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A Comparative Study of India Versus USA Aerospace Industry

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Abstract:- The aerospace industry has undergone significant changes in the past few decades due to industrial impact. Technological advancements like Artificial Intelligence, Machine Learning and Internet of Things have led to the development of more efficient and sustainable aerospace systems that have had a profound impact on the industry in the long run. This article aims to explore the industrial impact of aerospace industry from a future perspective. It examines the various technological advancements that have been made and their impact on aerospace system design, fuel efficiency, and overall operational costs. This work also discusses the role of government regulations and policies in promoting sustainable aerospace practices and the need for continued research and development of new technologies, policies, and practices that can lead to more sustainable aerospace industry.

Keywords:- *Airbus, Boeing, Space X, Hindustan Aeronautics Limited, ISRO, DRDO, NAL, , TASL.*

I. INTRODUCTION

The aerospace industry has been greatly impacted by the growth of industrialization. Industrialization has led to the development of new technologies and production methods, which have greatly influenced the long-term growth of the aerospace industry. The industry has grown from producing simple planes to developing more complex aircraft, rockets, and spacecraft. One of the most significant impacts of industrialization on the aerospace industry has been the development of more efficient and reliable manufacturing processes. This has allowed aerospace companies to produce higher-quality products at a lower cost, making them more competitive in the global market. The use of advanced materials and advanced manufacturing techniques has also allowed for the development of new types of aircraft that are more fuel-efficient, have longer ranges, and are safer to operate. Another important impact of industrialization on the aerospace industry is the growth of the space sector. The development of space technologies has opened up new opportunities for the industry, such as the launch of satellites, the exploration of space, and the development of new space-based products and services [1]. This has led to the creation of a new market for the industry, which has driven innovation and growth. Overall, industrialization has had a significant impact on the long-term growth of the aerospace industry. The industry has been able to develop new technologies, improve manufacturing processes, and enter new markets, which has allowed it to grow and evolve. As industrialization continues to advance, the aerospace industry is likely to continue to grow and innovate, developing new technologies and products that will shape the future of air and space travel. Indian aerospace industry primarily comprises public sector units (PSUs) promoted by the government of India over several decades. While Bangalore has emerged as the hub of aerospace industry in India, smaller aerospace clusters are located around the cities of Delhi, Chennai, Hyderabad and Nagpur.[2] The city of Bangalore qualifies as the hub of aerospace industry of India, thanks to the mushrooming of aerospace industry, research institutions and increased global connectivity in the last five decades. The State owned Aerospace major, the Hindustan Aeronautics Ltd (HAL) set up its shop in the year 1964.. Bangalore also hosts the prestigious National Aerospace Laboratory (NAL), the Indian Space Research Organization (ISRO) and the Indian Institute of Science (IISc). These three organizations created the R & D infrastructure to drive forward the initiatives of HAL The aerospace industry in the United States is one of the most significant and technologically advanced sectors in the country. It encompasses a wide range of activities related to the design, development, manufacturing, and operation of aircraft, spacecraft, satellites, and their components. With a rich history dating back to the early 20th century, the USA has played a pioneering role in aerospace technology and has remained a global leader in the field. The United States aerospace industry is characterized by a strong collaboration between government agencies, private companies, and research institutions.[3]

II. INDIA AEROSPACE INDUSTRY OBJECTIVES

Self-Reliance and Indigenous Capability: India aims to develop self-reliance and indigenous capabilities in the aerospace sector. The country has been working towards reducing its dependence on imports and establishing a strong domestic aerospace industry that can design, manufacture, and maintain aircraft, satellites, and defense systems.

Defense Preparedness: As a rapidly growing economy and a country with security concerns, India's aerospace industry focuses on enhancing defense capabilities. This includes the development and production of advanced fighter aircraft, unmanned aerial vehicles (UAVs), missile defense systems, and surveillance technologies.

Commercial Aviation Growth: India is experiencing a significant growth in commercial aviation with a growing middle class and increased air travel demand. The aerospace industry aims to support this growth by manufacturing and maintaining commercial aircraft, improving air traffic

management systems, and ensuring safe and efficient operations.[4]

➢ *United States Aerospace Industry Objectives:*

Technological Leadership: The USA aims to maintain its position as a global leader in aerospace technology. This involves continuous research and development, innovation, and pushing the boundaries of what is possible in areas such as aircraft design, space exploration, satellite technology, and defense capabilities.

National Security: The aerospace industry plays a crucial role in enhancing national security by providing advanced military aircraft, surveillance systems, missile defense technologies, and space-based assets for intelligence gathering. Ensuring technological superiority and readiness is a significant objective for the US aerospace industry.

