockades of ports and the geographical fact that the common hostile country, Germany, lay between Russia and France and Great Britain—the source countries of the Russian Air Force's equipment—led to a severe shortage of spare parts and essential equipment. This rendered Russia's large and 'on paper' potent air arm practically useless against the enemy.[12] More recently, India faced a similar issue with some of its imported equipment. After Pokhran-II nuclear weapon tests in May 1998, the US and its close allies imposed sanctions on India resulting in stoppage of supply of spare parts for the Indian Navy's fleet of Sea King helicopters. As a result, these helicopters became less operationally available till some urgently needed parts were manufactured in India's HAL.[13] Reliance on imported equipment renders a country vulnerable to disruption in the supply of essential spare parts to keep the imported equipment serviceable and available. Disruption in the smooth supply of spares can render the imported

12. Vivek Kapur, *Indian Aircraft Industry Possible Innovations for Success in the Twenty-first Century* (New Delhi: KW Publishers Pvt. Ltd., 2017), pp. 205, 206.
13. Sangeeta Saxena, "IMP Aerospace & Defence hopeful of keeping Indian Navy's Sea Kings flying", July 20, 2018, at https://www.aviation-defence-universe.com/imp-aerospace-defence-hopeful-of-keeping-indian-navys-sea-kings-flying/. Accessed on March 12, 2021.

equipment unavailable and near useless. This is possibly the greatest danger and risk of reliance on imported aircraft and allied equipment. Hence it is essential to a country striving to develop its power to invest in design, development and manufacture of the military equipment that it needs.

- Disruptions for any reason in the source country can also have serious consequences for one's own military equipment. More than 60 per cent to 70 per cent of India's military equipment, in the late 1980s and early 1990s, was sourced from the former Soviet Union and its successor state, the Russian Federation.[14] When the former Soviet Union disintegrated, some factories that supplied spare parts to India were within the new Russian Federation while others came to be located in the now newly independent countries such as Ukraine, etc. The relatively smooth supply lines for spares were severely disrupted. This caused great problems to India's defence forces in keeping Soviet/Russian origin equipment serviceable. An analogy is useful here to illustrate the main point. To become strong and powerful, a person cannot go to a shop and buy a few kilos of, say, biceps or other muscles and become powerful. It is only through discipline and hard work involving the required physical effort of exercising and disciplined eating that a person can become powerful. The same applies to an air force, or any other kind of power, military or economic/industrial. In order to build a powerful air force, the aircraft and equipment as also the operational philosophy for the air force must be designed, developed, manufactured and conceptualised in the country itself. This is the path that has been followed by all the powerful air forces in the world, such as the British Royal Air Force (RAF) and German Luftwaffe of World War I and II, the USAF, the French *Armee de l'Air*, the Soviet Air Force, *Voyenno-Vozdushnye Sily* (VVS), Soviet Air Defence Forces, *Voyska Protivovozdushnoy Oborony* or *Voyska PVO*[15] and the PRC's

14. Dipanjan Roy Chaudhary, "More-Than-60-70-of-India-Armed-Forces-Equipped-With-Russian-Origin-Weapons-Indian-Envoy", July 11, 2020, at https://m.economictimes.com/news/defence/more-than-60-70-of-india-armed-forces-equipped-with-russian-origin-weapons-indian-envoy/articleshow/76903811.cms. Accessed on March 13, 2021.
15. The Voskaya-PVO was a separate military service and not a part of the VVS in the Soviet military system.

People's Liberation Army Air Force (PLAAF). All these powerful air forces have reached their positions of globally recognised power through the tireless efforts of their scientific communities and military personnel towards developing and manufacturing the kind of equipment and usage philosophies that they needed.

Induction of the IAF while under colonial rule comprised British aircraft for the most part with very few American aircraft types supplementing them. This was perhaps because the first aircraft building enterprise in India—the privately set up Hindustan Aeronautics Limited (HAL)—based at Bangalore had, at inception in December 1940, obtained a licence from the American companies to build the Curtiss Hawk biplane fighter and Vultee Vengeance dive bomber and Harlow trainer aircraft.

PAST IAF EQUIPPING

1932-1947

At formation, IAF comprised four Westland Wapiti-IIA biplanes forming 'A' Flight of No. 1 (Army Cooperation) Squadron. In April 1936 'B' Flight was formed. 'C' Flight, formed in June 1938, brought the Squadron up to full strength.[16] Thereafter, six coastal defence flights were formed equipped with Westland Wapiti-IIAs and later with Armstrong Whitworth Atlanta transports, while No. 1 Squadron converted from Wapitis to the Hawker Hart. By 1940, new aircraft, such as the British Lysander, Hurricane, and Spitfire as well as the American Vultee Vengeance and Douglas DC-3/C-47 "Dakota" were in service.[17] These were followed by the British Typhoons.

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16. Indian Air Force, n. 1.
17. Akshay Chavan, "Indian Air Force: The Beginnings", October 8, 2018, at https://www.livehistoryindia.com/history-daily/2018/10/08/indian-air-force-the-beginnings. Accessed on March 9, 2021.

a licence from the American companies to build the Curtiss Hawk biplane fighter and Vultee Vengeance dive bomber and Harlow trainer aircraft. At that time, the British had no equivalent transport aircraft to match the rugged and very widely used—hence readily available—C-47 "Dakota".

