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Applications of Internet of Things (IoT) in the Aerospace Industry

***Yash Jain* [a], *Naman Seth* [b], *Vardaan Singh* [c], *Karan Kumar* [d], *Shivam Aggarwal* [e], *Arpit Singh* [f], *Shiv Ranjan* [g]**

[a] *MBA Business Intelligence and Data Analytics (BIDA), Amity Business School, Amity University, Greater Noida, Uttar Pradesh, India*
[b] *MBA Human Resources (HR) and Marketing, Amity Business School, Amity University, Greater Noida, Uttar Pradesh, India*
[c] *MBA Human Resources (HR) and Marketing, Amity Business School, Amity University, Greater Noida, Uttar Pradesh, India*
[d] *MBA Human Resources (HR) and Marketing, Amity Business School, Amity University, Greater Noida, Uttar Pradesh, India*
[e] *MBA Finance and Operations, Amity Business School, Amity University, Greater Noida, Uttar Pradesh, India*
[f] *MBA Finance and Marketing, Amity Business School, Amity University, Greater Noida, Uttar Pradesh, India*
[g] *Assistant Director, Executive Programs, Amity Business School, Amity University, Greater Noida, Uttar Pradesh, India*

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ABSTRACT

As we transition to a technology-driven age, it is essential for us to understand the various technologies working behind it, across various industries. The aerospace industry is one such industry that has been massively impacted by the new-age technologies. This study aimed to explore the implementation of one such technology – Internet of Things (IoT) in the Aerospace industry. The study adopted a qualitative, secondary research design which fetched data from published sources (books, news snippets, publications, industry, and company reports) to conduct a thematic and comparative analysis of IoT implementation in the Aerospace industry. The thematic analysis segmented various applications of IoT across 7 segments – Supply Chain, Aero-Manufacturing, ITeS, Research and Development, Avionics, Aero-Operations and MRO (Maintenance, Repair and Overhaul). The comparative analysis studied the variation in applications across the two major sub-industries – Aeronautics and Astronautics. The research conclusively determined the plethora of IoT implementation happening across the segments and sub-industries, while also exploring its challenges and future opportunities.

Keywords: aviation, industry 4.0, internet of things (IoT), aerospace, aeronautics, big data, cloud computing

BACKGROUND

As humans, we constantly find ourselves in pursuit of exploring the unexplored, and in that pursuit, one thing has become our most formidable ally – **Technology**. The constant and rapid evolution of technology has enabled us to reach places we never imagined possible. Currently, we have probes that are orbiting the outskirts of our solar system (Voyager-1), cars that drive themselves (Self-driving cars), and glasses that can place calls for us (smart glasses). Think that just over a century ago, our species took transportation to the skies (Wright Flyer, 1903 [1]), and shortly after that, landed on the moon for the first time (Apollo 11, 1969 [2]). Think that computers were invented just around 80 years ago (ENIAC, 1946 [3]), and only made accessible to the public around 47 years ago (Apple II, 1977 [4]).

In retrospect, it is truly remarkable just how the technology landscape has boomed. In a similar pursuit of understanding the role of technology, this study embarks on a journey to explore how exactly this *technology* enabled us to achieve such monumental feats in a shorter period than expected. Limited by several constraints, this study only explores the impact on **Aerospace industry**.

The centre stage of this technology revolution is the **Internet of Things (IoT)**. It refers to the interconnected network of devices (also called ***Smart Devices***) via network protocols that allow them to communicate, exchange data, perform actions etc. The emergence of IoT-enabled devices functioned as a catalyst to an already rapidly developing technology industry. To specifically understand this dynamic, let us adopt an atomic approach – understand the components of this dynamic one by one, and then explore its connection.

THE AEROSPACE INDUSTRY

To understand the fundamentals of this industry, we will start with the basic meaning of the word ***Aerospace***. The word ***Aerospace*** constitutes of two words (**Figure 1**) – *Aero* (Greek word *aero*, means *atmosphere*), and *Space* (means *outer space*) [5]. In simple words, it means **the study of the elements of our atmosphere and outer space from an applied sciences perspective** (specifically, engineering).

Aerospace is one of the most evolving industries in the past few years. According to market research by PwC (**Figure 2**), the global industry has grown **3% from 2021 to 2022**, with an **8% annual growth** in the **operating profit**.

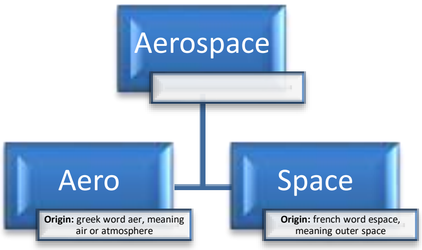

Fig.1 Etymology of Aerospace [5]


Key industry metrics

	2022	2021	Change
Revenue	US$741 billion	$714b	3%
Operating profit	$67b	$62b	8%
Operating margin	9.1%	8.7%	40 bps

Source: PwC analysis

Fig.2 PwC Global Aerospace and Defence Outlook - Annual Report 2023 [6]

Very often, the industry is referred to as A&D Industry (short for Aerospace and Defence). This is because often, Aerospace is considered different from Defence industry. In textbook definition, it is not that case, though.

Classification of Aerospace Industry

According to Wikipedia [7], Aerospace is classified into two sub-disciplines –

- **Aeronautics** (the discipline that studies the principles of flight, design and development, and operation of aircrafts within the atmosphere (hence, the word “Aero”), and
- **Astronautics** (which concerns itself with the study, design and development of spacecrafts and modules (hence, “astro”) that are built to go beyond our atmosphere in the outer space).

Aeronautics is the discipline of studying flight and its elements, and designing, manufacturing, and operating aircrafts that fly within our atmosphere [9], while **Astronautics**, the lesser explored part of the Aerospace industry, focuses on the design, development, implementation, and operations of spacecrafts, satellites, rovers, mission modules and all other exploration equipment that goes beyond our planet Earth.

Fig.3 Classification of Aerospace [8]

Aeronautics is very much used interchangeably with the term **Aviation**, but Aviation is a small subset of Aeronautics that concerns itself with the operations (ground stations, radio towers, weather reports etc) associated with the flights [9].

Inside Aeronautics, we have 2 broader categories –

Civil and General Aeronautics - Civil Aeronautics concerns itself majorly with the cargo and passenger aircrafts, which we most commonly refer to as Airline Business (production, operations, management). These typically include 3 categories of aircrafts– Private Planes (**Fig. 4**), Passenger Aircrafts, and Business Jets (**Fig. 5**).

Fig.4 Beachcraft Baron Private Airplane [10]

Fig.5 Gulfstream G450 Business Jet [10]

Military and Defence Aeronautics - Military Aeronautics, or Defence Aeronautics, concerns itself with the manufacturing, design, development, operations, and management of military-grade aircrafts, to be used for special forces. These are specifically used for aerial warfare and operate with a very different complexity than the civil aircrafts [11] (See **Figures. 6 to 11**).

