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Startups and their contribution to the future of sustainable aviation

*A qualitative study on the role of startups in the transition of the aviation industry
toward sustainable air mobility.*

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List of Abbreviations

<i>Abbreviation</i>	<i>Meaning</i>
<i>ATC</i>	Air Traffic Control
<i>AUAS</i>	Amsterdam University of Applied Science
<i>CO₂</i>	Carbon Dioxide
<i>DOA</i>	Design Organization Approval
<i>EASA</i>	European Union Aviation Safety Agency
<i>eVTOL</i>	Electric Vertical Take Off & landing
<i>IATA</i>	International Air Traffic Association
<i>MRO</i>	Maintenance, Repair & Overhaul
<i>NO_x</i>	Nitrogen Oxides
<i>OEM</i>	Original Equipment Manufacturers
<i>POA</i>	Production Organization Approval
<i>R&D</i>	Research & Development
<i>SAF</i>	Sustainable Aviation Fuel
<i>TRL</i>	Technology Readiness Level

Abstract

The aviation industry is faced with a challenge, unlike the ones it faced before. Climate change is posing an impending threat to many industries, and also aviation is urged to reduce its carbon footprint. There is an abundance of research available about the transition of the aviation industry toward a sustainable future, but not on the topic of startups in the aviation industry, or in this transition. Even though many startups are emerging in this sector and as they become more and more involved, the topic becomes increasingly relevant.

This thesis aims to identify the role of startups in the transition of the aviation industry toward sustainable air mobility, through qualitative exploratory research. 12 semi-structured interviews with professionals in the aviation industry were conducted in pursuit of answering the research question.

Through the research, it can be concluded that there is an apparent consensus about the value and necessity of startups in the transition of the aviation industry and the introduction of radical innovation in the sector. Their main value-adding characteristics have been identified as a diverse perspective and management style, less bureaucracy resulting in a faster pace, a culture that facilitates innovation, and the freedom to take risks and reinvent themselves when making mistakes. Incumbent firms are generally open to collaboration with startups in different forms. It was pointed out that combining the startup's strength with the experience, expertise, and network of the incumbent firm results in a win-win situation. There still are many obstacles to be overcome on the way to a sustainable future in aviation, both for incumbents and for startups. Besides developing the technology, challenges include the development of infrastructure and energy production that the technologies require. Additionally, the mindset in the industry needs to become more open to sharing ideas and the threat of a lack of manpower should be addressed before it becomes a major bottleneck. Regulation and certification of innovation is another challenge that both incumbents and startups are faced with, but it is rather a guideline for safe operations rather than an obstacle to overcome. Startups have a particularly difficult time getting their product certified, often due to a lack of experience and connections. The collaboration between startups and incumbents can offer useful solutions in this regard. Finally, it can be concluded that business models in all different branches will inevitably adapt to this transition. Particularly the changing supply chain of OEMs and the adapting network structure of operators could present opportunities for new entrants.

Keywords: Aviation industry, Startups, Sustainability, Innovation

Preface

This thesis has been written as a dissertation for the Master of Innovation & Industrial Management, at the School of Business, Economics & Law, at the University of Gothenburg. The research was conducted from March to May of 2023. Before diving into the inspiring world of the aviation industry and the incredibly exciting role of startups therein, I would like to take this opportunity to thank a few of the people who made this thesis possible.

I would like to start by thanking my supervisor, Marouane Bousfiha, for his support and encouragement. He provided a fresh perspective and inspired me to challenge myself to get the best out of this research. For that, I am immensely grateful.

I would also like to thank the 12 professionals from all over the world and from all over the industry, who took the time out of their full schedules to answer my many questions. Their input gave meaning and value to this research. Andrea Luebke, Arlette van der Veer, Baptiste Arribe, Carlos Roberto Ilário Da Silva, Jacob Verhaart, Jolanda Stevens, Karel Bockstael, Nando van Arnhem, Philip Ideström, Reynard de Vries, Rob Koedijk, and Tristan Oppeneer. Thank you for your time, effort, support, and willingness to share your knowledge with me.

1. Introduction

Amelia Earhart, the first pilot to fly solo across the Atlantic Ocean, once said: “My ambition is to have this wonderful gift produce practical results for the future of commercial flying and for the women who may want to fly tomorrow’s planes.” Standing on the shoulders of those who came before, the aviation industry is on the brink of welcoming tomorrow’s planes once more. Since Otto Lilienthal first glided through the air in the late 19th century, and the Wright Brothers put the first powered airplane in the sky in 1903, unbelievable things have been achieved. After more than a hundred years of aircraft development, the industry is faced with a new challenge, unlike the ones it faced before. Climate change is imposing an impending threat to the future of the aviation industry. Conventional aircraft are propelled by burning kerosene. Kerosene is a fossil fuel, the burning of which releases among other things, carbon dioxide (CO_2), nitrogen oxide (NO_x), and water vapor resulting in contrails. These emissions contribute to the changing of the climate, which in turn is urging industries in all sectors to change their ways and reduce emissions. Aviation is responsible for approximately 5% of emitted greenhouse gasses from fossil fuel combustion. (Lai, et al., 2022)

Climate change is creating a need for the aviation industry to reduce emissions. The aviation industry is traditionally an industry that is resistant to change due to strict regulations and high priority for safety. In this transition, however, a substantial number of startups are emerging to bring new technologies to the market. It is yet to be determined what exactly these startups contribute to the development of the aviation industry and what role they are playing/will play in the pursuit of sustainable air mobility. But it is undeniable that they are starting to take up more and more space and that they are starting to make a difference. There is an abundance of research on the sustainability movement in the aviation industry and the technologies that will be a part of this change. There is an incredible amount of research on startups entering conservative industries and the role they can play in changing the established order. However, there is a noticeable gap in knowledge when it comes to startups in the aviation industry and specifically in this transition towards a sustainable future. Hence, the incentive to conduct this research.

1.1. Research

This research aims to define what role startups play in the transition of the aviation industry toward sustainable air mobility, why that role is of value and what obstacles lay in the way of it. These points are elaborated on following the findings of the research to reach a conclusion.

This research answers the main research, along with three sub-questions. The main research question answered in this thesis is as follows: *How can startups initiate meaningful change in the transition of the aviation industry toward sustainable air mobility and what does their role in this transition entail?*

The sub-questions that are answered to reach a conclusion are as follows:

- I. *Why are startups necessary in the transition of the aviation industry toward sustainable air mobility?*
- II. *What are the main industrial prerequisites and challenges that startups face in the pursuit of sustainable air mobility?*

1.1. Industry Background

In the aviation industry, there are basically four categories of parties to be identified in the aviation industry: The parties that contribute to producing an aircraft, the parties required to operate an aircraft, the parties needed to ensure the airworthiness of that aircraft, and overarching organizations that are not financially motivated. These parties in the aviation industry are visualized in Figure 1. The first category, parties contributing to producing an aircraft, consists of Original Equipment Manufacturers (OEM). Among the OEMs, there is a rough distinction between airframe manufacturers, engine manufacturers, and component manufacturers. Not to say that one organization cannot be involved in more than one element of this. In order to operate the aircraft that the OEMs build, the most obvious party that is required in the airline, but Air Traffic Control (ATC) and Airports should also not be overlooked. Aircraft leasing is also depicted in the figure since they are often a link between OEMs and operators. To ensure continuous airworthiness as required by law, Maintenance, Repair & Overhaul (MRO) organizations are required. Lastly, the industry is influenced by a number of overarching forces which are generally not financially motivated. Government, legislators, associations, educational institutes, and Research & Development (R&D) are parties and institutions that are part of this category. (Delfmann, Baum, Auerbach, & Albers, 2005)



Figure 1: Map of the aviation industry

The aviation industry is unlike most others because it is characterized by small margins, international competition, and strict regulations ensuring a high level of safety. Due to these characteristics, it is an industry that is very sensitive to international fluctuations, as was most recently demonstrated during the COVID-19 pandemic but was also illustrated over the years by numerous exogenous events. The high level of safety that is ensured through strict regulation and certification requirements, is the number one priority throughout the aviation industry. Over the years, aviation has been improved, increasing the reliability of the aircraft, making it now arguably the safest mode of transportation there is. Additional factors to take into consideration in the aviation industry are the high R&D costs for most parties in the industry and the long lifecycle of the products. Because of the high-level technology and the high quality that is expected, any part of the product needs to be high-end. Thus, increasing production costs as well as R&D costs. Because of these high costs prior to the life cycle of the products, they are built to last. The average life of a commercial aircraft is approximately 30 years. (Delfmann, Baum, Auerbach, & Albers, 2005)

1.3. Delimitations

The delimitations of this research are related to the nature of the research and the context in which it takes place. Firstly, there is a time limitation that restricts some actions. The topic that is being researched is quite broad and opened doors to many related branches and questions. These specific findings have been proposed for future research in the discussion chapter. This research analyzes the

transition of the aviation industry toward sustainable air mobility and the role of startups in this transition, from a strictly business-related perspective. This research will not assess the technical viability of discussed innovations and does not include perspectives of supporting parties in flight operations, such as airports and ATC. This research is exploratory and will therefore focus on a broad picture and general overview of the industry, rather than analyzing specific details. The limitations associated with this type of research and the approach will be further elaborated on in the methodology chapter. In the context of the research, the scope has been limited to focus mostly on aircraft production and operation, rather than supporting capabilities like airport services. The perspective of airports is therefore also not included in this research. Other than that, a range of actors' perspectives are included in the research and provide a good understanding of what is currently happening in the industry, their stake in this transition, and a general view of the sustainable future of aviation. The focus of this research is furthermore outlined by the research questions, as they will lead to the topics perceived as most important and they will provide structure for some parts of this thesis.

1.4. Structure of the thesis

This thesis starts by presenting the existing body of knowledge in a literature review. This literature review leads to a theoretical framework in which the position of startups and their perceived potential in the industry is described related to the discussed theories and concepts. This is followed by a methodology explaining how the analysis was performed and why certain choices were made in this process. The empirical findings that were gathered from the primary data are then presented and an analysis is conducted, linking the empirical findings to the established concepts uncovered in the literature review. The analysis is finalized with a discussion answering the research questions, proposing topics for future research, and stating the contributions of this research. The thesis is concluded in the final chapter, after which the references are listed, and the appendices are attached.

2. Literature Review

This literature review includes scientific articles published in recognized journals. The overview of the articles can be found as an appendix at the end of this thesis. The articles relate to three broad topics: Changing the aviation industry, the proposed new technologies, radical innovation, the dominant design theory, and the innovation ecosystem. The review of the literature resulted in a theoretical framework that defines the place that startups presumably take in the system and the concepts that define this position.

2.1. Changing the aviation industry

Barke et al. talk about the current state of the aviation industry and its growth perspective for the future. They discuss how current studies show that the aviation industry is predicted to grow steadily on an annual basis and in contrast to that, how it aims at reducing its emission. They refer to Flightpath 2050, which is a strategy aimed at reducing aircraft emissions. It used the year 2000 as a baseline and the goal is to achieve a 75% reduction in CO_2 emissions, 90% in NO_x , and 60% in noise. (European Commission, 2011) This strategy is introduced to counteract every growth amount of global air traffic. They discuss how additionally, numerous programs are adopted in pursuit of reaching these goals, but most of them are concerning incremental innovations, rather than the radical innovation that is needed in the industry. (Barke, et al., 2022) Rohacs also describes why the aviation industry pursues sustainable operations in the name of reducing emissions, they define sustainability as follows: “Sustainability is the ability to be maintained at a certain rate or level.” (Rohacs, 2023, p. 417) Lastly, Rohacs points out that technological advancement on a radical level is essential for persevering the future of the aviation industry. (Rohacs, 2023)

Lei et al. also discuss the incentives for the aviation industry to change and the challenges it faces in this transition. They also point out that the aviation industry has adopted several measures that should reduce the climate impact of the industry. They state that the challenges that are faced in this context are mostly of socio-economic and political nature. However, they state that these aspects are often neglected when implementing new measures in pursuit of lower emissions. (Lai, et al., 2022) This highlights the importance of seeing the industry as an interconnected network of elements that are all aligned and dependent on each other. They describe the aviation industry as: “...a socio-technical system, with a myriad of stakeholders and actors, in need of complex changes at multiple levels, including technology, regulation, markets, cultural meaning, infrastructure, science, and networks, etc.” (Lai, et al., 2022, p. 1) Radical innovation requires not only the introduction of new technology, but it

requires this network to change and the first step to changing it is understanding it. Geels discusses this socio-technical system in depth and provided an overview of the socio-technical system for the aviation industry, which is shown in Figure 2. (Geels, Co-evolutionary and multi-level dynamics in transitions: The transformation of aviation systems and the shift from propeller to turbojet, 2006) This map of the industry gives a clear idea of the different elements that should be taken into consideration when attempting radically change the industry and highlights how complex such transitions truly are.

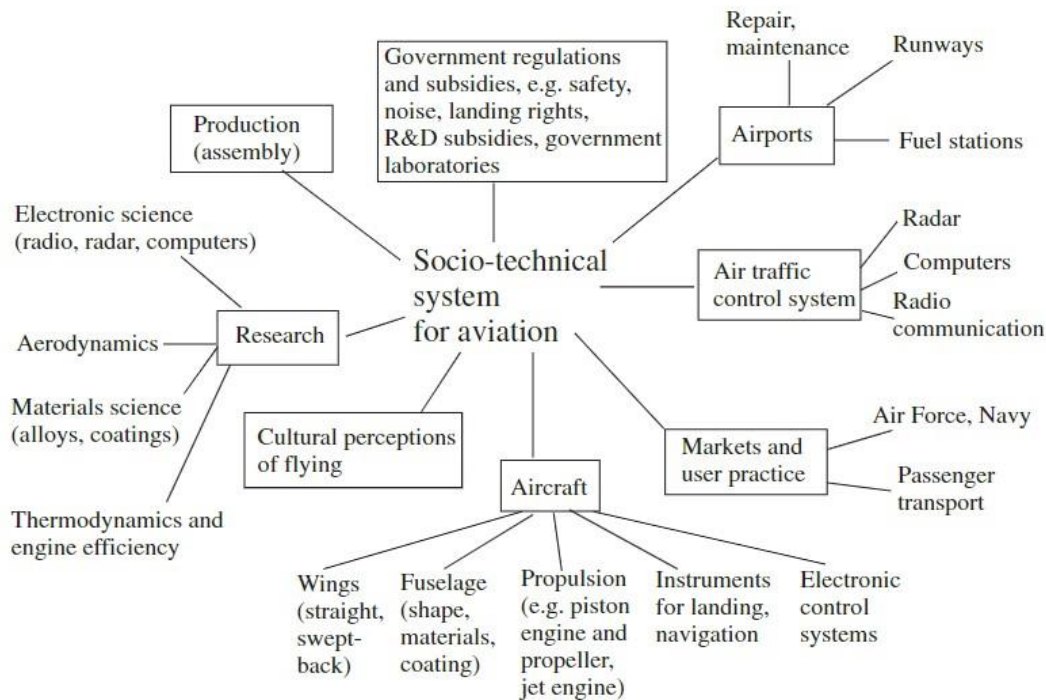


Figure 2: Socio-technical system for aviation (Geels, Co-evolutionary and multi-level dynamics in transitions: The transformation of aviation systems and the shift from propeller to turbojet, 2006, p. 1001)

Kivits et al. also approach the industry as such a system and state that in order to increase meaningful output, the traditional process of implementing technological innovation should be reconsidered. They highlight the importance of consensus between the different parties connected in the industry. According to them, a shared goal and understanding of this goal significantly increased the potential for successfully reaching that goal. (Kivits, Charles, & Ryan, 2010) Climate change can be considered to pose such a shared goal for the aviation industry. It is a shared problem and the industry as a whole is challenged by it, not just a few actors in it. This situation urges for a consensus, which should be a major driver of actually achieving this goal of reduced/eliminated emissions from aviation.

Besides it being clear that the industry is a complex network of relations, the industry is also inherently difficult to change. One of the phenomena that make the industry so hard to change is Carbon Lock-in. Unruh explains this phenomenon as follows: “Industrial economies have become locked into fossil fuel-

based technological systems through a path-dependent process driven by technological and institutional increasing returns to scale. This condition, termed carbon lock-in, arises through a combination of systematic forces that perpetuate fossil fuel-based infrastructures in spite of their known environmental externalities and the apparent existence of cost-neutral, or even cost-effective, remedies.” (Unruh, 2000, p. 817) In the aviation industry, every element in the socio-technical system is tailored to fit the current technology which is based on the usage of fossil fuels. Unruh proposes that corrective policy from institutions is necessary to incentivize the industry to change and escape carbon lock-in. (Unruh, 2000)

This approach, taking into account the socio-technical context of the industry can and arguably should be used to evaluate the innovations and new technologies proposed in the aviation industry.

