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Business Models for Commercial Aerospace Batteries

A case-study of Heart Aerospace, a reserve-hybrid electric aircraft manufacturer

Master's thesis Management and Economics of Innovation

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CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2023
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Report No. E2023:032

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Abstract

This master thesis analyzes various business models for aerospace batteries and evaluates their compatibility with long-term strategy, risk tolerance, market fit, and financial implications. The study aimed to identify the business model most suited for a new entrant in the commercial aerospace industry by investigating the activities and costs introduced in the industry as a result of electrification, and the strategic and financial implications of aerospace battery business models. The research methodology included an analysis of four pre-selected business models, an industry analysis to gain insights into the broader market dynamics and trends, an internal analysis to evaluate the alignment of Heart Aerospace's long-term strategy with the selected business models, and a thorough financial analysis to assess the economic viability and potential outcomes of each model. The findings indicate that all models have their advantages and disadvantages. However, a strategic partnership or joint venture (JV) business model had the strongest mix of net present value, internal rate of return, risk-sharing, and retention of strategic control of the battery business. The business model structure was supported by the literature, allowing airlines to fully focus on their core business by outsourcing battery operations. Reviewing the industry key success factors, Heart Aerospace must have a value proposition that offers low and predictable operational costs for airlines and maintain strategic control of the battery aftermarket to attain a sustainable competitive advantage. Overall, the study's results provide valuable insights for new entrants in the commercial aerospace industry, by mapping advantages and disadvantages of different business models and identifying challenges and ways to mitigate them.

Keywords: business models, service management, aerospace batteries, electrification of aviation, sustainable competitive advantage

Acknowledgement

We would like to express our sincere gratitude to the following individuals for their contributions and support in the completion of this master thesis.

First and foremost, we would like to extend our appreciation to Rinaldo De Araujo. As an industry expert and a personal knowledge bank, Rinaldo's guidance and expertise were instrumental in helping us understand and estimate the costs associated with the introduction of batteries in commercial aviation. His insights and willingness to share his wealth of knowledge were remarkable, and we are grateful for his support throughout this research.

We are also indebted to Lauren Burns for her interest and hours devoted to the business models and financial analysis. Her dedication and attention to detail greatly enhanced the quality of our work. We are grateful for her insightful discussions and unwavering commitment to this project.

Furthermore, we would like to express our appreciation to Luis Aguilera. Serving as both the battery expert and our supervisor from Heart Aerospace, Luis played a crucial role in guiding us through this research journey. His Ph.D. background and expertise proved invaluable in addressing various technical aspects of the thesis. We are sincerely thankful for his continuous support and mentorship.

We would also like to acknowledge the contributions of Simon Newitt, Guilherme Brito, and Claudio Camelier from the commercial team at Heart Aerospace. Their investment in the project and their availability for discussions greatly enriched our research. We are grateful for their insights and the stimulating conversations we had throughout the course of this study.

Additionally, we extend our gratitude to our supervisor, Robert Heurlin, from Chalmers University of Technology. We are thankful for his expertise, constructive feedback, and commitment to ensuring the successful completion of this research.

Lastly, we would like to express our appreciation to all the individuals who, in one way or another, provided assistance, encouragement, and feedback during the development of this master thesis. Your contributions have been vital to the overall success of this work.

Thank you all.

Hugo Cliffordson,
Christoffer Segerdahl

List of Acronyms

AEA	All Electric Aircraft
AES	Asset Efficiency Services
BTM	Behind the Meter
CAMO	Continuous Airworthiness Management Organization
DOC	Direct Operating Costs
EOL	End of life
FTM	Front of the Meter
HEA	Hybrid Electric Aircraft
IRR	Internal Rate of Return
JV	Joint Venture
KPI	Key Performance Indicator
MEA	More Electric Aircraft
MRO	Maintenance, Repair, and Overhaul
NPV	Net Present Value
OEM	Original Equipment Manufacturer
OES	Original Equipment Supplier
PBC	Performance Based Contracting
PCS	Process consulting services
PLS	Product Life Cycle Services
PSS	Product-Service System
ROI	Return on Investment

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1. Introduction

The objective of this chapter is to introduce the study and its context. Additionally, the chapter includes the purpose of the study, and articulates the research questions that will be addressed within the thesis. Finally, the chapter concludes with an exposition of the limitations that may affect the scope and generalizability of the study.

1.1 Background

This study is part of a thesis project conducted in collaboration with a Swedish Aircraft manufacturer that will be entering the market for commercial aviation. Heart Aerospace, hereby referred to as Heart, is an electric aircraft original equipment manufacturer (OEM) that is developing the ES-30 model, a 30-seat reserve-hybrid electric aircraft to be operational by 2028. The company's mission is to electrify regional air travel to reduce the climate impact of the aviation industry, an enormous challenge as the industry has long been dominated by a few incumbents. As the electric aerospace industry is still in its early stages of development, adopting innovative business models to increase the willingness to pay for early adopters will be critical to succeed. A major difference between the ES-30 and a conventional aircraft is the incorporation of batteries that must be installed within the aircraft's structure. Since the batteries make up a substantial part of the overall costs of the aircraft, Heart is considering business models for the batteries that are separate from the full aircraft. This is also because the batteries are affected by degradation and strict safety regulations are demanding the airline to swap out the used batteries for new ones as soon as the performance level drops below a certain point. To justify high investment costs related to developing an aircraft, the aircraft is expected to be operational for decades with normal usage and regular maintenance. However, the lifetime of the batteries is significantly lower than the aircraft due to the degradation of the battery health. Once the batteries reach their end of life (EOL) for aircraft usage, they still retain a substantial value that can be leveraged to be repurposed for 2nd life applications or recycled for valuable materials. Given the contrasting requirements of the aircraft and the batteries, it is worthwhile to analyze how to best capitalize on the batteries of the ES-30 to overcome the challenges of entering the commercial aviation industry.

The commercial aviation industry is a vital component of global transportation networks, providing efficient and convenient means of travel for millions of passengers each year. However, this industry is also characterized by several unique features that distinguish it from other sectors of the economy. Firstly, the commercial aviation industry is extremely capital intensive (Knoll-Csete & Kárász, 2021). The cost of designing, manufacturing, and maintaining aircraft is significant, and requires substantial investment. This high level of investment means that the industry is dominated by a few large companies, who are able to leverage their scale and resources to compete effectively (Knoll-Csete & Kárász, 2021). Secondly, the commercial aviation industry is one of the most technology intensive sectors (Knoll-Csete & Kárász, 2021; Chattopadhyay, 2015). Advances in engineering,

materials science, and software have led to the development of increasingly sophisticated aircraft designs and systems. These technological advancements have also enabled airlines to improve their operational efficiency, reduce costs, and enhance passenger experience. However, the development cycles for aircraft and related technologies are long and complex, often taking years or even decades to bring a new product to market. This means that the commercial aviation industry is characterized by high levels of uncertainty and risk, with companies investing significant resources in research and development without a guarantee of success. Given these factors, the commercial aviation industry can be seen as a global oligopoly (Knoll-Csete & Kárász, 2021) with a small number of dominant players controlling a significant portion of the market. The industry is also heavily regulated, with safety and reliability being of the highest priority. This regulatory environment can be both a blessing and a curse for companies operating in the industry, as compliance with safety standards can be expensive and time-consuming, but failure to do so can have catastrophic consequences.

The commercial aviation industry faces a growing challenge in meeting the increasing pressure to become more environmentally sustainable (Knoll-Csete & Kárász, 2021. With more people flying each year, the industry must balance the demands for air travel with the need to reduce its carbon footprint. The aviation industry is responsible for a significant portion of global greenhouse gas emissions, which has led to increased pressure from governments, environmental groups and customers for the industry to reduce its emissions and become more sustainable.

For Heart, being a new firm entering the commercial aerospace industry presents several challenges, such as high barriers to entry, intense competition, complex regulations and certification requirements, high capital and operating costs, and a long and uncertain path to profitability. Additionally, the COVID-19 pandemic has further exacerbated these challenges, leading to reduced demand for air travel and heightened financial pressure on airlines and aviation-related businesses (Sun et al., 2022). Breaking into a complex industry with high entry barriers is a difficult task for any company and will put emphasis on the market strategy (Porter, 1980). A way to achieve this is by developing a unique value proposition that fills an unmet need in the market, which differentiates them from established players and creates a competitive advantage (Porter, 1980). Building a strong network is another critical strategy. This involves establishing relationships with key industry stakeholders such as suppliers, customers, and regulators to gain access to essential resources and knowledge (Porter, 1980). A way to provide a unique value proposition and to work in closer cooperation with customers and suppliers is through servitization (Feng et al., 2021). In complex industries with diverse customer needs, manufacturing organizations are operating in an increasingly competitive environment. In order to obtain and sustain a competitive advantage, offering services has become a popular trend (Kastalli et al., 2013). Breaking into an industry with high barriers can also be done by changing the game through innovation (Christensen et al., 2013). Disruptive innovation refers to the introduction of a new product, service, or business model that

creates a new market and disrupts the existing market, typically by offering lower cost, higher convenience, or better performance (Christensen et al., 2013). Disruptive innovations often start by serving a niche market that is underserved by existing products or services, but then gain broader acceptance and eventually displace existing products or services in the market (Christensen et al., 2013). As the batteries will be critical to the success of Heart Aerospace, it is important to analyze go-to-market strategies in relation to the batteries.

1.2 Purpose & Research Questions

As discussed in the background, the aircraft industry is inherently complex with its operation of sophisticated machinery, such as aircraft, engines, and avionics, which require highly skilled personnel to operate, maintain and repair. The industry is highly regulated, with many government agencies responsible for ensuring safety, security, and compliance with various rules and regulations. Thirdly, the industry involves a complex network of stakeholders, including airlines, airports, air traffic control, maintenance providers, suppliers, and customers, each with their own priorities, goals, and challenges. Being a new entrant in this industry, with new aircraft technology, will certainly present a lot of challenges. The core challenge for the business case of the aircraft is the batteries. The batteries will represent a significant cost of the aircraft, their expected lifetime will be different compared to the aircraft, and the batteries will need to be subject to different activities while in operation, such as maintenance. Furthermore, the market for 2nd life batteries is evolving. This creates questions about how to monetize the batteries in the aircraft offering, and how to structure aftermarket activities. The purpose of the master thesis is therefore to:

> *Analyze different business models for the batteries and assess them in relation to Hearts long term strategy, risk willingness, market fit and financial implications.*

To effectively achieve this objective, it is important to gain an understanding of the activities and costs associated with electrification. Moreover, considering the strategic and financial implications of various business models is necessary to fulfill the purpose. The purpose is therefore decomposed into the following research question and sub questions:

Research question:

> *RQ1: What business model for aerospace batteries is most suited for a new entrant in the commercial aerospace industry?*

Sub questions:

> *RQ2: What activities and costs are introduced as a consequence of electrification?*
> *RQ3: What are the strategic & financial implications of possible aerospace battery business models?*

1.3 Limitations

This section aims to describe the limitations of this research. First, a limitation of this thesis is its exclusive focus on the business model for batteries, neglecting the interdependence of the battery business model with the overall aircraft business model. The decision to narrow the scope was driven by the case company's specific interest in analyzing the battery business model in isolation, prioritizing a detailed examination of this specific aspect rather than encompassing the broader context. Secondly, a limitation is that the thesis focuses solely on one case company. As a result, no benchmarking or comparison will be made for a similar company. This limitation is inherent to the study design since the case company is a novel entity, and other comparable companies for benchmarking purposes are hard to come by. However, benchmarking can be done with some implications of the industry with companies that exist but have different offerings. Another limitation of this master thesis is that the research area is relatively new, with limited prior research and data available. While this provides an opportunity to explore a novel area of study, it also presents challenges in terms of sourcing relevant literature and data. Consequently, this study relies on theoretical frameworks, input from experts, and assumptions to fill the gaps in the existing literature. As a result, the findings of this study may not be widely generalizable and may only be applicable to the specific context under investigation or context that are similar. Additionally, due to the lack of prior research, there may be limitations in terms of the validity and reliability of the findings. Future research in this area will be needed to verify or challenge the findings of this study. Another limitation is that not all possible business models are analyzed. The business models that are examined are the ones that are of most interest for the case company as a result of internal discussion with the management and advisory board. Lastly, a limitation for the business models analyzed will be the 2nd life of the batteries. Since it is too grand a task to investigate what the market value of second life batteries is, expert guesses and ranges will be used in the form of estimated residual values on the 1st life battery costs.

2. Frame of reference

This chapter contains the theoretical foundation that will serve as the academic basis for the analysis and understanding of problems and patterns throughout the rest of the work. This chapter will provide a comprehensive overview of the relevant theories, concepts, and frameworks that are necessary to contextualize the research questions and objectives, and to provide a solid grounding for the empirical investigation that follows. This chapter will assist in evaluating the findings and conclusions in light of the relevant literature.

2.1 Business models

Business models are a widely used but poorly understood concept (Grant, 2021). They are referred to as "statement", "representation", "architecture" or "framework" (Zott et al., 2011). The lack of a shared view on the business model concept can potentially create confusion in the discussion. A common representation of the Business Model is referred to as the "business model canvas" (Lewandowski, 2016; Wirths, 2019; Grant, 2021). The business model canvas is a framework that include the firm's infrastructure (comprising of key resources, key activities, and partners), customers (comprising of segments, channels, and relationships), the value proposition as well as the financial viability (comprising of costs and revenue structure) (Grant, 2021). Another framework that has gained attention is the Value framework. It organizes the business model around the concept of value and composes "the value proposition", "the value creation and delivery system" and "the value capture" (Richardson, 2005). The firm's value proposition encompasses what it will provide to customers, why they will be willing to pay for it, and the approach to achieving competitive advantage. This includes the offering, target customer, and the generic strategy and building blocks of competitive advantage. The value creation and delivery system focus on how the firm will generate and deliver value to customers while maintaining its competitive advantage. This involves assessing the resources, examining the organization's value chain, activity system, and business processes, as well as determining its position in the value network with respect to suppliers, partners, and customers. Finally, value capture refers to how the firm generates revenue and profit. This involves evaluating revenue sources and analyzing the economics of the business (Richardson, 2005).

It's important to distinguish between a business model and a strategy. While a strategy outlines how a company will compete, a business model connects that strategy to the company's activities and execution. This framework helps evaluate business operations in detail (Porter, 2001). Business models are especially valuable because strategies can be too narrow, focused only on cost or differentiation advantage. With a business model, it is possible to envision more complex business scenarios and opportunities (Grant, 2021).

2.2 Competitive advantage

In the strategic management literature, competitive advantage is referred to as "the value a firm is able to create for its buyers that exceeds the firm's cost of creating it" (Porter, 1985). Porter (1985) mention three generic strategies to achieve competitive advantage; (1) cost leadership, (2) differentiation and (3) focus, each with its own set of advantages and disadvantages. (1) Cost leadership, the most adopted strategy, refers to the aim of achieving low-cost operations to offer a product or service at the lowest price possible. (2) Differentiation aims at developing one significant aspect of a product or service to differentiate from competitors. (3) Focus can be viewed as a variation of the differentiation strategy but aims at targeting a specific market segment, ideally by achieving both a differentiated and low-cost position in that market segment (Porter, 1985).

2.3 Industry key success factors

To evaluate the sources of competitive advantage within an industry, Grant (2021) proposes a two-dimensional framework to identify an industry's key success factors, determining the firm's ability to outperform competitors (Figure 1). The framework consists of first identifying who the customers are and what they want. By understanding what customers seek from the industry, it is possible to determine the factors that affect the performance of competing firms. The second dimension of the framework focuses on what the firm must do to survive competition. Analyzing what dives competition, what the main dimensions of competition are, the competition intensiveness as well as how the firm can obtain a superior competitive position are factors that are important to consider. Grant (2021) cites the example of the airline industry, where key success factors require not only meeting customer demand for low-cost tickets but also possessing financial stability to withstand economic downturns and developing strong relationships with airports and regulators.

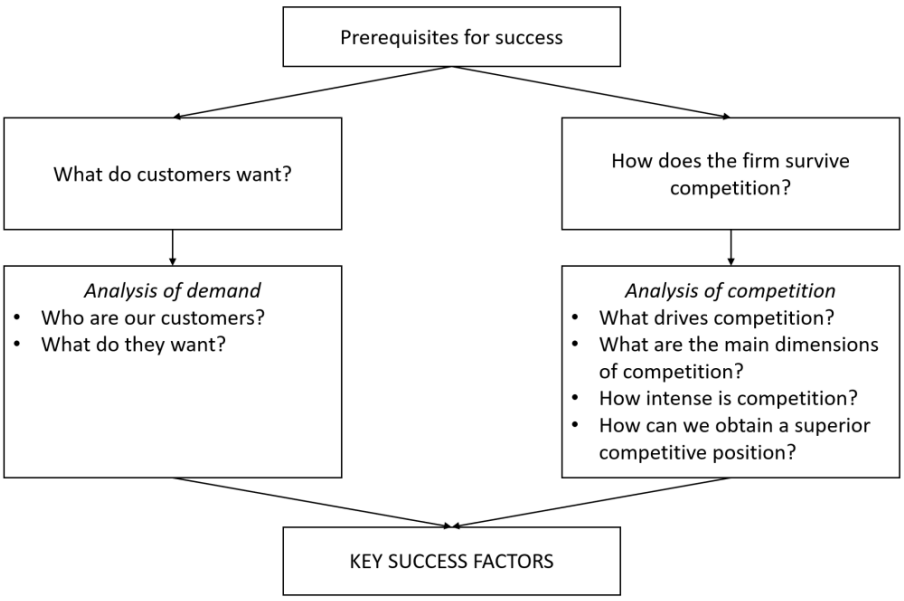

Figure 1: Identifying key success factors. Based on Grant (2021)

2.4 Resources and Capabilities

To understand how the firm's internal and external environment interact to create competitive advantage, Grant (2021) developed a framework where resources and capabilities play an important part (Figure 2). The importance of the firm's resources and capabilities as a source for superior performance are based on the "resource-based view", first developed by Barney (1991). The perspective of the resource-based view acknowledges that every company has its own distinct set of resources and capabilities. Rather than imitating what other firms do, the crucial factor for achieving profitability is to capitalize on these differences. Creating a competitive advantage requires developing and executing a plan that leverages a company's particular strengths (Barney, 1991).

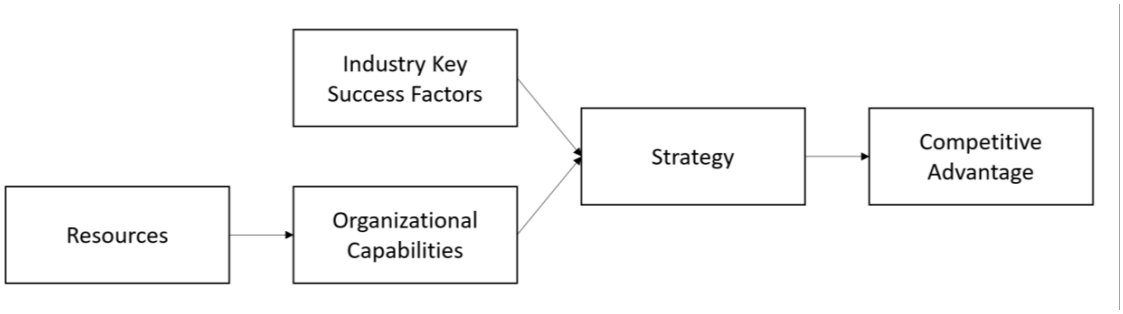

Figure 2: Links between resources, capabilities, key success factors, and competitive advantage. Adapted from Grant (2021)

A firm's resources can be structured into tangible, intangible and human resources. Tangible resources are the financial resources and physical assets that are valued in the firm's balance sheet. This involves financial resources such as cash and securities as well as physical assets such as plants, equipment, and land. Intangible resources include the IP assets, brand reputation and organizational culture. These resources can be difficult to

value and are often the major reason why companies' market valuation differs from the balance sheet valuation (book value). Finally, human resources encompass the skills and know-how of the organization, the capacity for communication and collaboration as well as the employee's internal motivation (Grant, 2021).

Although resources play an important part in a firm's strategy and quest for competitive advantage, they are not productive on their own. Instead, the firm must deploy the resources effectively to build up organizational capabilities. Core competences, introduced by Hamel & Prahalad (1990), describe the firm's capabilities that are fundamental to the firm's strategy and performance. A firm that manages to match its core capabilities with the industry's key success factors will reach a competitive advantage in the market (Figure 2).

2.5 Sustainable competitive advantage

While obtaining a competitive advantage might pose a challenge, maintaining it can be an even greater obstacle. Barney (1997) defines sustainable competitive advantage (SCA) as when a firm is "implementing a value creating strategy not simultaneously being implemented by any current or potential competitors and when these other firms are unable to duplicate the benefits of this strategy".

To appraise a firm's resource or capability's ability to create SCA, the VRIO framework developed by Barney (1997) can be used (Figure 3). The framework evaluates whether the resource or capability is valuable, rare, inimitable, and organized. Only if the resource or capability is passing all four tests, it can be considered a source to sustainable competitive advantage. A resource or capability is valuable when it enables the firm to implement strategies that improve its efficiency and effectiveness. Moreover, a firm's resource or capability is considered rare when it is not possessed by a large number of competitors. Furthermore, valuable, and rare resources and capabilities can only be sources of sustainable competitive advantage if the competitors cannot obtain them. Finally, the firm must have an organized management system, processes, structures, and culture to capitalize on the resource or capability (Barney, 1997).

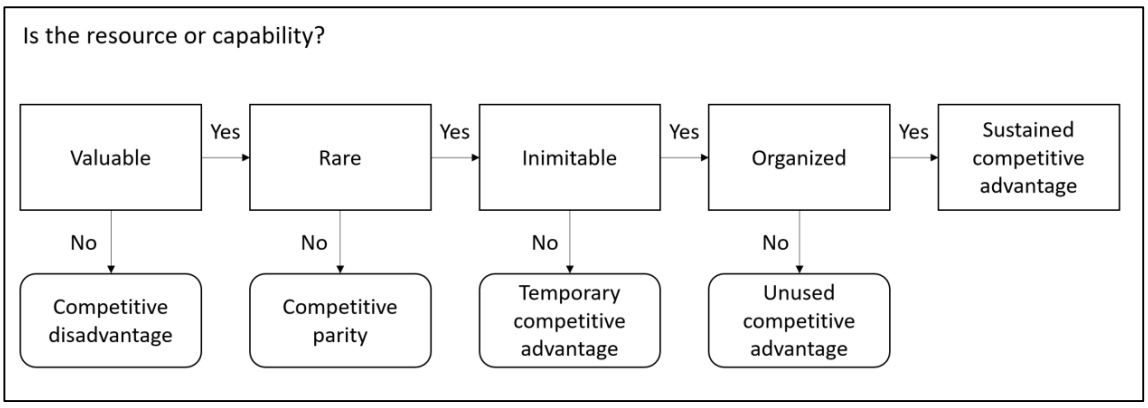

Figure 3: VRIO framework. Adapted from Barney (1997)

2.6 Servitization in manufacturing and aircraft manufacturing

Research on the concept of servitization in manufacturing has become increasingly popular. This is not without motivation as manufacturing firms, and especially innovative manufacturing firms on an increasing rate choose to compete strategically through servitization (Spring & Araujo, 2009). This is especially true in areas where companies can compete against lower cost economies through integrated product service offerings (Wise & Baumgartner, 1999). A widely cited example of this happening in the aerospace industry is Rolls Royce who introduced the "Power-by-the-hour" concept in the commercial aerospace industry (Smith, 2013). Under the Power-by-the-hour model, customers are charged a fee based on the number of hours the engine is in use, rather than purchasing the engine and maintenance services upfront (Smith, 2013). Servitization is not unique to any industry. In 2014, a substantial proportion of European manufacturers, around 80%, provided services and subsequently generated service revenues of 10-15% (Dachs et al., 2014).