Economic Growth and Job Creation: The aerospace sector contributes significantly to the US economy through job creation, exports, and revenue generation. It aims to foster economic growth by supporting a robust supply chain, attracting investment, and driving innovation that leads to spin-off technologies benefiting other industries.[5]

➢ *Indian Aerospace Industry*

The aerospace industry in India has a rich history dating back to the 1940s. The industry has grown significantly over the years and has contributed to India's technological advancements and economic growth. One of the earliest initiatives in the aerospace industry in India was the establishment of Hindustan Aeronautics Limited (HAL) in Bangalore in 1940. HAL was established to produce indigenous aircraft to support India's defense needs. Over the years, the role of HAL in the Indian aerospace industry is very significant due to its vast range of manufactured aircraft which includes fighters, trainers, and other jets and helicopters also. The Indian Space Research Organization (ISRO) was established in the year 1960s, for the development of space technology. ISRO has achieved significant milestones in space exploration, including the launch of satellites for communication, remote sensing, and navigation. ISRO also launched its first mission to the moon, the Chandrayaan-1, in 2008 [6]. The government of India in the year of 1980s initiated a program named the Integrated Guided Missile Development Program (IGMDP) to develop indigenous missile technology. The program was a huge success and it included the AGNI and PRITHVI series In recent years, the Indian aerospace industry has witnessed significant growth, driven by the government's focus on promoting the sector. The government has established policies and programs to encourage investment in the aerospace industry, including the Make in India initiative, which aims to boost manufacturing in the country. Today, India has a vibrant aerospace industry, with several private players operating in the sector. The country has made significant progress in developing indigenous technologies in areas such as aircraft manufacturing, space exploration, and missile technology. The aerospace industry in India is poised for further growth, with several initiatives underway to boost research and development, manufacturing, and export of aerospace products and services. [7]

➢ *USA Aerospace Industry*

The USA aerospace industry is a critical sector that encompasses a wide range of activities related to the design, development, manufacturing, and operation of aircraft, spacecraft, satellites, and their components. It is known for its technological advancements, innovation, and global leadership in aerospace technology. One of the most prominent organizations in the industry is the National Aeronautics and Space Administration (NASA). Established in 1958, NASA has been at the forefront of space exploration, scientific research, and technological development. NASA's achievements include the Apollo moon missions, the Space Shuttle program, the Hubble Space Telescope, and ongoing missions to study Mars, Jupiter, and other celestial bodies. The USA aerospace industry is home to many private companies that contribute significantly to its growth and success. Companies like Boeing, Lockheed Martin, Northrop Grumman, and Raytheon Technologies are major players in the industry, specializing in the design and manufacturing of commercial and military aircraft, missiles, satellites, and defense systems.[8] These companies often collaborate with NASA and other government agencies on various projects. SpaceX, founded by Elon Musk, has emerged as a game-changer in the industry. It focuses on space transportation and has made remarkable achievements in developing reusable rockets and launching spacecraft. SpaceX's accomplishments include the successful launch and recovery of the Falcon 9 rockets and the Dragon spacecraft. The company has also been instrumental in reducing the cost of space launches, making it more accessible for commercial and scientific purposes. The USA aerospace industry has a significant impact on national security and defense capabilities. It plays a crucial role in the development of advanced fighter jets, unmanned aerial vehicles (UAVs), surveillance systems, and missile defense technologies. The industry works closely with the Department of Defense and other defense agencies to ensure the country's military readiness.

I. INDIAN SPACE AND RESEARCH ORGANIZATION (ISRO), INDIA

ISRO was founded in 1969 to develop India's space capabilities and advance scientific research. It is the first space agency in India. In its early years, ISRO focused on developing the infrastructure for satellite-based communication, remote sensing, and meteorology Its low-cost technology has made it an attractive partner for other countries, and it has collaborated with many international space agencies on various missions [9].

➢ *Mission Profiles*

- Remote Sensing: ISRO has launched several remote sensing satellites, including the Cartosat series, RISAT series, and Resources at series, which are used for earth observation and natural resource management.

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- Communications: ISRO has launched a series of communication satellites, including the INSAT series and the GSAT series, which provide a range of communication services, including TV broadcasting, internet connectivity, and emergency communication.
- Navigation: ISRO launched the IRNSS (Indian Regional Navigation Satellite System), which was a constellation of seven navigation satellites, that provides accurate positioning and navigation services within India and the surrounding regions.
- Planetary Exploration: India's first interplanetary mission was the ISRO's Mars Orbiter Mission (MOM) which reached Mars in 2014 successfully.
- Space Science: India's first multi-wavelength space observatory, ASTROSTAT, and its first mission to study the sun, Aditya-L1, were launched by ISRO.

➢ *Current Missions*

- Chandrayaan-3: It's a mission follow-up to Chandrayaan-2 (India's second lunar mission) which suffered a landing failure. Chandrayaan-3 is expected to have a similar mission profile to its predecessor, including a soft landing on the Moon's surface.
- Gaganyaan: India's first manned mission to space, that is expected to launch in 2024. Gaganyaan will carry a crew of three astronauts to low Earth orbit for a period of up to seven days.
- Venus Mission: ISRO is planning a mission to study Venus, which will include an orbiter and a lander. The mission will study the planet's atmosphere, surface, and geology.
- Exoplanet Mission: Additionally, ISRO intends to launch a mission to study exoplanets, which are planets outside our solar system. The mission will include a telescope that will be placed in space to observe exoplanets [10].
- Small Satellite Launch Vehicle (SSLV): ISRO is developing a new rocket, the SSLV, which will be capable of launching small satellites into orbit. The SSLV is expected to be a low-cost alternative to ISRO's existing launch vehicles.