IAF's first jet bomber was the British Canberra while helicopters were initially sourced from the USSR, the Mi-4, followed by the Alouette-III and Lama from France, both of which were built under licence at HAL as the "Chetak" and "Cheetah", respectively.

1947 Onwards

After Independence, the IAF initially sourced aircraft from the United Kingdom perhaps due to familiarity with their equipment. Thus, the Percival Prentice trainer was inducted, followed by the Vampire fighter in several variants, some of which were manufactured in India at HAL under licence. The British Folland Gnat and Hawker Hunter followed, with the former manufactured under licence at HAL. The Hawker Siddeley HS 748 "Avro" was selected for licensed manufacture as the first transport/ passenger/cargo aircraft to be built in India, initially by one of the IAF's Base Repair Depots (BRD). Alongside British aircraft, the IAF also inducted aircraft from other countries, notably the French Dassault *Ouragan*, "*Toofani*" in Indian service, and the Mystère IV, also from Dassault. Later, the American C-119 "Packet" was inducted to augment the transport fleet.

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18. Rajat Pandit, "Sanctioned in '83, LCA Tejas is yet to take off", February 12, 2008, at http://timesofindia.indiatimes.com/articleshow/2774912.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst. Accessed on March 16, 2021.
19. PIB, "Light Combat Aircraft (LCA) 'Tejas' inducted into no 45 Squadron of Indian Air Force", July 1, 2016, at https://pib.gov.in/newsite/PrintRelease.aspx?relid=146697. Accessed on March 9, 2021.
20. "First FOC Standard LCA Tejas inducted into IAF Squadron", Defenseworld.net, at https://www.defenseworld.net/news/27073/First_FOC_Standard_LCA_Tejas_inducted_into_IAF_Squadron#.YEsGY9zhU2w. Accessed on March 9, 2021.
21. "Induction of Rafale in Indian Air Force", Indianairforce.nic.in, July 29, 2020, at https://indianairforce.nic.in/content/induction-rafale-indian-air-force-0. Accessed on March 16, 2021.

Radars were sourced from a mixed bag of countries. Soviet radars served alongside British and American types. Surface-to-Air Missiles (SAMs) initially came from the USSR in the form of SAM-2 (S-75 Dvina), SAM-3 (S-125 Neva/ Pechora), SAM-6 (2K12 Kub/Kvadrat), SAM-7 (9K32 Strela), SAM-8 (9K33 Osa), and SAM-16 (9K38 Igla). DRDO replaced some of the older imported SAMs with the development of the Akash SAM system which entered IAF service in July 2015[22] after extensive user trials. In collaboration with Israeli companies, DRDO is developing a modified variant of the Israeli Barak SAM system to meet India's Long-Range SAM (LR-SAM) requirement. Work is continuing on the Medium-Range SAM (MR-SAM), also with Israeli cooperation.

Interestingly, India's HAL had started design of its first powered aircraft, the HT-2 immediately after independence. This machine saw extensive service with IAF and was retired only in the late 1980s. The design of India's first jet trainer was undertaken a few years later to produce the HJT-16 "Kiran" that is flying even today, albeit in reduced numbers due to a shortage of Rolls Royce Viper-II engines on the Kiran Mk-1/1A and the Bristol-Siddeley Orpheus engine on the Kiran Mk-II. The 1960s saw the foreign assisted design of India's first indigenous fighter at HAL, the HF-24 "Marut". HAL built 141 copies of the HF-24 with 18 two-seat and 123 single-seat versions being delivered to IAF which equipped three fighter squadrons, No. 10, No. 31 and No. 220 Squadrons, with the "Marut".[23]

INDIGENOUS R&D EFFORTS IN AVIATION

The HT-2

Hindustan Aeronautics Limited (HAL), formed as an aircraft design and manufacture agency, was taken over by the Government of colonial India

22. "Ingeniously-built Aakash missile inducted in IAF", IANS, July 10, 2015, at https://www.indiatoday.in/india/story/ingeniously-built-aakash-missile-inducted-in-iaf-281780-2015-07-10. Accessed on March 9, 2021.
23. Abhishek Saxena, "11 Facts India Completely Forgot About Its First Jet Fighter", April 15, 2015, at https://www.indiatimes.com/technology/news/11-facts-india-completely-forgot-about-the-jet-fighter-231867.html. Accessed on March 9, 2021.

in 1942, and later handed over to the US to serve as No. 84 Air Depot, an aircraft repair and overhaul agency to support the Allied World War II effort in the Asian theatre. In 1948, a year after HAL reverted to Indian control as a nationalised aircraft factory, Dr. V. M. Ghatage rejoined HAL as head of its reconstituted Design Department, and proposed the design and manufacture of a piston engine trainer primarily for use by IAF. Government of India (GoI) sanction was received on October 11, 1948.[24] The refinement of the design proceeded rapidly with extensive involvement of the IAF, and the aircraft—to be called the Hindustan Trainer (HT)-2—was formally launched on August 13, 1951. These trainers commenced IAF service in 1955 and were phased out in 1989.[25]

