Validating and Developing LeydenJar's New Product Marketing

Internship report

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Utrecht, February 3rd, 2025

Executive Summary

LeydenJar is a producer of pure silicon anodes for high energy density lithium-ion batteries. Currently, LeydenJar focuses on reaching customers in the electronic applications sector, as they appear to perceive a high benefit/price ratio in LeydenJar's product. Specifically, drone manufacturers are targeted, because of the assumed product-market fit, which stems from high energy density and high power demands in the drone industry, significant market size, and high product value of commercial drones.

Based on previous insights into drone market requirements, LeydenJar designed a specialized drone cell containing their pure silicon anodes to launch and enter this market. The design was based on feedback from a limited set of customers, who may not represent the broader drone industry. Additionally, little is known about potential integration challenges. Proceeding in the drone market without addressing these uncertainties could result in low product-market fit and disappointing product sales. Therefore, the first objective of this research is to study the alignment of LeydenJar's drone cell with the requirements of potential customers in the drone industry and the limitations of the product and its integration, according to the drone market.

To reach potential customers, LeydenJar markets its drone cell through a product datasheet, which is a short overview showcasing the drone cell's performance. Since it was never tested with real customers, it remains unclear whether this marketing medium is effective and attracts the desired attention from potential customers in the drone industry. Therefore, the second objective of this research is to study the suitability of the datasheet as a medium for marketing the drone cell and potential alternatives.

The datasheet contains all information that is believed to be important for drone market players to assess the drone cell. The level of detail is tailored to the assumed knowledge of battery procurers in the drone industry. These assumptions were never validated with drone industry players and datasheet validation and optimization is required to ensure effective drone cell marketing. Therefore, the third objective of this research is to study the drone market evaluation of the completeness and clarity LeydenJar's drone cell datasheet and potential datasheet improvements.

To reach these three objectives, semi-structured interviews were conducted with different potential customers in the drone industry. During these interviews the datasheet and its contents were discussed to gain insight on the customer validation of the drone cell, the marketing medium, and the contents of the datasheet. The methodology is iterative as the datasheet was updated based on market insights in between interviews.

Based on the interview results, the alignment of the drone cell with customer requirements appears to be high, indicating product-market fit. Different challenges and points of uncertainty were discussed, such as what the cell cycle life increase would be at 80% depth of discharge, which appears to be commonly applied in drones. Accounting for these uncertainties is expected to further improve the product-market fit. Therefore, LeydenJar is advised to persevere in offering their drone cell to the drone market.

The results indicate that the datasheet is an integral medium for marketing the drone cell. Additionally, a proof of concept showcasing the drone cell's performance in a real drone appears to contribute to the marketing, as it supports the tangibility of LeydenJar's drone cell. LeydenJar

is advised to persevere with drone cell marketing, using the datasheet, and to pursue the proof of concept. To deliver this proof of concept, collaborating with student drone teams is accompanied by lower risks, whereas partnering with commercial drone manufacturers provides higher potential financial gains.

The reception of the datasheet was mixed. Incorporating critically assessed customer feedback appears to enhance the evaluation of the datasheet. Consequently, customer feedback helped produce a new version of the product datasheet and advice on how to further enhance it. The incorporated customer feedback includes more information on pack integration, a more compact cell size, and more details explaining the presented data and addition of a burst discharge rate and maximum charge rate is advised. The resulting datasheet is recommended for future marketing of the drone cell.

LeydenJar is advised not to continue validating the datasheet after the execution of this study due to its time-consuming nature and potential pitfalls. Instead, it is recommended that LeydenJar perseveres using the currently improved version of the datasheet for its drone cell marketing.

Contents

1 LeydenJar Business Background

This chapter introduces LeydenJar's technology, its business landscape, and LeydenJar's first product launch. The chapter explains where the commercial problems and uncertainties lie for LeydenJar, leading to the focus of this study.

1.1 LeydenJar's Technology

One of the biggest bottlenecks in electronic innovation is the energy density of current lithium-ion batteries. The energy density is the energy of a battery per volume (L) or mass (kg) units. A higher energy density means that a battery can be smaller or lighter than other batteries while holding the same amount of energy, or that a battery of the same size can hold more energy [1]. Higher energy density batteries improve the use time of electric vehicles and smart devices, with less need for frequent charging. Electrical aircraft and drones especially benefit from lower-weight batteries with higher energy. Higher energy densities would improve their flight range or their maximum amount of payload. In smart devices, such as smartphones, laptops, or wearables, smaller batteries allow space for additional hardware features or allow smaller, sleeker, and more practical designs [2].

The main compounds of a lithium-ion battery are cathodes, anodes, and electrolyte. During charging, lithium ions are removed from the cathode and moved through the electrolyte, after which they are stored in the anode material. The energy density of a charged battery is determined by the lithium ion uptake of the anode (its capacity) [3]. Different anode materials have different theoretical capacities [4].

Conventional lithium-ion batteries typically contain graphite anodes. A factor limiting its energy density is the limited capacity of these graphite anodes, while they take up approximately half the size of the battery. To accommodate the electronic innovation that was mentioned before, extensive research is ongoing to find higher capacity anodes to improve the energy density of lithium-ion batteries [5].

Pure silicon anodes can theoretically store ten times more lithium ions per kilogram than graphite anodes due to silicon's ability to form lithium-rich alloys [4–6]. This means that silicon could store higher capacities, accounting for higher energy density batteries [4, 5].

The idea of placing pure silicon anodes in lithium-ion batteries is nothing new, as its high-energy storage capabilities were recognized by scientists decades ago. However, their greatest limitation was often the swelling and breaking of the silicon during lithiation [5].

In 2016, the silicon anode producer LeydenJar was founded by Christian Rood and Gabriel de Scheemaker, after a unique process was discovered for the production of pure silicon anodes at ECN, now TNO [2]. LeydenJar eliminates silicon's swelling problem via its plasma-enhanced chemical vapor deposition (PECVD) production process in which silane gas is deposited on a substrate material as a thin silicon anode layer. The resulting sponge-like pure silicon columns are porous and flexible. This allows the anodes to be break-proof and ultra thin, which accommodates high energy density batteries [2].

1.2 Business Landscape

To analyze LeydenJar's position in the high energy density battery anode market, Porter's five forces model was followed [7]. The different forces in this specific market were evaluated and showcased in Figure 1. The following sections explain the strength of each of the forces and the subsequent conclusion. It is important to note that LeydenJar focuses on two different customer segments. Lithium-ion battery producers are their direct market, but electronics producers can become original equipment manufacturers (OEMs) for lithium-ion batteries containing LeydenJar's silicon anode.

Rivalry among competitors	**Threat of new entrants**	**Threat of substitute products**	**Bargaining power of suppliers**	**Bargaining power of battery producers**
Low	Medium	Medium	Medium	High
• Big market size. • Rapid market growth. • Low number of competitors. • High concentration of competitors. • Different production methods. • Similar products. • High switching costs.	• High growth potential. • Patented knowledge. • High production costs. • High switching costs.	• Graphite anodes are market standard. • Polluting alternatives. • Low energy density alternatives.	• Silicon is an abundant material. • Little silane suppliers. • Growing silane market. • Low switching costs suppliers.	• Low product benefit/price ratio. • High implementation costs. • Backward integration theat.
				Bargaining power of OEMs
				Medium
				• High product benefit/price ratio. • Many OEMs. • Standardized procurement.

Figure 1: Porter's 5 forces model, showcasing LeydenJar's business landscape.

Rivalry among competitors

In the high energy density battery anode market, the competitor rivalry is relatively low. The market includes pure silicon anode producers, producers of silicon-graphite composite anodes, and lithium anode producers. There is a large number of customers, especially in the electronics sector and this number is rapidly growing due to the increasing need for smaller and more powerful electronic devices, resulting in low competition for the same customers [8, 9]. Besides, the number of competitors in the high energy density battery anode market is rather low [9], which further reduces the competitor rivalry. On the other hand, the pure silicon anode producers are located in only two countries, stimulating rivalry for the same customers and resources in these regions. In addition, the similarity between the pure silicon anodes produced by different companies is high, increasing the competition. However, the companies differentiate themselves by using different production methods, diminishing their rivalry. The rivalry is even further reduced by the high anode switching costs that battery manufacturers and OEMs perceive. This is because battery producers need specific cathodes and electrolytes to work with different anodes and OEMs tailor their product size and battery management systems to the specific anode requirements.

Threat of new entrants

The threat of new entrants in the market for high energy density battery anodes is moderate. Due to the aforementioned rapid growth of the customer market, it will be easier for new entrants to establish themselves by capturing unoccupied parts of the market, increasing the threat of new entrants. However, the threat is diminished due to the following factors. The large amount of patented knowledge held by current high-energy density battery anode producers and the typically high manufacturing costs create significant barriers to entry, reducing the threat of new entrants. Besides, the aforementioned high switching costs between anode suppliers make it more challenging for new entrants to win existing anode customers, further reducing this threat.

Threat of substitute products

The threat of substitute products in this market is also considered medium. As graphite anodes are the industry standard and battery manufacturers have established systems to incorporate these anodes, there are high costs involved in switching to new anodes. Therefore, graphite anodes as a substitute product form a significant threat. Traditional energy storage solutions such as gasoline, kerosene, and coal pose no significant threat as substitutes since their use emits greenhouse gasses, which many governments want to reduce. Simultaneously, alternative no-emission energy solutions like hydrogen or electrochemical conversion have a low volumetric energy density, meaning that they require a significant amount of space, posing no great threat to applications such as electric vehicles or consumer electronics.

Bargaining power of suppliers

The bargaining power of suppliers in the silicon anode market is assumed to be moderate. Silicon is one of the most abundant materials in the earth's crust [10]. The widespread availability of the material ensures independence from a single source, causing a reduction in the supplier's bargaining power. However, the production of the silicon anodes via PECVD requires silane gas, which is a processed form of silicon. There are few silane gas suppliers, corresponding to a higher bargaining power. Nevertheless, the silane market is continually growing [11], which reduces the bargaining power of silane suppliers. Besides, because the different silane suppliers provide similar products, the switching cost between the suppliers is low, further diminishing their bargaining power.

Bargaining power of battery producers

Overall, lithium-ion battery producers have an especially high bargaining power, which is attributable to several factors. Firstly, lithium-ion producers perceive a low benefit/price ratio in LeydenJar's pure silicon anode. Leydenjar's anode would make a cheap lithium-ion battery significantly more expensive, while the perceived benefit is relatively low because battery manufacturers currently have little trouble selling their standardized products [12]. Secondly, battery producers face high implementation costs, needing to customize their battery compositions and production processes to accommodate pure silicon anodes. Thirdly, battery producers are often significantly larger than LeydenJar and sometimes capable of backward integration, meaning that they can acquire silicon anode-producing companies. This reduces their need for collaboration with silicon anode producers.

Bargaining power of OEMs

Overall, OEMs are expected to have a lower bargaining power than battery producers. This is mainly due to the high benefit/price ratio they perceive in LeydenJar's silicon anodes. The anode pricing will only cause a small increase in the relatively expensive pricing of electronics. This tiny price increase is outweighed by the significant benefits of LeydenJar's pure silicon anodes, such as the ability to produce smaller devices, devices with more space for additional hardware features, and devices containing more energy. Moreover, the presence of many OEMs across different sectors, including smartphones, laptops, wearables, electric vehicles, and drones, further diminishes their bargaining power, since there is more competition for the same suppliers. On the other hand, many OEMs have standardized procurement procedures for off-the-shelf batteries, illustrating a significant effort to switch suppliers, which moderates their bargaining power.

Implications from the business landscape analysis

Porter's model shows that the battery producer's bargaining power is a strong force. To be able to reach the battery producers, LeydenJar can focus on reaching the OEMs first because their force is weaker. The interest of these OEMs can function as a means for convincing battery manufacturers of the value of producing batteries with LeydenJar's silicon anode, increasing their benefit/price ratio and weakening their force. Therefore a big focus point of LeydenJar is currently on obtaining and sustaining OEM customers.

1.3 Drone cell launch

Following the conclusion of Section 1.2, the focus of LeydenJar is currently on OEM customer development. One of the OEM sectors that LeydenJar is considering entering is the drone industry. The suitability of this market and LeydenJar's market entry strategy is discussed in this section.

Through previous collaboration with commercial drone manufacturers, insight was gained into the battery requirements of these parties. Drone flight time and carrying capabilities (payload) appear to be important themes and to improve these values, drone manufacturers expressed their need for small batteries with high energy contents (high gravimetric energy densities). Besides, since drone takeoff and landing appear to be powerful operations, drone manufacturers require high battery power capabilities. As drones are frequently used for multiple consecutive operations, and replacing a battery involves both time and costs, a sufficient battery cycle life also seems to be an important theme. In addition, a longer cycle life promises a more consistent battery performance throughout its lifetime. To fit their format, the different drone manufacturers also expressed their need for a specific cell capacity. A general list of drone battery requirements is shown in Table 1.

Based on these requirements, LeydenJar produced a battery cell, containing their pure silicon anode, that was optimized for use in drones. Partly because the properties of the resulting battery cell were similar to the requirements in the drone market (Table 1), product-market fit was assumed. Besides, a significant drone market size and a high product value for commercial drones were observed. Therefore, the drone market was determined to be the appropriate entry market for the launch of LeydenJar's first product, the drone battery cell.

LeydenJar's strategy in the drone market involves marketing and selling the specialized drone cells, containing their pure silicon anodes, to both drone manufacturers and drone pack manufacturers. The latter produces battery packs containing single or multiple cells together with a battery man-

Table 1: Initially expressed drone market requirements vs LeydenJar's drone cell properties.

Properties	**Initial market requirements**	**LeydenJar's drone cell**
Pouch cell capacity	5 Ah	5 Ah
Energy density	$\geq$ 350 Wh/kg	334 Wh/kg
Discharge rate	High discharge rates	$>$ 7C continuous discharge
Cycle life	$\geq$ 200 cycles	$>$ 200 cycles

agement system (BMS) to fit the dimensions and voltage requirements of specific drones. The cell requirements for these drone pack manufacturers are assumed to be similar to the requirements of drone manufacturers, as the battery packs are produced for use in drones.

To ensure that LeydenJar's anode production is profitable, the company aims to sell multiple MWh (megawatt hours) of drone cells, containing their pure silicon anodes, to the drone industry. To ensure profit, smaller sales volumes per customer would be accompanied by higher pricing per cell. Small sampling volumes can be produced in-house, but larger drone cell numbers would be produced through third-party cell manufacturers, using LeydenJar's silicon anodes and production technique.

Since the value of the drone cell is largely determined by its performance, it is essential to highlight these key performance metrics in its marketing. A product datasheet, which is a one-page specification overview of the cell is considered to be the appropriate medium for said marketing. This is because a datasheet allows all key performance metrics to be displayed in one overview, giving a quick and comprehensive impression of the product.

Therefore, LeydenJar's commercial team developed a datasheet, displaying the properties of the drone cell, which is displayed in Supplementary Figure 1a. The datasheet consists of the important cell requirements from Table 1, together with information that is assumed to be important for drone manufacturers to evaluate the alignment of the product with their requirements. For instance, to make the general information more tangible, the datasheet contains the benefits that the battery cell can deliver in a drone. These benefits include the increase in flight area, flight time, and payload that a drone can carry. These relative values were calculated for a range of commercial drones and are presented as a range of percentages to ensure the data is representative of most of the drone industry. The level of detail of the information in the sheet is based on the presumed understanding of drone industry employees who are regularly evaluating drone batteries.

