# Data-Driven Skies:

## Boeing Data Management Infrastructure

Muhammad Mattin Sharif
40418446

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# INTRODUCTION

Founded over 100 years ago, Boeing – An American multinational corporation- has established itself as the world's largest aerospace company. It is a leading manufacturer of commercial jetliners, defence, space, and security systems, supporting airlines and allied government customers in over 150 countries (Boeing, 2023a).

Boeing, a century old pioneer in aircraft and aerospace manufacturing has transformed into a data driven enterprise. This transformation is not merely a technological shift but a strategic adaptation to the increasing importance of data in complex and competitive aviation manufacturing and operations. Currently they have more than 11,000 active suppliers across the globe to run their operations (Perry, 2023). Boeing leverages the power of data to impact supply chain, aircraft designs, market trend forecasting (Petrescu, 2017).

**Market Analysis and Competitiveness**: Boeing operates in a highly competitive and dynamic market. Its main competitor in commercial aircraft manufacturing is Airbus, performing slightly well recently because of Boeing in trouble after the crash of the 737 Max in 2018 and furthermore, exploded with the COVID pandemic (Finder, 2023).

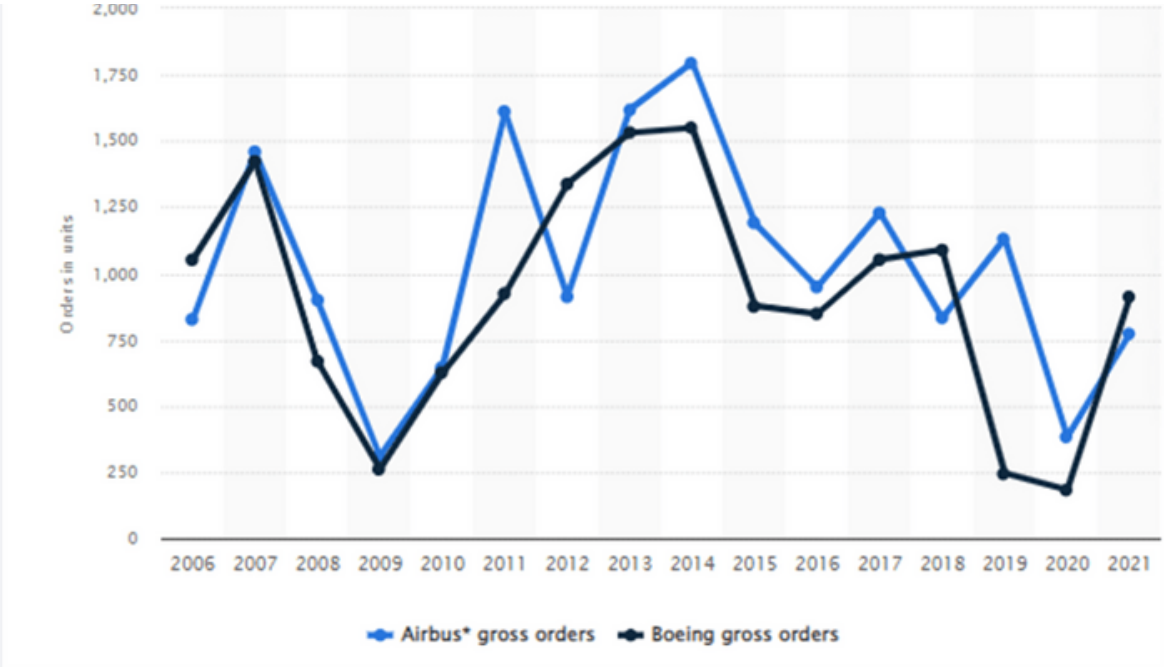


**Figure: Historical data of Aircraft order of Boeing Vs. Airbus**

The company's venture into big data is a strategic response to the evolving demands of the aerospace industry. Each month airlines and suppliers send tons of raw data for processing into Teradata ecosystem for analysis and screening of errors. This move represents a exemplary shift from traditional manufacturing to a data-centric approach, focusing on predictive algorithms, historical data, and real-time insights to gain a competitive edge over its competitor – Airbus (Howard, 2016).