Fig.6 Fokker Eigendecker, German Fighter Plane, World War I [11]

Fig.7 Caproni Bomber, Italy [11]

Fig.8 Dassault Rafale Attack and Fighter Aircraft [12]

Fig.9 MiG-35D Fighter Aircraft [13]

Fig.10 SR-71 Blackbird Reconnaissance Aircraft [14]

Fig.11 P3C Orion, Maritime Surveillance Aircraft [15]

This was about the aerospace industry and the major aircrafts that this industry deals in. Now, let us look at some cross-functional industries with this industry.

Cross-functional Industries in Aerospace

According to Britannica [16], the Aerospace industry has major functionalities in the following industries –

1. **Supply Chain** – The aerospace industry heavily relies on supply chain. It includes aircraft MRO (maintenance, repair and overhaul), timely supply of parts and composite materials, quality control on assembly and testing of aircraft and remote-control operations amongst others.
2. **Manufacturing and Design** – The aerospace industry also relies a lot on the manufacturing and design industry. The onus is on them to provide with updated, optimized designs as per the use (civil / military), to provide maximum value delivery.
3. **R&D** – The research and development industry work in combination with all other components for the growth of the industry. Setting new benchmarks, adopting new technologies, streamlining business processes are a few ways through which it makes its contribution.
4. **ITeS** – The ITeS companies work as supporting functions to the primary industries by providing them with consultancy and auditing services, alongside technology adoption services to help the industry grow adequately.
5. **Operations (Aviation)** – The operations industry contributes directly to the supply chain industry, to optimize processes, identify bottlenecks, run value chain, and cost benefit analysis to get the best outcome from the resources.

These are the areas which together constitute the entire industrial landscape for Aerospace Industry. Now, let us look at some of the popular key players for the industry in India, and globally.

Key Players

There are some players that play a key role in every industry. Considering the vast amount of cross-functionality in the aerospace industry, we have narrowed down 10 key players, both globally and in India, for the aerospace industry. For better understanding purposes, we have omitted the national space agencies for the countries. This is because it is quite straightforward that these agencies contribute majorly to the aerospace industry.

Fig.12 Top 10 Global Aerospace Companies [17]

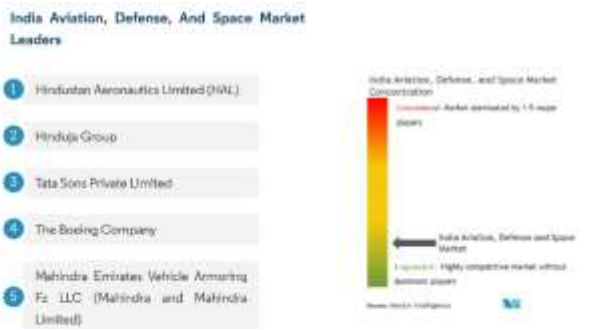

Fig.13 Top 5 Aerospace Companies in India [19]

Global: Globally, the United States (USA) dominate the countries that reside these companies. Besides them, only France is the other company that has more than 1 companies in the list. The entire list is given in **Figure 12**. We can notice that majority of these companies are manufacturers of military and civil aircrafts and their systems. A few of them, like Boeing, Northop Grumman, General Dynamics offer cybersecurity and logistics solutions alongside the manufacturing [18].

India: When we talk about India, we need to understand that India is still in a very new state, in terms of aviation. Hence, it may not contain as much volume as expected. Having said that, according to Mordor Intelligence [19], the key players in India are mentioned in **Figure 13**.

All these companies deal with the manufacturing of either aircrafts, or their parts. This is synchronized with what we noticed with the global players as well. We can think of manufacturing as the primary money-making activity within this industry. Now that we have completely familiarised ourselves with the industry, let us now understand the main component that we would be studying – Internet of Things (IoT).

Introduction to Internet of Things (IoT)

The phrase Internet of Things may be misleading sometimes, since although Internet is an integral part of the ecosystem, but it does not signify it in its entirety. Let us dive into the foundations of IoT.

Definition: IoT refers to a system of interconnected devices that collect, share and exchange data, communicate with each other via internet protocols over a network. They are the key drivers to automation and have assisted industries in saving valuable resources on tasks that do not require human intervention [20]. Since its inception, IoT has quite revolutionized. A brief timeline of IoT development is given in **Figure 14**.

Fig.14 Brief Timeline of IoT [21]

Now that we have established the intricacies of IoT, let us check how an IoT ecosystem works. Since it has many components, it is important for us to understand the working behind IoT.

IoT Ecosystem and its components

The ecosystem majorly comprises for 5 components, that work interconnectedly to provide a systematic model that works to perform designated tasks. Let us study these components one by one [22][23]. **Figure 15** demonstrates a simple diagram, that explains the elements of an IoT Ecosystem, and their intricacies. Let us learn these elements individually.

1. **Environment** – These are the stimuli from the environment that are captured by our smart devices or normal transducers based on which they start the flow. This environment includes any kind of big data we can capture in real-time.

2. **Things** – These devices are the building blocks of our ecosystem. All our smart devices, and the data capturing devices come under this umbrella. These are the devices embedded with transducers (sensors, actuators to name a few), or are connected to the data capturing devices that capture data from the environment, convert them into signals that can be read and understood by the processing engine. Once it is done, they send the data to the interfaces. From there, the interface shares the data to the user, and performs action based on user's instructions.
3. **Interfaces (Apps)** – Interfaces are the applications that are used by the end-user to interact with the IoT ecosystem. The processed data from the smart devices are sent through network protocols to the centralized storage unit (cloud storage), and they are used to generate reports to be shared with the user.
4. **Users** – These are the common people, like us – who use the smart devices via the apps that enable us to understand how the device is working, and what we are getting out of it.
5. **Internet** – This is the main component binding all the ecosystem together. It is the star in the solar system of IoT. Internet protocols are used in transmitting data from one device to another, using gateways that act as a bridge connecting the devices, as well as transmitting data from the things to the cloud storage, where they can be processed.