Within the context of servitization, the academic literature employs various terminology to describe the transformation of manufacturers towards service-oriented business models, encompassing the emergence of product-service offerings, as well as the practices and strategies employed throughout this transition. For the purpose of conformity, this study will use the definition of Kowalkowski et al., (2017) who describes servitization as the change procedures through which a company transitions from a product-centered to a service-centered business model and mindset.

The structure of the following subchapters in servitization and especially servitization in aircraft manufacturing is largely influenced by Wirths (2019) who has contributed with research about innovative business models for service companies within the aerospace industry, a genre of academic literature not heavily explored.

2.6.1 Service Typologies

Employing servitization as a manufacturing company often involves a Product-Service System (PSS) which Wirths (2019) describes as a combined service and product offering that provides value-in-use. In the research area of servitization, the literature has undertaken a considerable effort to categorize the various forms of Product-Service Systems through different typologies. These typologies serve a dual purpose, firstly, to classify different PSS business models, and secondly, to evaluate the level of servitization adopted by the manufacturer. The most recognized typology is the Product-, Use-, and Result oriented PSS Offerings framework by Tukker (2014). Three main categories are divided into subcategories to a total of eight PSS configurations (Figure 4).

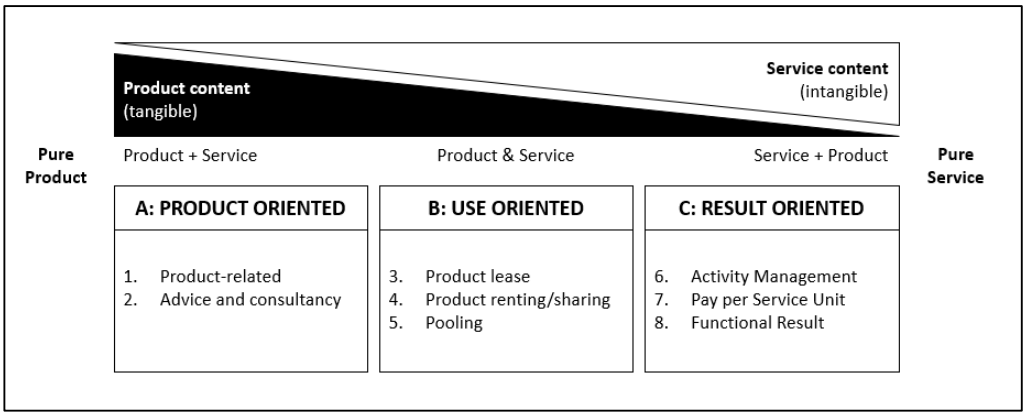

Figure 4: PSS offering framework, adapted from Tukker (2014)

Notwithstanding its prominence in academic literature, the framework in question poses challenges in a business model context for a manufacturing firm pursuing servitization to compete strategically. The framework's limitations stem from its exclusive focus on revenue stream classification, thereby disregarding other critical aspects of a business model.

Ulaga and Reinartz (2011) present a service typology framework (Figure 5), which is based on both theoretical and empirical foundations. The typology clusters services based on two dimensions, namely the "Nature of the Value Proposition" (input- or output-based) and the "Service Recipient" (product or customer's process). The authors' classification provides a framework for understanding and categorizing different types of services, which can be useful for businesses in designing and implementing effective service strategies.

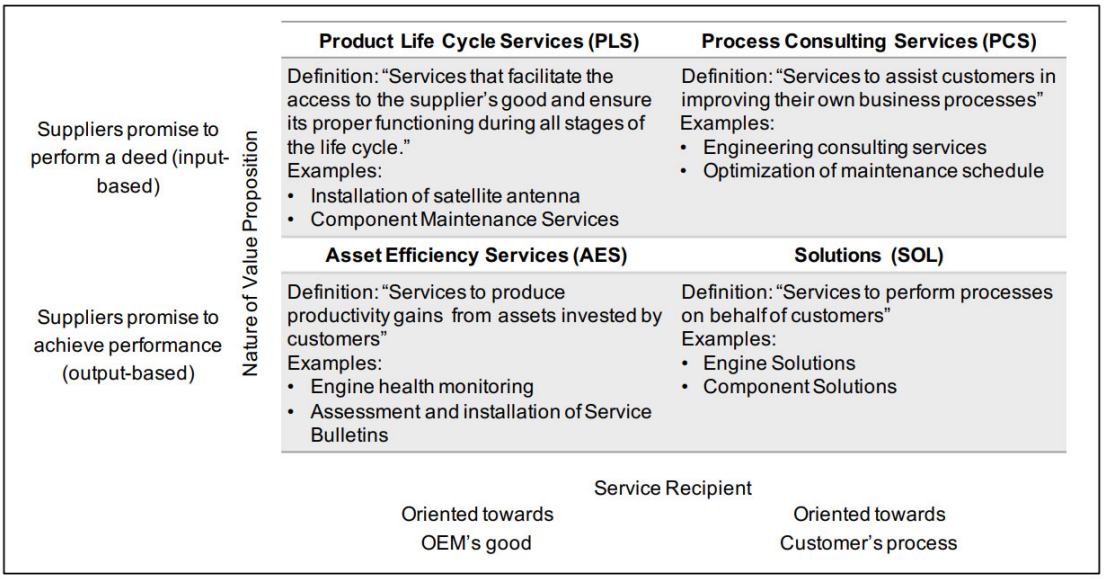

Figure 5: Two-Dimensional Service Typology Framework, adapted from Ulaga and Reinartz (2011)

The framework can, according to (Wirths, 2019), be used to give various options for strategic differentiation by outline necessary resources and capabilities in different context. By using this framework, businesses can gain a better understanding of the distinctive features that are necessary for success in each type of service, which can inform their strategic decision-making and resource allocation. The framework also highlights the importance of aligning a business's capabilities and resources with its service offerings, as each type of service requires a different set of competencies and resources for achieving competitive differentiation. As a result, this framework can be an invaluable tool for businesses seeking to optimize their service portfolio and maximize their competitiveness in the marketplace.

Product Life Cycle Services (PLS) refers to services that include installation, maintenance, and support, ensuring customers' seamless access to the manufacturer's product and its optimal performance throughout its entire life cycle—pre-sale, during sale, and post-sale (Wirths, 2019). Since PLS are essential services for optimizing a product's condition, manufacturers may have to provide these services to sell their products. As PLS are considered a "must-have" by customers, there may be limited opportunities for competitive differentiation, and customers may not be willing to pay much for these services. Hence, using a cost-effective approach like cost leadership strategy could be the best way for suppliers to offer these services. While this approach can help manufacturers remain competitive, it is crucial to carefully consider the potential trade-offs between cost efficiency and service quality, as this can affect customer satisfaction and loyalty (Wirths, 2019).

According to Ulaga and Reinartz (2011), **Asset Efficiency Services** (AES) refer to the services offered by suppliers to help customers achieve productivity gains from their invested assets. These services, such as condition monitoring or reliability management, are focused on improving asset performance and are not considered to be a core offering by customers. Unlike Product Lifecycle Services, AES offers potential for competitive differentiation and profit potential due to the added value they provide in improving asset performance. An example could be guaranteed uptime of a system, which could be used as a means of competitive advantage by the supplier. Therefore, AES can be seen as a means of providing additional value to customers, which can increase their willingness to pay and enhance customer satisfaction.

Process consulting services (PCS) refer to "the range of services provided by manufacturers to assist customers in enhancing their business processes", including consulting services and audits (Ulaga and Reinartz., 2011). Wirths (2019) describe that these services aim to accomplish tasks without taking responsibility for the outcomes. The services prioritize the customer's actions and activities, including product use.

This service category relies on specialized knowledge in asset operation and can be provided separately from the asset's sale, including assets from competitors (Wirths, 2019). PCS is characterized by tailor-made services that cater to individual customer requirements and involve a detailed understanding of asset operations. As a result, customers are willing to pay a premium for these services.

Ulaga and Reinartz (2011) describes solutions as a comprehensive package of products and services that are customized to meet the specific needs of individual customers, and which entail the service provider assuming responsibility for the performance and operation of the customer's processes. These offerings typically involve a complex combination of products and services that are tailored to the customer's unique requirements, and which require active customer involvement and risk-transfer to the service provider (Wirths, 2019). As a result of their outcome-based nature and focus on services, solutions are positioned on the service-oriented end of the product-service continuum (Wirths, 2019).

2.6.2 Service Triads

The concept of service triads, introduced by Wynstra et al. (2015), helps in understanding the roles of different actors in service systems. It goes beyond the traditional focus on service providers and customers by adding a third actor, usually an intermediary. Service triads expand the analysis by considering the interactions and interdependencies among service providers, customers, and intermediaries. Service providers deliver the core service and ensure its quality, while customers contribute to value co-creation through their participation and feedback. Intermediaries facilitate smooth service delivery by connecting providers and customers. This perspective, introduced by Wynstra et al. (2015), offers valuable insights into complex service ecosystems. It encourages a holistic approach that improves value creation, customer satisfaction, and overall system performance.

In service triads, it can be useful to identify risk and opportunities for supply chain disintermediation Wynstra et al. (2015). This refers to the removal or bypassing of intermediaries within the supply chain to establish a more direct connection between producers and end customers. It involves eliminating unnecessary middlemen or intermediaries to streamline the flow of products or services (Wynstra et al., 2015).

2.6.3 Service contracting considerations

Researchers have consistently emphasized the significance of contracts in outsourcing relationships. Gellings & Wüllenweber (2006) highlight the risk of outsourcing and emphasize the role of "complementary" outsourcing clauses in effectively addressing these risks. They underscore the importance of proactively managing outsourcing risks through contractual mechanisms. These contractual mechanisms outline events, contract clause for the event, and a result for the outsourcer. This structure assists in clarity and

understanding within partnerships, mitigates risk, and defines accountability (Gellings & Wüllenweber, 2006).

2.6.4 Drivers for Servitization in manufacturing

Servitization can be driven by financial, marketing, and strategic considerations (Baines et al., 2009). Financial drivers include the potential for higher profit margins and income stability. Services can also create marketing opportunities and influence purchasing decisions, particularly in B2B markets where increased customer connection through service delivery can result in products that stand out more and therefore increase the level of loyalty from the customer (Wirths, 2019). Furthermore, servitization can be a response to the commoditization of product markets in mature industries, as a means of achieving competitive differentiation (Lightfoot et al., 2009). A summary of drivers can be seen in Figure 6.

	Strategic Drivers	Financial Drivers	Marketing Drivers
OEMs	• Differentiation on the market • Services are harder to imitate • Customization possibilities	• Stability of income over time • Profit margins • Less sensitivity to cost competition • Avoiding price discussions • Less sensitivity to economic cycles	• Demand for services requested • Using services to sell more products • Customer loyalty • Development of customer relationships
Customers	• Focus on core business	• Avoid initial investments • Predictability • Avoiding risks associated with investments	• Access to latest technology and continuous updates • Network building and partnerships

Figure 6 Servitization Drivers, adapted from Baines et al. (2009)

In addition to responding to changing customer demands and market forces, servitization can also be viewed as a proactive strategy for actively shaping the market to achieve desired competitive positioning (Gebauer et al., 2011). Achieving the desired market position requires a strategic alignment of the organization with the external environment. The servitization strategy should be founded on either differentiation or cost leadership (Wirths, 2019). Furthermore, the Resource-Based View (RBV) states that manufacturers through developing valuable, rare, and inimitable service-specific resources, create a sustainable competitive advantage (Wirths, 2019). A summary of defensive and offensive strategic drivers for servitization is illustrated in Figure 7.

	Customers	Providers (OEM)
Defensive	**Seeking to improve financial, risk & asset management through:** • Initial cost savings • On-going cost reductions • Transfer fixed costs to predictable variable costs • Improved asset security • Improved asset reliability	**Seeking to improve commercial viability through:** • Response to customer demand • Competitor lock-out • Smooth revenue streams • Response to legislation • Product-life-cycle extension
Offensive	**Seeking to improve focus & investment through** • Focus on core competences • Higher capital investment • Advanced technology adoption and access to associated skills	**Seeking to improve growth through:** • Greater customer intimacy • Market adoption of product innovation • Market adoption of business process innovation

Figure 7 Strategic Drivers for Servitization, based on Baines et al. (2009)

2.6.5 Challenges for Servitization in manufacturing

Despite the potential advantages of servitization in terms of financial, marketing, and strategic drivers, it can also present significant challenges for manufacturers. In practice, the implementation of servitization strategies does not always yield success, and firms may encounter the service paradox, which refers to the phenomenon where manufacturers fail to realize the anticipated benefits from their initial investments in transitioning to service-oriented models (Gebauer et al., 2011). In 2004, a study indicated that the success rate of service strategies is relatively low, with only a minority of companies (21%) being able to achieve their objectives. Moreover, companies providing services may not always surpass their competitors focused solely on goods when it comes to margins, revenue growth, or return on equity (Wirths, 2019).

Manufacturers encounter various difficulties when moving toward servitization, which can be grouped into four categories: how their company is set up, their processes for creation, dealing with customers, and handling risks. Changing their internal structures and culture from being focused on products to supporting services is part of the organizational challenge (Wirths, 2019). The reason for this is that service provisioning involves intangible and bundled services, which require a different approach to value creation compared to traditional transaction-based product businesses (Grönroos, 2007).

Oliva et al. (2012) discusses the challenge of integration versus separation decisions in a service organization. The decision is centered around distinguishing the company's products, services, and associated activities. This distinction becomes necessary because services can be easily overshadowed within a product-oriented organization. Separating the service organization involves assigning profit-and-loss responsibility, aiming to enhance managerial commitment.

There are several advantages of separating the service organization. Firstly, it fosters procedures that support services, enabling the development of a service-oriented mindset. This protects the emerging service culture from being suppressed by the established product-oriented culture. Secondly, separation creates a profit and loss responsibility which can be used to show advancements in the service organization. Lastly, separation enhances customer experience by facilitating the identification of service personnel, clarifying the service offering, and streamlining communication for customers (Oliva et al., 2012).

However, there are several disadvantages of separating the service organization that are important to considered. Firstly, separation creates a risk of silo thinking in the organization. When the service and product organizations are not working together, it can be challenging to align knowledge and working processes, making each business unit work less efficiently. There is also a risk of sub-optimization, making the separated organizations work in different directions that are not aligned with the overall goals of the firm. Additionally, by not having an integrated organization, it becomes difficult to establish a company-wide service-oriented culture aiming to unite the company and foster cross-sectional collaborations. Lastly, in a separate service organization, there may be limited authority to influence the decisions of other functions within the company. This can potentially result in employee dissatisfaction and reduced motivation (Oliva et al., 2012).

The development of services requires a different approach compared to that of products, hence manufacturers cannot solely rely on their existing product development process. Instead, establishing a dedicated service development process should be given top priority (Baines et al., 2009; Kindstrom et al., 2015). This requires the development of new tools and techniques and the establishment of relational processes with customers (Baines et al., 2009). Compared to traditional product offerings, servitization involves the co-creation of value with customers during product-service system (PSS) provision. This co-creation process poses challenges in terms of customer management, as the intended value by the supplier may not always align with the perceived value by the customer (Grönroos, 2007).

Furthermore, there is a risk in servitization from increased financial requirements and challenges in result-based offerings if the service does not live up to the performance expected. Additionally, servitization can lead to an increased risk of bankruptcy (Ulaga & Reinartz, 2011). These risks highlight the importance of effective risk management strategies to ensure the success of servitization initiatives.

3. Method

In this section, the methodology of the thesis is described. It includes the strategy of the research and how data is collected and analyzed in order to fulfill the purpose of the thesis and answer the research questions.

3.1 Research Strategy

According to Bell et al. (2018), research strategies are divided into quantitative and qualitative approaches. What strategy to use depends on the author's preference for what is best suited to meet the report's goals and address the research questions. Bell et al. (2018) highlights the key differences between the two approaches, with qualitative research relying on words and images instead of numerical data. Due to the abductive nature of the research questions, where observations of the case company and the aerospace industry are in focus, a qualitative study is selected as the research strategy for the report. The design of the research is a case study of Heart Aerospace battery business strategy, as the company plans to be first to introduce electric aircrafts within commercial aviation. Bell et al. (2018) states that the utilization of a case study design facilitates the integration of diverse data collection methods as opposed to relying solely on a single method. This is particularly relevant since the boundaries of business strategy are indistinct. Therefore, the selected approach is deemed suitable for arriving at a conclusion that incorporates multiple perspectives. To fully understand the impact of electrifying commercial aviation, the case study needs to take a comprehensive approach that considers both internal factors at Heart Aerospace, and external factors of internal workings and operational processes within the industry. Moreover, a financial analysis of potential business set-ups is included to evaluate the feasibility of the transition to batteries from an economic perspective. All research processes in the research strategy are illustrated in Figure 8 and are described in detail below.

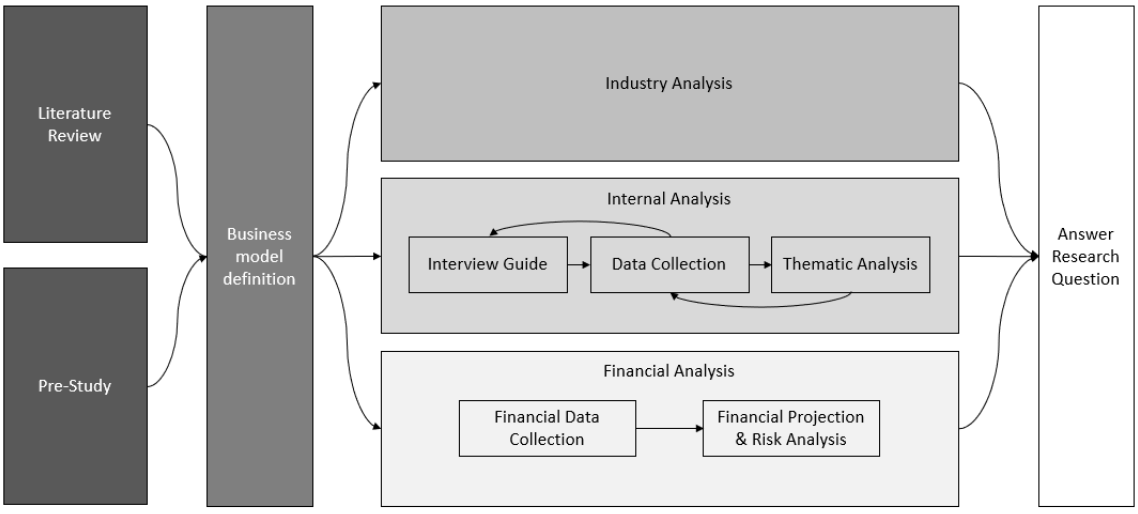

Figure 8: Research Strategy

3.2 Literature Review

Initially, a review of the relevant academic literature was conducted to inform the data collection and analysis process. Bell et al. (2018) suggest that a literature review can provide a comprehensive overview of existing research on a particular topic. Accordingly, the review served as a theoretical foundation and starting point for the study, consistent with Easterby-Smith et al. (2021). This approach also allowed for the identification of prior methods, theories, and concepts used by other researchers in similar cases. To conduct the literature study, several keywords such as "business model innovation," "servitization in manufacturing", "outsourcing decisions" and "competitive advantage" were utilized in the Google Scholar and Scopus databases. The identified articles were thoroughly examined, and their cited sources were further analyzed to uncover additional literature. This process ensured the comprehensiveness and reliability of the literature review, consistent with best practices in academic research. It is a technique known as snowball sampling which results in a comprehensive framework of references that incorporates various perspectives on the subject (Bell et al., 2018).

3.3 Pre-Study

Concurrently with the literature review, an exploratory pre-study was conducted to gain a deeper understanding of Heart Aerospace and its industry. This was done through unstructured interviews with industry experts and through reviewing relevant industry reports. Bell et al. (2018) suggests that the use of multiple sources and types of data can enhance the validity of a study by offsetting the limitations of a single source and producing more reliable data. This approach enabled the incorporation of diverse perspectives and insights from industry experts, which complemented and enriched the findings from the literature review. By utilizing both primary and secondary sources, this study aims to provide a comprehensive and accurate analysis of Heart Aerospace and its industry. This approach aligns with best practices in academic research, as it allows for a rigorous and multifaceted investigation that can uncover new insights and generate novel perspectives (Bell et al., 2018).

3.4 Business Model Definition

In the pre-study, it became evident during the unstructured interviews with company representatives that the organization was specifically interested in gaining insights into four distinct battery business models that had fundamental differences from each other. The last business model, Supplier ownership, exists with two configurations (Figure 9). Further analysis revealed that these four business models had significant implications for the future decision-making processes of the company. Therefore, the decision to focus the analysis on these four models was made based on the desire to both answer the research question with this limitation, but also to provide a comprehensive analysis that would enable the organization to make informed decisions regarding its battery strategy. This approach ensured that both the thesis purpose was fulfilled and that the case study provided insights that would be relevant to the organization's future objectives. The

analysis of these business models was based on both the literature review and the pre-study, but also on industry reports and various unstructured interviews with Heart representatives. Figure 9 illustrates the four battery business models as they were presented to the researchers, and a short description highlighting the fundamental differences between them. A more thorough clarification and analysis of these business models is presented in the business model definition section in the empirical findings chapter.

Business model		Description
1 Selling		Heart sell the batteries to an airline or lessor. Aftermarket services are sold separately.
2 Power-by-the-cycle leasing		Airline pay per battery cycle. The model assumes Heart as owner of all aftermarket services.
3 Strategic partnership		Heart and Supplier create a strategic partnership and lease the batteries to the airline. They share costs, revenues and risk.
4 Supplier ownership	Selling	Supplier **sell** directly to airline and Heart receives royalties for providing the aircrafts.
	Leasing	Supplier **lease** directly to airline and Heart receives royalties for providing the aircrafts.

Figure 9: Business model description

3.5 Industry Analysis

Building on the literature review, pre-study, and the business model definition, the research was further developed and branched out into three distinct areas of investigation (Figure 8). Firstly, an industry analysis was conducted to explore the broader external environment and to evaluate the value chain, actors, and trends on a practical level, with a particular focus on understanding the challenges of introducing batteries to the commercial aviation industry. The process of industry analysis has evolved over the years to become an integral part of strategic management (Grant, 2021). The practice involves a thorough examination of the various actors and factors that shape a particular industry. The initial documentation of this process is attributed to the analysis of commercial aviation, which provided insights into the industry's value chain, actors, and trends. Subsequently, the analysis of batteries and electric aviation was carried out, building upon the foundational knowledge obtained from the commercial aviation industry analysis. This approach enabled usage of the knowledge developed from commercial aviation to a new and emerging industry. As such, the analysis of batteries and electric aviation was not carried out in isolation but was informed by the insights generated from the analysis of commercial aviation. Overall, the industry analysis provided critical insights into introducing batteries to the industry from a business strategy point of view. By understanding the broader industry trends and challenges, as

well as the specific value chain actors and their roles, this analysis informed the development of effective strategies and recommendations and helped analyzing the feasibility of business models to help answer the research question. This process was built upon knowledge from the literature review and pre-study but was extended by various unstructured interviews with Heart representatives and analysis of industry reports, combining multiple sources in accordance with Bell et al. (2018).

3.6 Internal Analysis

The second branch of investigation after the literature review and pre-study was the internal analysis (Figure 8). This was done to gain a better understanding of Heart's long-term strategy, resources and capabilities and ambition to offer battery related services to airlines. This was viewed as an essential component of the answering the research questions as the internal analysis of Heart Aerospace was critical for aligning other components of the analysis with the company's internal objectives and goals to compete in the industry.