**Big Data Application in Boeing**: Boeing's venture into a data-driven organization revolves around effectively managing and processing large volumes of diverse data e.g., data from aircraft sensors, supply chain operations, and market trends. The company employs a comprehensive data-management infrastructure which incorporates technologies like parallel databases, Hadoop, and Teradata Aster platform for large-scale data management and processing (Howard, 2016). This technological adoption aligns to reshape Boeing's operational strategies, forecasting market trends and moreover optimize aircraft design. As evident in the development of more innovative, safer, more fuel efficient, and more environmentally friendly aircraft like the Boeing 777X, 737 MAX, and 787 Dreamliner.

As Boeing continues to leverage data, it set a new standard for the future of aviation industry where data is leveraged for informed strategic, operational decisions as a key differentiator (Cook, 2015). This report highlights the key aspects of data management practices and the technologies incorporated at Boeing that aligns with the company's mission.

# Data Utilization at Boeing

Boeing's use approximately 8,000 to 10,000 sensors on each aircraft to improve airplane fuel efficiency, speed up delivery of parts by anticipating maintenance, and optimize flight paths for the better interest of their customers. This accumulates more than 100 Petabytes of data by Boeing, as noted by Harish Rao, Director of Business Analytics at Boeing indicating the huge volume of data (Baig, 2018).

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# Data generated by the engines only?


**Figure: Amount of data generated by enjines by an airplane in one year**

**What Data is used?**

Boeing, a multinational global leader in aircraft manufacturing, utilizes a wide array of data to drive its operations and calculated decision-making processes. Every decision is assessed based on the safety standards and what-if scenarios because even a smallest decision can lead to catastrophic outcomes (Boeing, 2022). This includes processing of the following data, but is not limited to:

- **Aircraft Sensor Data**: This incorporates real-time data from thousands of sensors on each aircraft, providing information on various aspects of flight performance and aircraft health, and the external environment and factors.
- **Operational Data**: Includes flight logs, maintenance records, and other operational metrics essential for day-to-day management of flight operations and maintenance scheduling.
- **Customer Data**: Data related to Boeing’s commercial clients, including airlines, which can involve sales data, customer service interactions, and contract details.
- **Supply Chain Data**: Data about suppliers, inventory levels, procurement details, and logistics that is crucial for managing Boeing's extensive supply chain.
- **Financial Data**: Covering areas like sales, revenue, expenditures, and other financial metrics significant for strategic planning and financial reporting.

# Structured and Unstructured Data

**Structured Data**: This is data that adheres to a predefined structure and is easy to search and organize. Boeing's structured data includes:

- **Financial Records**: Such as sales figures, revenue, costs, and other quantifiable financial metrics.
- **Supply Chain Management Data**: Inventory, supplier information, procurement costs, these are typically stored in relational databases.
- **Customer Relationship Data:** Including client details, contract information, and sales transactions.

**Unstructured Data:** This type of data does not follow a specific format or structure. Boeing's unstructured data consists of:

- **Sensor Data:** Generated by aircraft during flights, providing a vast array of information in formats not structured for conventional databases.
- **Maintenance Logs and Operational Reports:** Often in text form, containing detailed records of aircraft performance, maintenance activities, and other operational aspects.
- **Images and Video Data**: From various sources, including surveillance, maintenance, and testing activities etc.

Boeing's strategic use of both structured and unstructured data, leveraging technologies like Hadoop for unstructured/semi structured data and Teradata for structured within the Teradata environment, enables the company to gain comprehensive insights into its operations. This data-driven approach is crucial for enhancing operational efficiency, aircraft safety, and business performance.

# Technical Infrastructure of Data Management at Boeing

Being's data architecture is a comprehensive and unified Teradata ecosystem that integrates Hadoop, Teradata, and Microsoft Cloud for data storage, each playing a critical role in managing structured and unstructured data. This integration reflects Boeing's strategy to leverage the strengths of these technologies for efficient data management and analytics. This ensures that large volumes of unstructured or semi-structured data can be effectively managed and analysed alongside structured data within Teradata's system (Merai et al., 2014). Data is stored at a unified level for easy access of data to do further analysis.

