Chapter 1

The Flight from Defance to Civilian Space: Evolution of the Banglore Aerospace Cluster

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The Flight from Defence to Civilian Space: Evolution of the Bangalore Aerospace Cluster

Sunil Mani

Abstract

The paper maps out the contours of the aerospace cluster in Bangalore, India and tracks its evolution from one dominated by defence contracts to one that is having civilian aircraft ambitions. All the leading constituents of the sector are identified and the knowledge flows between the various agents charted out. The study concluded with a comparison of the performance of the cluster in terms of exports and competitiveness and also delves on the policy instruments that are required for placing the industry on a sure flight path.

1. INTRODUCTION

India is one among the few developing countries which have attempted to create a domestic sectoral system of innovation in a truly high tech sector such as the aerospace industry. The country is currently having one of the fastest growing aerospace sectors in the world: exports of aerospace products from India have grown at a rate of 82 percent per annum during the period 1988 through 2008. Although the sectoral system of innovation of the industry is almost five decades old, for much of that period both manufacturing and innovative efforts of the sector was geared solely towards the defence sector, but this orientation of almost entire defence and governmental hold of the sector started diminishing with the opening up of the sector to private sector actors in 2001. So the evolution of the SSI neatly falls itself into two phases: phase 1 is period, 1959-2001 when both the research and manufacturing were entirely geared towards the defence sector and phase 2 is period since 2001 when the government opened up the sector to private sector participation. In fact this radical shift in policy appears to have made the sector very dynamic in the sense that it has considerably enhanced the breadth and depth of its activities in both research and manufacturing in both the aeronautical and astronautical components of the aerospace industry. Historically speaking Indian public policy has been disproportionately directed towards the astronautical part than the aeronautical so much say that in terms of public expenditure intensity on space related activities (defined as expenditure on space as per cent of GDP), India is second only to the USA, but ahead of many other OCED and BRIC countries. See Figure 1.

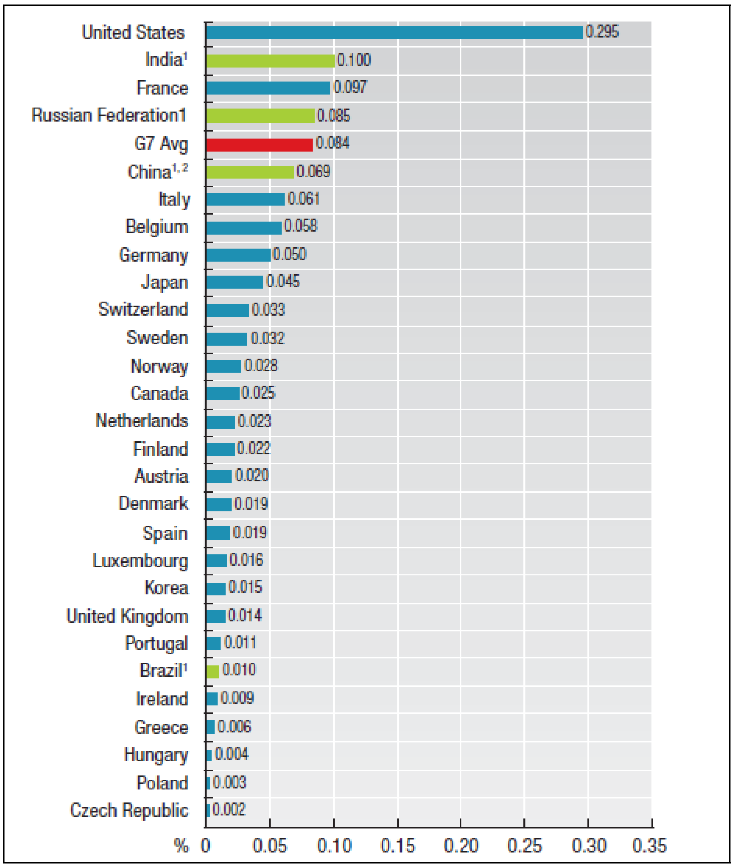

Figure 1 Public Space Budgets for OECD and BRIC Countries as a Per Cent of their GDP, 2005

Notes 1: BRIC countries are Brazil. Russia, India and China.
2: Chinese data based on unofficial estimates.
Source: OECD (2007), p.35.

According to Malerba (2004), a sectoral system of innovation has essentially three building blocks, namely, the actors, technology or knowledge domain and the demand or the market. Significant changes have taken place in all the three building blocks. For instance, during phase 1 the knowledge and technology domain depended to a great extent or almost in its entirety on domestic sources, the actors and institutions were lead by one public laboratory, one public sector research organization which did both research and manufacturing and one leading public sector enterprise in the manufacturing sector and demand was almost entirely and driven by public technology procurement. But during phase 2 there has been a dramatic change in all the three building blocks with the knowledge domain now composed of both domestic and foreign sources, there has been considerable increase in the number and types of actors and institutions and the demand has shifted from domestic public sector to foreign private and public sector enterprises.

Aerospace industry across the world is structured in the form of clusters. This is because at the centre of the cluster is a large aircraft manufacturer with a whole host of component manufacturers. In India, the southern city of Bangalore has emerged as one of the leading aerospace clusters in the country. This is essentially due to the existence of four major actors in the SSI of the sector, namely Hindusthan Aeronautics Ltd (leading manufacturer of aerospace products). The National Aerospace Laboratory (leading research facility on aerospace domain under the CSIR network of laboratories across the country), the Indian Space Research Organization (leading researcher and consumer of especially astronautics products from the country, and the Indian Institute of Science (leading centre for training of aerospace engineers). The cluster development policy has received a fillip with the state governments of Andhra Pradesh, Karnataka and Gujarat establishing special economic zones (SEZs) for the aerospace industry. These include:

- The Rs 3,000-crore Aerospace and Precision Engineering Special Economic Zone to be set up at Adibatla, Ranga Reddy district in Andhra Pradesh
- The specialised aerospace park of around 1,000 acres, proposed near the Bangalore International Airport;
- The 2,500-acre SEZ for the aerospace and avionics industry, proposed to be established in south Gujarat, close to the Delhi-Mumbai industrial corridor. This is likely to have a number of MRO (Maintenance, Repair and Overhauling) facilities.

In the case of the Indian aerospace industry, its sectoral system of innovation overlaps very well with the Bangalore Aerospace cluster as the major components of SSI are located within the Bangalore cluster. So in our study we use the term, sectoral system of innovation of India's aerospace industry and the Bangalore aerospace cluster interchangeably.

Systematic academic literature on India's aerospace industry is scanty and focuses almost exclusively on the astronautical part. Three sets of issues have come up for inquiry and analysis in this literature. The first one deals with overall assessment of past and future public policies on space programmes (Rajan (1988), Kasturirangan (2004), Murthi, Bhaskaranarayana and Madhusudan (2009)). The second one is a more detailed study on the evolution of the space sector from one being more science oriented to one that is more commercial oriented. The studies in this set also deals with the way India has acquired technological capability in this area (Baskaran (2005) and Sankar (2006). The last one deals with one particular kind of space technology namely remote sensing in which India has managed to have considerable technological capability. The only study in this set (Satheesh (2009) deals with the extent of diffusion of this technology and the factors that have contributed to its diffusion. To the best of our knowledge no studies exist on the aeronautical part of the sector. The present study seeks to fill in this gap by focusing on both the sectors and especially on the aeronautical part of the industry.

The basic objective of our study is to understand and map out the Bangalore aerospace cluster and its performance over time. In very specific terms we are interested in identifying and analyzing the major actors in this cluster, research and manufacturing as well and identifying the linkages that these actors have which each other especially in the generation of new technologies. In keeping with these objectives the study is structured into three sections. The first section maps out in detail the Bangalore Aerospace Cluster, identifies and discusses the key players or actors from the knowledge generation point of view. The second section measures the performance of the cluster and the last section distils out the policy implications of the study.

