DEVELOPMENT OF THE AEROSPACE INDUSTRY IN US AND USSR/RUSSIA

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INTRODUCTION

Research efforts into the science of fluid dynamics by the Europeans such as Otto Lilienthal, Sir George Cayley and Daniel Bernoulli, amongst others, led to the development of the science behind aviation[1]. This science led to less scholarly but more technically and mechanically minded men attempting to apply the new theory to practice towards the development of mankind's first heavier than air flying machines, capable of carrying human beings aloft[2]. These efforts bore fruit with the Wright Brothers' flight of 12 seconds duration over 120 ft on December 17, 1903, at Kitty Hawk, in Flyer 1, ushering in the aviation age.[3]

US AEROSPACE INDUSTRY

The US stole a lead over Europe in conducting the first documented flight of a heavier than air aircraft despite the theory behind heavier than air flight being primarily European in origin. Inadequate investment and lack

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1. Johan Hoffman, Johan Jansson and Claes Johnson, "The Secret of Flight", pp.293-330, http://www.csc.kth.se/~cgjoh/ambsflying.pdf. Accessed on June 24, 2015.
2. Ibid., pp.295-330.
3. Eyewitness to History.com, "The Wright Brothers First Flight, 1903", http://www.eyewitnesstohistory.com/wright.htm. Accessed on June 21, 2015.

The active involvement of private companies that were the driving force behind these achievements can be attributed in part to their attempts to win government support, including funding, and to obtain firm orders for their aircraft designs from potential customers.

of government support for aviation in the US[4] thereafter resulted in Europe regaining the lead towards newer developments and advancements in aircraft technology, spurred on, as the Europeans then were, by the pressing demands and necessities of total war during World War I. In 1913, the US Army Air Corps (USAAC) had just six active pilots and the whole of the US had less than 170. When the US started its active participation in World War I in Europe, American pilots flew primarily British and French designed and built aircraft due to the lack of suitable high performance American aircraft.[5]

Development of US Aviation Companies

Not forced to divert resources towards the war on the scale that the Europeans were, US *private entrepreneur promoted companies* (emphasis intended), led by Glen Hammond Curtis, James Smith McDonnell, and Donald Wills Douglas,[6] amongst others, established the US industry on its own feet, leading to landmark achievements such as the first trans-Atlantic flight by the US Navy flying boat NC4 and the first trans-global flight by the Douglas world cruisers.[7]

These achievements were also spurred on by the demands of the US government and military for ever more capable aircraft to be designed and built for specific national requirements. The active involvement of private companies that were the driving force behind these achievements can be attributed in part to their attempts to win government support, including

4. what-when-how.com, "Aerospace Industry, US", http://what-when-how.com/flight/aerospace-industry-u-s/. Accessed on June 23, 2015.
5. Geaviation.com, "Aviation History", http://www.geaviation.com/company/aviation-history.html. Accessed on June 22, 2015.
6. Information from web page http://en.wikipedia.org/wiki/McDonnell_Douglas. Last accessed on September 3, 2015.
7. Air Mrshl SR Deshpande, *Aerospace Industry* (New Delhi: Manas Publications, 2004), pp. 25-28.

funding, and to obtain firm orders for their aircraft designs from potential customers. Throughout the process of carrying out ever longer duration flights, the potential military applications of the technologies and techniques being developed were not lost on the US government and its armed forces. The wide publicity accorded to the new records being set in aviation also led to a situation of ever more aircraft design and building companies being started by skilled entrepreneurs.

In the early years of modern aviation, aircraft design and construction was considered more of an art and skill than a science. This view was supported by the large number of aircraft manufacturing companies that came up in the US in the early 20th century, despite a total lack of any specific formal training for aircraft design and construction at the time.

In the early years of modern aviation, aircraft design and construction was considered more of an art and skill than a science. This view was supported by the large number of aircraft manufacturing companies that came up in the US in the early 20th century, despite a total lack of any specific formal training for aircraft design and construction at the time. What almost all these companies had in common was that they were established, and led, in the most part, by brilliant designers who included such famous names as Jack Northrop, who established the Northrop Corporation in 1939, the brothers Allan and Malcom Loughhead, who later changed their family name to Lockheed and founded the Loughhead Aircraft Manufacturing Company, later called the Lockheed Corporation, Glen Hammond Curtiss, founder of the Curtiss-Wright Corporation, James Smith McDonnell and Donald Wills Douglas, founders of the McDonnell Aircraft Corporation, and Douglas Aircraft Company respectively, to name a few.

General Electric (GE) Corporation in the US responded to a US government requirement and contract from the US National Advisory Committee on Aeronautics (NACA) for the development of a turbocharger for aircraft engine application in 1915-17; the successful demonstration of the

GE turbocharger device saw it being utilised from 1918 onwards to improve altitude performance of existing aero-engines in the USAAC inventory.[8] From this humble beginning, GE went on to develop ever more capable power plants for aviation applications. Towards the end of World War II, it became clear that the US was lagging behind England and Germany in engine technology as both these countries had already deployed jet engines in service while the US still utilised high performance piston engines. GE thereafter successfully made the transition from piston engines to jet engines, with the help of some friendly access to British technology provided by the British government, and continues to make cutting edge jet engines for civil as well as military applications even today.[9] Alongside Pratt and Whitney, GE is one of only two[10] designers and manufacturers of high performance jet engines in the US today.[11] More than half of the US led coalition aircraft deployed in "Operation Desert Storm", for the Gulf War of 1991, flew with GE engines.[12] In 2003, as many as 80 percent of US led coalition aircraft deployed for "Operation Iraqi Freedom" used GE engines.[13]

The American aircraft industry started to develop through private entrepreneurs building aircraft to meet the US Army's military requirements initially for primarily scout or reconnaissance machines. Military requirements slowly expanded to include fighter, bomber, and transport aircraft also. The Wright Brothers, despite their much touted first flight, were unable to compete effectively and other designers took the lead in designing and building practical machines that were usable in real world conditions. The commencement of World War I, soon after the invention of the aircraft, led to the output of aircraft from American aircraft factories

8. Kimble D. McCutcheon, "The First Turbosupercharged US Aircraft Engine", http://www.enginehistory.org/superchargers.shtml. Accessed on July 1, 2015.
9. Geaviation.com , n.2..
10. Modern jet engines continue to be very difficult technology to master. Despite decades of experience, the US has just two high performance jet engine makers, GE and Pratt & Whitney; Western Europe too had just two: Rolls Royce and SNECMA. The USSR/ Russia have Saturn NPO, Klimov, Turmansky, Kuznetsov, Soloviev and Lyulka.
11. Nish Amarnath, "World's Top 3 Jet Engine Makers Exploit Booming Airline Market", *International Business Times*, July 10, 2012, http://www.ibntimes.com/worlds-top-3-jet-engine-makers-exploit-booming-airline-market-722046. Accessed on June 27, 2015.
12. n.2.
13. Ibid.