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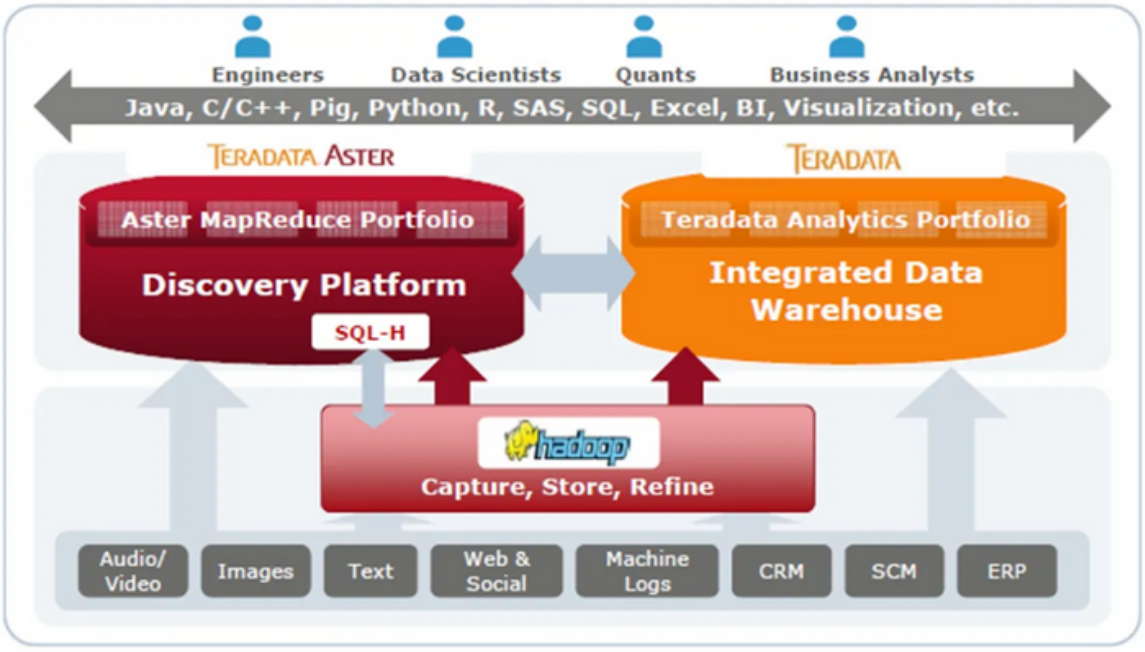
# Unified data Architecture