2 Problem Statement and Research Questions

Since the drone cell launch will be LeydenJar's first public product launch, several problems and uncertainties remain that are discussed in the following paragraphs.

LeydenJar's drone cell was produced to align with previously assessed customer requirements (section 1.3). However, those initial requirements were retrieved from a limited set of commercial drone manufacturers. If these requirements are not representative of the rest of the drone industry, the drone cell will only be developed for a niche, which is not preferred as the sales potential will be significantly lower than expected. Besides, little is known about the integration of LeydenJar's drone cell into a drone and the related challenges. Continuing market entry without further addressing these uncertainties could result in a low product-market fit and unprofitable product sales (Section 1.3). Therefore, it is necessary to address these uncertainties first, which leads to the following research question.

1. To what extent does LeydenJar's drone cell align with the requirements of potential customers in the drone market and what are their observed limitations in the product and its integration?

The product datasheet is assumed to be the appropriate marketing medium based on the belief that the value of the drone cell is determined by its performance and on the assumption that people in the drone industry want a short overview to be able to quickly assess the cell (Section 1.3). As this was never validated with real customers, it is uncertain whether this marketing medium is effective and leads to the desired attention of drone industry players and profitable product sales (Section 1.3). This leads to the next research question.

2. Is a datasheet the most appropriate medium to market the drone cell and what alternative marketing medium would be appropriate?

The datasheet that is used for marketing the drone cell (in Supplementary Figure 1a), contains all the information that is assumed to be important for evaluating the battery cell. The level of detail of the information in the sheet is based on the assumed understanding of battery procurers in the drone industry (Section 1.3). These assumptions were never validated with drone industry players. Proceeding without validating and optimizing the datasheet could yield ineffective marketing, limiting customer traction and potentially resulting in unprofitable product sales volumes (Section 1.3). This leads to the last research question to be answered.

3. How do potential customers in the drone market evaluate the completeness and clarity of LeydenJar's drone cell datasheet and how can this evaluation be improved?

3 Concepts and Literature

Key to answering the research questions is understanding the drone market requirements. This chapter explains how new product development and the Lean Startup are valuable concepts for obtaining drone market understanding and for shaping the methodology of this study.

3.1 New product development in a small-sized high-tech company

New product development (NPD) is a structured process for designing and launching a new product, intending to reach product-market fit in a specific market. Since the introduction of a product to a specific market depends on a variety of factors unique to that market, NPD models do not suggest a single standardized solution for successful development. Instead, these models often provide methods for understanding market requirements and aligning the specific product development to the specific market [13, 14].

Traditional NPD models, such as the original Stage-gate model, are plan-based and linear. Although these models may involve some customer feedback, most time and effort is invested in developing the product through in-house analysis and validation to reach pre-determined targets. While these traditional NPD models might still hold up for larger stable enterprises, they do not for startups and scale-ups, which operate in more extreme and uncertain environments. Additionally, startups in high-tech sectors are often innovation-driven and not always able to fully describe and plan their product or customer segment, before product-market fit is reached. Therefore, more modern NPD models attempt to address these uncertainties [14, 15].

These modern NPD models focus more on experimenting and obtaining new insights into the product and market. The models prioritize flexibility and adaptability to these new insights, suggesting radical strategy changes if necessary, to achieve product-market fit. Moreover, modern NPD models often focus on more frequent customer involvement to be able to optimize the alignment of the product with the target market requirements. One of the most popular modern NPD models is the Lean Startup, which will be discussed in more detail in the following section [15, 16].

3.2 The Lean Startup method

The Lean Startup methodology was first introduced by Eric Ries to help minimize the time and resources wasted on building products with insufficient market fits [16]. The method helps validate aspects of a product or business model to determine whether an idea is commercially feasible or scalable [14, 16, 17]. The Lean Startup method involves iterative product development and validated learning, while heavily relying on customer feedback [16]. Ries explained that this methodology is meant for all companies "designed to create new products and services under conditions of extreme uncertainty" and that "the Lean Startup approach can work in any size company, even a very large enterprise, in any sector or industry" [16]. This means that the Lean Startup methodology would also apply to the product development processes at LeydenJar. The different aspects of the Lean Startup methodology are discussed in the following paragraphs.

Customer development

Before Ries, Steve Blank introduced the concept of customer development, which suggests that involving customers is just as important as in-house product development and serves as an important foundation for the modern Lean Startup approach [16, 18]. Customer development aims to stop

relying on assumptions and to "get out of the building" to test these assumptions with real potential customers to ensure alignment between product development and market requirements [17]. The Lean Startup approach suggests following the build-measure-learn feedback loop to achieve this aim [16].

Build-measure-learn

The build-measure-learn feedback loop (Figure 2) helps startups and scale-ups to test their ideas with the market and to retrieve market insights, which could stimulate new ideas. As the name suggests, the feedback loop is a non-linear iterative process and Ries explains that continuous cycling through the different steps helps refine a product [16].

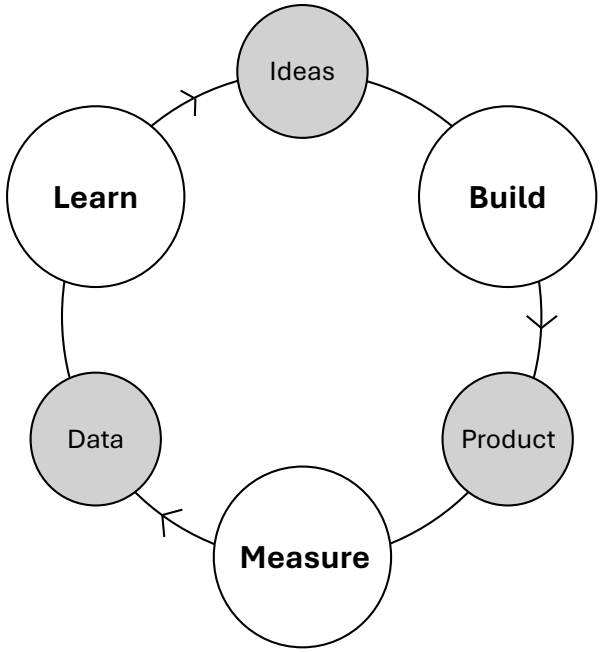

Figure 2: The build-measure-learn loop as proposed by Eric Ries. The figure was reconstructed from [16].

The build step of the feedback loop involves building a representation of a product, based on initial ideas and assumptions. Examples of product representations are prototypes, mock-ups, or landing pages [16, 17]. The product representation is intended to be presented to potential customers to gather insights into their requirements. A minimum viable product (MVP) is a representation of the final product that enables gathering a significant amount of customer insights with a minimal amount of effort and development time. Presenting an MVP is believed to be the most efficient way of following through the feedback loop [16, 19].

During the measuring step of the feedback loop, customer response to the product representation, built in the previous step, is measured. Measuring could yield quantitative or qualitative data. Quantitative data includes metrics such as the number of users, frequency of use, or the percentage of people who filled out an inquiry form. Alternatively, qualitative data includes responses

to interviews or surveys, containing questions about customer preferences regarding specific aspects of the product [16, 20].

The learn stage of the feedback loop involves analyzing the data gathered in the previous stage to achieve validated learning. Validated learning is obtaining empirical insights that either support or refute the initial assumptions on market requirements that were used for building the product representation in the build stage [16]. Based on the outcome, the executing party decides whether to use their new insights for building new product representations and continuing in the feedback loop, to continue market entry, or to pivot away from their current strategy [16, 20]. These different options are discussed in the following paragraphs.

To pivot or to persevere

After following the build-measure-learn feedback loop, companies have different strategic options, based on the obtained insights.

If the tested ideas and assumptions are validated and customer feedback does not suggest a change in direction, the company is generally advised to persevere on its current path. This means either continuing to test remaining or new assumptions or, once all assumptions are validated, to continue market entry and scaling [16, 20]. Different literature suggests that even during and after scaling, companies can benefit from experimentation of their product or business model and are advised to do so [20, 21].

Alternatively, if the tested assumptions are refuted, or if customer feedback suggests a more optimal business strategy than the one pursued, the company may choose to pivot. Pivoting means fundamentally changing the current strategy [16, 20]. There are different ways in which a company can decide to pivot, related to the different aspects of the business model. The relevant types of pivot for this study are the channel pivot, the customer needs pivot, and the customer segment pivot. A channel pivot is done when a specific marketing medium is not appropriate for the product and/or customer segment, but an alternative medium is. The customer needs pivot is done when the original problem, solved by the product, is not important to the customer segment, but related problems seem to be. The customer segment pivot is done when the product solves the problem for a different segment than originally intended [16]. It is important to be able to realize when the current strategy is not appropriate anymore and when a change in strategy is needed [16]. However, company founders commonly feel reluctant to such a change, as they tend to feel psychological ownership over their ideas [22, 23].

Several variations of the Lean Startup method suggest considering a third strategic decision, which is to perish or terminate the business. These variations suggest that if business failure can be predicted through market testing, costs and effort can be saved by terminating the business in time. Business failure could be predicted when market testing rejects a fundamental part of the business model and no appropriate pivot could be identified [19, 20, 24]. However, since many pivot strategies are possible and perishing is often not a proportional conclusion to single market tests, Lean Startup models often tend to be more optimistic by leaving out the option to perish [16, 19].

A general overview of the Lean Startup process, including envisioning a business strategy, building, measuring, learning, and subsequent decision making was presented by Eisenmann et al. (Figure 3) [20]. The figure showcases the build-measure-learn-loop, together with subsequent decision-making.

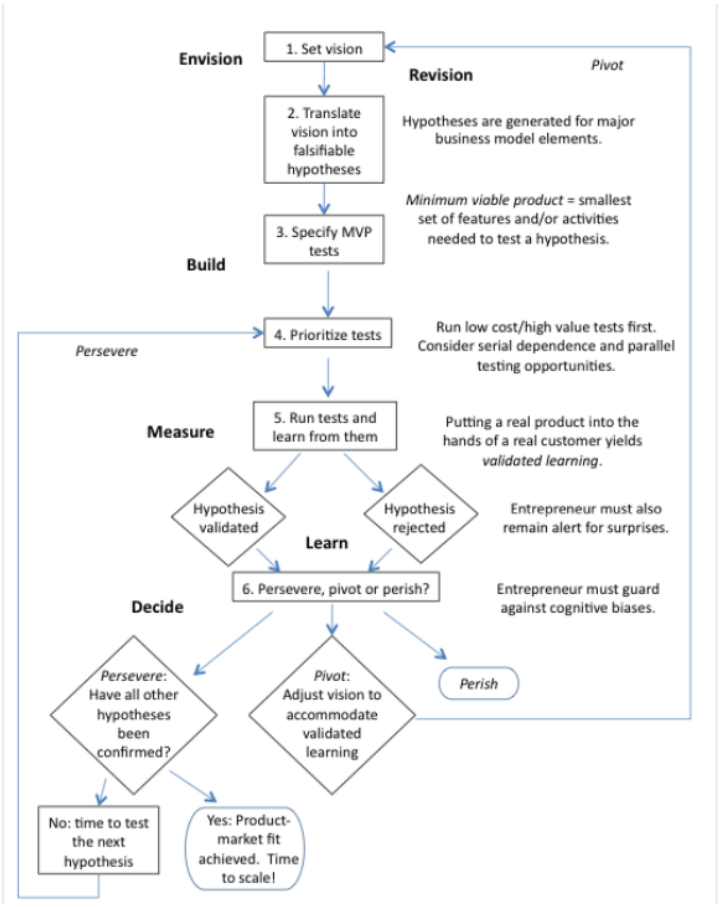

Figure 3: The Lean Startup methodology and an extensive version of the build-measure-learn loop. The figure was obtained from [20].

Downsides of Lean

Although the Lean Startup method generally seems to improve the alignment of a company's business strategy and product with market demands, several pitfalls of this method are mentioned throughout the literature.

First, since Lean involves human reflection on test data, cognitive biases could reduce the effectiveness of the method, as entrepreneurs tend to see what they want and expect to see in the data. This could result in premature persevering or pivoting [16, 20].

Simultaneously, since Lean relies on pivoting when business model assumptions are invalidated, taking every piece of negative customer feedback seriously might result in excessive pivoting while neglecting the importance of persevering [23]. Third, Lean could get in the way of groundbreaking innovation that requires taking bigger risks and challenging conventional knowledge. This is because Lean focuses on rapid experimentation that often results in small incremental changes, potentially neglecting more significant innovation opportunities [16, 20].

Lastly, the Lean Startup method does not seem applicable to all companies. The method involves learning from mistakes, but for some companies making mistakes is not tolerable. For instance, when the mistakes impact the critical activities of customers, or when there is no time or resources

to correct the mistakes, the Lean Startup method is not applicable [20]. Some companies face low demand uncertainties and testing relatively certain assumptions would take an unnecessary amount of time and resources [20]. In companies with long development cycles, such as deep-tech startups, building and testing an MVP would take a disproportional amount of time and resources, which also limits the applicability of the Lean Startup method [20].

3.3 Case studies

To explain the relevance of the Lean Startup approach, two company case studies are highlighted.

Webvan was an early online grocery store that went bankrupt several years after it was founded in 1996 despite significant funding and positive initial customer feedback. A major reason for Webvan's failure seems to be the fact that the company followed a rather linear traditional product development model that focuses on execution and rapid scaling [18]. Since Webvan introduced a relatively new and uncertain concept to the market, a linear NPD model seems to be inappropriate compared to more modern NPD approaches that focus on experimentation and obtaining new insights, as also discussed in Section 3.1 [18, 22, 23]. Reflected by their product development model, Webvan did not undergo extensive customer development to validate key assumptions about customer needs and market demands [18]. One of these assumptions was that people did not want to shop in supermarkets anymore [25]. Based hereon, Webvan underwent rapid scaling, investing $40 million in their first automated warehouse before shipping a single item. The company eventually spent over $800 without validating their strategy and product after, apart from initial customer feedback [18, 25]. The disappointing revenue after these big investments eventually led to the company's bankruptcy. Literature suggests that validating product and strategy throughout development and scaling, by adopting more modern NPD approaches like the Lean Startup method, could have mitigated the consequences of failure or even ensured success for the company [16, 18, 25].

Alternatively, Votizen's story showcases how startups can achieve success through strategic pivoting, after validated learning [16, 26]. Votizen was founded in 2009 as a social network for American citizens to verify as committed voters, learn about civic issues, and share ideas with other committed voters. Votizen's first MVP was launched quickly for just $1,200. This MVP focused on user verification as registered voters and providing activism tools. The initial customer adoption was too low, which prompted the need for iteration and optimization. Based on validated learning, the organization eventually underwent three different pivots, changing its product, target audience, and platform. The eventual product was completely different than the initial one, as it was a social lobbying platform for larger organizations, professional fund-raisers, and companies interested in political campaigning via a platform where users could sign up with their credit cards. The final product was well adopted by the market and caused significant company revenue [16]. This demonstrates that, although it could seem counter-intuitive for founders, pivoting a business strategy after validated learning, and doing this multiple times if necessary, can ensure success for new ventures [16, 22].

3.4 Literature gap

Although extensive literature can be found on the use and application of Lean for testing and optimizing products, there seems to be little literature on using Lean for developing product marketing materials. Although the development of marketing for a specific product is linked to understanding general market requirements for that product, different questions for product marketing remain.

For instance, important questions for developing marketing materials are what product data is necessary for quick evaluation of the product, or how to represent this data to the potential customers. The literature does not seem to explain whether the Lean Startup methodology can be used to answer these questions and to optimize product marketing materials. This study attempts to optimize the drone cell marketing materials through Lean-inspired iterative customer validation tests. The literature gap is addressed by discussing and concluding whether this optimization was successful in Chapter 6 and 7, respectively.

