Aerospace Technology in India: An Overview and Outlook for Future

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Abstract

Aerospace scenario in India is going through a very challenging period now. Apparently there seems to be a boom in the aero related activities. This paper makes a brief and objective overview of the current status and points out the important challenges of the immediate future.

Key words: Spacecraft Recovery Experiment (SRE), Lh_2, Liquid O_2, (LOX), RLV,PSLV, GSLV, ALH, IJT Differential GPS Automatic dependant Surveillance

I. INTRODUCTION

Major constituents in the aero related activities up to mid 1990s were in the governmental sector. The Hindustan Aeronautics Ltd (HAL) with its sixteen production units and nine R& D units spread over seven locations in the country is the only major aircraft manufacturing industry in the country. Then there is the chain of laboratories and R&D units coming under the Defence Research & Development Organisation (DRDO). The mission of DRDO is to make India prosperous by establishing world class science and technology base and to provide our defence services decisive edge by equipping them with internationally competitive systems and solutions. In the realms of aeronautics, armaments and missiles, DRDO has fifteen laboratories and establishments. The space related activities in the country are spearheaded by Indian Space Research Organisation (ISRO). Government of India set up Space Commission and Department of Space (DOS) in 1972. Indian Space Research Organisation (ISRO) under DOS executes space programs through its thirteen centres located all over the country from Dehradun to Mahendragiri. The prime objective of ISRO is to develop space technology and its application to various national tasks. National Aerospace Laboratories (NAL), located in Bangalore and a constituent of Council of Scientific and Industrial Research is India's pre-eminent civil R&D establishment in aeronautics and allied disciplines. NAL's primary objective is the development of aerospace technologies with strong science content and with a view to their practical application to the design and construction of flight vehicles.' NAL is also required 'to use its aerospace technology base for general industrial applications'. The Indian Air Force (IAF) is the air arm of the armed forces and has the prime responsibility of conducting aerial warfare and securing the Indian airspace. IAF is 75 years old and has a fleet of 1,350 combat aircraft making it the fourth largest and one of the best air forces in the world. In addition, Indian Army and Indian Navy also have air wings. One other major constituent of Indian aerospace activities is the civil aviation. The expansion of air transport in India is among the fastest in the world. It is noticed that an 'air travel revolution' is happening in the country. Also significant is the development of human resources required for the aerospace related activities in the country. Starting with about four institutes/ colleges in 1950's, the number of institutes providing degree level instruction in aeronautics/aerospace engineering is more than thirty across the country. In the following sections of this paper, an overview is done on the current status of activities of the different constituents and lacunae in various sectors. An outlook for the future decades is proposed based on the status review.

II. PERFORMANCE OF THE MAJOR PLAYERS IN AEROSPACE TECHNOLOGY

A. Aircraft Manufacturing and Services

As mentioned in the previous section, HAL is the only major industry in the country, involved in the manufacture and overhaul of aircrafts, helicopters and avionics equipment. HAL has an impressive product track record - 12 types of aircraft manufactured with in-house R & D and 14 types produced under license. HAL during its more than forty years of existence, has manufactured 3550 aircraft (which includes 11 types designed indigenously), 3600 engines and overhauled over 8150 aircraft and 27300 engines.

Among the major accomplishments of HAL are production of Jaguar - the deep penetration strike and battlefield tactical support aircraft- including the engine, accessories and avionics under license from British Aerospace. On the other hand, Aircraft Division, Nasik, manufactures the Russian make aircrafts. The Nasik division manufactures MiG-21FL aircraft & K-13 missiles, MiG-21M, MiG-21 BIS AND MiG-27 M aircraft. Along with manufacturing, HAL also carries out overhaul of the MiG series aircraft. The current manufacturing range includes Sukhoi (Su 30 MKI), the twin seater multi role-long range fighter/bomber.

HAL has bulk orders from the export market for the supply of aero-structural components such as Airbus A320 Forward Passenger Doors, Boeing 757 Over Wing Exit Doors, Boeing 777 Uplock Box Assembly, Boeing 767 Bulk Cargo Doors, for helicopters such as Chetak, Lancer and ALH, for the manufacture and supply of engines under license from world renowned Rolls Royce, Turbomecca and Honeywell. These orders from the internationally reputed aircraft manufacturers bear testimony to the meticulous and well kept standards of manufacturing that HAL maintains.