➢ *Budget*

The budget of ISRO (Indian Space Research Organization) varies from year to year, depending on the specific projects and missions being undertaken. However, according to reports, the average annual budget of ISRO for the last five years (2016-2021) has been around 10,000 crore rupees (approximately 1.4 billion USD). It's important to note that ISRO has a reputation for being one of the most cost-effective space agencies in the world, with a focus on achieving maximum results with minimum resources. Despite its relatively small budget compared to other space agencies, ISRO has achieved significant milestones in space exploration, technology development, and scientific research, and has become a key player in the global space industry. example-Mars Orbiter Mission (MOM): The total cost of the MOM mission, which successfully reached Mars in 2014, was approximately 450 crore rupees (approximately 74 million USD).Chandrayaan-1: The total cost of Chandrayaan-1(first lunar mission of India), was approximately 386 crore rupees (approximately 80 million USD)[11].Chandrayaan-2: The total cost of Chandrayaan-2(the second lunar mission of India), which included an orbiter, lander, and rover, was approximately 978 crore rupees (approximately 135 million USD).Cartosat-2 series: The approximate cost of each satellite in the Cartosat-2 series, which is used for earth observation and natural resource management, is around 150 crore rupees (approximately 21 million USD).

➢ *Products*

Satellites: ISRO has designed and launched several satellites for various purposes such as communication, remote sensing, navigation, and scientific research. Launch Vehicles: ISRO has developed a series of launch vehicles for placing its satellites into orbit as well as for commercial launches. Cryogenic Engines: ISRO has successfully developed and tested indigenous cryogenic engines, which are used to power its launch vehicles. Ground Systems: ISRO has developed several ground systems, including tracking and control stations, communication networks, and satellite data processing centers. Remote Sensing Applications: ISRO has developed a range of remote sensing applications for various sectors such as agriculture, forestry, disaster management, and water resources management. Space Science Missions: ISRO has undertaken several space science missions such as Chandrayaan-1 and Mars Orbiter Mission (MOM). Human Spaceflight Program: ISRO is developing capabilities for human spaceflight, and has already undertaken several experiments and tests towards this goal [12].

II. HINDUSTAN AERONAUTICS LIMITED (HAL), INDIA

HAL is a defense organization and is owned by the state, and is located in Bangalore, India. It was founded in 1940 by Walchand Hirachand, an Indian business tycoon. In the post-independence era, HAL started manufacturing licensed versions of British and Soviet aircraft, such as the Vampire and Gnat fighter jets, as well as transport planes like the Dakota and Avro. HAL also developed indigenous aircraft like the HF-24 Marut, the first fighter jet to be designed and developed in India. Over the years, HAL has grown to become one of Asia's largest aerospace companies. HAL has partnerships with several leading aerospace companies from around the world, such as Rolls-Royce, GE Aviation, and Safran, and has exported its products to over 30 countries. Today, HAL is a key player in India's defense sector and is involved in several critical defense programs, such as the Light Combat Aircraft (LCA) Tejas, the Advanced Light Helicopter (ALH) Dhruv, and the Sukhoi Su-30MKI fighter jet. This organization has also diversified into the civilian aerospace sector, with products like the Dornier 228 aircraft and the Chetak helicopter [13].

➢ *Mission Profile*

- Light Combat Aircraft (LCA) Tejas: The development of the LCA Tejas was delayed by several years, and the project suffered from cost overruns and technical

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problems. The aircraft has also faced criticism for being underpowered and having limited range.

- Intermediate Jet Trainer (IJT) Sitara: The IJT Sitara is a jet trainer aircraft that was developed by HAL for the Indian Air Force. However, the project faced several delays and technical issues, and the IAF has expressed dissatisfaction with the aircraft's performance.
- Dhruv Helicopter: The Dhruv helicopter is a multi-role helicopter that was developed by HAL for both civilian and military use. However, the helicopter has faced several crashes, leading to concerns about its safety and reliability [14].
- Sukhoi Su-30MKI: HAL has been involved in the licensed production India's fighter aircraft, Sukhoi Su-30MKI for the IAF. However, there have been several incidents of engine failures and other technical issues with the aircraft.
- Developing India's first indigenous jet aircraft: HAL developed India's first indigenous jet aircraft, the HAL HF-24 Marut, which was in service with the Indian Air Force from 1967 to 1985.
- Designing and developing advanced fighters: HAL has designed and developed several advanced fighter aircraft, HAL AMCA, HAL Sukhoi Su-30MKI, and HAL Tejas are some examples.
- Upgrading and modernizing Indian military aircraft: HAL has been involved in the upgrade and modernization of several Indian military aircraft, including the Mirage 2000, Jaguar, and MiG-27.
- Developing helicopter platforms: HAL has developed several helicopter platforms, including the HAL Dhruv, which is in service with the Indian Armed Forces and has been exported to several countries.[15]
- Designing and developing unmanned aerial vehicles (UAVs): HAL has designed and developed several UAVs, including the HAL Rustom, which is capable of conducting surveillance and reconnaissance missions.

➢ *Current Missions*

- HAL Light Combat Aircraft (LCA) Mk 1A: An upgraded model of HAL Tejas is currently in progress to meet the requirements of the Indian Air Force. It's expected to have advanced avionics and weapons systems.
- HAL Multi-Role Helicopter (MRH): The HAL MRH is a new medium-lift helicopter being developed by HAL for the Indian Armed Forces. It is expected to have advanced avionics and weapons systems.
- HAL Indian Multi-Role Transport Aircraft (IMRTA): The IMRTA is a new military transport aircraft being developed by HAL in collaboration with the Indian Air Force. It is expected to have a range of up to 2,500 km and will be used for troop and cargo transport [16].