3.6.2 Data Analysis

The examination of the data acquired during the semi-structured interviews has been systematically analyzed with the aim of detecting patterns. As asserted by Bell et al. (2019), the general large amount of data commonly produced in qualitative research can pose challenges. Consequently, a structured and efficient approach to analyzing data is essential to effectively uncover insights and mitigate the potential for skewed data interpretation from the researchers. To combat this, the data was analyzed using a thematic analysis approach. Thematic analysis is a qualitative data analysis technique that involves identifying and analyzing patterns, themes, and categories within a dataset (Guest et al., 2011). In this case the dataset consists of the interview transcripts. Thematic analysis involves several stages, including data familiarization, coding, theme identification, and interpretation. In the first stage, the researcher becomes familiar with the data by reading and re-reading the interview transcripts. In the coding stage, the researcher identifies and labels different sections of the data with relevant codes, which may be descriptive or interpretive. In the theme identification stage, the researcher reviews the codes and groups them into broader themes or patterns. Finally, in the interpretation stage, the researcher seeks to understand the underlying meaning of the identified themes and patterns (Guest et al., 2011). Thematic analysis is useful on interview data in case studies because it allows researchers to identify the most salient themes and patterns within the data which may relate to the case study's research questions.

The transcripts from the interviews were familiarized and 1st order concepts were documented in a table in the form of a description of event or a direct quote from the interviewee. The 1st order concept was then given a relevant descriptive code. This was done in an iterative manner in a joint effort by both researchers. Lastly the 1st order

quotes, and 2nd order quotes were aggregated into themes. See full illustration of the thematic analysis result in the Appendix.

3.6.1 Data Collection

The internal analysis focused on the collection of primary data through interviews with Heart Representatives. According to Bell et al., (2018), the utilization of interviews offers researchers a flexible approach to combine multiple viewpoints. This method was effectively employed to develop a comprehension of Hearts internal objectives and goals to compete in the aerospace industry.

Sampling of Interview Objects

Bell et al., (2018) states that the data collection through interviews is strengthened when it comes from a variety of sources. In the case study related to the business strategy and battery strategy of Heart Aerospace, it was therefore important to obtain input from individuals with varied roles at the company to bring multiple perspectives. The selection of interview subjects was conducted using a purposive sampling method, whereby subjects were chosen based on their potential to provide valuable insights relevant to the research questions at hand. Bell et al., (2018) have categorized this sampling technique into two distinct types: sequential and non-sequential sampling. In this study, a sequential sampling approach was employed, which enables the inclusion of new interview subjects as the research progresses, allowing for the investigation of additional aspects related to the research questions.

To effectively investigate the long-term strategy and aims of Heart Aerospace, it was important to gather information from executives at the highest level of the organization. These individuals possess a unique perspective on the overall business strategy and could provide valuable insights into the company's vision for the future. Furthermore, the executive team have the authority to make strategic decisions that will shape the future direction of the organization. On the other hand, obtaining input from the energy storage and engineering sections of the company was equally important in the context of battery technology. These individuals possess technical expertise and knowledge of the latest technological advancements in the field, which are essential for understanding the current state of the battery business and the opportunities for future growth. Thus, it was crucial to conduct interviews with individuals from both the executive level and the energy storage and engineering sections of the company to provide a comprehensive understanding of the business and battery strategy. The combination of input from these diverse sources facilitated a more thorough analysis and helped to answer the research question. Each Heart Aerospace representative that was interviewed is presented in table 1.

Role	Date	Time
CEO	2023-03-30	45min
CFO	2023-03-22	45min

Head of Energy Storage	2023-03-23	45min
Head of Marketing	2023-03-29	45min
CCO	2023-03-30	45min
Corporate and Product Strategy Manager	2023-03-29	45min
Senior Investment Manager	2023-03-29	45min
Head of Customer Support & Services	2023-03-27	45min
Sales Engineer and Product Strategist	2023-03-22	45min
CTO	2023-04-12	45min

Table 1: Interviewees

Interview Method

The interview format that was selected was semi-structured interviews. An advantage of using semi-structured interviews is that it allows for a rich and in-depth understanding of the research topic (Bell et al., 2018). The open-ended nature of the questions allows the interviewee to provide detailed responses and to share their personal experiences and perspectives on the topic. This can provide valuable insights that may not be obtained through other research methods such as surveys or experiments (Bell et al., 2018). Another advantage of using semi-structured interviews is the flexibility it provides in terms of the research design. The interviewer can adjust the questions based on the responses of the interviewee and can probe further into areas of interest. This allows the researcher to explore unexpected or emerging themes and can lead to new avenues of inquiry (Bell et al., 2018). An interview-guide was developed for the interviews and was largely based on the pre-study and the literature review but also iteratively updated through the process of interviews if the researchers identified new opportunities for insights yielded from previous interview. The interview guide was divided into three themes: *long term strategy, battery operations, and business models.* Each theme contained broad questions where the interview subject was asked to discuss freely. The interview-guide also contained sub-questions for the broad questions which could be used if the researcher noticed that the interview was going off-track. See full interview guide in the Appendix.

To improve the reliability of the data collected during interviews, one researcher was responsible for taking notes while the other researcher monitored the recording of the interview. This approach was used to ensure that the complete interview was captured accurately, and no important details were overlooked. The recordings were then used in combination with a software program called Otter.ai to automatically transcribe the full interview. To further enhance the accuracy of the data collected, the transcriptions of the interviews were reviewed by both researchers to ensure that the interpretations were consistent.

3.7 Financial Analysis

The aim of the financial analysis was to answer the research question on what financial and risk implications were associated with each business model. By combining strategic

analysis with financial analysis, the researcher can establish performance targets for the company and its business units (Grant, 2021).

3.7.1 Financial data collection

The collection of data for the financial analysis was done through unstructured interviews with Heart representatives and by reading industry reports and internal documents. The unstructured interviews were conducted with employees at Heart's commercial and aftermarket divisions to receive relevant data input for the financial analysis. Employees in the finance team were also involved for proof-reading the model and providing certain data points such as the WACC and depreciation period. As the electric aerospace industry is still in its early stages of development, internal company projections and qualified estimates were necessary for gathering the data needed to conduct the analysis. To limit the effects of inferior data quality, scenarios were chosen to analyze the impact of optimistic versus restrictive values on the selected key performance indicators (KPIs). Industry reports provided external objective data sources to the analysis for selected values. Due to a lack of published research on the aerospace battery aftermarket subject, the use of industry reports was limited in the financial data collection process. Furthermore, internal company documents were used when possible, providing a reliable source for data collection. For example, the battery memorandum of understanding was referenced, giving data points on the battery and installations costs.

3.7.2 Financial Projections & Risk Analysis

The financial analysis resulted in a projection of Heart's income statement for the battery business per aircraft contract with expected revenues, costs and required investments from 2028 until 2043, calculated for each business model. The calculations generated yearly unlevered free cash flows which were used to calculate the selected KPIs: internal rate of return (IRR), net present value (NPV) and payback period. NPV, IRR and payback period are commonly used as a foundation for making investment decisions (Lohmann & Baksh, 1993). In addition to these KPIs, "Airline cost per battery cycle" and "Airline battery cost per month" were also calculated to simulate the expected costs for the airline given different scenarios. The KPIs were chosen during the pre-study and in discussions with Heart representatives.

After calculating the various KPIs for each business model, a sensitivity analysis was conducted to evaluate the effect of selected pre-defined risks on the different KPIs. The risks were simulated as different business scenarios and chosen during the pre-study and the unstructured interviews with Heart representatives. The risks are shown in table 12 in the empirical findings chapter.

4. Empirical Findings

The following chapter presents the results of the business models definitions, industry analysis, internal analysis, and financial analysis conducted in this study. The four sections provide insights into the industry value chain, its actors and trends, the findings from interviews at the case company, and the risk and financial aspects of different business models. The outcomes of these analyses contribute to a comprehensive understanding of industry, the firm and business models for batteries within commercial aviation that will be the foundation for answering the research questions.

4.1 Business Model Definition

The introduction of electric aircrafts, and especially aircraft batteries, is expected to have far-reaching effects on all the actors in the aviation industry network. The effects of this transition will depend on the specific configurations of the business models for batteries. Different configurations of business models will have varying effects on the actors involved in the adoption of electric aircrafts. For example, battery manufacturers that choose to lease batteries to airlines may have more control over the supply chain but may not have as much responsibility for the maintenance and upkeep of the batteries. Conversely, airlines that choose to own their batteries may have more control over the maintenance and upkeep of the batteries but may also face higher upfront costs.

The identified stakeholders affected by Heart Aerospace introducing aerospace batteries into the industry are presented in table 2.

STAKEHOLDERS
Aircraft OEM
Battery Supplier
Operator (Airline, Lessor)
Airport
MRO
Electricity Network
2nd Life Technical Partner
2nd Life Customer
Recycling Partner
Recycling Customer
Joint (Heart + Strategic Partner)

Table 2: List of stakeholders

The introduction of electric aircrafts will also introduce new activities and costs in the aftermarket. These activities and costs can be substantially different from the ones that exist today in traditional aircrafts. An easy example of these differences can be seen when comparing re-fueling vs charging, which would require different ground support equipment, and would differ in costs. To structure the costs for the new battery business, a cradle-to-grave analysis was conducted and is presented below in table 3.

DEVELOPMENT, SALES & PRODUCTION COSTS	
COST	**DESCRIPTION**
Developing and certifying battery for entry into service	Development costs of 1st Gen batteries included in aircraft delivery
Battery contract administration cost	Setting up leasing/transaction contracts of batteries
OEM battery cost	Battery cost of batteries included in aircraft delivery
Installation cost on OEM production aircraft	Installing batteries included in aircraft delivery
Transport, freight, and logistics for OEM batteries	Transports, freight, logistics, handling of batteries included in aircraft delivery
Taxes for import of OEM batteries	Importing batteries included in aircraft delivery
Developing and certifying new batteries (cell upgrades)	Costs of developing 2nd, 3rd etc generation of batteries for battery replacements
Warranty reserves	Reserves if warranties need to be paid for batteries in storage or in aircraft
TRAINING COSTS	
COST	**DESCRIPTION**
Internal Training for Heart staff (Production, Customer Support)	Internal Training for Heart staff (Production, Customer Support)
Basic training for Operators included in Cost of Sales (Battery handling, Recharge procedure)	Basic training for Operators included in Cost of Sales (Battery handling, Recharge procedure)
Training for Operators who want to insource Maintenance, Repair and Overhaul	Training for Operators who want to insource Maintenance, Repair and Overhaul
OPERATIONS & MAINTENANCE COSTS	
COST	**DESCRIPTION**
Battery performance & monitoring	System for Battery Health monitoring and costs of man-hours managing the system
Documentation and traceability	Paper trail of batteries, materials, battery passport and logistics
Line maintenance checks (daily)	Daily check for airworthiness of aircraft
Heavy maintenance checks (scheduled)	Longer 10+ hour maintenance check / year
Unscheduled battery maintenance	Maintenance and aircraft-on-ground due to unscheduled events
Battery replacements / Upgrades (Batteries + installation costs)	New batteries and the instalment of those batteries
Global logistics network (warehouses, maintenance workshops etc.)	Building up Business Unit for managing aftermarket activities
Customer / Technical support	Employee battery experts in Technical Support
Spare batteries inventory cost	Ordering and holding inventory
Transport, freight and logistics of spare batteries	Costs associated with shipping spare batteries
Taxes for import of spare batteries	Depending on geographical area, and if sent back or not. Costs tied to responsibility of dangerous goods
Storage and handling of spare batteries	Warehousing and handling spare batteries
Insurance of spare batteries prior to installation	Insurance for damages, warehouse, etc
SECOND LIFE & RECYCLING COSTS	

COST	DESCRIPTION
SECOND LIFE / REFURBISHING	
Transport, freight and logistics of used batteries to and from Airport	Costs associated with shipping used batteries
Storage and handling of used batteries	Warehousing and handling of used batteries
Refurbishment of used batteries	Process of restoring and rejuvenating used or worn-out batteries, typically by replacing their internal components or reconditioning their cells to improve their performance and extend their lifespan
SECOND LIFE / REPURPOSING	
Conversion to second life	e.g., containerized energy storage system
Installation in second life facility	Installing repurposed packs for new purpose
END OF LIFE / RECYCLING	
Transport, freight, and logistics of used batteries	Costs associated with shipping used batteries at End-of-Life
Storage and handling of used batteries	Warehousing and handling of End-of-Life batteries (Dangerous goods)
Processing to recycle metals etc.	removal of both electrical, mechanical parts, and recycle materials
Disposal of what can't be recycled	Disposal of what can't be recycled
GROUND INFRASTRUCTURE COSTS	
COST	**DESCRIPTION**
Ground Service Equipment (GSE) - Lift / Install	Specialized lift for removal and installation of heavy battery packs in aircraft
GSE - Temperature conditioning	Therman Management for batteries before charging
GSE - Fast charger	Fast charger of 2+ megawatt allowing quick turnarounds
Electrical upgrades - Within airport perimeter	Upgrades and transformers enabling fast charging operations of multiple aircrafts within airport
Electrical upgrades - External to airport	Upgrades and transformers enabling fast charging operations of multiple aircrafts external to airport

Table 3: Cradle-to-Grave Cost Description

In the analysis of the four different business models, it is evident that three main actors, namely the operator, the manufacturer, and the battery supplier, have significantly different responsibilities in each of the models. Given the significantly different responsibilities of the main actors, it is essential to consider the value proposition for each actor in each of the four business models. In table 4, the value proposition matrix for the different models, and the actors are presented.

Business Models	Overview	Value Proposition		
		Customer	Heart	Battery Supplier
Heart Selling	Heart sells the batteries to an airline, operator, or lessor	• Heart sells certified batteries to airlines / operators • Airlines / operators manage battery maintenance, replacement and own the residual value of used batteries. More levers to control costs and develop in-house capabilities.	• Reduced cost, complexity, and customer support • Customer takes on the risk of battery in-service performance, actual cycle life etc.	• Straight-forward procurement contract. • Defined revenues from sales of OEM and replacement batteries, no risk-sharing. • Leverage Heart's market knowledge to enter the aerospace market as a battery supplier
Heart Leasing: Power-by-the-cycle	Airline / operator pays per battery charge cycle. Baseline package includes Training,	• Heart provides a total care service, taking care of battery maintenance, replacement, and upgrades at a fixed cost	• Long term aftermarket revenue stream • Customers ideally sign long-term contracts, which can be monetized	• Straight-forward procurement contract. • Defined revenues from sales of OEM and replacement batteries, no

	Line maintenance, Customer support, Replacement batteries + Optional extras such as Battery health monitoring, Upgrades.	to airlines / operators • Known cost, simple, avoids need to build facilities and recruit and train maintenance staff • Heart can discount battery cost, based on battery second life / salvage value	• Enables Heart to underwrite and / or subsidize early high battery costs to encourage higher uptake of electric aircraft	risk-sharing. • Leverage Heart's market knowledge to enter the aerospace market as a battery supplier
JV / Strategic Partnership	Heart and Battery Supplier (and others such as second life partner?) create a JV / strategic partnership and lease the batteries to the airline. They share costs, revenues, and risk.	• JV provides a total care service, taking care of battery maintenance, replacement, and upgrades at a fixed cost to airlines / operators • Known cost, simple, avoids need to build facilities and recruit and train maintenance staff • JV can discount battery cost, based on battery second life / salvage value • Repurposing batteries within airports could potentially add further value to Operator	• Share costs and risks with Supplier • Leverage Supplier capabilities and facilities, such as global logistics network, second life, Recycling for circular economy critical minerals • Alignment of incentives between Heart and Supplier, e.g., keep supply cost of batteries low • Corporate / Structural separation of aircraft and aftermarket businesses enables each to pursue separate (but complementary) strategies	• Larger slice of aftermarket revenues and services • Deeper insight / learnings in how to operate in the full value chain of the aerospace market, from battery supplier, to sales, customer support, maintenance, second life and recycling • Larger involvement in Second Life / End of Life recycling enables recovery of critical minerals to control input costs for battery cells
Supplier Ownership (Selling model)	• Supplier sells directly to the operator and Heart receives royalties for providing the planes	• Airlines / operators purchase the certified batteries from the supplier with additional services at request. • The airlines/ operators are responsible for coordinating the battery operations and own the residual value of the used batteries. • More levers to control costs and develop in-house capabilities.	• By not engaging in aftermarket activities Heart reduces risk, complexity and can focus on core business. • Heart receives royalties from the net profit of the Supplier for providing the business opportunity.	• Reduced cost, complexity, and customer support • Customer takes on the risk of battery in-service performance, actual cycle life etc.
Supplier Ownership (Leasing model)	• Supplier leases directly to the operator and Heart receives royalties for providing the planes	• Supplier provides a total care service, taking care of battery maintenance, replacement, and upgrades at a fixed cost to airlines / operators • Known cost, simple, avoids need to build facilities and recruit and train maintenance staff • Supplier can discount battery cost, based on battery second life / salvage value	• By not engaging in aftermarket activities Heart reduces risk, complexity and can focus on core business. • Supplier takes on the risk of battery in-service performance, actual cycle life etc. • Recurring Revenue streams from royalties on lease compared to individual sales.	• Largest slice of aftermarket revenues and services • Larger involvement in Second Life / End of Life recycling enables recovery of critical minerals to control input costs for battery cells

Table 4 Business Model Value Proposition

The costs in the cradle-to-grave cost analysis shown previously in table 3, will vary. For example, in a business model where the manufacturer retains ownership of the battery, the manufacturer will be responsible for the cost of recycling or disposing of the battery at the end of its life cycle. In contrast, in a business model where the operator owns the battery, the operator will be responsible for the cost of disposal. To summarize the cost responsibilities for each actor in each of the four business models, table 5 below presents an analysis of the costs paid by the different actors involved in the battery aftermarket.

DEVELOPMENT, SALES & PRODUCTION COSTS					
COST	**SELLING**	**LEASING**	**JV/ STRATEGIC PARNERSHIP**	**SUPPLIER OWNERSHIP 1**	**SUPPLIER OWNERSHIP 2**
Developing and certifying battery for entry into service	Heart	Heart	Joint	Joint	Joint
Battery contract administration cost	Heart	Heart	Joint	Supplier	Supplier
OEM battery cost	Heart	Heart	Joint	Supplier	Supplier
Installation cost on OEM production aircraft	Heart	Heart	Joint	Supplier	Supplier
Transport, freight, and logistics for OEM batteries	Heart	Heart	Joint	Supplier	Supplier
Developing and certifying new batteries (cell upgrades)	Heart	Heart	Joint	Joint	Joint
Warranty reserves	2 years Supplier	2 years Supplier	Joint	Supplier	Supplier
TRAINING COSTS					
COST	**SELLING**	**LEASING**	**JV/ STRATEGIC PARNERSHIP**	**SUPPLIER OWNERSHIP 1**	**SUPPLIER OWNERSHIP 2**
Internal Training for Heart staff (Production, Customer Support)	Heart	Heart	Joint - Heart led	Heart	Heart
Basic training for Operators included in Cost of Sales (Battery handling, Recharge procedure)	Heart	Heart	Joint	Heart	Heart
Training for Operators who want to insource Maintenance, Repair and Overhaul	Operator	N/A	N/A	N/A	N/A
OPERATIONS & MAINTENANCE COSTS					
COST	**SELLING**	**LEASING**	**JV/ STRATEGIC PARNERSHIP**	**SUPPLIER OWNERSHIP 1**	**SUPPLIER OWNERSHIP 2**
Battery performance & monitoring	Heart	Heart	Joint	Supplier	Supplier
Documentation and traceability	Operator	Heart	Joint	Supplier	Supplier
Line maintenance checks (daily)	Operator	Operator	Operator	Operator	Operator
Heavy maintenance checks (scheduled)	Operator	Heart	Joint	Supplier	Supplier
Unscheduled battery maintenance	Heart	Heart	Joint	Supplier	Supplier
Battery replacements / Upgrades (Batteries + installation costs)	Operator	Heart	Joint	Supplier	Supplier
Global logistics network (warehouses, maintenance workshops etc.)	Heart	Heart	Joint	Supplier	Supplier
Customer / Technical support	Heart	Heart	Joint	Supplier	Supplier
Spare batteries inventory cost	Operator	Heart	Joint	Supplier	Supplier
Transport, freight, and logistics of spare batteries	Operator	Heart	Joint	Supplier	Supplier
Taxes for import of spare batteries	Operator	Heart	Joint	Supplier	Supplier
Storage and handling of spare batteries	Operator	Heart	Joint	Supplier	Supplier
Insurance of spare batteries prior to installation	Operator	Heart	Joint	Supplier	Supplier
SECOND LIFE & RECYCLING COSTS					
COST	**SELLING**	**LEASING**	**JV/ STRATEGIC PARNERSHIP**	**SUPPLIER OWNERSHIP 1**	**SUPPLIER OWNERSHIP 2**
SECOND LIFE / REFURBISHING					
Transport, freight, and logistics of used batteries to and from Airport	Operator	Heart	Joint	Supplier	Supplier
Storage and handling of used batteries	Battery Supplier	Battery Supplier	Joint - Battery Supplier led	Supplier	Supplier
Refurbishment of used batteries	Battery Supplier	Battery Supplier	Joint - Battery Supplier led	Supplier	Supplier
SECOND LIFE / REPURPOSING					

Conversion to second life	Operator	Heart	Joint	Supplier	Supplier
Installation in second life facility	Operator	Heart	Joint	Supplier	Supplier
END OF LIFE / RECYCLING					
Transport, freight, and logistics of used batteries	Operator	Heart	Joint	Supplier	Supplier
Storage and handling of used batteries	Operator	Heart	Joint	Supplier	Supplier
Processing to recycle metals etc.	Recycling Partner	Recycling Partner	Recycling Partner	Recycling Partner	Recycling Partner
Disposal of what can't be recycled	Recycling Partner	Recycling Partner	Recycling Partner	Recycling Partner	Recycling Partner
GROUND INFRASTRUCTURE COSTS					
COST	**SELLING**	**LEASING**	**JV/ STRATEGIC PARNERSHIP**	**SUPPLIER OWNERSHIP 1**	**SUPPLIER OWNERSHIP 2**
Ground Service Equipment (GSE) - Lift / Install	Operator	Heart	Joint	Operator	Supplier
GSE - Temperature conditioning	Operator	Heart	Joint	Operator	Supplier
GSE - Fast charger	Operator / Airport	Heart / Airport	Joint / Airport	Operator / Airport	Supplier / Airport
Electrical upgrades - Within airport perimeter	Airport	Airport	Airport	Airport	Airport
Electrical upgrades - External to airport	Electricity Network	Electricity Network	Electricity Network	Electricity Network	Electricity Network

Table 5: Cradle-to-Grave Cost Allocations

Similar to the cradle-to-grave cost allocations, the revenue streams in the aftermarket can also vary significantly for the different actors in the four business models. To make informed decisions about which business model to adopt, it is important to consider the revenue streams associated with each model for each actor. Table 6 below summarizes the analysis of the potential revenue streams for the operator, manufacturer, and battery supplier in each of the four business models.

REVENUES ALLOCATIION					
REVENUE STREAM	**SELLING**	**LEASING**	**JV/ STRATEGIC PARNERSHIP**	**SUPPLIER OWNERSHIP 1**	**SUPPLIER OWNERSHIP 2**
1st battery (delivered on aircraft)	Heart	N/A	N/A	Supplier	N/A
Leasing - Baseline package includes Training, Line maintenance, Customer Support, Replacement batteries	N/A	Heart	Joint	Supplier	Supplier
Royalties	N/A	N/A	N/A	Heart	Heart
Training (MRO)	Heart	N/A	N/A	N/A	Heart
Maintenance	Heart	N/A	N/A	N/A	N/A
Customer Support	Heart	N/A	N/A	N/A	N/A
Battery health monitoring	Heart	Heart	Joint	Supplier	Supplier
Replacement batteries	Heart	N/A	N/A	N/A	N/A
Upgraded batteries	Heart	Heart	Joint	Supplier	Supplier
Battery Residual value (2nd life)	Operator	Heart	Joint	Operator	Supplier
Battery End-of-life value	Operator	Heart	Joint	Operator	Supplier

Table 6: Revenues Allocations

With the costs and revenues allocations defined for each of the business models, a SWOT analysis was conducted to identify the strengths, weaknesses, opportunities, and threats associated with each model. Table 7 illustrates the SWOT analysis for each model.