3.5 Implications for research methods

To answer the customer-oriented research questions in Chapter 2, this study borrows aspects of the Lean Startup method and follows the build-measure-learn feedback loop to obtain insights into the drone market requirements. The product representation to be tested will be the product datasheet, as it allows for the assessment of customer validation of the product, the product marketing medium, and the contents of the product datasheet. Since a limited number of potential customers in the drone industry could be reached, quantitative data analysis would yield insignificant results. Therefore, a qualitative assessment, through executing interviews, is the preferred method for this study. To optimize the evaluation of the product datasheet, the build-measure-learn loop is followed iteratively. Eventually, subsequent decision-making is advised, which involves pivoting or persevering. The research methods are explained in more detail in the following chapter.

4 Methods

Previous to this research, based on drone market insights (Section 1.3), a drone cell was produced, the datasheet was determined to be the appropriate marketing medium, and a datasheet showcasing the drone cell properties and benefits was constructed. The initial datasheet is added as Supplementary Figure 1a. This datasheet was used for the initial customer interviews in this study.

4.1 Sample group

Before executing those interviews, this study started by determining the sample group to be interviewed. To ensure the drone cell marketing is developed based on feedback from its target audience, the sample group of this study consists of 'potential customers in the drone industry.

To find interviewees within this sample group, different strategies were executed. First, several drone and drone pack manufacturers who previously collaborated with LeydenJar were contacted via email. These emails explained that LeydenJar is in the process of releasing a new battery cell, containing their 100% silicon anode, that is optimized for use in drones, with flight time increase and payload increase as main themes. The respondents were invited to an online interview to validate LeydenJar's drone cell and its accompanying product marketing. Through this strategy, interviews 1 and 2 (chronologically) with commercial drone manufacturers, and interview 6 with a commercial drone pack manufacturer, were organized. Second, nine drone-producing parties that LeydenJar was not in previous contact with were contacted on their emails for general inquiries. The storyline in these emails was similar to that in the emails to LeydenJar's previous collaborators. Through this second tactic, only interview 3 was obtained with two respondents from a student drone team. However, one of these respondents recommended contacting two other student drone teams and provided the names and email addresses of the relevant people in those teams. These people were contacted with a similar storyline as to the other respondents, while also mentioning

the successful conversation with the other student drone team and that their contact information was obtained through them. This third strategy resulted in interviews 4 and 5 with student drone teams. An overview of the different interview respondents is shown in Table 2. Different versions of the drone cell datasheet were used for the interviews. Part of the insights obtained during the first interviews were used for updating the initial datasheet to a second version, shown in Supplementary Figure 1b. This second version was used for subsequent interviews, as displayed in Table 2.

Table 2: The respondents of the different interviews

Interview	**Company type**	**Drone type**	**Role**	**Datasheet test**
Interview 1	Commercial drone manufacturer	Agricultural drones	CEO	Version 1
Interview 2	Commercial drone manufacturer	Package delivery drones	Senior Scientist	Version 1
Interview 3	Student drone team	Medical aid drones	3.1: Chief of Manufacturing & Marketing	Version 2
			3.2: Chief of Electronics & Testing	
Interview 4	Student drone team	Solar powered drones	Leader of Drone Team	Version 2
Interview 5	Student drone team	Drones that can perform an aerial battery swap	Business & Personnel Manager	Version 2
Interview 6	Drone pack maker	n.a.	Battery Specialist	Version 2

4.2 Interview strategy

As explained in the previous chapter, the product datasheet was discussed with the interview respondents to assess the customer validation of the product, the product marketing medium, and the contents of the product datasheet. The datasheet was sent to the interviewees several days before the interviews so the respondents could already review its contents. The interviews with the different respondents were semi-structured, meaning that a list of pre-determined questions was asked, while also asking follow-up questions to relevant responses [27]. The list of pre-determined questions is showcased in Supplementary Section D. The questions were constructed to address the three main topics of this study (Chapter 2). To assess product validation, the interviewees were asked whether the drone cell, as described in the datasheet, fits their requirements and what improvements and additional features they would propose for the drone cell to better their requirements. Additionally, to assess the integration of the product, the interviewees were asked whether they foresee challenges in terms of implementing the drone cell into their application. To assess the marketing medium, the interviewees were asked whether the datasheet was the best way to explain the value of the drone cell to them. Consequently, they were asked for suggestions for alternative

marketing media. To assess the drone market evaluation of the drone cell datasheet, questions were asked on the completeness and clarity of the datasheet. Before discussing the datasheet, the interviewees were asked what the most important data is to them when evaluating a battery for their application. Answers to this question would provide insight into the perceived completeness of the datasheet. Additionally, to study the completeness further, the interviewees were asked whether they could fully evaluate the drone cell based on the information in the datasheet and what information would have to be added to complete the picture. To assess the clarity of the datasheet, the interviewees were asked what specifics in the datasheet were unclear to them and how those specifics could be explained better.

The interviews were recorded through note-taking or video recording in Teams. The video recordings were transcribed in their original language. The interviewee responses are showcased in Supplementary Section F to K.

4.3 Qualitative data analysis

The interview responses were labeled, by assigning codes in Word, initially through open coding [28]. After recognizing general commonalities related to the research questions of this study, the codes were modified to fit these common themes. Thereafter, the codes were put in an Excel file in a provisional codebook in which the occurrence of each code was counted. The codes with minimal occurrence were combined or deleted and the themes were refined to ensure accurate representation of the data. The final codebook showcases the codes and themes, organized by the three main concepts, being product, marketing medium, and datasheet. This codebook is added as Supplementary Table 1. Descriptions of the coded interview responses, together with relevant interviewee quotes, were organized and interpreted in chapters 5 and 6, respectively.

4.4 Next steps

The insights from the interviews were used to produce the recommendations on LeydenJar's next steps in the drone market in Chapter 7. An overview of the possible next steps is showcased in Figure 4, which was based on the Lean Startup methodology in Figure 3. The next step could be to persevere datasheet optimization by applying the recommended changes, discussed in this study and testing the datasheet with the drone market again by following a similar methodology as described in this chapter. Another option is to cease market research for datasheet optimization and to persevere in marketing the drone cell with the latest version of the datasheet. Alternatively, the advice could be to pivot away from the strategy envisioned beforehand through the following pivots. Using the datasheet as a marketing medium could be stopped and replaced by more appropriate marketing, which is a channel pivot (Chapter 3). Besides, changes to the drone cell could be made to better fit the market, which is a customer needs pivot. Lastly, the drone market could be abandoned altogether, for instance, if there is no product-market fit, which is a customer segment pivot (Chapter 3). Since LeydenJar develops more products than only the drone cell for more markets than only the drone market, perishing business, as showcased in Figure 3, would not be a proportional conclusion to this study and is left out of Figure 4.

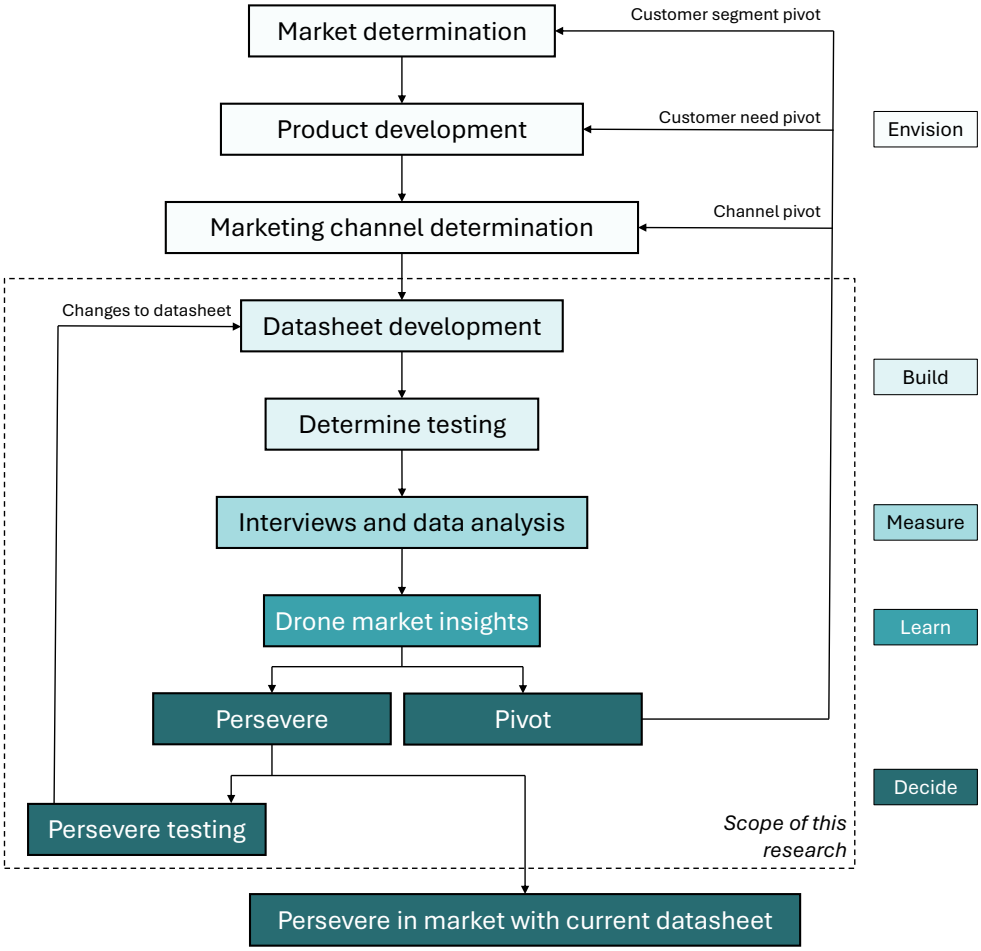

Figure 4: Lean Startup methodology in this research.

5 Results

This chapter presents the findings of this qualitative study, which involved conducting, coding, and analyzing interviews with different interviewees in the drone sector. An overview of the interview groups is presented in Table 2. In the interviews, LeydenJar's drone cell datasheet, which is presented in Supplementary Figure 1, was discussed. The results are organized into the sections Drone cell validation (5.1), Drone cell marketing medium (5.2), and Datasheet validation (5.3), representing the research topics from Chapter 2. The findings are presented without significant interpretation, which will be addressed in the subsequent discussion section.

5.1 Drone cell validation

An overview of the qualitative results on the validation of the drone cell with potential customers is showcased in Table 3. The results in the table were retrieved from the coded interviews in Supplementary Section F to K and based on interview statements that were labeled with the codes in the left column of the table. The results were not based on a quantitative occurrence of the codes. The following sections elaborate on the product alignment with customer requirements, the points of misalignment, and the foreseen integration challenges, as presented in the table. Quotes from the different interviews are used to illustrate the key topics.

Table 3: Results on product validation.

Aspect	Interview 1	Interview 2	Interview 3	Interview 4	Interview 5	Interview 6
Product alignment (Codes: alignment, misalignment)	High	n.a.	High	High	High	High
Misalignment (Code: misalignment)	No misalignment	Need larger cell & longer cycle life	Need higher discharge rating	Uncertain about cycle life	Uncertain about performance after scaling	No misalignment
Challenges for integration (Code: integration)	Cell heating	Cell heating & cell dimensions	Compact casing	Flight cycles under trickle charge	Need for concrete test data	Cell heating & cell dimensions & anode tabs

Product alignment with requirements

To gain insight into the fit of LeydenJar's drone cell with the drone market, the interviewees were asked if LeydenJar's product, as described in the datasheet, aligns with their drone battery requirements. As presented in Table 3 almost all interviewees indicated that the drone cell, as presented in the datasheet, is highly aligned with their requirements. For example, interviewee 1 answered: *"The battery is much better than what we are currently using."* Interviewee 2 did not specifically comment on the alignment of the product with their needs.

Different interviewees mentioned the high energy density of the cell in their answers. Interviewee 4 stated: *"I think your battery would work really well in a drone. As a drone manufacturer,*

you might be crazy if you do not choose to improve the energy density of your battery. Looking at your energy density, a drone manufacturer would have to say yes." Similarly, interviewee 3.2 stated: *"Your energy density is perfect, your voltage is okay, you have good data in comparison to other batteries."*

Based on the product that is presented in the datasheet, interviewee 6, the drone pack manufacturer, showed clear interest in offering LeydenJar's cells in packs to their customers and adding those packs to their portfolio. This further supports a high alignment between the needs of the potential customer and the drone cell that is presented in the datasheet.

Points of misalignment

Although a significant alignment was observed between the product and the potential customer requirements, some uncertainties and small points of misalignment were mentioned in the different interviews, as showcased in Table 3.

Interviewees 4 and 5 were both wondering how the cell would perform in terms of cycle life when tuning the cell to their specific drone formats. Interviewee 4 mentioned that their protocol demands continuous discharge and recharge of the battery. They were curious if the number of flight cycles in the datasheet would not go down using their protocol. Similarly, interviewee 5 mentions that their application might demand a higher amount of energy than delivered by one LeydenJar drone cell. They question what would happen to the re-usability, meaning the number of cycles that a cell can be used for when scaling for their application: *Translation: "The only question is what happens when you would scale up the battery in terms of capacity. Is the battery still decently re-usable then? Does it become some kind of consideration between different specs?"*

Interviewee 2 also mentioned that they need to scale the cell to appropriately fit their format. Not only were they uncertain about the cycle life after scaling, but they noted that the current cell cycle life as described in the datasheet was too little for them: *"We need a larger cell. We have a longer cycle life requirement."*

Interviewee 3.2 noticed that the discharge rating that is depicted in the datasheet (7C) is significantly lower than what they normally use, which are cells with discharge rates up to 70C. They stated that improving upon the discharge rating would make LeydenJar's battery cell one of the best: *"With such a high energy density and a high C-rating you would have one of the best batteries. That's it."*

Integration challenges

To complete the overview of LeydenJar's product fit with the drone market, the interviewees were asked what challenges they would foresee in the integration of the drone cell into their application. Different challenges and uncertainties were mentioned, as represented in Table 3.

Interviewees 1, 2, and 6 all mentioned the necessity of understanding to what degree the cell heats up during cycling, indicating that cell heating is a common problem in drones. Interviewee 1 explained: *"Battery pack makers told us about cells that heat up too much, so that could be an issue."* Interviewees 2 and 6 explained that testing of this *"thermal runaway"* would eliminate uncertainties regarding smooth cell integration into their drones or packs, respectively.

Interviewees 4 and 5 also mentioned the need for more cell test data for integration into their specific designs. Interviewee 5 asked for general test data for further evaluating LeydenJar's drone cell: *Translation: "I think that for us it is mainly important that we receive the concrete test data and that we get to see what the battery can actually do."* Simultaneously, interviewee 4 specifically asked for flight cycle data using their specific trickle charge protocol: *"We are working on trickle charge, meaning that the battery charge rate changes depending on the amount of sunlight. What would be the chance that your battery degrades faster than 200 cycles using this protocol? Based on the answer to that question we can determine how to program our battery management system."*

Another integration obstacle that was commonly mentioned by the interviewees is the size and dimensions of LeydenJar's drone cell. While interviewee 2 expressed the need for a larger cell and that the cell format is not *"plug and play"*, interviewee 6 indicated the utility of a small drone cell. They stated: *"The shape and dimensions of the presented battery do not always fit in a drone. The terraces on the sides of the cells take up significant space."* Interviewee 3.2 stated their need for a compact battery pack, also indicating the need for small drone cells to fit the compact casing: *"If you have a compact case it would be nice. Our use space is small because we also need enough space for the package we're going to send. We want to use as little space as possible."*

Lastly, interviewee 6 mentioned a clear integration challenge by stating that aluminum anode tabs are difficult to solder onto a cell pack. They stated their desired alternative: *"We would prefer that you use thicker copper tabs."*

5.2 Drone cell marketing medium

An overview of the qualitative results on the product marketing medium is showcased in Table 4. The results in the table were retrieved from the coded interviews in Supplementary Section H to J and based on interview statements that were labeled with the codes in the left column of the table. The results were not based on a quantitative occurrence of the codes. The following sections elaborate on the validation of the datasheet as a medium for marketing LeydenJar's drone cell and on alternative marketing forms that were suggested by the different interviewees. Quotes from the different interviews are used to illustrate the key topics.