HJT-16 "Kiran"

The basic jet trainer programme to replace Vampire trainers was initiated in December 1959 and the first aircraft flew in September 1964. The "Kiran" continues in service to date. The numbers, however, have declined due to reduced availability of the Kiran Mk-1/1A, and Kiran Mk-II aircraft's Viper-II and Orpheus engines respectively.[26]

HF-24

Professor Kurt Tank joined HAL at the invitation of GoI in August 1956. He led a design team of 18 German engineers, alongside 150 Indian personnel, and design work on the HF-24 started in June 1957. The aircraft carried out its first official flight on June 24, 1961.[27] The HF-24 was underpowered to the extent of 3,010 kgst against its planned thrust. Despite this, on December 7, 1971 an HF-24 piloted by then Sqn Ldr KK Bakshi of No. 10 Sqn, IAF got the better of a "pedigreed dogfighter", a Pakistan Air Force (PAF) operated American F-86 Sabre jet being flown by then Flt Lt Hamid Khwaja of No. 15 Sqn, PAF,[28]

24. Vivek Kapur, n. 12, pp. 25-29.
25. Ibid., p. 26.
26. Ibid., pp. 29-30.
27. Ibid., pp. 41-43.
28. Polly Singh, "HAL HF-24 Marut—Where the wind blows", at http://www.bharat-rakshak.com/IAF/aircraft/past/1199-marut-polly.html#gsc.tab=0. Accessed on March 14, 2021.

in close combat while returning from a deep strike mission in Pakistan. A total of 141 HF-24 aircraft were built and delivered to IAF by 1977. Attempts to upgrade the performance of the HF-24 by incorporating an afterburner on its Orpheus 703 engines did not find favour with IAF. Attempts by HAL to re-engine the HF-24 did not fructify either. These attempts to improve the HF-24 were then abandoned in preference to imported aircraft.

RECENT DEVELOPMENTS

After the ill-fated HF-24 "Marut" project, domestic aircraft design and development languished while IAF resorted to import of aircraft from Western Europe and the Soviet Union to meet its needs. Trainer aircraft, such as the Hindustan Piston Trainer (HPT)-32 were designed but had a limited and less than distinguished service record. A few other trainer aircraft projects, the Hindustan Turbo Trainer (HTT)-40 and Intermediate Jet Trainer (IJT), the HJT-36 "Sitara", are making progress. Things changed when in 1983 the GoI initiated the design and development of the Light Combat Aircraft (LCA) to replace the ageing MiG-21. Alongside this, HAL took it upon itself to design and develop an Advanced Light Helicopter (ALH). These projects, amongst others, initiated in the late 1970s to 1990s, continue till date and have breathed new life into the Indian indigenous aircraft industry. The LCA itself has given birth to a variety of variants and extensions of the original project which in themselves indicate a bright future for India's military aviation sector in the years to come.

ALH

The ALH project was launched in 1976 based upon the learning gained from the licensed production of French origin Alouette-III and Lama helicopters. ALH, named "Dhruv", is a 4-5-ton class helicopter and is designed to undertake many diverse roles, such as heliborne assault, casualty evacuation, reconnaissance, logistics support, air observation post, logistics, and passenger transport. It is even capable of shipboard operation.

Dhruv is the first helicopter designed and built in India. It has a few shortcomings, the significant one being the reported high vibration level. In all likelihood this is the result of meeting another design requirement, that is, a very quick response and high manoeuvrability which required the use of a hingeless composite material rotor system.

The aircraft has two engines and uses the Ardiden 1H1 "Shakti"[29] engine co-developed with France's Turbomecca to deliver 12-15 per cent higher thrust than the Turbomecca TM 333-2B2 engine to meet India's requirements of operating at high altitudes in the Himalayas in the hot summer months, resulting in very challenging high-density altitudes. The engine drives a hingeless four-blade composite main rotor with electrometric bearings. The rotors have advanced configuration for higher lift generation combined with noise reduction, and are built to survive hits by bullets up to 12.7mm in calibre. The ALH has been built in four variants from Mk-I to Mk-IV, and as on October 1, 2020, 300 ALH Dhruv have been built and delivered into service.[30] Dhruv is the first helicopter designed and built in India. It has a few shortcomings, the significant one being the reported high vibration level. In all likelihood this is the result of meeting another design requirement, that is, a very quick response and high manoeuvrability which required the use of a hingeless composite material rotor system. A rigid rotor, lacking rotor hinges, transmits more vibration to the aircraft fuselage. HAL has been working on reducing the vibration levels.

The ALH Dhruv—given its fairly wide utilisation in both military and civil fields and the large number of aircraft built—is a welcome success story of the Indian aircraft industry. It forms the bedrock of expectations that in the years ahead the aviation equipment for India's military forces will become more and more indigenous.