Business Models	Strengths	Weaknesses	Opportunities	Threats
Heart Selling	• Airlines / Operators manage battery maintenance, replacement and take on risk of cycle life and residual value of batteries.	• Loss of control over battery strategy and costs. • Potentially give up aftermarket revenue if Operators insource MRO. • Requires large CapEx / staffing to build global logistics network to capture Aftermarket revenue.	• Airlines / operators potentially have more levers to control costs and develop in-house capabilities.	• Loss of control over High / variable / uncertain battery costs could discourage customers from buying more electric aircraft if batteries underperform.
Heart Leasing: Power-by-the-cycle	• Heart provides a fixed-cost, simple, total care service, removing Airline risks and burden of battery maintenance, replacement, upgrades, disposal.	• Requires large CapEx / staffing to build global logistics network to capture Aftermarket revenue.	• Enables Heart to underwrite and / or subsidize early high battery costs to encourage higher uptake of electric aircraft. • Long term aftermarket revenue stream contracts, which can be monetized.	• Heart assumes all the financial risk of battery in-service performance, actual cycle life, residual value etc.
JV / Strategic Partnership	• Share costs, risks and leverage battery supplier capabilities e.g. Global logistics network, 2nd life refurbishing. • Maintain strategic control over high / variable / uncertain battery costs and performance. • Corporate / Structural separation of aircraft and aftermarket businesses, with Alignment of incentives between Heart and battery supplier, e.g. keep supply cost of batteries low.	• Sharing revenue streams. • Requires longer term negotiation to create the strategic agreement / joint venture.	• Battery supplier strategic involvement in Second Life / End of Life recycling enables recovery of critical minerals to control input costs for battery cells. • Deeper insight / learnings in how to operate in the full value chain of the aerospace market, from battery supplier, to sales, customer support, maintenance, second life and recycling.	• Risk that battery supplier as much larger company could unfairly negotiate better deal in JV.
Supplier Ownership (Selling model)	• Reduced complexity and avoid CapEx / staffing costs to deliver customer support. • Battery supplier takes on the risk of battery in-service performance, actual cycle life, residual value etc.	• Loss of control over battery strategy and costs. • Give up long-term aftermarket revenue stream. • Loss of big data from battery operations in service and organization capability on battery support.	• Grow passive revenue though favourable royalties based on sales contracts.	• Loss of control over High / variable / uncertain battery costs could discourage customers from buying more electric aircraft if batteries underperform.
Supplier Ownership (Leasing model)	• Reduced complexity and avoid CapEx / staffing costs to deliver customer support. • Battery supplier takes on the risk of battery in-service performance, actual cycle life, residual value etc.	• Loss of control over battery strategy and costs. • Give up long-term aftermarket revenue stream. • Loss of big data from battery operations in service and organization capability on battery support.	• Grow passive revenue though favorable royalties with predictable revenues based on long term lease contracts.	• Loss of control over High / variable / uncertain battery costs could discourage customers from buying more electric aircraft if batteries underperform.

Table 7: Business Model SWOT Analysis

In strategic decision-making, it is essential to weigh the disadvantages against the risks associated with each option. Table 8 presents the analysis of the major disadvantages for Heart in each model.

Business Models	Disadvantages for Heart
Heart Selling	• Requires a large investment in CapEx and staffing to build global logistics network to capture Aftermarket revenue • Potentially miss out on long-term aftermarket revenue stream if airlines insource MRO • High / variable / uncertain battery costs could discourage customers from buying more electric aircraft • Transfer of financial, commercial and reputational risk back to Heart if batteries underperform
Heart Leasing: Power-by-the-cycle	• Requires a large investment in CapEx and staffing to build global logistics network to build customer support capabilities and capacity • Heart takes on the financial risk of battery in-service performance, actual cycle life etc.
JV / Strategic Partnership	• Need complete trust in partner, since enter a long-term business 'marriage' • Sharing revenue streams
Supplier Ownership (Selling model)	• Loss of control over battery strategy and costs • Loss of big data from battery operations in service • Loss of organizational capability regarding battery customer support • Miss out on long-term aftermarket revenue stream • High battery costs could discourage customers from buying more electric aircraft • Transfer of financial, commercial and reputational risk back to Heart if batteries underperform
Supplier Ownership (Leasing model	• Loss of control over battery strategy and costs • Loss of big data from battery operations in service • Loss of organizational capability regarding battery customer support • Miss out on long-term aftermarket revenue stream • High battery costs could discourage customers from buying more electric aircraft • Transfer of financial, commercial and reputational risk back to Heart if batteries underperform

Table 8: Business Model Disadvantages

Table 9 describes the identified risk variables and their respective allocation based on the different business models. The aircraft utilization rate is recognized as a risk variable due to the strong correlation between the frequency of battery degradation and replacement and the extent of aircraft usage. The in-service battery cycle life until replacement is also classified as a risk variable as it is closely tied to the timing of battery replacement. Furthermore, procurement costs are deemed to be a risk variable since the fluctuations in demand for batteries and their materials can significantly impact the operational costs. The residual value is likewise regarded as a risk variable because the battery will be replaced while still in a relatively healthy state and is therefore assumed to hold some second-hand value. Additionally, the aircraft is perceived as an appreciable asset where customers can gain increasing value through battery upgrades, making the costs and time intervals between these upgrades a risk variable.

Major Risks / Uncertainties	1. Selling	2. Leasing: Power-by-the-cycle	3. JV / Strategic Partnership	Supplier Ownership 1	Supplier Ownership 2
Aircraft utilization rates (battery recharge, frequent AOG)	Operator	Heart	Joint	Operator	Supplier
Actual in-service battery cycle life to 80% capacity fade	Operator	Heart	Joint	Operator	Supplier
Procurement of battery cells impact on Hardware cost	Heart	Heart	Joint	Supplier	Supplier
Actual battery residual value	Operator	Heart	Joint	Operator	Supplier
Variable qualification costs of battery upgrades	Heart	Heart	Joint	Joint	Joint

Time between battery upgrades	Heart / Operator	Heart / Operator	Joint / Operator	Heart / Operator	Heart / Operator

Table 9: Business Model Risk Allocations

4.2 Industry Analysis Findings

This chapter contains the analysis of the commercial aerospace industry with a particular emphasis on the implications of introducing batteries in aircrafts and the industry. The analysis comprises of an assessment of the actors involved, value-chain dynamics, and emerging trends within the industry. Moreover, the chapter provides an evaluation of batteries and the expected impact of the introduction of electric aircrafts to the industry. The first sub-chapter; 4.2.1 commercial aerospace industry is influenced by Wirths (2019) who has conducted a comprehensive and unique analysis of aerospace actors and industry dynamics.

4.2.1 Commercial Aerospace Industry

The commercial aerospace industry has played a key role in the globalization, connecting people from all around the world. An increased welfare and a rising middle class in the developing world has contributed to the rise in demand for air travel, leading to a double in air traffic every 15 years (Strube et al., 2017). As the demand for air travel continues to rise, scientists and politicians worldwide are increasingly expressing environmental concerns, citing global warming as a pressing issue. According to estimates from 2022, aviation is responsible for 3.5% to 4% of global greenhouse gas emissions, and if left unmitigated, this Figure could increase to as much as 22% of global emissions by 2050 (Mission Possible Partnership, 2022). The worrying development is putting pressures on aerospace industry actors to reduce their $C0_2$ emissions which has increased the demand for fossil free propulsion alternatives. In the transition towards a more sustainable aerospace industry, battery electric aircrafts have been emphasized as a viable option. However, as the aviation sector has long been characterized by stability and rigid market structures, the transition to electric will be an immense challenge… (Knoll-Csete & Kárász, 2021).

Wirths (2019) mentions several actors in the aerospace industry, however, in connection to electrification of the industry, the commercial aviation value chain consists of six main actors:

STAKEHOLDERS	DESCRIPTION
Manufacturers	Producing the aircrafts.
Suppliers	Producing the components
Lessors	Acquire ownership of the aircraft/engines and then lease them to the airline or economic operator.
Airports	Contribute with the infrastructure for air traffic
Aircraft Maintenance, Repair, and Overhaul providers (MROs)	Providing maintenance services that ensure the airworthiness of the aircrafts
Airlines	Providing flight services to end customers

Table 10 Commercial Aerospace Actors, based on Wirths (2019)

The profitability varies in the industry and between actors but is generally the highest for MRO companies and the lowest for Airlines (Figure 10).

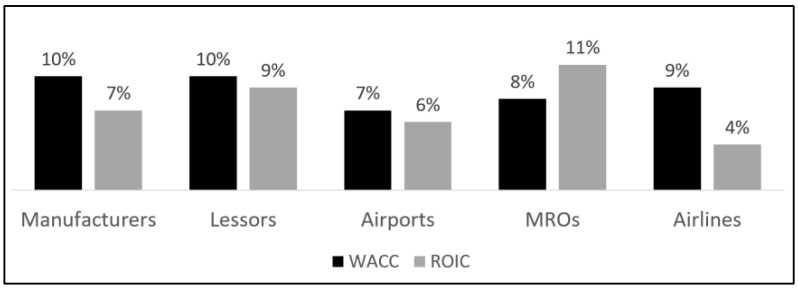

Figure 10: Actors and their profitability in the aerospace industry, based on Wirths (2019)

Manufacturers:

The market for wide body aircrafts has become concentrated with Boeing and Airbus dominating, largely due to high entry barriers steming from high technology and capital requirements. In the narrow body aircraft market, Bombardier, Embraer, and ATR have previosly been recognized as market leaders (Wirths, 2019). However, in recent years, consolidations have taken place where Airbus and Boeing have acquired a share of the regional and medium haul market segment. Boeing's deal with Embraer, taking over a majority stake in the commercial aerospace business and Airbus acquisition of Bombardier's mid-size aircraft segment are examples of the incumbants' offensive strategy to gain even greater control in the aerospace market. The relationship between Boeing and Airbus has been characterized by fierce competition, resulting in periodic pricing of aircrafts below the static marginal cost (Wirths, 2019).

Suppliers:

Generally, there are three main categories of suppliers to aircraft manufacturers: engine manufacturers, first tier original equipment suppliers (OES) and second tier suppliers. First tier OES typically produces larger systems that are integrated in the aircraft while second tier suppliers produce components or subsystems to tier 1 suppliers. Engines are the most advanced systems on the aircraft and require large capital investments. Developing new engines is expensive which is why engine manufacturers often share the risks in the development phase through joint ventures with system suppliers (Wirths, 2019). To finance the engines, engine manufacturers rely heavily on aftermarket services throughout the amortization period of 15 to 25 years (Wirths, 2019). The commercial aerospace engine market is consolidated with three main actors: Rolls-Royce, General Electric and Pratt & Whitney controlling most of the market (Wirths, 2019).

Lessors

An aircraft lessor is defined as an investment entity that operates as a leasing company, purchasing aircrafts from manufacturers and leasing them to airlines. In addition to leasing aircrafts, lessors offer leasing services for engines and other high value assets. In 2015, approximately 42% of the world's total aircraft fleet was owned by lessors (Wirths, 2019). Almost all airlines today use operating leases as a component of their capital

structure. This provides airlines with flexibility, cost savings and the latest technology, without the significant upfront costs of purchasing. The leasing contract is usually valid for a pre-defined number of years where the airline or in this case the lessee, pay the lessor on a regular basis until the termination of the contract. At expiration date, the lessee is typically required to return the asset to the lessor, unless the lessor offers the opportunity to purchase the asset based on market value (Zou, 2011). For lessors, the aircraft is a financial asset rather than an operational tool. This is because the lessor gains a steady income from leasing the asset while also maintaining the value for the next lessee. The lessors are more concerned with maintaining aircraft value than its operation (Wirths, 2019).

MRO

To ensure the safety of flight operations and maintain airworthiness, aircraft operators are obliged to provision Maintenance, Repair, and Overhaul (MRO) services. Maintenance activities are aimed at minimizing the deterioration of the aircraft and its parts, while repair and overhaul encompass measures that aim to restore the aircraft or its components to their original state (Wirths, 2019). Airlines bear legal responsibility for ensuring the airworthiness of their aircraft, which they must fulfill through active involvement and control. To meet this requirement, they must establish and maintain a Continuous Airworthiness Management Organization (CAMO). Airlines are not obligated to handle all MRO tasks internally. They can outsource these duties to external entities with CAMO approval, as long as a direct interface is established to ensure oversight and control (Wirths, 2019).

MRO is divided into four market segments: Line maintenance, base maintenance, engine overhaul and component maintenance. Line Maintenance encompasses routine, minor inspections and repairs of aircrafts that are conducted on a regular basis to maintain their airworthiness. This involves identifying malfunctions and conducting minor trouble-shooting procedures. The key objective of Line Maintenance is to quickly address any issues that arise without causing undue delays or disrupting the flight schedule. Base maintenance involves major inspections and structural repairs of the aircraft that are typically conducted in a dedicated Base Maintenance facility or hangar. Engine Overhaul refers to the complete set of restoration, maintenance, and predefined tasks carried out on a removed engine (called off-wing) to bring it back to its original working condition (Wirths, 2019). Component maintenance encompass the repair, replacement, and testing procedures carried out on the components that facilitate the fundamental operations of the aircraft, such as control and navigation, steering, communications, electrical power generation, cabin air conditioning, as well as landing and braking mechanisms (Kinnison, 2013).

The market for MRO services is more diverse in comparison to the aircraft manufacturing market. Major airlines have developed their own MRO organizations such as Lufthansa Technik and AFI KLM Engineering. There are also independent MRO providers that

mainly focus on offering services within one MRO segment, such as HAECO and AAR Corp. A third type of actor that has entered the MRO market in recent years are the manufacturers of aircrafts and first tier suppliers, including Rolls-Royce, Airbus and GE (Wirths, 2019). The vertical integration of these companies is due to a higher profit potential in the aftermarket (Figure 10) and a stronger focus on delivering complete service solutions to the customers (Dachs et al., 2014).

Considering the operations of electric aircrafts, MRO services will be required to maintain the airworthiness. Although batteries require significantly less maintenance work in comparison to other parts of an aircraft such as jet engines, MRO services will still be needed for regular line maintenance checks, occasional overhauls, and the swap of new batteries. This will require training in mechanics, battery logistics, storage and handling, battery monitoring and other activities to be conducted (Heart, 2022). Since the market for battery MRO services is yet to be established, there are still uncertainties of which actors will be entering this new business area. One scenario is that the market structure will be similar to the general MRO service market for commercial aircrafts. Another scenario is that battery MRO services will require entirely new capabilities which differ from the ones that existing MRO actors already possess. This will create new business opportunities for entrants that develop such capabilities.

Airlines

Airlines are central in the aviation value chain and essential for air travel. Despite high growth in customer demand and heavy cost reductions in airline operations, the high competitiveness of the industry has led to low profitability among airlines. Between 1965 and 2007, the return on invested capital (ROIC) was just around 5%, 3% below the weighted average cost of capital (WACC) (Wirths, 2019). The low profitability can be explained by both external and internal factors. All five forces, introduced by Porter (1979) are present in the airline industry including: high bargaining power of suppliers, high bargaining power of distribution channels and customers, medium but rising threat of substitutes, high threat of new entrants as well as high competition among airlines (Wirths, 2019). The forces on the industry have resulted in price pressures that has contributed to yield deterioration and limited the opportunities to attract capital. Consequently, airlines are striving to reduce their costs to increase the profitability. However, the opportunities for cost reductions are very limited, as most cost components such as fuel, taxes and landing fees are non-negotiable. MRO services is one area where the airlines are focusing their cost reduction efforts as they represent between 15-18% of the airlines direct operating costs (DOC). Recent trends show that an increasing number of airlines are focusing on their core business, outsourcing MRO services with the aim of reducing the costs of operation (Wirths, 2019).

Airports

Airports play a critical role in the aerospace industry, serving as the primary link between air transportation and the ground. Airports provide essential services such as take-off and landing infrastructure, air traffic control, ground handling and passenger services. The growth of air travel has led to an increase in the number of airports worldwide, and their importance in the aviation industry continues to grow. The number of yearly passengers is expected to grow by 20-40% worldwide from 2023 until 2030 (Weston et al., 2023).

Though aircraft manufacturers are envisioning a new future of electrification, airports and airport operators have only just begun the process of electrifying their ground vehicles. The introduction of electric aircrafts provides a new challenge for airports as the need for power is expected to increase. Airports will need to develop and maintain charging infrastructure to support the electrification of aircrafts which includes providing the necessary electrical power supply, charging stations, and battery storage facilities (Schwab et al., 2021; Alfredsson, 2023). To offer airlines a price competitive alternative to conventional aircrafts, the aircraft batteries need to be charged within a 30–90-minute time frame (Doctor et al., 2022). The quick turn-around times for aircrafts will demand ultra-fast chargers to be built at the airport facility with a power capacity exceeding 1 MW. Such chargers are heavy investments and may require expensive grid upgrades to handle the peak load effects (Cox et al., 2023).

4.2.2 Batteries and Electric Aviation

There has been an increased demand for batteries in recent years. The reasons behind this can be attributed to several factors, such as the growth of electric vehicles, consumer electronics, and renewable energy and its need for energy storage systems (Zhao et al., 2021; Roland B, 2022; Edström et al., 2022). Technological advancements and improved manufacturing processes have also contributed to increased efficiency of the batteries while at the same time lowering the cost by a factor of 15 (Roland B, 2022; Edström et al., 2022). As a result, the demand for batteries has risen sharply.

The battery technology that has experienced the most growth is Lithium-Based batteries. The reason behind this growth is due to its capability of high energy density (Zhao et al., 2021). This allows the batteries to store more energy in a smaller and lighter package compared to other battery chemistries. High energy density is particularly useful in the applications that were described to have had a major role in escalating the battery demand, as weight and space constraints are important considerations (Zhao et al., 2021). Additionally, lithium-based batteries have a relatively long lifespan and can withstand many battery cycles (Zhao et al., 2021). This refers to the number of complete charge and discharge cycles a rechargeable battery can undergo before experiencing a noticeable decrease in performance. The reduced performance happens because in each cycle there are non-reversible reactions that affects the performance negatively. The number of cycles a battery can withstand before degrading is dependent on multiple factors such as its chemical composition, operating conditions, usage patterns, charge and discharge patterns, and time (Roland, 2022).

As a combination of an increasing demand for sustainable transportation solutions, and the improvements in battery technology and costs, a new market for electric aircraft is emerging. This market is still in its infancy and is characterized by high technological uncertainty. A few new entrants are exploring different options to gain a first mover advantages in the growing new industry (Ponomarev 2022). There are different trajectories within electrified air travel solutions such as, More-Electric Aircrafts (MEA), Hybrid-Electric Aircrafts (HEA) and All-Electric Aircrafts (AEA). A MEA is a type of aircraft that relies more heavily on electrical power for its various systems and functions. A HEA is an aircraft that uses a combination of traditional fossil-fuel-powered engines and electric motors to provide propulsion. Lastly, An AEA is an aircraft that relies solely on electric power for propulsion and all other systems, with no traditional fossil-fuel-powered engines (Barzkar & Ghassemi, 2020). The HEA and AEA differ from the MEA in that it relies on batteries for propulsion which presents a much larger challenge. These aircrafts require large sized batteries to be integrated into the airframe of the aircraft which significantly increases its weight, cost, safety requirements, and complexity of operations (Barzkar & Ghassemi, 2020).

Even though price reductions have been significant and have played a key role in the adoption of lithium-based batteries, the price is still high compared to alternatives. For EVs the batteries still account for as much as 40% of the total cost (IER, 2022). In aviation, batteries are expensive compared to traditional aviation fuel and other components of the aircraft. As a result, the high cost of batteries can account for a significant portion of the overall cost of a hybrid electric aircraft. Additionally, the weight of batteries can also impact the performance and efficiency of the aircraft, requiring further optimization to achieve the desired balance between cost, weight, and performance (Damiano et al., 2018). Battery degradation makes this even more problematic. With the long innovation cycles in aerospace industry, a new model produced is expected to last for decades. Because batteries degrade over time, they must be replaced periodically, which can be costly and time-consuming. Additionally, the limited lifespan of batteries means that they need to be replaced multiple times over the operational life of an aircraft, further adding to the cost and complexity of maintenance and repair programs.

Regulatory agencies will also affect the use of batteries in electric aviation. These agencies establish rules and standards for the development, production, and use of batteries in aircraft, which can affect both the cost and compliance requirements for battery systems (Müller, 2021). For example, regulations related to safety and environmental impact may require expensive testing and certification procedures, which can increase the overall cost of battery systems. Compliance with these regulations aims to ensure safe and reliable operation of the electric aircraft (Müller, 2021), but an effect of these are additional complexities and costs to the development and operation of these systems. Furthermore, these agencies operate within different geographical jurisdictions, so compliance needs to be met for multiple agencies if the batteries are to operate in aircrafts

within different jurisdictions (Müller, 2021). The three largest aircraft regulatory agencies are the Federal Aviation Administration (FAA), the European Union Aviation Safety Agency (EASA), and the Civil Aviation Administration of China (CAAC).

Aerospace batteries utilized in HEA, with today's level of energy density, are only useful for commercial aerospace operations until they reach a State of Health (SOH) of around 80% or above. SOH refers to their current condition and capacity when compared to original specifications, measured through internal resistance, capacity, and voltage characteristics (Ungurean et al., 2017). The batteries need to be replaced at such a high level in order to comply with safety requirements and successfully meet take-off parameters such as climb-rate. The complicated value chain of these aircraft batteries includes mining and processing of valuable materials, manufacturing of pack components, aircraft integration, use and maintenance and lastly end-of-life (Laurent, 2021). With a Global pandemic, war in Ukraine and related events destabilizing supply chains, for the first time in the 21st century, batteries became more expensive, reaching $151/kWh for new packs globally in 2022, a 7% rise from the last year in real terms (Marthaler et al., 2022). This has sped up the development of a 2nd-life market for batteries. There are different areas of applications for 2nd life batteries such as front of the meter (FTM), behind the meter (BTM) and mobile energy storage. Front of the meter refers to energy storage systems that are connected to the grid and are used to support large-scale energy management, while behind the meter systems are installed on-site at a building or facility and are used to manage local energy consumption and reduce peak demand charges, and mobile energy storage systems are portable and can be used to power remote locations or as a backup power source during emergencies (Marthaler et al., 2022). The 2nd life market can be considered critical to the business case of the aircraft given the significant cost of the batteries, their expected lifetime difference compared to the aircraft, and their high-performance potential after being removed from the aircraft. Consequently, the battery ownership at EOL becomes an important factor to include in the business case analysis.

4.3 Internal Analysis Findings

Based on the thematic analysis of the interviews conducted with Heart's executive team, the following 8 themes were identified:

THEMES
Heart's long-term strategy and value proposition
Key challenges
Strategic importance of the battery aftermarket
Insource or outsource decision
Battery second life ownership
Strategic partnership
Heart's relative strengths related to the battery business
Preferred business model structure

Table 11: Themes from thematic analysis

4.3.1 Long term strategy and value proposition

The long-term strategy relates to Heart's long-term ambition and goals to compete in the aerospace industry. It covers the company's differentiation strategy, its key capabilities and scope of the firm.

Heart's long-term vision is to be the global market leader in the short and regional haul segment. This includes all routes below a 1500km distance. The value proposition is to bring affordable, accessible, and sustainable products to the market. For the past 20-30 years, the industry has been affected by a centralization phase where air travel has been centralized to larger hubs, leaving smaller airports with empty capacity unused. By bringing sustainability and affordability to the segment, Heart would unlock a new market for regional air travel that has been dormant for years. The commoditization of aviation was mentioned as a strategic goal for the company, to make air travel accessible to more people. Heart would leverage a first mover advantage to take market shares in the new emerging industry. This would be possible by taking advantage of the combined knowledge from years of industry experience that the company possesses and leveraging economics of scale to decrease costs over time. Furthermore, Heart aims to be technology agnostic, starting with electric propulsion but exploring alternatives to improve range, reliability, affordability, and safety to increase the value creation to airlines.