Table 4: Results on the product marketing medium.

Aspect	Interview 3	Interview 4	Interview 5
Datasheet medium (Codes: right channel, wrong channel)	Appropriate	Appropriate	Appropriate
Alternative suggestion (Code: alternative)	Short video showcasing the drone flight time	Drone benefits calculator	Real drone test results

Validation of the product datasheet as marketing medium

To validate whether the product datasheet is the appropriate marketing medium for showcasing LeydenJar's drone cell, the interviewees were asked: *"Is a data overview like this the best way to explain the value of our product to you?"* Due to time constraints, this question was only asked to interviewees 3 to 5. The three interviewees all confirmed that they think LeydenJar's product

datasheet is the appropriate medium.

Interviewee 3.2 stated that *"This sheet is integral and should always be added together with the product."* Similarly, interviewee 5 mentioned that *Translation: "I would not say that there are better ways to showcase your product at the moment."* Interviewee 4 stated: *"Yes, I think it works."*

Suggested alternative marketing media

The interviewees were also asked what alternative media they would suggest for marketing LeydenJar's drone cell. They all mentioned different ideas that could be presented together with the datasheet.

Firstly, to deliver proof of concept, interviewee 3.2 suggested the addition of a time-lapse video in which the flight time of a drone containing LeydenJar's cells is visually showcased. They explained that this would help prove LeydenJar's capabilities: *"If you can show it, it gives you way more integrity and shows that you can and did do it."*

Secondly, as the drone benefits at the top of the datasheet are only showcased for an industry-standard drone, interviewee 4 suggested enabling drone manufacturers to calculate these benefits themselves. They suggested adding a calculation tool on LeydenJar's website: *"A fun addition could maybe be a tool on your website where drone manufacturers can fill out their drone and battery specifics and receive a calculated increase in flight time, flight range and payload."*

Lastly, interviewee 5 stressed the importance of delivering a proof of concept in a real drone. They stated: *Translation: "You can promise anything and eventually it's still about the results in a drone. If you can showcase 'our battery allows a specific drone to fly twice as long and execute twice as many operations', then it is tangible for the people in the industry."* They added that it is enough to showcase these benefits using numbers, rather than visually showcasing them, as long as they were measured in a real drone.

To deliver the suggested proof of concept, multiple respondents offered a testing platform. Interviewee 3.1 suggested that LeydenJar could use one of their applications as a test platform to deliver the visual proof they suggested: *"And if you need any test platform for it, interviewee 3.2 still needs to do their thesis and they were planning to do it with solar panels on drones. So keep that in mind as a test platform."* Interviewee 4 also offered their application as a test platform for delivering drone data: *"We could measure battery data in our drone for you. We then have to know what the largest uncertainties are in your product so we can test these aspects."*

5.3 Datasheet validation

An overview of the qualitative results on the validation of the drone cell datasheet with potential customers is showcased in Table 5. The results in the table were retrieved from the coded interviews in Supplementary Section F to K and based on interview statements that were labeled with the codes in the left column of the table. The results were not based on a quantitative occurrence of the codes. The following sections elaborate on the completeness of the datasheet, the clarity of the datasheet, and on the additions to the datasheet that were suggested by the different interviewees. Quotes from the different interviews are used to illustrate the key topics.

Table 5: Results on datasheet validation.

Aspect	Interview 1	Interview 2	Interview 3	Interview 4	Interview 5	Interview 6
Completeness (Codes: completeness, incompleteness, important aspects)	Moderate	Moderate	High	Moderate	High	n.a.
Clarity (Codes: clarity, unclarity)	Moderate	n.a.	High	Moderate	High	n.a.
Suggested addition (Code: addition)	DoD & charging data & cycle life retention & absolute drone benefits	DoD & resistance measurement moment & pressure information	Product understanding & pack integration & raw data graphs	Pack integration & burst discharge rate & BMS requirements	No suggested addition	Charging data & more temperature data & terrace folding & voltage data

Datasheet completeness

To assess the qualitative evaluation of the product datasheet by different potential customers, two traits of the datasheet were studied. First, the opinion of the interviewees on the completeness of the datasheet was assessed. The completeness scoring in Table 5 (High or Moderate) was determined by a combination of factors. Before discussing the datasheet, the interviewees were asked what the most important aspects are to them when evaluating a battery for their application. The correspondence between their answer and the contents of the datasheet is the first feat by which the completeness was scored. The second feat is the response of the interviewees when asked if they could fully evaluate LeydenJar's drone battery based on the information in the datasheet and what additional information should be provided for a more complete overview. This resulted in a divided completeness scoring by the different interviewees.

Interviewee 1 named three aspects that were most important to them when evaluating a battery for their application, namely energy density, price, and flight cycles. The price of the cell is not showcased on the datasheet. Besides, the interviewee clearly stated a few points of additional information that should be provided for a more complete picture. However, they stated: *"For the rest, the datasheet is fairly complete."* Since both points of completeness and incompleteness were mentioned by the interviewee, this accounts for a moderate datasheet completeness scoring by interviewee 1.

All of the most important evaluation aspects of Interviewee 2 are present in the datasheet, namely power, energy, and cycle life. The interviewee stated that: *"The datasheet is very detailed."* However, they also mentioned several pieces of necessary information that they were missing in the datasheet. Similar to interview 1, this accounts for a moderate datasheet completeness scoring by interviewee 2.

Interviewee 4 also clearly indicated that some necessary data for them was missing from the product datasheet. They mentioned a list of aspects they analyze when evaluating a datasheet, including gravimetric energy density, discharge rating, volumetric energy density, the number of cells that can be sampled, the kind of cell pack, whether a battery management system (BMS) is provided with the cell, and the necessary pressure. However, they stated: *"To us, the most important aspects are gravimetric energy density and discharge rate"*. Since both of these aspects are important themes in the datasheet, the datasheet completeness scoring by interviewee 4 was concluded to be moderate.

In both interviews 3 and 5, the interviewees clearly stated that they perceived the information in the datasheet as complete. Interviewee 3.2 said: *"I think it's well written, it's to the point, doesn't have a lot of unnecessary information and from what I see I think it has everything to evaluate the battery."* After this, interviewee 3.1 added: *"You can see that it was written and made by an engineer."* Similarly, interviewee 5 stated their perceived completeness of the datasheet: *Translation: "Yes, when I get this datasheet in front of me I am able to make a reasonably sound assumption of the product itself, indeed. I could not quickly think of anything that is missing. The really important aspects of drones are on there."* Besides, important evaluation points for these interviewees are present in the datasheet. For interviewees 3.1 and 3.2 these points are gravimetric energy density and C-rating, which are both present in the datasheet. For interviewee 5 these points are energy use efficiency and re-usability, which is depicted by the number of flight cycles in the datasheet. Overall, these points account for the high datasheet completeness scoring in interviews 3 and 5.

Interviewee 6 did not comment on their perceived completeness of the datasheet and due to time constraints they were not asked for their most important evaluation points.

Datasheet clarity

After assessing the completeness of the datasheet, the customer evaluation of the datasheet was further studied by assessing the opinion of the interviewees on the datasheet clarity. The interviewees were asked what parts of the information in the datasheet were unclear to them. The scoring for datasheet clarity in Table 5 was determined by analyzing the response of the interviewees to this question. If nothing was unclear to the interviewee, a high datasheet clarity scoring was assigned. If the interviewee acknowledged the clarity of the sheet but also mentioned points of unclarity, a moderate clarity score was assigned. If only points of unclarity were given, a low clarity score would have been assigned. As presented in the table, this resulted in a divided clarity scoring between the different respondents.

The respondents of interviews 3 and 5 stated that the information in the product datasheet was clear to them. Interviewee 5 stated: *Translation: "For me, it is quite clear and just like the people in the industry I work on it every day, so we get stuff like this in front of us often enough.* They added: *Translation: "Also very nice that a comparison is made with a standard drone. I see at the*

bottom 'The data is compared with a standard inspection drone with the following properties', no okay, that is all pretty clear." Interviewee 3.1 said: *"Clarity overall is okay in my opinion"*, after which interviewee 3.2 added: *"Yeah it's understandable, it gives all the statistics and qualities."*. These respondents did not mention any points of unclarity, so a high datasheet clarity scoring was assigned for both interviews. Interviewee 3.1 mentioned that they foresaw possible unclarities for non-engineer decision makers, but that was unrelated to their own opinion on the datasheet clarity.

Interviewees 1 and 4 both mentioned one aspect of the datasheet that was unclear to them. Interviewee 1 stated that *"The percentual flight time increase range is rather vague"*, while interviewee 4 stated: *"I do not understand what flight area increase means or how you determined this."* Interviewee 1 indicated that the rest of the information in the datasheet was clear to them by saying *"That's it"* and interviewee 4 stated: *"I think the information sheet is completely clear for the rest."* Overall, this accounted for a moderate datasheet clarity scoring for both interviews.

Due to time constraints, interviewees 2 and 6 were not asked about the clarity of the datasheet.

Suggested additions to the datasheet

For improving the completeness and clarity of the product datasheet, the different respondents suggested a variety of additions to the datasheet, as displayed in Table 5.

Firstly, multiple interviewees suggested adding the depth of discharge to the flight cycles and preferably tailoring the flight cycles to 80% depth of discharge, which is more commonly used in the drone industry. Interviewee 1 stated that *"The depth of discharge is missing from the reported flight cycles. The flight cycles can best be quoted to a normal depth of discharge, which is 80% of the nominal capacity."* Similarly, interviewee 2 asked: *"Could you tailor the flight cycle life to 80% depth of discharge?"*

Secondly, interviewee 1 and 6 mentioned their need for data presenting the charging of the drone cell. Interviewee 6 asked for a recommended and maximum charge rate. Interviewee 1 also mentioned the maximum charge rating and stated: *"The maximum charge rating would be a helpful addition."* They continued by suggesting that adding the ideal charging temperature *"would also be beneficial for the overall completeness."*

Interviewee 1 also suggested adding the cycle life retention to the charge and discharge rating in the datasheet: *"It should be a number that can retain the cycle life by a significant percentage. Also quoting the cycle life retention for discharge C-rating would be useful."*

As mentioned before, interviewee 1 stated that they think that the numbers for the percentual product benefit increase range at the top of the datasheet (V1) are rather unclear. They proposed the following solution: *"It would be better to look at a specific case study to be able to report on an absolute flight time."*

Subsequently, interviewee 2 asked for some simple additions to the datasheet. They requested the addition of the battery cycles at which the reported resistance values were measured. They also asked for more information on the applied pressure.

Although the respondents of interview 3 scored high on their perception of the datasheet com-

pleteness and clarity (Table 5), they still proposed some possible additions to the datasheet. The respondents suggested the addition of a description text to provide more information on the product. Interviewee 3.1 stated that: *"if you want some information on the product I would put some small text in there about how it's tested or about marketing understandings"*. They added that such a description could include information on *"how and why these sizes and how you came up with the idea, just a small text."* The interviewee explained their reasoning: *"Product understanding is nice for a customer to have and that's not something that you get from a first glance at the sheet."*

Next, different interviewees requested more clarification on the integration of the drone cell into a battery pack. Interviewee 4 stated that *"Looking at the datasheet, one has to make the step from battery to pack level themselves."* They asked: *"How can a battery pack be produced? Is that our responsibility or can you deliver a battery pack?"* Similarly, interviewee 3.2 asked *"Do you work on casings for the cell?"*. After explaining that LeydenJar plans on collaborating with third-party pack manufacturers, interviewee 3.1 proposed: *"Maybe that's something to add to the sheet as well. That you guys are capable and willing to help and assist with engineering a casing"*. Interviewee 3.1 also mentioned that it might not be clear to non-engineer decision-makers that it is possible to stack multiple drone cells in a battery pack and that that could be mentioned in the datasheet. They added: *"that small piece of description would eliminate some of the unclarities in the sheet if there are any. Like the stackability, that would be in the description. Non-engineer decision makers in companies would benefit from such a description."* Interviewee 4 added that *"It would help if possible battery packs were showcased. I would like to see the dimensions and properties of a battery pack containing 4 to 6 of your cells for example."* Similarly, interviewee 3.2 suggested: *"maybe showcase different casings, 1s, 2s, 3s, 6s, and you can probably put a 12s battery in one casing because yours is so small and lightweight."*

Interviewee 3.2 also proposed the addition of a graph showcasing raw cell testing data: *"Something else you could add is test data. Like raw test data and graphs of how the cell operates under different temperatures et cetera. That could be in an appendix on a second page. On the second page, you would have graphs et cetera. That would help for very specific applications of the battery."* They stated that *"You get a more comprehensive look at it then."* Interviewee 3.1 added that adding graphs with raw data *"would take a lot of time away from the engineers that are considering your product and are willing to invest in it as well."* They stated that these graphs would be especially beneficial for larger companies that focus on flight cycles and specific temperatures. However, interviewee 3.2 states that this addition is not necessary for their team as they *"do not really care about these very specific details and we won't look in a graph extensively."*

Subsequently, interviewee 4 mentioned that their drone requires a fast discharge burst during take-off and that looking at the datasheet they *"miss the maximum pulse discharge rate of this cell."* As the interviewee's drone team designs their own battery management systems, the interviewee was also interested *"What the requirements are for building a battery management system for your battery."*

Interviewee 6 requested the addition of a list of data regarding the applied voltage. They asked for the maximum cell voltage, the minimum cell voltage, and the recommended landing voltage.

As mentioned earlier, interviewee 6 expressed their need for a compact cell. If the terraces of LeydenJar's cell can be folded away, they suggest adding that to the datasheet to display the cell's true size.

Lastly, the interviewee mentioned the addition of more temperature data. Specifically, they were interested in the cell capacity under different temperatures and C-rates, but also in the cell temperature increase during cycling. They offered to measure this temperature data with LeydenJar's cells themselves.

6 Discussion and Recommendations

This chapter provides an interpretation of the results in Chapter 5 and explains how the results help answer the main research questions in Chapter 2 and shape subsequent recommendations presented in this chapter. The chapter addresses the three research topics in the sections Drone cell validation (6.1), Drone cell marketing medium (6.2), and Datasheet validation (6.3).

6.1 Drone cell validation

One of the objectives of this research is to study the extent to which LeydenJar's drone cell aligns with the requirements of potential customers in the drone market and the limitations of the product and its integration according to these potential customers. To do so, this section discusses and interprets the results on this topic, as mostly presented in Section 5.1.

Drone cell alignment with market requirements

As showcased in Section 5.1, high alignment between the requirements of the interviewed participants in the drone industry and LeydenJar's drone cell, as presented in the datasheet, was indicated by different respondents. A significant number of interviewees mentioned the energy density as an important evaluation aspect of a cell (Section 5.3) and different interviewees acknowledged the significant gravimetric energy density of LeydenJar's drone cell. This indicates that one of the main reasons for the high alignment of the presented product with the interviewee needs was the high gravimetric energy density of the drone cell. This is in agreement with the previous drone market insights, which include that high gravimetric energy density is an important aspect in said market, as explained in Section 1.3.