2. THE BANGALORE AEROSPACE CLUSTER

The city of Bangalore, capital of the southern state of Karnataka, has shot into international fame as the centre for India's information technology industry and also as an innovation hub. Besides it has a very high density of national level research institutes focusing on a range of technology disciplines, same basic and some applied as well. It has also a very density of undergraduate and graduate institutions in science and engineering and some of it like the Indian Institute of Science is of international repute. Further it has a very large number of new technology based firms especially in electronics hardware, computer software and in biotechnology industries. India's aerospace industry has its origin in Bangalore with the establishment of three major institutions in that city, namely the National Aerospace Laboratory, the Hindusthan Aeronauticals and the Indian Space Research Organization. No other place in India has such a large density of aerospace related institutions as Bangalore has. Although the Bangalore aerospace cluster is now more than 50 years old, over the last ten years or so it has evolved into a fairly sophisticated and clearly identifiable cluster. Three factors appear to have contributed to this change. First is the increasing market for aircrafts within the country thanks to the phenomenal growth in domestic air travel and the increasing success of India's space programme which has also increased with India emerging to have capability in designing and launching satellites using her own indigenously designed satellite launch vehicles. Second, is the launching of research and development of India's first civilian aircraft, the HANSA and SARAS in 1991 and the establishment of the Antrix Corporation in 1992 for the promotion and commercial exploration of products and services from the Indian space programme. Third is the growth of R&D outsourcing by foreign aerospace companies and one does hear, with increasing frequency, of an increasing number of such outsourcing outfits being located in the country and most of them again happen to be in Bangalore. An indication of the growing importance of Bangalore's aerospace potential can be gauged from the fact that during a recently concluded Aero India 2009 air show – billed as the largest in South Asia – deals worth more than $1.2 billion were signed between Indian and foreign aerospace firms. For all these reasons, we restrict our study to the Bangalore Aerospace cluster. However given the importance of Bangalore in India's aerospace industry, this is tantamount to analyzing India's aerospace industry itself.

Regarding the Bangalore cluster, we first map out the contours of this cluster in terms of the institutions that constitute this cluster. This is followed by a detailed analysis of some of the leading constituents of this cluster. Finally we end with a discussion of the performance of the cluster in terms of some standard indicators such as exports and R&D.

2.1. Mapping the Bangalore Aerospace Cluster

Based on my field visits and on the basis of secondary source material, I have been able to map out the Bangalore aerospace cluster. See Figure 2. At the core of the cluster are two different sets of aerospace organizations: one set representing the research system and the other representing leading aerospace manufacturers. Around the core are ten different types of parts and machinery manufacturers and two different types of business support, marketing and technology transfer firms.

At the core of the cluster are three major aerospace research organizations. These are the National Aerospace Laboratory (NAL) of the Council for Scientific and Industrial Research

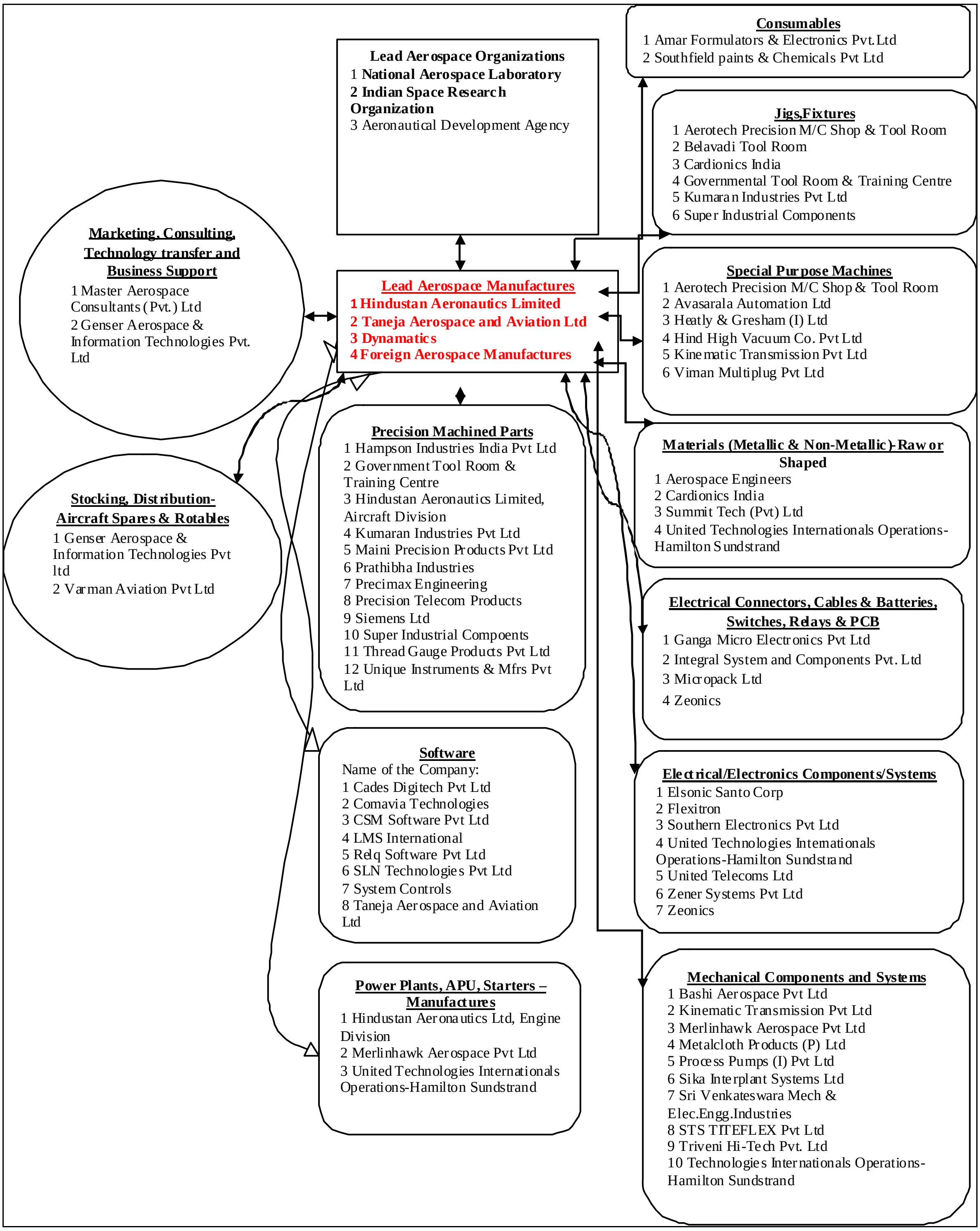

Figure 2 The Bangalore Aerospace Cluster (c2010)

Source: Own compilation.

2.2. Lead Actors in the Bangalore Aerospace Cluster: Based Aerospace Players

In this section, we discuss some of the leading actors within the aerospace cluster in

Bangalore. The focus is on the activities of these actors and the S&T linkages that these actors have with other actors both in the cluster, elsewhere in India and even abroad. We first start with the research or knowledge base of the cluster followed by the manufacturing base although this division is by no means fool proof as some of the manufacturers themselves have their own in house knowledge production centres. The research base in aeronautics is led by the NAL (although the Indian Institute of Science, Bangalore has also a strong contribution to the research base with a stead supply of high quality human resource) and the Indian Space Research Organization in the case of astronautics. This is followed by a discussion of four of the leading manufacturing enterprises. Through this discussion we hope to track the knowledge flows that are taking place within this cluster.

Research and Development entities

(i) National Aerospace Laboratory

National Aerospace Laboratories (NAL), Bangalore is a constituent laboratory under the Council of Scientific and Industrial Research of India. NAL is a high technology oriented institution concentrating on advanced topics in the aerospace and related disciplines. Originally started as National Aeronautical Laboratory, it was renamed National Aerospace Laboratories to reflect its major involvement in the Indian space programme, its multidisciplinary activities and global positioning. It is India's only civilian aerospace R&D organization in the public sector as the other.

NAL is well equipped with modern and sophisticated facilities that include:

- Nilakantan National Trisonic Aerodynamic Facilities (NTAF) with three wind tunnels is one of the finest of its kind in the world and is used for testing of aircraft, missiles and launch vehicles.
- Full-scale Fatigue Testing Facility for fighter aircraft life extension programmes. Many versions of the MiG aircraft have been evaluated at NAL's fatigue testing facility.