increasing rapidly. However, the lack of cutting edge performance from these aircraft resulted in the American World War I pilots who took part in operations against Germany, flying French and British designed and built aircraft. The American designed and built aircraft did help to widely popularise aviation as a viable activity and also served effectively in the pilot training role, especially in the years after World War I.[14] The large scale production of these aircraft helped build up the capabilities of American aircraft companies in manufacturing skills and also led to the development of several innovations that helped establish a few companies firmly in the aircraft design and building field. The transition of viewing aircraft design and manufacture as a science and not an art or craft commenced in the 1920s and was supported by Research and Development (R&D) establishments in the US and in Europe.[15]

Designers such as Curtiss designed and built effective light aircraft that were adapted to the air-to-air fighter aircraft role. The worth of military aviation was proved during World War I and the importance of military aviation was pushed further by aviation champions such as Brig Giulio Douhet in Italy, Brig "Billy" Mitchell in the US, and Air Mshl Hugh Trenchard in Britain, amongst others. In the years leading up to World War II, US aircraft companies such as Boeing, Lockheed, Douglas, McDonnell, North American, and Grumman established themselves as major operators in the designing and building of aircraft. These companies, despite the slow and steady growth of civil aviation, relied primarily on military orders for their sales volumes and financial survival.[16] In fact, a few of these US aviation firms dealt almost exclusively with the military[17].

Several of these American aircraft firms established in the early years of the 20th century are in operation even today, close to a century later. The aviation innovator, the company set up by the Wright Brothers, failed to compete effectively. Companies such as Boeing, and Lockheed, etc. moved

14. Ibid. what-when-how.com, "Aerospace Industry, US", http://what-when-how.com/flight/aerospace-industry-u-s/.Accessed on June 23, 2015.
15. Rosa Maria Moller, Ph.D, "Aerospace States' Incentives to Attract the Industry", California Research Bureau (CRB) 08-005, May 2008, California Research Bureau, California State Library.
16. n.4.
17. Ibid.

ahead while the Wright Brothers' company was bought out a few years later by the Curtiss Aeroplane and Motor Company to form the Curtiss-Wright Corporation. Later entrants were able to build up a strong foundation on the errors and learning of the early entrants and innovators to build up viable capabilities at sustainable cost-profit ratios and, thus, build technologically and economically viable businesses that have stood the test of time and are viable, going concerns, even today, a century later.

The interest of the US military in an effective aviation arm led to demands for greater performance and ruggedness from new military aircraft. The large number of aircraft manufacturers promoted competition to win the lucrative military contracts. Heavy investment was required in R&D of new materials, design and construction techniques and component parts and technologies. By the beginning of World War II, the US had a robust aircraft industry that was turning out a large number of aircraft for different requirements. While the American aircraft lacked in pure performance over their European and Asian counterparts such as the British Spitfire, the German Messerschmitt Me-109, and the Japanese Mitsubishi A6M "Zero"[18], in the early years of World War II, the US, backed by its massive resources, maintained an advantage in numbers to enable it to hold its own till it could catch up technologically. The later introduction of the US Lockheed P-38 "Lightning" and the North American P-51 "Mustang" gave the US military fighter aircraft that could outperform any aircraft produced in England, Germany, the Soviet Union, and Japan. In 1944, there were 300 companies operating in the aircraft and aircraft component supply business, with 66 aircraft building plants in the US, employing 1.6 million workers. A mere year later, there were just 15 companies with a total of 16 plants and 138,700 employees[19]!

The post World War II years saw an inevitable scaling down of production of aircraft, putting the US aircraft industry through a stressful

18. Larry Dwyer, "Mitsubishi A6M Reisen (Zero-Sen)", http://www.aviation-history.com/mitsubishi/zero.html. Accessed on July 3, 2015.
19. Jorge Niosi, in his presentation at the DIME / Catching Up Conference, Milan, December 10-11, 2009.

period. The earlier investments in large production facilities for the large war-time production orders led to idle facilities and underemployed or unemployed skilled workers with major aircraft manufacturers in the post war years. This situation was mitigated by the commencement of the Cold War. The Cold War forced the US to develop and build military hardware on a scale that, though not as massive as during World War II, was still quite respectable. The Soviet Union, the US' rival during the Cold War, had an advantage over the US and its allied forces in numbers, backed by an industrial philosophy of rapid construction of very large numbers of relatively simple and rugged machines. The US government relied upon advanced technology to counter the Soviet Union's larger numerical strength. This requirement led to the US military demanding very advanced performance from the aircraft designers in the US. Such demands led to expensive and intense R&D effort into new cutting edge technologies by US aircraft companies. The performance of the resultant aircraft exceeded anything built hitherfore, though these, at times, fell short of the most demanding US military requirements in performance. Cases of the initial performance parameters of aircraft not fully meeting the requirements of the US military led to a planned programme of progressive and continuous improvements being initiated, in consultation and agreement with the US end user, the US Air Force (USAF). This process involved induction into service of the baseline aircraft. Then, in a planned manner, these inducted aircraft were to be upgraded, as and when the required fixes for performance shortfalls became available, to reach, in a progressive manner, the final performance demanded by the USAF. Through initiating a steady process of incorporating improvements in the concerned aircraft, the needs for high performance were met while keeping the R&D, design and production expertise and skills intact. The financial future of the aircraft and component parts manufacturers was also protected through adoption of this system, especially as the US establishment realised that these personnel and facilities would be required in the future also and so it had a vested interest in ensuring their survival. The cutting edge nature of the aircraft, which consistently incorporated several new,

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very advanced, and unique, 'nice to have' technologies, produced by the US in the second half of the 20th century, resulted in an exponential increase in the cost of these machines. The high costs were exacerbated by the aviation companies' practice of paying their personnel extremely high salaries and bonuses in appreciation of the efforts put in by them. A quick look at the average salaries in the US' aerospace and defence industry follows later in this paper. These problems of ever increasing costs of developing and manufacturing aircraft and associated equipment led in time to the government putting in place a system to monitor the companies more closely, with an aim of controlling the spiralling costs of equipment. The risk for most aircraft companies now became the fear of political considerations leading to project cancellations after large sums of money had been spent on R&D for a project. Availability of the best research facilities and brains to the aircraft companies meant that technological challenges were less of a problem in most cases.[20] The major pressures on aircraft and associated technology companies now became not the development of the aircraft or weapon system with the required performance, but obtaining an adequately large production run to recoup the development costs and to obtain the desired profits. This requirement came at a time when the US military started placing orders for significantly fewer numbers than it had earlier.[21] The US order numbers reduction was a function of more capable aircraft being able to do more, thus, lesser numbers being able to deliver the results required, and the effects of higher prices per unit in a time of inelastic procurement budgets.[22] US aircraft companies were,