Inside these components, there are some key elements that govern the entire ecosystem. These elements are -

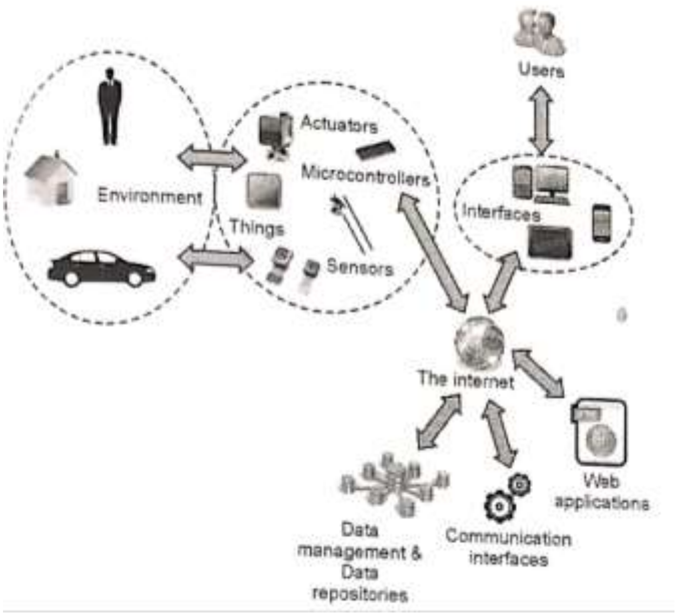

Fig.15 IoT Ecosystem [22]

Connectivity – Network protocols that are used in establishing connections within the ecosystem, so that data can be shared amongst the devices in real time, play an important role in the efficient working of IoT.

Big Data Analytics – **Big Data** refers to the continuously flowing, huge amounts of data that are collected from the environment via things. **Big Data Analytics** refers to the process of analyzing this big data to extract hidden insights from it and share it to the users. In terms of IoT, we call it **Stream Analytics.**

Based on this analysis, the user can perform an action on their own (which happened before AI). With the new emergence of **BI (Business Intelligence) systems**, AI is embedded in stream analytics platforms, which studies the historical data about which action to take place on which data scenario, and it automatically enables those triggers when the scenario comes in future.

Edge Computing – Edge Computing is a part of cloud computing that concerns itself with the processing and computation of data collected from IoT devices. It includes the storage, processing, and management of data on cloud, which is eventually used by Stream Analytics platforms to enable users to supervise the entire IoT ecosystem.

This is, in its entirety, the ecosystem of IoT. These elements are essential for the efficient deployment and implementation of IoT in the business landscape. Now it is time to examine the role of IoT in the Aerospace Industry.

Examining the Role of IoT in the Aerospace Industry

Previously, we noticed that majority of the important players in the Aerospace industry were manufacturers – either of the aircrafts or their components. These companies also dealt with the supply chain, as well as digital services for their clientele. Taking that into account, we could assume that IoT would be used majorly in the manufacturing, supply chain, and operations (aviation) inside the industry. However, this is still a preliminary hunch. This is what we need to explore in our study.

OBJECTIVES OF THE STUDY

This study aims to combine all the existing research regarding the industry-wide applications of IoT in the Aerospace industry. The specific objectives include –

- Thorough examination of existing literature to extract the applications of IoT within the Aerospace Industry.
- Understand the extracted applications, and segment them into broader themes to better understand and provide a detailed overview. Compare these applications across various segments to better understand the dynamics of the industry.
- Find out the implications of these applications, and the impact they have created in the industry.

- Interpret the future trends, challenges, and scope of the application of IoT in the Aerospace Industry and recommend measures for the same.

SCOPE OF THE STUDY

This study is entirely focused on a specific segment of the Aerospace Industry – the applications of IoT. It is taken from both global and Indian perspective, covering all the essential components of the industry, using authentic sources of data. In all hindsight, this study should provide enough evidence to generalize any claims made regarding the current industry landscape.

LIMITATIONS OF THE STUDY

Of course, this study is not flawless. It has its own shortcomings, which may contribute to some conclusions being different from the general norm. These limitations include –

- **Time Limitation**: This study was conducted in quite a short period, which might affect the depth of analysis, and consequently, the conclusions.
- **Data Source Limitation**: This study has been conducted on the back of reliable and authentic, but still, secondary data sources. It does not include first-hand industry insights from people involved in this landscape.
- **Collation of Data**: Majority of the study's data has been scattered across the digital cyberspace. Integrating it posed its own challenges and may have left out some keen details.
- **Industry-specific Variation**: This study has very limited scope, in terms of industrial research. Not to mention the inaccessibility of some authentic data sources made it difficult to derive a strongly reliable conclusion. Hence, the insights could very well not be generalized within the industry.

RESEARCH METHODOLOGY

The Research Design for this study is a **Qualitative Research Design**, with a focus on Descriptive Research. Due to lack of availability, and accessibility of relevant data, we have decided to move forward with Secondary Data for our study. The major secondary data sources identified for this study are –

- **Literature Review** – One of the most popular secondary data sources are research papers and articles published in recognized journals by seasoned professionals.
- **Government and Regulatory Reports** – A very authentic data source we found are government and regulatory reports regarding the industry landscapes. These reports provide a bird-eye view of the industry and its dynamics.
- **Industry Publications and Reports** – Another helpful resource for our study is industry publications and reports by expert market-research companies.
- **Online Published Blogs / Articles** – The majority of data for this study is extracted from this data source. These sources are easily accessible and available to all.
- **Published Textbooks** – The most reliable data source of all time – books. The books referenced in this study are written by legendary authors of our field, like John D. Anderson Jr.
- **Official News Sources** – Once again, a slightly less reliable data source is official news channels. Due to the free nature of the press, certain facts could seem biased.

These data sources combined built a data repository for us to analyze and interpret. Based on this data collection, we decided to move ahead with **Purposive Sampling**, due to the vast scope of our study, and unreachable population, along with the time and resources constraints.

Data Analysis Technique adopted

Considering the qualitative nature of the study, we have refrained from conducting any statistical tests. Instead, we would be adopting the following data analysis techniques in our study to mine a meaningful conclusion:

- Thematic Analysis – This is conducted within the existing literature and all the data sources to extract a theme out of it, to determine the major areas of IoT implementation.
- Comparative Analysis – After the thematic analysis, we segmented the applications into various cross-industries and conducted a simple comparative analysis.

- Synthesis of Information – Finally, we synthesized hidden insights from both the analysis to define the various IoT implementation in Aerospace industry.

LITERATURE REVIEW

First, let us understand the current dynamics of the Aerospace industry, and how IoT is playing a role in it.

Current Industry Landscape for IoT in Aerospace

According to the report by the GMERC (Global Market Estimates Research and Consultants) [24], the IoT-enabled global aerospace market is projected to increase at an annual rate of 11.26%. Within this, it is expected to grow to a US $70 Bn. market by 2026. The report has segmented the findings amongst various criteria – component (Hardware, Software and Services), applications (fleet management, health monitoring), end user (space systems, ground systems).

Another report by Market Wide Research (MWR) [26] and Verified Market Research [25] tells us that major manufacturers like Boeing, Airbus and Lockheed Martin are dominating the market, producing not only aircrafts and their components, but also IoT hardware (sensors, gateways) that seems to dominate the current IoT landscape in aviation.

According to a **TOI Article** on Aviation Revolution in India [27], Remi Maillard (President and Managing Director, Airbus India and South Asia) claimed that India would need 2840 new aircrafts, 47000 technicians and 41,000 pilots over the next 2 decades. This interview also had them claim that India would soon become the fastest growing Aviation Market globally. This certainly clarifies that not only aerospace industry is going to be essential in the future, but IoT technology implementation in it as well.