2.2. Technologies: SAF, Electrification, Hydrogen

Currently, there are three main pillars of technologies being developed in the aviation industry in pursuit of sustainable air mobility. The first technology and currently the most widely accepted one, is Sustainable Aviation Fuel (SAF). SAF are biofuels that reduce CO₂ emissions in production, but does not eliminated emissions during composition. SAF is already used by operators on a low scale, they sometimes mix a small portion of SAF with regular kerosene, since it has largely the same properties in use. The second technology is electrification, which is most commonly thought of since the emergence and widespread uptake of electric vehicles. This encompasses the use of battery-powered engines. The third technology that is being developed is hydrogen-powered engines. Hydrogen as a fuel offers a zero-emission alternative by internally transforming the chemical energy of compressed hydrogen gas into electricity which can feed an electric engine. Bauen et al. does a good job of summarizing these technologies and highlighting the main challenges that each technology faces today, as they state: “Currently, alternative fuels make up a very small share of fuel used in aviation, but their commercialization is making good progress. Hydrogen offers a longer-term alternative fuel option but requires aircraft design and fueling infrastructure changes. Electrification is emerging as an option for providing propulsion in aircraft, either in pure form in small aircraft or in hybrid mode in larger aircraft.” (Bauen, Bitossi, German, Harris, & Leow, 2020, p. 263) Each of these proposed technologies offers unique opportunities and comes with its own set of challenges. They explain that SAF is currently a very attractive innovation to lower emissions because it doesn’t require changing the combustion system in jet engines or the fueling infrastructures that are currently in place at airports. However, it is a reduction of the emissions, not an elimination, and the price of SAF is currently significantly higher than traditional kerosene because there is simply not a lot of it. They also express the expectation that hydrogen fuel cells and battery-powered propulsion will have a significant impact on the transportation industry as a whole. A major challenge with both these technologies is, however, that it requires changes to the infrastructure. Hydrogen is still complicated to store safely and has a much lower volumetric

density than jet fuel, meaning that you would need to bring more of it on board. Since there is very limited space on board an aircraft, this poses a major challenge. Another critical characteristic taken into account in aircraft design is the weight of components. Electric flying faces a barrier in the performance and reliability of batteries, but certainly also in the current capacity of the batteries available. Lower capacity means that a bigger battery is needed and a bigger battery is going to be heavier. (Bauen, Bitossi, German, Harris, & Leow, 2020) Baroutaji et al., elaborate on the potential of hydrogen, calling it the ‘future of energy generation’. However, they point out that hydrogen may be emission-free in use, but the production process of hydrogen is currently not emissions-free. (Baroutaji, Wilberforce, Ramadan, & Olabi, 2019) This is a point of conversation that can also be brought up concerning electric flying since there is not currently an abundance of green energy. On the topic of reliability and safety with regard to the new technologies, Emmanouil raises a solid concern by stating the following: “With an increasing amount of electrification projects in aviation, reliability becomes a key question. Integrating electric and electronic equipment in areas that have been dominated by thermal machines poses big challenges and opportunities.” (Emmanouil, 2020, p. 1)

In 1999, Allen already published a paper in the *Journal of Progress in Aerospace Science* on this topic. At the time they even forecasted that energy supply would be a major bottleneck in the development of the aviation industry. They concluded that synthetic kerosene from natural gas or SAF (Sustainable Aviation Fuel) would become the short-term alternative to fossil fuel, but in the long term, liquid hydrogen would become a necessity in order to avoid fuel shortage. (Allen, 1999) This is of course in line with what current research is also confirming.

Related to the previously mentioned view of the aviation industry as a socio-technical system, Kivits et al. relate this to the introduction of new technologies in the industry today. They also talk about the three pillars of technological development and point out that these technologies will have an impact on the entire industry, including the supply chain, maintenance, and other facets of the industry. Additionally, they point out that although this is necessary the industry is not well equipped for that level of change. They suspected that high fuel prices and emissions trading schemes would become major drivers of this transition. (Kivits, Charles, & Ryan, 2010)

Baledón and Kosoy analyze these technologies with regard to policy making and the role of ICAO (International Civil Aviation Organization) in this. They relate their analysis largely to ICAO CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation), which was a measure to reduce CO_2 through improving technology and operations. CORSIA was approved in 2016 and is still in use. (Baledón & Kosoy, 2018) (IATA, 2023)

2.3. Radical innovation

Rohacs describes the different kinds of innovation that can be introduced in an industry. They name incremental innovation, disruptive innovation, and subversive or radical innovation. The introduction of incremental innovation is a process of continuous improvement, essential to the development of an industry. Disruptive innovation develops a new solution and evens the market for that solution. Radical innovation causes a multi-level change and redefines the value proposition in the market. (Rohacs, 2023)

On the topic of introducing new innovation into the industry and seeing this industry as a socio-technical system, Geels describes how radical innovations are usually introduced in niches and eventually break out of this to change the existing order. Geels states that niches are the locus of generating variety in radical innovation. The established regime is stable with the connections of actors in the socio-technical system and when it is stable there is mainly room for incremental innovation. Radical innovation breaks out of the niches when the established order is challenged by tension or a shared threat. Climate change imposes such a threat on a broader industry level. This tension creates the opportunity for radical innovation to get out of the niche and be adopted by the bigger market. (Geels, Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study, 2002) Kvits et al are aligned with this theory and add to this by explaining that technology is rarely stand-alone, rather it is always affecting multiple elements in a system. Additionally, they say that radical innovations are usually of the kind to substitute the existing technologies. They point out that it has been observed that with the introduction of such substituting technologies, incumbent firms and even market leaders fail to keep their position. According to them, this can be explained by one of two things: “(a) lack sufficient financial resources to cut their losses, thereby allowing them to overarch their sunk costs in the supplanted technological paradigm, and switch to the new technology; or (b) simply fail to change rapidly enough to keep up with the rate at which new companies using the new technology grow.” (Kivits, Charles, & Ryan, 2010, p. 201)

Radical innovation and the introduction thereof can be related to the theory of dominant design. Since radical innovation describes the type of innovation that is introduced to the market and dominant design theory describes what could happen to it in the market place.

2.4. Dominant design theory

Unruh was referred to before in this chapter on the topic of decarbonization, but on the topic of innovation, they also interestingly state the following: “A period of uncertainty, termed the `era of ferment, ensues as variants compete for performance improvements (including cost reductions) and market share. The era of competition ends when one of the variants captures a critical mass of the market

and becomes the de facto standard. Following the establishment of a dominant design, a shift occurs from product (Schumpeterian) innovation to incremental process (Usherian) improvement” (Unruh, 2000, p. 820) This description of the dominant design theory can be a good predictor of the development of the aviation industry. In which the aviation industry is currently in the first phases of this phenomenon, where there are still many different technologies being developed, and at some point, one will become the dominant design.

The theory of dominant design is connected to the innovation ecosystem, acknowledging the different forces at play in the industry, which determine what innovation will become dominant and take the majority of the market.

2.5. Innovation ecosystem

Another theory that is interesting to consider in this transformation is the innovation ecosystem. This theory in turn is related to the previously mentioned socio-technical approach, as both address the complexity of an industry. Stephens et al define that such an ecosystem includes ten dimensions: Policy, Finance, Culture, Support, Human Capital, Markets, Business Incubation, entrepreneurial education, Business Networking, and Infrastructure. All of which would be interesting to consider in the development and implementation of innovation in the aviation sector. (Stephens, McLaughlin, Ryan, Catena, & Bonner, 2022) Isenberg also thoroughly discusses the innovation ecosystem and adds the following: “The entrepreneurship ecosystem consists of a set of individual elements—such as leadership, culture, capital markets, and open-minded customers—that combine in complex ways. In isolation, each is conducive to entrepreneurship but insufficient to sustain it. That’s where many governmental efforts go wrong—they address only one or two elements” (Isenberg, 2010) This quote from Isenberg emphasizes the importance of seeing innovation in the relevant context and acknowledging the complexity of said context. Sometimes the success of innovation does not depend on the quality of the innovation itself but on the implementation thereof. The innovation ecosystem is a useful concept to consider in the aviation industry since it is similar to the socio-technical system described earlier in this chapter. It takes into account the multi-level approach that is needed to initiate meaningful change in an industry and successfully bring innovations to the market.

2.6. Theoretical framework

Considering the research question that this thesis aims to answer, it has been established what the aviation industry looks and functions like, what dynamics can be observed, and what factors play into a transition of the industry. The role of startups connects to all the previously discussed topics.

When approaching the industry as a socio-technical system and considering Geels description of how Technical Transitions are the change of that socio-technical configuration, not only replacing technologies but replacing many elements in the system. Because the elements in the system are normally aligned with one another, such a change is hard. These emphasize the effects startups have on all parts of the system. Geels also describes a challenge that startups that are proposing new technologies should take into consideration. They point out that new technologies often do not match the established regime, in the sense that it ignores the infrastructure and supporting capabilities in place. New technology is more than the adoption of the technology itself, users need to make the technology part of their standard practices. This makes it complicated for such a new technology to be adopted by the wider industry. (Geels, Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study, 2002) This socio-technical approach is strongly related to the theory of innovation or entrepreneurial. It incorporates the complexity of change in an industry and emphasized the necessity for collaboration. This theory is not only applicable for incumbent firms but for startups entering the industry. Both as a tool for designing impactful innovation and as a backbone of the industry. It reminds the innovator to focus on the individual elements but also on how they relate to the rest of the ecosystem. A good understanding of these theories can arguably aid in the performance and success of a startup in the industry. If the startup is focused solely on the technical aspect of the innovation they are proposing and does not account for the system in which that innovation ought to be applied, chances of success decrease. (Isenberg, 2010)

As mentioned before, research on startups in the aviation industry is very limited, supposedly because it was not much of a topic before this transformation started taking shape. Sun et al did however describe the emergence of startup airlines. They highlight that the competitive advantages of startups in the aviation industry are often underestimated. The business model that a startup proposes is usually quite different from the commonly applied business models of incumbent firms and it is not yet sure how this will work out for them in the long term. The fact that startups adapt the business model can be an example of how they take into account the socio-technical elements of the industry and the entrepreneurial ecosystem that is being addressed. Additionally, startups are usually more flexible to implement new technologies such as AI (Artificial Intelligence), which could give them a significant competitive advantage. (Sun, Wandelt, & Zhang, 2022) Kivits et al elaborates on this and explains that

another advantage that new companies have is that they do not have to deal with sunk costs which incumbents usually are burdened by. (Kivits, Charles, & Ryan, 2010)

When looking at the three main streams of technology development in the aviation industry today, they address largely the same problems but have different approaches. SAF for example, can not be labeled as radical innovation. It is aimed at reducing CO₂ emissions, but it is applied to the traditional mode of propulsion that is commonly used in aviation. Hydrogen and electrification, however, can be categorized as radical innovations. Although the specifications of their technology have not been made concrete yet, it is likely that the adoption of such technology will require the entire value chain to adapt. Besides changes to the airframe, the supply chains of OEMs will have to make significant adaptations, and the infrastructure required to support these innovations does not exist yet. In that sense, the importance of the socio-technical approach and the entrepreneurial ecosystem is again of value. Addressing all the elements in the system, rather than the technology alone. (Geels, Co-evolutionary and multi-level dynamics in transitions: The transformation of aviation systems and the shift from propeller to turbojet, 2006)

In terms of radical innovation, it should be remarked that startups are in a good position to introduce such innovations to the market. Especially in the aviation industry, where incumbents deal with low margins and fierce international competition, they are unlikely to go beyond incremental innovation, since the risks involved are simply too significant. Startups face less risk and do not have another primary business that is depended on the suggest of their proposed innovation. They are in a position to introduce radical innovation and demonstrate the potential of it to the industry. Taking into account the dominant design theory, a range of radical innovations might be proposed by startups, which only a few being successful and capturing a part of the market. Currently, the aviation industry is in the phase where many new technologies are emerging, mainly in the three categories that were previously discussed, but with many variations and alternative designs or approaches. Startups are free to experiment with this and bring many possible solutions to the market. Through extensive research and further development, it is very likely that a dominant design will emerge, which will then be taken over by a larger proportion of the industry. (Unruh, 2000)

3. Methodology

This chapter describes the methodology applied in this research. Firstly, the research approach and its design will be presented, followed by the method of data collection. The method of analysis of this data is also documented and the structure in place to ensure the quality of the research is described. Lastly, some additional empirical background information is profited to contextualize this research.

3.1. Research Approach

With the aim and problem statement of this research in mind, this research can be labeled as exploratory research. Since the idea is to gain a better understanding of the transition happening in the aviation industry and the role that startups play in it. It is largely contextual and concerns the ‘bigger picture’. For these reasons, a qualitative approach was selected as the most logical option. The benefit of applying quantitative methods is that it allows for a broader perspective on the industry and the contextual interpretation of data. For this type of research question, a qualitative approach was the most suitable. A quantitative approach was ruled out because the aim of this research is not to test a hypothesis, but rather to gain a broader understanding of a situation. Therefore, numerical data was deemed irrelevant for the purposes of this research, and qualitative data is preferred. This type of data allows for the interpretation of meaning and nuance, as well as the analysis of dynamics and attitudes in the industry. Analyzing this type of data can help to define insights and patterns in the data that point to more concrete topics. (Sekaran & Bougie, 2016)

Subsequently, a bottom-up approach, or inductive approach was selected as the most suitable option. The inductive approach derives a conclusion from observation, and this is the most commonly used approach in qualitative research. In contrast, the top-down approach, or deductive approach most commonly used in quantitative research, derives a conclusion from reasoning. The inductive approach generally starts with a hypothesis and seeks consensus. That is not in line with the proposition of this research. The inductive approach is suitable because it ends with a hypothesis and/or grounded theory about the situation. This approach seeks pluralism and complexity, which is what defines this topic and the research question that is posed. This research seeks a deep and complex understanding of the situation and the role of startups in it. In that regard, the validity of the results is prioritized over reliability. The aim is to provide a solid and valid answer to the research questions, not to proof its generalizability. (Patten & Newhart, 2018)

With regard to the limited period of time that was available for performing this research, it concerns a cross-sectional study. Data was collected from one point in time and analyzed accordingly. A longitudinal approach would have been interesting for the analysis of this topic, but regarding the limitations, it was not an option.

3.2. Data collection

In practice, the data collection includes 12 semi-structured interviews with professionals in or related to the aviation industry. An overview of these interviews is represented in Table 1. The interviewees represent parties in the industry (incumbent, startup, third party) or they can be described as experts on the subject (because of relevant experience). The selection of interviewees was based on their position, experience, and company portfolio. The majority of interviewees were approached through email and referred by connections. The interviews were conducted online or in person and ranged from 30-60 minutes. Four of the interviews were conducted in English, the rest was conducted in Dutch, the native language of both the interviewee and interviewer. The interviews were all recorded and transcribed. Transcripts are available upon request and the abstracts of the interview (in English) can be found in the appendices.

The topics outlined in the research questions were used as guidelines in the interviews and approached from different perspectives, depending on the interviewee's position. The interviews were linked, and some statements were double-checked with other interviewees. The interviews were fact-checked and supported by secondary sources. Questions that were raised by the interviewee or resulted from the interviews were answered with secondary sources, where possible. The perspectives of parties in the industry that could not be represented in the form of an interview in this research were included through secondary sources and original publications from said parties.

This method of data collection was selected because it is most suitable for the nature of the research. Exploratory research requires a broad approach and a relatively wide scope. With the 12 interviews that were conducted, a significant range of angels was covered. The interviewees represent OEMs, airlines, MRO organizations, startups, and overarching forces. It allows for an open attitude, following the narrative of the interviews, and identifying patterns, similarities, and contradictions. The method proved effective and insightful. (Sekaran & Bougie, 2016)

Table 1: Interviews

Interviewee	Type of company	Company name	Position	Duration of interview
<i>Andrea Luebke</i>	Engine manufacturer	MTU Aero Engines	Senior Vice President Corporate Strategy	30 minutes
<i>Arlette van der Veer</i>	Airline	KLM Royal Dutch Airlines	Senior Manager Radical Innovation	1 hour
<i>Baptiste Arribe</i>	Currently: N/A	Currently: N/A	Currently: Consultant	30 minutes
	Formerly: Startup, Component manufacturer	Formerly: SeaBubbles (2023), Safran (2020)	Formerly: Strategic director, CEO Corporate start-up	
<i>Carlos Roberto Ilário Da Silva</i>	Aircraft manufacturer	Embraer	Head of Zero Emission	20 minutes
<i>Jacob Verhaart</i>	University	Amsterdam University of Applied Science	Teacher and researcher at the Aviation Academy (Engineering)	1 hour
<i>Jolanda Stevens</i>	Airline	KLM Royal Dutch Airlines	Program Manager Zero Emission Aviation	30 minutes
<i>Karel Bockstael</i>	Currently: N/A	Currently: Self-employed	Currently: Consultant	30 minutes
	Formerly: Airline	Formerly: KLM Royal Dutch Airlines (2022)	Formerly: Vice President of Sustainability	
<i>Nando van Arnhem</i>	Startup	VÆridion	Aerodynamics Lead Engineer	1 hour
<i>Philip Ideström</i>	Startup	Heart Aerospace	Legal Counsel	40 minutes
<i>Reynard de Vries</i>	Investment company	Panta Holdings	Program Manager New Aircraft Technologies	1 hour
<i>Rob Koedijk</i>	Airline	KLM Royal Dutch Airlines	Product Development Manager	1 hour
<i>Tristan Oppeneer</i>	Startup	NRG2Fly	Program Manager	30 minutes
	University	Amsterdam University of Applied Sciences	Lecturer Aviation Engineering	

3.3. Data analysis

The data from the interviews were transcribed by hand and summarized for easy access and comprehensible analysis of the discussed topics. The interviews were revisited on multiple occasions. The interviews were interlinked during the interview itself and afterward. The transcripts were dissected

to identify what content was applicable to which research question and to define what data was directly or indirectly connected to data from other interviews.

The data was contextualized with the framework resulting from the literature review and the themes of the interviews were interpreted based on the acquired knowledge. The risk involved in this type of analysis is that a statement can be misinterpreted or contextualized incorrectly. Where possible and where needed, clarification and confirmation were asked during the interviews and afterward.

