The flight from defence to civilian space

Evolution of the Bangalore Aerospace Cluster

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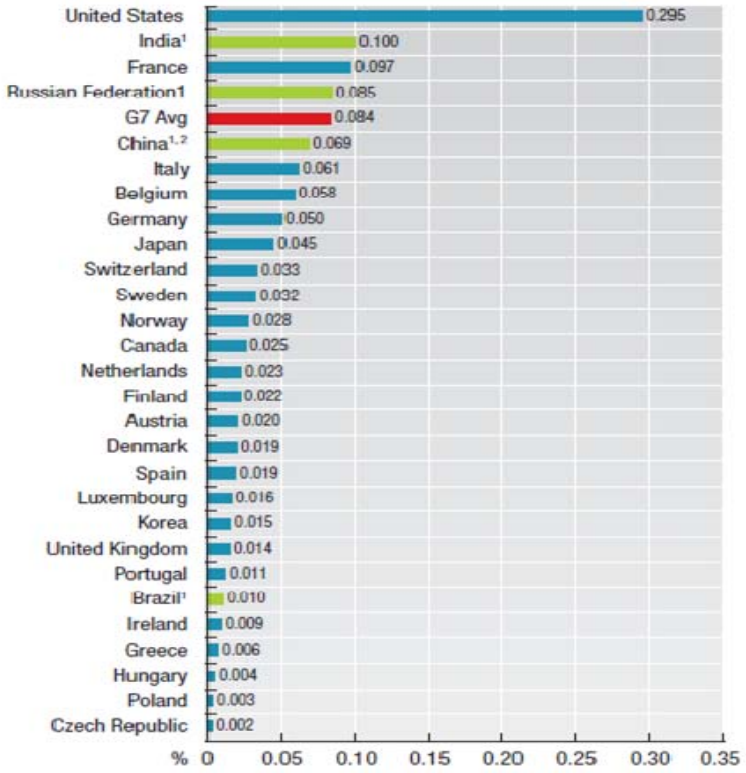
Outline

- Significance of Aerospace Industry
- Analytical Framework
- Engagement with the literature
- Three building blocks: (i) Lead Actors; (ii) Knowledge domain and development; and (iii) Demand
- Performance of India's aerospace industry
  - Inter temporal performance
  - Inter spatial performance
- Towards some policy conclusions

Significance

- 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.

India has one of highest research intensities in space



Analytical Framework

- Eclectic one by combining elements of the literature on clusters and the one on sectoral systems of innovation (SSI);
- The eclectic SSI framework identifies *three* crucial elements of the sector, namely:
  - Lead actors in the sector
  - Knowledge domain and development
  - Demand