➢ *Budget*

According to HAL's latest yearly report (2020-21), the total revenue of the company was Rs. 22,700.92 crores and its profit after tax was Rs. 2,070.48 crores. The report also provides a detailed breakdown of the company's financial performance, including its expenses, investments, and revenue sources.[17] You can refer to the latest financial reports or contact HAL directly for more information on their current budget.

➢ *Products*

Aircraft: Some of the notable aircraft produced by HAL are HAL Tejas, Sukhoi Su-30MKI, HAL Dhruv, and HAL Do-228.Engines: Some of the notable engines produced by HAL are the Shakti engine, HTFE-25 engine, and AL-31FP engine. Avionics: Some of the notable avionics systems produced by HAL are Mission Computer and Display System (MCDS), Radar Warning Receiver (RWR), and Digital Map Generator (DMG). Accessories: HAL has also designed and manufactured various aircraft accessories, such as landing gears, wheels, brakes, and hydraulic systems.

III. NATIONAL AEROSPACE LABORATORIES (NAL), INDIA

NAL was established in 1959 as the National Aeronautical Research Laboratory (NARL) by the Indian Government, located in Bangalore, India. It is a leading research laboratory that comes under CSIR.In the early years, the laboratory focused on developing indigenous technology for aircraft design, manufacturing, and testing. Later, the scope of research was expanded to include areas such as advanced materials, avionics, and propulsion systems [18].

➢ *Mission Profile*

- *Saras Aircraft Program:*

NAL developed the Saras aircraft, which was aimed at providing a low-cost alternative to commercial planes. However, the program faced several setbacks, including two accidents in 2009 and 2011, which led to the suspension of the program.

- *National Trisonic Aerodynamic Facilities (NTAF) Project:*

The NTAF project aimed to develop India's first supersonic wind tunnel for aerospace research. The project faced multiple delays due to technical difficulties, and the completion date was pushed back multiple times.

- *SARAS (Saraswati):*

NAL designed and developed the SARAS aircraft, a 14-seater multi-role transport aircraft, which was successfully tested in 2004.

- *Hansa:*

NAL developed the Hansa aircraft, a two-seater trainer aircraft, which has been widely used in flying schools in India and abroad.

- *Nishant:*

NAL designed and developed the Nishant unmanned aerial vehicle (UAV), which is used for surveillance and reconnaissance purposes by the Indian armed forces.[19]

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- *Rustom*:

NAL is currently working on the Rustom UAV program, which is aimed at developing a medium-altitude long-endurance (MALE) UAV for the Indian Air Force.

➢ *Current Missions*

- *Regional Transport Aircraft (RTA):*

NAL is developing a 70-90 seater regional transport aircraft that is expected to meet the requirements of regional airlines in India. The project is being carried out in collaboration with the Council of Scientific and Industrial Research (CSIR) and other aerospace organizations.

- *Multirole Transport Aircraft (MTA):*

NAL is working on the development of a 20-25 tonne multirole transport aircraft in collaboration with the Russian aerospace company, United Aircraft Corporation (UAC). The MTA is being developed to accomplish the needs of the Indian Air Force and other armed forces.

➢ *Budget*

The budget of national aerospace laboratories varies greatly depending on the country and the specific laboratory in question. For example, the budget of NASA was approximately $25.2 billion for the fiscal year 2020. In contrast, the budget of the ISRO, which is one of the top space agencies in Asia, was approximately $1.5 billion for the fiscal year 2021-2022.[20]

➢ *Products*

- *Hansa-3 Aircraft*
- *Saras Aircraft, Rustom UAV*
- *NAL-HAL Civil Aircraft*

IV. TATA ADVANCED SYSTEMS LIMITED (TASL), INDIA

TASL is a subsidiary of Tata Sons, the holding company of the Tata Group. TASL was established in 2007 to focus on the aerospace and defense sector. The company has its headquarters in Hyderabad, India, and has manufacturing facilities in Hyderabad, Bengaluru, and Lucknow. In the 1990s, the Tata Group established Tata Technologies, which provides engineering and design services to global aerospace companies. Tata Technologies was found to be a key player in the development of the Airbus A380 superjumbo. In 2007, the Tata Group established TASL to focus on the aerospace and defense sector. TASL has partnered with global aerospace companies such as Lockheed Martin and Boeing to manufacture aircraft components and assemblies in India.[20]

➢ *Mission Profile*

- Indian Mars Orbiter Mission (MOM): For India's first interplanetary mission, the Mars Orbiter Mission which successfully positioned a spacecraft in orbit around Mars in 2014, TASL produced essential components. The spacecraft's propulsion system, comprising the main engine and the thrusters, was provided by TASL.
- International Space Station (ISS): TASL has supplied critical components to NASA's International Space Station program, including the assembly of the Common Berthing Mechanism (CBM) used to dock spacecraft to the ISS.
- Boeing 787 Dreamliner: TASL has been a supplier to Boeing's 787 Dreamliner program, manufacturing composite floor beams and interior components for the aircraft.
- F-16 Fighting Falcon: TASL has a joint venture with Lockheed Martin to manufacture F-16 fighter aircraft in India. The F-16 is a multi-role fighter aircraft used by air forces around the world.