Fig. 16 GMERC Aerospace Global Report [24]

Fig. 17 VMR Aerospace and Defence Report [25]

Historical Development of IoT Technology in the Aerospace Industry

Let us trace through our history, and check where and how exactly did the IoT implementation evolved from the early adoptions to the latest scenario.

The very first implementation of IoT could be dated back to the 1930s, through **wired telemetry** systems [28]. These were used to link the data in-transit flights with the ground control engineers or flight test engineers. Although it is arguable whether it would be called as IoT or not, it was the earliest mode of data collection through external transducers.

It evolved during the WWII, which led to the development of **radio telemetry**, and further, the **missile telemetry** apparatus. These led to the mechanism of remote control and monitoring of aircrafts. In this scenario, the further developments into **real-time monitoring** systems led to the development of CRD (Cathode Ray Displays) and then transitioned to the digital FBW (Fly-by-wire) systems. We started progressing into the Wireless Communication era.

While this paradigm shift happened, another major area of concern was regarding the **maintenance of health of aircrafts and their components**. Initially driven by a more reactive-based approach, it quickly transitioned to an IoT-enabled proactive approach [29], where the components were monitored using IoT-enabled sensors, that allowed for real-time health tracking and monitoring of these components.

After this, the demand rose for the **integration of in-flight and ground operations** through IoT-enabled architecture [30]. This connectivity paradigm not only allowed for a better flight experience to the customers, but also enabled companies to monitor and maintain their fleet more efficiently. Many systems came forward, helping companies to deploy IoT-enabled solutions more efficiently for interconnectivity. This gave emergence to **Avionics** [31].

The emergence of **RFID (Radio Frequency Identification)** technology further enhanced this integration [32], and streamlined the logistics and supply chain integration for aviation companies. In fact, it is claimed that the emergence of IoT started with the success of RFID technology.

Come the 21st century, it was all about the emergence of cloud computing and Big Data Analytics. With the increasing use of IoT devices, multiple SaaS companies emerged [33].

The demand for intelligent aircraft systems rose, and as the world was shifting to a cloud-based service spectrum, companies started transitioning from server-based enterprise systems to cloud-based enterprise systems.

In the past decade or so, the emerging trend has been of using **UAVs (Unmanned Aerial Vehicles)** such as drones for commercial purposes [34]. The air and traffic control management systems (ATCMS) have been integrated with UAS (Unmanned Aircraft Systems) to better streamline the monitoring and traffic management for aerial vehicles. This integration has several implications, both positive and negative.

Historically, this was where IoT was implemented within the Aerospace industry. Now, to understand where it is currently being implemented, let us first understand the key technologies of IoT implementation in the current industry landscape.

Key Technologies for IoT Implementation

Firstly, let us understand what the key technologies for IoT implementation in the industry landscape are (i.e. IIoT technologies). Connecting the findings from here to our historical application areas and existing literature on current implementation in the aerospace industry, we will arrive at a common standpoint regarding IoT implementation in this industry. There have been numerous studies regarding the key technologies for IoT implementation.

According to a study [35], the key technologies for IoT implementation are **cloud computing**, dew computing, fog computing, edge computing, M2M (Machine-to-Machine) communication, IPv6 (Internet Protocol Version 6), RFID and Wireless Sensor and Actuator Networks (WSANs). Another study [36] classified IoT implementation under the industry 4.0 umbrella, and recognized Cyber-Physical Systems (CPS), Cloud Computing, and Big Data Analytics. It emphasized the importance of interconnectivity and interoperability in the IIoT for enhanced implementation.

A study [37] focusing on enabling 5G-IoT identified Wireless Network Function Virtualization (WNFV), 5G-IoT Architecture, Advanced Spectrum Sharing, Heterogeneous Networks (HetNet) and **Device-to-Device (D2D) Communication** as the key technologies for implementation and deployment. Another research [38] highlighted the key technologies for rapid prototyping and development of IoT-enabled solutions for industrial use. The technologies they focused on were RFID, **WNS (Wireless Sensor Networks)** and **TCP (Transmission Control Protocols)**.

A book published on **IIoT** [39] explains the IIoT ecosystem across various industries and conducted different case study-based research. Extracting data from those studies, the technologies that were frequently mentioned for IIoT implementation were Big Data Analytics, Cloud-Fog-Edge Computing ecosystems, RPA (Robotic Process Automation), Artificial Intelligence (AI) and Machine Learning (ML), Network Connection Protocols among various few others. Another book section on **IoT Technology for Industry 4.0.** [40] mentions sensors and actuators, connectivity medium, data analytics and cloud computation as key technologies for IoT implementation. Within these broader technologies, they explained the various intricacies of these technologies, and what particulars would be required to deploy them.

A book on **emerging technologies in IIoT** [41] highlighted some new technologies, which, in the future would be incorporated into the IIoT ecosystem. It highlighted the technologies of Blockchain, AR (Augmented Reality) / VR (Virtual Reality), Edge Computing and Big Data Analytics, specifically AI implementation and integration. Another study [42] explored the technologies of IoT implementation in a specific use case of smart cities. Throughout this study, they identified the key technologies while exploring and formulating an integrated IIoT framework. For the deployment of the same, they identified some key technologies like cloud computing, **embedded systems**, stream analytics, communication protocols among others.

A specific IIoT implementation study [43] on real-time waste-water management tells us which technologies were implemented to deploy the ecosystem. From the study, we can extract the technologies such as **RPA** (use of Arduino), cloud computing, and big data analytics. A book on **Fog computing** [44] explored the IIoT architecture and mentioned various technologies that have proven to be the pillars for IoT implementation. These technologies are embedded systems, cloud computing, big data analytics, networking connectivity, RFID, and sensors.

Hence, all the published material has revolved around some core technologies. Now, we have a clarity of which technologies are used in the aviation industry. Let us study previous IoT implementations in Aerospace to conduct our research more efficiently.

Previous Studies of IoT Implementation in Aerospace

The Aerospace industry is very vast. As seen before, it is majorly dominated by players in the manufacturing, supply chain, or operations segments. Let us build on this knowledge and find what we can regarding IoT implementation in Aerospace.

A study on 3D Printing, or **Additive Manufacturing** [45] discussed the importance of additive manufacturing on the aerospace industry's manufacturing ecosystem. Its ability to produce critical components of aircrafts without compromising its integrity, and reducing resource consumption allows for a better, more agile manufacturing process for companies.

Another study on Additive manufacturing [46] explored the power of **Design Simulations and Modelling** using CAD (Computer aided Designing) tools by implementing FEA (Finite Element Analysis) to conduct linear stress analysis tests on component structures to test their integrity and strength. Another study [47] noticed that additive manufacturing not only helped the manufacturing segment, but the R&D as well. It enabled **rapid prototyping**, fast deployments, and simulation tests to optimise the component designs for best value.