Challenges and uncertainties

Although high alignment between the product and the market was indicated by the interviewees, different challenges and points of uncertainty were mentioned regarding the drone cell and its integration into drones or battery packs for drones.

Some uncertainties relate to the cell performance when customized to fit the specific formats of potential customers. Many participants indicated that a major difference between the proposed format and theirs is the set of dimensions of the cell. The uncertainties in eventual performance can only be fully eliminated through a joint development agreement in which both parties collaborate to produce and optimize a custom cell, which is not part of the general product development. However, to address these uncertainties, LeydenJar could consider demonstrating the robustness of their cells by showcasing consistent performance across drone cells of various sizes. The overview of these different sizes can be added to a PowerPoint format showcasing a general overview of the product to the customers after interest is generated through the datasheet.

Another mentioned challenge is the relatively low cycle life of the drone cell. However, the cycle life that was reported in the datasheet was measured at 100% depth of discharge (DoD), while several respondents noted that drone cell cycle life is typically measured at 80% DoD (Section 5.3). An increase in cycle life is expected when measuring at 80% DoD, as the cycle life of lithium-ion batteries is generally inversely related to the DoD [29]. To be able to report a higher cycle life under conditions that resemble actual drone conditions better, LeydenJar should consider measuring their drone cell cycle life at 80% DoD. The presentation of this information in the datasheet will be discussed in Section 6.3.

Another challenge mentioned by one of the respondents is that they require a significantly higher discharge C-rating than what is reported in the datasheet. However, it is important to note that the C-rate in the datasheet refers to continuous discharge and is reported as more than 7C, as that is the highest rate that could be applied within operational safety limits in LeydenJar's labs. The drone cell is expected to be able to deliver higher C-rates with reasonable capacity retention, especially when applying a short burst discharge (not continuous). Additionally, the respondent mentioned that the need for such a high C-rate is specific to their application, which involves medical delivery drones. Nevertheless, it would be worthwhile for LeydenJar to test higher C-rates when possible, as the respondent indicated that the combination of LeydenJar's high energy density and a higher C-rate would account for a significant product-market fit. This aligns with the initial expectation that both high energy density and high C-rate are important themes for achieving market fit in the drone market.

An important topic mentioned regarding the integration of the drone cell into the application of the potential customers is the extent of heating or thermal runaway of the cells during cycling. Respondents mentioned that too much thermal runaway could be an issue to them. Interestingly, this concern was raised only by the commercial drone and pack manufacturers and not by the student drone teams. This could be due to more extensive risk management practices by commercial parties, or their greater experience with product use, including the effects of excessive cell heating on their hardware. To eliminate integration uncertainties for these commercial parties, LeydenJar should consider testing for thermal runaway. For instance, opening the cycler door during cycling and using a laser thermometer to capture snapshots of the cell temperature at specific moments could be effective. Alternatively, the interviewed drone pack manufacturer offered to measure temperature data in-house. This offer should be considered upon further collaboration, as the pack manufacturer might be able to continuously monitor cell temperature, providing valuable insights into thermal runaway and its influencing factors. Section 6.3, discusses how to market the resulting data.

Conclusion of topic

To what extent does LeydenJar's drone cell align with the requirements of potential customers in the drone market and what are their observed limitations in the product and its integration?

Overall, a high alignment was observed between the drone cell and the market requirements, suggesting a positive product-market fit of LeydenJar's drone cell in the drone market. Nevertheless, different challenges and uncertainties were discussed regarding the product and its integration. Accounting for the different challenges and uncertainties through the proposed tests is expected to further improve this product-market fit. However, from the data in this study alone, it cannot be definitively concluded that product-market fit is or will be reached, as it depends on a multitude

of other factors that were not assessed in this study. Some of these factors include the alignment of the cell pricing with the perceived value of the cell and the alignment between the cell demand and the production and distribution capabilities of the cell. Also important for determining the product-market fit better is the evaluation of all the pieces of data that are important to potential customers in the drone industry, but were not presented in assessed versions of the datasheet. This supports the usefulness of optimizing the completeness of the datasheet, not only for marketing purposes but also for assessing the product-market fit more accurately. This datasheet optimization will be discussed in Section 6.3.

6.2 Drone cell marketing medium

Another one of the objectives of this research is to study whether a datasheet is the most appropriate medium for marketing the drone cell and what alternative marketing medium would be appropriate. To do so, this section discusses and interprets the responses from the student drone teams on this topic, as mostly presented in Section 5.2.

The product datasheet as marketing medium

The student drone teams expressed that along with the product, the product datasheet is an integral way to market the drone cell to the drone market. This is in line with the expectations stated in Section 1.3. To contribute to the marketing of the product, the drone teams suggested several additional marketing media, which will be discussed in the following paragraphs.

Additional marketing media

Firstly, a tool was suggested for calculating the benefits of the drone cell, like the flight time or payload, in different drones. In the tool, a drone manufacturer could fill out their drone specifics and receive these calculated absolute benefits. Although such a tool might be useful for drone companies to evaluate the drone battery's performance specifically in their application, incorporating such a tool is not advised. The reason for this is that adding such a calculation tool, to the website for instance, is time-consuming, and not many drone manufacturers are expected to use the tool, since they would have to fill out their drone specifics, of which some are rarely stated on their websites, such as their current battery weight, their payload and flight velocity.

Secondly, different respondents highlighted the importance of showcasing the drone cell performance in a real drone. Such a showcase could function as a proof of concept, proving the drone benefits that were promised in the datasheet, such as flight time increase and payload increase. Besides, showcasing the cell performance in a real drone, for instance in video format, would make the product more tangible for drone manufacturers. Therefore, delivering such a proof of concept is expected to be beneficial for drone cell marketing, improving generated interest in the drone cell. Besides marketing purposes, testing LeydenJar's drone cell in a real drone could provide insights into unforeseen integration challenges that need to be overcome before launching the drone cell to the public drone market.

To attempt to deliver such a proof of concept in-house, tests were executed with a market-standard drone containing LeydenJar's batteries of the same weight as the original drone battery. The in-house tests highlighted the importance of integrating LeydenJar's drone cell into a custom battery pack and BMSto optimize the cell performance and to be able to showcase the cell benefits in a drone. Through third-party pack manufacturers, such a modular battery pack could be designed.

For this pack, design is important to find a drone manufacturer that is willing to integrate the cell pack into their application.

Several of the interviewed student drone teams (interviews 3 and 4) have offered one of their drones as a test platform for delivering a proof of concept. Since these student teams operate on a limited budget, the financial benefits of collaborating with them are relatively small compared to collaboration with commercial drone manufacturers. However, this also means that, regarding student-team collaboration, the financial risk is lower if the drone pack fails to perform well, making student drone teams a relatively safe testing platform for learning. Therefore, collaboration with these student drone teams for delivering the proof of concept should be considered.

However, collaboration with commercial drone manufacturers could also be considered to obtain the proof of concept. If the battery pack is presented as an early-stage prototype, commercial manufacturers might lower their expectations and be willing to set up a joint development agreement to optimize the product for their application.

Conclusion of topic

Is a datasheet the most appropriate medium to market the drone cell and what alternative marketing medium would be appropriate?

The datasheet appears to be the most appropriate medium for marketing the drone cell. Therefore, LeydenJar is advised to continue marketing its drone cell, using a product datasheet. Different alternatives were discussed, of which showcasing proof of concept in a real drone is expected to contribute to the marketing of the product the most. Besides, pursuing such a proof of concept could provide insights into challenges that need to be foreseen before bringing the drone cell to the public drone market. For delivering the proof of concept both student drone teams and commercial drone manufacturers should be considered. The risks accompanied by failure are lower with student drone teams, while the potential financial gain is higher when collaborating with commercial drone teams.

Overall, the datasheet appears to be essential and the proof of concept in a real application appears to be an appropriate complementary medium for marketing the drone cell.

6.3 Datasheet validation

One of the main objectives of this research is to study the evaluation of LeydenJar's drone cell datasheet by potential customers in the drone market and how this evaluation can be improved. Hence, this section discusses and interprets the qualitative results on this topic, as mostly presented in Section 5.3.

Datasheet evaluation

The evaluation of the datasheet was studied by having various respondents from the drone industry assess its completeness and clarity. As presented in Section 5.3, the assessment of both the completeness and clarity of the datasheet varied between the different respondents (Table 5). Only high scoring on clarity and completeness was provided by the student drone teams, whereas the commercial drone manufacturers would only provide moderate scoring. A reason for this could be that the commercial drone manufacturers are more critical, because they have more experience with evaluating drone batteries or because little can be left to chance when developing drones

for commercial applications with many stakeholders. However, the reason could also be that the student drone teams evaluated a second version of the datasheet in which some feedback from the commercial drone teams was already implemented (as showcased in Table 2). This would indicate that implementing customer feedback improves the perceived quality of the datasheet. This topic will be further discussed in the conclusion of this section. Nevertheless, moderate clarity and completeness scoring were given before and after updating the datasheet. This indicates that there is still room for improving the datasheet quality. Many interviewees provided suggestions to improve the clarity and completeness of the datasheet as showcased in Section 5.3. These suggestions are discussed in the following paragraphs.

Clarifying the presented information

Different suggestions were proposed to improve the clarity of the information presented in the datasheet. The following paragraphs explain the benefits of implementing some of these suggestions in future versions of the datasheet.

First, one major update for improving the quality of the datasheet will be discussed. One of the commercial drone manufacturers mentioned that the drone benefits at the top of datasheet V1 (Supplementary Figure 1a) could be improved on clarity, as the numbers were presented as percentages and ranges. They suggested comparing the benefits to one specific case study drone to be able to state the drone benefits as absolute numbers. The flight area increase could then be expressed in square kilometers, the flight time increase in minutes, and the payload increase in kilograms. The idea of stating product benefits in one application instead of multiple was already considered during the design of datasheet V1. Presenting absolute drone benefits would make the data more accessible to the general public. However, these absolute numbers were initially not used because they were not considered to accurately represent different drones in the industry. Instead, percentage increase ranges for a significant number of reference drones were deemed more accurate. Since the commercial drone manufacturer confirmed that absolute would be accurate enough and improve the overall clarity of the datasheet, their suggestion was implemented in datasheet V2 (Supplementary Figure 1b). In this second version, the comparison was made to an industry-standard drone, allowing for the presentation of both percentage and absolute benefits. This version of the datasheet was used for subsequent interviews. When asked about the clarity of datasheet V2, one of the respondents from the student drone teams specifically mentioned the clarity of the absolute benefits of the drone and the comparison with an industry-standard drone. This further supports the idea that reporting on these drone benefits as absolute numbers improves the clarity of the datasheet and the need to showcase these absolute benefits in future versions of the datasheet.

The positive feedback on the datasheet changes that were made based on customer feedback also suggests that implementing customer feedback helps improve the quality of the datasheet. This was also indicated earlier by the more positive general evaluation (on completeness and clarity) of the second version of the datasheet in comparison to the first version.

Next, minor updates for improving the clarity of the datasheet will be discussed. Different commercial drone manufacturers suggested including the depth of discharge (DoD) for the cycle life measurements in datasheet V1. They recommended quoting the cycle life at 80% DoD, as this is the most commonly used standard for drone batteries and is expected to improve the cycle life compared to the 100% DoD currently quoted. LeydenJar is advised to consider measuring their drone cell cycle life at 80% DoD (as discussed in Section 6.1). However, since this data is not readily

available, stating the 100% DoD at which the current cycle life is measured would already provide more context and relativize the presented number of cycles. Therefore, LeydenJar is advised to always state the DoD in the following versions of the datasheet. The 100% DoD was added to the second version of the datasheet (Supplementary Figure 1b), which was used for subsequent interviews.

The pack manufacturer was uncertain if the cell would universally fit different formats. They thought this fit would be better if the terraces of the cell could be folded away but found it unclear if this was possible. They suggested showcasing this possibility more clearly. Since folding the terraces is possible and limited clarity on this topic seems to undersell the compactness of LeydenJar's cell, showcasing this feat in the following versions of the datasheet is recommended. A proposed third version of the datasheet, which contains the cell dimensions without terraces is showcased in Supplementary Figure 1c.

A commercial drone manufacturer mentioned that the specific moments in time at which the resistance values were mentioned would improve the clarity of the numbers. As it is a minor change that provides more context to the resistance values, the cycles at which the resistance values were measured could be specified in future versions of the datasheet. The change was implemented in the second version of the datasheet, which was used for subsequent tests.

It was also suggested by the commercial manufacturer of agricultural drones that adding the cycle life retention to the C-rating in datasheet V1 would improve the clarity of the number, as the C-rate is meaningless without context. In the current datasheet, the C-rate is put into context by quoting it to a specific capacity retention, which is the short-term durability of the battery. However, this capacity retention is only shown in the subtext of the datasheet. The suggestion indicates that it is beneficial for the specificity of the C-rate to showcase its context more prominently. Therefore, the following versions of the datasheet could showcase the capacity retention in the main table behind the continuous discharge current. This change was implemented in the second version of the datasheet, which was used for subsequent tests.

Addition of new information

The interviews also provided valuable insights on themes that are important to the drone industry but were not presented in the datasheet. The respondents provided multiple suggestions on how to incorporate these themes into the datasheet and improve its completeness.

The results of this study indicate that more general information is needed on integrating the drone cell into a battery pack to make the datasheet more complete. Although the product in the datasheet is presented as a single battery cell, in drones it is incorporated into a battery pack that often contains multiple cells. Drone manufacturers commonly need a higher amount of energy than a single drone cell can deliver. By incorporating multiple cells into a battery pack, either in series or in parallel, the battery energy is increased. The respondents indicated that explaining that it is possible to combine multiple drone cells in a battery pack would eliminate possible uncertainty. The integration of the drone cell into a battery pack is not executed by LeydenJar, but LeydenJar assists in the pack integration through third-party pack makers. The results state that it is unclear to different student drone teams who is responsible for this pack integration and explaining this would eliminate this uncertainty. As drone manufacturers often do not have the means to integrate the battery cell into a pack, it is important that drone manufacturers understand that

this is possible through third-party collaboration. Ambiguity on the integration of the drone cell into a battery pack could negatively influence the perceived alignment of the cell with market demands. Therefore, LeydenJar is advised to incorporate an explanation of the possible stackability of the drone cell into a pack and the third-party execution of this pack integration. A proposed third version of the datasheet, containing this explanation is showcased in Supplementary Figure 1c.

The results also indicated that showcasing the dimensions and properties of an existing battery pack containing LeydenJar's drone cells would make the product more tangible. While this data would be valuable for further discussions, including it in the datasheet might cause confusion about whether the marketed product is the cell or the battery pack. Nevertheless, it would be worthwhile to pursue the dimensions and performance metrics of a battery pack once it is developed with LeydenJar's cells. This information could be effectively presented in a PowerPoint presentation to drone manufacturers that are interested in collaboration after reviewing the datasheet.