- Acoustic Test Facility for acoustic qualification of satellites and launch vehicles. Over 2000 tests, involving every Indian satellite and launch vehicle, have been carried out at this facility. The reverberation chamber has a volume of 1100 cu m; the design of the chamber's massive door ensures that 99.9% of the acoustic noise is successfully reflected internally.
- Composite Structures Laboratory for design and fabrication of composite fins, rudders, fuselage, etc. for fighter aircraft. There is probably no fighter aircraft being built anywhere in the world with as many composite components as India's Tejas – and a large fraction of Tejas's composite structures have been designed and developed at NAL.
- Black box readout facility. NAL has developed readout systems for the digital flight data recorder (DFDR) and the cockpit voice recorder (CVR) – commonly referred to as the `black boxes' – compatible with all aircraft flying on Air India and Indian Airlines fleets. Readout services have been offered for practically every major flying incident in the Indian skies since 1990. An integrated flight data readout system, developed by NAL, is now operational both at Indian Airlines and Air India. A new Windows-based software, NALOQA, for flight operations quality assurance, was unveiled at the Singapore air show in February 2004.

NAL has also developed significant technologies related to the field and is an acknowledged centre of excellence in many fields including composite structures, high speed wind tunnel testing, aircraft fatigue and aerospace acoustics, failure analysis and accident investigation.

Although NAL was established in 1959, it was only in 1993 that it set up a commercial wing, NAL Tech, to commercialise the internally generated technologies and to interact with other actors in the cluster. NAL tech has technological capability in the following 7 areas:

- Surface Engineering
- Composites Technology
- Resin and Fibre Technology
- Failure analysis and accident investigation
- Non-destructive and destructive testing and evaluation

- Materials charecterisations
- HANSA 3 trainer aircraft

Two of the major R&D projects in the civilian aircraft space that the NAL has worked on in recent times are the development of two different types of aircraft; first a two-seater trainer aircraft called HANSA and the second a multi role light transport aircraft called SARAS. The development of these two aircraft has added to the technological dynamism of this evolving cluster. Of the two, HANSA trainer aircraft has been developed and is currently in use in India and abroad.[1] The Hansa programme got under way in the early 1990s, with the first prototypes flying in 1993 and 1996. In February 2000, Hansa received its type-certification from the Directorate General of Civil Aviation (DGCA) and was cleared for day and night operations. Though NAL had initially manufactured the Hansa on its own and are again doing so, in the interregnum they had had one produced by the only private sector Aerospace company, Taneja Aerospace and Aviation Limited (TAAL).[2]

The second and more complex one, SARAS is essentially a twin turboprop[3] multi-role aircraft with air taxi and commuter services as its primary roles. It has a maximum take-off weight of about 6100 kg and a seating capacity of up to 18 passengers in the high density version. With a pressurised cabin, the aircraft will have a level of comfort comparable to regional aircraft such as the Embraer or ATR aircarft. The aircraft is well-

[1] The main competition for the Hansa comes from the Cessna 152 and the Cessna 172. The Hansa 3 is priced around Rs. 6 million (approximately 0.13 million dollars)
[2] NAL had entered into an equal cost and work sharing collaboration with Mahindra Plexion to develop a four-five-seater general-purpose aircraft. The aircraft is being designed and developed to perform a variety of missions, including 4 to 5 passenger transport, cargo operations, air taxi, etc. A combination of state-of-the-art composite technology as well as advanced sheet metal fabrication techniques are proposed to be used. It will be contemporary in design with advanced cockpit and comprehensive safety features which include energy absorbing seats and lightening protection. Yet another unique feature is the integration of a number of indigenous components and proven systems and technologies. During the design and development phase, a combined technical team from both the organizations would be jointly involved followed by design validation and testing using the extensive facilities of NAL.
[3] Saras is one of the few aircraft to make use of a pusher propeller configuration. The basic configuration resembles very closely the platform of the Embraer/FMA CBA 123 Vector which never went into production.

suited to fulfill a variety of other roles such as executive transport, light package carrier, remote sensing and aerial research services, coast guard, border patrol, air ambulance and other community services. The project started in 1991, had some interruptions in 1998 due to the sanctions imposed on India by the international community[4]. The first prototype was field tested in 2003-4 and the second one in 2007. But the technology is yet to be commercialised as it still has to solve some technical issues with regard to the weight of the aircraft. Although the project is of indigenous in terms of its conception and design, NAL has actually collaborated only with a limited number of international agencies. For instance, (a) a contract has been signed with Honeywell Technologies, Bangalore for the joint development of digital autopilot for the SARAS aircraft; (b) three engines (PT6A-67A) with a power rating of 1200 SHP at 1700 RPM have been procured from Pratt and Whitney, Canada; (c) pusher propellers developed in collaboration with MT Propeller, Germany; and (d) NAL has worked out flow computational programme for a transport aircraft in flight in collaboration with the University of Cambridge.

A more detailed analysis of the HANSA and SARAS cases are attempted in the second section analyzing the performance of the cluster.

NAL is at the moment initiated a new project to design a 70-90 seat Regional Transport Aircarft (RTA) in a public-private partnership mode. Our inquiries reveal that currently it is the drawing board stage. It will be an aircraft which could land in an all weather condition even in airfields which do not have adequate ground infrastructure facilities like Instrument Landing System (ILS). The first test flight is to be done in 2015 and expects to commercialise the new technology by 2016. Once again NAL is working in close collaboration with a number of other actors in the cluster like academic

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[4] According to NAL sources, technological and procurement problems - arising out of US sanctions - have adversely affected the development of Saras and raised the cost of its development by Rs 15 crores although this view was contested by the CAG(2008) in its auditing of NAL's R&D projects.

institutions and manufacturing enterprises.

(ii) Indian Space Research Organisation (ISRO)

Government of India established the Department of Space in 1972 to promote development and application of space science and technology in the country for the socio-economic benefits. Indian Space Research organization (ISRO) is the primary agency under the Department of Space for executing space programmes. During the early seventies, India undertook demonstration of space applications for communication, television broadcasting and remote sensing building experimental satellites namely, APPLE, Bhaskara – and experimental satellite launch vehicles, SLV-3 and ASLV.

At present, India has an impressive array of achievements with the largest constellation of domestic communication satellites called Indian National Satellite System (INSAT) in the Asia pacific region with about 210 transponders in orbit. And, India has plans to augment the capacity with the launching of INSAT satellites and increase it to about 500 in 4-5 years to meet its growing needs. Bangalore occupies an important place in India's space programme. See Figure 3.

Figure 3 Importance of Bangalore in Astronautical Sector in India

Source: Indian Space Research Organization.

India also has the largest constellation of earth observation satellites called Indian Remote Sensing (IRS) satellites with better than one meter resolution. IRS data is being used for a variety of applications such as crop yield estimation, drinking water missions, waste land development, forest cover mapping and a host of other applications benefiting the common man. Using INSATs, besides TV Broadcasting, telecommunications and meteorological applications societal applications such as tele-education, telemedicine applications have been operationalised. Village Resource Centers (VRCs) combining the services of IRS and INSAT satellites for providing an array of services have been established. India, today is considered as a leader in the application of space technology. INSAT and IRS satellites are also providing invaluable services in disaster management.

To put the IRS and INSAT satellites into orbit, India has developed two work horse launch vehicles namely the Polar Satellite Launch Vehicle (PSLV) and Geo-synchronous Satellite Launch Vehicle (GSLV). PSLV weighing about 300 tons at lift off has the capability to put 1500 kg satellite in polar sun-synchronous orbit. PSLV with eleven consecutively successful launches has demonstrated its high reliability. PSLV has launched eight satellites for various customers from abroad. GSLV with four successful flights is capable of launching 2200 kg satellites into geo-stationary Transfer Orbit. India has also created world class facilities at its space port in Sriharikota near Chennai with launch pads besides a host of test facilities for testing satellites and launch vehicle systems.

ISRO has established linkages with more than 500 firms in small, medium and large scale sectors, either through procurement contracts, know how transfers or provision of technical consultancy. The association with the space programme has enabled these firms to adopt advanced technologies and handle complex manufacturing jobs. With Antrix Corporation, the commercial front of DOS, having established itself in the global market, Indian firms have begun participating in the fabrication of space hardware to meet the requirement of international customers also.