3.4. Quality assurance

In order to ensure the quality of this research, attention was paid to the internal validity of the research, and the credibility of external sources. Furthermore, triangulation of sources was applied to validate findings and conclusions.

Internal reliability relates to the applied practices and the research process. The process has been documented in this chapter to demonstrate transparency and elaborate on the choices that were made in the process. Additionally, the data used in this research is accessible to the reader and this research could be reproduced by other researchers.

The selection of credible sources for primary data was based on credentials, experience, and expertise. All the interviewees either could be considered experts in the field based on their experience and credentials, and/or they represented recognized companies that have a significant stake in the transformation of the aviation industry. The secondary data originals are exclusively from publications done by recognized sources and official information distributed by the companies or organizations that are referenced to.

3.5. Limitations of the research approach

Representation is always a point of discussion in qualitative research because it is not possible to include all of the stakeholders in in-depth interviews. However, the aim was to include and present the perspectives of most key stakeholders in this transition based on representation. Since it concerns exploratory research, the aim is not for this research to be generalizable, but rather to give a valid overview of the dynamics and actors in the system. There is a wide range of startups, all in different phases and with different propositions. Three startups have been interviewed to represent different types of startups: Heart Aerospace (SE), NRG2Fly (NL), and VÆridion (DE). These startups have different origins, and different business models, and are in different phases of development. The pool of

incumbent firms includes airlines, airports, maintenance organizations, aircraft manufacturers, engine manufacturers, and component manufacturers. Since airports are mainly related to the infrastructure supporting sustainable aviation, they are outside of the scope of this research and have not been included. The other types of incumbent firms are represented in this research. In most cases, this applies to one interview per type of organization, and in other cases, multiple interviews have been conducted in different departments within an organization. The third parties include legislators, associations, and academic institutions. EASA, as the European legislator, and IATA as the association of airlines, have been included through secondary resources and the testimony of interviewees from other companies and organizations. The Amsterdam University of Applied Sciences (AUAS) has been interviewed to embody the academic perspective and secondary sources from the Technical University in Delft have been included to elaborate on this perspective. (Sekaran & Bougie, 2016)

Since there is limited hard data on this topic, most of the interview questions rely on the interviewee's experiences and expertise. Qualitative data always leaves some room for speculation, but with the sample size and method of data collection, the research is objective and covers a significant portion of the types of parties active in the industry. Additionally, secondary sources are consulted to "fill the gaps", between the perspectives represented by the interviewees. Primary sources would have been preferred, but with regard to time, opportunity, and manpower, there were certain limits that prohibited this.

3.6. Empirical context

The context of this research is the industrial landscape of the aviation sector. In the introduction chapter it was defined that there are three main categories of actors that are necessary in the industry, along with a number of overarching forces. The organizations responsible for producing the aircraft, the organizations that operate the aircraft, and the organizations that are required to ensure continuous airworthiness. The parties that create the aircraft are OEMs, which include aircraft manufacturers, engine manufacturers, and component manufacturers. Companies like Boeing, Airbus, Bombardier, and Embraer are big companies in the business of manufacturing aircraft. In the business of aircraft engine manufacturers, companies like GE Aviation, Rolls-Royce, Pratt & Whitney, and MTU Aero are big producers. Aircraft component manufacturers include companies in both of the previously mentioned categories along with other, usually more specialized companies. Behind these OEMs are again more elaborate supply chains of material suppliers. In order to operate said aircraft there is an airline that performs the flights, an airport that facilitates the infrastructure and landing/take-off slots, and Air Traffic Control (ATC) that guides and moderates the flights. To ensure the airworthy state of an aircraft

the operator needs Maintenance, Repair, and Overhaul (MRO). MRO companies can be independent entities or part of an operator. Examples of this are KLM Engineering & Maintenance (E&M) or Lufthansa Technik. Said “in-house” MRO companies can however perform maintenance for other operators as well. Aircraft Leasing companies are sometimes a medium through which airlines operate airplanes without purchasing them. Overarching forces that play a significant role in the industry include government, legislators, associations, educational institutions, and Research & development (R&D). The government is involved in the regulation of air traffic, both on a national and international level. Legislators are specific per region, in Europe the European Union Aviation Safety Agency (EASA) is in charge of law and regulation. Associations represent the needs of different parties in the industry, International Air Traffic Association (IATA) is an example of such an entity that represents the needs of operators. Lastly, Educational institutions play a significant role in training the people who will work in the industry, and they partly influence what knowledge is delivered to the industry. (Delfmann, Baum, Auerbach, & Albers, 2005)

Over the past years, a trend has been observed of more and more startups attempting to enter the aviation industry with objectives aimed at sustainable air mobility. These startups propose alternatives on many different fronts, a majority is focused on sustainable propulsion and electric or hybrid aircraft. To name a few, the following are examples of commonly mentioned startups in this transition toward sustainable air mobility. Heart Aerospace is a Gothenburg-based startup developing the ES-30, a regional electric aircraft that is expected to go into service in 2028. Their aircraft has four electric motors, a capacity of 30 pax, and a range between 200 and 800 km, depending on full electric or hybrid flight and the weight. (Heart Aerospace, 2023) Pipistrel is a Slovenian startup owned by Textron, producing a line of lightweight 2-to-4-seater electric aircraft. (Pipistrel, 2023) Maeve is a Dutch startup based at the YesDelft Incubator, developing the Maeve 01 a zero-emission aircraft. Their aircraft should seat 44+ passengers, have a range of 460 km, and have a charging time of 35 minutes. (Maeve, 2023) Lilium is a German startup developing an electric vertical take-off and landing jet (eVTOL) for regional air mobility. (Lilium, 2023) Ampaire is an American startup, developing a line of hybrid-electric aircraft models. (Ampaire, 2023) VÆridion is a Munich-based company a zero-emission regional aircraft, in which the aerodynamics of the wing design are at the center of its innovation. (Vaeridion, 2023) NRG2Fly is a Dutch startup focused on the development of the charging infrastructure required for electric air mobility. (NRG2Fly, 2023) There are many more to mention, but this gives a sense of context regarding the type of startups that are emerging and the alternatives that they are proposing.

4. Empirical findings

This chapter presents the empirical finding derived from the conducted interviews. This chapter is divided into five subchapters, based on the input of the interviewees. The chapter starts with presenting the value that the interviews recognized in startups. This is followed by a subchapter focusing on how different parties in the industry describe the collaboration with startups, and following from this, the described expected changes in industry-wide business models are presented. Furthermore, the findings on the perceived industrial prerequisites and the topic of law and regulation are presented.

4.1. The value of startups

There was an overall consensus among the interviewees about the value that startups add to this transition in the industry. Some even stated that the involvement of startups is not only beneficial but necessary for the industry to move toward sustainable air mobility. The most commonly mentioned points that were brought up in terms of value-adding aspects of startups include a diverse perspective, a faster pace due to less bureaucracy, more freedom to take risks, and a culture that facilitates change.

On the topic of innovation, Carlos Ilário explains that at Embraer they work in innovation verticals with specific focuses. He is the Head of the Zero Emissions vertical, meaning that he is responsible for creating a technology roadmap, choosing the correct projects to invest in, building strategic partnerships, and identifying new business opportunities. All with the consideration that the steps they take now should be in line with their strategic plans and ensure that they are ready for the future of aviation. He explains that they actively work together with many actors in the industry, but that startups are certainly a key contributor in this transition. Embraer has venture capital and also organized a Startup-day during which startups were invited to share their ideas and this contributed to the Energia project. Energia is a family of four sustainable aircraft that Embraer is working on. (Embraer, 2023) He highlighted the specific advantages of startups in the following statement: *“Startups bring a fast pace. They are fast, they need to do things fast, and they don’t have a lot of bureaucracy, so things usually go fast. They can make mistakes, quicker. Then it is easier for them to reinvent themselves. If you look at a big company, big companies have a big bureaucracy, so it is not as fast as a startup. It is difficult for us to make mistakes. On the other hand, we do have a lot of experience. We have the best engineers, and we can leverage our knowledge with the speed and benefits of the startups. When we put these together, it makes a very good recipe to win.”*

Jolanda Stevens, Program Manager Zero Emission Aviation at KLM Royal Dutch Airlines, highlights a similar point. She explains that an established company like KLM, which has been operating for over

100 years is very safe and reliable, which is a great asset, but startups are needed to shake up the industry. Startups question how things have always been done and pose new alternatives. A fresh perspective is incredibly valuable. She also points out that, in the transition of the aviation industry, KLM takes a proactive approach to their involvement, but as an airline they also rely on the rest of the industry for developing sustainable alternatives. She explains that operators are eager for a sustainable solution, and they collaborate with the industry in order to bring these alternatives to the operation. At KLM they already make an effort to make their operations more sustainable, but to take the bigger steps towards emission-free air travel they also need the rest of the industry. She is regularly in touch with startups to speak about the future and how a company like KLM can help. A lot of different parties are involved in developing the technologies that will allow aviation to become sustainable and KLM is part of that discussion because they want to see where and how they can help.

Baptiste Arribe is currently self-employed but in the past years, he worked both at a startup and was responsible for a corporate startup within Safran, a major aircraft component manufacturer. He describes that the main differences he experiences in a corporate startup compared to a 'regular startup', relate to how the performance of a corporate startup is not critical for the survival of the company, the corporate startup is backed by the rest of the business, it is very people-oriented, and it works with stronger competencies because of the ecosystem within the company and its existing network. He states the following in this regard: *"The aim is different. The growth of the startup was not critical for Safran's success or survival. Whereas for people in a regular startup, it certainly is. Additionally, we were backed by Safran as a big company. So, it was calmer."* However, he also remarks that in a corporate startup, innovation often focuses on improvement for the company itself and not for its customers. He observed that in a 'regular startup', it is easier for people to be market-oriented, and he said that: *"In startups when there is business and hope, there are people to help you."*

Arlette van der Veer, Senior Manager of Radical Innovation at KLM, brings up another topic, the value of diverse management. She sees the benefits of a more diverse management strategy like at many startups, and she states the following: *"Yes, I even believe that startups could do 'reverse mentoring' for corporate. In the sense that in that case, the mentor would not be the senior for a change. That the senior would be coached by a startup, in order to show that it is in fact 2023, the world is changing and in this way it can work too."* Jacob Verhaart, researcher, and lecturer at the AUAS, brings up a related point about incumbent firms in contrast to startups. He stated the following: *"Startups can do something different from incumbent firms. Large organizations often struggle with what they call 'historical momentum'. That means that they are set in their ways and would need to discard their business model in order to do something new, or otherwise they change too slowly. A startup is often better equipped to pick the correct things."*

Reynard de Vries, Program Manager New Aircraft Technologies at Panta Holdings, also highlights the importance of the involvement of startups, with the following statement: *“I think that startups are necessary for bringing the technology to a phase in which it will be a niche product, or at least to bring it to a higher TRL for the bigger market.”* Secondly, he highlights the cultural benefit that startups have. He said: *“Startups have a cultural benefit. You need to have a culture that facilitates innovation. A culture that wants to change and challenge the status quo.”* He also mentioned a more negative side of having a lot of startups in the industry. He notices that there are also startups emerging that, according to him are possibly having too much hope and are making outrageous claims of what is achievable. He points out that it is good that people have hope and are optimistic about what is possible but that straying too far from reality can have a polarizing effect on the population.

Karel Bockstael, former VP of Sustainability at KLM, makes a very similar remark to the previously mentioned topics. He remarks that startups offer a different perspective, and he elaborated on this in the following quote: *“Yes, especially in terms of diversity in management, and the adoption of the right priorities. I think and I hope, also the attraction of a different segment of the market.”* He also discussed the difference in the type of innovation that incumbent firms are mostly capable of implementing and why startups are needed. He said: *“In all honesty, what we did in those 3 years at KLM mostly involved incremental innovation. The big difference between incremental improvement and radical change will have to be made by startups.”*

When asked whether or not she believes startups are necessary for the transition of the aviation industry toward sustainable air mobility, Andrea Luebke, Senior Vice President of Corporate Strategy at MTU Aero Engines, does not recognize the necessity of startups but does acknowledge their value. She stated the following in this regard: *“I think MTU itself and our official answer would be that we definitely see ourselves being very innovative and being also a front runner in developing these new technologies, therefore it is not necessary to have a startup. My personal view on that is, nevertheless, working with startups probably makes us even faster and gives us the opportunity to come up with a bit more diverse thinking which can also be helpful. The startup is more the diversity factor, rather than that we really need their innovative ideas.”*

This is how the incumbent firms perceive the value of startups, but how do startups themselves envision their value-adding qualities? Philip Idestrom from Heart Aerospace points out that one of the benefits a startup has as opposed to an incumbent firm in the aviation industry is that a startup is free to set up a whole new structure which can facilitate innovation. This was previously also pointed out by representatives of the incumbent firms as both a burden and an asset for established organizations. He additionally characterizes the attitude of the aviation industry as open to change and willing to share and collaborate. Nando van Arnhem, Aerodynamics Lead Engineer at VEridion, recognizes three main topics in which startups have an advantage over incumbent firms. Firstly, he points out an advantage

related to human capital, he stated the following: *“When they develop a new aircraft, they always first relocate people from within the company to that project. That means that they will not quickly attract new people with the ambition to take on such a role.”* He explains that startups naturally need to attract new people and ones they do, they can put them exactly where they need to be. Secondly, and related to the previous topic, he remarked that startups have a cultural benefit. He stated the following: *“The fact that a startup has a structure but not such hierarchy, also makes it attractive. You can more easily attract people with very specific knowledge or skills because you can put them in exactly the right place, without it being set in stone.”* Lastly, he pointed out that startups are generally more flexible to make mistakes, which is necessary for such an endeavor. He stated the following: *“Startups are the opposite. They take the risk because they do not have another business depending on it. In our case, the business is developing a new aircraft and of course, you are going to make mistakes in that process, it is a learning curve.”* This is similar to what Carlos Ilário said, in terms of startups being able to take more risks, make mistakes, and reinvent themselves. There is a general agreement about making mistakes is a necessary part of innovating. Nando van Arnhem also explains why incumbent firms have less freedom to take risks. He illustrates this fact with the Flying V that he worked on, a sustainable aircraft design that has recently gotten a significant amount of media attention. He explains that Airbus was involved but did not want its logo on the plan before a successful test flight with a prototype. The damages that a failed test flight could do to the reputation of such a firm and the risk of having their other processes put on hold for examination, is not worth it.

4.2. Collaboration between startups and incumbent firms

During the interviews, the attitude of incumbent firms toward collaboration was discussed and there was mainly a general consensus about the importance of collaboration in pursuit of developing a sustainable aircraft. The nature of such collaborations was discussed as well as the attitude of the industry toward the changes that startups are pushing.

Carlos Ilário stated the following on the topic: *“We see a lot of value in the collaboration with startups and we are interested in enhancing the collaboration.”* He goes on to explain that the collaborations Embraer has with startups are not the delegation of work, but the active discussion and participation in which they combine their strengths. He elaborates on this in the following quote: *“We don’t go and just give work to the startups. We don’t say: do it and then bring it back to me. That is not the way in which this works the best. We want to go and work together, sit together, and have the best strengths of each party so that we can go forward harder.”* Jolanda Stevens made a similar remark about how KLM collaborates with startups. She said: *“It is not like we say: You have to come up with something and we will wait until you are ready. Absolutely not. We want to help and together with those players see what*

we can do to accelerate this development.” Carlos Ilário goes on to explain that combining the values of startups with the experience and expertise of an incumbent like Embraer is a win-win collaboration. He illustrates his point by explaining that there are different phases to development. First is the ‘virtual space’ during which research is done and calculations are performed. After that comes bench testing and eventually putting it into practice. Startups need incumbent firms for the latter two steps because established organizations have the capacity to apply technologies in practice and have the capital to test. He elaborates on this in the following statement: *“When I say virtual world, I mean the first step of doing the calculations, analytical methods, and numerical methods. Then you go to the next phase, which is bench testing. You learn quite a lot on the bench tests as well, but when you go to the aircraft it is a completely different story. I like to say that it’s a flying laboratory, where you learn quite a lot. There are opportunities for startups, to leverage what we already have. We have aircraft prototypes, we have flight test engineers, we have test pilots.”* Andrea Luebke describes a similar phenomenon. She explains that the current collaboration that MTU has with startups is limited, but they aim to increase this in order to involve startups in all parts of the process. She elaborates by stating that MTU is intrinsically a very innovative company, and they consider themselves a frontrunner. The benefits of collaborating with startups, in her opinion, lie in their fast pace and more diverse thinking. Especially the agile way of working is something that startups have successfully integrated, and incumbent firms often haven’t adopted it yet. On the topic of finding startups to collaborate with she states the following: *“If we see startups that can produce products that either support the technology itself or - and that is probably even more significant- that supports the processes to accelerate the technology development, than we think about approaching those startups first with a cooperation and if it makes sense for us than later on also by being able to do mergers or acquisitions.”* Recently, MTU also acquired such a startup, and that is something that they consider doing in the future if opportunities arise.