29. "Dhruv", Hal-india.co.in, at https://hal-india.co.in/Product_Details.aspx?Mkey=54&lKey=&CKey=24. Accessed on March 15, 2021.
30. "HAL Rolls Out 300th Dhruv Advanced Light Helicopter from Bengaluru Hanger", News18.com, at https://www.news18.com/news/auto/hal-rolls-out-300th-dhruv-advanced-light-helicopter-from-bengaluru-hanger-2922077.html. Accessed on March 15, 2021.

RUDRA AND LIGHT COMBAT HELICOPTER (LCH)

Rudra. The first opportunity to more fully utilise the successful ALH platform was to develop the Weapon System Integrated (WSI) version of an ALH Mk-IV helicopter, named the "Rudra". Initial Operation Clearance (IOC) was obtained in early 2013. There are 58 Rudra aircraft in Army service with two more on order, while the IAF has 12 in service with 4 more on order. This machine has a top speed of 270 kph and can fly up to altitudes of 20,000 ft.; apart from a modern cockpit, sensors and self-protection suite, it carries a chin-mounted 20mm turreted gun, rocket launchers and helicopter-launched Nag (Helina) anti-tank guided weapons.[31] The Helina—called "Dhruvastra" in its Air Force version—has a range of about 8 km. The Rudra demonstrates the opportunities open for spin-offs from a successful aircraft platform being developed indigenously.

While Rudra is an armed version of the ALH Mk-IV, the LCH is a dedicated attack helicopter derived from the basic Dhruv design and weighs about 5.5 tonne. The LCH has a maximum speed of 270 kph, a service ceiling of 6,500 metres and ferry range of 700 km.

LCH. While Rudra is an armed version of the ALH Mk-IV, the LCH is a dedicated attack helicopter derived from the basic Dhruv design and weighs about 5.5 tonne. The LCH has a maximum speed of 270 kph, a service ceiling of 6,500 metres and ferry range of 700 km. It has been landed at an altitude of 16,000 feet, and is the first attack helicopter to land in Siachen. The LCH was certified in 2016 and its limited series production (LSP) began in 2017. As of now, 176 aircraft are expected to be built, of which 114 are planned for the Army and 62 for the IAF. So far only two prototypes have been deployed by the IAF. The LCH is expected to field all the weaponry currently integrated with the Rudra. A helmet mounted sighting and guidance system is likely to be integrated with the LCH thereby increasing its potency further. Two

31. Air Marshal BK Pandey (Retd.), 2020-09, "Combat Helicopters with the Indian Armed Forces", at http://www.sps-aviation.com/story/?id=2820&h=Combat-Helicopters-with-the-Indian-Armed-Forces. Accessed on March 15, 2021.

LCHs were deployed for operations in Eastern Ladakh during the border stand-off with China in 2020.[32] HAL is expecting an order for an initial batch of 15 aircraft to equip IAF and the army. Increasing confidence with the initial ALH spin-offs bodes well for more such successful projects in future.

HTT-40

The IAF's primary trainer aircraft from the late 1950s onwards was the old HT-2. It was retired from service in the late 1980s, when the HPT-32 became the sole primary trainer. Shortage of this aircraft forced IAF to train a few courses purely on jets in the mid-1980s, using the HJT-16 for the purpose. With ab initio basic training being conducted on jet trainers, attrition was high. A new primary trainer was certainly needed and the already in-service HPT-32 was pushed to meet it. However, an apparent mismatch between the HPT-32's aircraft fuel system and the engine fuel system led to several instances of in-flight engine failure, evidently due to fuel starvation. These failures could not be resolved. Since the HPT-32's induction in 1984 there were persistent engine cuts in flight resulting in 108 incidents of unplanned engine stoppage, causing 23 fatalities.[33] HPT-32 was grounded and withdrawn from service in 2009 after a fatal crash killed two senior instructors on July 31, 2009.[34] Initially the utilisation of the HJT-16 for basic training was contemplated but an acute shortage of Viper-II and Orpheus engines forced IAF to continue to use the HPT-32 with a parachute recovery system.[35] Finally, it was decided to import 38 Pilatus PC-7 Mk-II, with another 68 to be built at HAL under licence[36] to meet immediate needs. HAL initiated the HTT-40 project to meet the IAF's primary trainer needs in the year 2013. HAL chose a tandem seat configuration

32. "Two HAL Light Combat Helicopters Deployed for Operations at Leh", PTI, August 12, 2020, at https://www.livemint.com/news/india/two-hal-light-combat-helicopters-deployed-for-operations-at-leh-.11597236997702.html. Accessed on March 16, 2021.
33. "HPT 32 Deepak trainer aircraft to fly no more", *India Strategic*, October 2011, at https://www.indiastrategic.in/topstories1221_HPT32_Deepak_trainer.htm. Accessed on April 12, 2021.
34. Ibid.
35. Ravi Sharma, "IAF gives nod for HPT-32 revival", *The Hindu*, May 16, 2010, at https://www.thehindu.com/news/national/IAF-gives-nod-for-HPT-32-revival/article16301107.ece. Accessed on April 12, 2021.
36. "HAL HTT-40 Trainer Aircraft", Airforce-technology.com, at https://www.airforce-technology.com/projects/hal-htt-40-trainer-aircraft/. Accessed on April 12, 2021.