Hitherto, 289 technologies have been transferred industries for commercialisation and 270 technical consultancies have been provided in different disciplines of space technology. Technology transfer activities have made further progress during the year (2008-09). Four new technology transfer agreements were concluded during 2008-09. The technologies licensed to industries for commercialisation include PF 108 Resin, Umbilical Pads, Ammonium Dinitrimide (AND) and ASIC Based Demodulator. A number of technologies licensed during the last few years have entered into regular production. The technology for manufacture of ISRO patented OLFEX has been in great demand and now has been additionally licensed to two more firms considering the expanding market. A number of technologies and application software packages are in various stages of development and will soon be available for commercialisation. Domestic GIS software (IGIS) jointly developed by ISRO was taken up for know how transfer. Through a Memorandum of Understanding (MoU) with industry, the development and supply of Cryo Adhesives (CAS resin) and Crystobalite, a filler material used in silica tiles, has been entered into with industry.

Manufacturing Enterprises

These are divided into domestic and foreign manufacturers.

A. Domestic manufacturers

(i) Hindustan Aeronautics Limited (HAL)

HAL is a major player in the global aviation arena. It is a defence state owned company and has built up comprehensive skills in design, manufacture and overhaul of fighters, trainers, helicopters, transport aircraft, engines, avionics and system equipment. Its product track record consists of 12 types of aircraft from in-house R&D and 14 types by licence production inclusive of 8 types of aero engines and over 1000 items of aircraft system equipment (avionics, mechanical, electrical).

HAL has produced over 3550 aircraft, 3650 aero-engines and overhauled around 8750 aircraft & 28400 engines besides manufacture/overhaul of related accessories and avionics. The Company has the requisite core competence base with a demonstrated potential to become a global player. HAL has 19 production divisions for manufacture and overhaul of aircraft, helicopters, engine and accessories. It has also 9 R&D Centres to give a thrust to research & development.

HAL’s major supplies/services are to Indian Air Force, Indian Navy, Indian Army, Coast Guard and Border Security Force. Transport aircraft and Helicopters have been supplied to airlines as well as State Governments. The Company has also achieved a foothold in export in more than 20 countries, having demonstrated its quality and price competitiveness. HAL is a major partner for the Space Vehicle programmes of the Indian Space Research Organisation (ISRO). It has also diversified into the fields of industrial and marine gas turbine business and real-time software business. HAL is now ranked 34th in the list of world's top 100 defence companies.

The company has made supplies to almost all the major aerospace companies in the World like Airbus, Boeing, IAI, IRKUT, Honeywell and Ruag etc. In 1988 Airbus entered into an agreement with Airbus to make doors for its A320. Primary interviews with HAL reveal that 50 percent of the doors for Airbus are manufactured by HAL. The company has also entered into an agreement with for the production of flaperons[5] for use on Boeing's 777 series commercial jetliner.

All the production Divisions of HAL have ISO 9001-2000 accreditation and sixteen divisions have ISO-14001-2004 environment management system (EMS) certification. Six divisions have also implemented the aerospace sector quality management system requirements stated in AS 9100 standard and obtained certification. Four of these divisions have also obtained NADCAP certification (National Aerospace Defence Contractors Accreditation programme –USA) for special processes such as NDT, heat treatment, welding etc.

In order to meet with the challenges in the 21st Century, the Company has redefined its mission as follows: "To become a globally competitive aerospace industry while working as an instrument for achieving self-reliance in design, manufacture and maintenance of aerospace equipment, Civil Transport Aircraft, helicopter & missiles and diversifying to related areas, managing the business on commercial lines in a climate of

[5] The 777 flaperons are a highly complex composite assembly that is instrumental in controlling the airplane's maneuverability in flight.

growing professional competence."

HAL has successfully designed and developed the Advanced Light Helicopter, which is currently being operated by the defence services of India and private companies. The Advanced Light Helicopter also has great export potential. Apart from licence production of front line fighters like Su-30 MKI, HAL is also developing the following products through design and development:

(i) Intermediate Jet Trainer (IJT);

(ii) Light combat helicopter (LCH);

(iii) Weaponization of Advanced Light Helicopter (ALH); and

(iv) Tejas-Light Combat Aircraft.

As a result of these expansions of its activities, HAL's total sales have increased on an average at a rate of 16 per cent per annum. See Table 1. Its export intensity has doubled during the period under consideration while it has maintained its research intensity around 7.4 per cent of its sales turn over. This is in fact one of the highest research intensities in the country.

Table 1 Trends in HAL's Domestic Sales, Exports, Export Intensity and Research Intensity

	Domestic sales (Rs Millions)	Export Sales (Rs in Millions)	Total Sales (Rs in Millions)	Export Intensity (%)	R&D Expenditure (Rs in Millions)	Research Intensity (%)
1994-95	13529.5	358.9	13888.4	2.65	961.2	6.92
1995-96	15387.8	281.3	15669.1	1.83	1258.7	8.03
1996-97	17305.7	396.4	17702.1	2.29	819.5	4.63
1997-98	18288.8	410.5	18699.3	2.24	1298.3	6.94
1998-99	20037	440.3	20477.3	2.20	1463.5	7.15
1999-00	23539.2	469.6	24008.8	1.99	1716.6	7.15
2000-01	23879.4	586.1	24465.5	2.45	2040.9	8.34
2001-02	27079.6	668.5	27748.1	2.47	2037.2	7.34
2002-03	30165.3	1038.9	31204.2	3.44	2650.6	8.49
2003-04	35844.3	2153.5	37997.8	6.01	3138.1	8.26
2004-05	43837.5	1500.5	45338	3.42	3066.3	6.76
2005-06	51553.1	1861.9	53415	3.61	4335.8	8.12
2006-07	75131	2705.1	77836.1	3.60	6377.9	8.19
2007-08	82842.5	3410.9	86253.4	4.12	6621.4	7.68
2008-09	99368	4365.8	103733.8	4.39	6747.8	6.50

Source: Hinduthan Aeronautical Limited (2009).

(ii) Taneja Aerospace and Aviation Limited (TAAL)

TAAL is the only listed company in aerospace manufacturing in India. It manufactures small civilian aircraft, aero-structures and aircraft parts, provides aircraft maintenance services and represents Cessna Aircraft Company, USA, for the sale of its aircraft in India. It is the only private sector company manufacturing entire aircraft in India.

Part of the Pune based Indian Seamless group, TAAL was established in 1994 as the first private sector company in the country to manufacture general aviation i.e. non-military aircraft. The company's vision at the time was to create a nucleus facility for the development of an aeronautical industry in India and in particular to promote affordable general aviation in the country. To kick-off this process, TAAL entered into a collaboration with Partenavia of Italy to manufacture the six-seat twin piston-engine P68C aircraft and the eleven-seat twin turbo-prop Viator aircraft.

While TAAL continues to manufacture Light Transport and Trainer Aircraft, the company has since diversified its activities and has established a significant presence in many segments of the aviation and aeronautical industries in India.

TAAL has three distinct Business Divisions, namely, aerostructures, airfield & MRO and aircraft sales and support. Aerostructure business division has evolved from the initial business of the company, which was to manufacture the Partenavia P68C, six seat, twin-engine aircraft in India TAAL currently manufacture aero structures for Hindustan Aeronautics Limited (HAL), Indian Space Research Organization (ISRO), National Aerospace Laboratories (NAL) Aeronautical Development Establishment (ADE). Of these, the largest structures that the firm manufactures are for ISRO where the company builds most of the structural assemblies for the Booster rockets of the GSLV program. The company has also built major structures of SARAS.

TAAL’s core competence in this area is in the manufacture of sheet metal details, machining, composites and assemblies. Facilities are augmented and upgraded to address the domestic and Global Technological requirements on a continuous basis.