When asked about the attitude of the industry toward change, Jolanda Stevens expressed an understanding of the contradiction that is perceived in this attitude. She explains that aviation is a conservative sector, and that the conservativeness of the industry is the biggest blessing because it has allowed for an incredible level of safety that should not be taken for granted. She thinks that that should not be forgotten and that it should be recognized for what it is, not an obstacle but a fortitude. On the other hand, she points out that aviation has also been very entrepreneurial and pioneering, and that incredible things have been achieved since the Brothers Wright first flew an airplane. She recognizes that discrepancy in her role, as she is tasked with making space for that pioneering attitude that sparks innovation but at the same time to be careful, protect the brand, and always stay mindful of safety concerns. She stated the following: *“It is incredibly good that those two can exist next to each other. On the one hand, the established industry that knows how to achieve things in the aviation sector, how to build something, and how to certify it. That is a difficult process, and they have that knowledge. On*

the other hand, they also feel less inclined to pursue sustainability, because the product functions perfectly fine in their current portfolio. What kind of urgency do they feel? Maybe a moral one, but not from a business perspective. Then you also have startups, who go straight through that.” KLM sees an opportunity, as a major incumbent firm in the Netherlands and the industry, to be a part of this change, to leave a mark, and to support. They recognize that as such a firm, they carry a responsibility to help accelerate this development, especially in the face of climate change. Arlette van der Veer also emphasized that collaboration is essential because not one manufacturer will come up with the most sustainable aircraft alone. She expresses concerns about the closed-off attitude of the industry and the natural reluctance to show ‘unfinished’ work to others. She sees this as one of the main obstacles in the move toward a sustainable future. Reynard de Vries also remarked that because an aircraft is so complex in design collaboration is always necessary. The supply chain is vital and aircraft manufacturers will always collaborate with suppliers and manufacturers of different parts because you cannot do everything alone. He also recognizes how people in startups can experience the attitude of the industry very differently from how people in incumbent firms experience this. Startups often surround themselves with well-willing people who are equally innovative, whereas the culture in an incumbent firm is often different. Additionally, startups are not burdened by another business that is dependent on their success. He stated the following on this topic: *“Startups have less risk, less resources. In my ideal scenario, a startup would develop the technology, and spend maybe millions or billions on technology demonstrators. When they start approaching a full-scale prototype it will get expensive, because then you need to certify and start building an assembly line. That is when you would hope that a bigger company would take over.”* Baptiste Arribe agreed with this point and stated the following: *“I think the most efficient system is buying startups. Finding the right ones and buying the ones that are mature.”*

Philip Idestrom from Heart Aerospace discussed how they are currently in contact with many different parties in the industry in order to get a good understanding of what is needed and how things should come together. He emphasized the importance of listening to your customers and stated the following in this regard: *“As with any aircraft, you work very closely with your customer and their need direct your requirements and you need to flow those requirements down into your supply chain. So, it varies how integrated you need to be, but you certainly do well to listen.”* He also explained that at Heart Aerospace they recognize and appreciate the importance of collaboration in pursuit of sustainable air mobility. He stated the following in this regard: *“We realize that we can’t do everything. It is a whole industry to create an aircraft. We decide on our place in the ecosystem but realize that we need to be part of the discussion in a lot of different areas.”* Lastly, Philip Idestrom describes how they experience the attitude of the aviation industry and stated the following on the topic of collaboration: *“I think the Ethos of the industry is really collaborative. It’s a very trust-based industry, I find. You have to work in a very integrated way with your suppliers. Sometimes I don’t like the term ‘supplier’ because you are often more of a partner. In this industry, you can be a partner, competitor, customer, and supplier at*

the same time. Because the same company may be producing subsystems and their own aircraft. It's often very large organizations, with a lot of history that are quite diversified.”

Rob Koedijk, Product Development Manager at KLM, highlights a similar point about startups and incumbent firms. He points out how an incumbent firm always takes its legacy with it, as well as existing structures and procedures. That can be a great asset but in an innovation context, it can sometimes also be a burden. Furthermore, he explains that at KLM, they are currently working on building partnerships with startups to truly understand what is happening in the industry. He also explains that they are looking into how they can offer supporting capabilities to future aviation. Some of the things he mentions are maintenance and infrastructure. These are topics that not all startups are yet focusing on, but in which he hopes the incumbent firms can play a role.

Nando van Arnhem brings up yet another topic when describing his experience in how VÆridion collaborates with other parties in the industry. He remarked that in his experience, suppliers are sometimes more willing to work with startups. He elaborates on this in the following statement: *“Incumbent manufacturers usually want to have all kinds of contracts with their suppliers, and they set high demands because they are used to doing that, especially for engine suppliers. They also have a much longer time span.”*

Lastly, when asked about the necessity of startups and the collaboration with startups in pursuit of sustainable air mobility, Baptiste Arribe changed the question when he stated the following: *“Startups are part of the solution, but as long as the solution is not only technological but also in the way we consume, they are not the only solution.” “We can imagine startups with something other than technology. Business model innovation, rather than purely technology innovation.”* This remark emphasizes the different layers of the challenge that the aviation industry is facing and highlights the importance of looking beyond the technology, which leads to the next subchapter on the changes that are to be expected in the current business models throughout the aviation industry.

4.3. The expected changes in business models

In terms of changes to the business models in the aviation industry, two topics were discussed; changes related to the value chain and changes to the network of operators. Most of the interviewees agreed that business models throughout the industry will inevitably change with the introduction of new technologies. Additionally, startups are emerging in the industry, not only with new technologies but with business innovations as well.

When asked if he foresees Embraer's business model changing with the introduction of sustainable air mobility alternatives, Carlos Ilário stated that he believes these new technologies will change the whole industry's business model. He explains that the new technologies open a new degree of freedom, not only in aircraft design and urging manufacturers to think outside of the box, but it will disrupt the existing business models and the supply chain. He points out that there is currently a natural oligopoly in the aeronautics supply chain, related to huge technological barriers and the necessity for massive investments. The changing technologies offer opportunities for new entrants to find their place in the industry. Hence, the required changes in the business model show a great opportunity for startups, not only to propose new business models but to take up space in the changed business model of the industry as a whole.

Andrea Luebke agrees that business models will change with the adoption of new technologies. Before 2050 she doesn't expect a tremendous impact on MTU's business model, since the technologies expected to be ready before then mainly target aircraft with up to 50 seats, which is not their main market. In the long run, however, she sees these developments changing business models all throughout the industry. She also explains that any transition in the aviation industry takes time, in part due to the long product life cycle of aircraft. An aircraft's life cycle is around 40 years, meaning that, even with the introduction of new technologies it will take time for the industry to trade its old technology for a new one. In other words, changing the business model will become inevitable in this transition, but it will happen gradually, and it will take a bit of time. She also stated the following in this regard: *"The most important thing is that you need to move yourself and not wait for Tesla to move you. The question 'How much are you involved in new technologies?', is definitely important. In order to not be too disrupted by external influences, and if you would like to keep your business model."* Karel Bockstael was mostly aligned with his view and stated the following in that regard: *"A successful airline will be capable of developing these types of niches. That would determine a successful transition, but I don't see that happening any time soon."*

Tristan Oppeneer from NRG2Fly points out another element of change that this technological transition brings. He expresses the expectation that not only business models will change, but the networks of airlines will change with the adoption of sustainable aircraft. As mentioned before, the current technology is largely being proposed for short-haul distances. He explains that there will be a two-part transformation. On the one hand, operators will move to another mobility system that will facilitate the new technology, which would be more of a point-to-point network, rather than a hub-center network. On the other hand, current operators will adapt parts of their network in order to incorporate sustainable air mobility in the current network. He elaborates on this in the following statement: *You can see this happening at Transavia, in their collaboration with Fly with Lucy. They want to offer flights with whatever electric aircraft that will be available. In that case, you can imagine, that for example,*

Transavia flies to Athens and offers sustainable flights to the islands.” When discussing other ways that incumbent operators will embrace sustainable aviation, he states the following: *“KLM Flight Academy has already announced that they would be open to purchasing an electric aircraft once it is available and conforms to their requirements. I think that, for the big operators, you will firstly see it in the training segment.”* Philip Idestrom related these expected changes to the history of the aviation industry. In this regard, he stated the following: *“If you go back in time, there used to be a lot of smaller communities, tying together a large network. That largely disappeared in the 90s when everyone started using jets and it became very uneconomical to run a regional airline. That’s what we are trying to change now.”*

Nando van Arnhem also mentioned that besides working on the technology, startups are required to consider their business model more carefully. At VÆridion they are developing a sustainable aircraft that is supposed to operate with 9 passengers and a maximum distance of 400 km. When asked about the future operators of such aircraft, he stated the following: *“I do not think it will be entirely new operators. It is a new aircraft, and it is a new technology, so people want to have a familiar perspective. So, it should perhaps be medium-sized operators, that have been around for years, on existing routes, from existing airports, with recertified pilots. I think that is how it will go, but I have no doubt that larger operators will follow.”* He proceeds to explain that although people often think of long-distance flights when conjuring aviation, approximately 20% of routes are about 400 km or less. He sees this as currently the part of the market with the biggest potential. At some point in time, the technology might be so far developed that it can cater to the larger aircraft market with long-haul routes, but the technology is simply not there yet. The technology that is there now needs to be developed and tested and since it is currently well-suited for regional flights, it seems like the most logical place to start. Among the startups that have emerged in the aviation industry with sustainable alternatives for air mobility, a majority of the ones that propose new aircraft designs, are focused on this regional short-haul market. Circling back to the previous subchapter in which the exemplary role that startups can have in this transition was described. This situation is a good example of where startups are not necessarily solving a current problem but helping to develop a solution for the future. Sustainable regional flights might not seem like the biggest step up, but if anything, they have the role of demonstrating that sustainable air travel is possible.

This is related to the question of what is required to change in the industry, both in terms of industrial prerequisites for change and the topic of consumer behavior related to the business models in the industry. This will be discussed in the next subchapter.

4.4. Industrial Prerequisites for sustainable air mobility

There were a number of topics that came up when discussing what needs to change in the industry in order for it to adopt alternative technologies pursuing sustainable air mobility. The first thing, which followed from the previous subchapter, was consumer behavior. Additionally, infrastructure, energy production, mindset, and manpower are among the most commonly mentioned topics.

In terms of industrial prerequisites for sustainable air mobility, Andrea Luebke brings up three important topics. Firstly, the infrastructure at airports needs to be suitable to service the aircraft of tomorrow. She stated the following in this regard: “...*The importance of infrastructure. That is what we definitely try to get a better understanding of, based on automotive. This is even a bit more complicated with regard to planes because you need a less distributed infrastructure, but that comes with a benefit and with a disadvantage at the same time.*” Secondly, she mentions the production of energy/fuel needs to be increased, and thirdly she points out that there is a need for common understanding. She stated the following: “*The second thing is production, which is needed for SAF as well as for full hydrogen power technology. Last but not least, a common understanding among aircraft passengers, cargo customers, the airline industry, and ourselves, because at least at the beginning, those flights will be more expensive. Today we try to reduce costs massively and airlines offer tickets for 30 euros to fly from Hamburg to Madrid. That probably would not be possible if we need to invest in all those infrastructure and hydrogen production facilities.*” These are elements that MTU does not actively invest in currently, but they are part of the discussion and Andrea Luebke also highlights how important it is to be connected and to explain why the demand is there and that there is a business model. Tristan Oppeneer highlights some similar points in the following statement: “*It all starts with a large electric aircraft. That is where the main focus lies, also for startups. Yet, it is often forgotten that the regulations around that, the operations at the airports, the charging-infrastructure, and all those kinds of matters also need to be accounted for.*”

Rob Koedijk sees manpower as the greatest bottleneck to be expected in the gradual transition toward sustainable air travel. He points out that there is already a lack of trained and certified technical personnel. He expects this demand only to rise in the future and he also points out that new aircraft designs will require new knowledge and skills from people. Philip Idestrom mentioned a similar point in the following quote: “*I think one of the challenges is attracting and maintaining the right competencies. You need competencies from all over the world and they are in high demand.*” Nando van Arnhem also shares this sentiment and emphasizes the importance of bringing the right people together in order to realize change. The first step is to have the available manpower, but the second step is to make sure the right competencies are coupled. He sees this as one of the things that the aviation industry could learn from the electrification of the automotive industry. He says that aviation should

not take the automotive industry as an example in everything, because in terms of regulation and technological criteria, it is different. However, what Elon Musk did in the automotive industry was bringing the right people together, and he thinks that that is in fact something valuable for the aviation industry as well. The comparison with the automotive industry was made more often. Both industries concern transportation and both pursuing a more sustainable future, however regulation of the aviation industry was among the biggest differences that were identified. Aviation is strictly regulated to ensure a high level of safety and reliability; it is unlike the norm in the automotive industry and poses several challenges for aviation that the automotive industry faces in lesser severity during their transition towards electric vehicles.

Jacob Verhaart from the AUAS points out that one of the main things the aviation industry can gain from collaboration with the automotive industry is the acquisition of knowledge. He notes that especially in terms of battery development and utilization there are great similarities, and the automotive industry is currently ahead in its efforts. He points out that the technology remains the same and that the knowledge can be shared across industries. Automotive does not have an issue with the volume, weight, or lifecycle of batteries, but it needs to be cheap, aviation is more high-end. However, Jacob points out that there is another thing that was observed in the automotive industry, which the aviation sector and particularly startups can learn from. It is setting an example, someone being the first. In the automotive industry, Tesla was practically the first company to be bold and ambitious in their pursuit of bringing electric vehicles to the market. They demonstrated that it can be done. Jacob describes the naturally hesitant attitude of the aviation industry and points out that startups could play a valuable role in inspiring optimism. He explains that someone needs to demonstrate that this is possible, and startups are in a good position to do so, to take risks even when they have other obstacles to overcome. Andrea Luebke mentioned this exemplary role that organizations can play as well. She said: “We feel that at MTU we are responsible for setting an example and being ambitious. It’s good to be ambitious! But we are also inspired by other companies.” She, in turn, mentions the Airbus ZEROe project as an initiative that is inspiring to them. Airbus ZEROe is a project developing three sustainable aircraft designs. (Airbus, 2023) Karel Bockstael mainly sees an example in the automotive industry in terms of leadership. He feels like the aviation industry needs a strong leader to set the tone, be an example, and show courage. According to Reynard de Vries, the automotive industry has set some good examples but there are also major differences that cannot be overlooked. He states that the automotive industry has first and foremost demonstrated that disruption is possible. He also said that: “*You should not try to implement a new technology in the existing way of doing things, you should change the system in order to use these technologies.*” This is something that the automotive industry is demonstrating.

Arlette van der Veer goes on to define mindset as one of the greatest obstacles in the aviation industry, not just in sustainable change but in innovation in general. As Radical Innovations Manager at KLM,

she is constantly involved in the development and implementation of innovations, but she is often met with skepticism. She mentions that in her experience, people often tend to talk about all the problems, but not the solutions. Also in investment organizations, such as Groei Fonds, she sees that conflicting interests between stakeholders get in the way of investing in promising innovation.

Jolanda Stevens speaks of a related topic when she mentions courage as something that is needed in the industry. She said the following: *“I think that we need a bit of courage. Courage from the existing players, such as KLM, but also from other companies. Courage to dare say: We are just going to do it. We are going to see what we can achieve together. This is daunting because they are a new group of people, whom you don’t know and who don’t have a 100-year-long track record. It is a matter of researching who you will be collaborating with and what kind of people they are. That requires a bit of courage. Finding that courage can take time. Within KLM, I see that that courage is certainly there.”* Reynard de Vries also mentioned courage, he stated the following: *“It has given hope, maybe even too much hope. There are startups that are claiming ridiculous things. Which is frustrating and has a polarizing effect on the population. However, it does inspire courage and shows that change is possible.”* Additionally, he goes on to mention money and time as the bottlenecks in the industry. Like any industry, he points out that aviation is driven by financial interest. New technologies need to be financially attractive to take into service and those technologies simply require time to not only be developed but to be certified. He stated the following in this regard: *“Time, in the sense that you do research, you increase the TRL, you do a small demonstrator, you get funding, you are already a few years along. Eventually, you will need to get certified and that takes a while. You cannot accelerate that by putting more money into it. Assembling a supply chain and production also takes time. With more money, you can do some steps simultaneously, but you will still not be able to get a new aircraft on the market within 5 years.”* Reynard de Vries also expressed how he believes consumer behavior should change in the pursuit of sustainable air mobility but contrasted this thought by focusing on the broader picture. Firstly, he stated the following: *“When you look at the aviation sector, we have always kept growing and improving efficiency. However, the growth has always been faster than the improvements in efficiency. Hence, the impact has continuously been growing.”* Baptiste Arribe brings up a similar point and stated the following: *“I am not sure that there is a business model change that will drastically lower the emissions of aviation. That is why I quit the industry. The scale of change that is needed is beyond what is achievable.”* He expresses that he sees the reduction of air mobility as an inevitable part of the solution. Additionally, he also made the following statement: *“All the means of reducing emissions are good, even flying less. Simply using less of everything.”* Karel Bockstael partly reciprocates those feelings and adds that he has his concerns about the short-distance, regional flights that are being proposed as part of the new business models. He feels that this new emerging form of transportation is not challenging the real problem of aviation, but rather adding to it. According to him, it will put an even greater strain on the already high energy demands on the aviation industry and it will

require scarce supplies of green energy. He states the following regarding the nature of the aviation industry towards change, which is important to keep in mind: *“The aviation industry is a slow improver. Everything goes step by step, because it has to be safe, it cannot be too expensive, we cannot lose passengers, it has to be international, and competition is growing. For those reasons, everything goes quite slowly, and it actually goes too slowly according to what the boundaries of our planet are indicating. We need to go toward radical change and I think we need startups for that.”* He also makes the following statement about the attitude of the industry: *“I find the aviation industry an incredibly closed system. They consciously keep innovation out. Very defensive and a strong lobby.”* Lastly, he brings up Jevons Paradox, to illustrate why the aviation industry’s emissions have been steadily growing: *“Jevons Paradox states that efficiency always leads to more emissions and more consumption. More efficiency makes a product cheaper, which in turn makes it more attractive to the consumer. Hence, you sell more, you generate more revenue, and you emit more. That is essentially what drives the aviation industry as well.”*

Reynard de Vries agreed that 9-seater, short-distance aircraft might be a niche in the aviation sector but implementing these innovations also has an exemplary and developmental role. He thinks that it is important to use these technologies, in order to gain knowledge and experience so that they can be further developed and eventually grow and be applied to larger aircraft. He recognized that this is a necessary first step in a long-term perspective on sustainable air travel. In terms of consumer behavior, he also emphasizes that there is another part of the picture that should be taken into account. He makes the following two statements: *“Aviation accounts for maybe 2% of all emissions, but it is always the same people. Maybe we should be flying less but we cannot say that all the worldwide aviation should decrease.”* & *“We cannot expect the whole world to change their behavior. That is unfortunate, but not realistic. Technological change is hard, but societal change is even harder.”*

4.5. Law and regulation

When discussing challenges that the aviation industry and startups in particular face in the pursuit of sustainable air mobility, regulations, and the difficulty with certification often come up. Strict regulation is a major topic that characterizes the aviation industry. Additionally, the role of government and legislators was often discussed during the interviews.