in keeping with IAF preference, a low wing with two Martin Baker zero-zero ejection seats under a large bubble canopy, conventional empennage and a retractable tricycle undercarriage for the project. The HTT-40 first flew in May 2016.[37] It is powered by the widely used and reliable Honeywell TPE331-12B turboprop engine. The TPE331-12B is equipped with Full-Authority Digital Engine Control (FADEC) system and develops a maximum power output of 950 shaft horsepower (shp),[38] enabling the aircraft to meet its performance objectives. In initial testing, the HTT-40 failed to meet the IAF's spin entry and recovery requirements. HAL worked on the issue and in 2019 the aircraft cleared IAF testing for six-turn spin and recovery to both left and right, allowing HAL to seek Final Operational Clearance (FOC).[39] Since then, GoI and IAF have ordered 70 HTT-40s with an option for a further 38 aircraft. The purchase of additional Pilatus PC-7 was cancelled.[40] This success is even more remarkable in view of the fact that, since 2012, IAF has persistently opposed the HTT-40 while pushing GoI to import more Pilatus PC-7 aircraft.[41]

Contrary to popular belief, a successful trainer design and development is no mean achievement. A basic trainer must be fully aerobatic with a respectably wide operational envelope in terms of acceleration or 'g' capability; negative flying ability; high enough service ceiling; high endurance, low take-off and landing speeds coupled with high maximum speed; possess benign stall and recovery characteristics; and the ability to spin and recover safely. This high flight performance must come with no surprises tucked away in its operational envelope. It must be reliable and rugged enough to survive gross mishandling by raw pupil pilots both

37. Ibid.
38. Ibid.
39. Huma Siddiqui, "Success! HAL's HTT 40 Trainer aircraft completes six-turn spin test, now awaits FOC", October 2, 2019, at https://www.financialexpress.com/defence/success-hals-htt-40-trainer-aircraft-completes-six-turn-spin-test-now-awaits-foc/1724459/. Accessed on April 13, 2021.
40. Snehesh Alex Philip, "Defence Ministry clears purchase of indigenous basic trainer aircraft, upgrade of Israeli UAVs", August 11, 2020, at https://theprint.in/defence/defence-ministry-clears-purchase-of-indigenous-basic-trainer-aircraft-upgrade-of-israeli-uavs/479711/. Accessed on April 13, 2021.
41. Ajai Shukla, "HAL-built trainer aircraft HTT-40 clears crucial flight test successfully", September 7, 2019, at https://www.business-standard.com/article/companies/hal-built-trainer-aircraft-htt-40-clears-crucial-flight-test-successfully-119090700956_1.html. Accessed on April 13, 2021.

in-flight and during take-off and landing. The fact that HTT-40 cleared IAF's stringent testing specifications holds out hope for a new generation of experienced and capable designers coming of age in India to take on more complex projects in future.

HJT-36 INTERMEDIATE JET TRAINER (IJT)

The HJT-16 has been in service since the 1960s. Seeing a need for a replacement intermediate trainer to smoothly transition pupil pilots from basic to advanced trainers, HAL initiated the development of the IJT— dubbed HJT-36—in 1999. The aircraft was initially planned to be powered by the SNECMA 04-30 "Larzac" turbofan. However, the thrust of this engine at 1,400 kgst proved inadequate hence the Russian AL-55I engine delivering 1,700 kgst was selected.[42] The IJT first flew in 2003 but problems soon emerged. The stalling speed of the aircraft was found to be too high and its spin characteristics unacceptable. With HAL unable to solve these problems, delays built up. During the Aero India air show at Bengaluru in 2007, an IJT skidded off the runway due to a tyre burst.[43] In flight trials the controllability of the aircraft at high angles of attack was found poor, leading to unsafe stall and spin performance. Unable to locate the problem HAL obtained consultancy from British Aerospace and from America's Bihrle Applied Research.[44] The result is a modified airframe at the forward fuselage and empennage to improve stall and spin characteristics. The modified aircraft has recommenced flight trials. The normal flight envelope that had been achieved earlier was first revalidated with the modified airframe and the spin trial phase

42. Air Marshal BK Pandey (Retd.), "A Shot in the Arm for IJT", August 2008, at http://www.sps-aviation.com/story/?id=43. Accessed on April 13, 2021.
43. Siva Govindasamy, "Picture: India's HAL scrapes Intermediate Jet Trainer, becoming second aircraft to crash at Bangalore's Aero India air show after Friday's Dhruv", February 9, 2007, at https://www.flightglobal.com/picture-indias-hal-scrapes-intermediate-jet-trainer-becoming-second-aircraft-to-crash-at-bangalores-aero-india-air-show-after-fridays-dhruv/71914.article. Accessed on April 13, 2021.
44. Rahul Bedi, "India Is Still Throwing Good Money at Hopeless Military Programmes", December 15, 2020, at https://thewire.in/security/defence-spending-hal-drdo-military. Accessed on April 13, 2021.

initiated, reportedly with one turn spins to both sides being performed successfully.[45]

In fact, the IJT HJT-36 project is likely to have taught Indian aircraft designers a lot more than it would have if the initial trials had encountered no problems. Transfer of learning really happens when a person is stuck trying to solve an issue and is assisted in finding the solution. This learning is likely to be invaluable to Indian designers of future aircraft of all types. MiG-29 operators from the early years will recall the story of the humble metal wedge at the base of that high performance aircraft's pitot tube and its significance as a fix to a massive design and performance problem. HJT-36 should soon be replacing the old HJT-16 as the Stage-II aircraft in IAF service.