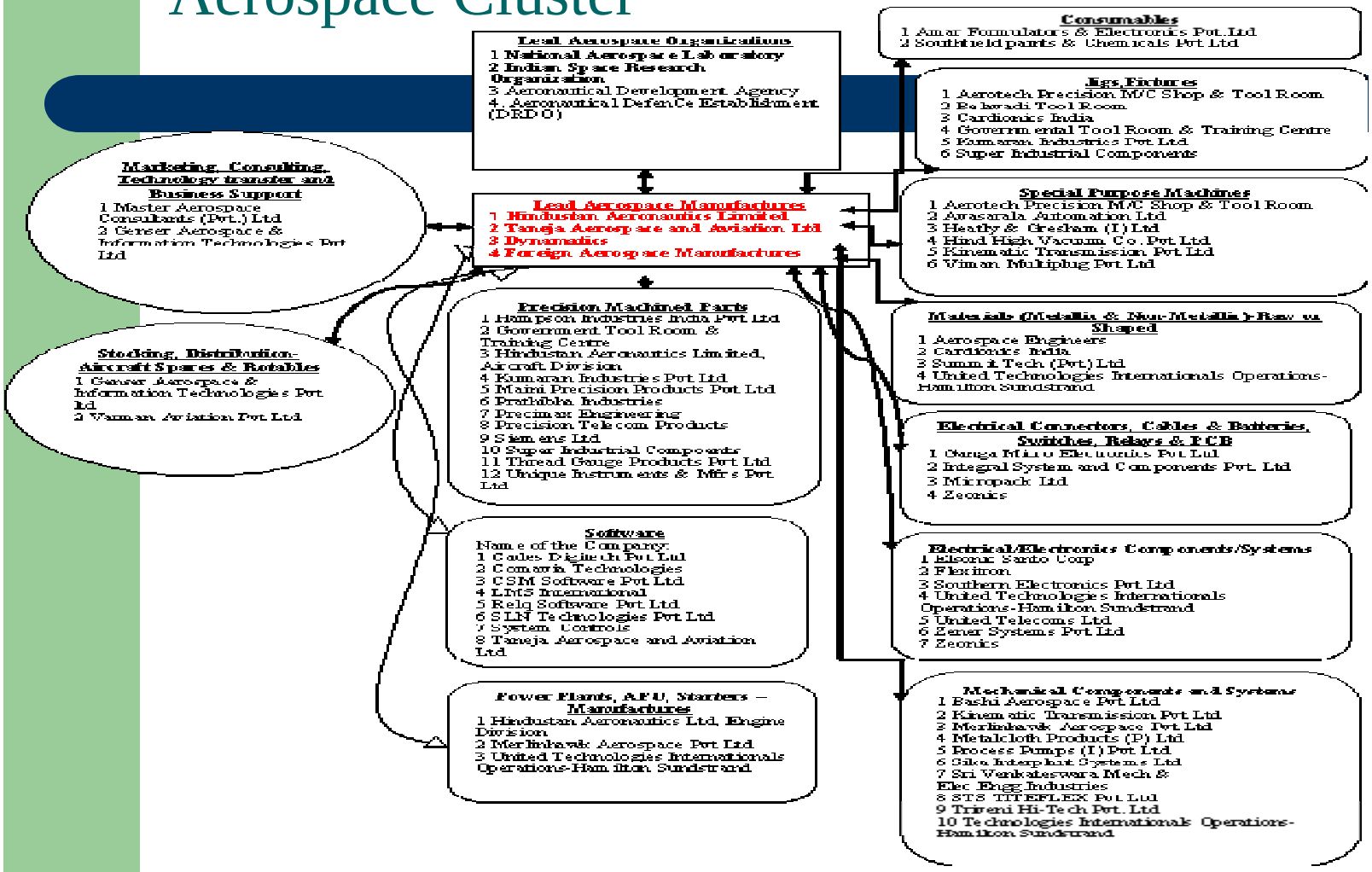
Engagement with the literature

- 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 (2007);
- 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

Building Block 1: Lead Actors within the SSI

- To identify the lead actors in the cluster, I undertake a cluster mapping. This done on the basis of information culled out from a variety of secondary source material, primarily using the membership details of the Society of Indian Aerospace Technologies and Industries (SIATI).
- The result of this exercise is presented in the following slide.

Current Structure(c2010) of the Bangalore Aerospace Cluster



Historical evolution of the aerospace sector or the BAC

Year	Major actor/policy instrument
1940	Hindustan Aircraft Limited (first aircraft company)
1942	Formation of Indian Institute of Science and Council of Scientific and Industrial Research
1948	Aeronautical Society of India established
1958	Establishment of Defence Research and Development Organization (DRDO)
1959	National Aerospace Laboratories (NAL) formed
1964	Hindustan Aeronautics Limited (HAL) formed
1969	Indian Space Research Organization (ISRO) formed
1972	Space Commission and Department of Space formed
1991	Society for Indian Aerospace Industries and Technologies (SIATI) formed
1992	Antrix Corporation formed
2001	Defence production opens to private players
2005	Offset clause added to India's Defence Procurement Procedures (DPP). The clause was elaborated further in 2006 and 2008.
2006	Defence Offsets Facilitation Agency (DOFA) formed
2009	Entry of foreign aerospace manufacturers such as Boeing and Airbus

Lead Actors in the Bangalore Aerospace Cluster (BAC)

- **Knowledge production**: Primarily for aeronautical: The National Aerospace Laboratory of the CSIR (NAL) and the R&D divisions of Hindusthan Aeronautics (HAL); Primarily for astronutics: Indian Space Research Organization(ISRO)
- **Material production (design and manufacturing)** : HAL and NAL
- **Capacity building** : Department of Aerospace Engineering, Indian Institute of Science

NAL

- Leading aerospace lab within the CSIR network;
- Established in 1959 to provide scientific support to the [redacted] its mandate in 1997 to '*development of aerospace technologies with strong science content with a view to their practical application to the design of flight vehicles and to use this general aerospace technology base for general industrial applications*' ;
- It has 23 divisions and very good infrastructural facilities;