On this topic, Nando van Arnhem says the following: *“Certification is not something ‘to deal with’, but rather a guideline to follow. There is no shortcut and there should not be, because you are developing an aircraft that will transport many people. The process that is currently in place for certification is there for a reason. We should not see it as a restraint but rather as a guideline.”* Carlos

Ilário made a similar remark when initially asked what the needed to change in the industry in order to become sustainable. He countered by challenging the question ‘What should change?’ and felt it is more critical to start by asking ‘What cannot change?’. The answer is safety. He takes safety as point zero, it is nonnegotiable. What then needs to change in the industry more concretely according to him, depends strongly on the route (technology) that is chosen. However, all three routes (SAF, electrification, hydrogen) will require a large investment in infrastructural changes and the development of global-scale production. SAF is already an accessible alternative, but there is simply not a large-scale production of it. There are also not many places where green hydrogen can be produced, and green electricity is not in abundance yet either. The development of these streams of energy production requires time and a lot of money. Philip Idestrom made a similar remark and stated the following: *“The requirements are so high and I’m happy that that is the case, but it does make it sometimes difficult to introduce new technologies. Well, it takes time. You need to prove that it works on many different levels and that is completely natural.”*

Arlette van der Veer mentions that certification is one of the first topics she brings up in conversations with startups. She stated the following *“Certification and the difficulty of it, is the most complex innovation topic in our industry. So, the problem is in the mindset. Whether you have organized it well or not, certification will always be there. Hence, it is a matter of thinking: With what things can we start?”* She pointed out that many startups do not understand that designing and producing even simple parts intended to be installed in an aircraft, is not very straightforward. In order to be able to do so, EASA assigns DOAs (Design Organization Approval) and POAs (Production Organization Approvals). A company like KLM is not allowed to produce anything that will end up in an aircraft. She explains that new technologies can however be tested on a different scale, for example in non-flight-critical components.

Rob Koedijk illustrates the level of regulation in the aviation industry as follows: *“In aviation, nothing is allowed unless it is described. You can only describe it if it is in the law. You see that this entire chain of regulation is behind on the technological developments.”* Karel Bockstael elaborates on this and explains the aviation industry has to make a joint decision to become more sustainable because sustainable air travel will inevitably become more expensive and possibly less efficient. He believes that government should put pressure on the industry to change. Reynard de Vries also agrees that the government should play an active role in urging the aviation industry to embrace sustainability. He believes that there should be incentives that make it cheaper to fly sustainably or more expensive not to. He points out that like any industry aviation is driven by money. Every party is looking to stay competitive and as long as it is not financially possible to make the transition towards sustainable air travel, the industry will not change by itself. Arlette van der Veer mentioned this as well. She recognizes that the industry should change as a whole, but external pressure is required to make this happen.

Reynard de Vries does add that he believes that once it is demonstrated that sustainable air travel is technically possible and a feasible alternative, that governments, especially in Western countries will be inclined to start doing this. Andrea Luebke also brings up the role of government and legislators in this transition. She tells us that at MTU they are working on several initiatives to increase the Technology Readiness Level (TRL) of sustainable innovations. One of these projects is the Clean Air Engine (CLAIR). (MTU Aero Engines, 2023) She furthermore, explains the motivation behind MTU's proactive approach to sustainable and that they take climate change very seriously. MTU Aero strongly believes in the role of regulators in the transition of the aviation industry toward sustainable air mobility. They expect that society will at some point in time, force regulators to push out the current technology. And they want to have an answer for how to make aviation sustainable by then. Otherwise, they see a risk of being pushed out of the market. She further elaborates on this by explaining that especially at the beginning of this transition, regulators should incentivize the uptake of new technologies, with regulations about CO_2 and NO_x emissions, as well as contrails resulting from engine operations. She also explains that for an incumbent firm like MTU, the process of certification is easier, mainly because they have many longstanding relationships with authorities worldwide, and they have an extensive network at their disposal. She stated the following: *“We already have an established relationship with the authorities and therefor it is easier for us to go into discussions about what is needed and how we can set it up, or what is important to do so. The most important part of that is that we have those connections, not only with the authorities within our country but also with the overall European authority and the FAA in de US. So, we basically have a worldwide network of authorities to talk to. Whilst a small startup probably starts with one of these.”*

5. Analysis

In the literature review, a number of topics were discussed, which all were confirmed and elaborated on in the interviews. The topics include the aviation industry as a socio-technical system, radical innovation, the theory of dominant design, and the innovation ecosystem. In this chapter, the connection between the empirical findings and the literature review will be explored and the empirical findings will be further interpreted.

Many of the interviewees emphasized the importance of approaching the aviation industry as a system of interconnected and codependent elements. Jolanda Stevens mentioned in the interview that all actors in the industry are bound together, and an airline like KLM depends on a number of other players when it comes to realizing this transition toward sustainable air mobility. She also highlighted the importance of this when discussing the viability study that they are conducting. In this regard, she stated the following: *“It is a very important milestone because that study does not just include the options, but also the risks involved, the uncertainty, the match between what is emerging in the market and how that fits with us as a company. What can we do? What are we doing now? How does that fit together? And if we have/want to do something new, how would that fit in our organization?”* Taking into account the socio-technical changes in the aviation industry, Carlos Ilário also mentioned the opportunity that this presents in the aviation supply chain. He stated the following: *“I think that with the new technology, they open a new degree of freedom. Not only for the design of the aircraft that we are used to but now we can really think out of the box. I do see this as a possibility to disrupt the model and the supply chain. If you look at the current supply chain for aeronautics, there is a natural oligopoly. There is a huge technology barrier. It’s a massive investment that is necessary, so this technological change brings opportunities for new entrants. This is very good for startups; they can find their way and their right to play in this new market. I think that it will change the business model of the entire industry.”* In terms of taking into account the entire socio-technical network, he also stated the following: *“It’s not only on the technology side. It is the technology, the cost, the safety, certification, regulation, infrastructure, availability, and so on. Everything needs to be considered when we are talking about developing a new aircraft.”* This quote highlights the importance of considering all the implications of introducing new technology into the industry, and what aspects need to be considered in order to potentially achieve success in such an endeavor. (Geels, Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study, 2002) Tristan Oppeneer also related to this topic, when describing what NRG2Fly aims to do when working on the infrastructure of electrical aviation. He stated the following: *“It all starts with a large electric aircraft. That is where the main focus lies, also for startups. Yet, it is often forgotten that the regulations around that, the operations at the airports, the charging-infrastructure, and all those kinds of matters also need to be accounted for.”* Philip Ideström also mentioned this and emphasized that it takes more than one organization to develop a new

aircraft. Lastly, Baptiste Arribe, made the same connection, when talking about the consumer behavior that needs to change, in order for sustainable air mobility to be successful. He stated the following: *“Startups are part of the solution, but as long as the solution is not only technological but also in the way we consume, they are not the only solution.”*

Most of the interviewees pointed out that startups can play a role in different elements of the system and that startups who are entering the OEM field should pay attention to the implications that their innovations have on the broader system. Andrea Luebke states in the interview that changing the industry is not only about adopting the right technology but about all the related supporting capabilities that that technology requires. Arlette van der Veer also highlights in the interview that the industry as a whole is required to change in order to constitute a meaningful change and reach ambitious sustainability goals. They all take into account not only the introduction of new technologies but the need for the socio-technical system to change. This is illustrated by the changes that they discussed in terms of the business model and in terms of industrial prerequisites. All of which relate to the socio-technical system around the technologies, rather than the technologies themselves. (Geels, Co-evolutionary and multi-level dynamics in transitions: The transformation of aviation systems and the shift from propeller to turbojet, 2006) Reynard de Vries also emphasized this when he stated the following: *“You have to think differently. You should not try applying new technology to the current way of doing things. You have to look at how the system should change in order for the new technology to be used well.”* He also remarked something significant regarding knowledge that relates to what Arlette van der Veer later refers to as the Ecosystem of Intellectual Properties. Reynard de Vries stated the following: *“Scientific research is supposed to be broad and vague; it does not have to have a direct application. Scientific research often looks at what happens if we work with one minor thing. You might never need that one minor thing again, or in 20 years’ time, the knowledge of that one minor thing could be of value for another project.”* This concept of having the value of money change according to its application was also mentioned by Arlette van der Veer when she discussed the ecosystem of innovation. She first discusses the innovation ecosystem of KLM which she orchestrates. In this regard, she stated the following: *“KLM’s innovation ecosystem, is the internal and external network of innovators that we interact with. Whether that interaction is commercial, E&M, or passenger services. The goal is mainly to share knowledge and expertise. You often see that, in research on the future of aviation, many things are done double, but when the ecosystem is aligned properly, this occurs less frequently.”* She also discusses the potential of an industry-wide innovation ecosystem in which firms would be able to share their knowledge in return for a ‘token’ that can fluctuate in value. This is required because not one manufacturer is going to be able to design the most sustainable aircraft alone, collaboration is required. But organizations should be assured that their knowledge if applied to a product, will be priced according to the value that it adds. She described this as the fastest way to a sustainable solution for air mobility. She stated the following in this regard: *“Ecosystem Intellectual*

Property. Statistically speaking, one aircraft manufacturer will not come up with the most sustainable aircraft. If this ecosystem would exist, and if every input that a party contributes can fluctuate in value, that you would get a token for that, then you have a chance at designing the most sustainable aircraft.” These remarks are in line with how Isenberg described the entrepreneurial ecosystem and the benefits thereof, as was discussed in the literature review. (Isenberg, 2010)

From the empirical findings, it became clear that radical innovation was a term commonly used by the interviewees. It was the word that many interviewees used to describe the level of innovation that is required for the aviation industry to transition. Karel Bockstael stated that: *“Although incumbents are already realizing incremental innovation, startups are needed to initiate radical change in the industry.”* Not only did the majority of interviewees state radical innovation as what was needed in the industry, but most also agreed that startups are necessary for implementing radical change. Since radical change is the replacement of technology and the value chain, it seems most logical to assume that such innovation will come from a startup. Additionally, all the points that interviewees mentioned as value-adding characteristics of startups, contribute to this task of bringing radical innovation to the market. However, Andrea Luebke also pointed out that incumbents are making great efforts in innovating, and they are certainly needed for putting the proposed technologies into practice. Their strategy is in part, to scout for startups that develop technology that is complimentary to what they are working on, in order to then collaborate and potentially acquire that startup. The need for radical innovation that was described by the interviewees can be explained with how Rohacs described radical innovation and the necessity thereof, which was discussed in the literature review. (Rohacs, 2023)

When discussing the different routes of innovation, the theory of dominant design sometimes came up. On the development of the three pillars of sustainable technology in air mobility, Carlos Ilário states the following: *“There is not one solution. We need to look for all the possibilities. You can have a different optimum depending on the mission. It’s not just about the fuel and energy that a vehicle runs on. The vehicle and the mission will determine the best solution. This depends not just on the technology, but on costs, safety, certification, and regulation. Infrastructure, availability, and so on.”* In this quote, Carlos Ilário very accurately describes the theory of dominant design in the aviation industry. Nando van Arnhem gets to a similar point when talking about manpower and the shortage thereof in the industry. He stated the following: *“What we currently see is that there are many players. There are many small startups, but the actual number of people that can help in this development is simply limited. There are only so many people currently available, who are looking for work and have the expertise. So, you cannot come to a scenario in which a few hundred players are successful. If there will be a few who become successful, and they bring the right people together, then it is mostly about that.”* Reynard de Vries made a very similar statement during the interview when describing the anticipated bottleneck as a lack of sufficient trained technical personnel in the industry. Rob Koedijk related this same

phenomenon to what happened in the aviation industry when it first started out. In the beginning, there were also many different companies building aircraft and nowadays there are only a few major actors and most aircraft conform to the dominant design that resulted from that conversion. He stated the following: *“I like to compare it with what happened in the aviation industry before the first world war. Back then, there were also a lot of startups, or rather just people who thought they could build an airplane in their garage. What happened then was basically a Double Diamond effect. In a short period of time, a lot of parties emerged wanting to build something and if you look at what remains now on the big market, it is a very small part of that. We will see that same convergence in this situation as well.”* These phenomena and expectations are in line with what Unruh described with regards to the dominant design theory, which was discussed in the literature review. (Unruh, 2000) Rob Koedijk does however add that the industrial climate has changed significantly since then. The level of safety and reliability has reached a level that makes it hard for new entrants to test their technologies. Karel Bockstael also mentioned this and said that the aviation industry has worked itself into a tight spot, through years of improvement and regulatory involvement. Its level of safety is one of aviation’s greatest assets, but in aviation, there is no room for experimentation.

6. Discussion

This chapter formulates the answers to the posed research questions, discussed the contributions of this research, and finally offers some suggestions for future research, based on the empirical findings and analysis.

Research question 1: *Why are startups necessary in the transition of the aviation industry toward sustainable air mobility?*

Startups are necessary for the transition of the aviation industry toward sustainable air mobility because they are in a good position to introduce the radical innovation that such a transition requires. Their value lies mainly in their faster pace due to less bureaucracy, the diverse perspective that they offer both in management and innovation, as well as a greater degree of freedom to take risks, and a culture that facilitates change. These are all characteristics that are required for change, but which incumbent firms struggle with. Incumbent firms collaborate with startups to varying degrees. Numerous of them invest in startups with venture capital, others collaborate with startups in the development of new designs, and many incumbent firms chose to merge with or acquire startups when they develop a technology that is complementary to their business. However, as long as the aviation industry is considered as a socio-technical system, startups are not only necessary for introducing radical innovation but for proposing business model innovation. Changing the business models of actors in the aviation industry during this transition toward a sustainable future was described as inevitable. Changes will occur in the product that is offered to the customer as well as in the supply chains. This is because the sustainable technology will (at least at first) be more expensive to use than what customers are used to, and the technology is currently most suitable for short-haul regional flights. This will likely change the networks of flight routes that operators offer. These changes great opportunity for new entrants to take up a place in the supply chain of the new technology or in the supporting capabilities, such as the infrastructure.

Research question 2: *What are the main industrial prerequisites and challenges that startups face in pursuit of sustainable air mobility?*

The main industrial prerequisites for meaningful and sustainable change in the aviation industry were identified as infrastructure to support the new technology, production energy, mindset of the actors in the industry, and manpower. Infrastructure relates to the supporting capabilities that need to be developed in order for the technology to be taken into use. It was pointed out that especially for hydrogen and battery-powered propulsion, significant changes need to be made to the existing infrastructure. Energy production takes different forms, depending on the route that will be chosen as

the dominant design. For alternative fuel in the existing technology, there needs to be an upscale of the production of SAF. For the electrification of aircraft, there needs to be more production of green electricity. For hydrogen-powered fuel cells, there needs to be more opportunities for the production of green hydrogen. The general mindset in the industry relates to the discrepancy that is observed in the industry being both conservative and hesitant to change, but historically also pioneering and innovative. Manpower is perceived as a major potential bottleneck in the transformation of the industry toward a sustainable future. At the moment there is already a lack of trained and certified technical personnel, and the new technologies will additionally also require new capabilities that need to be trained.

Regulation and certification are a topic that strongly defines the aviation industry and that is a challenge for startups. It was made clear that this is not an obstacle, but rather a guideline, a nonnegotiable element in the development of aircraft technology. Startups are not certified to design or produce for the aviation industry, and this presents an opportunity for them to seek help from incumbents who do have the applicable certifications.

The main research question: *How can startups initiate meaningful change in the transition of the aviation industry toward sustainable air mobility and what does their role in this transition entail?*

Startups can initiate meaningful change in the transition of the aviation industry toward sustainable air mobility by introducing radical innovation and making an effort to also affect the socio-technical environment of the industry. Collaboration with an incumbent firm helps to overcome some of the challenges, especially the ones related to certification and testing of the product. The role of startups in this transition should entail being bold and ambitious, demonstrating that sustainable air mobility is possible. Besides introducing radically innovative technology, they should propose new business models that suit this technology, as well as pay attention to the infrastructure and supporting capabilities that the use of the new technology requires.

The contributions of this research include an addition to the body of knowledge. Providing insight into the role of startups in the aviation industry and the role of startups in this transition toward sustainable air mobility. The contributions also include insights on the managerial level, mainly in terms of the collaboration between startups and incumbent firms and the position/opportunity for startups in the value-chain of sustainable aviation.