Although initially not considered a significant topic for the drone industry (Section 1.3), the need for assessing charge rate data was highlighted by multiple respondents, indicating its importance. Respondents mentioned the need for a maximum charge rate, the recommended charge rate, and the ideal charging temperature. Adding the maximum charge rate to the datasheet could contribute to the marketing of the drone cell, as it informs drone manufacturers of the time required between operations when relying on a single battery. The recommended charge rate and ideal charging temperature seem solely important for the correct use of the product when received by the customers. Since the datasheet aims to market the product by sparking initial interest, this use of data may not be appropriate for inclusion. However, it is important for LeydenJar to obtain this data to provide it alongside the product, ensuring optimal battery use. Therefore, LeydenJar is advised to pursue this data, together with the maximum charge rate, through internal testing of the drone cells or by collaborating with pack manufacturers who might be able to measure this data in packs containing LeydenJar's drone cell. The latter might provide more relevant data as drone manufacturers will be charging and using battery packs and not single cells.

The pack manufacturer indicated that adding the cell temperature increase to the datasheet would support their efficient assessment of the product. Section 6.1 discusses the importance of discovering this thermal runaway of the drone cell throughout its cycling protocol. The pack maker also mentioned their interest in the cell capacity under different applied temperatures and C-rates. Both displaying the thermal runaway and the capacity under different conditions would add to the robustness of LeydenJar's drone cell. However, including the data in the datasheet might detract from its conciseness and focus. Nevertheless, having this robustness data in graphs and tables is beneficial for addressing related customer questions and for inclusion in a PowerPoint presentation showcasing the cell's performance during further collaboration discussions. Therefore, LeydenJar is advised to pursue this robustness data. As discussed in Section 6.1, the pack manufacturer's offer to measure the temperature increase during cycling should be considered. The cell capacity measurements are possible can be conducted in-house within the operational safety limits that determine the maximum applied C-rate and temperature.

The results indicate that including the maximum burst discharge rate in the datasheet could support the consideration of the presented drone cell. As also explained in Section 6.1, significant discharge C-rating is essential for achieving market fit in the drone market. Therefore, showcasing a higher discharge C-rate is expected to greatly benefit the marketing of the drone cell. For that reason, it is recommended that LeydenJar tests the possible burst discharge C-rate of the

drone cell and includes this value, along with its capacity retention, in the datasheet. However, the operational safety limits in LeydenJar's lab restrict the execution of high C-rate testing. It would be advisable to conduct these tests externally, possibly through collaborations with pack manufacturer.

Conclusion of topic

How do potential customers in the drone market evaluate the completeness and clarity of LeydenJar's drone cell datasheet and how can this evaluation be improved?

Overall, the evaluation of the datasheet was mixed. However, incorporating select customer feedback appears to enhance this evaluation. This is indicated by the improved general feedback following the implementation of certain customer suggestions, as well as the positive response to specific implemented suggestions. This suggests that the customer-centered approach and validated learning, as proposed in the Lean Startup method (Chapter 3), do not only aid the development of products but also the development of product marketing materials. Although the Lean Startup indicates that customer input is valuable, it is still important to critically assess customer input before implementing it, as is done in this chapter.

Consequently, critically assessed customer feedback was incorporated for updating the second version of the datasheet to a third version (Supplementary Figure 1c). This version includes most of the recommended additions discussed in this chapter, including the absolute drone benefits, the depth of discharge of the flight cycles, the capacity retention of the discharge current, a more compact cell size, and information on the cell integration into a battery pack. The burst discharge rate and the maximum charge rate have not been incorporated yet, as they require appropriate testing. Once obtained, the addition of these values is recommended. Besides, quoting the cycle life in the datasheet at 80% DoD, after accompanying tests, is recommended, as it is expected to increase the cycle life value. The third version of the datasheet, including these suggested additions, is recommended for future marketing of the drone cell.

Some suggested additions were not included in the datasheet, but are recommended for inclusion in a PowerPoint presentation that provides a general overview of the product. This presentation can be shown to customers after interest is generated through the datasheet. To support the tangibility of the product, LeydenJar is advised to showcase the dimensions and properties of cell packs containing different amounts of drone cells in this PowerPoint. Furthermore, for this PowerPoint, LeydenJar is advised to obtain test results showcasing the robustness of the cells, including thermal runaway and cell capacity under various conditions. As discussed in Section 6.1, showcasing a consistent performance in different cell sizes would also contribute to this robustness narrative.

The respondent evaluation of the last assessed version of the datasheet suggests that there is still room for improvement and further datasheet evaluation tests. Based only on this result, continuing the optimization of the drone cell datasheet through customer interviews, as presented in this study, would be recommended. However, there are several downsides to this approach. Firstly, the methodology is time-consuming, as it takes a significant amount of time to find respondents, conduct interviews, and analyze and make sense of the obtained qualitative data. Secondly, customer validation might bring about a focus on optimizing the marketing and a reluctance to persevere in the market, as is described as a pitfall of the Lean Startup method in Chapter 3. Thirdly, customer feedback could be misinterpreted or applied before sufficient consideration, as also described in

Chapter 3. This might reduce the generally perceived quality of the marketing materials, instead of optimizing them. Since the evaluation of the drone cell datasheet seems to have improved after implementing customer feedback, the third version of the datasheet is expected to mostly receive high completeness and clarity scoring. For these reasons, LeydenJar is advised not to pursue further extensive drone cell datasheet development using the same methodology.

7 Conclusions and Implications

This chapter explains the overall conclusions based on the results of this study and discusses its implications for LeydenJar and academic research.

7.1 Implications for LeydenJar

The following paragraphs provide a conclusion of the three different topics that were highlighted in the research questions of this study regarding product evaluation, datasheet optimization, and the appropriate product marketing medium (Chapter 2).

Product validation

LeydenJar's drone cell shows promising alignment with the drone market requirements. However, challenges and uncertainties were highlighted by different drone market players, and further tests are necessary to address these issues. For instance, testing the drone cell cycle life at 80% DoD and testing higher C-rates and reporting the outcome in the datasheet would be beneficial for the product evaluation. Although the overall product-market fit also depends on factors, such as pricing and production capabilities, that were not assessed in this study, based on the presented results, LeydenJar is advised to persevere in marketing and selling their drone cell in the drone market. This means that, based on the results of this study, LeydenJar should not undergo a customer need or customer segment pivot, showcased in Figure 4 and explained in Section 4.4.

Drone cell marketing medium

The datasheet appeared to be the integral medium for marketing LeydenJar's cell to the drone market. In addition to this, pursuing a proof of concept in a real drone also appears to be beneficial for marketing purposes and for gaining insights into potential integration challenges. For delivering this proof of concept, collaborating with student drone teams poses lower risks, while collaborating with commercial drone manufacturers provides higher potential financial gains. Overall, both the product datasheet and proof of concept seem to be appropriate media for LeydenJar's drone cell marketing. Since the datasheet appears to be integral for marketing the drone cell, LeydenJar is advised to persevere in presenting the datasheet, when continuing drone cell marketing. This means that, based on the results of this study, LeydenJar should not undergo a channel pivot, showcased in Figure 4 and explained in Section 4.4.

Datasheet optimization

The evaluation of LeydenJar's drone cell datasheet was mixed, but incorporating customer feedback appeared to improve its perception. This aligns with the Lean Startup theory, which emphasizes the value of customer input. An updated version of the datasheet that includes most of the additions that appear to be important to the drone market is showcased in Supplementary Figure 1c. Cell testing is required to obtain other important additions, such as the burst discharge rate

or the maximum charge rate, after which these values should also be added to the datasheet. The resulting datasheet is the recommended version to be used for future drone cell marketing.

Different information that appeared to be important to the market was not appropriate for inclusion in the datasheet, but is recommended for inclusion in a PowerPoint on the drone cell that can be shown after the customer interest in collaboration is expressed. This PowerPoint could include information such as the showcase of the drone cells in different cell packs, the cell capacity under varying conditions, or the performance of different cell sizes.

LeydenJar is advised not to persevere extensive development of the drone cell datasheet using the methodology of this study, as it is time-consuming and contains potential pitfalls, such as misinterpreting customer feedback or focusing too much on optimization instead of perseverance in the market. Instead, persevering drone cell marketing, using the updated version of the datasheet that is described above is advised, which is showcased as the final strategy in Figure 4 and explained in Section 4.4.

7.2 Academic implications

The methodology of this study was based on the Lean Startup method in which products are iteratively validated and optimized based on customer feedback (Chapter 3). As indicated in Section 3.4, the Lean Startup method is mostly used for validating products, and there seems to be little literature on the effectiveness of using the Lean Startup method for validating and optimizing product marketing materials. This study does not only apply the Lean Startup for validating LeydenJar's product but also for validating and developing LeydenJar's product marketing materials (Chapter 4). The procedure of this study was iterative, meaning that the datasheet was updated by implementing select customer feedback, after which the updated version of the datasheet was used for subsequent interviews, as showcased in Table 2. The results indicate that incorporating the customer feedback appeared to improve the customer evaluation of the clarity and completeness of the datasheet, as discussed in Section 6.3. This suggests that the Lean Startup, on which the methodology of this study was based, does not only aid in the development of products but can also aid the development of a drone cell datasheet, targeted towards the drone market. This partly addresses the literature gap on this topic described in Section 3.4. However, it is important to note that this conclusion is based on the evaluation of a product datasheet with a limited number of respondents from one specific sector. Therefore, more research should be conducted, assessing the usefulness of customer feedback on different product marketing materials in different sectors before more general conclusions on Lean for product marketing materials can be drawn.

8 Limitations of study

This chapter briefly discusses several limitations encountered during this study and explains how to address these uncertainties.

First, the study attempts to provide insight into customers' requirements in the broader drone industry, but this insight is based on the response of a limited set of respondents. Besides, not all respondents are actual potential customers, as the student drone teams are too small to account for the desired MWh product sales (Section 1.3). Based on the results of the study, assumptions on the potential customers in the broader drone industry requirements are made that lead to the presented recommendations. LeydenJar should carefully consider the origins of these assumptions before implementing the recommendations.

Second, as discussed in Section 6.1, the alignment of the drone cell with market demands indicates product-market fit, but more information is needed to confirm this product-market fit. To obtain more insight into this product-market fit, future validation interviews, either with the drone industry or with other markets, can include questions on the product pricing and its alignment with the requirements of the potential customers.

Third, as discussed in Section 6.3, the methodology of this study contains several pitfalls. In short, these pitfalls include the methodology's time-consuming nature, the stimulation of fixating on optimization, rather than persevering, and possible misinterpretation of customer feedback. Therefore, LeydenJar is advised not to pursue further extensive validation using the methodology of this study, as also mentioned in Chapter 7.

Acknowledgments

First and foremost, I would like to thank my daily supervisor throughout this project, Tim Aanhane. I would not only like to thank Tim for helping me define my research and for the great discussions and feedback on the topic, not only for helping me execute interviews with potential customers, not only for providing me with input on planning strategies throughout my internship, not only for supporting that I familiarized myself with the different teams in the company, which was not only fun but also gave me a nice impression of different jobs in the labor market, but also for gradually giving me more responsibility and believing in me, which gave me confidence in my own capabilities. Second, I would like to thank Hellen Dawo, as she provided me with necessary literature concepts and because of the fun discussions on Fridays in which she gave me great input for writing my thesis. Next, I would like to thank the members of the PM team, especially Chris van de Stadt and Pieter Swarts for discussions that helped me define the scope of my thesis. I would also like to thank Jacob Firth for helping me apply the insights from the interviews, by trying to deliver an in-house proof of concept together and by measuring battery data that was learned to be important. I want to thank the rest of the people at LeydenJar for making it such a welcoming workplace. I want to thank Gerben van der Scheer for introducing me to this great workplace and for introducing LeydenJar to me. Last but not least, I want to thank my girlfriend for helping me through the ups and downs that came along with the internship process and for believing in me throughout.

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Supplementary Materials

The following information is supplementary to this work.

A Layman's Abstract

LeydenJar is a company that makes pure silicon anodes, which are compounds that allow for high-energy batteries. They are targeting drone manufacturers as potential customers because it is believed that LeydenJar's product fits well in this market (product-market fit) in which high energy is essential.

LeydenJar designed a battery that is specialized for use in drones, based on feedback from a small group of customers. However, it is uncertain whether this initial feedback represents the entire drone industry, and if LeydenJar's drone battery is a fit throughout the market. Proceeding without addressing these uncertainties might result in poor product-market fit and low sales. Therefore, the first goal of this research is to find out if LeydenJar's drone cell meets the broader drone industry's needs.

To attract potential customers in the drone industry, LeydenJar uses a product datasheet that highlights the battery's performance. Since the datasheet was never tested with real customers, it is uncertain whether the use of this specific marketing tool effectively grabs the attention of potential customers in the drone industry. Therefore, the second goal is to evaluate if the datasheet is an appropriate marketing tool for the drone battery and to explore other options.

The datasheet includes all information that is believed to be important for drone market players to assess the drone battery. The level of detail is based on the assumed understanding of battery buyers in the drone industry. To ensure that the datasheet is effective, these assumptions need to be validated. Therefore, the third goal is to evaluate how well the datasheet's contents meet the needs of the drone market and to study possible improvements.

To achieve these goals, interviews were conducted with potential customers in the drone industry. They discussed the datasheet to understand customer validation of the battery, the marketing tool, and the contents of the datasheet itself. During the interview process, the datasheet was updated based on feedback from these interviews.

The interview results showed that the battery fits well with customer requirements, indicating a good product-market fit. Therefore, LeydenJar is advised to continue offering their drone battery to the drone market.

The results also showed that the datasheet seems to be a key marketing tool. Additionally, demonstrating the battery's performance in a real drone seems to support the marketing, as it makes the drone battery more tangible. LeydenJar is advised to continue using the datasheet and to showcase its battery performance in a real drone.

Incorporating customer feedback appeared to improve the datasheet. An updated version of the datasheet, containing all useful additions discussed in this study, is recommended for future marketing.

LeydenJar is advised not to spend more time developing the datasheet using the method presented in this study, as it is time-consuming and has potential pitfalls. Instead, they should continue marketing their drone battery using the optimized datasheet from this study.

B Personal reflection

Within LeydenJar I am part of the product management team as a B2B product marketing intern. Since my only previous "internship experience" was lab research, I knew the internship was going to be something completely different than what I had experienced before. Although the subjects of the FBE program introduced me to the different business concepts that could be applied in companies, I was unfamiliar with actually being part of a business and applying these concepts in practice. I was quite nervous before starting the internship, as I did not believe my knowledge and skills obtained through my studies could completely prepare me for what was about to come.

Eventually, I learned that a lot of the necessary skills and knowledge were obtained through experience. Learning that I was not expected to know or do everything perfectly from the start made me more confident and motivated me to learn.

Although experience played a significant role in obtaining the necessary knowledge, my background in chemistry and technical research helped me become familiar with LeydenJar's technology quickly. I enjoyed being able to combine my technical knowledge with more applied marketing practices.

As LeydenJar is a startup that operates in a fluctuating environment, I have many different tasks that could vary from week to week. Simultaneously, I executed my research, which is presented in this thesis. Combining all the different tasks was intense at first, but eventually, I learned to divide my focus quite well, as I became better at planning the different activities and setting realistic deadlines.