20. Ibid.
21. Ibid.
22. Ibid.

thus, forced to look for export orders to retain profitability. The fact that the US government was reluctant to allow unfettered exports of advanced American weaponry due to the security implications of the latest American weapons falling into the hands of the Soviets meant that even exports required a number of government clearances. Several US aircraft companies resorted to underhand methods to obtain export orders. Notably, Lockheed Corporation is known to have indulged in widespread bribery both in the US and abroad in order to win adequate export orders for its F-104 "Starfighter" fighter aircraft[23].The Northrop Corporation was similarly cited for having resorted to bribery to obtain sales for its F-5 "Tiger" fighter.[24] Boeing was infamously involved in a major domestic scandal when a former Pentagon official, Ms. Darleen A. Druyun, who oversaw contracts worth $23 billion for In-Flight Refuelling (IFR) aircraft being awarded to Boeing, was hired by the company after she retired from her government job, at very high compensation, as an apparent pay-off for earlier favours concerned with the Pentagon's procurement contracts.[25] The desperation to secure sales and stay afloat in an expensive business comes through very clearly in these publicly known cases of the largest and most 'respectable' US aerospace companies having been involved in major unethical activities.

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World War II had showcased the importance of rocket technology in modern warfare. Hence, the US military, in the post World War II years, started to devote considerable effort in rocket development, with contracts for development of effective long range rockets being issued to companies

23. W.H.Hartung, *Prophets of War* (New York: Nation Books, 2012), pp.131-132.
24. n.14.
25. Jerry Markon and Renae Merle, "Ex-Boeing CFO Pleads Guilty in Druyun Case", *Washington Post*, Tuesday, November 16, 2004; page E01, http://www.washingtonpost.com/wp-dyn/articles/A51778-2004Nov15.html. Accessed on July 4, 2015.

involved till that time in aircraft design and production. While rockets were developed for use as surface–to-surface ballistic missiles, their utilisation to access outer space began to be debated. Theorists also examined the potential national security utilisation of space and the new term "aerospace" came to be coined as an amalgamation of air and space technology and operation. The rocket development effort was helped in large measure by the US capture of significant German personnel and documentation on rocket technology, and several German war-time rockets of various types, including the liquid fuelled 500 mile range ballistic trajectory Nazi V-2 weapon, for examination and reverse engineering. In the early years, the Soviet Union was able to steal a lead over the US, as demonstrated by its being the first to put an artificial Earth satellite into orbit in 1957[26] followed by the first human being to go into space in 1961.[27] In response, the US launched a massive focussed space technology development programme. Expertise was rapidly built up and the aerospace industry emerged from the earlier aircraft industry.[28] At first, government contracts to different suppliers obtained different major parts of aerospace systems for assembly at government controlled facilities. Later, single point orders were given to one major aerospace company. This company would then order sub-parts from sub-contractors, assemble the final product and deliver it to the arm of the government that had ordered the item in the first place. This latter system proved to be more efficient and practical in terms of costs incurred as well as the quality of the product and on time delivery. The prime contractor or assembler carried overall responsibility to the ordering agency for all aspects, including managing the sub-contractors.[29] Over time, this system has come to be adopted by ever increasing parts of the US aerospace industry. The first US programme to use this system was the Minuteman missile project that used Boeing as the

26. Nasa.gov, "Sputnik and the Dawn of the Space Age" ,http://history.nasa.gov/sputnik/. Accessed on August 20, 2015.
27. Nola Taylor Redd and Robert Roy Britt, "Yuri Gagarin: First Man in Space: The Greatest Moments in Flight", http://www.space.com/16159-first-man-in-space.html. Accessed on August 20, 2015.
28. n.14.
29. Ibid.

prime contractor.[30] From the 1950s, the major US aircraft companies had started to steadily increase the share of missiles in their business portfolio from a paltry 5 per cent to 44 per cent by 1960.[31]

Civil aviation also played a major role in the US aerospace industry's development. This sector was spurred on by the newly affluent US population's desire for air transport services. McDonnell Douglas, Boeing and Lockheed were the most active airliner builders in the US. Financial woes forced McDonnell Douglas to be bought out by Boeing. Problems with the L-1011 Tri-Star and Electra aircraft at the same time as issues were being faced with military aircraft developments such as the C-5 "Galaxy" heavy transport aircraft forced Lockheed to abandon its airliner business, in large part due to the support available to the military business from the USAF and Pentagon, with no such support available in the civil field, and concentrate only on military aircraft.[32]

Government Influence and Support to US Aerospace Industry

The US government realised the importance of aviation technology for the prosperity and security of the country quite early and, as a result, in 1915, established the NACA. The NACA was tasked to explore the science behind aviation with the aim of discovering new insights that could benefit American aviation. Research and developments by the NACA were the property of the US government. However, these were made available either free or at very nominal cost to US aircraft companies. Some noteworthy early contributions from the NACA included streamlined shapes to reduce drag, aerofoil sections for various applications, optimum engine nacelle design, etc.[33] This enabled the aircraft companies to capitalise on the development R&D effort put in by the US government for practical application. In this manner, the US government fully supported its national aviation industry. After World War II, the NACA developed designs for supersonic flight and

30. n.14.
31. Ibid.
32. Hartung, n.23.
33. Elizabeth Suckow, "National Aeronautics and Space Administration, History", last updated on April 23, 2009 http://history.nasa.gov/naca/overview.html. Accessed on July 2, 2015.

was involved in the design of the X-1 that carried 'Chuck' Yeager to speeds beyond Mach 1.0. The area rule concept was also a contribution of NACA R&D.[34] In 1958, the NACA was reorganised as the National Aeronautics and Space Administration (NASA) and all the responsibilities of the NACA, in addition to space research and exploration fell under the ambit of the new organisation.[35] The trend of the US government carrying out or sponsoring high end scientific research in aerospace science and technology, and making the results available to its private sector aerospace companies, continues even till date. In a capitalist country and economy, this is a rare example of institutionalised state support to private industry. The apparent incongruity of the US government's support to private industry becomes easier to understand in the context of the US' clear understanding that its domestic aerospace industry is an essential component of its national power in the economic, military and technological domains and, hence, essential for the country to maintain its relevance and prime position on the global stage.