Suggestions for future research:

- The perspective of the airport in this transition, especially on the challenges associated with the infrastructure of new technologies. Airports have intentionally been left out of this research. The question of infrastructure and with it the perspective of airports would be incredibly relevant and valuable to include in future research.
- A historical study on legislation in the aviation industry. It was pointed out in the literature review, as well as in the analysis that the aviation industry has a pioneering nature from its origins. At the rise of the industry, there was also trial, error, and innovation. It would be interesting to thoroughly analyze how the industry went through those developments and how it came to the standards that it is at currently. Interesting would be to see what can be learned from the past.
- Opportunities in cargo aviation for startups. Over the course of the research, it became prevalent that most of the startups proposing new aircraft configurations and/or new modes of propulsion, market this for the transportation of passengers. Some did not specify, but it was unheard of that startup purposefully targeted the cargo industry as their main market. It would be interesting to see if the adoption of new technologies in sustainable air mobility might even be easier to realize in the cargo industry, as opposed to passenger transportation.
- The supply chain of OEMs and the production of various types of green energy/fuel were identified as major industrial prerequisites for successful and sustainable change. Further research is required to identify how these elements can be developed and potentially also the role of startups therein.
- A longitudinal study of the aviation industry and its pursuit of sustainable air mobility. Due to the limited time that was available, this research was designed as a cross-sectional study. However, a longitudinal study could uncover other elements that play a role in the transition of the industry and the role of startups. Especially now that startups are becoming more and more involved in the industry.

7. Conclusion

This chapter provides an overview of what has been done and the choices that have been made in the research process, along with the highlights of the empirical findings, the main takeaways from the analysis, and a conclusion on the research questions that were discussed.

This thesis documented qualitative research on the role of startups in the transition of the aviation industry toward sustainable air mobility. It is exploratory research that relied mainly on primary data from semi-structured interviews with professionals from different parts of the aviation industry. The choice for this approach was made because it was most suitable for the nature and context of the research. In total 12 interviews were conducted, representing most of the relevant actors in the industry's transition. Secondary sources have been consulted to substantiate the primary data and to conduct a literature review of the existing body of knowledge.

From the analysis and the empirical findings, it became apparent that the value and necessity of startups are recognized by the industry with regard to the transition toward sustainable air mobility. Startups are expected to bring radical innovation to the sector and their main value-adding characteristics include a diverse perspective and management style, less bureaucracy resulting in a faster pace, a culture that facilitates innovation, and the freedom to take risks and reinvent themselves when making mistakes. The collaboration between startups presented itself in many different forms, but in general, it was agreed upon that combining the strengths of startups with the experience, expertise, and established order of incumbent firms gives a win-win situation. The industry faces many challenges in the transition toward a sustainable future, besides developing effective sustainable technology, the infrastructure and energy production needs to be able to support this. Additionally, the mindset in the industry needs to become more open to sharing ideas and the threat of a lack of manpower should be addressed before it becomes a major bottleneck. Startups experience many challenges connected to the certification of their product and this is an aspect in which collaboration with incumbent firms can provide assistance. Lastly, it can be concluded that with the transition of the industry, business models in all different branches will adapt to it. It will have a significant impact on the supply chain of OEMs as well as the networks operated by airlines. Startups can make use of the changing supply chain by filling the gaps that this creates and utilize the changing network structure to serve a segment of the market that becomes available.

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Appendices

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I. Interview Andrea Luebke

Interviewee: Andrea Luebke (AL)

Interviewer: Marilot Molewijk (MM)

Company: MTU Aero Engines

Position: Senior Vice President Corporate Strategy

Date and time: May 3rd, 2023, 18:00-18:30

Location: Microsoft Teams

Transcript available upon request.

Abstract:

Andrea Luebke explains MTU's view of the future and why that has urged to company to invest in their CLAIR project. She states the following: *"We strongly believe that our society will force regulators at some point in time to push out our current technology. If we don't have an answer from a product and technology perspective, on how to make aviation sustainable, we see a risk to be pushed out of the market."* She elaborates by explaining that this is driven by society and based on all the discussions happening around the world regarding climate change and global warming. MTU believes that government will play a major role in this transition, by setting regulations with regard to CO2 emissions, NOx emissions, and contrails.

At MTU they recognize the importance of collaboration and Andrea Luebke points out that she expects many players to join the initiative, including companies from other industries. An industry that was discussed in this regard was the automotive industry, due to their pursuit of EVs. When asked whether the aviation industry can learn something from the electrification of the automotive industry, Andrea Luebke stated the following: *"The most important thing is that you need to move yourself and not wait for Tesla to move you. The question 'How much are you involved in new technologies?', is definitely important. In order to not be too disrupted by external influences, and if you would like to keep your business model." ... "The second thing is the importance of infrastructure. That is what we definitely try to get a better understanding of, based on automotive. This is even a bit more complicated with regard to planes because you need a less distributed infrastructure, but that comes with a benefit and with a disadvantage at the same time."* In this comparison, she mentions two important things; the anticipated challenge to keep an existing business model, and the difficulty of building an infrastructure that supports the alternative technology. Andrea Luebke expects that business models through out the industry will inevitably change with this transition, however, she does not expect any significant changes in MTU's business model before 2050, because the currently proposed technology is not

concerning their main market. When asked whether she believes some players in the industry will eventually be replaced by startups, with the changing of the business models, she replied with the following statement: *“Yes, there will be some industry players that will be replaced at some point in time. I am a bit reluctant because as the aviation business model and the aviation product life cycle is up to 40 years, we will probably see that happening much slower than we see it in automotive for example.”* In terms of infrastructure, Andrea Luebke goes on to identify this as one of the many challenges that the industry is facing in pursuit of sustainable air mobility. She continues to point out two other major challenges, in the following statement: *“The second thing is production, which is needed for SAF as well as for full hydrogen power technology. Last but not least, a common understanding among aircraft passengers, cargo customers, the airline industry, and ourselves, because at least at the beginning, those flights will be more expensive. Today we try to reduce costs massively and airlines offer tickets for 30 euros to fly from Hamburg to Madrid. That probably would not be possible if we need to invest in all those infrastructure and hydrogen production facilities.”*

In terms of collaboration and involvement with elements of the aircraft, other than the engine, Andrea Luebke explains that MTU is involved in a clean aviation project, which focusses on applying for European funding. Later on, she explains that this is also one of the occasions where they collaborate with small to medium-sized companies because they need to be included in such applications. Besides this example, she elaborates by explaining that adjustments to, for example, the airframe, are part of their technology roadmap, but not their focus. She highlights the importance of being part of the discussion and having synergy within the technology development. When asked about MTU’s collaboration with startups, she explains that it is at the moment somewhat limited, but they recently bought a startup, which is something they would be interested in doing more often in the future. She states the following in this regard: *“If we see startups that can produce products that either support the technology itself or - and that is probably even more significant - that supports the processes to accelerate the technology development, than we think about approaching those startups first with a cooperation and if it makes sense for us than later on also by being able to do mergers or acquisitions.”* In terms of collaborating with startups, the point of certification came up. Andrea Luebke elaborates on the benefits incumbents first have in this process as apposed to startups. She remarked the following on the topic: *“We already have an established relationship with the authorities and therefor it is easier for us to go into discussions about what is needed and how we can set it up, or what is important to do so. The most important part of that is that we have those connections, not only with the authorities within our country but also with the overall European authority and the FAA in de US. So, we basically have a worldwide network of authorities to talk to. Whilst a small startup probably starts with one of these.”*

When asked whether or not startups are necessary for realizing this transition in the industry, Andrea Luebke addresses points out that they might not be necessary from an MTU perspective, but they do

present certain benefits. She explains this in the following statement: *“I think MTU itself and our official answer would be that we definitely see ourselves being very innovative and being also a front runner in developing these new technologies, therefore it is not necessary to have a startup. My personal view on that is, nevertheless, working with startups probably makes us even faster and gives us the opportunity to come up with a bit more diverse thinking which can also be helpful. The startup is more the diversity factor, rather than that we really need their innovative ideas.”* Besides a diverse perspective, she mentioned the agile way of working as another thing that incumbent firms can learn from startups.

II. Interview Arlette van der Veer

Interviewee: Arlette van der Veer (AV)

Interviewer: Marilot Molewijk (MM)

Company: KLM Royal Dutch Airlines

Position: Senior Manager Radical Innovation

Date and time: April 5th, 2023, 11:00-12:00

Location: KLM Headquarters, Amstelveen

Transcript available upon request.

Abstract:

Arlette van der Veer shares some insights about her job and here responsibility for orchestrating KLM's innovation ecosystem. She explains this ecosystem in the following quote: *“KLM's innovation ecosystem, is the internal and external network of innovators that we interact with. Whether that interaction is commercial, E&M, or passenger services. The goal is mainly to share knowledge and expertise. You often see that, in research on the future of aviation, many things are done double, but when the ecosystem is aligned properly, this occurs less frequently.”*

When discussing KLM's collaborations with startups, Arlette van der Veer mentions KLM's investment fund, which exists since 2014. She explains that there are a number of partners involved in this fund, such as KLM, but also Schiphol Airport, and others. These partners make a commitment to investing a certain amount of money over a certain period of time. The fund managers are then responsible for investing that money according to the criteria. She remarks that it sometimes occurs that in such a fund there are conflicting interests.

In terms of challenges faced by startups in pursuit of sustainable air mobility, the first thing Arlette van der Veer mentions is certification. She explains that the industry is strictly regulated and that for example, KLM has a DOA, meaning that they are certified to maintain, modify, and repair, but not to produce anything that ends up in and aircraft. A limitation that can have a suffocating effect on innovation. She points out that they are often in discussion with startups, who propose new technologies and want KLM to 'add' them to their aircraft, but it is sometimes hard for them to understand that KLM is certainly not allowed to do that in the majority of cases. She elaborates by explaining, in contrast to for example the automotive industry, the number of certified suppliers in the aviation industry is relatively very low. She explains that in the collaboration between airlines and startups, she often hears arguments like “You won't get the product certified. It is hard and OEMs often don't want to work with startups”. She points out that those kinds of arguments stand in the way of innovation, and it is a matter

of mindset. She states the following: *“Certification and the difficulty of it, is the most complex innovation topic in our industry. So, the problem is in the mindset. Whether you have organized it well or not, certification will always be there. Hence, it is a matter of thinking: With what things can we start?”* In terms of mindset, Arlette van der Veer also remarks that, in the aviation industry there is a certain hesitation toward sharing unfinished projects, that people only want to show things to the world when they have already figured it out. She elaborates on this and explains that in pursuit of ‘the most sustainable aircraft’, this is detrimental because not one organization will be able to design ‘the most sustainable aircraft’ alone. To tackle this problem, she proposes the following: *“Ecosystem Intellectual Property. Statistically speaking, one aircraft manufacturer will not come up with the most sustainable aircraft.”* ... *“If this ecosystem would exist, and if every input that a party contributes can fluctuate in value, that you would get a token for that, then you have a chance at designing the most sustainable aircraft.”* This concept would rely on the idea that you can cut knowledge into small pieces and each of those pieces can be worth something based on its contribution to any project.

Another topic that is discussed with regard to the value of startups, is their diversity. When asked whether she believes startups urge incumbents to become more diverse, when they collaborate, she stated the following: *“Yes, I even believe that startups could do ‘reverse mentoring’ for corporate. In the sense that in that case, the mentor would not be the senior for a change. That the senior would be coached by a startup, in order to show that it is in fact 2023, the world is changing and in this way, it can work too.”*

Arlette van der Veer explains that this transition relies heavily on incumbent firms and how well they take in knowledge. She remarks that it is like changing the course of a large ship. It goes slowly, but as sustainability is take a more prominent role in corporate strategy, it is definitely moving in the right direction.

III. Interview Baptiste Arribe

Interviewee: Baptiste Arribe (BA)

Interviewer: Marilot Molewijk (MM)

Company: Safran, SeaBubbles, Self-employed

Date and time: April 25th, 2023, 15:00-15:30

Location: Zoom

Transcript available upon request.

Abstract:

Baptiste Arribe talks about how he was involved in creating a corporate startup at Safran and later on, resigned to join a startup in water mobility. When asked about the differences he experienced between working in a corporate startup setting and working in a ‘regular startup’, he stated the following: *“The aim is different. The growth of the startup was not critical for Safran’s success or survival. Whereas for people in a regular startup, it certainly is. Additionally, we were backed by Safran as a big company. So, it was calmer.”* He goes on to elaborate that the competencies he worked with from the position of a corporate startup were different, as it was part of the Safran ecosystem. He adds that the corporate-startup was very people-oriented in the sense that much depended on who the manager was. In contrast, he says: *“In startups, when there is business and hope, there are people to help you.”* When asked about the corporate startups versus the merger with, or acquisition of startups. Baptiste Arribe stated: *“I think the most efficient system is buying startups. Finding the right ones and buying the ones that are mature.”* He explains that in the corporate-startup he was involved in they did learn a lot and change a lot, thanks to the specific atmosphere and ecosystem at that moment. However, generally speaking, a large existing organization, requires a change of mindset in order to be market-oriented and user-experience-oriented.

When discussing the necessity of startups in this specific transition, Baptiste Arribe points to the socio-technical system in which technologies take place. He states: *“Startups are part of the solution, but as long as the solution is not only technological but also in the way we consume, they are not the only solution.”* He elaborates by explaining that, he believes startups are necessary, but technology is not the only part of the solution that is relevant as it is part of a more complex system. He adds: *“We can imagine startups with something other than technology. Business model innovation, rather than purely technology innovation.”* As another part of the solution, consumer behavior is brought up as a point of discussion. Baptiste Arribe states: *“All the means of reducing emissions are good, even flying less. Simply using less of everything.”* He, however, does not believe that there is a business model change

that will drastically lower aviation emissions. He added the following: *“There are things to gain in the aeronautical industry, but the scale of change that is needed is beyond what is achievable.”* He means this in a general sense. He elaborates with some examples, explaining that if pursuing hydrogen it would require nuclear power stations everywhere, and batteries might be worse, whilst also not allowing a wide range. He also discusses SAF and explains that the production of SAF uses crops that would otherwise be used for food production. He says: *“If we collectively make a choice, maybe we prefer to eat, rather than fly. So, to me, it is more about what is really needed to live.”*

Baptiste shares his pessimism about the industry's capacity to change. He brings up a number of changes that would be necessary for sustainable air mobility but states the following: *“I am not very confident that the aircraft industry can change as much as it needs to in order to be able to grow as planned and lower the carbon footprint.”* He goes on to explain that additionally, there is a lack of green energy sources and once that would be established there is a competition of usage. He also points out that this is not an issue that the aviation industry faces alone. Sharing resources is a current topic in nearly all industries.

IV. Interview Carlos Roberto Ilário Da Silva

Interviewee: Carlos Roberto Ilário Da Silva (CI)

Interviewer: Marilot Molewijk (MM)

Company: Embraer

Position: Head of Zero Emissions

Date and time: May 5th, 2023, 13:50-14:10

Location: Zoom

Transcript available upon request.

Abstract:

Carlos Ilário explains that at Embraer they work in innovation verticals, the responsibility of which is to focus investments and to create the path and the roadmap for future applications. He leads the zero-emission vertical and describes his job as follows: *“I have mainly two responsibilities. The first one is very much related to technology roadmap, research, and technology. basically, I need to guarantee that we are investing in the correct projects so that when the time comes, we will be ready to have the capabilities and the TRL, to apply these technologies to the new products. My second job responsibility is to really develop strategic partnerships and to come up with new business opportunities related to zero emission.”* He elaborates on this by explaining that the projects in which the company invests are determined based on the priorities of the company, which are continuously being revisited, and projects should be in line with the strategic plan of Embraer to be equipped for the future of aviation. He highlights that in order to be ready for this future, whether it comes in 10, 15, or 20 years, you need to start now.

When asked about the collaboration that Embraer is currently involved in, in terms of sustainability, Carlos Ilário there are countless, he states the following: *“We really see the need for collaboration, especially when it comes to new technologies and developing safe aviation. Collaboration is key and we have an excellent history of collaborating. In everything that we do, the first thing that we look at is whether we can do it together.”* He explains that they have partnerships with universities, research centers, and private companies, to name a few. With regards to startups, he points out that Embraer has venture capital, and that last year they organized I startup day, which contributed to the Energia project. He sees the value of collaborating with startups and describes these benefits as follows: *“startups bring a fast pace. They are fast, they need to do things fast, and they don’t have a lot of bureaucracy, so things usually go fast. They can make mistakes, quicker. Then it is easier for them to reinvent themselves. If you look at a big company, big companies have a big bureaucracy, so it is not as fast as a startup. It is*

difficult for us to make mistakes. On the other hand, we do have a lot of experience. We have the best engineers, and we can leverage our knowledge with the speed and benefits of the startups. When we put these together, it makes a very good recipe to win.” He goes on to call it a win-win collaboration. When asked about the nature of these collaborations, he states: *“We don’t go and just give work to the startups. We don’t say: do it and then bring it back to me. That is not the way in which this works the best. We want to go and work together, sit together, and have the best strengths of each party so that we can go forward harder.”*

Carlos Ilário discusses a solid point in which collaboration with incumbent firms is attractive for startups. He talks about how incumbent firms have the capabilities necessary for putting new technologies into practice. He speaks about moving from the ‘virtual world’ into practice. He describes this as follows: *“When I say virtual world, I mean the first step of doing the calculations, analytical methods, and numerical methods. Then you go to the next phase, which is bench testing. You learn quite a lot on the bench tests as well, but when you go to the aircraft it is a completely different story. I like to say that it’s a flying laboratory, where you learn quite a lot. There are opportunities for startups, to leverage what we already have. We have aircraft prototypes, we have flight test engineers, we have test pilots.”* With this quote, he highlights some of the capabilities that will most likely be out of reach for most startups, but which incumbent firms can offer them in collaboration. He further specifies that collaboration with incumbent firms is a good way for startups to validate their new technologies, and to bring them to a higher TRL.