- Manufacture of the P68C, a six seat twin piston-engine aircraft. All detailed parts and assemblies including seats, electrical looming, cable assemblies etc. were manufactured at TAAL's facilities;
- was involved in building up the first three prototypes of the 14 seat, SARAS aircraft for the National Aerospace Laboratories (NAL). TAAL has manufactured the entire airframe of the aircraft (excluding the wings which are manufactured by HAL) including tooling, parts and assembly.
- was associated with the National Aerospace Laboratories (NAL) for the production of the two-seat all composite (glass fiber) trainer aircraft called the “HANSA”;
- is manufacturing the airframes for the full composite (carbon and glass -wet lay up and room temperature cured) NISHANT, Remote Pilotless Vehicle developed by the Aeronautical Defense Establishment (ADE);
- is manufacturing all the composite components (Tail cone, Nose cone and air-intake) for the LAKSHYA, Pilotless Target Aircraft (PTA). This aircraft is now in series production;
- is manufacturing the Elevator and Stabilizer for the Intermediate Jet Trainer (IJT) manufactured by HAL;
- is manufacturing a variety of aircraft tooling (bakelite), Sheet Metal Parts etc., for the Advanced Light Helicopters (ALH); Light Combat Aircraft (LCA) Light Combat Helicopter (LCH); Sukhoi (SU-30) & MIG Series projects of Hindustan Aeronautics Limited (HAL);
- is manufacturing auxiliary fuel tank, stretcher, Armour Panel and interiors for Advanced Light Helicopters of HAL and also interiors for Defence Service Helicopter;
- parts for Jaguar Drop tanks and Incendiary Containers;
- is doing space structures for PSLV and GSLV of Indian Space Research Organization (ISRO);
- manufacture of THORP T211 two seater aircraft for Domestic and Export Markets; and
- In the past TAAL has undertaken certain sub-contract work for the Israel Aircraft Industries (ISI) in Indi

In other words TAAL is very much linked to HAL and NAL deriving both contracts and knowledge from these two actors in the cluster. In addition it has also formal contacts for knowledge transfer from western aerospace firms.

(iii) Dynamatic Aerospace

Dynamatic Aerospace is known for the development of complex aero structures like wing, rear fuselage, ailerons flaps, fins, slats, stabilizers, canards and air brakes. Dynamatic Aerospace closely partners with agencies like Ministry of Defence, Hindustan Aeronautics Limited and other defence establishments on several key projects. It has the largest infrastructure in the Indian private sector for manufacture of exacting air frame structures and precision aerospace components.

(iv) Bharat Electronics Limited (BEL)

BEL was established in 1954 to meet the specialised electronic needs of the country's defence services, is a multi-product, multi-technology, multi-unit company. It serves the needs of domestic and foreign customers with the products/services manufactured in its nine state-of-the-art ISO 9001/2 and ISO 14000 certified manufacturing plants in India.

BEL manufactures a wide repertoire of products in the field of Radars, Naval systems, Defence Communication, Telecommunication and Broadcasting, Electronic Warfare, Opto Electronics, Tank Electronics and Electronic Components. With the expertise developed over the years, the company also provides turnkey systems solutions and Electronic Manufacturing Services (EMS) on "Build to Print" and "Build to Spec" basis. BEL has become a US $ 1 billion company in the financial year 2007-08.

BEL has entered into MoUs with aerospace majors like:

- Lockheed Martin, Boeing, EADS & Northrop Grumman for opportunities arising out of offsets
- Elisra, Israel, for working on various airborne electronic warfare programmes for the Indian defence
- IAI-Malat for working in the field of Unmanned Aerial Vehicles (UAV)

- BEL signed a term sheet with Rafael, Israel, which is expected to lead to the formation of a joint venture, for missile electronics and guidance technologies

B. Foreign Companies in the aerospace cluster

(i) The Airbus Engineering Centre India (AECI)

AECI – a 100 per cent Airbus-owned subsidiary is one of the most important foreign aircraft manufacturing enterprises in the Bangalore aerospace cluster. Specialising in high-tech aeronautical engineering, the India engineering centre works hand-in-hand with other Airbus Engineering offices around the world, as well as with the Indian aviation industry. As of early 2009, 100 people were working at the facility – including home-grown engineers and other employees – and this number is expected to grow to 400 over the next four years.

The Bangalore-based centre focuses on the development of advanced capabilities in the areas of modelling and simulation, covering such areas as flight management systems, computational fluid dynamics (CFD), as well as digital simulation and visualisation – which are critical factors in the design and production of high-performance aircraft such as the A380 and the A350 XWB. As part of the Airbus Engineering Centre India's activity, a simulated A380 flight management system is being developed in cooperation with Airbus engineers in Toulouse, France. This effort will help Airbus systems engineers provide mature specifications for the suppliers of flight management systems (FMS) – which are key elements of modern jetliners, and also can be used in research and development work on evolved FMS functions for new programmes such as the A350 XWB. As part of AECI Research & Technology activity, Airbus is in negotiations with the Indian Institute of Science, Bangalore, the Indian Institute of Technology and the National Aerospace Laboratory to commence several projects during 2009. In addition, Airbus Training India (ATI) initiated its operations in Bangalore and has since provided maintenance training to Indian-based airline operators.

Airbus is working in partnership with CAE of Canada to establish ATI as a full-fledged flight training centre, with the capability to train up to 1,000 pilots annually utilising 10 simulators. It also will offer maintenance courses in fully equipped, state-of-the-art classroom facilities. This centre currently is under construction near the new Bengaluru International Airport, and the facility's initial two simulators have been operational since 2008 for recurrent training.

Airbus also works directly with Indian companies in the design and manufacture of aerostructures and strongly encourages its major Tier 1 partners to do so as appropriate. Dynamatic Technologies Limited from Bangalore has partnered with Spirit AeroSystems to manufacture a complex machining component and assembly (Flap-Track Beams) for the A320, the world's most popular single-aisle aircraft programme.

Through its Tier 1 suppliers, Airbus also is engaging local companies such as TATA, HAL and Quest for the manufacture of sub-assemblies and detail parts. Additionally, the Airbus Aero-structures Supplier Council has identified India as one of the top "Cost Competitive Country" destinations for aerostructure manufacturing. Furthermore, Airbus has initiated several engineering projects with Indian companies. Infosys, HCL, CADES, Satyam and Quest have been selected to provide Engineering Services to various aircraft programmes, including the A380 and A350. In addition, Sonovision-Aetos in Bangalore (and Infotech in Hyderabad) have been set up as dedicated centres for work on Airbus Technical Publications.

(ii) Boeing in the Bangalore cluster

In 2005, Boeing entered a research partnership with the Indian Institute of Science (IISc), Bengaluru. The Boeing-IISc partnership focuses on research in nanotechnologies, structural alloys, composites, smart materials and structures, process modeling and simulation, manufacturing technologies, prototyping through substructure fabrication and testing. The strategic alliance with the IISc—the first of its kind at Boeing in the area of materials science—is expected to spur aerospace innovation and contribute to the advancement of Boeing's aircraft design capabilities. Approximately a year ago (in March 2009) Boeing opened its Boeing Research and Technology-India centre, which marks a major milestone for Boeing's aerospace research and technology activities in India. The centre will be the focal point for all Boeing technology activities in India, collaborating with Indian R&D organizations, including government agencies and private sector R&D providers, universities, and other companies. It will work with strategic research and technology partners to develop high-end technology, particularly in the areas of aero structures and avionics. This is Boeing's third advanced research centre outside of the U.S.

Software firms in the cluster:

Apart from this hardware related entities in the cluster, the Bangalore cluster is also very well known for a number of software firms which have become important players in the software requirements of some of the international aerospace industry. Mention may be made of two of them, namely WIPRO and Quest. See Box

Box: Software firms active in the Bangalore aerospace Cluster

WIPRO

- Agreement to work jointly on commercial aerospace projects with Britain's BAE Systems
- Entered into an agreement with Boeing to develop wireless and other network technologies for aerospace-related applications (PPP)
- Partnered with Lockheed Martin to create demonstration centers showing new capabilities for linking multiple control centers, aircraft and vehicles
- Wipro became the largest hydraulics company in India and the second-largest globally after an acquisition in Sweden. It is assessing the possibility of creating new designs for smart landing gears and brakes.

Quest

QuEST supports its aerospace customers on global programmes related to aero structures, engines, accessories, actuation systems, aircraft interiors and ground support equipment.It also specializes in complete end-to-end solutions for the aerospace industry right from design and analysis to manufacturing

• QuEST has been selected as EADS E2S preferred supplier for engineering services, manufacturing capabilities, ability to offer offset fulfillment and Risk Sharing Partnerships. The firm recently entered into a JV to launch India's first independent processing facility for aerospace manufacturing and has setup a Special Economic Zone (SEZ) in Belgaum

Source: PricewaterhouseCoopers (PWC) and Confederation of Indian Industry (CII) (2009).