4.3.2 Key Challenges

The theme of Key Challenges (Table 11) was identified through multiple discussions with participants regarding the most significant obstacles they face in achieving their long-term strategic objectives. This theme is of particular interest as it allows for an assessment of potential barriers and obstacles across different business models, enabling a comparison of the relative ease with which challenges can be overcome between these models.

Managing costs and risks is a great challenge in this industry due to high capital requirements. This challenge is multi-faceted and involves various aspects of the manufacturing process, such as research and development, production, and distribution. This challenge is also closely linked with another identified challenge, certifications. In the aircraft manufacturing industry, certifications are a critical aspect of ensuring safety and reliability. However, obtaining these certifications can be a significant challenge for manufacturers. The certification process involves a rigorous evaluation of the aircraft's design and manufacturing processes, and compliance with strict regulatory standards is necessary to obtain certification. This process can be time-consuming and expensive, and especially so for an aircraft manufacturer working with novelties within the industry. For electric propulsion systems, most of the regulations are not tailored to this type of aircraft which may increase complexity and costs for this process.

Introduction of a new aircraft usually requires an extensive process which includes research, development, testing and certification. For this reason, major OEMs typical have long development cycles. Heart, being start-up, has to develop the internal processes which presents and additional risk to the already complex development process, but can also be considered an advantage as it is easier to adapt or have clean start more suitable to the emerging technologies and ways of working.

Heart needs to develop an aircraft that is able to match existing competitors. One of the key enablers of electric aviation is the increase in energy density of the battery systems. Although during the last decades there has been a substantial improvement in both energy density and cost, the introduction of next generation technologies usually comes with a premium, which might affect either the distances achieved by the product or its operational cost.

Lastly is the challenge of infrastructure. Developing an electric aircraft presents a major challenge that extends beyond the aircraft and the company itself, as it may require upgrades to the existing airport infrastructure. This includes the need for upgraded ground support equipment, specialized training for airport personnel, and other aftermarket activities to support the product and facilitate market adoption.

4.3.3 Strategic importance of the battery aftermarket

The theme discusses the strategic importance of the battery aftermarket to Heart and the difference between the short term and long-term perspective.

The batteries play a strategically important role in the business of Heart as they serve as a core component of the aircraft. It is necessary that Heart maintain a degree of control over the batteries as they are an essential part of the value proposition of making aviation green and affordable. To speed up the adoption of electric aircrafts, the battery aftermarket will be critical to ease operations for the airlines and remove any uncertainties in the transition. Additionally, the battery aftermarket presents promising opportunities for Heart's financial growth and enables them to diversify their revenue streams. When observing the existing aerospace industry, both Boeing and Airbus have been successful in implementing a business model where they sell their aircraft at marginal cost and generate profits through aftermarket support services for their products. There seemed to be no significant difference in strategic importance between the short-term and long-term perspective in relation to the battery aftermarket.

4.3.4 Insource or outsource decision

The insourcing/ outsourcing theme discusses what activities in the battery aftermarket are preferably done in-house by Heart or outsourced to the battery supplier or a third party. The aftermarket activities are shown in table 3.

The insourcing/ outsourcing decision depends on multiple variables such as strategic importance to Heart, core capabilities, relative cost benefits and reliability of the system. The aim is to lower the operational costs for the airlines and increase the reliability to offer a competitive alternative to conventional aircraft operations. Furthermore, it is important to understand the stakeholder requirements of the battery operations to improve the customer experience throughout the life span of the aircraft, regardless of insourcing/ outsourcing decision.

The subjects were aligned on outsourcing as much as possible to focus on the core business of the company. This means outsourcing all aftermarket activities except battery health monitoring, training, technical support, and technology upgrades. These activities are preferably insourced by Heart or in partnership with the battery supplier since they require close collaboration with the airlines and are strategically important for Heart to engage in. Battery health monitoring was specifically mentioned as a potential service offering that could bring additional revenues to Heart and prolong the battery lifetime for the airlines, improving the customer value. Therefore, it would be strategically important for Heart to insource this activity. Conversely, battery production, logistics, storage and handling, maintenance, refurbishment, and recycling are better outsourced because they are of less strategic importance, require significant investments and new capabilities that Heart is lacking. Building up the logistics network that would be required for global battery operations would be costly and is therefore better handled by a third party that can leverage existing supply chain networks and scale economies.

The risk of outsourcing was further discussed in the interviews. One of the risks that was identified was the Intellectual Property (IP) risk of outsourcing battery production. As the batteries are a strategically important component of the aircraft, outsourcing the battery IP could have negative effects on the possibilities of integrating the technology with the rest of the aircraft. Another risk that was highlighted was the perceived service quality if Heart were to outsource battery aftermarket services. As the ultimate provider of the product, Heart bears the responsibility of ensuring that the outsourcing partner delivers on the service agreement. Consequently, any complaints arising from poor service delivery will ultimately be directed towards Heart. Moreover, the risk of supplier bargaining power was also mentioned as a potential risk factor. If Heart decides to outsource battery production and aftermarket activities, there is a risk of the supplier exploiting its relative bargaining power to negotiate better terms which would have negative consequences on the profitability for Heart.

The short term versus long term perspective was discussed in relation to the insourcing/ outsourcing decision. In the short term, Heart should focus on its core business, signing service agreements with the battery supplier to outsource parts of the aftermarket. In the long term, Heart should consider vertical integration and pursue more activities in-house depending on market potential, relative cost benefits and strategic fit.

4.3.5 Battery second life ownership

This theme relates to the ownership of the batteries once they reach their end of life (EOL) and are either recycled or refurbished to be used in 2nd life applications.

All interviewees shared a similar view that Heart lacks the relevant knowledge and experience to engage in 2nd life ownership of the batteries themselves. The purpose of engaging in 2nd life ownership would be to subsidize first life battery cost for the airline to improve the economics of the aircraft. However, the market for second life battery sales is still immature and building the required capabilities would be complex and require significant investments. Alternatives that were mentioned were to create a joint venture or a strategic partnership with the battery supplier and share the risks, revenues, and costs for setting up the business. If the supplier would be uninterested in such an engagement, establishing a JV or a strategic partnership with an external company with experience in energy storage could also be of interest. In the event that the batteries prove to be too expensive for sale in the energy storage market, having a recycling partner capable of extracting battery minerals and selling them back to the cell manufacturer would prove to be advantageous. This approach would facilitate the creation of a circular business model while simultaneously serving as a hedge against potential supply chain shortages.

4.3.6 Strategic partnership

The strategic partnership theme describes the advantages and risks of establishing a business arrangement between Heart and the battery supplier.

The purpose of establishing a strategic partnership for the battery business is to leverage both companies' combined resources and capabilities in the battery aftermarket to offer a reliable and affordable service for the airlines. Heart would handle the "soft" parts of the operations such as technical support, while the battery supplier would handle the "hard" parts of the business such as logistics and maintenance. One advantage of committing to a partnership is the shortened learning curve that is enabled from leveraging the combined resources and capabilities of both companies. A quicker time-to-market would further be an advantage of the partnership set-up. However, there are several risks of establishing a strategic partnership that need to be considered. First, the partnership would be built on trust between the two parties. If one party does not live up to their responsibility of the business agreement, it can put the whole business at risk. It is therefore important to align incentives between the two companies to avoid potential friction and work toward a common goal.

4.3.7 Heart's relative strengths related to the battery business

This theme discusses Heart's relative strength related to the battery business compared to the airlines and the battery supplier.

Heart strengths lie within the market expertise and technical knowledge for how the batteries are best used to optimize the performance of the aircraft. The batteries will generate large amounts of data which can be used by Heart to consult airlines of how to minimize battery degradation and get better performance of the assets. The airlines lack the technical knowledge of how to handle the batteries and will need support to simplify their operations so they can focus on their core business.

Heart has a distinct advantage over the supplier as they have direct communication with airlines and a deep understanding of their challenges and requirements. This positions them ideally to act as an intermediary, overseeing battery operations and serving as the primary point of contact for airlines. Additionally, Heart is well-suited to provide training services to airlines due to their comprehensive knowledge of airline operations, enabling them to offer valuable insights and guidance.

4.3.8 Preferred business model structure

The theme discusses the preferred business model structure for Heart Aerospace in relation to the batteries and the advantages and disadvantages of different business model set ups.

Each business model comes with its own strengths and weaknesses. The selling business model is simple for Heart to pursue as it is based on battery transactions where services are sold separately. However, this model puts a burden on the airlines to coordinate the battery operations by themselves. Additionally, it creates uncertainty for the airlines where they are risking quicker battery degradation and higher costs than expected. The incentive for Heart would be to sell more batteries, which contradicts the objective of the airlines to reduce the costs of operations.

The leasing model provides a better alternative for the airlines as it relieves stress from the operations and creates more predictability. If Heart were to offer a total-care service program, the battery maintenance, replacement, and upgrades etc. would all be known to the airlines. Preferably, long term contracts are signed with the airlines which makes it possible for Heart to subsidize battery costs initially for recurring revenues later on. Additionally, Heart would be incentivized to prolong the battery health to lower depreciation costs. This aligns well with the airlines' goal of reducing operational costs.

Outsourcing battery operations is a way for Heart to reduce business complexity, minimize risks and have a steady and predictable income from royalties. However, outsourcing all activities presents several risks for the company. One risk is the vendor lock in effects that can be a consequence if Heart were to outsource the entire battery business to the supplier. Long-term contracts with a supplier that do not live up to the expectations of Heart risk negatively affecting the company's reputation and momentum in the market. Moreover, the incentives of the battery supplier would be to sell more batteries to increase revenues which misaligns with the targets of the airlines to minimize

costs of operations. Finally, Heart would lose control of the battery strategy and costs as well as give away a significant share of the aftermarket profit potential to an external part.

All interviewees agreed on the strategic partnership/ JV business model with a power-by-the-cycle leasing structure as the preferred go-to-market option for Heart. In this set-up, Heart and the supplier would share risks, costs and profits and combine their resources and capabilities to offer an affordable and reliable service to the airlines. This would allow Heart to be in control of the battery ecosystem without taking all the risk that comes with it. At the same time, the incentives of Heart and the supplier would be aligned with the goals of the airlines, creating a more functional ecosystem overall.

4.4 Financial Analysis Findings

The findings from the financial analysis include the result from the base scenario presented in the KPIs: NPV, IRR, payback period, cycle cost and cost per month as well as a sensitivity analysis of each business model and the associated risks.

4.4.1 Financial model result

The following Figures present the results from the financial analysis. The result is based on an all-base assumption scenario including a 15-year contract length and a fleet assumption of 10 aircrafts. All KPIs except payback period are presented in relative terms to the Heart Selling business model of confidentiality.

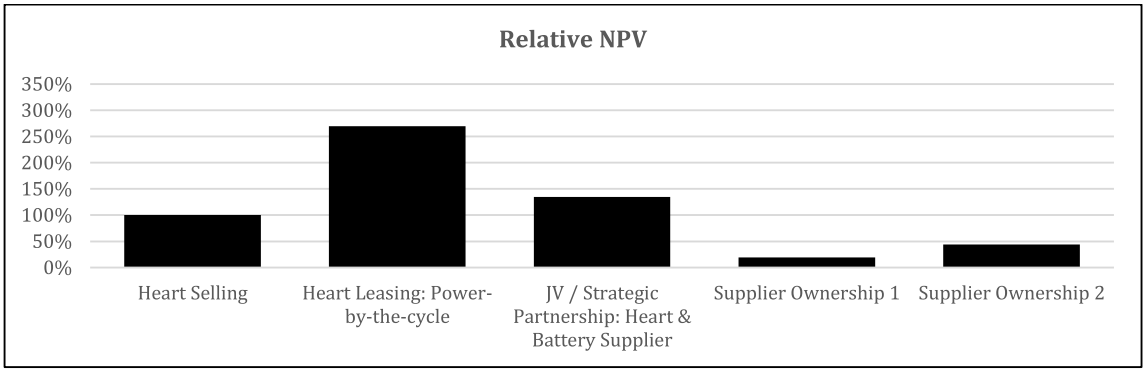

Figure 11 Business model NPV in base scenario

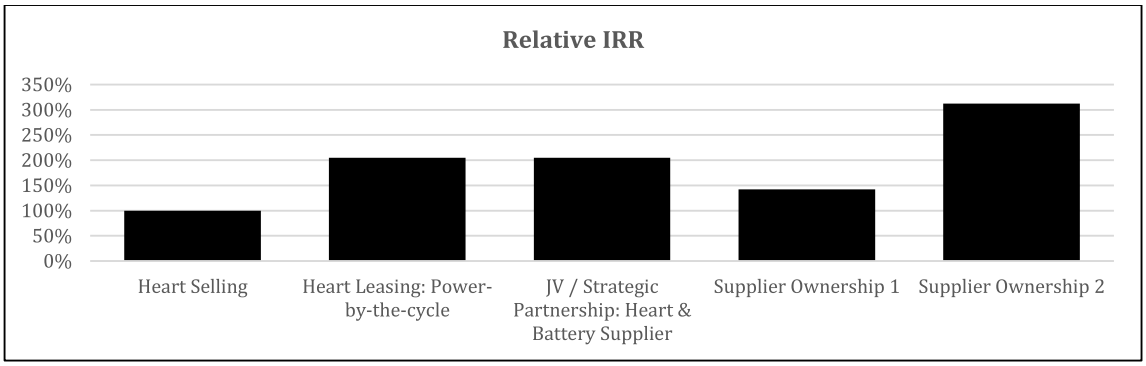

Figure 12: Business model IRR in base scenario

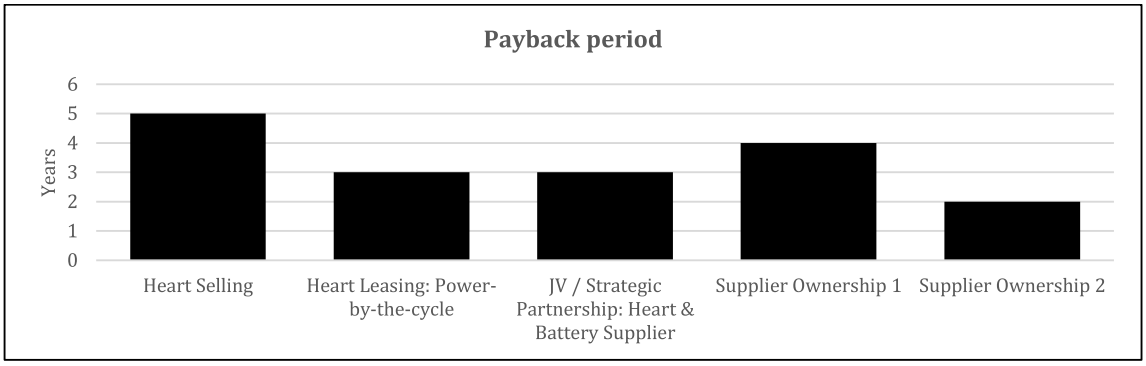

Figure 13: Business model payback period in base scenario

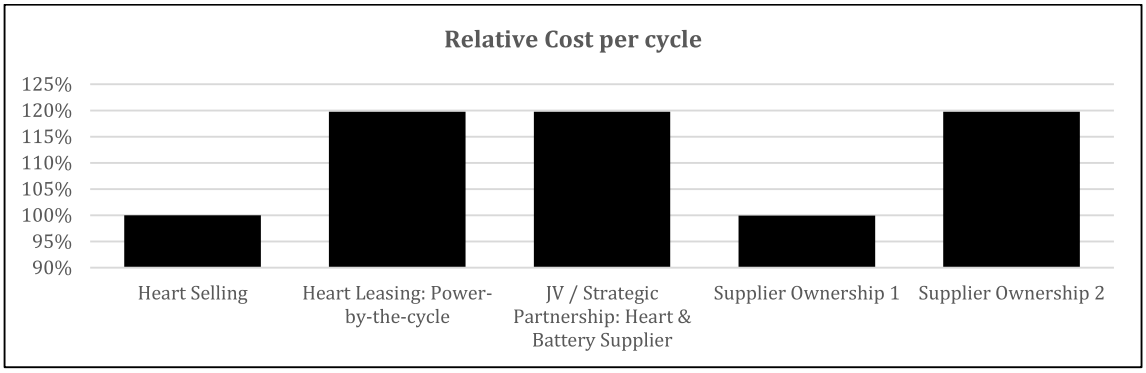

Figure 14: Business model cost per cycle in base scenario

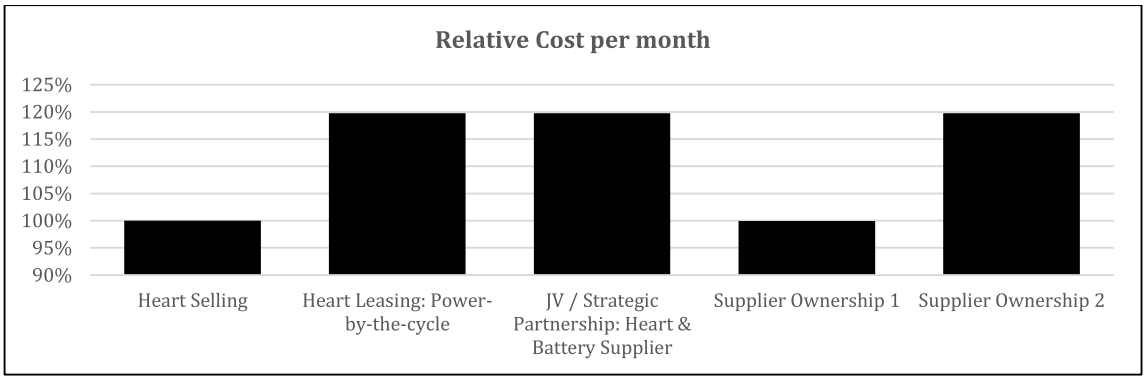

Figure 15: Business model cost per month in base scenario

Selling

Despite having the lowest IRR and highest payback period (5 years) compared to the other business models, the selling model still presents a promising investment opportunity. This model's simplified service offerings make it easier to pursue, although it generates less cash flows than the leasing model.

Leasing

Figure 11 illustrates that the Heart Leasing: Power-by-the-cycle business model has the highest net present value, a high IRR and a short payback period (3 years). This is attributed to several factors, including the higher cost per battery depicted in Figure 14.

The leasing model offers a total-care service program, resulting in a higher monthly cost for the airline (as shown in Figure 15), but it also provides complete coverage of the battery operations.

JV/ Strategic Partnership

The JV/Strategic Partnership business model demonstrates identical results to the leasing model in terms of IRR, payback period, cost per cycle, and cost per month. However, the net present value of this model is only half of the leasing business model due to a similar offering, but with half the cost and revenues resulting from a 50% partnership split between the battery supplier and Heart. The main difference compared to a leveraging strategy through debt are the added capabilities of the Supplier that are present in this model, further described in the discussion section.

Supplier Ownership 1 (selling)

The first Supplier Ownership business model shows a low NPV, and a payback period of 4 years. The cost per cycle as well as the cost per month is the same as the selling business model due to similar pricing.

Supplier Ownership 2 (leasing)

The second Supplier Ownership business model has a higher NPV than the previous model but can be considered low compared to the first three business models. The high IRR is due to a low investment cost and recurring revenues from royalties. The cost per cycle and cost per month is the same as the Leasing and JV/ Strategic Partnership models due to comparable pricing structure.

In summary

All five businesses models show promising results from the financial analysis in terms of NPV, IRR and payback period in the base scenarios. The leasing model presents the highest potential concerning NPV and payback period.

4.4.2 Sensitivity analysis

The financial KPIs depend on several risk and stress test factors that were identified during the financial data collection and pre study phase. Two scenarios; one optimistic and one pessimistic, were used to simulate the effect of each risk in the financial analysis. The risk and stress variables are presented in table X

ID	Risk/ stress variable	Explanation
1	Battery utilization	Higher utilization of the battery leads to a shorter lifetime and higher depreciation
2	Residual value	Residual value of the batteries at EOL
3	Operating margin	The operating margin determine sales price of the batteries and aftermarket services
4	Qualification cost of battery upgrades	The cost of developing the next generation of batteries
5	Battery cycle life	Number of cycles that the battery can handle until EOL
6	Battery cost	Global supply and demand of batteries may influence the cost for Heart
7	Time between battery upgrades	Time between two generations of batteries
8	Business unit set up cost	Building up an organization for the battery aftermarket require a non-recurring investment
9	Fleet size	Number of aircrafts in the contract
10	Contract length	Years of contract

Table 12: Risk and stress variables

The following tables present the high and low scenario effects on the KPIs: NPV, IRR, payback period, cost per cycle and cost per month. The result is calculated as the deviations from the base scenario with all other variables unchanged.