A study on **Smart Manufacturing** [48] discussed the implementation of **Digital Twin** technology, which aims to replicate a physical infrastructure with its digital counterparts, to optimize the manufacturing ecosystem. It involved the use of CAD designs and connecting them to the real-time data collected via IoT sensors to facilitate lean manufacturing. It is also said to have optimized the product development and research aspects of the industry.

A comprehensive study **on sustainability in the Aerospace sector** [49] highlighted the role of IoT in the **Aerospace Supply Chain**. It implied that IoT is essential in adopting Industry 4.0 for the aerospace segment, and streamlining supply chain by enhancing Inventory Management solutions, ensuring supply chain visibility to the customers and suppliers through an integrated EMS (Enterprise Management System). It also emphasized the importance of PLM (product lifecycle management) systems to enhance the customer experience and supplier experience. This case study also highlighted how IoT is used in Route Optimization using Big Data Analytics, Smart Warehouses using IIMs (Intelligent Intra-logistics Machinery), while providing real-time visibility for Asset Monitoring using RFID tags. It also proposed Smart Logistics including fleet management, fuel efficiency optimization, and green transportation standards to further explain IoT's role.

A Study on Cyber-Physical Spare Parts Intralogistics System [50] explored how IoT can be used effectively in **remote monitoring** and **asset management**. It emphasized a workflow to enhance the visibility of the intralogistics operations, and optimize them, wherever needed.

Another study on **Internet of Drones (IoD)** technology [51] discussed an application area where drones are used in daily operations of MRO business processes. It discussed some key application areas such as Quality control (defect object detection), Optimizing technician work schedules, intralogistics automation among other things. This study also discusses the roles that drones play in the PLM for airports' MRO systems. It also discusses the role of UAVs in the MRO industry, and how they can be used for Aircraft and Components' real-time Health Monitoring and Remote Maintenance.

Another study [52] explores how **Augmented Reality (AR)** is used in the Aircraft Maintenance Training and Support to reduce human intervention and optimize operations. We call it CBM (Condition-based Monitoring). It proposes a Digital Twin framework, through which the aircraft component parts are studied and analyzed using AR technology, allowing for a more efficient diagnosis of its current health, and maintenance protocols to be used at that point.

A study [53] described how IoT is used as a complete solution for Aircraft and its components' predictive maintenance. It describes how the aircraft components would undergo **PHM (Prognostic Health Monitoring)** to determine the product life cycle, and accordingly, IoT sensors would collect real-time data on various parameters of the components and their health, to act proactively for predictive maintenance using Edge Computing and Big Data Analytics. Another study [54] implied the design of an Aircraft Health Monitoring System using IoT, which would be used for **CBM (Condition-based Maintenance)** of aircraft and its individual components. It would facilitate Automated Diagnostics and Health Monitoring System, based on historical data about the aircraft's health, and predict its product lifecycle as well for PLM and sustainability.

An interesting study on **Smart Aircrafts** [55] conceptualized an emerging trend where aircrafts are intelligently connected to each other through SATCOM technology (Satellite Communications), which further helps in Route Optimization, Flight Scheduling and Tracking, as well as Air Traffic Management. Another study on **Connected Aircrafts** [56] further intensified this claim, by integrating Electronic Flight Bags (EFB) with the System-Wide Information Management System (SWIMS) which allows for a more centralized operational ecosystem. It discovered how Connected Aircrafts are driving next-generation A2G (Air-to-Ground) Systems connectivity forward using IoT.

A study on **Airborne Internet** [57] explored the wireless connectivity technologies that enable connected aircrafts to operate and be monitored remotely by ground stations. It discussed the framework to enhance A2G connectivity for better and smooth operational efficiency. Same concept is discussed by another research on **Aeronautical Networks** [58] which enable IFC (In-Flight Connectivity). These were recognized as A2G, SATCOM, and AANET (Aeronautical Ad-hoc Networks).

A presentation on **Digital Avionics** [59] further classified airspaces into 2 flight domains – Space (more than 100km above sea level), and ATM (Air Traffic Management). This presentation proposed the use of ACP (Automated Cyber Physical) Systems using IoT-enabled connectivity between the objects in space / air and ground. It also discussed various aspects of GPS and INS (Inertial Navigation Systems) for real-time tracking and surveillance purposes.

A book chapter on **Internet of Space Things (IoST)** [60] describes how IoT is used in the astronautics landscape, as part of Industry 4.0. It describes the emergence of SSNs (Space Sensor Networks) that work with micro-satellites and CubeSats to create a network of satellites (or satellite constellations) that allow for remote sensing, in areas with little to no internet connectivity. A similar study [61] discusses the use of LEO (Low-Earth Orbits) satellite with UAV and Edge Computing framework to provide connectivity within the NTNs (Non-Terrestrial Networks), enabling an efficient **Space-Air-Sea integrated network**.

Recently, there have been efforts to create aerospace subsystems ***smarter***. A Study on **Smart Cabins** [62] tell us how an intelligent cabin can lead to better in-flight experience, and optimized cabin management. These cabins leverage real-time data using IoT sensors to assist pilots and cabin crew in providing best user flight experience, whether it be in terms of their services, or facilities [63]. Similarly, **Smart Cockpits** [64] are assisting pilots in making better flight decisions, by tracking the aircraft's route in real time, studying the pilots' eye patterns to improve the aircraft-pilot interaction [65], and weather monitoring.

The role of ITeS in Aerospace industry has been explored by previous studies as well. A Study on **IT enabling MRO** [66] describes and proposes an all-in-one EMS for streamlining companies' business processes, integrating various verticals within the industry, and leverage real-time Big Data Analytics to enable optimization of resources. They named it SAMS – Sky Aircraft Management System.

Another study on IIoT-based **Decision Support System (DSS)** [67] discussed the architecture for building a DSS for the aeronautics industry. It included leveraging corporate ERPs for day-to-day operations, while leveraging an IaaS Cloud Computing infrastructure, alongside real-time data analytics or Stream Analytics to facilitate instant decision-making capabilities for the stakeholders.

Another study [68] proposed a **Smart Aviation Management System** using Big Data Analytics. It proposed an Aviation Big Data Platform that would have separate information systems for various functions (aircraft performance health and monitoring, supply chain and MRO, customer experience, route planning and traffic management among others), and integrate them into a single EMS, to centralize their operations.

Another study leverages Deep Learning with AR technology to create **Intelligent Cockpits** [69] that would facilitate a pilot's decision making throughout the flight journey. It discusses the use of IoT sensors to track pilots' flight patterns and use real-time navigation systems and weather monitoring systems to assist the pilots in decision-making while in-flight. This would be further facilitated by Big Data-enabled smart cockpits that would display real-time monitoring dashboards to the pilots for enhanced decision-making.