When discussing the different streams of technological development that are at the center of the aviation industry’s pursuit of sustainable air mobility, Carlos Ilário states the following: *“You can have a different optimum, depending on the mission. It’s not about the fuel or the energy that will drive the vehicle itself, but the vehicle and the mission will determine the best solution.”* ... *“It’s not only on the technology side. It is the technology, the cost, the safety, certification, regulation, infrastructure, availability, and so on. Everything needs to be considered when we are talking about developing a new aircraft.”* With this, the changing business models in the industry were discussed. Carlos Ilário expresses the expectation that the business model of the entire aviation industry will be changed, with the introduction of new technologies. He sees that this opens up a new degree of freedom, not only in aircraft design but in all aspects. He points out the possibility of disruption of the supply chain and further points out that this could present a good opportunity for startups to take a place in this market.

Lastly, when discussing what needs to change in the aviation industry in order to become sustainable, Carlos Ilário starts by asking what cannot be changed. Safety remains the base line priority. Beyond that, he points out infrastructure and energy production as major prerequisites for this movement.

V. Interview Jacob Verhaart & Tristan Oppeneer

Interviewees: Jacob Verhaart (JV) & Tristan Oppeneer (TO)

Interviewer: Marilot Molewijk (MM)

Company: Amsterdam University of Applied Science (AUAS) & NRG2Fly

Date and time: April 4th, 2023, 15:30-16:30

Location: HvA Jakoba Mulderhuis (JMH)

Transcript available upon request.

Abstract:

Jacob Verhaart starts by explaining how they work at incorporating sustainable aviation more and more in their curriculum and activities. He mentions that they have a ‘Sustainable Aviation Studio’ for graduate students. There have not been startups resulting from this studio, but he expresses the hope that it will be at some point. He later also explains that in the first year of aviation studies, they do a case study related to SAF on an intercontinental flight and that sustainability is now part of the BOKS (Body of Knowledge & Skills), outlining what students should be able to know and do after completing their studies. They also work together with DEAC (Dutch Electric Aviation Centre). He goes on to explain that DEAC is located at Teuge airport, together with the e-flight academy. E-flight academy is a startup, and he describes this collaboration as very good and fruitful. In terms of the benefits that startups offer compared to incumbent firms, he states the following: *“Startups can do something different from incumbent firms. Large organizations often struggle with what they call ‘historical momentum’. That means that they are set in their ways and would need to discard their business model in order to do something new, or other wise they change too slowly. A startup is often better equipped to pick the correct things.”*

In terms of challenges, faced by the aviation industry in pursuit of sustainable air mobility, the first topic Jacob Verhaart brings up is infrastructure. In this regard, he turns to the automotive industry and expresses that there is much to learn from how they established the infrastructure for EVs but that the aviation industry should be much quicker. He mainly sees an opportunity for knowledge sharing between the automotive industry and the aviation industry. He also remarks that the most significant difference in maintaining an electric aircraft versus maintaining a traditional aircraft is regarding the maintenance of the battery. This is a topic on which he thinks the aviation industry can also look to automotive for the research that has already been done. When discussing the challenges that need to be overcome by the industry in order to facilitate commercialization of sustainable air mobility for passenger transport, Tristan Oppeneer later on also comments and states the following: *“It all starts*

with a large electric aircraft. That is where the main focus lies, also for startups. Yet, it is often forgotten that the regulations around that, the operations at the airports, the charging infrastructure, and all those kinds of matters also need to be accounted for.”

Tristan Oppeneer explains that NRG2Fly, the startup at which he is Program Manager, is active in the entire aviation sector and they specialize in the charging infrastructure for electric aircraft. He highlights that the industry is very connected in this transition and in his experience, there is a lot of hope and energy related to realizing the ambitions of sustainable air mobility.

When asked about the applications of electric aircraft, Tristan Oppeneer expresses the expectation that existing operators will partner with startups and change their mobility systems. On the one hand, this happens by moving away from a hub-centered network to suit the short-haul flights in reach for current electric aircraft, and on the other hand, this includes incumbent operators changing parts of their networks, in order to incorporate electric aircraft in some parts of their network. He illustrates this with the following example: *“You can see this happening at Transavia, in their collaboration with Fly with Lucy. They want to offer flights with whatever electric aircraft that will be available. In that case, you can imagine, that for example, Transavia flies to Athens and offers sustainable flights to the islands.”*

When discussing other ways that incumbent operators will embrace sustainable aviation, he states the following: *“KLM Flight Academy has already announced that they would be open to purchasing an electric aircraft once it is available and conforms to their requirements. I think that, for the big operators, you will first see it in the training segment.”*

VI. Interview Jolanda Stevens

Interviewee: Jolanda Stevens (JS)

Interviewer: Marilot Molewijk (MM)

Company: KLM Royal Dutch Airlines

Position: Program Manager Zero Emissions

Date and time: April 6th, 2023, 13:00-13:30

Location: Phone

Transcript available upon request.

Abstract:

Jolanda Stevens begins to explain that, already for a significant amount of time, at KLM they have been occupied with the thought of how the future of aviation should look and what their role should be in that future. She states the following: *“We have been frontrunners in that regard, but what has changed in the past years, is that we now really have the new technologies on our radar. We understand that hydrogen and battery-electric flying are options for the future that we ought to start seriously considering soon, in order to assess what steps, we can take. Not just for ourselves, but for the continuation of aviation.”* The Zero Emissions program, that Jolanda Stevens manages, was born from that vision. The goal of the program is to conduct a ‘feasibility study’ on what they can achieve, in what period of time, and which decisions KLM wants to make with regard to new technologies, and how far they want to go with that. She explains that the first milestone will be to finish that study, the relevance of which she describes as follows: *“It is a very important milestone because that study does not just include the options, but also the risks involved, the uncertainty, the match between what is emerging in the market and how that fits with us as a company. What can we do? What are we doing now? How does that fit together? And if we have/want to do something new, how would that fit in our organization?”*

In collaborations and in the search for new technologies, Jolanda Stevens explains that they look both at startups that come with radical ideas and at established companies that are also working on sustainability. She says the following on this matter: *“It is incredibly good that those two can exist next to each other. On the one hand, the established industry knows how to achieve things in the aviation sector, how to build something, and how to certify it. That is a difficult process, and they have that knowledge. On the other hand, they also feel less inclined to pursue sustainability, because the product functions perfectly fine in their current portfolio. What kind of urgency do they feel? Maybe a moral one, but not from a business perspective. Then you also have startups, who go straight through that.”*

She proceeds to explain that said startups, however, often have less knowledge of the procedures that are needed to ensure safety. She also believes that startups are definitely necessary for realizing this transition in the industry and she highlights the value of a fresh perspective.

In terms of what is needed in the industry to realize this transition together with startup companies, the first thing Jolanda Stevens mentions is courage. She states the following: *“I think that we need a bit of courage. Courage from the existing players, such as KLM, but also from other companies. Courage to dare say: We are just going to do it. We are going to see what we can achieve together. This is daunting because they are a new group of people, whom you don’t know and who don’t have a 100-year-long track record. It is a matter of researching who you will be collaborating with and what kind of people they are. That requires a bit of courage. Finding that courage can takes time. Within KLM, I see that that courage is certainly there.”* Additionally, she goes on to discuss the obstacles that a company like KLM faces today, in pursuit of sustainable air mobility. Jolanda Stevens explains that as an airline, they have to depend on other players in the industry to make the big steps in terms of technological development. She elaborates on this by explaining that each of the current streams of technological development comes with its own challenges, but she adds the following: *“It is not like we say: You have to come up with something and we will wait until you are ready. Absolutely not. We want to help and together with those players see what we can do to accelerate this development.”* She also raises another point of concern, in terms of industrial prerequisites, by pointing out that the energy source and availability of alternatives should be at a significant level. With regard to SAF, she points out that, in order for SAF to be used widely and primarily, production should be scaled up radically. A similar objective is faced in the development of battery electric technology and hydrogen, since green electricity and green hydrogen are not in abundance at the moment.

Lastly, when discussing the different attitudes toward change that are observed in the industry, Jolanda Stevens says she understands these dynamics and experiences a similar discrepancy in her current work. She says the following about it: *“The aviation industry is historically a conservative sector, and that conservativeness is our biggest blessing because it has allowed us to ensure an incredible level of safety.”* ... *“The industry is on the one hand, very pioneering and on the other hand, conservative and careful.”*

VII. Interview Karel Bockstael

Interviewee: Karel Bockstael (KB)

Interviewer: Marilot Molewijk (MM)

Company: Independent

Date and time: April 6th, 2023, 09:00 - 09:40

Location: Phone

Transcript available upon request.

Abstract:

When asked about his career and his former position as VP of Sustainability at KLM, Karel Bockstael highlights some of the milestones that were achieved. During his time as VP of Sustainability, KLM committed itself to science-based targets, effectively becoming more ambitious than what ICAO's CORSIA outlines for aviation. Furthermore, he mentions the following: *"We proposed 10 ambitious plans regarding sustainability, to the board. We called them Bold Moves. We proposed them to the board and asked which ones they wanted to execute because we think that we should move forward. They decided to elaborate on all of them, and a few have been realized. One of them is the structural adding in of SAF. Another is the Sustainable Flight Challenge, which is a friendly sustainability competition between airlines."* When asked, he explains that startups were not a big part of these milestones, but he does believe that they are necessary for realizing this transition in the aviation sector. He states the following in that regard: *"In all honesty, what we did in those 3 years at KLM mostly involved incremental innovation. The big difference between incremental improvement and radical change will have to be made by startups."* He elaborates and explains that incremental improvements will simply not change the industry fast enough, an industry that is already slow to change. He explains this in the following quote: *"The aviation industry is a slow improver. Everything goes step by step because it has to be safe, it cannot be too expensive, we cannot lose passengers, it has to be international, and competition is growing. For those reasons, everything goes quite slowly, and it actually goes too slowly according to what the boundaries of our planet are indicating. We need to go toward radical change and I think we need startups for that."*

When discussing what needs to change in the industry in order to bring incumbent firms and startups together, Karel Bockstael mentions a few points to keep in mind. The first point he brings up is the conservative nature and guarder attitude of the industry. He states the following: *"I find the aviation industry an incredibly closed system. They consciously keep innovation out. Very defensive and a strong lobby."* In addition to this, he mentions leadership as something the industry needs. He expresses that

the industry could use a strong leader, preferably one with a background in other industries, who dares to take the necessary steps. Continuing on the topic of obstacles in the industry, regulation, and safety are brought up. Karel Bockstael is very clear in highlighting the incredible level of safety that is a standard in the aviation industry. However, he also points out that with the continuous increase of efficiency and safety, the aviation industry has worked itself into a position that is hard to get out of, because fear of change and chaos is ever present. In terms of efficiency increase versus emissions, he also mentions Jevons Paradox and explains the following: *“Jevons Paradox states that efficiency always leads to more emissions and more consumption. More efficiency makes a product cheaper, which in turn makes it more attractive to the consumer. Hence, you sell more, you generate more revenue, and you emit more. That is essentially what drives the aviation industry as well.”* He goes on to explain, that the economics perspective, the safety perspective, and the controlling nature of the industry, stand perpendicular to sustainability.

Another point that was discussed is the culture, in terms of leadership and the difference between incumbent culture and startup culture. When asked whether he believes that startups can help change the corporate culture of incumbent firms, Karel Bockstael mentioned the following: *“Yes, especially in terms of diversity in management, and the adoption of the right priorities. I think and I hope, also the attraction of a different segment of the market.”* When talking about attracting another market segment, he explains that the success of implementing radical innovation might not only be about it being commercially competitive, but truly changing the proposition. He believes such a proposition should fit the business model of existing airlines and adds the following: *“A successful airline will be capable of developing these types of niches. That would determine a successful transition, but I don’t see that happening any time soon.”* In this regard, he also discussed consumer behavior and the standard that is expected by consumers. He states that we should get used to ‘low & slow’ travel. He also expresses his stands on the role that government and legislators should play in this transition. He mentions that government should for example put a price tag on CO2 emissions and recognizes that the basis for such steps has already been laid.

VIII. Interview Nando van Arnhem

Interviewee: Nando van Arnhem (NA)

Interviewer: Marilot Molewijk (MM)

Company: VÆridion

Position: Aerodynamics Lead Engineer

Date and time: April 19th, 2023, 15:00-16:00

Location: Microsoft Teams

Transcript available upon request.

Abstract:

Nando van Arnhem explains that in his role at VÆridion, he acts as the connection between a number of disciplines, but his focus is on aerodynamics. He states the following, regarding the importance of aerodynamics in designing an electric aircraft: *“My focus is on aerodynamics, and in electric aviation that is very important since you need to be much more efficient than a current airplane. So, you need to design your model differently, for a different airspeed, for a different mission.”* He also describes his other experiences in the industry. Based on his previous experience of being involved in the Flying-V project, he describes the reluctance of incumbent firms to connect their name with a new project. He elaborates on this in the following quote: *“In general, I think that incumbent firms are much stricter with taking risks. They definitely do not want to connect their name to a concept that effectually fails. The flying V is a solid example of this. Airbus did not want to have its logo on it before the first flight was performed. Once this was done, rather successfully so, they did want to be on it. They explained that if their logo would be on it and the prototype would crash, it could spiral out of control in the media and they would risk having their processes evaluated and even seized for a while. They only want to take a step if the risk is small enough. That is also why companies like Airbus have numerous subsidiaries.”* In contrast to the risk-averse attitude of incumbent firms, he explains how startups position themselves in the industry. He states the following: *“Startups are the opposite. They take the risk because they do not have another business depending on it. In our case, the business is developing a new aircraft and of course, you are going to make mistakes in that process, it is a learning curve.”*

Nando van Arnhem goes on to highlight another difference between incumbent firms and startups, regarding human capital. He points out that when incumbent manufacturers develop a new aircraft ‘from scratch’, they tend to first look for people within the company to relocate to that project, rather than attracting new people. He states the following in this regard: *“The fact that a startup has a structure*

but not such hierarchy, also makes it attractive. You can more easily attract people with very specific knowledge or skills because you can put them in exactly the right place, without it being set in stone.”

Nando van Arnhem points out another benefit that startups have, with regard to collaborations with suppliers. He states the following: *“Incumbent manufacturers usually want to have all kinds of contracts with their suppliers, and they set high demands because they are used to doing that, especially for engine suppliers. They also have a much longer time span.”* He explains that for startups, connecting with suppliers is usually easier. The results are visible faster, and they can spread their risk by collaborating with a number of startups. He elaborates on this by explaining that suppliers might also be more willing because the aircraft that they are working on at VÆridion fits in category CS-23 level 3, which makes certification somewhat easier. With regard to this type of airplane he also states the following: *“We believe that there is a business model for this type of airplane. Eventually, you will need an aircraft for longer distances. So, this is not the solution for all of aviation, but it is the key to that solution.”*

When discussing the future operators of sustainable aircraft, Nando van Arnhem expressed the expectation for existing, medium-sized operators to start taking on sustainable aircraft. He states the following in this regard: *“I do not think it will be entirely new operators. It is a new aircraft, and it is a new technology, so people want to have a familiar perspective. So, it should perhaps be medium-sized operators, that have been around for years, on existing routes, from existing airports, with recertified pilots. I think that is how it will go, but I have no doubt that larger operators will follow.”*

Maintenance was also a topic that was discussed during the interview. Nando van Arnhem explains how maintaining an electrical aircraft presents some differences from the maintenance of a traditional aircraft. He states the following: *“Of course, the aspect of maintenance is very important. Approximately once a year, batteries need to be changed. At that stage, they are not useless yet. You can for example, use them on the ground, for solar energy plants, as a buffer zone. Our battery is located in the wing, so we have to take into account how they can be inspected, removed, and installed. We also take into account what qualifications maintenance personnel would be required to have and where the maintenance tasks can be performed. On the other hand, you do have fewer rotating parts, so less maintenance. You will see that the maintenance is more for the batteries and less for the engines.”* Furthermore, he explains that many of the traditional maintenance tasks will remain, regarding the cabin, cockpit, landing gear, and control services for example. There is only a number of systems that will be radically different in maintenance. He does also express the expectation that there will develop a more diverse portfolio of aircraft models.

When asked about the lessons that aviation can learn from the automotive industry, Nando van Arnhem points out that in some ways, it is all about finding the right people. He thinks that, in general, there is

enough money available for this transition, but right now it is about bringing the right people together. Furthermore, he points out that the automotive industry is much less regulated than the aviation industry. He states the following in this regard: *“There is no shortcut and there should not be, because you are developing an aircraft that will transport many people. The process that is currently in place for certification is there for a reason. We should not see it as a restraint but rather as a guideline.”*

IX. Interview Philip Ideström

Interviewee: Philip Ideström (PI)

Interviewer: Marilot Molewijk (MM)

Company: Heart Aerospace

Date and time: March 24th, 2023, 15:00-15:30

Location: Microsoft Teams

Transcript available upon request.