High	Battery cost	Battery cycle life	Battery utilization	Business unit set up cost	Developing and certifying new batteries	Operating margin	Residual value	Time between battery upgrades
Heart Selling	31%	-55%	52%	-31%	-5%	107%	0%	7%
Heart Leasing	-75%	104%	76%	-5%	-2%	0%	40%	3%
JV / Strategic Partnership	-75%	104%	76%	-5%	-2%	0%	40%	3%
Supplier Ownership 1	24%	-33%	41%	1%	-14%	83%	0%	21%
Supplier Ownership 2	-66%	103%	75%	-5%	-6%	0%	41%	9%
Low								
Heart Selling	-32%	78%	-69%	24%	5%	-120%	0%	-13%
Heart Leasing	77%	-175%	-55%	9%	2%	0%	-39%	-6%
JV / Strategic Partnership	77%	-175%	-55%	9%	2%	0%	-39%	-6%
Supplier Ownership 1	-25%	61%	-43%	-2%	14%	-85%	0%	-37%
Supplier Ownership 2	77%	-109%	-53%	5%	6%	0%	-41%	-19%

Table 13: Sensitivity analysis of NPV

High	Battery cost	Battery cycle life	Battery utilization	Business unit set up cost	Developing and certifying new batteries	Operating margin	Residual value	Time between battery upgrades
Heart Selling	20%	-39%	33%	-33%	-8%	68%	0%	15%
Heart Leasing	-60%	128%	110%	-17%	-7%	0%	28%	13%
JV / Strategic Partnership	-60%	128%	110%	-17%	-7%	0%	28%	13%
Supplier Ownership 1	15%	-27%	25%	-5%	-26%	48%	0%	135%
Supplier Ownership 2	-43%	148%	132%	-14%	-28%	0%	33%	171%
Low								
Heart Selling	-21%	50%	-47%	67%	10%	-81%	0%	-20%
Heart Leasing	62%	0%	-36%	23%	8%	0%	-28%	-18%
JV / Strategic Partnership	62%	0%	-36%	23%	8%	0%	-28%	-18%
Supplier Ownership 1	-16%	36%	-33%	2%	61%	-62%	0%	-51%
Supplier Ownership 2	69%	-167%	-31%	16%	71%	0%	-31%	-53%

Table 14: Sensitivity analysis of IRR

High	Battery cost	Battery cycle life	Battery utilization	Business unit set up cost	Developing and certifying new batteries	Operating margin	Residual value	Time between battery upgrades
Heart Selling	0%	40%	-20%	40%	0%	-20%	0%	0%
Heart Leasing	33%	-67%	-67%	0%	0%	0%	-33%	-33%
JV / Strategic Partnership	33%	-67%	-67%	0%	0%	0%	-33%	-33%
Supplier Ownership 1	-25%	25%	-25%	0%	0%	-25%	0%	-50%
Supplier Ownership 2	50%	-50%	-50%	0%	0%	0%	0%	-50%
Low								
Heart Selling	20%	-20%	60%	-20%	0%	120%	0%	20%
Heart Leasing	-33%	0%	0%	-33%	-33%	0%	0%	0%
JV / Strategic Partnership	-33%	0%	0%	-33%	-33%	0%	0%	0%
Supplier Ownership 1	0%	-25%	25%	-25%	-25%	75%	0%	25%
Supplier Ownership 2	-50%	0%	0%	0%	0%	0%	0%	50%

Table 15: Sensitivity analysis of Payback Period

High	Battery cost	Battery cycle life	Battery utilization	Business unit set up cost	Developing and certifying new batteries	Operating margin	Residual value	Time between battery upgrades
Heart Selling	19%	-29%	-1%	0%	0%	9%	0%	0%
Heart Leasing	0%	0%	0%	0%	0%	0%	0%	0%
JV / Strategic Partnership	0%	0%	0%	0%	0%	0%	0%	0%
Supplier Ownership 1	19%	-29%	-1%	0%	0%	9%	0%	0%
Supplier Ownership 2	0%	0%	0%	0%	0%	0%	0%	0%
Low								
Heart Selling	-19%	49%	-5%	0%	0%	-9%	0%	0%
Heart Leasing	0%	0%	0%	0%	0%	0%	0%	0%
JV / Strategic Partnership	0%	0%	0%	0%	0%	0%	0%	0%
Supplier Ownership 1	-19%	49%	-5%	0%	0%	-9%	0%	0%
Supplier Ownership 2	0%	0%	0%	0%	0%	0%	0%	0%

Table 16: Sensitivity analysis of Cost per cycle

High	Battery cost	Battery cycle life	Battery utilization	Business unit set up cost	Developing and certifying new batteries	Operating margin	Residual value	Time between battery upgrades
Heart Selling	19%	-29%	32%	0%	0%	9%	0%	0%
Heart Leasing	0%	0%	33%	0%	0%	0%	0%	0%
JV / Strategic Partnership	0%	0%	33%	0%	0%	0%	0%	0%
Supplier Ownership 1	19%	-29%	32%	0%	0%	9%	0%	0%
Supplier Ownership 2	0%	0%	33%	0%	0%	0%	0%	0%
Low								
Heart Selling	-19%	49%	-36%	0%	0%	-9%	0%	0%
Heart Leasing	0%	0%	-33%	0%	0%	0%	0%	0%
JV / Strategic Partnership	0%	0%	-33%	0%	0%	0%	0%	0%
Supplier Ownership 1	-19%	49%	-36%	0%	0%	-9%	0%	0%
Supplier Ownership 2	0%	0%	-33%	0%	0%	0%	0%	0%

Table 17: Sensitivity analysis of Cost per month

	NPV		IRR (%)		Payback period		Cost per cycle		Cost per month	
Risk	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**
Battery utilization	52%	-69%	33%	-47%	-20%	60%	-1%	-5%	32%	-36%
Residual value	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Operating margin	107%	-120%	68%	-81%	-20%	120%	9%	-9%	9%	-9%
Developing and certifying new batteries	-5%	5%	-8%	10%	0%	0%	0%	0%	0%	0%
Battery cycle life	-55%	78%	-39%	50%	40%	-20%	-29%	49%	-29%	49%
Battery cost	31%	-32%	20%	-21%	0%	20%	19%	-19%	19%	-19%
Time between battery upgrades	7%	-13%	15%	-20%	0%	20%	0%	0%	0%	0%
Business unit set up cost	-31%	24%	-33%	67%	40%	-20%	0%	0%	0%	0%
Fleet size	1226%	-93%	162%	-37%	-60%	40%	-1%	5%	-1%	5%

Table 18: Sensitivity analysis of Selling Business Model

	NPV		IRR (%)		Payback period		Cost per cycle		Cost per month	
Risk	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**
Battery utilization	76%	-55%	110%	-36%	-67%	0%	0%	0%	33%	-33%
Residual value	40%	-39%	28%	-28%	-33%	0%	0%	0%	0%	0%
Operating margin	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Developing and certifying new batteries	-2%	2%	-7%	8%	0%	-33%	0%	0%	0%	0%
Battery cycle life	104%	-175%	128%	0%	-67%	0%	0%	0%	0%	0%
Battery cost	-75%	77%	-60%	62%	33%	-33%	0%	0%	0%	0%
Time between battery upgrades	3%	-6%	13%	-18%	-33%	0%	0%	0%	0%	0%
Business unit set up cost	-5%	9%	-17%	23%	0%	-33%	0%	0%	0%	0%
Fleet size	1074%	-110%	48%	-99%	-33%	367%	0%	0%	0%	0%

Table 19: Sensitivity analysis of Leasing Business Model

	NPV		IRR (%)		Payback period		Cost per cycle		Cost per month	
Risk	High	Low	High	Low	High	Low	High	Low	High	Low
Battery utilization	76%	-55%	110%	-36%	-67%	0%	0%	0%	33%	-33%
Residual value	40%	-39%	28%	-28%	-33%	0%	0%	0%	0%	0%
Operating margin	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Developing and certifying new batteries	-2%	2%	-7%	8%	0%	-33%	0%	0%	0%	0%
Battery cycle life	104%	-175%	128%	0%	-67%	0%	0%	0%	0%	0%
Battery cost	-75%	77%	-60%	62%	33%	-33%	0%	0%	0%	0%
Time between battery upgrades	3%	-6%	13%	-18%	-33%	0%	0%	0%	0%	0%
Business unit set up cost	-5%	9%	-17%	23%	0%	-33%	0%	0%	0%	0%
Fleet size	1074%	-110%	48%	-99%	-33%	367%	0%	0%	0%	0%

Table 20: Sensitivity analysis of IRR

	NPV		IRR (%)		Payback period		Cost per cycle		Cost per month	
Risk	High	Low	High	Low	High	Low	High	Low	High	Low
Battery utilization	41%	-43%	25%	-33%	-25%	25%	-1%	-5%	32%	-36%
Residual value	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Operating margin	83%	-85%	48%	-62%	-25%	75%	9%	-9%	9%	-9%
Developing and certifying new batteries	-14%	14%	-26%	61%	0%	-25%	0%	0%	0%	0%
Battery cycle life	-33%	61%	-27%	36%	25%	-25%	-29%	49%	-29%	49%
Battery cost	24%	-25%	15%	-16%	-25%	0%	19%	-19%	19%	-19%
Time between battery upgrades	21%	-37%	135%	-51%	-50%	25%	0%	0%	0%	0%
Business unit set up cost	1%	-2%	-5%	2%	0%	-25%	0%	0%	0%	0%
Fleet size	816%	-89%	-4%	6%	-25%	-25%	-1%	5%	-1%	5%

Table 21: Sensitivity analysis of Supplier Ownership (selling) Business Model

	NPV		IRR (%)		Payback period		Cost per cycle		Cost per month	
Risk	High	Low	High	Low	High	Low	High	Low	High	Low
Battery utilization	75%	-53%	132%	-31%	-50%	0%	0%	0%	33%	-33%
Residual value	41%	-41%	33%	-31%	0%	0%	0%	0%	0%	0%
Operating margin	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Developing and certifying new batteries	-6%	6%	-28%	71%	0%	0%	0%	0%	0%	0%
Battery cycle life	103%	-109%	148%	-167%	-50%	0%	0%	0%	0%	0%
Battery cost	-66%	77%	-43%	69%	50%	-50%	0%	0%	0%	0%
Time between battery upgrades	9%	-19%	171%	-53%	-50%	50%	0%	0%	0%	0%
Business unit set up cost	-5%	5%	-14%	16%	0%	0%	0%	0%	0%	0%
Fleet size	1004%	-100%	31%	-94%	0%	150%	0%	0%	0%	0%

Table 22: Sensitivity analysis of Supplier Ownership (leasing) Business Model

Comparison between business models

In the following discussion, the results from the sensitivity analysis (table 13 – 22) are commented on in relation to each business model.

Selling Business Model

Variations in *battery utilization* have a significant impact on the NPV, IRR, payback period and cost per month. The low scenario shows a higher effect on these KPIs compared to the high scenario. Cost per cycle is barely affected by variations in battery utilization. The scenarios show no effect on the *residual value*. Furthermore, the variations in *operating margin* are highly affecting the NPV, IRR and payback period with as much as -120% downside in the low scenario and +107% upside in the high scenario on the NPV values. In contrast, the *developing and certifying new batteries* risk show minimal effect on the KPIs. Moreover, scenarios in *battery cycle cost* result in modest effects on the KPIs, with NPV being affected the most (+31% vs -32%). The same is true for *time between battery upgrades*, showing conservative impacts on the NPV, IRR and payback period and no effects on cost per cycle and cost per month. Changes to the *business unit set up cost* demonstrate high impacts on the NPV, IRR and payback period with as high as +67% upside in the high scenario on the IRR values. Cost per cycle and cost per month are not affected by the scenarios. Lastly, *fleet size* is by far the variable that has the highest impact

on the NPV, IRR and payback period with as high as +1226% upside in the high scenario. The variable shows low effects on cost per cycle and cost per month.

Leasing business model

In the leasing model, cost per cycle is not affected by the risk scenarios due to a fixed price per cycle towards the operator. The scenarios in *battery utilization* show high effects on all other KPIs with as high as +110% upside in the high scenario on the IRR. The scenarios of the *residual value, battery cycle life* as well as *battery cost* show considerable impact on the NPV, IRR and payback period, but no effect on the cost per month or the cost per cycle. Among these variables, *battery cycle life* has the highest impact on the NPV with as much as -175% downside in the low scenario and +104% upside in the high scenario. The NPV, IRR and payback period are slightly affected by the scenarios in *developing and certifying new batteries, time between battery upgrades* and *business unit set up costs.* For these variables, the cost per cycle and month are unaffected by the scenarios. Since the revenues depend on a fixed cost per cycle, the scenarios in the *operating margin* are not affecting the KPIs. Like the Selling business model, *fleet size* is the variable that shows the greatest impacts on the KPIs with +1074% in the high scenario and -110% in the low scenario on the NPV values.

Partnership business model

Due to a similar revenue and cost structure as the leasing business model, the partnership business model shows identical results in the sensitivity analysis.

Supplier Ownership 1 (selling) business model

The supplier ownership 1 (selling) business model sensitivity analysis show similar results as the Selling business model in relative terms. The difference is that the scenarios show a slightly lower effect on the KPIs due to the business model set up of Heart receiving royalties from the net profit of the supplier. The only variable that deviates in relative terms from the Selling model is the *time between battery upgrades* variable. The business model set up assumes that Heart and the Supplier split the development and certification cost of new batteries 50/50. Heart takes this cost on the balance sheet and depreciates it for as many years as the variable *time between battery upgrades* is determined to. Since the business model assumes no further costs for Heart in this set up, the variable has a higher effect on the NPV, IRR and payback period KPIs for the Supplier Ownership 1 (selling) business model in comparison to the Selling business model.

Supplier Ownership 2 (leasing) business model

With similar arguments as the previous discussion for the Supplier Ownership 1 (selling) business model, the Supplier Ownership 2 (selling) business model show comparable results as the leasing business model in relative terms. Also here, *time between battery upgrades* present bigger variations of the NPV, IRR and payback period in the different scenarios compared to the leasing model. The variable shows a +171% upside in the high

scenario and -53% downside in the low scenario on the IRR values. Like the leasing model, the cycle cost is fixed, showing zero effect in the scenarios.

5. Discussion

This chapter will include reflections about the different business models presented in the study. These reflections will be grounded on the definitions of business models and analysis of results from industry analysis, internal analysis, and financial analysis. The discussion will make use of theories related to the topics discussed.

5.1 Selling Model

From the results of the internal analysis, it became clear that this model is viewed as a simple model in terms of execution as it requires relatively little investment in terms of resources and infrastructure. By leveraging existing sales channels and customer base, additional services can be offered. From a value capturing point of view (Richardson, 2005), the results of the financial analysis indicate that this model is also a financially viable option. The net present value (NPV), internal rate of return (IRR), and payback period of 5 years in the base scenario suggest that the business model offers a high return on investment and can be recouped within a reasonable timeframe.

The selling business model can provide Heart with the opportunity to focus on its core competencies as an aircraft manufacturer. According to Barney's (1991) resource-based view, a firm's resources and capabilities are critical determinants of its competitive advantage. By leveraging their expertise in aircraft manufacturing, they can choose to develop additional services or outsource them to third-party vendors. Heart could then streamline its operations and enhance its competitive position in the market. By emphasizing its strengths in aircraft design and production with this new propulsion system, Heart can gain a unique market position and differentiate themselves from competitors. The model also allows the option of selling additional services, such as battery health monitoring, that optimize battery health and extend battery life. This classifies as Asset Efficiency Services (AES) in the service typology framework by Ulaga and Reinartz (2011), which refers to the services offered to help customers achieve productivity gains from their invested assets. According to the authors, this can offer potential for competitive differentiation and profit potential due to the added value they provide in improving asset performance.

While the selling business model with potential for selling additional services offers several advantages, it is not without its drawbacks. The most significant drawback is the industry trend of airlines outsourcing non-core services, which is evident in the industry analysis. This trend reflects a broader strategy of focusing on core competencies and outsourcing non-essential services to third-party vendors. As a result, airlines may be less inclined to invest themselves in battery operations and may prefer to outsource this function to specialized providers. This finding is further supported by our interviews with Heart representatives, who indicate that airlines are primarily interested in providing air transportation services to passengers and cargo and are less interested in owning and managing such an uncertain asset. Additionally, the variable and uncertain nature of

battery costs can discourage additional purchases of electric aircraft, as it significantly impacts their overall cost of ownership. Furthermore, an additional challenge associated with the selling business model is the potential for misaligned interests between the OEM and the operator. Since a significant portion of the revenue generated by this model comes from selling new batteries to the operator once the batteries reach the end of their life, the OEM may have an incentive for frequent replacements as a boost of revenue, which would be at the expense of the aircraft customer. To address this issue and align the interests of the OEM and the operator, it is essential to offer additional services such as battery health monitoring. By providing services that extend the life of the batteries, the OEM can shift its revenue focus from selling new batteries to selling services that maintain battery health and optimize their performance. This realignment of interests can improve the long-term relationships between the OEM and the operator, promote customer loyalty, and enhance the overall financial performance of the selling business model. This is in line with what Ulaga and Reinartz (2011) describe with AES offered to help customers achieve productivity gains from their invested assets, which for Heart can offer potential for competitive differentiation and profit potential. This is further strengthened from the finding in the internal analysis where it was mentioned that there is a risk of transferring financial, commercial, and reputational risks back to Heart if the company solely sells batteries without taking ownership or offering asset efficiency services. If the batteries underperform, the operator will bear the financial burden of the related issues, which could lead to commercial risks for Heart. Additionally, any negative experiences with the batteries would damage Heart's reputation in the industry, leading to reputational risks both for the company and ES-30 as an aircraft.

As mentioned, the financial analysis revealed that the model is viable on high-level NPV, IRR, and payback analysis. However, this is mostly true when looked at in isolation. Compared with the leasing model, the NPV is rather low. From the sensitivity analysis we also see that there are high risks from the operating margin and battery utilization. That is if that battery would not have a high utilization rate, making additional sales less frequent, the KPIs change drastically, and you would need a much higher operating margin. As discussed earlier, this could be dealt with by the sales of additional services, but when the ownership of the batteries is with the operator, there is also a risk of them insourcing those from other third-party vendors.

5.2 Leasing Model

The Financial Analysis of the power-by-the-cycle leasing model for Heart's electric aircraft indicates that this business model has impressive results, as it has the highest NPV among the analyzed models. This model also possesses several advantages that align with the drivers of servitization presented by Baines et al (2009). The power-by-the-cycle model offers stable and predictable income for Heart over time, which aligns with the financial driver of servitization. Furthermore, this business model structure allows for long-term contracts leading to lock-in effects which in turn can lead to sustainable competitive advantage (Baines et al., 2009). The low investment costs for the customers

align with the economic driver of servitization. Furthermore, this model offers customers the flexibility to adjust the number of aircraft and associated batteries based on their operational requirements, which aligns with the customization driver of servitization. The internal analysis considered the strategic advantage of subsidizing battery costs in the early stages to promote the adoption of the ES-30 hybrid-electric aircraft. This approach aligns with Baines et al.'s (2009) assertion that servitization can be leveraged to strategically increase the sale of the core product. The industry analysis revealed that aftermarket service firms in commercial aviation enjoy high profit margins. Moreover, the trend towards outsourcing in the airline industry, which was also identified both in the industry analysis and in the internal interviews, suggests that airlines prefer to focus on their core business of flying passengers. The industry analysis also highlighted the commonality of operating leases as a component of airlines' capital structure. This further supports the potential value of leasing programs by offering a performance-based solution to the customer, as explained by Ulaga and Reinartz (2011) in their service typology framework. In this model, Heart would offer the solution of "up-time" where airlines pay a predictable fee for each discharge of the batteries for a trip. Ulaga and Reinartz (2011) discuss how solution offerings lead to closer collaboration and stronger relationships between companies and their customers. By offering ongoing support and service, Heart can build trust and loyalty with airlines, allowing airlines to focus on operational up-time of the aircraft, which can lead to increased customer retention and referrals. Furthermore, Baines et al. (2009) mention that drivers of servitization allow the customer to get access to the latest technology. In this case, this would mean that airlines would get access to improved batteries as soon as they are available which would further improve the operational capability of the aircraft.

Although the leasing model exhibits the highest NPV, it is not without its limitations. The model entails taking on the responsibility for the entire battery aftermarket, requiring substantial investment costs and a significant focus on developing this aspect of the business. This may not align with the core business and competencies of the company, which is aircraft manufacturing. Consequently, it deviates from the perspective put forth by Barney (1991), which emphasizes the importance of concentrating on core business activities and competencies. Furthermore, managing more parts of the value-chain inherently increases the risk due to higher complexity. The sensitivity analysis showed that the leasing model is highly sensitive to variables such as battery cost, utilization, cycle life, and residual value. Therefore, it is crucial to set appropriate pricing to avoid the possibility of incurring significant losses. The internal analysis also identified the risk of setting a cycle price on an extensive solution offering with many uncertainties, where it was described as two scenarios where they either win or lose depending on pricing. Therefore, battery health monitoring, utilizing big data, assumes a critical role in the assessment and management of aircraft batteries. Through monitoring of battery health, valuable insights can be gained regarding the influence of various operational factors and customer profiles on battery lifespan. These insights enable the optimization of battery cycle life for the 80% SOH and act as a basis for setting the cycle price. This is similar to

the selling business model but with different motivation. In the leasing model the risk is at the OEM and the inclusion of these services are necessary from an operational and economic viewpoint, whereas in the selling model stems from aligning interests as the effects of battery degradation is owned by the operator.

The leasing model also introduces a challenge of misaligned incentives, in this case between Heart and their battery supplier. As the battery packs are outsourced rather than produced internally, the leasing model can create misalignment between these entities. Heart aims to subsidize costs and enhance battery efficiency to ensure that the aircraft becomes a valuable and appreciable asset for customers. However, the revenue source for the supplier is dependent on battery sales to Heart, leading to weak incentives to keep costs low and maximize efficiency. This issue assumes significance given the limited competition among suppliers and the diminished impact of switching suppliers due to the supplier's high bargaining power.

Lastly, offering service solutions presents inherent challenges, as discussed by Ulaga and Reinartz (2011). One challenge is the financial aspect, including potentially higher capital requirements. This can pose difficulties for a company like Heart, heavily reliant on external capital investments. Moreover, there is the risk of not meeting customer performance expectations, which can adversely impact Heart's overall reputation. Additionally, Gebauer et al. (2011) highlights the profitability challenges faced by firms that offer both products and services, such as Heart with their aircraft. In practice, the implementation of solution strategies does not always guarantee success. Firms may encounter the service paradox, whereby manufacturers fail to realize the expected benefits from their initial investments in transitioning to service-oriented models. These challenges underscore the complexity and uncertainties involved in the adoption and execution of solution strategies. Heart must carefully evaluate the financial requirements, manage customer expectations, and address profitability concerns to navigate these potential obstacles and achieve sustainable success with this model.

Heart Aerospace's leasing options provide them with ownership of the batteries following replacements, which presents an advantageous opportunity considering the expanding market for second-life batteries (Marthaler et al., 2022). By subsidizing the battery costs through this approach, Heart can promote wider adoption of their aircraft. However, it is important to recognize the associated risk, as there is an assumption that a portion of the battery investment can be recovered through resale or repurposing.

5.3 Strategic Partnership

Establishing a strategic partnership between Heart Aerospace and the Battery Supplier prove major advantages for all parties in the service triad by enabling collaboration, shared expertise, and mutual growth opportunities (Wynstra et al., 2015). While the value proposition is similar to the leasing business model with the power-by-the-cycle leasing program, the value delivery and value capture system (Richardson, 2005) differ to the

model. By combining both companies' resources and capabilities, Heart could focus on building its core business within battery system integration, health monitoring, training and customer service while leveraging on the Battery Manufacturer's resources and capabilities within battery operations including logistics, warehousing, and maintenance. This collaboration enables Heart to offer an even more competitive value proposition compared to the leasing business model, with additional benefits from the service structure.

From the internal analysis it was found that a strategic partnership would lower the financial, reputational, and commercial risk for Heart's battery business. Similar findings can be concluded from the financial risk analysis whereby sharing the risks with the Supplier, Heart would decrease its exposure to market uncertainties and external forces, potentially reducing the profitability of the business. In comparison to the two Supplier ownership business models, Heart would maintain strategic control over the battery business, allowing for better oversight of airline operations, fostering stronger customer relationships. Moreover, by combining both companies' resources and capabilities, Heart would not have to build up all the required capabilities of the battery business itself, leading to a faster learning curve and reduced time-to-market. A quicker execution would enable Heart to secure a first mover advantage in the emerging market for aerospace batteries. Establishing a strategic partnership is further supported by Van Wheele (2010) who argues that the firm can benefit from lower costs when engaging in a strategic partnership for strategically important services impacted by supply risks. Other benefits of the business model are the aligned incentives between the companies in the service triad. Since Heart and the Battery Supplier would share the battery business, they would both strive to reduce the cost of operation to offer more competitive pricing to the airlines while sustaining a desirable return on investment (ROI). The partnership model builds on the value proposition of the power-by-the-cycle leasing model which incentivizes Heart and the Battery Supplier to extend the lifetime of the batteries. This aligns closely with the objective of the airlines; to increase the aircraft uptime and reduce the costs of operations. Regarding the 2nd life battery ownership, a strategic partnership facilitates comprehensive involvement across the aerospace value chain, fostering knowledge transfer, operational efficiency, and innovative solutions throughout the battery lifecycle.

In addition to the internal analysis findings, proving the strategic partnership to be a desirable option, the financial analysis shows impressive results in comparison to the Selling model and the Supplier Ownership models. Although the NPV is only half of the Leasing model, assuming a 50% cost and revenue split, the benefits of sharing the risks with the Battery Supplier should be considered.

Despite the evident advantages for Heart, the partnership business model also entails certain challenges that require attention. In addition to the drawbacks of servitization, it became apparent in the internal analysis that the partnership will be reliant on maintaining a strong foundation of trust between the two parties, influencing the success

of the battery business. By aligning incentives in the partnership, the trust between Heart and the Supplier can be improved, leading to a more functional relationship where both parties are working towards the same goals. Another disadvantage of the Partnership business model is the risk of single sourcing, leading to the Battery Supplier exploiting bargaining power to negotiate better terms in the agreement. This could be a consequence of both low competition and relative size differences between the two companies. Finally, establishing a strategic partnership would mean that Heart would have to share the profit from the aftermarket with the Battery Supplier. The loss from the partnership split should be compared to the additional costs and risks of the leasing model, where Heart assumes 100% ownership of the aftermarket.