The US aerospace industry comprised 2.8 percent of the US manufacturing workforce in year 2008. The aerospace industry contributed $57.7 billion to the US trade balance, with aerospace exports to Europe and other allies globally totalling up to $ 95 billion in the year 2008.[36] In the year 2008, the US aerospace industry accounted for 1.4 percent of the US Gross Domestic Product (GDP) compared to 1.5 percent in the year 2000 and 1.7 percent in the late 1990s.[37] US aerospace manufacturers depend heavily on exports for their sales.[38]

Attraction for Skilled Workforce

The US aerospace industry has been built upon the base of a highly educated and suitably skilled workforce.[39] These basic skills and knowledge built

34. Ibid.
35. Ibid.
36. Michaela D. Platzer, "US Aerospace Manufacturing Industry Overview and Prospects", Congressional Research Service, 7-5700, December 3, 2009, www.crs.gov, R40967. Accessed on July 5, 2015.
37. Ibid.
38. Ibid.
39. Deloitte, "The Aerospace and Defense Industry in the US: A Financial and Economic Impact Study", http://www.aia-aerospace.org/assets/deloitte_study_2012.pdf. Accessed on June 28, 2015.

up in the population have enabled the US to develop and build a robust aerospace industry that for several decades has enabled its participants to earn wages well above the national average.[40] The high wages earned by aerospace industry workers have helped set up a cycle of these well-paying jobs, motivating more people to build up the knowledge and skills required to enter the industry as effective participants. The US aerospace industry employed 458,525 people in the year 2005, increasing to 480,668 people in the year 2010.[41] The US aerospace and defence industry directly employed 1.005 million people in the year 2005 and 1.05 million people in the year 2010.[42] The total aerospace and defence industry payroll in the year 2010 in the US amounted to $84.2 billion and the average wages in the aerospace and defence sector were $80,175 in the year 2010 when the average national wage in the US was $ 44,410.[43] The large numbers of people employed in the aerospace and defence industry and the total payroll of these personnel helps bring out the importance of this industry for the security and economy of the US. The fact that the robust US aerospace and defence industry had sales revenue in the year 2010 of $324 billion[44] brings out that the aerospace industry can contribute considerably to the GDP of a country. In the year 2010, the US aerospace and defence industry contributed foreign sales, hence, exports, of $89.6 billion.[45]

US Government Support for Development of a Viable Aviation Industry

The US government has, at times, actively supported the private aerospace companies apparently to encourage healthy competition among these for government and private contracts. The apparent aim has been to pit one company against another to develop advanced cutting edge capabilities for the US military. The US also often carried out development programmes that involved government funding for R&D activities in private companies. Depending upon the circumstances, a few of these deals involved the

40. Ibid.
41. Ibid.
42. Ibid.
43. Ibid.
44. Ibid.
45. Ibid.

The US government utilised a wide variety of means to encourage cutting edge R&D to enable its armed forces to field the very latest and futuristic aerospace equipment. The US set up the Defence Advanced Research Projects Agency (DARPA) in 1958 to specifically explore new technological concepts and to oversee their development and operationalisation in concert with US institutes of higher learning, government owned facilities and private industry.

government bearing all costs of the R&D while, at other times, the government and the concerned private companies shared the costs and risks in a pre-determined ratio, and, at times, the private company bore the entire cost of R&D, apparently with the surety that if the technology proved successful, the company would have assured orders in a near monopolistic situation, with attendant high profits.

In the 1970s, in view of the Vietnam War experience, the USAF came up with a requirement for a Light Weight Fighter (LWF) able to engage, and win against, the latest Soviet fighters exemplified by the Soviet MiG-19, MiG-21 and their successors. The LWF programme saw the Northrop Corporation entering its YF-17 "Cobra" design against the General Dynamics YF-16. The USAF chose the YF-16 as the winner and this aircraft entered USAF service as the F-16 "Fighting Falcon". The YF-17 was later developed by Northrop, in close collaboration with McDonnell Douglas Corporation, for aircraft carrier-based use as the F/A-18 "Hornet" in the US Navy (USN) service and with the US Marine Corps (USMC). The Fifth Generation Fighter (FGF) competition, called the Advanced Tactical Fighter (ATF) programme in the US, to develop a new fighter able to defeat the Soviet SU-27 and MiG-29 then under development, saw both Boeing and Lockheed competing through developing their own concepts for a high performance Low Observable (LO) fighter, the YF-23 and YF-22 respectively. After evaluation by the USAF, the Lockheed entry, the YF-22, was chosen to enter USAF service as the F-22 "Raptor". Thus, the US government utilised a wide variety of means to encourage cutting edge R&D to enable its armed forces to field the very latest and futuristic

aerospace equipment. The US set up the Defence Advanced Research Projects Agency (DARPA) in 1958 to specifically explore new technological concepts and to oversee their development and operationalisation in concert with US institutes of higher learning, government owned facilities and private industry. This model is of interest in view of the obvious results that it has delivered over the past several decades. On examining any discrete time block since the advent of aerospace technology, the US is seen to possess higher capabilities than any other nation state or alliance in the aerospace field. In later years, the striking similarity of new technology and knowhow used on aircraft from different manufacturers in the US also indicates the dissemination of advanced knowledge from a central source to many operators. The General Dynamics YF-16 and McDonnell Douglas YF-17 demonstrator aircraft taking part in the USAF Light Weight Fighter (LWF) competition both featured the then new technology of sharp Leading Edge (wing) Root Extensions (LERX) and highly blended wing fuselage design, pointing towards the benefits of such features having been proven by a central research agency and shared for actual implementation with aircraft design and building companies, in view of the fact that the chances of separate entities, working in widely separated locations, coming out with such similar new design features at the same time, are quite remote. In fact, the US system of tasking two separate companies to develop prototypes for a new weapon system and then going for a face-off / fly-off to select the better or more suitable weapon system commenced in the years after World War II, and continued till very recently when the prohibitive costs and losses incurred by the company that failed to qualify for a firm contract made it no longer feasible. The Joint Strike Fighter (JSF) F-35 "Lightning-II" project did not see two competing designs being evaluated, as the cost of R&D was seen to have risen to the extent

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that the loser in such a competition would be forced to declare bankruptcy and close shop. Hence, a single vendor situation was accepted as the only option. NASA, however, still remains engaged in high end R&D alongside DARPA to conceive of, and promote, development of the next generation of equipment for aerospace applications in pursuit of the US' national security. The US model described above could find application in other countries.