Any user , Any data, Any Analysis




Below is the image of the process happening in Teradata Aster platform

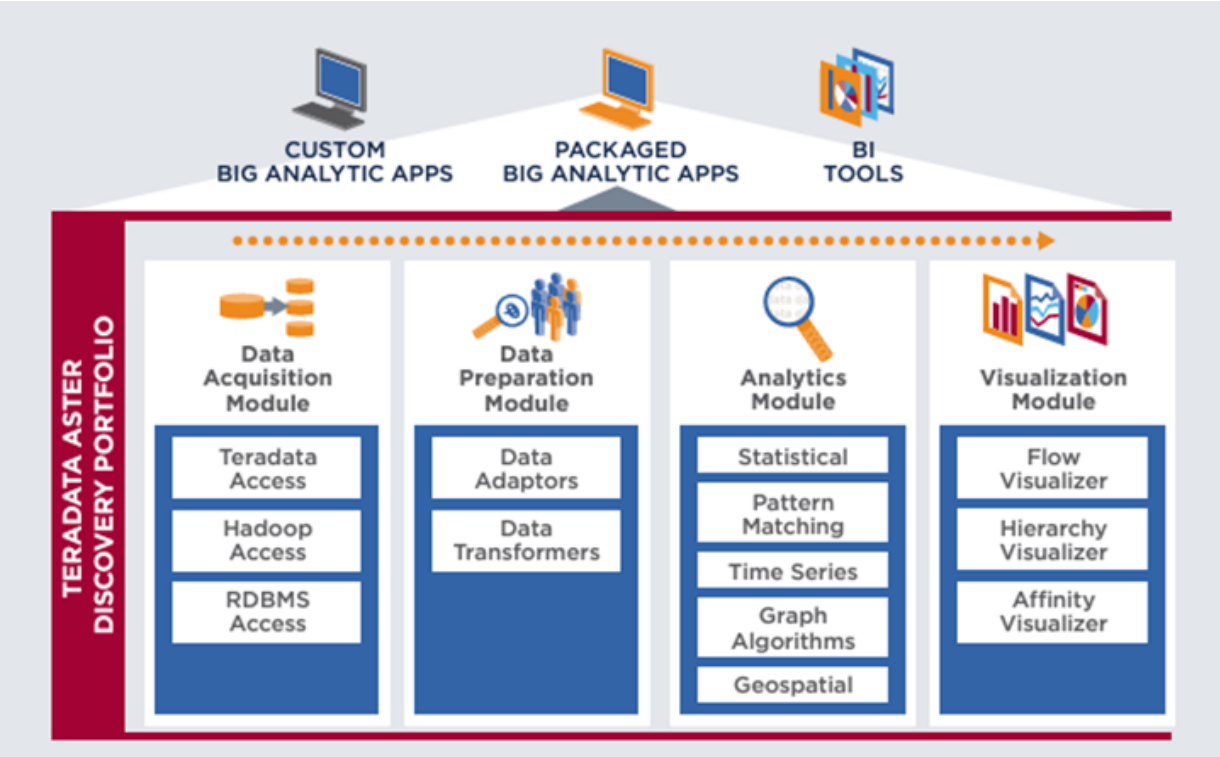


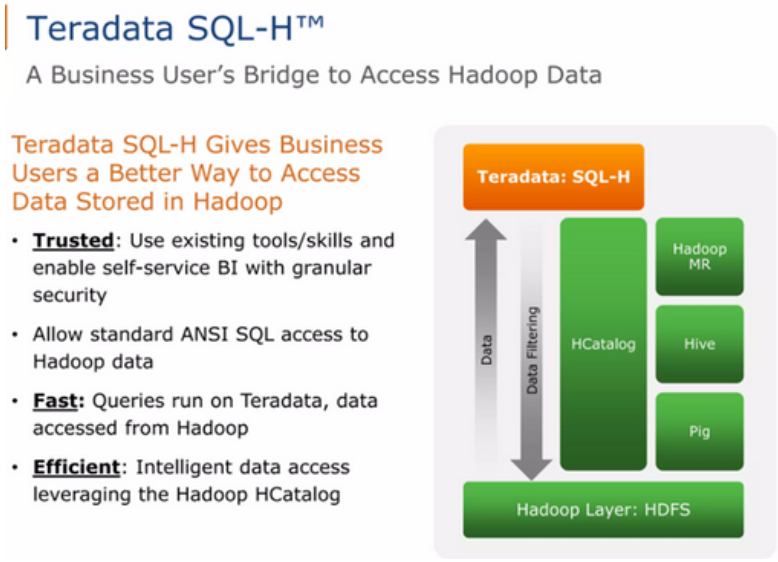

**Figure: Teradata Aster platform**

**Hadoop Integration within Teradata**:

Hadoop works seamlessly within the Teradata ecosystem. Boeing leverages this integration as particularly evident in the Teradata Aster Big Analytics Appliance in the figures above (Brueckner, 2014). It combines Hadoop's capabilities with Teradata's massive parallel processing technology by integrating them at a deep metadata level. Furthermore, this integration supports both MapReduce and a fully ANSI-compatible instance of SQL (SQL-H) to facilitate queries on structured, semi structured, and unstructured data.

Moreover, the appliance also includes over 50 pre-built functions for analytics, making it easier for Boeing to derive value from their data. Hadoop complements Teradata by managing the vast amounts of unstructured data generated in an enterprise setting. Its integration into Teradata's architecture ensures that all types of data, regardless of their format, can be stored, processed, and analysed effectively (Morgan, 2012).

**Handling Unstructured Data in Teradata:** Hadoop is primarily used to manage and process large volumes of unstructured or semi-structured data, such as aircraft sensor data, telemetry, and maintenance logs. This data is critical for predictive maintenance and operational optimization.
Advanced Analytics: Through the Teradata Aster Big Analytics Appliance, Boeing can perform advanced analytics on unstructured data using a combination of MapReduce and SQL (SQL-H) and this a lot faster than the tradition application (Hive) used in Hadoop ecosystem. Unlike Hadoop, Teradata is having primary keys making the whole query works faster (Pedamkar, 2023).




This allows Boeing to query across semi-structured, and unstructured data, thereby gaining comprehensive insights.