HAL has been a partner in numerous R & D programs developed for both Indian defence and civil aviation sectors. HAL has made substantial progress in its current projects such as Dhruv, the Advanced Light Helicopter (ALH), Tejas - Light Combat Aircraft (LCA),Intermediate Jet Trainer (IJT) and the various military and civil upgrades. HAL has played a significant role for India's space programs by participating in the manufacture of structures for satellite launch vehicles like Polar Satellite Launch Vehicle (PSLV), Geo-synchronous satellite Launch Vehicle (GSLV), Indian Remote Sensing Satellite (IRS) and Indian National Satellite System (INSAT).

HAL has gone past the Rs.7,500-crore mark of sales turn over for the first time with an impressive Rs.7,783.61 crores ($1.82 billion) during the financial year 2006-07, The value of production has also gone up by 55.54% to Rs. 9,201.88 crores, while the profit of the company soared to Rs.1,743.60 crores.

B. Indian Space and Aero Based Defence Programs

It is believed that India is a space super power. With simple beginning at Thumba Equitorial Rocket Launching Station (TERLS) near Trivandrum in1960's, ISRO has already become a household name with its very successful satellite launch programs. The two launch vehicles Polar Satellite Launch Vehicle (PSLV) and Geo-synchronous Satellite Launch Vehicle (GSLV) intended to place satellites at polar or geo synchronous transfer orbits are developed to the extent of being commercially successful. In the satellites programs, INSAT series satellites provide for the communication services and for meteorological imaging. The IRS series of satellites launched by the Polar Satellite Launch Vehicle serve to monitor earth and ocean resources and for cartographic applications. These satellites are equipped with indigenously developed high resolution cameras with more than 100 mega bits of data storing capability. The two separate satellite programs the INSAT series and the IRS series are completely indigenous. The launch vehicle technology can not only sustain the indigenous satellite programs but also has entered the space market through the commercial arm called the Antrix Corporation.

One more significant and successful achievement of ISRO is the Spacecraft Recovery Experiment (SRE) completed in early 2007.The SRE was projected to test reusable thermal protection system, navigation, guidance and control, hypersonic aero-dynamics, management of communication blackout, deceleration and flotation system and recovery experiments. In short, the SRE was designed to test the re-entry vehicle technology which is a pre-cursor to any manned space mission and reusable launch vehicle which India is now preparing for.

In the area of defence research and development, the most significant is the missile technology. The Integrated Guided Missile Development Program (IGMDP) is an Indian program for the development of a comprehensive range of missiles, including: the intermediate range Agni missile (Surface to Surface), and short range missiles such as the Prithvi Ballistic missile (Surface to Surface), Akash (Surface to Air), Trishul (Surface to Air) and Nag Missile (Anti Tank). Most of these missiles are in various stages of development and deployment. The Astra is being developed for an Air to Air, Beyond Visual Range (BVR) role.

The Agni missile, first intermediate-range ballistic missile of India has the first stage using the solid-fuel booster motor of the SLV-3 satellite launch vehicle. The 18-meter long, 7.5-ton Agni has a range of up to 2,500 km and is capable of delivering a 1,000-kg payload. Akash is a medium-range surface-to-air missile with an intercept range of 30 km. It has a launch weight of 720 kg, a diameter of 35 cm and a length of 5.8 metres. The Prithvi was India's first indigenously developed ballistic missile. Development of the. It has a range of up to 150 to 300 km. The land variant is called Prithvi while the naval operational variant of Prithvi I and Prithvi II class missiles are codenamed Dhanush. Both variants are used for surface targets.The Prithvi is developed as a battlefield missile, it could carry a nuclear warhead in its role as a tactical nuclear weapon. BRAHMOS, the product of a Russian Indian collaborative effort is a Supersonic Cruise Missile that can be launched from submarine, ship, aircraft and land based Mobile Autonomous Launchers (MAL). The missile is launched from a Transport-Launch Canister (TLC), which also acts as storage and transportation container. Primarily BRAHMOS is an anti-ship missile. It has the capability to engage land based targets also. The missile can be launched either in vertical or inclined position and will cover 360 degrees. These indigenously developed missile systems provide not only the necessary security environment to the Indian armed services but exemplifies the marvelous technological prowess of the country.

C. Growth of Indian Civil Aviation

Civil aviation in India was predominantly in the public sector domain until 1992. In recent years, Indian airports have registered double digit growth rate in both the number of passengers and aircrafts. From a modest 5.1million passengers in 1970, Indian airports handled 51.9million domestic and 22.4million international passengers in the year ending March2006.The forecast is that the passenger traffic will increase to 90million by 2010.