The US government has been remarkably tolerant of failures, time and cost overruns in advanced weapon system development projects. This is despite at least some information on cost and time overruns leaking to the media and receiving wide publicity, and undergoing scrutiny by US civil society as well as groups with vested interests, not the least of which is the political opposition in the US legislature and civil society led by a number of Non-Governmental Organisations (NGOs).

Recent trends in the aerospace industry, not just in the US, but elsewhere also include what could be called the 'merger mania' at both prime contractor and component supplier levels.[46] Thus, since the 1990s, Boeing bought out McDonnell Douglas while Martin of Marietta merged with Lockheed Corporation to form Lockheed Martin, a combine that also swallowed the aircraft business branch of General Dynamics. Northrop and Grumman also merged to form Northrop-Grumman. This trend has been driven by the imperatives of shrinking orders in a post Cold War world and the extremely high cost of operation in the modern aerospace industry. A similar process has been seen in Europe as well with British Aerospace swallowing up the earlier large number of British aircraft manufacturers such as Hawker, Folland, English Electric, etc. The European Aeronautic Defence and Space (EADS) company has included a large number of European aerospace companies, including even major players such as Airbus Industries, Aerospatiale, Matra, Deutsche Aerospace SA (DASA), etc.[47] These mergers have been forced by real world conditions of shrinking markets and increasing technological difficulties in pushing the frontiers of aerospace technology for future equipment in both the military and civil

46. "US Government Policy and the Defense Aerospace Industry", RAND Report MR 1537, Chapter 1.
47. Ibid.

fields of operation. Even development programmes have now tended to adopt a multi-national character apart from a multi-corporate involvement, indicating that even the resources of advanced countries are proving inadequate for developing cutting edge aerospace products. Europe has the European Space Agency (ESA) as a combined effort of several West European countries, while EADS likewise combines resources in aerospace. The US adopted a multi-national structure for its F-35 "Lightning-II" LO fighter in part due to the need to secure adequate sales numbers and also to share costs and project risks. Europe's Eurofighter Typhoon also adopted a multi-national development and manufacturing structure, as had been done earlier for the European Tornado aircraft. The newly consolidated European firms ,including Thales, which was earlier Thomson CSF, are now of a comparable scale as the earlier, always larger, US aerospace companies. Thus, the mergers give the European companies a feeling of parity with their consolidated US counterparts.

In the 1990s, the US and European governments supported and even encouraged consolidation of their aerospace companies to enable these to survive in the face of smaller and fewer orders, and shrinking budgets overall. However, of late, concerns have surfaced about the excessive concentration of the industry. Fears have been voiced about the possibility of smaller technological advances in a situation of less competition, higher costs and fewer bids for projects. The US authorities have put forth their fears that they may no longer benefit from the higher technology offerings at lower costs that are traditionally spurred on by a competitive contract seeking environment.[48] The US authorities blocked a proposed merger of Lockheed-Martin and Northrop-Grumman.[49] This indicates the possibility of these governments possibly encouraging the splitting of their mega firms into smaller entities at some time in the future.

It is clearly brought out in the American Institute of Aeronautics and Astronautics Information paper of the year 2012-13, titled "Strengthening the National Commitment to Aerospace Research and Development" that

48. Ibid., p.6.
49. Ibid., p.7.

American technological progress in the aerospace domain has been spurred on by government funded and monitored R&D activities. These R&D activities have not only developed new technologies but pursued these new technologies till such time as these were mature enough to be commercialised by the larger aerospace industry comprising primarily private aerospace companies. Such government support for R&D is the bedrock on which the American aerospace industry has been built. The paper further brings out that shrinking government budgets for, and reduced government involvement in, cutting edge R&D could sound the death-knell of the US' aerospace leadership. That even the large private companies in aerospace such as Lockheed-Martin and Boeing are unlikely to be able to afford carrying out R&D on their own is a sobering dose of reality.

THE SOVIET / RUSSIAN AIRCRAFT INDUSTRY

Interest in aviation theory in pre-Soviet Russia commenced in the later years of the 19th century. Several theoretical studies into the science of heavier than air flight were conducted by eminent Russian scientists. Russia at the time was the most industrially backward of the great European powers and was losing out on its share of the industrial goods market in Eurasia due to the backwardness of its manufacturing industry as compared with those of Britain, Germany, and France.[50] Russian scientists, most prominently Nikolai Kibalchich and Alexander Mozhaisky, contributed to the Russian research into the theory of heavier than air flight from the early 1880s[51]. As early as 1902-03, the Imperial Russian Army utilised tethered aerostats, organised into aerostat battalions, for ground observation and direction.

TsAGI

In 1904, Nikolai Zhukovsky, often regarded as the father of Russian aviation, established an Aerodynamic Research Institute at Kuchino village

50. Z. Ubaidulloev, ""The Russian-Soviet Legacies in Reshaping the National Territories in Central Asia: A Catastrophic Case of Tajikistan", *Journal of Eurasian Studies*, vol 6, issue 1, January 2015, pp. 79–87, URL: http://www.sciencedirect.com/science/article/pii/S1879366514000104. Accessed on July 9, 2015.
51. Scott W. Palmer, "Science and Technology(Russian Empire)", http://encyclopedia.1914-1918-online.net/article/science_and_technology_russian_empire. Accessed on July 6, 2015.

near Moscow. This institute, established on December 1, 1918, was named as "**Ts**entralniy **A**ero**g**idrodinamicheskiy **I**nstitut"**(**TsAGI), translated as the "Central Aerohydrodynamic Institute named in honour of Nikolai Zhukovsky" and is in existence even today. It was formed with the aim of carrying out research into various aspects of flight from a theoretical point of view, aimed at later practical application by the national aerospace industry, much the same charter that NACA (later NASA), TsAGI's American analogue, had when formed later in 1915.[52] TsAGI has also contributed towards the Soviet space programme through studies and developing shapes and structures for safe and reliable transit of spacecraft through the atmosphere as NASA did from 1958 onwards. TsAGI carried out theoretical as well as practical research, followed by prototype development and testing till proving and maturing of new concepts and technologies, prior to these being given to the specific Opytnoye Konstruktorskoye Buro (OKB), translated as "Experimental Design Bureau" for implementation on a wide scale.[53] The striking similarities in the aerodynamic design features of several Soviet era aircraft such as the MiG-29 and Sukhoi SU-27, which both feature highly blended wing body structures, with a lift providing fuselage design integrated with LERX, and extensive use of complex vortex generation and placement for extreme manoeuvrability, including extremely high angle of attack controllability, and chevron clipped tail fin tips, point towards new discoveries in aerodynamics at a central agency being shared equally with different design bureaus. Even earlier, the MiG-21 and Sukhoi (SU)-9 / SU-11 showed remarkable similarities in design, comprising slim, narrow and dense fuselages, with annular nose mounted air intakes coupled with a tailed delta wing configuration, the wings featuring boundary layer fences and ventral fins to supplement the dorsal tail fin. MiG-23 variants and the SU-24 also show remarkable similarities in design features. All these similarities in aircraft from different OKBs could be attributed to implementation of the TsAGI research findings at these OKBs.