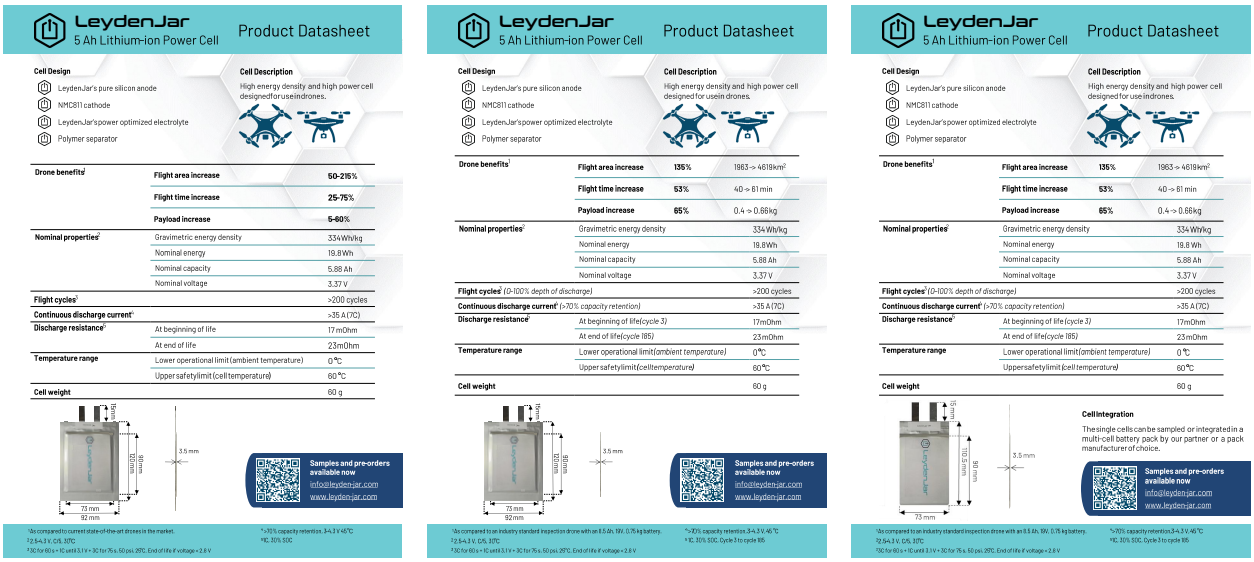
Throughout the internship, I became more confident in meetings for group projects with colleagues, as I knew I could deliver useful input and that there was room for me to do so.

I found it difficult to define the scope of my research. Asking for feedback from different colleagues helped me understand what was needed within the company and what gap my research could fill. I learned that, just as in the Lean Startup methodology, it is more important to ask for feedback at the right moment than to try to do everything autonomously.

During the writing of my thesis, I decided not to include different topics, among which was the survey that I sent out to the different interviewees. I tried to fit it into my narrative, but it made it too complex and vague. This made me realize that the goal of the report is to convey a message to the company, so clarity is more important than wanting to include everything.

Overall, I am pleased that I got to learn a lot during the internship and I understand now that learning has not stopped after university. This means that my first job will probably also be accompanied by a learning curve, which I have completely accepted.

C Datasheets



(a) **(b)** **(c)**

Figure 1: The first (1a), second (1b), and third version (1c) of the drone cell datasheet.

D Interview questions

The following are the questions used for testing the drone cell datasheet with potential customers.

- What are the most important data to you when evaluating a battery for your application?

Regarding the drone cell datasheet, I want to ask the following questions.

- Can you fully evaluate our drone battery based on the information in the datasheet and what information should be added to complete the picture?
- What parts of the information in the datasheet are unclear to you? How can we explain these details better?
- Is a data overview like this the best way to explain the value of our product to you? What alternative would you suggest?

Now I want to ask your opinion on our product itself:

- Does our product, as described in the datasheet, fit your drone battery requirements and what improvement or additional features would you like our battery to have to better fit these requirements?
- When it comes to implementing our battery in your product, are there any challenges or obstacles you foresee?

E Codebook

Table 1: Codebook containing concepts, themes and codes for analyzing the interviews in Supplementary Section F-K.

Concept	**Theme**	**Code**
Product	Product alignment with requirements	Alignment
		Misalignment
	Integration challenges	Integration
Marketing medium	Datasheet as medium	Right channel
		Wrong channel
	Suggested alternative	Alternative
Datasheet	Completeness of datasheet	Completeness
		Incompleteness
		Important aspects
	Clarity of datasheet	Clarity
		Unclarity
	Suggested addition to datasheet	Addition

F Answers interview 1 with commercial drone manufacturer

Due to time limitations, only a selection of the determined questions was asked during this interview. This interview was recorded by taking notes and presented below. The text is labeled with I for interviewer and R for respondent. To enable structuring the data, codes were assigned and presented in the right column next to the corresponding text.

I: What are the most important data to you when evaluating a battery for your drones?	
R: Energy density, price, and flight cycles.	Important aspects
I: Can you fully evaluate our drone battery based on the information in the datasheet? And what information should be added to complete the picture?	
R: How much over 200 cycles are we talking here? Its lower than what LiPo people are advertising. Is it because you do discharge your battery from 100% to 0%? The depth of discharge is missing from the reported flight cycles. The flight cycles can best be quoted to a normal depth of discharge, which is 80% of the nominal capacity.	Addition
For the rest, the datasheet is fairly complete.	Completeness
The maximum charge rating would be a helpful addition. It should be a number that can retain the cycle life by a significant percentage.	Addition
Also quoting the cycle life retention for discharge C-rating would be useful.	Addition
Adding the ideal charging temperatures would also be beneficial for the overall completeness.	Addition
I: What parts of the information in the datasheet are unclear to you? How can we explain these details better?	
R: The percentual flight time increase range is rather vague. It would be better to look at a specific case study to be able to report on an absolute flight time. That's it.	Unclarity Addition
I: Does our product fit your drone battery requirements? What improvement or additional features would you like our battery to have to better fit these requirements?	
R: The battery is much better than what the we are currently using.	Alignment
However, there might be issues on pack level integration that our engineers might know more about.	Integration
I: When it comes to implementing our battery in your product, are there any challenges or obstacles you foresee?	
R: Battery pack makers told us about cells that heat up too much, so that could be an issue.	Integration

G Answers interview 2 with commercial drone manufacturer

Due to time limitations, only a selection of the determined questions was asked during this interview. This interview was recorded by taking notes and presented below. The text is labeled with I for interviewer and R for respondent. To enable structuring the data, codes were assigned and presented in the right column next to the corresponding text.

I: What are the most important data to you when evaluating a battery for your drones? R: • Power • Energy • Cycle life	 Important aspects
I: Can you fully evaluate our drone battery based on the information in the datasheet and what information should be added to complete the picture? R: The datasheet is very detailed. The data that I am missing: • Time in resistance values • Could you tailor the flight cycle life to 80% depth of discharge? • Maybe more information on applied pressure	 Completeness Incompleteness Addition Addition Addition
I: Does or product fit your drone battery requirements and what improvement or additional features would you like our battery to have to better fit these requirements? R: We need a larger cell. We have a longer cycle life requirement. I: When it comes to implementing our battery in your product, are there any challenges or obstacles you foresee? R: The dimensions are different from what we are using, so not a plug and play. Thermal runaway test results are needed.	 Misalignment x2 Integration Integration

H Transcript interview 3 with student drone team

This interview was recorded through teams and transcribed after. The transcript is presented below. The text is labeled with I for the interviewer and R1 and R2 for respondents 1 and 2. To enable structuring the data, codes were assigned and presented in the right column next to the corresponding text.

I: Let me introduce what our datasheet is about. I already told you over e-mail that we are launching a battery that's optimized for drones, containing our silicon anode. For my research I want to find out what we can learn from evaluating our product description. All of your feedback will be well appreciated, but also might be implemented in developing our product and product marketing, so now you know what I will do with your answers. Before I share the actual sheet, I want to ask, what is it that you normally look for when evaluating a battery for your drone? You already said that high C-rates are important to you. Is there anything else? R1: Weight. R2: Yeah, basically energy density comprised of weight. Yeah that's basically it. For voltage you can always put stuff in series. Energy density and C-rating is the most important thing. We look at humanitarian aid drones so we want the mission to go as smoothly as possible. The amount of missions is not as important to us. I: Thank you. Let me share the datasheet now for the next questions. Have you already looked at it? R2: Yes, we noticed the energy density and the C-rating. I: When you look at the sheet with all its specifics, can you evaluate our battery completely for the use in your drone? If not, what information should be added for a more complete picture?	Completeness
R2: No, I think it's well written, it's to the point, doesn't have a lot of unnecessary information and from what I see I think it has everything to evaluate the battery. R1: You can see that it was written and made by an engineer. It's also very straight to the point, but that's what you want in a catalog for example. This would be a great one to put in a catalog, but if you want some information on the product I would put some small texts in there about how it's tested or about marketing understandings. Product understanding is nice for a customer to have and that's not something that you get from a first glance at the sheet. I: So do you mean, how we actually retrieved the data?	Completeness Addition Incompleteness
R1: Not exactly how you tested it, but some small text and explanation. At the bottom you have the nice QR code that of course adds something, but it could be downscaled to put some text there on how and why these sizes and how you came up with the idea, just a small text. R2: Also, do you guys work on the casing because this is a single cell right? I: Yes, this is a single cell. R2: Because usually we use 6s, 12s, and sometimes more than that. Do you work on casings for the cells?	*Explanation previous point*

I: No, but we are planning on collaborating with a pack manufacturer.	
R1: Maybe that's something to add to the sheet as well. That you guys are capable and willing to help and assist with engineering a casing and that's not the customers responsibility.	Addition
I: When you look at the sheet, do you understand that it is possible to stack this single cell in a pack with multiple cells?	
R2: Yes.	
R1: From a technical perspective it is possible to be seen, but when you're not well versed with batteries it might be a bit confusing that you can stack them, because it's not mentioned on the sheet. Maybe that's something to add to the little description text as well. That's the only thing I miss, the description.	Addition
I: This is some really useful feedback. If you think it improves the clarity of the sheet, it's really useful for future versions of the sheet. Thank you. Are there any more things that you think need to be added for a more complete picture?	
R1: Not from my perspective. It's really clear.	Clarity
R2: When I first saw it, it was fine. I got all the information I needed, but with these small tweaks I think its going to take it to a better level.	
I: Thank you so much for that. My next question is if there are any details or specifics in the sheet that you do not understand and how can we improve on the clarity of the sheet?	
R1: Clarity overall is okay in my opinion.	Clarity
R2: Yeah it's understandable, it gives all the statistics and qualities.	
R1: As mentioned before, that small piece of description would eliminate some of the unclarities in the sheet, if there are any. Like the stackability, that would be in the description. Non-engineer decision makers in companies would benefit from such a description. Four lines of text should be enough to clarify it for them. The QR code could be moved a bit more down and the descriptive text could be next to the nice picture of the battery. Otherwise there is not much to improve. The technical information is all well written and documented on there.	Unclarity *Explanation previous point* Clarity
R2: Something else you could add is test data. Like raw test data and graphs of like how the cell operates under different temperatures etcetera. That could be in an appendix on a second page. On the second page you would have graphs and that. That would help for very specific applications of the battery.	
R1: For example a graph of when it's under high load or when it's under low load, something like that. Then the engineers don't have to do research themselves and can use your datasheet for it. For example, when you have a CNC-mill, you have different diameters and different data for that. Like an operating window. You have the temperatures on there as an operating window, but not the	Addition

difference that it makes. I know from a technical perspective that there is a difference of course, but visualizing it always helps more. That would be nice to have as something to add to a second page with more technical data for engineers. For the flight time tests you can also for example have a graph in which you plot the lifetime and the deterioration of the battery, so you can make an estimate for the lifetime of the battery and when to replace it. That would take a lot of time away from the engineers that are considering your product and are willing to invest in it as well.	Addition
I: That's also some good and really clear imput. When you look at the bottom of the datasheet, there are specs shown like life conditions etcetera, but you say you think it is more clear to showcase it in a graph right?	
R2: Yeah, definitely. It also puts more emphasis on it. Like this is at the bottom of the page. If I look at a graph I know exactly how many cycles and at which temperature, what was the battery rating, and what was the voltage use and stuff like that. You get a more comprehensive look at it then. From our perspective we do not really care about these very specific details and we won't look in a graph extensively.	*Explanation previous point*
R1: But considering a company like DJI, they might be interested in this, because they do not need 70C, but they need a lower C. I think I've seen like 12C for them. For bigger companies it's more about flight cycles and specific temperatures then.	*Explanation previous point*
I: Thanks for the great input. One more question on the sheet itself. Do you think a datasheet like this would be the best way to showcase the value of our product to you?	
R1: With a second page and a description and everything, this could be a good secondary to introduce people to it.	Right channel
R2: But also a very nice addition, I suggest. This sheet is integral and should always be added together with the product. However, another something you can add is videos of the test flight of a drone. Like a timelapse. Like it flies for 35 minutes in a 30 second video. If you can show it, it gives you way more integrity and shows that you can and did do it.	Alternative
R1: And if you need any test platform for it, R2 still needs to do their thesis and they were planning to do it with solar panels on drones. So keep that in mind as a test platform.	
I: Great, could you explain your thesis a little more? What are you going to research?	
R2: Yeah, I'm still in the process of developing the proposition, but I want to make a drone that can fly for 24 hours. And a lightweight battery like yours will definitely help. We add some solar panels and make it as lightweight as possible.	
I: That's very cool. Do you know if it has already been done?	
R2: It's been done by big companies, but not in a research setting.	

I: Your project sounds great, and could really add something to the general understanding of how to make lightweight drones. To get back to the questions, I have two more on the battery itself. The first one, based on the product that you see in the datasheet, does our product meet your requirements and how can our product itself be improved?	
R2: Yeah, the C-rating. We normally go for 70C. With such a high energy density and a high C-rating you would have one of the best batteries. That's it. Your energy density is perfect, your voltage is okay, you have good data in comparison to other batteries. Get the C-rating as high as you can. And maybe showcase different casings, 1s, 2s, 3s, 6s, and you can probably put a 12s battery in one casing, because yours is so small and lightweight. There are not many 12s batteries in the market. The biggest I've seen was 10s and it was huge, like 2 kg or something. Yours will be around 1-1.5 kg. So look into batteries maybe and not only cells.	Misalignment Alignment
I: Thank you, any more things?	
R1: No, I think we mentioned everything.	
I: Thank you. The last question on our battery: Do you see any challenges in implementing our product into yours, so from cell to flying drone?	
R2: Other than the casing, no. If you have a compact case it would be nice. Our use space is small, because we also need enough space for the package we're going to send. We want to use as little space as possible.	Integration
I: That makes a lot of sense, thank you. One more small thing. How do you normally get in contact with battery suppliers?	
R2: We usually just order them. We don't have a specific battery supplier, because we change around to try new things, so we normally just order them online.	
R1: That's because aim to make our drone out of off the shelve products, so you can reproduce them.	
R2: We don't want to overcomplicate things because we are going to make this drone an open source drone, so everyone with a 3D printer and some tools can theoretically build it.	
R1: It could also be a great test platform to test different applications on. Your cells would come in handy where we fly with the batteries of our drone, but power the unit with a different battery set.	
I: Sounds fair enough. Those were all of my questions, do you have anymore questions for me?	
R2: No, we were interested to see if we could work together in some way, but we could discuss this maybe over e-mail with the responsible person in the company.	
I: I will definitely send you their contact then.	

R1: I also have some advice for you, maybe contact AeroTeam Eindhoven as well. They are currently making a drone that can land on another drone to change its own battery. They're still active and I will send you their contact information as well. I: Wow, that would be really helpful, thank you. R1: Yes, I'm in contact with them for organizing the Amsterdam Drone Week. R2: LeydenJar should definitely be at the Amsterdam Drone Week. I: I think we were already thinking about going. Unfortunately, that's after I am done with my Internship at LeydenJar, but I will definitely tell my supervisor to go! Thank you so much, Any more questions? R1: I don't R2: Yeah I think we're good. I: Than thank you guys, I had fun in this meeting. R1: Yeah me as well. R2: Yeah it was a nice meeting.	