NAL

- It is India's only civilian aerospace laboratory and has made significant contributions to a large number of aerospace programmes like aircraft (civil and military), space, engine development, defense and strategic programmes;
- NAL is an acknowledged centre of excellence in fields like composite structures, high speed wind tunnel testing, aircraft fatigue and aerospace acoustics, failure analysis and accident investigation;
- It has also successfully executed some innovative research projects in advanced topics like smart materials, parallel processing, advanced flow diagnostics, airport instrumentation etc; and
- NAL has been instrumental in the development of HANSA and SARAS aircrafts.

NAL knowledge production and transfer

- The lab does not have either a good patent record during the five year period 2002-03 through 2006-07 for which data are available. For instance during this five year period it has applied for 230 patents (21 in India and 9 abroad). Of these 30 patents filed, 22 were filed from 8 out of 456 completed research projects during the period and the remaining 8 were based on projects completed before April 2002. Therefore, during 2002-07, only two per cent of the completed projects yielded any patents;
- It has, of course, a good publication record.
- What is most worrying is its success in transferring and commercialising technologies developed by it.
- In a random sample of 146 projects that were analysed in depth, NAL could develop transferable technologies only in the case of 75 projects and out of this, only 25 (one third) was actually transferred to the end users. Of these 25, only 1 could actually be commercialised.
- In other words, its knowledge level interactions within the cluster or elsewhere was very low and this is further substantiated by a more quantitative assessment of this issue.

NAL's inter action within the Bangalore Aerospace Cluster (Rs in Millions)

	Funds received through external interaction	Total external cash flow	Total budget	IR1	IR2
2002-03	1.9	288	945.2	0.0066	0.0020
2003-04	1.1	334.5	1042.8	0.0033	0.0011
2004-05	1.8	277.4	1088.1	0.0065	0.0017
2005-06	3.1	305.80	1377.7	0.0101	0.0023
2006-07	3.4	336.90	1573.2	0.0101	0.0022

Distribution of ISRO's centres within India

ISRO

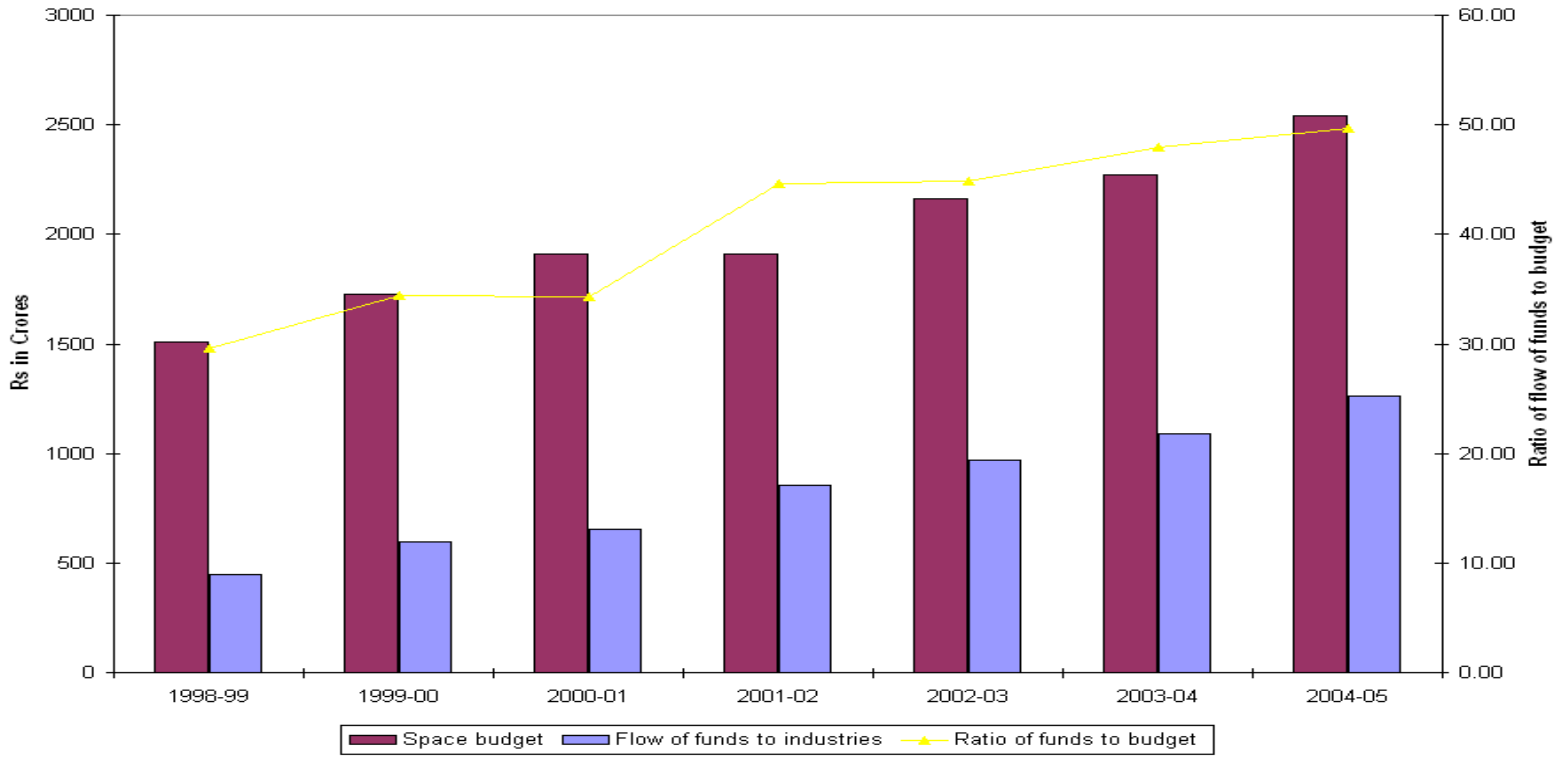
- Established in 1969
- Does both knowledge production and material production
- Government has placed much emphasis on space research (see next slide) by devoting significant budgets to it
- Has clearly demonstrated capability in *four* different areas: (a) earth observations (CARTO series); (b) satellite communications and navigation (INSAT series); (c) space science and environment (Chandarayan 1 and 2) ; and (d) launch vehicles (PSLV, GSLV)