5.4 Supplier Ownership

In the supplier ownership models, wherein the supplier leases or sells batteries to the operator and Heart receives a royalty for the business opportunity, there exist slight variations in the value creation and value delivery systems towards the customer. However, the value capturing system (Richardson, 2005) for Heart remains similar. Both the business model definitions and the internal analysis reveal that by not engaging in aftermarket activities, Heart effectively mitigates financial risk, reduces complexity, and aligns with the principles of Barney (1991) by concentrating on its core business. In this arrangement, the responsibility is shifted to the supplier, resulting in minimal costs for Heart and no necessity to develop new capabilities. The financial analysis indicates a relatively low NPV in this business model due to a low cut from the aftermarket business in terms of royalties. The minimal costs for Heart conversely contribute to a high IRR. While there is potential for profitability in this model, its primary advantages lie in risk transfer and a focused approach on aircraft sales. A notable advantage of the leasing configuration of the two supplier ownership models is its alignment with one of the advantages of servitization highlighted by Baines et al. (2009), namely the predictability of recurring revenues through royalties. However, for both configurations, by leveraging this supplier ownership model, Heart can capitalize on these advantages while minimizing financial commitments and strengthening its core competencies.

All these advantages come at a cost. As Heart sells the actual aircraft where the batteries, managed by the supplier, are installed, there is a consequential transfer of financial, commercial, and reputational risk back to Heart in the event of underperforming batteries. Given this ownership responsibility, any negative outcomes or shortcomings pertaining to the battery performance can directly impact Heart's financial stability, commercial viability, and overall reputation.

The internal analysis reveals that representatives from Heart express concerns regarding the potential loss of control over the battery strategy and associated costs. Furthermore, the loss of big data from airline battery utilizations will have a negative impact on Heart’s market knowledge. This is especially evident considering that Rolls-Royce’s power-by-the-hour model was a success due to their ability to price their contract based on actual

in-service performance data. Heart's value proposition includes operational cost advantages over competitors and the expectation that the asset performance will improve over time. If the supplier were to solely sell the batteries, it would result in a misalignment of interests, as their revenue would be driven by frequent sales rather than optimizing operational cost efficiencies. Consequently, a preferred approach would be a leasing contract between the operator and the battery supplier, which could help maintain alignment of interest between the parties. However, such an arrangement may lead to a loss of valuable data for Heart from the battery operations during service since this part is outsourced. Furthermore, there is an inherent risk of forgoing aftermarket revenues, as indicated by the industry analysis, which highlights the high profit margins for aftermarket actors.

Another important challenge to consider in this business model is the risk of supply chain disintermediation which refers to the removal or elimination of intermediaries or middlemen in the supply chain process (Wynstra et al., 2015). This is not entirely true for Heart as they are the producer of the aircraft and has a say in who puts batteries in it, but it relates more to the strong bargaining power that a supplier may gain in this triadic relation as a result of difficulties in sourcing batteries to the aircraft from another actor once they are installed.

5.5 Synthesis

It has been identified that all business models, except for Strategic Partnerships/Joint Venture, possess the risk of misaligned incentives. This misalignment can occur between the actors in the service triad, which Wynstra et al. (2015) mentions as a risk in service supply chain. Specifically, misalignment arises due to the conflict between battery life and revenue generated from battery sales. If Heart were to adopt any of these business models, it becomes crucial to emphasize robust contracting strategies to mitigate the risks associated with unaligned incentives. By focusing on contracting, Heart can establish agreements and frameworks that address conflicting interests between different stakeholders. To ensure the alignment of goals and objectives among all stakeholders, the proposed contractual arrangements seek to prioritize long-lasting battery life and additional services over short-term revenue gains from battery sales. These clauses are designed to incentivize the company's core operations, suppliers, and end customers towards a sustainable and customer-centric approach. The incorporation of such contractual provisions aligns with the insights provided by Gellings and Wüllenweber (2006), who emphasize the importance of efficient risk mitigation through contracting in service outsourcing.

Having analyzed the business models, it is apparent that each model has its own strengths and weaknesses. However, a critical factor in achieving long-term strategic goals, as observed in the case company internal analysis, lies in strategic control over batteries. As an electric aircraft OEM, Heart bears the responsibility for the performance of the aircraft. This underscores the significance of having control over costs, battery upgrades, and the

successful adoption of the aircraft. Furthermore, the strategic control of batteries becomes increasingly critical as the market evolves. The operational knowledge and expertise in batteries can become a core competence and a core business for Heart as the market progresses. This development can lead to the creation of valuable, rare, inimitable, and organized resources or capabilities, aligning with Barney (1997) that such factors contribute to sustainable competitive advantage. This strategic control is only available with ownership of batteries and aftermarket activities in the leasing or strategic partnership / JV business models.

A common theme identified in the leasing, strategic partnership / JV, and with the supplier ownership model with leasing configuration, is that the value proposition of the business model described by Richardson (2005) aligns with both the industry analysis and the internal analysis of airlines wanting to focus on their core business. Furthermore, these models align with Ulaga and Reinartz (2011) description of solutions that offers services that meets specific needs of individual customers, and which entail the service provider assuming responsibility for the performance and operation of the customer's processes, allowing the airlines to focus on flying passengers.

Considering the uncertainty of the emerging aerospace battery industry, it is important to minimize risks when choosing between different go-to-market strategies. Among various business models, the JV/Strategic Partnership model emerges as a strong option, considering a combination of factors such as net present value (NPV), internal rate of return (IRR), risk sharing, and the retention of strategic oversight over battery costs and upgrade schedules. This model provides a balanced mix of financial viability and strategic control.

If Heart chooses to pursue the JV/ Partnership business model, the decision must be made whether to enter into a contract agreement with the Supplier in case of a strategic partnership or create of a joint venture to separate the battery business from the rest of the organization. Olivia et al. (2012) argues for separating the service organization from the product business because it can enhance customer experience, foster a service culture, and increase management commitment. While it is technically possible to a certain degree separate the battery business from the manufacturing organization in a strategic partnership set up, the join-venture option facilitates a clearer separation with profit and loss responsibility. The joint venture would operate as a separate legal entity, transferring the risk from Heart to the battery organization.

Finally, developing a new service offering is preferably done in collaboration with the customers in accordance with Tukker (2014). Having a customer-centric approach increases the customer satisfaction and loyalty, enables deeper insights and innovation, and reduces risk by aligning customer needs with the service value proposition. Consequently, Heart should develop the leasing: power-by-the-cycle service offering

together with the airlines to strengthen the customer-provider relationship and increase the chances of success.

It is also crucial to evaluate the primary assumptions underlying the findings. Numerous key assumptions and uncertainties necessitate further investigation, which Heart should prioritize. Initially, it is vital to validate and refine the financial model to ensure the reliability of the results, avoiding the "garbage in, garbage out" scenario. Additionally, conducting further financial investigations is necessary to enhance the accuracy and dependability of the model. One possible approach is utilizing Monte Carlo simulations, accounting for uncertainty and variability in crucial parameters.

Furthermore, validating the assumption of subsidizing high battery costs is crucial and may require further investigation into potential avenues for offsetting these costs. One potential approach is exploring second-life applications for batteries, repurposing them for other uses after they are no longer suitable for electric aircraft but still possess energy storage capacity. Another potential avenue to investigate is the recovery of valuable materials from 1st life batteries to reduce costs of new batteries.

While independent research is essential to validate assumptions, it should be acknowledged that the supplier possesses granular data on battery operation costs and expertise in refurbishment and repurposing batteries. Therefore, it can be argued that the JV/Strategic Partnership model facilitates comprehensive insights and enables in-depth investigations into both the financial assumptions and possibilities for subsidizing high costs.

6. Conclusion

The aim of this master thesis report was to thoroughly analyze various business models for aerospace batteries and evaluate their compatibility with Heart's long-term strategy, risk tolerance, market fit, and financial implications. Specifically, the investigation set out to answer the following main research question: *What business model for aerospace batteries is most suited for a new entrant in the commercial aerospace industry?* With the help of two sub-questions: *What activities and costs are introduced in the industry as a consequence of electrification? What are the strategic & financial implications of aerospace battery business models?* To fulfill this aim, the research commenced with a comprehensive analysis of the defined business models agreed upon by the researchers and the case company. This involved identifying the costs, activities, and relevant stakeholders associated with the electrification of aviation. Subsequently, an assessment was conducted to evaluate the responsibility of costs and activities across different business models. When these were defined, a three-part analysis was employed. Firstly, an industry analysis was conducted to gain insights into the broader market dynamics and trends related to aerospace batteries. Secondly, an internal analysis was performed to evaluate the alignment of the case company's long-term strategy and capabilities with the identified business models. Finally, a financial analysis was undertaken to assess the economic viability, risk implications and potential outcomes of each model.

Findings from the industry analysis showed that airlines are prone to outsourcing services and want to focus on their core business. It also showed that aftermarket activities, and more specifically MRO activities show trends of high profitability. These findings align with the internal analysis, which emphasizes the importance for airlines to streamline operations, prioritize aircraft uptime, and allow Heart to strategically participate in the aircraft aftermarket for both control and financial benefits.

Additionally, the financial analysis further validated the profitability potential identified in the industry analysis and supported the internal analysis's indication of respondents' interest in participating in the aftermarket. It revealed a strong correlation between higher financial returns and downstream vertical integration within the battery aftermarket.

In general, all models have their respective advantages, but a main drawback of the selling model was the unalignment of Heart and the Airlines, as it was showed that airlines had limited interest in ownership of batteries. A main drawback of the supplier ownership model was unalignment between the supplier, Heart, and the airlines in relation to battery life and revenue generated from frequency of battery sales and replacements, with the addition of reputational risk for the aircraft if batteries underperform. The main drawback of the leasing model was identified to be the difficulty in pricing and the financial risk if it was done incorrectly. Lastly, the strategic partnership / JV had the strongest mix of NPV, IRR, risk sharing and retention of strategic oversight of battery costs and battery upgrade schedule. The main challenge in this model was deemed to be

structurally, where a JV was viewed most appropriate considering the benefits of service and product separation, in alignment with Oliva et al. (2012).

The literature supports the development of a leasing structure, allowing the airlines to fully focus on their core business by outsourcing the battery operations. Reviewing the industry key success factors (Grant, 2021), it is evident that in order to succeed in the commercial aerospace industry, Heart must have a value proposition that offers low and predictable operational costs for the airlines. Additionally, it is critical that Heart maintains strategic control of the battery aftermarket as it may become an important capability when the market evolves. As the commercialization of electric aircraft progresses, competition is expected to intensify. To withstand this increased competition, Heart needs to develop capabilities that are valuable, rare, difficult to imitate, and well-organized in order to attain a sustainable competitive advantage (Barney, 1997). By establishing the battery aftermarket as a core capability, Heart can strategically align its capabilities with the industry's key success factors, thereby attaining a sustainable competitive advantage.

The literature's contribution on the drivers of servitization further supports the development of a leasing value proposition. Baines et al. (2009) argue for both strategic, financial, and marketing drivers that benefit both the OEM and the customers. Heart has the opportunity to develop a service offering that either improves the commercial viability of the business in a defensive strategy or seeks improved growth, adopting a more offensive approach (Baines et al., 2009). Despite clear advantages from servitization, Heart must carefully manage the risks of developing the battery business as a service offering. These include organizational structure, development process, customer management and risk management. Separating the service business from the organization can prove advantageous to mitigate some of the challenges that arise (Oliva et al., 2012). Additionally, co-creating the service together with the airlines and having a customer-centric approach reduces the risk for failure and facilitates the adoption of electric aircrafts.

There are several improvements that could have enhanced the quality and reliability of the study's results. Firstly, it would be advantageous to include representatives from suppliers and airlines in the internal analysis interviews to comprehensively explore aspects related to outsourcing and airline perspectives, thereby enhancing the quality of the collected data. Further research could involve a deeper investigation into second-life applications of batteries to refine the financial analysis, as well as placing greater emphasis on acquiring more reliable data inputs to strengthen the analysis. Additionally, integrating an analysis of supply and demand dynamics for crucial battery materials, along with exploring the potential of introducing circular business models and their associated benefits for mitigating future risks, would add value to the overall business model analysis. Lastly, for further research, expanding the scope to encompass a broader range of models and configurations, and utilizing a more granular examination such as

the business model canvas framework, would provide a more detailed and comprehensive analysis.

In conclusion, this project has made valuable contributions towards enhancing our understanding of the introduction of batteries in the commercial aviation sector and the implications associated with various business models for new entrants in this industry. In addition, the insights gained from this project have the potential to benefit future scholars in the fields of strategic management and service management, providing a foundation for further research and exploration in this area.

7. References

Alfredsson, H. (2023). *Future airports can become energy hubs*. Retrieved from https://www.ri.se/en/our-stories/future-airports-can-become-energy-hubs

Baines, T. S., Lightfoot, H. W., Benedettini, O., & Kay, J. M. (2009). *The servitization of manufacturing: A review of literature and reflection on future challenges*. Journal of manufacturing technology management, 20(5), 547-567. https://doi.org/10.1108/17410380910960984

Barney, J. (1991). *Firm resources and sustained competitive advantage*. Journal of management, 17(1), 99-120. https://doi.org/10.1177/014920639101700108

Barney, J. B. (1997). *Gaining and sustaining competitive advantage*.
Barzkar, A., & Ghassemi, M. (2020). Electric power systems in more and all electric aircraft: A review. Ieee Access, 8, 169314-169332. https://doi.org/10.1109/ACCESS.2020.3024168

Christensen, C., Raynor, M. E., & McDonald, R. (2013). *Disruptive innovation*. Brighton, MA, USA: Harvard Business Review.

Cox, J., Harris, T., Krah, K., Morris, J., Li, X., & Cary, S. (2023). *Impacts of Regional Air Mobility and Electrified Aircraft on Local Grid Infrastructure and Airport Electricity Demand* (No. NREL/TP-5R00-84176). National Renewable Energy Lab.(NREL), Golden, CO (United States). https://doi.org/10.2172/1923874

Damiano, A., Porru, M., Salimbeni, A., Serpi, A., Castiglia, V., Di Tommaso, A. O., ... & Schettino, G. (2018, October). *Batteries for aerospace: a brief review*. In 2018 AEIT International Annual Conference (pp. 1-6). https://doi.org/10.23919/AEIT.2018.8577355

Doctor, F., Budd, T., Williams, P. D., Prescott, M., & Iqbal, R. (2022). *Modelling the effect of electric aircraft on airport operations and infrastructure*. Technological Forecasting and Social Change, 177, 121553. https://doi.org/10.1016/j.techfore.2022.121553

Easterby-Smith, M., Jaspersen, L. J., Thorpe, R., & Valizade, D. (2021). *Management and business research.* Sage.

Edström, K., Dominko, R., Fichtner, M., Perraud, S., Punckt, C., Asinari, P., ... & Weil, M. (2020). *Inventing the Sustainable Batteries of the Future*. Battery, 2030, 60-61.

Feng, C., Jiang, L., Ma, R., & Bai, C. (2021*). Servitization strategy, manufacturing organizations and firm performance: a theoretical framework*. Journal of Business & Industrial Marketing, 36(10), 1909-1928. https://doi.org/10.1108/JBIM-04-2020-0184

Gebauer, H., Gustafsson, A., & Witell, L. (2011). *Competitive advantage through service differentiation by manufacturing companies*. Journal of Business Research, 64(12), 1270–1280. https://doi.org/10.1016/j.jbusres.2011.01.015

Gellings, C., & Wüllenweber, K. (2006). The Impact of Contract Design on Outsourcing Success: Case Studies on Risk Mitigation Measures.

Grant, R. M. (2021). *Contemporary strategy analysis*. John Wiley & Sons.

Grönroos, C. (2007). ¨ *Service management and marketing: customer management in service competition*. John Wiley & Sons.

Guest, G., MacQueen, K. M., & Namey, E. E. (2011). *Applied thematic analysis.* sage publications.

Hamel, G., & Prahalad, C. K. (1990). *The core competence of the corporation*. Harvard business review, 68(3), 79-91. https://doi.org/10.1016/0148-2963(94)00060-R

IER, April 2022*, Electric Vehicle Battery Costs Soar*. Institute For Energy Research, Online, Retrieved 2023-02-24, From https://www.instituteforenergyresearch.org/renewable/electric-vehicle-battery-costs-soar/

Kastalli, I.V., Looy, B.V. and Neely, A. (2013), "*Steering manufacturing firms towards service business model innovation*", California Management Review, Vol. 56 No. 1, pp. 100-123. https://doi.org/10.1525/cmr.2013.56.1.100

Kinnison, H. A. (2013). *Aviation maintenance management*. McGraw-Hill Education.

Kowalkowski, C., Gebauer, H., Kamp, B., & Parry, G. (2017). *Servitization and deservitization: Overview, concepts, and definitions*. Industrial Marketing Management, 60, 4-10. https://doi.org/10.1016/j.indmarman.2016.12.007

Laurent, A. (2021). *Project GENESIS–Gauging the environmental sustainability of electric and hybrid aircraft*. In 11th EASN International Conference on Innovation in Aviation & Space to the Satisfaction of the European Citizens.

Lewandowski, M. (2016). *Designing the business models for circular economy—Towards the conceptual framework*. Sustainability, 8(1), 43. https://doi.org/10.3390/su8010043

Marthaler, L., Grudzien, P., Buysse, M., Ierides, M., Mccready, A., (2022). *Key technical, policy and market developments influencing the electric vehicle battery landscape*. Cobra Market Intelligence Report. Retrieved from: https://projectcobra.eu/wp-content/uploads/2022/10/Market-Intelligence-Report-October-2022.pdf

Mission Possible Partnership. (2022). *Aviation Transition Strategy*. Energy Transitions Commission, RMI, We Mean Business Coalition, World Economic Forum. Retrieved from: https://www.energy-transitions.org/publications/making-net-zero-aviation-possible/

Müller, R. (2021). *Authorities and regulations in aviation*. Aviation Systems: Management of the Integrated Aviation Value Chain, 303-333.

Oliva, R., Gebauer, H., & Brann, J. M. (2012). *Separate or integrate? Assessing the impact of separation between product and service business on service performance in product manufacturing firms*. Journal of Business-to-Business Marketing, 19(4), 309-334. https://doi.org/10.1080/1051712X.2012.647797

Ponomarev, I., (2022). *Meet the main electric planes companies*. Windy App. Online. Retrieved from: https://windy.app/blog/electric-planes-companies.html

Porter, M. (1980) *Competitive Advantage: Creating and Sustaining Superior Performance; and Competitive Strategy: Techniques for Analyzing Industries and Competitors*. Free Press, New York.

Porter, M. E. (1985). *Technology and competitive advantage*. Journal of business strategy, 5(3), 60-78. https://doi.org/10.1108/eb039075

Porter, M. E. 2001. *Strategy and the internet*. Harvard Business Review, 79(3): 62-78. Rappa, M. 2001.

Richardson, J. E. (2005). *The business model: an integrative framework for strategy execution.* https://dx.doi.org/10.2139/ssrn.932998

Roland B,. (2022). *The value chain in the field of tension between economy and ecology.* Battery Monitor. Retrieved from: https://www.rolandberger.com/en/Insights/Publications/Battery-Monitor-2022-Technology-and-sustainability-in-the-battery-market.html

Schwab, A., Thomas, A., Bennett, J., Robertson, E., & Cary, S. (2021). *Electrification of Aircraft: Challenges, Barriers, and Potential Impacts* (No. NREL/TP-6A20-80220). National Renewable Energy Lab.(NREL), Golden, CO (United States). https://doi.org/10.2172/1827628

Smith, D. J. (2013). *Power-by-the-hour: the role of technology in reshaping business strategy at Rolls-Royce*. Technology analysis & strategic management, 25(8), 987-1007. https://doi.org/10.1080/09537325.2013.823147

Spring, M., & Araujo, L. (2009). *Service, services and products: rethinking operations strategy*. International Journal of Operations & Production Management, 29(5), 444–467. https://doi.org/10.1108/01443570910953586

Strube, G., Eloot, K., Griessmann, N., Dhawan, R., & Ramaswamy, S. (2017). *Trends in the commercial aerospace industry*. *Supply Chain Integration Challenges in Commercial Aerospace: A Comprehensive Perspective on the Aviation Value Chain*, 141-159. https://doi.org/10.1007/978-3-319-46155-7_10

Sun, X., Wandelt, S., & Zhang, A. (2022). *STARTUPS: Founding airlines during COVID-19-A hopeless endeavor or an ample opportunity for a better aviation system*? Transport Policy, 118, 10-19. https://doi.org/10.1016/j.tranpol.2022.01.013

Tukker, A. (2004). *Eight types of product – service system: eight ways to sustainability? Experiences from SusProNet*. Business strategy and the environment, 13(4), 246–260. https://doi.org/10.1002/bse.414

Ulaga, W., & Reinartz, W. J. (2011). *Hybrid Offerings: How Manufacturing Firms Combine Goods and Services Successfully*. Journal of Marketing, 75(6), 5–23. https://doi.org/10.1509/jm.09.0395

Ungurean, L., Cârstoiu, G., Micea, M. V., & Groza, V. (2017). *Battery state of health estimation: a structured review of models, methods and commercial devices*. International Journal of Energy Research, 41(2), 151-181. https://doi.org/10.1002/er.3598

Van Weele, A.J. (2010). *Purchasing and Supply Chain Management: Analysis, Strategy, Planning and Practice*, Fifth Edition. Hampshire: Cengage Learning

Weston, G., Schulte, A., Gerow, D., Kurganov, Y., Khomenko., R. (2023). *Air Travel Forecast to 2030: The Recovery and the Carbon Challenge*. Bain. Retrieved from: https://www.bain.com/insights/air-travel-forecast-interactive/

Wise, R., & Baumgartner, P. (1999). *Go Downstream: The New Profit Imperative in Manufacturing*. Harvard Business Review, 77(5), 133–141.

Wynstra, F., Spring, M., & Schoenherr, T. (2015). *Service triads: A research agenda for buyer–supplier–customer triads in business services*. Journal of operations management, 35, 1-20. https://doi.org/10.1016/j.jom.2014.10.002

Zhao, Y., Pohl, O., Bhatt, A. I., Collis, G. E., Mahon, P. J., Rüther, T., & Hollenkamp, A. F. (2021). *A Review on Battery Market Trends, Second-Life Reuse, and Recycling*. Sustainable Chemistry, 2(1), 167–205. MDPI AG. https://doi.org/10.3390/suschem2010011

Zott, C., Amit, R., & Massa, L. (2011). *The business model: recent developments and future research*. Journal of management, 37(4), 1019-1042. https://doi.org/10.1177/0149206311406265

8. Appendix

8.1 Interview Guide

Questionnaire Guide for Heart Aerospace		
Area Of Interest	**Main Questions**	**Sub Questions**
Long Term Strategy	What is your understanding of Heart's long-term strategy to compete in the aerospace industry?	Where do you see Heart in 20 years from now?
		What is the differentiation strategy?
		What is the value proposition?
		What are the key capabilities?
	What will be the key challenges competing in the aerospace industry?	What are the financial challenges?
		What are the challenges related to capabilities needed?
		What are the regulatory challenges?
Battery Business	Is the battery operations business of strategic importance to Heart?	Short term?
		Long term?
	What part(s) of the battery business should Heart engage in by their own and why?	Do you think developing battery business in-house is the best option for Heart?
		Should Heart be involved in the ownership of the batteries?
		What risks do you see?
	What part(s) of the battery business would benefit from outsourcing and why?	Do you think outsourcing is the best option for Heart?
		What risks do you see?
	What part(s) of the battery business would benefit from a strategic partnership and why?	Do you think developing a strategic partnership is the best option for Heart?
		What risks do you see?
	What are Heart's relative strengths related to the battery business compared to the Airlines and the Battery Supplier?	

Business models	Given the option of outsourcing, owning or sharing the battery business, what model fits best with Heart?	Owning, partnership or outsourcing?