I Answers interview 4 with student drone team

Due to time limitations, only a selection of the determined questions was asked during this interview. This interview was recorded by taking notes and presented below. The text is labeled with I for interviewer and R for respondent. To enable structuring the data, codes were assigned and presented in the right column next to the corresponding text.

I: What are the most important data to you when evaluating a battery for your drones?	
R: To us, the most important aspects are gravimetric energy density and discharge rate, but also important are the volumetric energy density, the amount of cells that can be sampled, the kind of cell packs, and whether the cell supplier delivers a battery management system with the cells. Also the specific requirements for a battery management system would be important.	Important aspects
Another important point is the amount of pressure necessary. We currently need to apply around 50 psi to our cells.	
For our specific use, a light battery is more important than flight time increase. 3 battery packs of 16 Ah would give us 6 to 7 hours of flight time in the shortest night of the year. 4 battery packs would be ideal for us.	
I: Can you fully evaluate our drone battery based on the information in the datasheet and what information should be added to complete the picture?	
R: I miss the maximum pulse discharge rate of this cell. During take off, our drone requires a fast discharge burst.	Incompleteness Addition
How can a battery pack be produced? Is that our own responsibility or can you deliver a battery pack?	
I want to know what the requirements are for building a battery management system for your battery.	Addition
Looking at the datasheet, one has to make the step from battery to pack level themselves. It would help if possible battery packs were showcased. I would like to see the dimensions and properties of a battery pack containing 4 to 6 of your cells for example.	Addition
I: What parts of the information in the datasheet are unclear to you? How can we explain these details better?	
R: I do not understand what flight area increase means or how you determined this.	Unclarity
I think the information sheet is completely clear for the rest.	Clarity
I: Is a data overview like this the best way to explain the value of our product to you? What alternative would you suggest?	
R: Yes, I think it works.	Right channel
A fun addition could maybe be a tool on your website where drone manufacturers can fill out their drone and battery specifics and receive a calculated increase in flight time, flight range and payload.	Alternative
I: Now I want to ask your opinion about our product itself. Does our product fit the drone battery requirements for your drone team and what improvement or additional features would you like our battery to have to better fit these requirements?	
R: I think your battery would work really well in a drone. As a drone manufacturer you might be crazy if you do not choose to improve	Alignment

the energy density of your battery. Looking at your energy density, a drone manufacturer would have to say yes.	
For our use case we are constantly flying our drone while it unloads and reloads its battery with its solar cells. I am curious how your cycle life would be influenced by this continuous process. However, the flight cycles that are promised on the datasheet right now are a good fit with our requirements.	Misalignment Alignment
It would be useful if the lower operational limit was below 0 °C, especially for operations high in the air on winter days. For our specific use this is not a necessity as we mostly fly in summer.	Misalignment
I: When it comes to implementing our battery in your product, are there any challenges or obstacles you foresee? R: We are working on trickle charge, meaning that the battery charge rate changes depending on the amount of sunlight. What would be the chance that your battery degrades faster than 200 cycles using this protocol? Based on the answer to that question we can determine how to program our battery management system. We generate the battery management system ourselves as we need it to be programmed for switching between solar and battery energy. We could measure battery data in our drone for you. We then have to know what the largest uncertainties are in your product so we could test these aspects.	Integration

J Transcript interview 5 with student drone team

This interview was recorded through teams and transcribed after. The transcript is presented below. The text is labeled with I for interviewer and R for respondent. To enable structuring the data, codes were assigned and presented in the right column next to the corresponding text.

I: Allereerst, waarom we dit interview doen. LeydenJar is een batterij aan het lanceren, die onze zelfgeproduceerde silicium anodes bevat en die geoptimaliseerd is voor het gebruik in drones. Ik heb jou de productbeschrijving gestuurd en voor mijn onderzoek wil ik achterhalen wat we kunnen leren van het valideren van onze productbeschrijving met dronefabrikanten en dronebouwers. Uiteraard wordt je feedback erg gewaardeerd en het zal uiteindelijk verwerkt kunnen worden in het verder ontwikkelen van ons product en van onze productmarketing. Om te beginnen, wat zijn de belangrijkste punten van data waar jij naar kijkt bij het waarderen van een batterij voor in jullie drone? R: Nou, de twee belangrijkste dingen die me nu te binnen schieten zijn energieverbruik en herbruikbaarheid. Als je ons op project zou specificeren, zie je dat wij te maken hebben met hele hoge voltages en een batterij die energiezuinig is en zo min mogelijk gebruikt zou dus in ons geval heel goed uitkomen. Daarnaast is ook het aspect van herbruikbaarheid heel belangrijk. Je hebt bij ons namelijk een battery swap mechanism. Er is een onderdeel dat vastzit aan de grote drone en het andere onderdeel zit vast aan een kleinere drone, waarna ze geswapt worden. We proberen het systeem nu zo te ontwikkelen dat de grote cargodrone de batterij zoveel mogelijk laat leeglopen tot bijna aan de max en dan de batterij swapt. Daarom is de herbruikbaarheid erg belangrijk, dus ik weet niet of jullie cells daar zo op gemaakt zijn dat ze daadwerkelijk keer op keer zoiets zouden aankunnen. Voor ons is dat heel belangrijk. Het eerste waar we altijd naar kijken is het verbruik van de batterij, dus hoe zuinig is de batterij, en daarnaast ook of het herbruikbaar is en hoe vaak en wat de levensduur van de batterij is eigenlijk. I: Dat klinkt inderdaad als twee relevante punten. Met die herbruikbaarheid van de batterij bedoel je dan de herbruikbaarheid of heroplaadbaarheid van een batterij nadat je hem volledig ontlaadt toch? R: Ja, stel we zouden een batterij van jullie gebruiken dan is deze als het goed is bijna helemaal leeg en pas dan wordt die geswapt. De vraag is, net als met een telefoon, stel je laat hem helemaal leeglopen en laadt hem daarna weer helemaal op, wat is dan de levensduur? I: Helemaal duidelijk. Als volgt wil ik het hebben over de datasheet zelf. Heb jij die voor je op dit moment? R: Ja, ik heb hem nu voor me. I: Mijn eerste vraag hierover: Kan je ons product volledig valideren op basis van de informatie die in de datasheet staat en welke informatie zou volgens jou moeten worden toegevoegd om het beeld volledig te maken? R: Ja, als ik deze datasheet voor me krijg, zou ik toch een redelijk goede inschatting kunnen maken van het product zelf inderdaad. Ik	Important aspects Completeness

zou zo snel niks kunnen bedenken wat er ontbreekt. De echt belangrijke aspecten voor drones staan er op. De range staat erop, de flight cycles, discharge resistance, hoeveel de cell zelf weegt.	Completeness
Ook erg fijn dat er een vergelijking wordt getrokken met een standaard drone. Ik zie onderin staan "De data is vergeleken met een standard inspectiedrone met de volgende eigenschappen", nee oke, dat is vrij duidelijk allemaal.	Clarity
I: Fijn om te horen. Zijn er bepaalde specificaties in de datasheet die onduidelijk zijn voor jou en hoe kunnen we details beter toelichten?	
R: *kijkt nog eens zorgvuldig naar de sheet*. Eigenlijk niet nee, voor mij is het vrij duidelijk en ik ben er net als de mensen in de industrie dagelijks mee bezig, dus dit soort dingen krijgen we vaak genoeg voor onze neus. Ik vind dat het een hele compacte prima datasheet is waarbij je een goede inschatting kan maken als je die voor je neus krijgt.	Clarity Completeness
I: Ook erg goed om te horen. Dan de laatste vraag over de datasheet zelf. Vind je een datasheet als deze de beste manier om de waarde van ons product aan jou over te brengen of zijn er alternatieven die je voorstelt?	
R: In principe niet, het is altijd fijn als het product getest is. Dan heb je harde testdata en kun je vergelijkingen trekken met alternatieven die in de industrie voor handen zijn. Gezien de situatie en de datasheet zelf zou ik niet zeggen dat er betere manieren zijn waarin je op dit moment jullie product naar voren kan laten komen. Als jullie vanaf volgend jaar misschien de cellen op de markt gaan brengen, dan kan je ze testen en dan kan je het resultaat laten zien. Mensen in de industrie kunnen dan zien dat dit het fysieke resultaat is van die batterij. Maar voor nu zou ik niet zo snel een manier kunnen noemen waarop het beter zou kunnen.	Right channel Alternative
I: Het zou dus wel wat toevoegen voor jou als je de cell in een echte drone zou zien?	
R: Jazeker, het is altijd fijn om van alles op papier te zien, maar je kunt van alles beloven en uiteindelijk gaat het toch om de resultaten in een drone. Als jij kunt laten zien: door onze batterij kan een specifieke drone twee keer zo lang vliegen en kan deze twee keer zoveel operaties uitvoeren, dan is het concreet voor de mensen in de industrie. Dan weten ze wat ze kunnen verwachten van de batterij.	*Explanation previous point*
I: Zou dat dan voor jou het meest duidelijk zijn als het een visueel product is, bijvoorbeeld een video van een vliegende drone, of als het harde data is die vertelt wat bijvoorbeeld de flight time is in industriele drones?	
R: Visueel kan je ook maar een beperkt iets doen en uiteindelijk gaat het toch om de harde cijfers. Als je met cijfers kan laten zien: dit gebeurt er in de praktijk en dit zijn de verbeteringen in deze specifieke drone, dan is dat voor bedrijven die daarmee bezig zijn eigenlijk al genoeg.	*Explanation previous point*

I: Dat klinkt helemaal duidelijk. R: Je wil als bedrijf jezelf natuurlijk op de kaart zetten. We hebben hier bijvoorbeeld een elektrische race auto die kan opladen in 8 minuten. Dat zijn bepaalde punten waarop je adverteert en op die manier kan je ook naar de batterijen kijken. Zodra je die praktische testdata hebt kan je zeggen, dit zijn de punten hoe onze batterij er het beste uitkomt.	*Explanation previous point*
I: Dat is inderdaad nuttige feedback. Dan twee vragen over het product, voldoet het product, zoals die beschreven staat in de datasheet, volledig aan de batterij requirements voor AeroTeam Eindhoven en wat zou je voorstellen als verbeteringen of toevoegingen aan onze batterijcel?	
R: Ik denk dat het product op basis van de datasheet wel zou voldoen. Het is alleen de vraag wat er gebeurt wanneer je de batterij zou opschalen qua capaciteit. Is de batterij dan nogsteeds op een fatsoenlijke manier herbruikbaar? Wordt het dan een soort afweging tussen verschillende specificaties? Echter, op basis van de datasheet zou ik zeggen dat de batterij wel geschikt is voor ons project.	Alignment Misalignment
I: Dat klinkt goed. Als ik vragen mag, wat voor capaciteit batterij gebruiken jullie voor je drone?	
R: Dat is een goede vraag. Ik denk dat we nu rond de 6 Ah zitten. Het ligt aan het type drone waar we mee bezig zijn want we hebben verschillende projecten gehad, maar het zit altijd wel tussen die 5 en 6 Ah.	
I: Duidelijk. We hebben het er al even over gehad dat jullie een aerial battery swap willen doen en dat dat veel uitdagingen met zich meebrengt. Als het gaat om het daadwerkelijk implementeren van onze cel in jullie product en de stappen die daarbij komen kijken, zijn er bepaalde uitdagingen die je voorziet?	
R: Ik denk dat het voor ons vooral belangrijk is dat we van jullie de concrete testdata krijgen en dat we te zien krijgen wat de batterij daadwerkelijk kan en doet. Op basis daarvan kunnen we dan een veel beter design en mechanisme maken. We hebben de afgelopen jaren tussen batterijleveranciers ingezeten waardoor we telkens ons design moesten aanpassen. Als we met 1 specifieke batterijleverancier in zee gaan kunnen we ons daar ook gemakkelijker op aanpassen. Voor ons is dus de grootste uitdaging, wat is jullie testdata in een drone? Als we de batterij testen in onze drone en dat daarmee vergelijken kunnen we een veel beter geheel maken van wat er mogelijk is. Op dit moment hebben we Tulip Tech waar we de afgelopen 2 jaar af en aan batterijen van aangeleverd hebben gekregen, maar we zijn voor volgende kwartalen wel op zoek naar een nieuwe batterijleverancier. Dat is even zoeken.	Integration

I: Dat klinkt als een redelijke uitdaging op zichzelf. Dan als laatste een vraag die daaraan gerelateerd is: Hoe komen jullie normaal in contact met batterijleveranciers? Zoeken jullie hen op of zoeken zij jullie op? R: Aangezien we een studententeam zijn dat nog niet echt groot op de kaart staat zoeken wij de batterijleveranciers altijd op. We benaderen hen meestal direct of doen dit soms via het alumni netwerk van de TU Eindhoven of via de netwerken van Eindhoven Airport. We zijn aan Tulip gekomen door hen direct te benaderen. I: Hartelijk bedankt. Voor mij waren dat alle vragen. Heb je zelf nog vragen voor ons of voor mij specifiek? R: Voor nu is het voor mij vooral wat zijn de samenwerkingsmogelijkheden en op welke termijn zouden jullie de eerste testdata beschikbaar kunnen hebben? I: Wat betreft de eerste testdata, zodra de we cellen leveren in 2025 zou die eerste testdata vrij hard moeten gaan. Ik ga zelf niet over het samenwerkingsverband als stagiair, maar ik zal het emailadres doorsturen van degene waarbij je daarvoor terecht kan. R: Hoe gaat dat dan normaal in zijn werk met samenwerkingsverbanden met studenten drone teams? I: We zijn op dit moment nog niet aan het samenwerken met droneteams, maar ik zie zeker wel het nut hiervan in omdat jullie ons nuttige testdata kunnen leveren in ruil voor batterijen. R: Niet alleen dat, maar het is ook anekdotisch bewijs dat laat zien, dit kan de batterij doen in deze drone voor deze specifieke toepassing. Dit is voor jullie marketing en promotie ook heel goed. I: Zeker mee eens. Nogmaals hartelijk bedankt voor je tijd en succes met de werkdag verder!	

K Answers interview 6 with drone pack manufacturer

Due to time limitations, only a selection of the determined questions was asked during this interview. This interview was recorded by taking notes and presented below. The text is labeled with I for interviewer and R for respondent. To enable structuring the data, codes were assigned and presented in the right column next to the corresponding text.

I: Can you fully evaluate our drone battery based on the information in the datasheet? And what information should be added to complete the picture?	
R: Information that should be added to complete the picture:	Incompleteness
- The maximum cell voltage.	Addition
- The minimum cut off cell voltage.	Addition
- The recommended landing voltage.	Addition
- The recommended charge rate.	Addition
- The maximum possible charge rate.	Addition
- More temperature data:	Addition
o The cell capacity at different temperatures and under different C-rates.	
o The temperature increase during the flight protocol.	
I: Does our product fit your drone battery requirements? What improvement or additional features would you like our battery to have to better fit these requirements?	
R: Yes, the product fits the requirements.	Alignment
We are interested in offering the cells in packs to our customers. The company wants to add a pack containing the cells of LeydenJar to their portfolio. Based on the prototype pack, we could provide a pricing indication.	
I: When it comes to implementing our battery in your product, are there any challenges or obstacles you foresee?	
R: Silicium anode tabs often consist of aluminium. This is often thin and challenging to solder onto a cell pack. We would prefer that you use thicker copper tabs.	Integration
The shape and dimensions of the presented battery do not always fit in a drone.	Integration
The terraces on the sides of the cells take up significant space. It has to become clear if these can be folded back or not.	Addition
We need more temperature data, but we offer to measure that in-house.	Integration