Trends in public budget on space research in India

(Values are in Rs Crores)

	Public budget on space research	Growth Rate	GDP	Share (%)
1998-99	1511		1616082	0.09
1999-00	1726	14.22	1786526	0.10
2000-01	1909	10.58	1925017	0.10
2001-02	1909	0.04	2097726	0.09
2002-03	2164	13.33	2261415	0.10
2003-04	2274	5.10	2538170	0.09
2004-05	2540	11.69	2877701	0.09
2005-06	2675	5.31	3282386	0.08
2006-07	2997	12.04	3779384	0.08
2007-08	3290	9.78	4320892	0.08
2008-09	4074	23.83	4933183	0.08
2009-10	4167	2.28		
2010-11*	5778	38.66		

ISRO-Interactions with the industrial sector



HAL

- Hindustan Aeronautics Limited (HAL) has evolved into a large Aeronautics Complex.
- It has built up comprehensive skills in design, manufacture and overhaul of Fighters, Trainers, Helicopters, Transport Aircraft, Engines, Avionics and System Equipmen;
- . Its manufacturingtrack record consists of 11 types of aircraft from in-house R&D and 14 types of licenced production inclusive of 8 types of aero engines and over 900 items of Aircraft System Equipment (Avionics, Mechanical, Electrical).
- By 2005-06, the firm has produced around 3400 aircraft, 3600 aero engines and overhauled around 8320 aircraft & 27800 engines

- **Bangalore Complex** : Comprises 7 Production Divisions and 1 R&D centre situated in Bangalore for manufacture and overhaul of Western & Indigenous aircraft.
- **Design Complex** : Comprises 3 R&D Centres in Bangalore for indigenous development of aircraft, helicopters, small engines and engine test beds. Helicopter production Division at Bangalore also forms part of Design Complex.

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

Building Block 2: Knowledge domain

- The cluster up to the 1980 focused largely on defence related projects;
- In the late 1980s took up the design and manufacture of two different types of civilian aircraft, the HANSA and SARAS –both primary at the NAL.

HANSA

HANSA project

- 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.

HANSA continued

- 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.

What can we infer from HANSA case?

- NAL does not appear to have done a systematic project preparation in terms of first assessing the market for this technology;
- Keeping a tab on both the time and cost of the project and in developing an indigenous vendor network

- 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.*

SARAS

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.