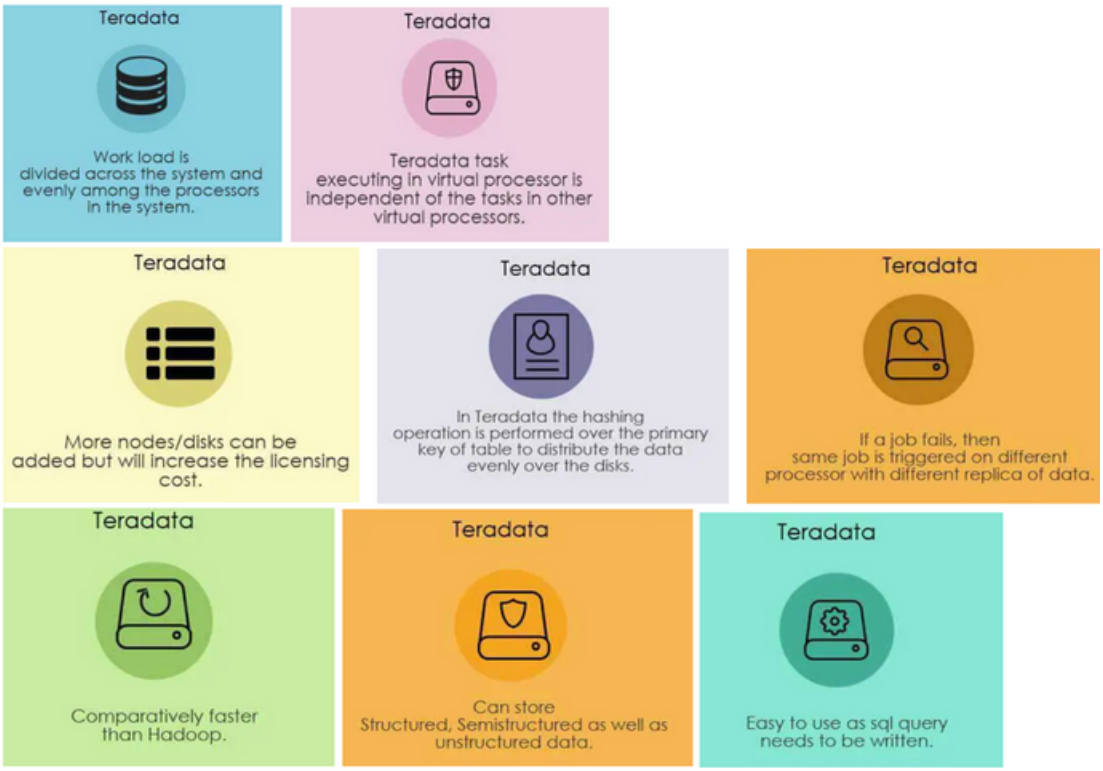
**Handling Structured Data in Teradata:** For structured data such as financial records, customer data, and supply chain information, Boeing utilizes Teradata's robust data warehousing capabilities. Due to parallel processing Teradata excels in managing large-scale structured data with high efficiency and speed as work load is divided across the systems or evenly among the processors among the systems (Pedamkar, 2023).

**Business Intelligence and Reporting**: Teradata enables Boeing to perform complex queries and generate insightful business intelligence reports. This is crucial for strategic planning, financial analysis, and operational decision-making.

**Use of Microsoft Cloud Platform by Teradata:**

- **Cloud Integration**: Teradata's integration with Microsoft Azure allows Boeing to leverage cloud capabilities for both structured and unstructured data. Azure offers scalable storage and computing resources, enhancing Boeing's data processing capabilities and flexibility to scale according to the requirements (Donahue, 2022).
- **Enhanced Analytics and Flexibility**: By using Microsoft Azure, Teradata can store and analyse data in a flexible and scalable cloud environment. This helps Boeing in handling peak loads and storing large data sets without worrying about physical hardware limitations. Moreover, Boeing can leverage the capabilities of AI, integrated within the Microsoft infrastructure (Donahue, 2022).

# FEATURES OF TERADATA




In summary, Boeing's data architecture is evidence of its commitment to leveraging leading-edge technologies for comprehensive data management. The integration of Hadoop with Teradata and the support of Microsoft Azure create a powerful combination that drives Boeing's data-driven decision-making, innovation, and operational excellence.

# BENIFITS FOR BOEING

Boeing's venture into big data analytics has brought significant benefits, it has enhanced informed decision-making, optimized operations, and improved productivity.

01

One of the primary benefits of Boeing's big data utilization is in product development and integration. The data-management and analytics hardware and software from Teradata have enabled Boeing to extract actionable insights from its data and furthermore, adopt a culture of fact-based decision-making. This approach has been helpful in guiding strategic direction and moreover, strengthening Boeing's competitive edge in a highly competitive and dynamic aircraft industry. Boeing has been able to reduce noise by 40% in their new aircraft -777 series - and subsequently made them more fuel efficient (Howard, 2016, Boeing, 2020).