LCA

The LCA project was sanctioned in 1983 and the design finalised by 1990. While earlier projects kept HAL as the designer and manufacturer, for LCA GoI set up the Aeronautical Development Agency (ADA), a national consortium of defence laboratories, industrial manufacturing organisations and academic institutions. Responsibility for developing the sub-parts and systems for LCA was divided between these constituent parts of ADA, while HAL was designated the agency for airframe manufacture, final assembly, flight testing and in-service support. In the process many advanced systems—such as fully digital quadruplex fly-by-wire system with flight control laws, a multi-mission Active Electronically Scanned Array (AESA), multi-mission radar (MMR), mission computers, cockpit display systems, etc.—have been successfully designed and developed in India. One notable failure has been the development of the GTX-35VS "Kaveri" engine for LCA. This has forced the use of US origin General Electric (GE) F-404 engines, with the F-414 selected for later variants. Kaveri is now split into two sub-parts, the K-9 "Kaveri" which has achieved full dry thrust but is heavier than planned, and falls short of desired reheat thrust by about 1,000 kgst. The K-10 "Kaveri"

45. "Intermediate Jet Trainer commences spin flight testing", PTI, November 2020, at https://www.thehindu.com/news/national/intermediate-jet-trainer-commences-spin-flight-testing/article33160015.ece. Accessed on April 13, 2021.

The LCA Mk-II was conceived as a capability enhanced variant of the LCA. Over time this morphed into redesign of the LCA to incorporate canard foreplanes, possibly a two-engine configuration, greatly enhanced capabilities similar to the "swing role" boasted by aircraft, such as the Dassault Rafale and the Euro fighter Typhoon.

is still undergoing work to develop its thrust to the initial design value while reducing its weight. The indigenous MMR is also lagging in development time frames thus forcing use of the imported Israeli ELTA-2032 radars on initial aircraft.[46] IAF placed an order for 40 Initial Operational Clearance-II (IOC) configuration aircraft in 2015[47] and ordered a further 83 Mk-1A fighters in 2021.[48]

LCA MK-1A

The LCA fell short of the capabilities desired by IAF. Hence it was agreed to develop an enhanced capability variant called the LCA Mk-1A. Compared with the LCA Mk-1, the Mk-1A comes equipped with an Active Electronically Scanned Array (AESA) radar, Air-to-Air-Refuelling (AAR) capability, integration of Beyond Visual Range (BVR) missiles, and an electronic warfare suite, apart from a further 43 modifications requested by IAF based upon the experience of operating the first squadron of LCA Mk-1 aircraft.[49] This development indicates the life cycle of weapons systems the world over. As a yardstick, the F-16E/F or Block 52 F-16 offered to India under the MMRCA competition is a slow upgrade over many years of the original F-16 Block 1, actually Block 15, which was a simple, day only, fighter with limited ground attack capability. There lie ahead many more enhancements to the LCA to keep it relevant in time to come, and

46. Vivek Kapur, n. 12, pp. 59-77.
47. Air Marshal BK Pandey (Retd.), "Hype vs Reality", January 2016, at http://www.sps-aviation.com/story/?id=1815. Accessed on March 16, 2021.
48. Huma Siddiqui, "After the Indian Air Force order for Tejas, HAL to export LCA Mk1A", February 4, 2021, at https://www.financialexpress.com/defence/after-the-indian-air-force-order-for-tejas-hal-to-export-lca-mk1a/2187839/. Accessed on March 16, 2021.
49. Air Marshal BK Pandey (Retd.), "Procurement of 83 LCA Tejas Mk 1A Cleared", January 2021, at http://www.sps-aviation.com/story/?id=2879&h=Procurement-of-83-LCA-Tejas-Mk-1A-Cleared. Accessed on April 13, 2021.

the LCA Mk-1 and Mk-1A should be considered projects in hand.

LCA MK-II

The LCA Mk-II was conceived as a capability enhanced variant of the LCA. Over time this morphed into redesign of the LCA to incorporate canard foreplanes, possibly a two-engine configuration, greatly enhanced capabilities similar to the "swing role" boasted by aircraft, such as the Dassault Rafale and the Euro fighter Typhoon. This involves a full redesign of a larger aircraft, with timelines for completion of development based upon the LCA systems and subsystems being reasonably shorter than seen hitherto.

More than just the LCA itself, it is the successful development of almost all subsystems of the LCA in India that creates optimism for the future.