➢ *Current Missions:*

- Indian Air Force (IAF) Fighter Jet Project: TASL is a key partner in a joint venture with Lockheed Martin to manufacture F-16 fighter aircraft in India for the Indian Air Force.
- Boeing Apache Helicopter Program: TASL is a supplier to the Boeing Apache helicopter program and manufactures critical components for the helicopter, including fuselage assemblies and vertical stabilizers.

➢ *Budget*

As a privately-held company, the exact budget of Tata Advanced Systems Limited (TASL) is not publicly disclosed. However, according to industry estimates, TASL's revenue was approximately INR 3,000 crores (about USD 400 million) for the financial year 2020-21 [21].

➢ *Products*

- Airborne Early Warning and Control Systems (AEW&CS)
- Composite Structures

Table 1 Growth Rate of DRDO with Defense Industries (after 15 years of Payback Period from R and D Investment)

SI. no	Years of investment in DRDO	DRDO budget (Rs lakh)	Payback period (years)	Production year after the DRDO project payback period	The production value on the DRDO project (Rs lakh)	Value-added ratio (production value to DRDO budget value) Z=(V/U)	Annual growth rate of production value from 15th year of DRDO budget(%age)13 r=100*{[Exp{(Ln(z)/15}]
1	1986	43775	15	2001	197676	4.52	10.57
2	1987	56056	15	2002	235061	4.19	10.03

3	1988	57777	15	2003	251795	4.36	10.31
4	1989	59642	15	2004	297858	4.99	11.32
5	1990	69887	15	2005	473377	6.77	13.60
6	1991	68670	15	2006	695067	10.12	16.69
7	1992	77468	15	2007	622057	8.03	14.90

By taking an example of a single industry to see the growth rate of aerospace industries worldwide. Here DRDO as an example have taken the issue regarding the technology transfers to defense sector industries which has 15 years after the payback period.

Figure 1 depicts the DR&D Annual budget and production value. Research obtained from DRDO gives the annual value of production of the nation where the public sector and similar factories in India from DRDO projects have grown from Rs 13 crore (1981-1982) to Rs 6,200 crore (2006-2007). For 15 years major R and D projects are developing systems of complex weaponry on an average in delivery in payback and economic and commercial. As shown in the figure the years mentioned from 1986 to 1992 with a gap of 15 years, after the review system the delivery production value got 4 to 8 times of DRDO budget (2001-2007).

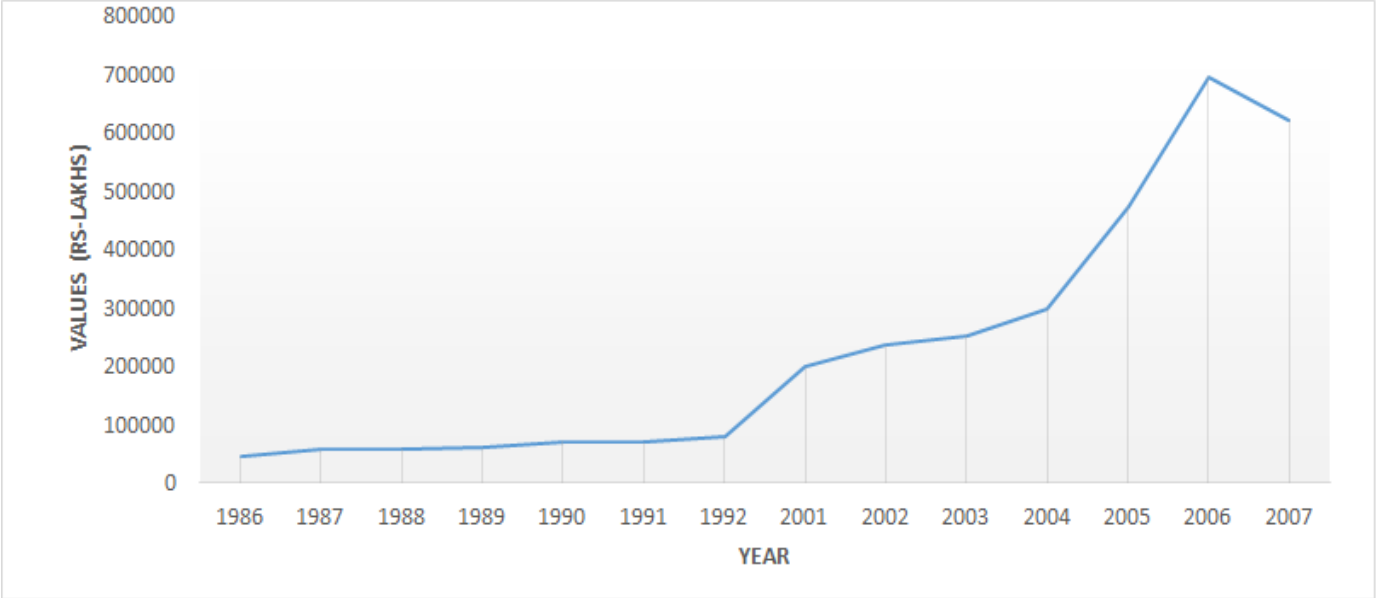

Fig 1 DR&D Annual Budget and Production (Rs-lakhs) [38]

V. DEFENCE RESEARCH AND DEVELOPMENT ORGANIZATION (DRDO), INDIA

The DRDO was established in 1958 by combining the Defence Science Organization. The premier agency under the Department of Defence Research and Development in Ministry of Defence of the Government of India, charged with the military's research and development, headquartered in Delhi, India [21].