Based on the qualitative and quantitative data on the major entities in the Bangalore cluster, the main difference between the aeronautical and astronautical components of the cluster is the important fact that the cluster is now increasingly getting organized around civilian projects especially in the case of the aeronautical sector. Further the aeronautical cluster is increasingly getting integrated with the international aerospace industry. The astronautical sector, on the contrary, focuses much more on forging linkages within the country even though here too we could detect change in the form of a number of emerging international linkages.

In the aeronautical sector some of the important linkages observed are:

(a) Airbus has been assessing ways to use India for component manufacturing and R&D. It had announced that India will be one of the key centers for design and development of their new A350 aircraft. Airbus Engineering Centre India is the company's high-tech aircraft component manufacturing facility in Bangalore. The facility works on the development of tools to design the aircraft, software for analyzing the stress and strain on airplanes and structural analysis of the aircraft, among other things.

(b) Snecma, a leading global aerospace company, established its R&D center in India in 2002. This center is engaged in carrying out studies and developing engine components, aircraft equipment and onboard software.

(c) Several foreign and private players that have entered the Indian R&D sphere followed the Public Private Partnership (PPP) model for sharing technology/knowledge and commercializing aerospace manufacturing. Prominent partnerships include:

(d) In 2008, Boeing had entered into agreements with Indian Institute of Science, Wipro and HCL to develop wireless and other network technologies for aerospace related applications.

(e) In 2007, Mahindra and Mahindra had signed an agreement for the design and development of a new general aviation aircraft with National Aerospace Laboratories (NAL), CSIR and the Government of India. This is the first public private JV in the aircraft design sector in India

2.3. Autoparts Firms Diversifying to Aerospace Industry

Finally important finding of the study is that a number of autoparts manufacturers have actually entered the aerospace industry: Indian automotive companies are also well-positioned to leverage their strengths towards aerospace. The auto component sector is growing at approximately 20 percent per year and many global OEMs and Tier 1 companies have started sourcing components from India, due to the high quality standards followed by Indian manufacturers. For instance, India has the largest number Deming Award winning companies outside Japan (11) in the auto component sphere and proven practices such as 5S, TPM, TQM and JIT are used by companies. The companies are also conversant with the multiple automotive standards followed in different parts of the globe. Several players are planning to enter the aircraft components production. Most are primarily becoming involved with precision engineering, machining, aircraft lighting, manufacture of tyres and transmission components. For example, Tata Automobile Ltd (TAL) entered into an agreement with Boeing to manufacture structural components for their 787 Dreamliner airplane programme.

The auto component majors have indicated several reasons (PWC and CII) for the entry of these

- Suppliers into the aerospace sector:
- Diversification of product portfolio and de-risking of business;
- Skills and manufacturing processes are similar to those required for aircrafts allowing them to effectively utilize existing capacities and capabilities;

- Higher margins in the sector; and
- Leveraging the benefits of the large quantum of work to come through the offset clause.

This is thus an extremely dynamic cluster evolving continuously.

3. PERFORMANCE OF THE BANGALORE AEROSPACE CLUSTER

In the previous section, we have mapped out the contours of the Bangalore cluster and then focused our attention on some of the lead players in the cluster. We found that there was fair amount of knowledge flows within the various actors and increasingly between these actors and foreign firms, customers and suppliers. Both the aeronautical and astronautical sectors have built up a fair amount of domestic technological capability in designing, manufacturing and selling aerospace products not only in India but even abroad. We therefore focus on the performance of this cluster. We do this separately for both the aeronautical and astronautical sectors of the industry in terms of two broad sets of indicators. First we discuss some macro performance indicators in terms of exports and competitiveness. Second, we discuss in detail a micro performance indicator, namely India’s attempt at developing civilian aircraft. However, before we actually presenting these indicators for measuring the performance of the two sectors, a caveat is in order. It is virtually impossible to get data on performance just for the Bangalore cluster alone. Therefore the data on exports that we have used refer to the country as a whole. However given the important place of Bangalore in the Indian aerospace industry, this may not to be a problem at all as most of the exports may have actually emanated from Bangalore-based entities.

3.1. Macro Performance Indicators

An important finding of the study is that the firms have, hitherto, been serving the export markets and the linkages that they have been having are more with other larger aircraft manufacturers outside the country. The main direct indicator of this link is the tremendous growth in exports, especially since the late 1990s. Exports have been growing at an average annual rate of 82 per cent (in nominal terms) during the period, 1988 through 2008. See Table 2.

Table 2 Exports of aerospace products from India, 1988- 2008 (in Millions of US $)

	Aeronautical	Astronautical	Aerospace	Growth rate
1988	5	3	8	
1989	9	2	11	38
1990	7	1	8	-31
1991	10	9	20	148
1992	10	0	10	-48
1993	5	0	5	-49
1994	6	1	7	31
1995	5	2	7	4
1996	6	1	7	-1
1997	43	1	44	516
1998	12	1	12	-72
1999	30	0	30	143
2000	52	1	53	77
2001	66	3	70	32
2002	86	3	89	28
2003	70	5	75	-17
2004	40	14	54	-28
2005	50	12	62	16
2006	43	14	57	-8
2007	292	80	372	552
2008	1210	275	1485	299
Average Growth Rate (%)				82

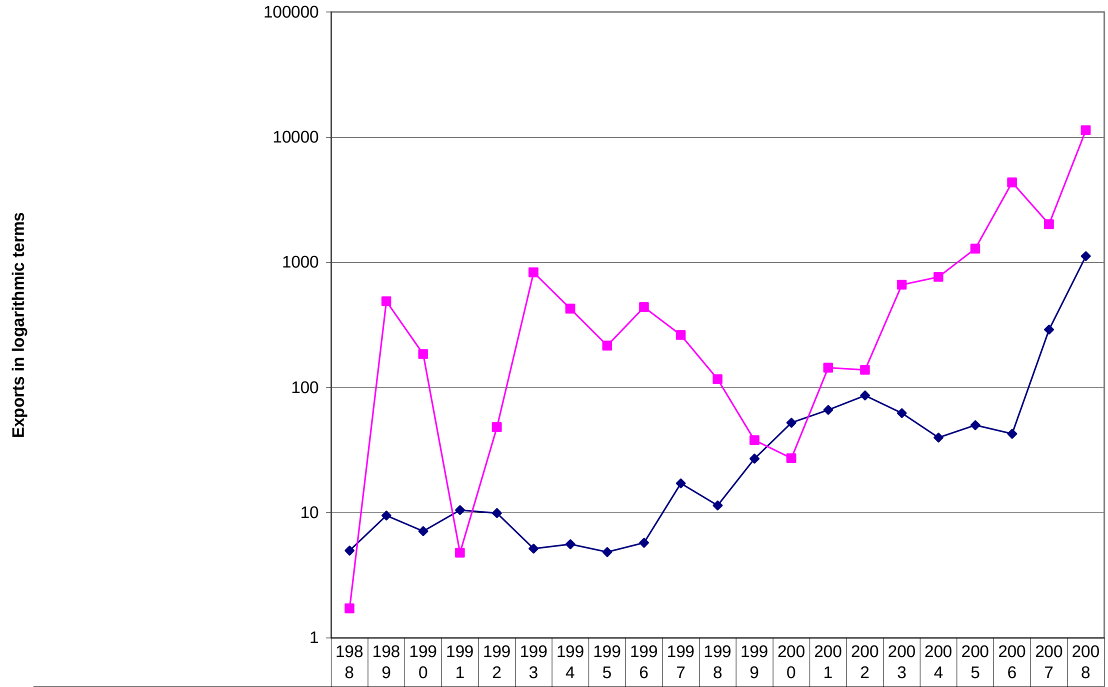
Source: Compiled from UN Comtrade.