The number of carriers operating in India has grown from the two state owned players to about 15 today. More than 60% of the domestic aviation market is accounted by private airlines. To meet the growing demand, the Indian carriers are placing major orders for aircraft. Of the 280 aircraft order received by Airbus at the Paris Air Show two years ago,135 are from Indian carriers. Of the $50billion that Airbus earns from these deals, the contribution of Indian carriers is over $15billion.Airbus forecasts that the number of new aircrafts it would sell to Indian carriers would go up to 400 by the year 2023.Not to be left behind, Boeing expects India to buy aircraft worth $35 billion in the next 20 years. These forecasts are based on the projection that India's domestic airlines would need 650 new aircraft by 2012.

To demonstrate the tremendous growth of passenger traffic, during the six year period 2000-2006 John F Kennedy(JFK) airport in New York recorded a passenger traffic growth by 28%,Chengi Airport, Singapore by 24%.The percentage growth by Mumbai and New Delhi airports during the same period are 58 and 93 respectively. The corresponding figure recorded by all major airports in the country is 105%.The aircraft traffic during the same period grew by 18% and 22% in JFK and Chengi where as Mumbai and Delhi recorded growth of 65% and 50% respectively.

India has a civil aviation network comprising of 449 airports/airstrips. The current situation is that, the Indian airports are choked due to ever increasing and never anticipated growth in passenger and aircraft traffic. Apart from the simple airport facilities, there are major inadequacies with regard to air traffic control and navigation.

III. OUTLOOK FOR THE IMMEDIATE DECADES

In order that India is able to sustain and support the current positive trends or the so called boom in aerospace activities in the country, the four important aspects requiring immediate attention are (i) Development of Propulsion Systems (ii) Study and development of hypersonic technology (iii)Developing civil aviation infrastructure on a war footing (iv) Generation of human resources

A. *Development of Propulsion Systems*

The propulsive devices for aerospace vehicles range from those required for aircrafts to those for high end space flights. The requirement of each of them is different The challenges in the development of the propulsion systems are non trivial. Take, for example, the development of gas turbine engines. Gas turbine technology has matured over the decades globally. Still, the Indian efforts on airplane development are centered around bought out engines. The lack of engines or inordinate delay in engine development affected nationally important projects from HF 24 of mid sixties to the LCA versions of today. The development of gas turbines encomposes vital technological considerations such as material evaluation and testing, structural analysis, stress analysis and life management, fluid dynamics and heat transfer, non-destructive evaluation, system and component testing, failure analysis etc. Highest levels of engineering related to rotating machinery, machine dynamics, fuel injection and flame holding, turbine materials and blade cooling are imperative for the successful realization of an engine. Collective efforts of multiple skills and expertise and very focused project management only can help engine development program.

Equally or more challenging is the development of cryogenic engines. They are liquid propellant rockets making use of Liquid H_2 (LH_2) and Liquid O_2 (LOX).High (mass/volume) ratio has to be achieved by compressing H_2 and O_2 to higher values. Turbo pumps are thus a vital component of the engines. LOX is non-corrosive and non-toxic; and evaporates rapidly. Very thick insulation is required due to the cryogenic temperatures involved. LH_2 when burned with fluorine or oxygen gives high specific impulse (T/m)./H_2 is a good coolant and is highly explosive in air. The specific impulse of a LH2, LOX cryo engine is of the order of 450 seconds. ISRO's GSLV has a cryogenic upper stage which has 12 tonnes of liquid oxygen and liquid hydrogen The indigenously developed cryo engine is not yet deployed in the GSLV flights so far.

Another vital technology requirement for the coming decades is the development of scramjets. Subsonic flights operate with piston engines. Flights up to low supersonic speeds make use of turbo engines. Up to about M~5.5, ramjet [which is an aero thermodynamic duct] is employable. Above M~5.5, stronger shocks change the gas dynamics in the internal flow. Scramjet is an inevitable component of the propulsion unit in the case of non rocket power plant for hypersonic operations. In scramjets, the combustion takes place at supersonic speed. There are numerous technological challenges to be overcome in the development of scramjets. There is a good number of topics not-so-well understood in relation to scramjet intake, materials and with regard to combustor such as mixing of fuel and air, flame holding, pressure losses and turbulent and reacting flow. This is one area of technology where Indian situation is not lagging considerably behind others in the international community. Full fledged and complete development of scramjets is still an incomplete task for almost all nations. An Indian consortium of researchers, scientists and engineers working in research laboratories, development centres together with the academia, if organized well, can develop scramjet technology even ahead of many other countries in the world.