(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 learnt 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

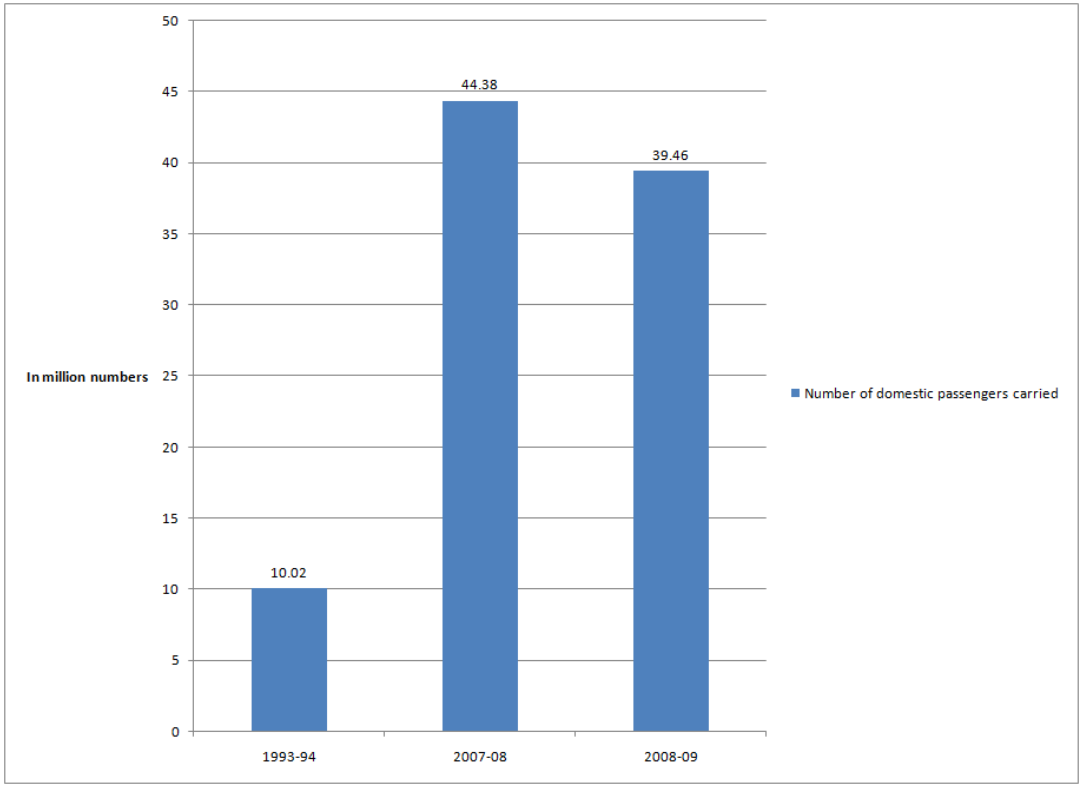
Building block 3: Demand

- This is where the two components, aeronautical and astronautic differ.
- In the case of aeronautical, the demand, especially for civilian aircraft of an indigenous design and manufacture is extremely limited and that too only for smaller aircraft; However there is demand for components not only from the domestic defence area but also from foreign aerospace firms;
- A fillip to this demand has been the offset policy in especially defence purchases.
- Offset clause added to India's Defence Procurement Procedures (DPP). The clause was elaborated further in 2006 and 2008.

Building block 3: Potential effect of Offset policy elaborated

- The new offset clause introduced for the first time in 2005 and elaborated in 2006 and 2008 stipulates a minimum 30 percent plough back of foreign outflows from defence procurement into the Indian defence industry for all contracts above Rs 3 billion.
- This policy allows foreign vendors to choose their Indian offset partner, private or public;
- PWC- CII (2009) estimates that the combined offsets could translate into an opportunity of between USD40 to 50 billion for the Indian market over the next 20 years;
- For example, the purchase of 126 medium multi-role combat aircrafts by the Indian Air Force will result in a potential offset opportunity in excess of USD5 billion;
- Though a formal civil offset policy is still being developed, players like Air India have already taken a lead in this direction by entering into an agreement with Boeing with a 50 percent offset obligation (allowing indirect offsets also);
- These policies will create an opportunity for Indian manufacturers to enter the high tech arena of aerospace manufacturing with its stringent requirements for safety, quality control and precision