An interesting study on Disaster Management using **GIS (Geographic Information Systems)** [70] explored how IoT sensor data was captured in real-time, analyzed using Stream Analytics frameworks, and connected to the stakeholders using Big Data Platforms incorporated in the GIS to facilitate disaster management strategies and principles.

Another study explored the role of IoT and Big Data Analytics in **Autonomous Navigation Systems (ANS)** [71]. It discussed an ICT (Information Communication Technology) framework that established an information flow between various entities in building an automated navigation system, using AI and ML. It also proposed an **Internet of Vehicles (IoV)** ecosystem connecting multiple autonomous vehicles.

A similar study [72] explored whether machine learning can be used to predict positioning of IoT devices in an optimized network for **Global Navigation Satellite System (GNSS).** It was conducted with an aim to optimize the entire GNSS network, as well as automate the positioning in the future. A study on analyzing surface water quality using **GIS** and **Remote Sensing** [73] showed us the importance of IoT in assessment of Water Quality. The study focused on establishing an A2G connection using a centralized GIS which had Business Intelligence (BI) capabilities that allowed for real-time quality inspection, and predictive quality control establishment.

An interesting study on an IoT-enabled **Airfield Lighting System** [74] described how airports are integrating IoT and Stream Analytics into their existing business processes to enhance productivity. It provided a much better, cost-effective, scalable, and agile framework for the airports to enhance their monitoring and control systems within the airport ecosystem. A similar study [75] talks about tracking customer journey inside the airport using IoT-enabled airport terminals. It aims to deploy an **IoAT (Internet of Aerospace Things)** by developing an interconnected ecosystem within the airport that would enhance customer experience during their traversal to flights.

A previous study on **Future Aeronautical Communications** [76] explored the transition of legacy aircraft operations to a more digital one. It discussed the transition to IT-enabled Aircrafts or **e-Aircrafts**. It discussed modern day avionics such as IFC, Intelligent Cockpits, and the communication protocols alongside the IoT infrastructure that has enabled connected aircrafts ecosystem.

A comprehensive study on **Military IoT (MIoT)** [77] explored how IoT is used in military aviation. It divided the **AMD (Air and** Missile Defense) operations into 4 segments – ISR (Intelligence, Surveillance and Reconnaissance) which is handled by IBCS (Integrated Battle Command System), Air Strikes which is handled by missiles, bombers and UAVs, Logistics which is handled by AILS (Automatic Intelligent Logistics System), and Command Control, which is operated by a joint C2 (command-and-control) system.

Another study on **Smart Baggage Tracking** [78] discussed the role of IoT-enabled RFID tags in tracking the journey of Customer baggage to optimize the airport operations and enhance customer experience within the airport. Similar outcomes can be seen from another study that uses **Blockchain** with RFID for baggage tracking and theft detection [79].

Aviation has a big role to play in the advent of Smart Cities. A Study on integrating **UAVs** within the current ATM ecosystem [80] is discussed, where IoT-enabled architectures are deployed to operate and monitor UAVs across the smart city using Business Intelligence (BI) Systems that assist in monitoring and decision-making. This claim is further backed by another study [81] which proposes that integration of UAVs in the current **UAM (Urban Air Mobility)** environment is the key to **Aviation safety** in the future.

Some more uses of IoT in Aero-Operations are **Smart Airports** [82], that leverage IoT-enabled technology such as biometrics, RFID and using related connectivity technologies to implement an interconnected ecosystem of business processes within the airport.

When we talk about Space, the applications of IoT further increases into various segments. A study on **Smart Robots** [83] discusses how RPA is used extensively in space applications for autonomous and dangerous missions. Another study talked about the role of **IoT in PHM** [84] of spacecraft crew and modules remotely, both from the ground stations, as well as the space stations. This is further backed by another study [85] which discusses on a concept of development of a robot for assistance in **space mining**.

Some studies [86][87] discussed the role of IoT in the emergence of **LPWANs (Low-Powered Wide Area Networks)** via LEOs that help in reaching data connectivity to remote locations. This has given rise to various applications of **IoST (Internet of Space Things)** such as environmental monitoring, disaster forecasting, remote sensing among others.

Another study expands the use of IoT for **real-time object tracking** in space [88]. Apart from these, there are many other various applications that have been explored. **Autonomous Spacecraft Operations** [89], **Intelligent EOS (Earth Observation Systems)** [90][91] while another study talks about **Autonomous Telemetry systems** for Spacecrafts [92].

From the existing literature, it is quite clear where IoT is exactly implemented in the Aerospace industry. We do have to look towards the future, though, right? Hence, let us see some challenges in IoT implementation, and prospects or opportunities that, as of now, exist for the Aerospace Industry.

Challenges and Opportunities in IoT Implementation in the Aerospace Industry

While the robust deployment of IoT technologies has contributed to the rapid growth in the Aerospace industry, it has brought upon its share of challenges.

Extensive research on IoST [93] highlighted the issue of **efficiency and reliability of WCT (Wireless Communication Technology)** in developing next-generation space applications. It also discussed the complexity of data management of cloud data servers as another major challenge. It described how this complexity could lead to issues in monitoring and interoperability. Another highlighted issue was the proficiency of RPA in enabling automation within the operations. It highlighted the reliability of IoT-enabled space architectures, and how efficient the Stream Analytics models would be, regarding autonomous navigation, control, and guidance.

A book on **Industry 4.0 and Aviation** [94] discussed some key challenges for enabling IoT-driven solutions in the aerospace industry. It discussed the maintenance and training costs for manufacturing professionals, as well as the product lifecycle management of IoT products. Cybersecurity concerns relating to data privacy, confidentiality, and authentication is another primary concern. Finally, re-usability concerns over the additive manufacturing components raise serious concerns not just over sustainability, but cost-effectiveness as well.

However, with challenges come opportunities as well. There are already many research areas actively exploring the 5.0. industry landscape for aerospace.

A conference proceeding on **Digital Twins** [95] proposed a framework for utilizing DTO for Sustainable Aviation. Similarly, another study on **Smart Airports** [96] discussed how **VR technology** can be utilized for enhancing Smart Airports. This was backed by another study that proposed a **Mixed Reality** (MR) [97] paradigm for **Smart Aviation**.

When it comes to cybersecurity, many researchers have turned to Blockchain. A study on **Smart Contracts** [98] discussed how Airport Security can be enhanced using Blockchain Smart Contracts. Another study combined it with **Cloud Computing frameworks** [99] for better customer experience and operational efficiency. Another study [100] explored how Blockchain can be used to **streamline civil aviation operations** – IFE (In-Flight Experience), Digital Identity, Payment Methods, Security among others.

When it comes to prospects, there are many developments being conceptualized. A study [101] discussed how the future is driven by **new-age datalink communication** technologies, integrated with AI-driven automation capabilities. Another study proposes a **futuristic NoT (Network of Things) architecture** in avionic systems [102] that facilitates wireless connectivity within the aircraft subsystems that have intelligence and automatic reconfiguration capabilities.