02

Boeing's big data strategies have led to significant improvements in its supply chain and anticipate the demand by leveraging business intelligence and Machine learning capabilities. By providing business intelligence insights to internal and external users (airline, etc.), the company has managed to streamline operations across various divisions and production lines to reduce the time and effort required. Moreover, have also improved the quality of outcomes, enhancing overall productivity and efficiency (Howard, 2016).

# BENIFITS FOR BOEING

03

Furthermore, Boeing's application of big data extends to safety and quality control. Data analytics play a critical role in predicting and preventing potential safety hazards. By integrating data from diverse sources like sensors, RFID tags and black boxes, Boeing has been able to make timely large-scale decisions significantly enhancing the safety and reliability of their products. Boeing approach towards data demonstrates bottom line impact (Howard, 2016).

04

Moreover, the partnership with Microsoft for digital transformation has further empowered Boeing's data analytics capabilities. Leveraging Microsoft Cloud and AI technologies, Boeing can create more efficient data-driven solutions utilizing NLP model capabilities. This partnership will prove to be pivotal in enhancing Boeing's operations and developing digital solutions for the broader aviation industry in future (Ehrlich, 2022).

# LIMITATIONS AND MANAGEMENT OF THE SOLUTION AT BOEING

While Boeing's transition to a data-driven business has brought significant benefits, it has also encountered several challenges and limitations, particularly in the area of data analytics and system infrastructure.

01

## Complexity and Integration Challenges

Integrating diverse systems like Hadoop, Teradata, and Microsoft Cloud presents significant complexity. Managing data across these platforms requires specialized skills and constant supervision to ensure seamless operation and data consistency as even a smallest error can led to catastrophic results (Cook, 2015).

02

## Data Security and Privacy Concerns

With vast amounts of sensitive data being processed and stored, Boeing faces high risks related to data breaches and cyber-attacks. Ensuring the security of data across multiple platforms especially in a cloud-based environment is crucial (Sriram, 2022).

03

## Compliance with Regulations

The aerospace industry is subject to emerging regulatory requirements including data protection and privacy laws. Boeing must ensure its data architecture complies with these regulations. This can be challenging given the global nature of its operations and the evolving regulatory landscape with respect to different locations (Shmelova et al., 2023).

04

### Scalability and Performance Issues - Cost Management

As Boeing's data volume continues to grow exceptionally, scaling its infrastructure while maintaining high performance will become challenging specifically in term of financial burdens (Trends, 2021).

# MANAGEMENT STRATEGIES

01

### Robust Security Measures

Implementing advanced cybersecurity measures and furthermore, regular audits and compliance checks to safeguard data privacy and integrity.

02

### Cost-Benefit Analysis

Regularly conducting cost-benefit analyses to ensure the financial feasibility report of the data infrastructure required and to guide decisions about more investments.

03

### Regulatory Compliance

Staying ahead of regulatory changes and ensuring all data processes comply with the latest standards and laws.

# FUTURE OUTLOOK

By 2025, Boeing aims to fully integrate its Safety Management System with the Boeing Safety Intelligence Solution. This new system will act as the central mind for monitoring design, helping to build, and oversaw operations throughout the company.

This integration is expected to enable Boeing to predict and then prevent safety issues more effectively. The main focus of the system will be on actively identifying hazards and risks by leveraging data in tracking and then mitigating them (Boeing, 2022). This highlights Boeing's commitment to continuous improvement and innovation in aerospace operations and safety.

# CONCLUSION

In conclusion, Boeing's sophisticated data architecture incorporating technologies like Hadoop, Teradata, and Microsoft Cloud, represents a whole story in how big data is leveraged in the aerospace industry. Hadoop's integration within the Teradata platform allows Boeing to efficiently manage a vast spectrum of different data - structured data to unstructured sensor and operational data.

This data architecture enables Boeing to extract actionable insights from complex datasets to drive innovation, enhance operational efficiency, and maintain a competitive edge in a rapidly growing industry. The addition of Microsoft Cloud into this architecture brings scalability, flexibility, and advanced analytical capabilities driven by AI.

Boeing's commitment to a data-driven future sets a benchmark for technological development and utilization in large-scale, data-intensive industries.

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