LCA NAVY

At the inception of the LCA programme, a maritime carrier-based variant was considered. Once the LCA Mk-1 approached IOC capability, effort was put in to realise the Navy variant. Primarily, this meant an increase in aircraft weight due to strengthening of the airframe and undercarriage to bear the heavy loads imposed by carrier deck operations. The LCA Navy variant has been tested for launch and recoveries from a shore-based ski jump mock deck, and has successfully carried out landings and take-offs from the Indian Navy's aircraft carrier, the INS Vikramaditya. More developments can be expected in this area.

More than just the LCA itself, it is the successful development of almost all subsystems of the LCA in India that creates optimism for the future. With a large number of essential combat aircraft subsystems already developed or approaching completion of development, the risks in development of follow-on aircraft, such as the LCA Mk-II, Advanced Medium Combat Aircraft (AMCA), etc., are likely to be much lower and costs and time overruns much less.

AMCA

Advanced Medium Combat Aircraft (AMCA) was conceived as India's first Fifth-Generation fighter incorporating the attributes of a fifth-generation fighter that include low observability (LO) design, sensor fusion, supercruise capability, and greatly enhanced networked warfare capability. With the ongoing trainer and LCA programmes, the AMCA remained a laboratory or classroom study for some time. The basic layout with several macro design features were finalised and wind tunnel models were tested and displayed in public events, such as Air Shows. Given the complexity of such a project, it is early days to write about or to hazard a guess on the progress of the project. However, going by the major attributes of a pure fifth-generation fighter, it is likely that the systems on board—much more than the platform comprising the airframe and power plants—will pose a greater challenge to the designers of the AMCA. Judging by the recent successes displayed by our scientific community, there is room for optimism.

AIRBORNE EARLY WARNING AND CONTROL SYSTEM (AWACS OR AEW&C): "NETRA"

DRDO initiated a technology development project for an indigenous AEW&C in 1985. Two HS-748 airframes were modified with a fuselage mounted radome to develop the software and radar techniques required for refining the radar performance for such an aircraft. This project remained a technology demonstrator and ended abruptly with the fatal crash of the modified HS-748 aircraft in January 1999. The programme was revived in 2002 using a more capable platform, the Embraer EMB-145 airframe,[50] mounting a fuselage top fixed 'beam shaped' antenna housing an indigenous AESA radar.[51] The resulting AEW&C aircraft dubbed

50. Dinesh C. Sharma, "Netra early warning system—the unsung hero of Indian armed forces", November 21, 2019, at https://vigyanprasar.gov.in/isw/Netra-early-warning-system-unsung-hero-of-Indian-armed-forces.html. Accessed on March 17, 2021.
51. Huma Siddiqui, "Atmanibhar Bharat boost for India's security: IAF to get Made in India AEW&C systems; Check details", December 18, 2020, at https://www.financialexpress.com/defence/atmanibhar-bharat-boost-for-indias-security-iaf-to-get-made-in-india-aew-check-details/2152494/. Accessed on March 18, 2021.

"Netra", was inducted into IAF in 2017 with two aircraft in service and more on order.[52]

The successful development of such complicated cutting-edge technology augurs well for further enhancements in AEW&C performance and for development of other applications of these advanced sensors and accompanying software. Plans are reportedly ready to develop a full size 360 degrees coverage AWACS on a larger aircraft by DRDO.

QUANTUM ENCRYPTION

Encryption of communications and data transmissions is essential for success in peacetime as well as in war for economic, other government and military purposes. Modern warfare is moving beyond the nature of war as emerges from the 'Treaty of Westphalia' towards a more total war best described in the PLA publication "Unrestricted Warfare"; securing our communications and other data becomes even more important. On Sunday, February 21, 2021, a research team in Bengaluru demonstrated quantum encryption involving open space quantum transmission of encryption keys across a 50-metre free space from one building to another. The team described the limited range of their demonstration as limited only by the space available to demonstrate the technology, and were optimistic that much greater distances could be achieved in future developments. To effectively transmit keys from ground stations to satellites means covering ranges in excess of 12 km from the surface of the earth to orbit altitudes. The team went on record to state that further developments could deliver practical encrypted quantum communication technology to the country. In 2017, China managed to transfer a key down from a satellite to a ground station. The team further stated that over time they would be able to achieve a two-way uplink to a satellite as well as downlink from a satellite quantum communication with

52. Rahul Singh, "Aero India-2017: IAF inducts first indigenously developed surveillance plane", February 14, 2017, at https://www.hindustantimes.com/india-news/iaf-inducts-netra-aew-c-the-first-indigenously-developed-surveillance-plane/story-UxyMeY9oH4XvamNEd9JNTP.html. Accessed on March 17, 2021.

encryption, thus catching up with the cutting-edge technology in this field, as demonstrated by the PRC and other technologically advanced countries.[53]

MISSILES

Brahmos. The Brahmos supersonic cruise missile needs no introduction. While India requested Russian assistance in modifying the missile to reduce its weight and profile to enable air launching the weapon, Indian scientists simultaneously went to work and by January 2020 had managed to reduce the weight and profile of the weapon to obtain "fleet release clearance" for the missile on the Su-30MKI.[54]

Helina/Dhruvastra. The Nag top attack Anti-Tank Guided Missile (ATGM) has been under development since the Integrated Guided Missile Development Programme (IGMDP) was initiated in 1983. The IGMDP was terminated in March 2012.[55] The Nag missile was taken up to develop an air-launched version for arming helicopters, notably the Rudra and LCH. This missile, boasting an imaging infra-red (IIR) seeker, has recently undergone trials with a 100 per cent success rate and been accepted for induction in the armed forces.[56] Videos of the test firings of the Helina, posted on YouTube, show a welcome lack of smoke trail from the test launched weapons. This is important as the presence of a smoke trail could betray the launch of the weapon to the enemy as well as give away the position of the launch platform.