Building block 3: Growth of the civil aviation market in India(based on domestic passengers carried in million numbers)



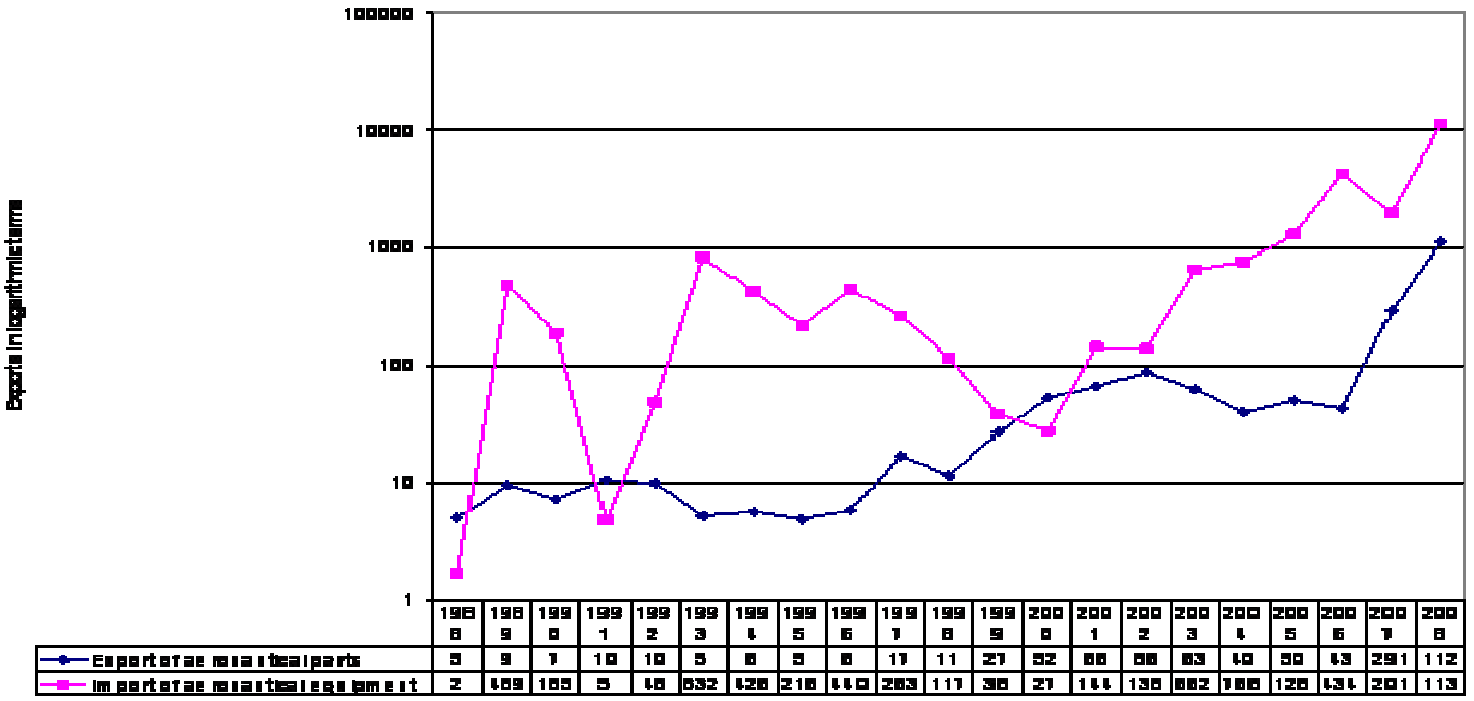
Building block 3: Demand in the case of astronautics

- In this case since knowledge and material production were happening in the same entity (more or less), demand was never a problem. So the demand is from domestic sources and it could easily been foreseen.

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

Relationship between imports of aeronautical equipments and exports of aeronautical parts, 1988-2008



	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Exports of aeronautical parts	5	9	7	10	10	5	6	5	6	17	11	27	52	66	66	83	40	50	63	291	112
Imports of aeronautical equipment	2	489	105	5	46	632	626	210	440	203	117	36	27	144	136	882	766	126	434	201	113

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)

Inter-spatial comparison: Brazil's Embraer case

- 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 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.

Towards some 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.

Conclusions (Continued)

- 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 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 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.