Our analysis shows that almost the entire quantity that is exported is composed of parts of aircrafts.[6]

It is seen that the country is largely an exporter of aeronautical rather than astronautic products. This is because between the two, there is relatively speaking a larger domestic market for the latter in view of the ongoing and increasing space

[6] We have used the HS 1996 classification system for extracting the data on exports from the database UN Comtrade. The following three types of parts (a) aircraft propellers, rotors and parts thereof (880310); (b) aircraft under-carriages and parts thereof (880320); and aircraft parts nes (880330) accounts for the largest share of exports from India.

programmes of the ISRO. So it is not incorrect to conclude that in the case of aeronautic component of the aerospace industry the most dominant linkage that you find in the cluster is between domestic component and smaller aircraft manufacturers with large aircraft manufacturers abroad. In the case of the astronautic component the linkages are between domestic manufacturers and their main consumer which is the ISRO. The link between ISRO and their suppliers is actually forged through a commercial subsidiary of ISRO namely the Antrix Corporation.



	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export of aeronautical parts	5	9	7	10	10	5	6	5	6	17	11	27	52	66	86	63	40	50	43	291	112
Import of aeronautical equipment	2	489	185	5	48	832	426	216	440	263	117	38	27	144	138	662	766	128	434	201	113

Figure 4 Relationship between Imports of Aeronautical Equipments and Exports of Aeronautical parts, 1988-2008

Source: Computed from UN Comtrade.

The government recently announced the new policy for capital acquisitions in which the minimum requirement is of 30 percent offsets in all acquisitions where the purchase cost exceeds Rs.3 billion. Nearly 80 percent of all offsets are in the area of aerospace. As result of this offset policy increasingly equipment suppliers to India are sourcing some portion of their components from India. So the increased exports of essential aeronautical parts from India are actually a result of this offset policy. In order to check this, we have plotted the export of aeronautical parts against import of aeronautical equipments. Given that the level of exports and imports vary considerably, we have transformed the two series into logarithmic values and this plotted against each other over time (Figure4). The figure shows that the two series are correlated with each other with the zero order correlation co-effient between the two working out to +0.92.

For measuring the performance of the astronautical sector, we rely on the space competitiveness index (SCI) computed by Futron Corporation (2008). The SCI evaluates the space faring nations across 40 individual metrics that represent the underlying economic determinants of space competitiveness. These metrics assess national space competitiveness in three major dimensions: government, human capital, and industry. The ranks obtained by the ten major space faring nations are presented in Table 3.

Table 3: India's rank in the Space Competitiveness Index in 2008 and 2009

Rank	Country	Government	Human Capital	Industry	2009 Score	2008 Score (Rank)
1	U.S	38.42	13.96	37.94	90.33	91.43(1)
2	Europe	19.32	9.03	18.46	46.80	48.07(2)
3	Russia	18.57	3.04	10.83	32.44	34.06(3)
4	Japan	15.80	1.72	3.65	21.16	14.46(7)
5	China	12.42	2.98	4.06	19.46	17.88(4)
6	Canada	12.89	3.42	1.82	18.13	16.94(6)
7	India	12.24	1.71	1.39	15.34	17.51(5)
8	South Korea	8.39	1.34	2.31	12.03	8.88(8)
9	Israel	6.72	0.56	1.42	8.70	8.37(9)
10	Brazil	6.10	0.49	0.50	7.08	4.96(10)

Source: Futron (2009).

India was ranked 5 in 2008. Her rank has since slipped to 7 out of 10, although her score is better than Brazil- a country that is very strong in the aeronautical sector.

Finally India's aerospace industry compares less favourably with that of China's (Table 4).

3.2. Micro Indicator of Performance

India's efforts at developing a civilian aircraft industry: It was seen earlier that NAL had developed two civilian aircraft, one a two-seater trainer and the second one a 14-seater multipurpose turbo prop one. In this section we discuss whether through these R&D projects NAL had actually fostered a cluster of aerospace units manufacturing a range of components and other parts required for these two projects. In discussing these two cases we supplement our primary data source with the data obtained from one of the recent Comptroller and Auditor General Reports (CAG, 2008) on scientific establishments in the country. Both the cases are first discussed separately and then some common threads are deduced from these two related cases.

The HANSA Case

The project was initiated in 1988 at a total estimated cost of Rs 5 million and was expected to be completed in about two to three years. Market research by NAL showed that considerable demand existed for this type of small aircraft to be used primarily for training and for remote sensing purposes. The project suffered serious time and cost overruns- the project could be completed only in 1998 at a final cost of Rs 55 million implying a time overrun of around 7 years a whopping cost overrun of 1000 per cent. While time and cost overruns are standard for especially high tech R&D projects, what was disquieting was that the aircraft was designed with 100 per cent foreign components and no effort was made by NAL to source even a small proportion of the total components required from domestic sources. Consequently the project had very little linkage effects within the Bangalore cluster or elsewhere in the country. NAL was also unable to transfer the HANSA technology to the only other private sector aeronautical manufacturing company namely TAAL. However TAAL refused to participate as a risk sharing partner but chose to work as a contractor. As result NAL decided to undertake the certification, production and marketing of the aircraft by itself. The initial demand for HANSA was restricted to 10 aircraft demanded by the Directorate General of Civil Aviation (DGCA) for eventual supply to the flying clubs around the country. NAL incurred a total expenditure of Rs 4.34 million per aircraft as against the initial target of Rs 0.05 million per craft. Of the 10, NAL was able to supply the DGCA with only 8 up to the end of June 2007. Nothing much is known about the remaining two as to whether it has been supplied or not. Of the eight, two met with accidents, but according to the CAG Report (p.25, para 1.8.1.3) NAL did not have any documents on investigations on these accidents done by either they themselves or the DGCA and so could not even create an institutionalized mechanism for learning from these mistakes. Also it was very clear that not much demand existed for these crafts beyond the original eight.

From the case, the following general points emerge. NAL does not appear to have done a systematic project preparation in terms of first assessing the market for this technology, second keeping a tab on both the time and cost of the project and in developing an indigenous vendor network and finally in instituting a framework within the lab to learn from its failures as these kind of failures are usually a fact of life in complex technologies such aerospace. Success lies in learning from these failures and then taking appropriate actions for further improvements.

The SARAS Case

This was one of the most ambitious projects that the NAL had undertaken. The idea, as noted before, was to develop a multi purpose Light Transport Aircraft (9 to 14 seats).

Under the project, two prototypes were to be fabricated to obtain DGCA certification. The competent financial authority (CFA) approved a budget of Rs1314 million for the project. Of this, Rs.653.1 (50 per cent) million was to be contributed by Technology Development Board, Rs.90 million (7 per cent) by HAL and balance Rs.571 million (43 per cent) by CSIR. While Prototype-I was targeted to fly in January 2001, the Prototype-II was expected to fly in December 2001. As against the target of January 2001, the Prototype-I flew in May 2004, i.e. after a delay of more than three years. Prototype-II undertook its first flight in April 2007, after a delay of more than five years. Due to the above time overrun, the cost of the project increased by Rs.225.30 million i.e., a cost over run of about 17 per cent. Right through the beginning the two prototypes developed had a problem wrt its weight (in specific terms it was over weight). This meant that its certification by DGCA has been delayed and from press reports it is leant that the certification may be available only towards the end of 2011 as a third and lighter prototype has to be made for that purpose. In the mean time, it is also understood that the Indian Airforce has expressed an interest to order 15 SARAS aircraft. The actual manufacturing of these aircraft will be by HAL. It is not immediately clear whether NAL has sourced the components and sub systems used in the aircraft were sourced from within the Bangalore cluster or from vendors elsewhere in the country. The only system that was purchased from indigenous sources was the auto pilot unit. However we had seen earlier that TAAL has manufactured the entire airframe of the aircraft (excluding the wings which are manufactured by HAL) including tooling, parts and assembly. In this way, the SARAS project did have linkages, albeit of a limited nature, with other units in the Bangalore cluster. Once the commercial manufacturing starts, these linkages are bound to increase manifold.

3.3. India's Performance in Comparison with Other Developing Countries:

In the realm of aerospace development there are essentially two success stories from among the developing countries. The earliest one is from Brazil and the more recent one from China. The Brazilian aeronautical industry could be traced as far back to 1969 and the only Brazilian aircraft company, Embraer is an important player in the world market for regional transport aircraft. The case of Embraer is very widely discussed in the literature (Ramamurthy, 1987; Frischtak, 1994; Marquess, 2004).