➢ *Mission Profile*

DRDO's first major project was known as Project Indigo, started in the 1960s was related to surface-to-air missiles (LATER TERMINATED) due to which new projects such as PROJECT DEVIL WITH PROJECT VALIANT (1970) were developed to acquire a short-range SAM and ICBM. This later led to the Prithvi missile under the Integrated Guided Missile Development Programme (IGMDP) (1980). Between 1980 - 2007(extensive range of missiles, including the Agni missile, Prithvi ballistic missile, Akash missile, Trishul missile, and Nag Missile) Since its formation, DRDO has developed several important systems and technologies, including avionics for aircraft unmanned aerial vehicle(UAVs), small weapons, artillery systems, electronic warfare(EW) systems, tanks and armored vehicles, sonar systems, command and control systems, and missile systems [22].

- Rudram-1:- On October 9, 2020, the DRDO Anti-Radiation Missile, also known as the NGARM but now officially known as the Rudram-1, was successfully test-fired from the Integrated Test Range in Balasore. The last test flight for Rudram-1 is scheduled for December 28 and 29,2021, with serial production beginning in 2022.
- Astra Mk-2: A Beyond Visual Range Air-to-Air missile system with an extended range of over 160 km.
- Hypersonic Technology Demonstrator Vehicle (HSTDV): It is a missile system that can travel at a speed of 6 times the speed of sound (Mach 6).
- For the usage of the Indian Air Force's Hawker Siddeley Avro and Boeing 737 aircraft, DRDO, and BEL created ELINT equipment. For the IAF and the Navy, DRDO has also created a radar fingerprint system. Included in high accuracy, the DRDO is creating an ESM system for the AEW&C project.[23]

➢ *Budget*

DRDO's budget varies from year to year and is allocated by the Indian government. As of 2021, the total budget allocated to DRDO for the financial year 2021-22 is approximately INR 11,625 crore (approximately USD 1.6 billion)

➢ *Products*

- Agni series of ballistic missiles
- Prithvi series of tactical surface-to-surface missiles
- BrahMos supersonic cruise missile

VI. SPACE X

SpaceX established in 2002 by Elon Musk, is a private American aerospace manufacturer and space transportation services company. Musk established SpaceX to lower the price of space travel and eventually make it possible to colonize Mars [24].

➢ *Mission Profiles*

- Commercial Resupply Services (CRS) missions: SpaceX has conducted numerous CRS missions for NASA to replenish the International Space Station (ISS) with cargo and experiments using the Dragon spacecraft and Falcon 9 rocket.
- Crewed Missions: In 2020, SpaceX became the first private company to send astronauts to the ISS as part of the NASA Commercial Crew Program, using the Crew Dragon spacecraft and Falcon 9 rocket.

➢ *Current Missions*

- Starlink missions: SpaceX is continuing to launch satellites for its Starlink constellation to provide global internet access. In March 2023, SpaceX launched 60 Starlink satellites into orbit.
- CRS-26 mission: In May 2023, SpaceX is scheduled to launch the CRS-26 mission for NASA to resupply the International Space Station (ISS) with cargo and experiments.
- Inspiration4 mission: In late 2023[28], SpaceX is scheduled to launch the Inspiration4 mission, a private spaceflight mission funded by billionaire Jared Isaacman.

➢ *Budget*

The company's annual budget is around $5 billion to $6 billion. This budget includes research and development costs for new rockets and spacecraft, as well as operational costs for conducting missions such as resupplying the International Space Station, launching satellites, and conducting crewed missions.[25] SpaceX has been able to reduce the cost of space transportation through its reusable rockets and spacecraft.

➢ *Products*

- *Falcon 9 Rocket*
- *Falcon Heavy Rocket*
- *Dragon Spacecraft*

VII. AIRBUS

Airbus is a global aerospace company based in Europe that develops, produces, and markets military and commercial aircraft, helicopters, and space equipment. To take on the dominant American aerospace industry, the company was established in 1970 as a coalition of European aerospace firms. The A220, A320, A330, A350, and A380 are just a few of the many commercial aircraft models made by Airbus. Worldwide airlines and operators employ the company's aircraft, and the A320 family of aircraft is among the most frequently operated single-aisle aircraft [26].

➢ *Mission Profile*

- Airbus A400M Crash - In May 2015, an Airbus A400M military transport aircraft crashed during a test flight near Seville, Spain, in which four of the six crew members died. The crash was attributed to software and human errors.
- Air France Flight 447 - Airbus A330 operated by Air France perished in a crash into the Atlantic Ocean in June 2009, resulting in the death of all 228 people on board. Pilot mistakes and defective machinery were found to be the root causes of the crash.
- Mission Accomplishments:
- Airbus A380 - Airbus' largest passenger aircraft to date, the A380 has been successful in the commercial aviation market since its introduction in 2007. It has a seating capacity of up to 853 passengers and is used by major airlines around the world.
- Airbus A320 Family - The A320 family of aircraft has been a success story for Airbus since its introduction in the 1980s. The A320, A321, and A319 models are used by airlines worldwide and have a reputation for fuel efficiency and reliability.