A very interesting study on **World of Things (WoT)** [103] described a concept of Graph database deployment for military aviation ecosystem, which facilitates real-time tracking and monitoring of performance of troops and asset management on the battlefield.

A **futuristic SAR (Synthetic Aperture Ranging) navigation** and remote sensing system is proposed in a study [104] that leverages dual-band lightweight digital array system to supersede the performance of RADAR (Radio Detection and Ranging) and LiDAR (Light Detection and Ranging) systems. It would leverage AI-driven imaging systems for better geographical mapping, and real-time updates.

Hence, there are a lot of developments happening parallel to each other. The future does seem bright for the Aerospace Industry. So far, we have calculated all the information we require to conduct our analysis. Let us proceed.

APPLICATIONS OF INTERNET OF THINGS (IoT) IN THE AEROSPACE INDUSTRY

In our literature review, we have seen a variety of applications across various segments of the aerospace industry. Let us begin with a simple thematic analysis, where we would segment the application based on its application industry.

Thematic Analysis

Based on the data collected from our previous studies, we have segmented the applications of IoT in the Aerospace industry in 7 major segments -

Aero-Manufacturing

In the manufacturing segment, IoT is leveraged to implement **Additive Manufacturing** (3D Printing) which allows for a better manufacturing ecosystem. It is also leveraged in **Smart Manufacturing** which leverages the use of robotic machinery and digital twin technology to conduct automation in real-time with minimal human involvement. Finally, we use IoT in the **Automated Quality Control** for the production and assembly of components, to facilitate lean manufacturing principles.

A few other applications were found in **Product Lifecycle Management (PLM)** which allows companies with an agile manufacturing complexity, allowing them to track and maintain their products' life. In recent years, a trend for **Process and Task Mining** has emerged to be an important use of IoT, where production and assembly lines are monitored in real-time and analyzed to optimize their functionality.

Supply Chain

In the supply chain segment, IoT is majorly leveraged in streamlining the companies' entire supply chain management framework, for better monitoring and control. **Smart Warehouses** are increasingly taking over, allowing for better management and movement of goods within the warehouse, while tracking their entire PLM. **Real-time Visibility** over the entire order management process, both to the vendors / customers and the company has allowed for better, transparent processing, enhancing companies' goodwill and trust in the minds of the customers.

Another popular use of IoT is in the **Smart Logistics.** It leverages real-time big data analytics (Stream Analytics) using RFID tags for better fleet management, inventory control, route optimization, asset monitoring and product lifecycle management. Recently, the increasing use of **IIMs (Intelligent Intralogistics Machinery)** has been on the rise, which leverage RPA, AI and IoT to automate workflows within the companies' current intralogistics system.

Research and Development

Another key implementation area found was R&D (Research and Development). The use of IoT majorly dialled down to **Rapid Prototyping**, which allowed for quick product development and testing with minimized resource utilization. Another interesting use of IoT was in **Design Simulation and Modelling**, which allowed companies to product better quality products with minimum defects. Another key application area was found out to be **Regulatory Compliances and Standardization**, which helped companies monitor and maintain their products' alignment with the industry standards regarding safety and environment.

Avionics

The major use of IoT has been observed in this segment. One of the ground-breaking uses of IoT has been the concept of **Connected Aircrafts.** This technology enables aircrafts to be connected via **Aeronautical networks**, which would allow them to have better control over their flight experience and monitoring. Another concept of **Smart Aircrafts** would leverage edge computing and big data analytics to assist the pilots in decision-making and crisis management.

IoT has a big role to play in the **Airborne Internet**, which has allowed for better sea-space-air-ground connectivity, among the aircrafts, as well as the ground stations. Another amazing aspect of this segment is **Air Traffic Management**, which has seen an increased use of IoD (Internet of Drones) being integrated into the current ATM ecosystem, allowing for better traffic management and monitoring of aircrafts in-transit.

Digital Avionics has been making the rounds for quite some time now. It has enabled real-time interactions of pilot, crew and the passengers with the aircraft, allowing for a better collective IFE (In-flight experience) for both parties. Some recent interesting developments have been in the implementation of **Smart Cabins and Cockpits**, that leverage new-age technology to assist the pilots in decision-making, enhance customer experience for the duration of the flight, and allow for a more optimized and sustainable flight.

Maintenance, Repair and Overhaul (MRO)

A very important segment of the Aerospace industry is the Maintenance, Repair and Overhaul (MRO) segment. In terms of this segment, IoT is also used extensively to streamline and automate business processes.

IoT is primarily used in **Predictive Maintenance** of aircrafts and their components, allowing for a more proactive approach towards dynamic changes of the market. Using **UAVs for Quality Inspection and Control** is another implementation of IoT that is increasingly being adopted. Using IoT in combination with Stream Analytics has allowed for better **Remote Monitoring and Asset Management** for components, allowing for a more streamlined MRO operation.

Some interesting new use-cases have emerged in the case of **Prognostic Health Monitoring (PHM)**, which leverages AR technology to monitor and track the health of components in real-time, allowing better control over the MRO processes. Another similar application is in the form of **Automated CBM (Condition-based Monitoring)** which leverages IoT to automatically monitor the health and status of components or individual aircrafts, and place triggers in case of damage / fault, based on company or industry safety and environmental standards.

IT-enabled Services (ITeS)

Another important application segment is the Information Technology-enabled Services (ITeS). Ever since companies are shifting towards a data-driven ecosystem, this segment has seen rapid growth.

IoT's major role to play here is in the technology integration with the companies' current business processes. Providing an **all-in-one EMS** tailored to the companies' needs is driven by the IoT integration with the business processes. Researchers are calling them out to be **Smart AMS (Aviation Management Systems).** Another use of IoT is found in the **Cloud, Edge and Fog Computing** frameworks that allow companies to process and analyze real-time data from their business operations. This is also aligned with how **Decision Support Systems (DSS)** use **Big Data (Stream) Analytics** from IoT frameworks to enable Smart Avionics.

Recently, the increased use of **GIS (Geographical Information Systems)** and **EOS (Earth Observatory Systems)** has emerged. These use IoT sensors to capture real-time data for disaster management, environmental monitoring, geographical mapping among other activities that involve **Remote Sensing**. Another interesting application is found in the enhancement of **In-Flight Connectivity (IFC) and In-Flight Experience (IFE)** for both customers and consumers (passengers, crew and pilots) which allows for real-time personalized recommendations to provide a better user journey. The new-age has been traversing around extensive use of **Blockchain technology** to enable **Aviation Security** regarding documentation, digital identity, payments.

Aero-Operations

The most use of IoT has been conducted by this segment. It extends to a variety of applications. The most popular use is **Smart Airports**, that track a consumer and/or customer's entire flight journey from the moment they enter the airport till they board their flight. This could be about streamlining their baggage collection using **Smart Baggages** or helping them reach their designated gates within the minimum possible time, using **Smart Terminals**. They also call it **Internet of Aerospace Things (IoAT)**.