The Embraer success could be traced to a number of favourable factors such as the timing of its entry, the active patronage of state in terms of public technology procurement, tax incentives and outright subsidies. Further the technology development was actually done in a company setting and not in a laboratory where the R&D team could constantly interact with the marketing and production departments so that the designs could be adapted to the requirements of the market and the availability of key components etc. The state-owned firm, Embraer, that was created in 1969 could inherit key R&D personnel from the Brazilian Aerospace Technical Centre (CTA, the Brazilian equivalent of India's NAL). Embraer also had foreign collaboration with an Italian aeronautical firm, Alenia Aermacchi, and this helped the firm to secure state-of-the art technologies and also get its technical personnel well trained at the latter's facilities. After a series of financial crises, the firm was privatized in 1994. In subsequent years, by launching new products for the defense market, and entering the executive aviation market, Embraer significantly increased its market share, resulting in growing revenues in diversified marketplaces. It has at the end of 2009, 17.000 employees, sales across the globe (but 43 per cent of its sales are in the competitive North American market), sales revenue of about US $ 6 billion, R&D expenditure of US $ 200 million, 244 aircraft deliveries and a firm order for 1762 aircraft (Embraer 2009). The Embraer story is one of a developing country state having a clear focus and strategy and very pro active in times of difficulties in taking bold decisions etc. Compare this with NAL's experience of the state not being having any clearly articulated policy or instruments of support.

The Chinese is still another case of strategy and support by the state to nurture a high technology industry. The Chinese also have managed to have close collaborations with large foreign aerospace companies such as Airbus industries. She has now become an assembler of a certain type of Airbus commercial jets in the country. A comparison of the aerospace industry in China and India is presented in Table 4.

Table 4: The Aerospace Industry in China and India

	China	India
Aircraft manufacturing	• China is ahead of India in production of commercial aircraft and also exports to the US. China merged its two largest aircraft makers (Avtc-I and Avtc-II) to form the Aviation Industry Corp. of China. This body has emerged as a world class aircraft manufacturer with aviation products including a 150-seat jumbo jet. • China flew its first passenger ARJ21 regional jet in September 2008 and also plans to develop 150 seater mainline jets in the medium term. • China started developing turbo propelled regional aircraft Modern Ark 700 (MA 700) for the high-end international market.	• India maintains capabilities in designing and manufacturing military aircrafts (by HAL) but has been unable to establish its presence in passenger aircrafts. • Recently, CSIR approved a plan for its Bangalore aerospace lab to design an airplane that can carry 90 passengers on short flights. • NAL is also building the regional transport aircraft. India is expected to launch the first series of regional jets only in 2012 partnership with Bombardier and Embraer.
Assembly	• Airbus assembly plant in China (Airbus Tlanjin Final Assembly Company) began operations in September 2008. The new plant is expected to assemble 44 aircraft a year by 2011. • China also jointly assembles the Embraer ERJ-145 regional jet.	• India still does not have a complete assembly line set up by any global OEM though the Government is looking to set up an assembly unit for 25-60 seater turboprop aircraft in collaboration with EADS. • India plans to assemble 108 Medium Multi Role Combat Aircrafts (MMROA) out of IAF's purchase of 126 planes. • BAE Systems partnered with HAL to produce Hawk which involves assembling 11,000 components sourced by BAE Systems from UK.

Source: PWC and CII (2009), p. 59.

In fact with a significant increase in India's exports in 2008 (300 per cent over 2007), her level of aerospace exports to both Brazil and China has improved considerably (Figure 5). It is expected that this ratio will continue to improve over time in view of the new manufacturing projects that are underway.

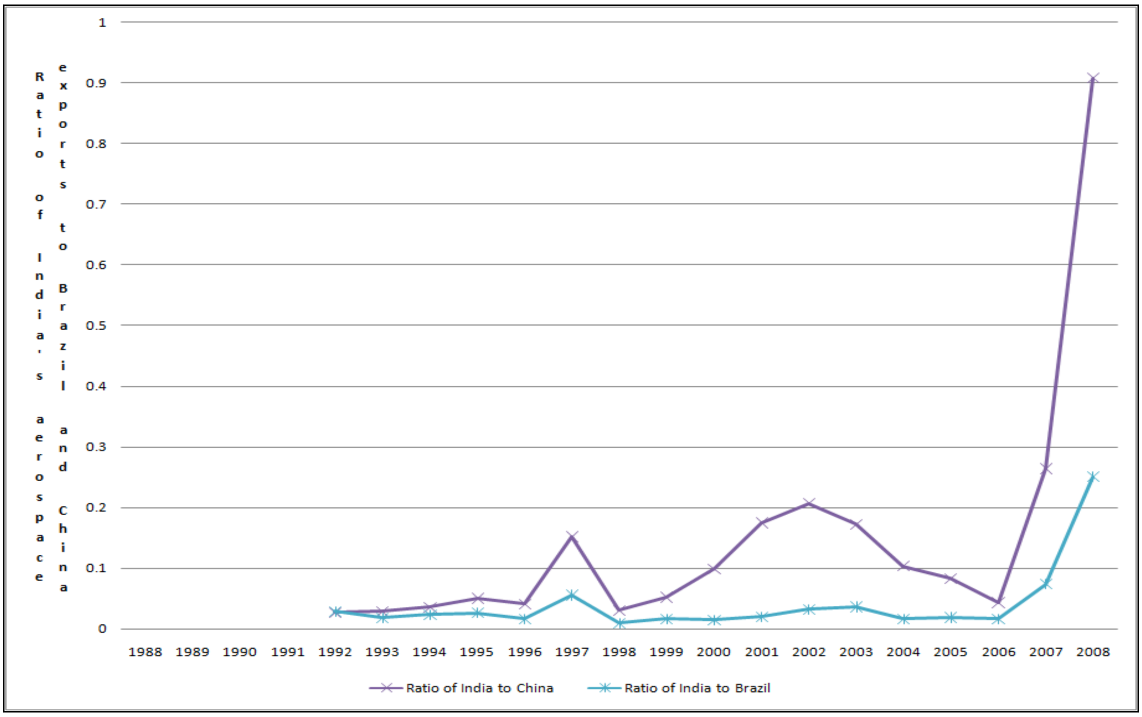


Figure 5 Ratio of India's aerospace exports to that of Brazil and China, 1992-2008

Source: Computed from UN Comtrade.

4. CONCLUSIONS

India's aerospace industry is slowly but steadily evolving from its defence focus to civilian ones. This can be seen in both its aeronautical and astronautical sectors. In the aeronautical sector, India is in the process of developing civilian aircraft which is capable of serving the regional routes- something which Brazil has accomplished several decades ago and that too with great success. Further the country has become a source of parts, components and software solutions to the International aerospace industry. The Bangalore cluster has been particularly dynamic from this point of view having been very successful in attracting two of the leading aerospace companies in the world, namely Airbus and Boeing to establish both research and manufacturing facilities in the cluster. The new policy on Special Economic Zones too have been very helpful in furthering the geographic spread of the Bangalore cluster to the periphery of the city of Bangalore thus relieving itself of the infrastructural bottlenecks that the city has now become rather notorious for.

Although India has a very clearly articulated policy and targets for the astronautical sector (see the government component of the SCI in Table 3), she does not have a clear policy for developing the aeronautical sector. The government hopes to turn this constraint into an advantage through the offset clause, mentioned in the Defence Procurement Procedure (DPP). It wishes to encourage private sector involvement, and is hoping to have $30 billion generated in offset opportunities. The effective implementation of such an offset policy can facilitate the absorption and indigenisation of foreign aeronautic technologies that accrue to the country by way of offset deals. In doing this, the government wishes to emulate the success of Brazil. Discussions with industry and an engagement with the relevant literature (Behera, 2009) shows that the government by fine tuning the offset policy can use public technology procurement as a policy instrument through which it can place the industry to a sure flight path to success. But the government seems to be too much preoccupied by the domestic aviation industry rather than the aerospace industry as such. Another area where concerted action is required is both in the quantity and quality of aerospace engineers although some efforts in this direction are already visible.

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