➢ *Current Missions*

- Developing eco-friendly aircraft: Airbus is committed to reducing the environmental impact of its aircraft by developing more fuel-efficient and sustainable planes. The company is investing in research and development to develop hybrid and electric planes.
- Improving safety: Airbus is continually improving safety features in its aircraft. This includes developing better cockpit technology, implementing safety systems that prevent accidents, and creating training programs for pilots and crew members.
- Expanding market reach: Airbus is working to expand its presence in emerging markets, particularly in Asia and Africa. The company is developing relationships with local airlines and investing in new production facilities to support these efforts.

➢ *Budget*

The budget of an Airbus can vary greatly depending on the specific model, configuration, and customer requirements. The list price of an Airbus A320neo is around $110 million, while an Airbus A380 can cost over $445 million. However, these are just list prices and the actual price paid by customers may be significantly lower due to discounts and negotiations. Airbus is a global aerospace corporation that creates, produces, and markets a variety of aircraft products [27].

➢ *Products*

- *Airbus A220*
- *Airbus A320*
- *Airbus A330*
- *Airbus A340*
- *Airbus A350*
- *Airbus A380*

In addition to these passenger aircraft, Airbus also produces military transport aircraft (such as the Airbus A400M), helicopters (such as the Airbus H125 and H225), and space systems (such as satellites and launch vehicles) [28].

Fig 2 Airbus Commercial Aircraft Order and Delivery
(Source- www.airbus.com)

Figure-2 depicts the number of delivered aircraft in the years 2019 and 2020, also it talks about the number of orders received, pending status, the number of aircraft delivered in a month and lastly, it gives an idea of aircraft order distribution over the continents.

VIII. BOEING

One of the top aerospace firms in the world, Boeing is well-known for designing, producing, and marketing aircraft, helicopters, rockets, satellites, and related equipment. William Boeing established this company in Seattle, Washington, in 1916, and it has since expanded into a multinational corporation with operations in more than 150 nations. The history of Boeing is dotted with significant events and accomplishments. The company was a pioneer in using metal monocoque construction in aircraft in the 1920s and 1930s, which facilitated the creation of swifter and more dependable aircraft. Boeing created enduring aircraft throughout World War 2, including the B-17 Flying Fortress and the B-29 Superfortress, which were essential to the war effort [29].

➢ *Mission Profile*

- Boeing 747: Boeing's most iconic aircraft, the 747, revolutionized air travel with its ability to carry more passengers and cargo than any other commercial airliner at the time of its introduction in 1970.
- Boeing 787 Dreamliner: The 787 is a highly fuel-efficient aircraft that features cutting-edge design and technology, making it one of the most advanced commercial planes in the world.
- Boeing 737 Max: The 737 Max was involved in two fatal crashes in 2018 and 2019, resulting in the grounding of the entire fleet and the loss of hundreds of lives. The crashes were caused by a faulty flight control system, which Boeing has since worked to fix.
- Boeing Starliner: The Starliner spacecraft was designed to ferry astronauts to and from the ISS but suffered a major setback during its first test flight in 2019 when it failed to reach its intended orbit due to a software glitch [29].

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- Boeing 787 Battery Fires: In 2013, several 787 Dreamliner planes experienced battery fires, causing the fleet to be temporarily grounded while Boeing investigated and implemented solutions to the problem.

➢ *Current Missions*

- Commercial airplanes: Boeing continues to produce and deliver commercial airplanes to airlines around the world, including the 737, 747, 767, 777, and 787 families of planes. The company also has several new aircraft in development, such as the 777X and the 797.
- Space exploration: Boeing is working with NASA on several space exploration projects, including the Space Launch System (SLS), which is a powerful rocket designed to take astronauts to the Moon and beyond.

➢ *Budget*

According to Boeing's 2020 annual report, the company's total revenue for the year was $58.2 billion, and its operating expenses were $69.7 billion. It is important to note that the expenses include not only production costs but also research and development, marketing, and administrative costs. Depending on the type of aircraft, the materials used, and the complexity of the manufacturing process, the cost of creating an aircraft can vary significantly. A significant aerospace firm [30].

➢ *Products*

- Commercial airplanes: Boeing is best known for its commercial airplane business. It has manufactured several popular models, including the 737, 747, 767, 777, and 787.
- Military aircraft: Boeing has also designed and manufactured a variety of military aircraft, such as the F-15 Eagle, F/A-18 Hornet, and the C-17 Globemaster III.
- Satellites: Boeing has been involved in the design and construction of numerous satellites for both commercial and government clients, including GPS and weather satellites.