Astra. The Astra is India's first indigenous air-to-air missile boasting of radar guidance and Beyond Visual Range (BVR) capability. After successful trials

53. Akhil Kadidal, "Bengaluru scientists make quantum technology breakthrough", February 23, 2021, at https://www.deccanherald.com/science-and-environment/bengaluru-scientists-make-quantum-technology-breakthrough-954329.html. Accessed on March 18, 2021.
54. "BRAHMOS-Air Launched Cruise Missile gets Fleet Release clearance", Drdo.gov.in, July 2020, at https://drdo.gov.in/sites/default/files/newsletter-document/NL_July_2020.pdf. Accessed on March 18, 2021.
55. "Missile Development Programme", Pib.gov.in, August 13, 2012, at https://pib.gov.in/newsite/PrintRelease.aspx?relid=85986. Accessed on March 18, 2021.
56. Shishir Gupta, "HELINA missile strikes 5 out 5, ready for induction", February 19, 2021, at https://www.hindustantimes.com/india-news/helina-missile-strikes-5-out-5-ready-for-induction-101613719486762.html. Accessed on March 18, 2021.

the Mk-I variant was cleared for IAF induction and is reported to have a range of 80 to 100 km, again with a smokeless rocket motor. A Mk-II variant of the missile with enhanced range is reported to be under development.[57]

SAAW. In a boost to the indigenous Hawk-i programme, defence PSU Hindustan Aeronautics Limited (HAL), on Thursday, January 21, 2021, successfully test-fired the Smart Anti-Airfield Weapon (SAAW) from a Hawk-i aircraft flown by HAL test pilots, Wing Commander P. Awasthi (Retd.) and Wing Commander M. Patel (Retd.).[58] This indigenous weapon had earlier been tested from the Jaguar aircraft. SAAW has been developed by Defence Research and Development Organisation's (DRDO) Research Centre Imarat (RCI). The SAAW is a 125 kg weight stand-off weapon that is designed to cause damage to airfield infrastructure, such as radars, bunkers, and taxi tracks and runways. SAAW has a stand-off range of 100 km. With this the Hawk-132 gets to field a stand-off attack capability. The weapon, being indigenous, can be further developed and integrated with other airborne platforms in IAF service. The ability of the Hawk to carry a stand-off ability smart weapon will enhance the aircraft's combat utilisation considerably. The Hawk-i combat enhancement—apart from the SAAW itself—is laudable, and marks the success of indigenous attempts to develop ever more capable airborne weapons. Indigenous technology provides the IAF precisely the weapons suited to its envisaged combat employment.

REASONS FOR OPTIMISM

Electronic Warfare, sensors, displays, materials, and several other aspects of advanced aerospace technology have been in the news in the past few months,

57. Snehesh Alex Philip, "India working on next 'Astra' missile with 160 km range as Mk1 is integrated in IAF & Navy", December 15, 2020, at https://theprint.in/defence/india-working-on-next-astra-missile-with-160-km-range-as-mk1-is-integrated-in-iaf-navy/566699/. Accessed on March 18, 2021.
58. Chethan Kumar, "Hawk-i test fires smart anti-airfield weapon that can destroy enemy assets from 100km", January 21, 2021, at https://timesofindia.indiatimes.com/india/hawk-i-test-fires-smart-anti-airfield-weapon-that-can-destroy-enemy-assets-from-100km/articleshow/80385067.cms?utm_source=google_newsstand&utm_source=contentofinterest&utm_campaign=rss_feed&utm_campaign=cppst&utm_medium=referral&utm_medium=text. Accessed on March 19, 2021.

all indicating the success of India's scientific community in developing cutting-edge capabilities. This is the fructification of many years of dedicated work by Indian scientists in DRDO as well as in civil institutes of scientific research. Given that many programmes have been successful augurs well for building further for greater success. Incremental improvements on technologies already developed will facilitate future advancements.

CONCLUSION

During colonial times India perforce had to use imported aerospace equipment. After independence, the low level of technological expertise in the country forced IAF to continue import of needed weapons and allied equipment. In the past few years, the efforts of the country's scientific community to develop indigenous capabilities have borne fruit. This is encouraging, for in the future we can look forward to an IAF equipped entirely with Indian equipment and weapons. Many of the weapons and systems touched upon earlier in this article deserve a complete independent treatment to derive the needed learning and understanding about aerospace technologies and Indian air power.