52. Tsagi.com, "About Us", http://tsagi.com/institute/. Accessed on July 6, 2015.
53. Ibid.

While the bulk of the Imperial Russian Air Force comprised imported or licensed built aircraft, domestic Russian designers did display high skill in design and manufacture of aircraft.

Imperial Russian Military Air Arm and Aircraft Industry

Impressed with the feats of early aviation such as the first trans-English channel flight by Louis Bleriot in July 1909, Tsar Nikolas II earmarked close to one million roubles for the formation of an air arm in the Russian military.[54] This was followed by a voluntary subscription campaign to raise funds for purchase of aircraft and engines. In 1910, Russia sent several officers to France to be trained as pilots and also bought several French and British aircraft to form an air arm of the military.[55] By mid-1914, Russia fielded the largest air arm of the military in Europe in terms of numbers, after France. However, being either direct imports, or foreign designs built under licence in Russia, the bulk of Russian aircraft were obsolete to the extent of their being barely useable in practical military operations.[56]

While the bulk of the Imperial Russian Air Force comprised imported or licensed built aircraft, domestic Russian designers did display high skill in design and manufacture of aircraft. Amongst the early Russian aircraft designers, Igor Sikorsky deserves special mention. In 1913, he had designed and built Russia's and the world's first multi-engine aircraft. Later the same year, he built a more practical four engined version named the "Ilya Muromets".[57] In 1913, designer Dmitry Grigorovich built several flying boats for the Imperial Navy.[58] By the end of World War I, 73 more Ilya Muromets were constructed, giving Russia, its and the world's first long range strategic strike air arm.[59] In 1916, Sikorsky designed his four-engined bomber called the "Alexander Nevsky". This aircraft was never put into

54. Palmer, n.51.
55. Ibid.
56. Ibid.
57. Ibid
58. Sovietbases. thecelotajs.com " Imperial Russian Air Force Service", http://sovietbases.thecelotajs.com/The-Imperial-Russian-Air-Force.php. Accessed on July 7, 2015.
59. Palmer, n.51.

production due to the Soviet revolution in Russia and Sikorsky's emigration to the US in 1919[60].

In the 19th century, Russia was the least technologically advanced European power. Apart from implications for the country's economy, this industrial backwardness affected its ability to develop and sustain high technology armed forces. The materials, technology and techniques for the advances in most fields, including aviation, came from outside the country. Foreign businesses and businessmen promoted development of advanced technologies in Russia from an investment point of view. The development of more advanced industries gave the foreign promoters the profits they sought. The resultant gain was that Russia benefited in catching up to some extent with its more advanced Western neighbours in Europe. The dependence on outside suppliers for strategic materials posed problems. In the first decade of the 20th century, earlier Russian efforts to generate the human resources to enable domestic production of required raw and intermediate materials began to bear fruit.[61] The earlier Russian investment in centres of excellence in scientific education, including several polytechnics, carried out in the 19th century onwards, began to make available well educated personnel able to effectively operate high technology enterprises; the most obvious and visible result of which was initially the reduction in the numbers of expatriates working in advanced technology sectors of the Russian economy as Russian graduates of Russian centres of higher learning began to take over the expatriates' functions effectively.[62]

The pitfalls of dependence upon foreign sources for raw materials, intermediate goods and finished products was brought out severely during World War I.

The pitfalls of dependence upon foreign sources for raw materials, intermediate goods and finished products was brought out severely during World War I. In this period, foreign supplies were severely disrupted by geography, with a hostile Germany situated between Russia and friendly France, and with Russian ports also facing a German blockade, thus,

60. Ibid.
61. Ibid.
62. Ibid.

disrupting imports of essential commodities. The domestic Russian industry was not prepared 'to go it alone' and faced major problems in delivering the required equipment.[63] This experience forced Russia to develop its industrial sector on a war-footing; however, these efforts were hampered by the general lack of literacy in the population at large. Progress was made in isolated fields such as development of Sikorsky's "Ilya Muromets".[64] An effect of this experience was the shift of the focus of Russia's scientific community from pure theoretical research to trying to ground their work towards a practical world of real orientation.[65] Building in simplicity and ease of rapid construction into the equipment, especially military equipment, was also an offshoot of the problems faced by Russian industries during World War I. This basic philosophy carried forward into the Soviet era and beyond.

Much as in the US, as seen earlier in this paper, in the Soviet Union too aircraft design commenced with the efforts of a few talented designers. In addition to the problems associated with setting up new facilities for aircraft design and production in any region of the world, in the Soviet Union, aircraft designers also had the requirement of being seen as conforming to the codes of conduct and behaviour stipulated by the Communist Party apparatus. Membership of the Communist Party was a starting point for successful operation in the aviation field. The Soviets set up several OKBs centred on talented designers such as Pavel Sukhoi [Sukhoi (SU) OKB], Artyom Mikoyan [Mikoyan (MiG) OKB], Andrei N Tupolev [Tupolev (TU) OKB], Sergei Ilyushin [Ilyushin (Il) OKB], Oleg Antonov [Antonov (AN) OKB], and Alexander Yakolev [Yakolev (Yak) OKB]. Each OKB established and headed by these eminent designers in the past remains named after them even today.

The Soviet Aerospace Industry Model

Nikolai Polikarpov was the Soviet Union's most successful designer of agile fighter aircraft during the 1920s and 1930s and into the early years of World War II. In the first few years of World War II, the Soviet Air Force

63. Ibid.
64. Ibid.
65. Ibid.

was equipped predominantly, indeed, almost exclusively, with Polikarpov designed fighter aircraft. Nikolai Polikarpov is known to have followed a tight dictatorial style of functioning in running his design bureau. This style of functioning did not allow for much development of his subordinates. The famous MiG OKB was formed by two designers, A I Mikoyan and M I Guryevich, who were moved out of the Polikarpov design bureau in 1939. Key personnel of the bureau were moved out of the Polikarpov design bureau in 1939 subsequent to disagreements that Nikolai Polikarpov had with Stalin after a series of crashes of aircraft designed by Polikarpov, especially the I-180 and I-185 fighters.