B. Hypersonic Technology

Conventionally, flight above Mach number of about 5.0 is hypersonic. Hypersonic flight is useful for intercontinental transport, launch vehicles, Reusable Launch Vehicles (RLVs), planetary missions, spacecraft recovery modules. There are technological challenges special and specific to the hypersonic regime in the areas of propulsion, aerodynamics, structural integrity of hypersonic bodies, flight dynamics and control. Some of the aero-thermal problems are occurance of strong shocks and heating due to shocks and friction. The large scale growth of high temperature boundary layer makes the body appear larger to the flow. Consequently, the pressure distribution on the body and the lift and drag get affected. Body of the vehicle gets thermally loaded. Thermal protection systems or heat shields become inevitable. Instead, active cooling system has to be engineered. High temperature of surrounding gas causes real gas effects and resultant thermodynamic changes. Communication problems arise due to the presence of charged particles in the gaseous envelope surrounding the vehicle. Yet another not-so well known aspects in the hypersonic flow regime are the low density flow problems which have no analytical solutions so far in the transitional regimes. Structures related hypersonic problems largely originate from excessive aerodynamic heating. This necessitates new generation materials such as graphite composites which are of ultra light weight and rigid. In order to reduce wave drag very thin wings are designed aiming at as weak shocks as possible. Design of thin structures to meet the load requirements under thermally demanding environment is a challenging task. The propulsion requirements for hypersonic flight are described in the previous section and need not be over emphasized again. It is heartening to note that efforts to develop scramjets are taken up quite seriously by Indian agencies.

C. Civil Aviation Infrastructure

Indian aviation scenario is going through a period of unprecedented activity. The restructuring of the airports to meet the unprecedented increase in passenger and aircraft traffic is a basic requirement. Technically and professionally demanding fast track activities in airport management, terminal construction and design, passenger and cargo handling, strengthening and extension of runways, aprons, aircraft parking stands, taxiways and aero bridges are ought to be undertaken. According to official sources, Govt. of India plans to spend $20 billion over the next five years upgrading the airports. The restructuring of the first phase of the Delhi airport is expected to be completed by 2009 at a cost of Rs.1.9billion.Expansion and up-gradation of the current facilities at Mumbai is already under way. The government has also decided to modernize 75 airports in non metro cities. Another notable feature is that government has decided to encourage private sector investment in air port development activities.

Apart from restructuring of airports, modernization of equipment in the airports is also needed .Short/long term plans to meet challenges posed by ever increasing air traffic and advancement in aircraft technology are required to be drawn. Some such plans of the Airports Authority of India are replacement of ground based Communication, Navigation and Surveillance (CNS) with satellite based system, establishment of Differential Global Positioning System (DGPS),Automation in the air traffic control services, establishment of Automatic Dependent Surveillance (ADS) and coverage of the Indian land mass through satellite communication.

D. Development of Human Resources

Aerospace Education in India began in 1950's, though in a limited way. Only a few Institutes such as Madras Institute of Technology , IISc, IITs and Punjab Engineering College started degree courses in Aeronautics. The number of graduates up to 90's from all these Institutes were less than 200 in total. A few more universities began aeronautics courses in 1990's.Training institutes of armed services and a few private sector institutes add to the development of human resource at various levels. Apart from aviation sector where there is a huge deficiency of flight and cabin crew, design centres, manufacturing houses, testing and certifying agencies, maintenance sector and ground support systems are also necessarily to be provided with human resources. Not only R&D experts and flight crew but large number of maintenance engineers and technicians are also required. Migration of multidisciplinary experts from areas such as computer science, electronic, material science helps to improve the human resources situation. Needless to mention that personnel with core competence is vital. Indiscriminate opening of Institutes and study centres with glaring shortage of facilities and teaching-cum-training faculty is not the solution to solve the deficiency of human resources. A well thought out policy on aerospace education is important and imperative.

IV. CONCLUSION

The current Indian situation is akin to a boom in aerospace scenario. Aircrafts and component development including manufacture made quantum leap already. Achievements in space programs are glorious. Our missile and weapons development programs are commendable. Civil aviation scenario is passing through a virtual revolution. To be competitive globally, our immediate attention should be focused on development of propulsion devices, hypersonic technology and in modernizing aviation facilities. Not to be left out is the development of human resources of the right kind, caliber and competence.