Abstract:

Philip Ideström explains what Heart Aerospace does and what kind of parties they currently work with. He states the following, about the current phase that the company is in, in terms of connecting to the market: *“It is really about getting the requirements right. We are listening to what the market wants.”* He explains that there are many parties to consider when developing a new type of aircraft and elaborates in the following quote: *“As with any aircraft, you work very closely with your customer and their need direct your requirements and you need to flow those requirements down into your supply chain. So, it varies how integrated you need to be, but you certainly do well to listen.”*

Philip Ideström goes on to explain how sustainable air mobility aims to target another segment of the market. He relates this to the history of the aviation industry and states the following: *“If you go back in time, there used to be a lot of smaller communities, tying together a large network. That largely disappeared in the 90s when everyone started using jets and it became very uneconomical to run a regional airline. That’s what we are trying to change now.”* With regard to the connection that they have with the industry and the collaboration with other players therein, he also emphasized that they are part of the ecosystem that is realizing this transition. He states the following: *“We realize that we can’t do everything. It is a whole industry to create an aircraft. We decide on our place in the ecosystem but realize that we need to be part of the discussion in a lot of different areas.”* In this regard, Philip Ideström characterizes the aviation sector as a very collaborative industry. He said the following about the ethos of the industry and the collaboration with large incumbent firms in the aviation industry: *“I think the Ethos of the industry is really collaborative. It’s a very trust-based industry, I find. You have to work in a very integrated way with your suppliers. Sometimes I don’t like the term ‘supplier’ because you are often more of a partner. In this industry, you can be a partner, competitor, customer, and supplier at the same time. Because the same company may be producing subsystems and their own aircraft. It’s often very large organizations, with a lot of history that are quite diversified.”*

When asked about the advantages that startups have in this transition, Philip Ideström pointed out the following: *“Being a startup, you have a lot of freedom to structure things your own way and perhaps you need to do that in order to create something completely new. You also need to realize that you can’t reinvent the wheel for everything. You need to decide where to innovate and I think the innovation in Heart Aerospace is taking all these diverse parts and putting them together in something that can make a difference here and now, and not many years in the future.”* In this regard, he also recognizes the importance of collaboration between different players in the industry and points out that the aviation sector has demonstrated that that point is widely understood. He explains the following to illustrate this statement: *“I think it was in the early 20th century when the industry decided to pool all the patents in one place and collaborate to make the first aircraft. The exact kind of thing hasn’t happened since, but the collaborative Ethos is still really there and it’s the reason why there are so many different aircraft in the world. One company by itself could not make its own aircraft. Even if you’re an enormous company like Airbus. They are the integrator of many different parts. And that’s where their innovation lies. It’s integrating the new technology, that’s where our innovation lies. We have the freedom to choose new ways but do it in a smart way so that we can make a difference in 2028, rather than in 2048.”*

In terms of the challenges that a company like Heart Aerospace faces, Philip Ideström mentioned the following point: *“I think one of the challenges is attracting and maintaining the right competencies. You need competencies from all over the world and they are in high demand.”* The point of safety and regulation was also discussed. Philip Ideström remarked that the authorities are keen on helping to find solutions but that they are more used to working with large organizations, rather than startups proposing entirely new designs. On the topic of safety, he states the following: *“The requirements are so high and I’m happy that that is the case, but it does make it sometimes difficult to introduce new technologies. Well, it takes time. You need to prove that it works on many different levels and that is completely natural.”*

X. Interview Reynard de Vries

Interviewee: Reynard de Vries (RV)

Interviewer: Marilot Molewijk (MM)

Company: Panta Holdings

Date and time: April 14th, 2023, 11:00-12:00

Location: Delft

Transcript available upon request.

Abstract:

Reynard de Vries explains the involvement of Panta Holdings in different parts of the industry and in terms of research, they also collaborate with researchers and students from the TU Delft. He highlights the importance of the research phase by stating the following: *“Scientific research is supposed to be broad and vague; it does not have to have a direct application. Scientific research often looks at what happens if we work with one minor thing. You might never need that one minor thing again, or in 20 years’ time, the knowledge of that one minor thing could be of value for another project.”* He explains that the TU and other universities are currently focusing on more applied research on how a sustainable aircraft should look at function. When discussing the three main streams of technological development (SAF, Electric, hydrogen), he points out the following: *“It is simply still at a low TLR, and research is needed to increase that. We will slowly go toward more concrete steps.”* Additionally, he points out that 10 years ago the focus was still on coming up with a wide range of configurations, whereas the focus has already narrowed down to just a number of designs for which other issues need to be resolved now.

When shifting focus from the technology and speaking about what needs to change in the industry in order to implement sustainable aviation technology. Reynard de Vries states the following: *“It will come, but it is going too slow if we keep going like this. I am not talking about electric aircraft, those will be there, those are even already here. But in my opinion, we should be addressing the real question of decarbonizing the whole aviation industry.”* This remark points to the fact that electric flying is currently only addressing a mere 1% slice of the entire emissions. He recognizes that this new form of mobility can also be a good business and comes with its own social benefits, but other steps need to be taken to resolve the bigger problems in the industry. Reynard de Vries recognizes the efforts of incumbent OEMs to make their current products more efficient. He remarks that these are great efforts, but it still only concerns improvements and in the bigger picture of the industry it will not make the difference in becoming climate neutral by 2050. He believes that the radical steps will not come from

large incumbent aircraft manufacturers. He elaborates on this by explaining that Boeing is financially not in a good place and that they have already announced they would not be building a new aircraft this decade. This puts Airbus, in a comfortable position as its main competitor. Hence it is unlikely that Airbus would take unnecessary risks in developing a new aircraft. Despite Airbus currently working on new technologies, he is pessimistic about having a sustainable aircraft that could make a significant difference by 2035. In contrast to this, he points out the following: *“Startups have less risk, fewer resources. In my ideal scenario, a startup would develop the technology, and spend maybe millions or billions on technology demonstrators. When they start approaching a full-scale prototype it will get expensive, because then you need to certify and start building an assembly line. That is when you would hope that a bigger company would take over.”* He remarks that this does not have to be done by Airbus or Boeing, it could well be an older or smaller aircraft manufacturer, which would present a good possibility for market penetration with a sustainable alternative. In that regard, he thinks that startups are necessary in this transition because the industry is very consolidated, and incumbent manufacturers are faced with too big of a risk when introducing new technologies. Not to mention, their shareholders would most likely not be excited about the prospects of it. Furthermore, on the necessity of startups, Reynard de Vries says the following: *“I think that startups are necessary for bringing the technology to a phase in which it will be a niche product, or at least to bring it to a higher TRL for the bigger market.”*

In terms of what is required for the development of sustainable technology and bringing it to the market, time, money, and manpower were initially discussed. Reynard de Vries states the following: *“Time, in the sense that you do research, you increase the TRL, you do a small demonstrator, you get funding, you are already a few years along. Eventually, you will need to get certified and that takes a while. You cannot accelerate that by putting more money into it. Assembling a supply chain and production also takes time. With more money, you can do some steps simultaneously, but you will still not be able to get a new aircraft on the market within 5 years.”* In terms of human capital, Reynard de Vries expresses concern about the lack of technical people on all levels. He sees that there are a lot of startups and whilst he believes there is probably enough money for them, there most likely are not enough people for them. However, he does point out that it is a good sign that there is apparently such a demand for that kind of thing.

Over the course of the interview, the parallels and differences that the aviation industry bears with the automotive industry were discussed. In terms of what we can take away from the electrification of the automotive industry, Reynard de Vries states the following: *“You have to think differently. You should not try applying new technology to the current way of doing things. You have to look at how the system should change in order for the new technology to be used well.”* In terms of industrial differences, he points out that aviation is much more consolidated. It is hard to compete with established players,

certification requirements are harder and take more time. Additionally, the budget and time that is required to get to production are much higher than for car production. He also states the following about the effects that the advancements in the automotive industry have had on other industries: *“It has given hope, maybe even too much hope. There are startups that are claiming ridiculous things. Which is frustrating and has a polarizing effect on the population. However, it does inspire courage and shows that change is possible.”*

The government was discussed as one of the powers that could or should play a role in this transition toward sustainable mobility. Reynard de Vries believes that government should incentivize the industry to change, mainly economically. Examples of such incentives could be, cutting taxes for flights that are performed emission-free, or setting a minimum for the percentage of SAF that should be used on each flight. He thinks this is necessary because he foresees that it will be quite challenging to make these new technologies cost-effective in the face of regular large aviation. He expects that in the Northern European countries, the government will be inclined to take such steps, once they see a viable alternative.

The different dynamics and attitudes that can be observed in the aviation industry were discussed, and on the topic, Reynard de Vries explains that there is mainly a cultural difference. He states the following: *“Startups have a cultural benefit. You need to have a culture that facilitates innovation. A culture that wants to change and challenge the status quo.”* In contrast to this, a major benefit of incumbent firms was pointed out to be their experience and expertise. He discusses the combination we see when experienced people from incumbent firms decide to join a startup. In those situations, experienced people are usually hired as managers, leading the young people who established this innovative culture.

Lastly, consumer behavior was brought up as a point of discussion. There is a frequently heard opinion in the industry that it should just not grow anymore, that we should fly less. Reynard de Vries states the following: *“When you look at the aviation sector, we have always kept growing and improving efficiency. However, the growth has always been faster than the improvements in efficiency. Hence, the impact has continuously been growing.”* A simple conclusion would be that the answer is to fly less, but Reynard de Vries also points out that it is also a somewhat hypocritical thing to say. He highlights that roughly two-thirds of the world population has never even been aboard an airplane, and we can hardly expect them to “fly less”. He states the following in that regard: *“Aviation accounts for maybe 2% of all emissions, but it is always the same people. Maybe we should be flying less but we cannot say that all the worldwide aviation should decrease.”* Besides the frequency of flight, the price and efficiency were also a point of discussion. On all accounts, Reynard de Vries states the following: *“We cannot expect the whole world to change their behavior. That is unfortunate, but not realistic. Technological change is hard, but societal change is even harder.”*

XI. Interview Rob Koedijk

Interviewee: Rob Koedijk (RK)

Interviewer: Marilot Molewijk (MM)

Company: KLM Royal Dutch Airlines – Engineering & Maintenance

Date and time: April 7th, 2023, 08:00-09:00

Location: Schiphol East 404

Transcript available upon request.

Abstract:

Rob Koedijk explains that his position at KLM entails that he works on new business cases concerning electric, hydrogen, and hybrid aircraft alternatives. He remarks that one aspect of this is a collaboration with external parties and identifying what KLM can offer within their existing approvals. In this regard, he states that the current phase in which the development of sustainable air mobility concerns still mostly the design and research, and not yet product support or financing of aircraft. Rob Koedijk sees an opportunity for KLM to play a part in the supporting value chain of the new technologies. He states the following: *“At this point in time, a major gap that I see is that no one is concerned with MRO yet. Although that is typically something that Airbus or Boeing are occupied with during the development of a new aircraft model.”*

One of the major bottlenecks that Rob Koedijk foresees in the industry, is a lack of manpower. He remarks the following: *“If I make a new business case today, you will see that they require a lot of people and skills. Those are often skills that are already scarce on the market. Good electric technicians and incredibly hard to find because the entire market is pursuing them, in the energy transition and everything regarding that.”*

Rob Koedijk also explains that they actively collaborate with startups and that they discuss how they can further develop the issues that the startups might not yet be actively concerned with. He states the following about these collaborations: *“They have knowledge of the technologies, which we don’t have. We have a large network, but if you would be looking for an expert on hybrid fuel cells over here, you are unlikely to find one. We can both learn a lot in these partnerships.”* He explains that KLM currently looks externally at startups rather than at organizing new capabilities internally. He points out that a company like KLM always takes its legacy with it when organizing something internally or creating a subsidiary, which can be positive, but can also be a burden.

When discussing the similarities and differences between the aviation industry and the automotive industry, Rob Koedijk mentions that one of the main things aviation can learn from automotive is concerning knowledge about charging infrastructure and batteries. As a major difference between the industries, he points out the following: *“In the automotive industry there is more room for experimentation, because of the difference in regulation.”* He elaborates on this point of regulation in the following quote: *“In aviation, nothing is allowed unless it is described. You can only describe it if it is in the law. You see that this entire chain of regulation is behind on the technological developments.”*

Rob Koedijk compares his view of the future with the history of the aviation industry. He explains that currently, there are about 700 startups in the industry that are pursuing battery technology. states the following: *“I like to compare it with what happened in the aviation industry before the first world war. Back then, there were also a lot of startups, or rather just people who thought they could build an airplane in their garage. What happened then was basically a Double Diamond effect. In a short period of time, a lot of parties emerged wanting to build something and if you look at what remains now on the big market, it is a very small part of that. We will see that same convergence in this situation as well.”*

XII. Overview of Literature Review

This table represents the scientific articles that were included in the literature review that was presented in chapter 2 of this thesis.

nr	Title	Authors	Year	Keywords	Journal	Pages
1	Analysing the opportunities and challenges for mitigating the climate impact of aviation: A narrative review	Y.Y. Lai, E. Christley, A. Kulanovic, C.C. Teng, A. Bjorklund, J. Nordensvard. E. Karakaya, F. Urban b	2022	Aviation, Climate impact, Air travel, Emissions reduction, Policymaking	Renewable and Sustainable Energy Reviews	
2	Technology and solution-driven trends in sustainable aviation	D. Rohacs	2023	Life cycle cost, Sustainability, Life cycle emission assessment, Total sustainable performance index	Aircraft Engineering and Aerospace Technology	416-439
3	Comparison of conventional and electric passenger aircraft for short-haul flights - A life cycle sustainability assessment	A. Barke, C. Thies, S.P. Melo, F. Cerdas, C. Herrmann, T. Spengler	2022	Life cycle sustainability assessment, Well-to-wake assessment, Electric aircraft, Sustainable aviation fuel	Procedia CIRP (105)	464-469
4	Global energy issues affecting aeronautics: a reasoned conjecture	J.E. Allen	1999		Progress in Aerospace Science (35)	413-453
5	"Problematizing" carbon emissions from international aviation and the role of alternative jet fuels in meeting ICAO's mid-century aspirational goals	M.S. Baledón, N. Kosoy	2018	Alternative jet fuels, Policy analysis, Weak sustainability, International aviation, Climate change	Journal of Air Transport Management (71)	130-137
6	Comprehensive investigation on hydrogen and fuel cell technology in the aviation and aerospace sector	A. Baroutaji, T. Wilberforce, M. Ramadan, A.G. Olabi	2019	Hydrogen, Fuel cells, Aviation, Renewable energy, Clean power	Renewable and Sustainable Energy Reviews (106)	31-40
7	Sustainable Aviation Fuels: Status, challenges and prospects of drop-in liquid fuels, hydrogen and electrification in aviation	A. Bauen, N. Bitossi, L. German, A. Harris, K. Leow	2020		Johnson Matthey Technology Review (64)	263-278
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9	Co-evolutionary and multi-level dynamics in transitions: The transformation of aviation systems and the shift from propeller to turbojet	F.W. Geels	2006	Co-evolution, Transition, Multi-level perspective, Turbojet, Aviation	Technovation (26)	999-1016
10	A socio-technical analysis of low-carbon transitions: introducing the multi-level perspective into transport studies	F.W. Geels	2012	Socio-technical transitions, Transport systems, Low-carbon, Multi-level perspective	Journal of Transport Geography (24)	471-482
11	Entrepreneurial ecosystems: Multiple domains, dimensions and relationships	S. Stephens, C. McLaughlin, L. Ryan, M. Catena, A. Bonner	2022	Entrepreneurial ecosystem, Small business, Simensions, Isenberg	Journal of Business Venturing Insights (18)	
12	The big idea: How to start an entrepreneurial revolution	D.J. Isenberg	2010		Harvard Business Review	
13	Regime resistance against low-carbon transitions: Introducing Politics and power into the multi-level perspective	F.W. Geels	2014	Climate change, Electricity, Incumbent regimes, Resistance, Transitions	Theory, Culture & Society (31.5)	21-40
14	Innovation towards sustainable technologies: A socio-technical perspective on accelerating transition to aviation biofuel	Y. Kim, J. Lee, J. Ahn	2019	Innovation, Socia-technical transitions, Aviation biofuel, Multi-level perspective, System dynamics	Technological Forecasting and Social Change (145)	317-329
15	A post-carbon aviation future: Airports and the transition to a cleaner aviation sector	R. Kivits, M.B. Charles, N. Ryan	2010		Futures (42)	199-211
16	Understanding carbon lock-in	G.C. Unruh	2000	Technological lock-in, Institutional evolution, Climate change	Energy Policy (28.12)	817-830
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19	Emerging from the COVID-19 pandemic: Aviation recovery, challenges and opportunities	K. Dube	2023	Labour challenges, Climate change, Russia-Ukraine war, High fuel costs, Sustainability	Aerospace (10.1)	19

20	Reliability in the era of electrification in aviation: A systems approach	K. Emmanouil	2020	More electric engine, Hybrid flight, Electric aviation, Systems safety and reliability	Microelectronics Reliability (114)	
21	The Role of Proximity in Technology Dynamics of High-Tech Industries: the Case of Biotechnology and Aviation Industries	M. Runiewicz-Wardyn	2022	Aviation, Biotechnology, Industry, Proximity, Technology dynamics	Triple Helix (9)	138-173
22	Outsourcing in Aviation Technical and Information Technology Services: A Comparative Study of Maturity Development	J. Holkeri	2022	Outsourcing, maturity development, aviation, technical services, information technology services	Journal of Industrial Engineering and Management 15(2)	367-383
23	Advancing Industry through Design: A Longitudinal Case Study of the Aviation Industry	R.A. Price, C. De Lille, K. Bergema	2019	System, Scale, Design, Impact, Methodology, Innovation	The Journal of Design, Economics, and Innovation 5(4)	304-326