A number of future chief designers of Soviet aircraft firms worked under the supervision of the famous French designer Paul Richard in his design firm, attached to TsAGI, in the USSR, in the 1930s and gained valuable experience: Lavochkin, Kamov, Korolev, Beriev, etc. were a few of these Soviet designers who gained through working under Paul Richard.[66]

Roberto Oros di Bartini left Italy and came to the USSR in 1923. He became a well-known aircraft designer and scientist. Bartini was imprisoned from 1938 till 1946 for political reasons. He worked in the SDB-29 with Tupolev and other designers. Bartini created over 60 projects of various aircraft, many of which were tested and saw limited production.[67]

The Soviet Union did not hesitate to utilise foreign experts working alongside Soviet scientists to help build up skill levels and competence in the Soviet scientific and engineering community.

After the death of Nikolai Polikarpov, in July 1944, his design bureau was closed down with its assets, including manpower, being transferred to other design bureaus such as the Lavochkin and Sukhoi design bureaus.[68] Hence, from the inclusion of the Polikarpov design bureau in the manufacturing establishment GAZ.84 in 1936 till 1944, this aircraft manufacturing organisation, which exists today at its location in Tashkent, Uzbekistan, as

66. Vladimir Zhuravlev, "Russian Approach to Aircraft Design and Aeronautical Education", http://www.dias.unina.it/EWADE2011/Presentations/Session_3/01_V_Zhuravlev_EWADE_2011.pdf. Accessed on July 10, 2015.
67. Ibid.
68. J.Greenwood, et al., *Russian Aviation and Air Power in the Twentieth Century* (New York: Routledge. 2014).

the Tashkent Aircraft Production Organisation named after V.I. Chkalov (TAPOiCh), effectively carried out both design as well as manufacture of aircraft which was very rare in the Soviet aircraft industry; the fighters manufactured by TAPOiCh in this period were primarily those designed by Nikolai Polikarpov.

The Soviet system, save for a few exceptions such as at TAPOiCh, from 1936 to 1944, was very different. OKBs were the designated aircraft design agencies. These designed aircraft based upon their areas of broad specialisation, fighters, attack aircraft, transport, civil aircraft, or helicopters.

The Soviets are not known to have carried out a 'fly-off' for selection between different competing designs for one requirement as the US did in the 1970s and 1980s. However, there is a coincidental development of similar aircraft by different design bureaus such as the MiG-29 and SU-27 around the same time. Both aircraft saw induction and series production as, despite their similar looks, these addressed the short range (tactical) and long range (strategic) segments of the Soviet Air Force need for Generation 4 aircraft.

The production of the designs of OKBs was not done by the concerned designing OKB but by separate aircraft production facilities that were often located at large distances from the OKBs. The OKBs, for the most part, were located in Moscow or its suburbs, an exception being the Antonov OKB which was located in the outskirts of Kiev city in the Autonomous Soviet Socialist Republic of Ukraine. The production agencies were located in various different parts of the Soviet Union; often the location of factories being dictated by wider regional development and other political aims and not based upon economies of scale or reasons of competitive advantage enjoyed by some geographical locations over others. Nor was there a system of a specific production factory being associated permanently with a specific OKB. Designs were allocated to specific factories by the Soviet Union's central bureaucracy with no consideration for market forces and / or technical issues. Generation of employment and or work to keep plants in operation and the meeting of required production volumes appear to have been the deciding factors in such assignments of production. There were

cases of a single factory in the USSR running two or more assembly lines, one for a fighter and the other for a transport aircraft or even a helicopter under a single roof.[69]

MiG OKB

The Artyom Mikoyan and Mikhail Guryevich team commenced independent design work in 1939 initially within the Polikarpov OKB[70] as a special cell and later, in 1942, was established at Zavod (the Russian word for factory) #155 as an independent MiG OKB led by Artyom Mikoyan, with Guryevich as his second in command.[71] The MiG OKB started designing aircraft with their MiG-1, upgraded (to overcome problems in the original design) later to MiG-3 standard.[72] It designed the USSR's first jet fighter, the MiG-9, which utilised captured Nazi era Bayerische Motoren Werke (BMW) jet engine technology, and made Soviet fighters a household name across the world with the MiG-15, MiG-21, MiG-25 and MiG-29 designs.[73] The MiG OKB was one of the Soviet aerospace industry's great success stories with its achievements spread consistently over a period of more than 60 years.

In the Soviet period, market forces and considerations were completely absent from the industrial system. The Soviet philosophy was akin to "if a thing is required, it will somehow be made available, with no extraneous considerations to the need coming in the way". This, in a larger context, meant that unlike in the West, cost was not a consideration in development of aerospace equipment. For national defence needs, cost was never a consideration. The Soviets appear not to have even kept track of the cost of developing and producing military and aerospace equipment in even the most rudimentary way. This freed the Soviet aerospace industry from the tyranny of cost control requirements. The ill-effect of this philosophy was that excessive amounts of national resources could be sucked into several

69. Zhuravlev, n.66.
70. Russiapedia.rt, "Prominent Russians: Artyom Mikoyan", http://russiapedia.rt.com/prominent-russians/science-and-technology/artyom-mikoyan/. Accessed on July 8, 2015.
71. Ibid.
72. The MiG-3 was essentially an improved MiG-1 which improved stability and other performance characteristics over the original aircraft.
73. Palmer, n.51.

A consequence of the state control of all industry in the Soviet Union was the inability of individual OKBs or production agencies to interact with customers. All Soviet arms and aerospace exports were dealt with through central state authorities. The prices fixed had much more to do with politics than actual production costs.

projects, with negative implications on the economy of the country. Some Western and Russian experts and analysts attribute the dismantling of the Soviet Union by President Gorbachev to the economic stress caused to the Soviet Union by its attempts to counter the US' high technology "Strategic Defence Initiative" or "Star Wars" initiative, aimed at global aerospace domination, which was commenced in the early 1980s in the tenure of President Reagan.[74]

A consequence of the state control of all industry in the Soviet Union was the inability of individual OKBs or production agencies to interact with customers. All Soviet arms and aerospace exports were dealt with through central state authorities. The prices fixed had much more to do with politics than actual production costs. Aerospace exports were usually utilised for furthering the Soviet Union's wider political aims.[75] In post Soviet Russia too, despite the initial move towards privatisation of the aerospace industry, the trend has of late been to consolidate the aerospace industry, in view of its national importance, under state control, making one umbrella state agency the only point of contact between foreign parties and the Russian aerospace industry.[76]

Post Soviet Russian Aerospace Industry

The Soviet Union had several aircraft design bureaus such as the MiG OKB, now reorganised as the Russian Aircraft Corporation MiG (RAC MiG);

74. Rt.com, "'Star Wars Destroyed Soviet Union' – Russian Space Chief", http://www.rt.com/politics/russian-chief-star-wars-762/. Accessed on July 8, 2015.
75. Introductory remarks by Mr Ajai Malhotra, former ambassador to the USSR, who was the chair for the seminar on "India-Russia Cooperation in Defence" and discussions and presentations during the seminar, on February 25, 2015, at the Seminar Room of Centre for Air Power Studies (CAPS), New Delhi.
76. Ibid.