8.2 Thematic Analysis

Theme 1: Long term strategy and value proposition		
ID	**Illustrative Example**	**Code**
5	"Our vision is to bring affordable, sustainable, accessible products to the air transport section"	Vision of Heart
2	"And our value proposition basically is basically based on three things (…) So environmental factors is one thing, and cost efficient	Sustainable aviation
2	"And our value proposition basically is basically based on three things (…) So environmental factors is one thing, and cost efficient	Lowering costs for airlines
2	"And our value proposition basically is basically based on three things (…) unlocking a lot of kind of remote areas that are currently not served anymore."	Unlocking new routes
9	"Well, I am coming from an airline background. I always felt that the need for a product that would help airlines should be profitable."	Lowering costs for airlines
9	" It is something which will help airlines to build new routes and foster new airport routes developed communities"	Unlocking new routes
10	"I think the original vision of the company still holds true, there's a, there's a segment of aerospace that's below sub 1500 kilometers."	Unlocking new routes
10	"And I think that sub 1500 Kilometer market comes from the icct data that shows that's about 30% of aviation's emissions are in that in that segment."	Sustainable aviation
3	"So, so having a sustainable aviation at affordable price, that will be for me, the two main goals of the company."	Sustainable aviation
3	"So, so having a sustainable aviation at affordable price, that will be for me, the two main goals of the company."	Lowering costs for airlines
3	"I mean, in 20 years, I will hope that that we are establishing regional aviation, and then we're expanding into longer segments, how long it depends on the technology."	Unlocking new routes
8	"The big airlines will buy our aircraft because it's green and they bring a commercial, or economical solution for them"	Sustainable aviation
8	"The big airlines will buy our aircraft because it's green and they bring a commercial, or economical solution for them"	Lowering costs for airlines

7	"Our ambition is to create the most green, accessible and affordable aircrafts in the world within regional air travel"	Sustainable aviation
7	"Our ambition is to create the most green, accessible and affordable aircrafts in the world within regional air travel"	Lowering costs for airlines
7	"Our ambition is to create the most green, accessible and affordable aircrafts in the world within regional air travel"	Accessibility
4	"The company's mission is to help airlines right to decarbonize aviation."	Sustainable aviation
6	"Our strategy is to be cost competitive"	Cost competitive
2	I think we have a lot of experience which helps us a lot in realizing it."	Leveraging the combined knowledge
1	"The point of electric aircraft is that we think that it's the only only zero emissions technology that's also commercially superior to the current technology."	Electric as propulsion technology
1	"And the third one is scale. So, economies of scale, basically, if you scale something, what's the name of the law now, but it's, you know, if you scale something so that it's twice, you sell twice as many planes, you get 20%, cheaper, right?"	Leveraging economics of scale
1	"And part of that is also vertical integration, which is something that I'm interested in pursuing more."	Exploring vertical integration
1	"But really, the ultimate strategy is to sort of commoditize aviation, which we think is really important than to democratize it to make more accessible to more people."	Commoditize aviation to increase diffusion
8	"15 years, I see us leading the regional aviation for short haul in the segment to 200 to 300 kilometers. We are a leader in the market for OEM selling airplanes"	Market leader in the short haul segment
4	"We should be technology agnostic"	Technology agnostic
4	" The aim of the company is to kind of address this market of short medium of flying up to about 1500 kilometers."	Short and medium haul market
6	"So, I think that's one of our competitive advantages is we want to be, if not first to market, one of the first within like, within this decade, the 2020s"	First mover advantage
6	"I don't think that we necessarily tied to battery electric or hybrid electric forever. I think it makes sense in the smaller regional aircraft, you know, the category, we're in like the 30 seats, perhaps scaling to 50 seats, but I think much beyond that will depend a lot on battery evolution. And we might find that if batteries kind of plateau a little bit, we might want to look to other sustainable power trains."	Technology options

5	"If we can bring affordability and sustainability to regional air travel, we can unlock a market that has been dormant for a while"	Unlock new market
5	"Airlines look for reliability, affordability and safety, so we need to have a strategy that combine these to explode the market"	Meeting airlines goals

Theme 2: Key Challenges		
ID	**Illustrative Example**	**Code**
1	"it's managing cost and risk of developing this venture."	Costs and risks
1	"The main challenges for me is around just the fact that it's so multidisciplinary, and there's so many workstreams."	Organizational/multidisciplinary
1	"Aviation is one of the most complex industries in terms of organizational challenges"	Organizational
2	"Even though we have a lot of experienced people whose come from larger organizations view how we have to get rid of the habits."	Organizational inertia
9	"I would say that the largest challenges to be able to compete in the aerospace industries are that it is very capital intensive, and that it relies on certifications."	Capital Intensive
9	"I would say that the largest challenges to be able to compete in the aerospace industries are that it is very capital intensive, and that it relies on certifications."	Relying on Certifications for approval and operating
10	"The first challenge is to bring something to market that's better than what's there today"	Technology
10	"The battery is a big part of that challenge, given its weight and energy density compared to aircrafts today"	Battery Technology
10	"But actually, the batteries part of the commercial challenge as well, profitability, I think, is the first thing the airlines are going to look at"	Operational Profitability for Customers
3	"I will say the acceptance and price, I think we will be more expensive in the beginning. And the acceptance of a new technology is very difficult to get acceptance by, by a broad audience."	Slow Market Adoption
3	"Regulations are a challenge, because of the electric propulsion system, most of the regulations are not tailored to this type of aircraft."	Regulations for new technology in a regulated industry
8	"We need to integrate infrastructure, regulations, and development. In the past, all my experience I worked in develop the product. And the regulations, I never, I never had to work with infrastructure"	Infrastructure
4	"Aerospace is extremely regulated... to bring an aerospace product to the market, they are hundreds, if not 1000s of regulations and approvals that are that are needed."	Regulations
4	"So, designing a new airplane, even for an established aircraft manufacturer is a difficult task, we are trying	Developing both Product and Company

	to do both things at the same time, right creating a new company and creating a new product"	
7	"A major challenge is that we have all the challenges that the other players in the industry have, but we also have the challenge of infrastructure"	Infrastructure
6	"The fact that the regulatory framework is not fully defined yet, I think that could be a potential for a delay or a challenge towards meeting our goals"	Undefined Regulatory Framework
6	"Automatically, you exclude quite a lot of capital that would have like a risk return profit profile that we would be outside of"	Outside Investments
5	"We need to build both a product and a company"	joint Organizational and Technology development
5	"In aviation, safety is the number one thing, and it will never change, so certifications and regulations steps that will require a lot of time and effort for new technologies"	Regulations and safety
5	"Ecosystem participation, key supplier and partners, and industry, and government, airlines etc."	Multiple stakeholder alignment and cooperation

Theme 3: Battery Aftermarket Strategic Importance		
ID	**Illustrative Example**	**Code**
1	"Embrace your sort of IP ecosystem, your sort of walled garden, then the activities around the batteries are very important"	Connection between IP and being involved in Batteries
1	"If vertically integrating and engaging in the battery operation side of business would drastically decrease the costs and help the goal of commoditization in aviation, then it is important"	Commoditization
2	"Because I think one of the others there, one of the things is, of course, we say that we are appreciating assets. So, when you buy the airplane flies a certain distance and given time it will fly longer. Given our goal of appreciating asset, the battery aftermarket is of importance"	Control of an Appreciating Asset
10	"So, in aerospace in general most if you think About Airbus and Boeing, their business model is, you know, they pretty much make nothing when they sell the aircraft. And they make all our money in supporting it."	Aftermarket Service profits
10	"I worry that as a startup with a novel technology, if we don't get that service offering, you know, the piece of the action, we can lose out on a lot of money."	Service Offerings
10	"We also need to be able to price it, and that's where data comes in. I'd say we can either win a lot of money on this or lose a lot of money on it"	Risk vs Return in aftermarket activities
3	"I believe it is important especially because there is so much uncertainty, we will have a straightforward solution. And we'll know how it works. Understanding this part is very important for us whether we do it, or we recommend somebody how to do it"	Understanding of usage
7	"The aftermarket activities and operations around batteries can becomes essential in terms of IP"	Connection between IP and being involved in Batteries

7	"It also creates opportunities for us to package our offering and create multiple sources of revenue"	Service Packaging Revenues
4	It's a high maintenance item, right, which affects very much the operating cost and more than that, it directly affects the performance of the airplane right, in terms of emission savings and so on. So, if you think about those value proposition or those pillars of the value proposition right, batteries are very much involved in in in, in the sustainability side in delivering a product that is green in the in the affordability side.	Control of Operational Economics of the aircraft
4	two very key things on the battery that we have to throughout the life of the program, right? And make sure it works is the reliability, right? Because airlines, they hate airplanes that that are not reliable will not.	Control of the reliability of aircraft in service
6	If we can control the battery maintenance cost, then we can achieve our targets of being affordable and being equivalent to a 50-seat turboprop.	Battery Maintenance Cost
6	Longer term, it could be really good revenue stream as well where operational side of the business are monetizable	Service Aftermarket Revenue
6	I think there's, you know, with new technology adoption, there's always a transitory period where often it's in the beginning, it's more difficult and expensive until you kind of had widespread adoption. So, I think it's really important. We have really good customer support	Aftermarket services as means to speed up adoption
8	Battery for me, it's our car business, okay? Or battery can affect our business. Okay, it's different from interior windshield wiper. Some system like that, okay, windshield, but battery, if battery fail, we're going to fail, or we are going to have a lot of damage your operation	Battery as a high risk and key successful item, need control.
5	The battery is a critical piece of the puzzle, it is expensive, and it is technology moving forward. And heart has selected battery as a solution, so Heart has a responsibility in moving this forward	Responsibility of key asset
5	The Battery is at the Heart of the product, so it becomes inherently important for our success, and we need some control	Control of Aircraft success means control of battery

Theme 4: Insource or outsource decision		
ID	**Illustrative Example**	**Code**
1	"So, it's also this thing's about how much are these technologies sort of part of the core IP we're trying to develop"	Intellectual property development
1	"But the way that we think about it more is like make it make a table, have the things what they are currently costing in the supply chain (...) And then say, Okay, this is really a big delta between these two, let's so but then also sort of how strategically important what's the other part of that is?"	Understanding the business opportunity
9	"We can go for its own customer support."	Insource customer support
10	"So, I think like, if we were to record and offload battery health on on a daily basis, we could sell that as you know, they the airlines will see a value because then maybe they can defer the replacement of the pack for another month or, or two"	Insource battery monitoring

3	"Like I said, it does not necessarily have to be a business for ourselves. But I do see the value of understanding what is required for the next stakeholders to make a business out of it."	Understanding the business opportunity
3	"Technical support could be implemented at heart with support of the of the battery supplier"	Insource technical support
3	"How do people treat the product, everything that gives us insight of how the operator is handling or or airplane and orbit or antibiotics on the airplane? I think it's good for her to be involved directly."	Insource battery monitoring
8	"When the battery is in the airplane, it's our business"	Insource battery operations inside the aircraft
6	"We should engage in customer support, technology upgrades and health monitoring"	Insource customer support
6	"We should engage in customer support, technology upgrades and health monitoring"	Insource technology upgrades
6	"We should engage in customer support, technology upgrades and health monitoring"	Insource battery monitoring
4	"So, cost and reliability of the system are two very key areas where it should always be on top of because I mean, without any of these to the product will not be commercially successful"	Focus on minimizing cost for airline
4	"So, cost and reliability of the system are two very key areas where it should always be on top of because I mean, without any of these to the product will not be commercially successful"	Focus on reliability
2	"I don't think you should take the Battery Park back apart, to be honest, because I think that's what they did for 787. That's why they have problems with the batteries."	Outsource battery pack
2	"Maintenance should always outsource, I think, yeah, I would think they would always go directly from whoever produced them for us"	Outsource maintenance
9	"So, making is not part of what I think we should go for."	Outsource battery cell production
10	"That doesn't sound like something we are if you compare it to our chosen supplier, which is ba right. So, I mean, they're new to aircraft batteries, but they've been in ground transportation forever, I'm sure they have a ton of data on exactly how reliable those cells and packs are and exactly how they behave"	Outsource battery logistics
3	"In the short-term terms of production of the product, I think we should rely on the supplier as much as possible"	Outsource battery production
3	"I think the biggest risk to give it to a supplier is cost related, we lose if we do not have any enablement, they will lose complete control. Knowledge is power. So, I think we want to learn, and we want to be involved. But I don't think we want to be responsible for the first years."	Risks of outsourcing battery aftermarket
3	"I think logistics, handling and maintenance should be handled by the supplier, because they have an international network of service and we don't, right? We will have to build that"	Outsource battery logistics

3	"I think logistics, handling and maintenance should be handled by the supplier, because they have an international network of service and we don't, right? We will have to build that"	Outsource battery handling
3	"I think logistics, handling and maintenance should be handled by the supplier, because they have an international network of service and we don't, right? We will have to build that"	Outsource battery maintenance
8	"Logistic of the battery. It's not our core business."	Outsource battery logistics
8	"Maintenance, repair of the battery, it's not our business."	Outsource battery maintenance
8	"If we choose to outsource, it's important that we have a service level agreement"	Service level agreement
6	"You know, potentially, you know, spec spares and distribution centers. We don't have the warehouses and logistics around the world. So be good to at least partner or possibly outsourced to someone that does have those logistics networks, because we have a lot to focus on and we can't really be building up."	Outsource battery logistics
6	" Potentially reap refurbishing of batteries that would naturally fall with the battery systems supplier if that we're going to take the old batteries and refurbish them again."	Outsource refurbishment
4	"Yeah, for instance, recycling after batteries, I don't see why heart would get involved on that."	Outsource battery recycling
7	"Our goal should be to outsource as much as possible to keep focus on core business"	Focus on core business
7	"By outsourcing logistics, we don't have to build up a service network that is required by our global customer presence"	Advantage of outsourcing logistics
7	"Risks of outsourcing is that the customer doesn't perceives the quality that they expect"	Quality risk of outsourcing
7	"There is a risk of not owning the IP of the batteries"	IP risk of outsourcing
7	"There is a risk of supplier negotiation power over Heart"	Negotiation power risk in outsourcing
5	"Logistics, handling of the batteries, storage, maintenance of those batteries when they are off wing is better outsourced"	Outsourcing battery logistics
5	"Logistics, handling of the batteries, storage, maintenance of those batteries when they are off wing is better outsourced"	Outsourcing battery handling
5	"Logistics, handling of the batteries, storage, maintenance of those batteries when they are off wing is better outsourced"	Outsourcing battery storage
5	"Logistics, handling of the batteries, storage, maintenance of those batteries when they are off wing is better outsourced"	Outsourcing battery maintenance
5	"Is this something that we can do overtime, maybe? But for now, I think of this as to outsource"	Business potential in the future

Theme 5: Battery second life ownership		
ID	**Illustrative Example**	**Code**
6	"There might be a strategic reason to recycle batteries with have a recycling partner and the recycling customer would be the battery cell provider."	Recycling partner for battery cell recycling
8	"There is a risk of losing focus in EOL ownership"	Loosing focus at EOL ownership

8	"One solution could be to develop a separate business entity for 2nd life"	Create separate business entity for 2nd life
6	"EOL is a way for us to subsidize 1st life battery ownership cost"	Leverage EOL to subsidize 1st life battery cost
4	"If we engage ourselves on it, and by engage ourselves, we assure more competitive pricing for the airlines flying the airplane, then yes"	Leverage EOL to subsidize 1st life battery cost
9	"We lack experience in 2nd life"	Lack of experience in 2nd life
10	"The capital investment in in owning battery packs, which then go to some Second Life Application and then ultimately end up in end of life like recycling. That, that feels to me like something we don't understand very well"	Outsource 2nd life ownership and recycling
7	"The market for second life battery sales is not mature yet"	Unmature market for 2nd life
2	"I think we own it together. No, they can be assuming that we don't sell them to the airlines, let's put it like that, then we and are we together with BA the battery pack supplier will be only off to Second Life."	Joint ownership with supplier at second life
3	"if the supplier doesn't want to take care of the aftermarket or Second Life, we can establish direct partnership agreements with, for instance, with a standard or somebody similar building energy storage devices out of use batteries."	Other partnerships for 2nd life
7	"We should not engage in battery ownership at EOL but instead have a partner that can service, swap out the batteries and sell them"	Have a partner for ownership at EOL

Theme 6: Strategic Partership		
ID	**Illustrative Example**	**Code**
10	"I think BA has expressed an interest in this approach."	Supplier interest in strategic partnership
9	"Hard parts are better outsourced to supplier and softer parts are better handled by Heart"	Partnership set up
3	"So, you commit and by having a partnership, your learning curve will be faster, and maybe be instead of having 15 years to implement, you will have seven"	Quicker learning curve
6	"We leverage the supply capability in facilities, we align incentives, and we have a corporate or structural separation of the aircraft in the aftermarket business, which enables each business to pursue its own strategy."	Aligning incentives
6	"We leverage the supply capability in facilities, we align incentives, and we have a corporate or structural separation of the aircraft in the aftermarket business, which enables each business to pursue its own strategy."	Leveraging supply chain capabilities of the battery supplier
6	"We need to have a lot of trust in each other."	Importance of trust in a partnership
4	"I see benefits Yes. But for me, the benefits should always be focused on those two aspects that I mentioned, right? lowering the costs and ensuring that the system will be reliable."	Focus on lowering cost in strategic partnership

4	"I see benefits Yes. But for me, the benefits should always be focused on those two aspects that I mentioned, right? lowering the costs and ensuring that the system will be reliable."	Focus on improving reliability in strategic partnership
4	"I mean, our our focus should not be on the maximum profit that we can make. But on those areas where we can make profit, but at the same time, increased reliability and lowered costs for for the airlines"	Profit as secondary importance
5	"We have to be careful, because when the JV is buying from one of the mother companies, it becomes an uneven relationship"	Risks of misaligned incentives

Theme 7: Heart's relative strengths related to the battery business		
ID	**Illustrative Example**	**Code**
1	We're the ones that are going to sit on the data on the use case of the batteries. And that is going to have tremendous implication for the design, the aftermarket, all of that stuff. And that's the obviously we can also share that data with our batteries.	Data is key for the aftermarket, and Heart will have the data
2	I think we will develop the knowledge about this area better than like airlines	Heart has better knowledge of batteries in operation
9	Airlines already have too much on their plate and will not want ownership of something which is really expensive in a very regulated environment.	Focus on core business
9	We know pretty well how airlines operate and we have some relative knowledge of the battery. So, we are we will be good in this middlemen position.	Heart has both understanding of airlines and batteries
10	one strength we have, we own the platform, right. So, nobody gets to put a battery on our platform, because it's certified by us, we own the type certificate.	Ownership of Platform
10	I don't think airlines would be interested in owning batteries any more than they're interested in owning gas turbines, I think they always the airlines are very good at focusing on their core business.	Focus on core business
3	compared to the battery supplier is the fact that we have the direct discussions with the airline, the airlines are discussing with us are buying aircraft from us, and therefore probably feel more confident having direct discussions about this with us than with the supplier.	Direct Contact with Airlines compared with battery supplier
3	The airlines do not know anything about the design of the battery, but we do.	Airlines lack battery knowledge
8	Given that we be involved in the aircrafts operations and involved in the battery system, we will be a company that will know more of batteries in operation than the supplier or the airline	Heart has both understanding of airlines and batteries
4	I think in health monitoring of the batteries because I mean, we own the design of the aircraft	Health monitoring and data
4	I don't see where we could add value to logistics. I mean, it's we are not a logistics company, we will not have a logistics structure right even for other systems.	Does not see the value of taking on activities such as logistics

4	training provided by the OEM is always much more accurate, it's usually higher quality when then training provided by a third party.	Services such as training better from Heart
6	I think that compared to the supplier side; we have a lot of market expertise. And compared to the Airline we are better technical and can also work close to the supplier.	Heart has both understanding of airlines and batteries
6	The airlines would also hate having an unknown cost, which it is for batteries in aerospace, so they would have more comfort with a fixed price from us	Airlines will prefer not to take the risk of unknown cost of operations
5	We are creating the product, and others make the business from your products. We are bringing the market, so we need to benefit from that.	Heart is at the core of this new business
5	I don't think we want to become a recycler, or a repair shop or to buy in trucks and do logistics. But we bring that market	Middleman position in new market

Theme 8: Business Model Structure		
ID	**Illustrative Example**	**Code**
1	where are we on the value chain or somebody else, somebody else has leverage on us that they can start, you know, if we say we want 50% or 80%, or you know, what, who was holding the cards	Exploitation of power in partnership and outsourcing
1	So, I would say so the first option of selling is the problem there is that you're incentivized to make bad batteries in a way, because you want them to break	Miss-alignment in incentives for batteries when selling
1	maybe leasing is more interesting, because then you're actually being incentivized to make the batteries last longer.	Aligned incentives for batteries when leasing
1	And also like, what are the vendor lock in effects? What if we do something and we find out that it's the wrong approach? How can we change?	Supplier Power and vendor lock-in
1	actually, the consumer experience is probably the most important one, which is incentivized to be better under some performance contract	Increased consumer experience in service model
1	In service programs you have predictable, predictable recurring revenue, which tends to be preferred. And that means that Airlines have predictable costs, which accounting would like	Predictable Revenues & Cost in Service Program
10	I think the motivation to invest in a new battery and new certification is probably going to be driven by us because we can sell more aircraft. So, I think we have to retain some ownership of the of the Destiny there.	Involved in aftermarket due to incentives to make batteries better
10	think with a good partner, like the supplier, probably the joint venture power by the cycle could be good. I think they have the knowledge to price that offer you know, so we don't lose money, but that they don't get in stinking rich at our customer's expense.	Joint Venture service program
10	We can always sell the batteries, and that removes a lot of the risk, but I don't think the Airlines want to buy it, because they are sort of the five-ton elephant in the room	Airlines don't want to deal with the aftermarket of batteries

3	I think we need to find somebody that wants to and is willing to look into this battery business together with us and share the benefits and risks	Joint Venture / Partnership program
8	I am afraid of complete outsourcing, because I don't see why the manufacturer of the battery would care about health and monitoring, because wrong usage just means that they can sell more new batteries	Issues of incentives in full outsourcing
8	We need to have a partnership with the suppliers, they will sell with less margin, we split the cost, they can do everything about repair (..) everything about operation. So, our business will be to keep the batteries in ongoing flying as much as possible for both companies to make money.	Maximizing incentives and value through Partnership
7	I think we need to go for a strategic partnership, where also the responsibilities are strategically mapped, and where we can share incentives, profits, and losses	Strategic Partnership to share responsibility, costs, and profits
4	I think it could be probably built both ways right either as a joint venture together with the supplier where we share certain responsibilities or as a Heart program, which we then hired the supplier is certain services from the supply.	Joint Venture or Partnership in service offering
4	I don't think complete outsourcing work because in the real world, if they have a problem with the battery, they will call us, the aircraft manufacturer	Unable to outsource everything
6	If there's high battery costs, this could discourage customers from buying more electric planes.	Problem of selling due to costs and reduced interest in aircraft
6	heart can provide a total care service taking care of all of the battery maintenance, the replacement, and upgrades at a fixed and known cost to the airlines. So, it's a known cost, it's pretty simple. It avoids the need for them to build a lot of facilities and recruit and train a lot of their own maintenance staff.	Known costs for airlines in service programs
6	I think the value proposition to heart in this is that there's a long-term aftermarket revenue stream available.	Aftermarket Opportunities for Revenue
6	Ideally, we get the customers to sign long-term contracts that we can actually monetize earlier on.	Long Term Service Contracts
6	We can also leverage the supply capability in facilities, we align incentives, and we have a corporate or structural separation of the aircraft in the aftermarket business, which enables each business to pursue its own strategy.	Joint Venture Focus benefits
6	In full outsourcing we have a loss of control over battery strategy and costs. We have a loss of organizational capability regarding battery customer support. We miss out on this longer-term aftermarket revenue stream.	Downside of complete outsourcing
5	Assuming no issues on supply/demand, I believe a JV is the best option, but that does not mean that we will have to do a lot in-house. Where we have a service level agreement where we can provide everything.	Fronting with partners the solution needed for airlines
5	A JV where we have capacity for different parts that are required from the Airline, we have a menu where we can provide the solution necessary for any situation	Flexibility of JV model in solutions and portfolio offering

5	We need to be part of and have control of this side of the business as it is critically important for us to have a driving seat in this ecosystem	Control of aftermarket and asset

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