Some interesting implementation has been done in the form of **Autonomous Navigation Systems (ANS)**, which has allowed for better Airborne internet connectivity, as well as easier traversal for astronauts and space modules. It has further been extended to the development and use of **Internet of Vehicles (IoV)**, through autonomous vehicles. Recently, AR has been used extensively with RPA to assist in **Space Mining and Space Operations** using Smart Robots. This has allowed humans to have better controls over the operations. This further extends to the **PHM of Crew and Modules** in the Space Vehicles and Structures.

New emerging trends tell us how IoT is leveraged in **LPWAN connectivity**, through CubeSats and Satellite Constellations, that allow for connectivity to reach remote locations. This further is used in the development and operations of **GNSS (Global Navigation Satellite System)** and **SSN (Space Sensor Networks)**. A new concept regarding **Military Internet of Things (MIoT)** has highlighted how IoT can be used in the **Air Missile Defense Systems (AMD)** to enhance **warfront operations**, using intelligent weapons and uniform to track their performance in real-time and enhance their impact.

Comparative Analysis

Now that we have conducted our thematic analysis, let us move ahead. This time, we would do a short comparative analysis among the 2 main industries within aerospace – Aeronautics (Civil and Military) and Astronautics.

Aeronautics

When it comes to Aeronautics, the majority of implementation has been conducted here only. It starts with the manufacturing applications, like **Additive Manufacturing**, **Smart Manufacturing**, **Quality Control, PLM, Process and Task Mining**.

It extends to the Supply chain applications such as **Real-time visibility, Smart Warehousing and Logistics, IIMs**. It also includes the R&D applications, such as **Design Simulation and Modelling**, **Rapid Prototyping, Regulatory Compliances and Standardization**.

Furthermore, it extends to MRO operations such as **Predictive Maintenance, IoD for Quality Control, Remote Monitoring and Maintenance, PHM and CBM**. It also involves Avionics such as **Connected and Smart Aircrafts**, **Smart Cabins and Cockpits**, **ATM, Airborne Internet connectivity**, and **Digital Avionics**.

It also involves the operations of **Smart Airports**, **Autonomous Navigation Systems** and **LPWAN connectivity** using Satellites Constellations. **Remote Sensing** operations such as disaster management, geographical mapping and weather forecasting are also a part of it. It also involves **MIoT**, which involves using AILS (Automated Intelligent Logistics System), IBCS (Intelligent Battle Command System) and C2 (Command-and-Control System) to enhance warfare operations and performance of resources and troops.

Astronautics

When it comes to Astronautics, there would be a few applications that would overlap with the Aeronautics. This is because at the core, the processes work in similar manner.

This holds true for manufacturing applications such as **Additive Manufacturing**, **Smart Manufacturing**, **Quality Control, PLM, Process and Task Mining**; R&D applications such as **Design Simulation and Modelling**, **Rapid Prototyping, Regulatory Compliances and Standardization**. It also extends true to Avionics applications such as **Aeronautical Networks, Connected Aircrafts, Smart Cockpits, and ATM for Space**. It involves a few of MRO operations, albeit in a different perspective. **Predictive Maintenance** and **Quality Control** are two of them, but they occur in aspect of Space Vehicles. Similarly, **PHM** and **CBM** also occur, but for the spacecraft Crew and Modules, and further, the extraterrestrial vehicles.

Finally, some astronautics-specific applications constitute of **Space Mining, Autonomous Telemetry Systems, Intelligent Spacecraft Operations, Autonomous Navigation Systems (ANS), LPWAN Connectivity, GNSS and SSN, GIS and EOS,** and **Remote Sensing Operations**. All these are cross-industry applications, utilized in both aeronautics and astronautics.

Synthesis of Information

Our analysis is complete. Now, we will summarize our interpretations from the analyses in this portion. This summary will provide a bird-eye view of the research we conducted, and insights we found in it.

Thematic Analysis classified our applications into **7 Segments**:

1. Aero-Manufacturing
2. Research and Development (R&D)
3. Supply Chain
4. Maintenance, Repair and Overhaul (MRO)
5. Avionics
6. Information Technology-enabled Services (ITeS)
7. Aero-Operations

These application segments covered a wide range of IoT implementation use-cases, from civil and military aeronautics to astronautics. Many applications overlapped within these cross-industries as well.

In our **Comparative Analysis**, we distributed our applications into the 2 main sub-industries – Aeronautics and Astronautics. We noticed many overlapping applications especially in the manufacturing, R&D, MRO, Aero-Operations segments, while the others had a few overlapping applications. This concludes our analysis part. Our study is complete. It is now time to conclude this research in the next segment.

CONCLUSION

This study was conducted to understand how Internet of Things (IoT) is used in the Aerospace industry. We have unfolded quite a few use cases, that spanned across various segments from Manufacturing, Aero-Operations, Supply Chain, MRO and others. We also compared how the uses change when we move from Aeronautics to Astronautics in terms of sub-industries. While Aeronautics is more manufacturing and Aero-Operations focused, Astronautics is more focused on R&D, ITeS and Aero-Operations.

This comprehensive study aimed to understand in-depth, how the IoTA (IoT in Aerospace) Industry works. We understood and tracked the evolution of both, the Aerospace Industry and IoT, before diving into the key technologies – Cloud, Edge and Fog Computing, Stream Analytics, Blockchain, AR/VR, AI and ML, RPA among other. This led to understanding of how IoT is used in the Aerospace industry, hence, bringing this research to a conclusion.

Implications and Benefits

The benefit of this research is that we clearly highlighted the specific IoT implementation area in the industry, as well as understood the technologies driving that implementation, that work complementary with IoT. Another benefit is that it gave us a bird-eye view to the studies till date on the topic and allowed us to segment the applications based on their application areas, and sub-industries.

Challenges and Future Scope

The major challenges for IoT implementation in the Aerospace industry, as discussed, included Cyber Security, Reliability of RPA and AI for autonomous operations, Sustainability, Complexity of Data Management, creating balance between interoperability, scalability, and efficiency. Future scope identified the potential implementations of new-age technologies such as Blockchain, AR/VR/MR, Digital Twin, SAR, WoT and NoT among others to drive the aerospace industry forward to a more technology-driven age.

Contributions to existing literature

The major contribution of this research is about integrating all the scattered information regarding IoTA into a single piece of literature. Another major contribution is to particularly identify the IoT implementation in each segment of the Aerospace industry and understand it for future planning.

Recommendations for future research

Recommendations for future research include a more comprehensive study on the industrial applications using real-world case studies. Conducting a critical analysis of those implementations, both successes and failures would allow us to determine the factors that contribute the most to the technological enablement of IoT in this industry, and further enhance our understanding of IoTA.

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