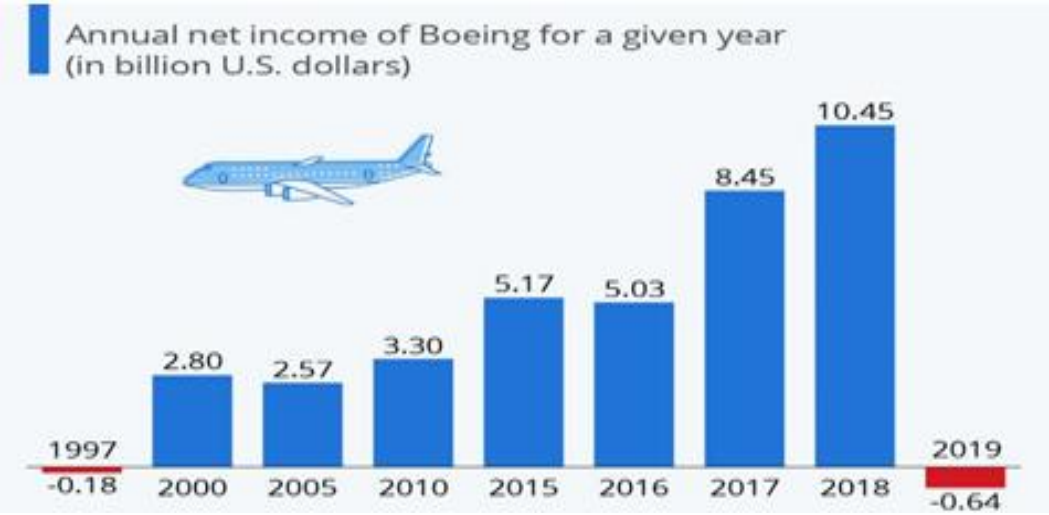

Fig 2 Boeing Annual Turnover
(Source- www.boeing.com)

Fig 3 Boeing During Pandemic
(Source- www.boeing.com)

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Figure-3 gives us an idea of Boeing's loss since 1997. As the company was growing exponentially since 1997 but it started to experience losses after 2018. Figure-3 says about the stock price of Boeing from Oct 2018 to Oct 2020 and there's a drastic fall in the prices due to the impact of covid 19.

- *United States Aerospace Industry Results:*

Technological Advancements: The USA has made groundbreaking technological advancements in aerospace. This includes the development of advanced military aircraft, such as the F-35 Lightning II and F-22 Raptor, as well as the commercial success of aircraft like the Boeing 787 Dreamliner. The USA is also a leader in space exploration, with milestones such as the Apollo moon missions and the ongoing Mars exploration missions.[31]

Commercial Aviation Dominance: American aerospace companies, such as Boeing and Airbus (with a significant presence in the USA), have dominated the global commercial aviation market. The Boeing 747, 777, and 737 families of aircraft have been widely adopted by airlines worldwide, contributing to air travel's growth and connectivity.

Space Exploration and Scientific Discoveries: NASA has been instrumental in exploring space and expanding human knowledge. The Apollo moon landings in the 1960s and 1970s, the Hubble Space Telescope, and ongoing missions to Mars and beyond have provided invaluable insights into our universe, including discoveries related to planetary science, astrophysics, and the search for life beyond Earth.

- *India Aerospace Industry Results:*

Satellite Technology: India has made remarkable progress in satellite technology. The Indian Space Research Organisation (ISRO) has launched numerous satellites for communication, remote sensing, weather forecasting, disaster management, and scientific research. The Mars Orbiter Mission (Mangalyaan) in 2014 made India the first country to successfully reach Mars on its first attempt.

Low-Cost Space Missions: India has gained recognition for its cost-effective space missions. The Mars Orbiter Mission and the Chandrayaan-2 mission to the Moon were accomplished at a fraction of the cost compared to similar endeavors by other countries. These missions have showcased India's ability to achieve impressive results within limited budgets.[32]

Indigenous Capabilities: India has been actively working towards developing indigenous capabilities in the aerospace industry. From the design and manufacturing of aircraft like the Light Combat Aircraft (LCA) Tejas to the successful development and launch of the Geosynchronous Satellite Launch Vehicle (GSLV) and the Polar Satellite Launch Vehicle (PSLV), India has demonstrated its ability to design and manufacture aerospace technologies domestically.

IX. DISCUSSIONS

Both countries have achieved notable technological advancements in aerospace. The USA has a long history of pioneering innovations, including the development of advanced military aircraft, space exploration missions, and commercial aviation dominance. India, on the other hand, has made remarkable progress in satellite technology, low-cost space missions, and the development of indigenous capabilities.[33]

The USA and India have actively pursued space exploration missions. NASA, with its rich legacy, has accomplished iconic missions like the Apollo moon landings and ongoing Mars missions. India's ISRO has made a mark with the successful Mars Orbiter Mission and the Chandrayaan-2 mission to the Moon.

Both countries have invested significantly in defense aerospace technologies. The USA has a robust defense industry, developing advanced fighter jets, missile defense systems, and surveillance technologies. India has been working to enhance its defense capabilities through the indigenous development of military aircraft, UAVs, and missile systems.

X. CONCLUSION

Collaboration and partnerships between the two countries can lead to mutually beneficial outcomes, leveraging their respective strengths and expertise. The USA and India can work together on space missions, research collaborations, technology transfers, and knowledge sharing, fostering advancements in aerospace technology and fostering a global aerospace ecosystem.[34]

In addition, industrial advancements have also led to the development of new materials and manufacturing techniques that have significantly reduced the cost of production. This has enabled aerospace companies to produce aircraft at a lower cost, which has made air travel more accessible to a larger portion of the population.

Moreover, advancements in the aerospace industry have also led to the development of new technologies, such as satellite technology, which has revolutionized the way of communicate, navigate, and monitor the planet.

The aerospace industry in both the USA and India plays a crucial role in driving economic growth, national security, technological innovation, and scientific exploration. It is an industry that inspires awe and fascination, pushing the boundaries of what is possible and shaping the future of aviation, space exploration, and scientific discovery.

Both countries face challenges, including global competition, budget constraints, regulatory complexities, and the increasing focus on environmental sustainability. However, they continue to invest in research, development,

and innovation to overcome these challenges and maintain their positions as leaders in the aerospace industry.[35]

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