Sukhoi OKB, now called the Sukhoi Aircraft Holding Company / Joint Stock Company (JSC) all the stock of which is held by the Russian United Aircraft Corporation(JSC) or (UAC); Ilyushin OKB, which today is known as the Ilyushin Aircraft Complex and forms part of the UAC; Antonov OKB, which is today called the Antonov Company and lies in present day Ukraine, outside the Russian aircraft industry, though with strong links to it, with the company headquarters outside Kiev city; Tupolev OKB, which today is called the Joint Stock Company Tupolev and is also part of the United Aircraft Corporation; and the Yak Aircraft Corporation which was earlier the Yak OKB and which is also today part of the UAC, to name a few of the more prominent ones since the end of World War II. A few of the more prominent aircraft building plants that lie within the Russian Federation even after dismemberment of the USSR are the Komsomolsk-on-Amur Aircraft Production Association (KnAAPO), Aviastar SP in Ulyanovsk, Kazan Aircraft Production Association (KAPO) in Kazan, and Irkutsk Aviation Plant, located at Irkutsk.[77] These aircraft manufacturing plants that lie within the Russian Federation are also now part of the UAC. The decision of where a design is to be manufactured is now done on lines closer to a commercial market driven process involving the designer and manufacturer, also unlike the earlier Soviet era bureaucratic decision process by the concerned ministry of the Soviet government. A severe resource crunch faced by Russia in the decade immediately following the dismantling of the USSR meant that new R&D projects in aerospace were not initiated till President Putin came to power and made the resurgence of Russia's aerospace industry a national priority.

The decision of where a design is to be manufactured is now done on lines closer to a commercial market driven process involving the designer and manufacturer, also unlike the earlier Soviet era bureaucratic decision process by the concerned ministry of the Soviet government.

77. K.Hull,"In Depth Look: Aircraft Production in the Former Soviet Union", http://www.airlinereporter.com/2014/03/aircraft-production-in-the-former-soviet-union/ Accessed on July 11, 2015.

ANALYSIS OF THE US AND SOVIET AEROSPACE INDUSTRY MODELS

The US is a capitalist country with an emphasis on free enterprise and it places a premium on individuality and has a highly competitive 'winner takes all' culture. Imperial Russia was a feudal society characterised by a wealthy landed elite that lorded over an illiterate and oppressed peasant class. The Soviet Union, through the Bolshevik Revolution, ushered in a Communist system that placed priority on the greater good over individual rights and put in place a rigid and regimented society. Socialist ideals replaced capitalist ideas and resources were to be distributed amongst the people based on need more than anything else. The two systems of Communism and capitalism could not be more different in their fundamentals and concepts. In such a situation, it was only natural that the paths followed by the aerospace industries in these two countries would be very different. There are, as we have seen in the preceding paragraphs, several differences in the approach followed towards putting in place an effective aerospace industry in the US and the Soviet Union. While these were only to be expected, the surprising part was the similarity in the way a few things were done in the two countries, especially as regards utilisation of state resources for the benefit of ostensibly a relatively small part of the population. An analysis of the aerospace industry in the US and USSR is given below.

Points of Interest from Analysis of US and Soviet / Russian Aerospace Industries

- In both the US and Imperial Russia, the genesis of the aircraft industry owes a lot to the interest taken by a few enthusiasts who took it upon themselves to develop basic theory and translate it into actual aircraft. In Russia, a central research institute was started by an academic who was an aviation enthusiast, while aircraft were built initially under licence, with a few Russian designers making their mark. In the US, the profit motive combined with enthusiasm for aviation for several individuals who started aircraft manufacturing companies. Both the Russians

and Americans realised the importance of an excellent scientific and engineering education to sustain the aircraft industry and took active measures to put this education system in place.

- In the US, barriers to entry were mostly those of a market economy with high economic wherewithal required to start a new enterprise. The US gained from its interaction with British and French designers and examination of European aircraft. The Soviets did not hesitate to utilise foreign designers working in Soviet research, design and development facilities alongside Soviet engineers and scientists to help the domestic scientific community assimilate the knowledge and skills of the foreign experts.
- Both the US and USSR systematically pillaged through the aerospace research carried out by the defeated Nazi Germany in order to leapfrog ahead in aerospace technology.
- In a situation of state ownership of all resources, it is not difficult to accept that TsAGI would carry our fundamental research, develop and prove new concepts and then pass these on to aircraft design bureaus for implementation as a part of the same monolithic state owned industry. However, surprisingly even capitalist America did the same with the NACA, later, NASA. Even America accepted that private industry, even an industry with high profit margins, could not carry out fundamental and applied research without state support and funding.
- The US aerospace industry relied upon exports as a means of maintaining financial viability in its market economy system. The USSR did not even track the cost of developing and building equipment and so had no concept of market prices for its products.
- Russia, and later the USSR, showed that a dedicated education and R&D effort with full state support can lead to achievement of global excellence.
- Aerospace R&D requires state support in terms of state involvement in the R&D process. R&D in aerospace is too expensive to be borne alone by even large and profitable private companies.
- Dependence upon foreign supplies of defence equipment can be very problematic in times of need and should be avoided.

- A country making an attempt to catch up with the global state-of-the-art in aerospace could do so more effectively through intelligent utilisation of collaboration with more advanced countries.

CONCLUSION

Since its advent, aerospace has come to occupy a prime position in the defence and security calculus of nations. A robust domestic aerospace industry has come to be seen as a guarantor of security as well as a significant contributor to the nation's economy. These facts make the study of the US and Russian / Soviet aerospace industry very educative. The process followed by the USSR and the US in developing their aerospace industries brings out the political and economic system neutrality of end user and governing system support for the development of a cutting edge technology-based industry. Cutting edge R&D is required for sustaining effective operation of an aerospace industry. Even very large multinational firms such as Boeing and Lockheed-Martin are unable to afford the resource outlays required for this purpose. Thus, government support of R&D, even with private companies involved, is essential. The study of the aerospace industries in the US and USSR throws up several more interesting points.