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Strategic concept of a manufacturing network for an Austrian/Swiss based helicopter for military and emergency services

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AFFIDAVIT

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Abstract

The background of this thesis was a proposal made by politicians, especially by Hans Peter Doskozil (SPÖ), that it was possible to build a helicopter for the army, entirely in Austria. The motivation was, to find out, if there were enough potential companies in Austria, and in which way such a project could be realized from a strategic point of view.

Therefore, it was suggested to depict a manufacturing network, hence a OEM consortium combined with a supply-/value- chain, involving qualified firms of the mutual neutral countries of Austria and Switzerland. The mapping of the value chain should be based on the product itself and a helicopter model chosen after an initial short requirement analysis. The MD 902 Explorer served therefore as the base model, as most information was available freely on this specific type. However, the model was later generalized by means of adding a standard tail rotor configuration as an alternative to the NOTAR system. The layout of the value chain is oriented on the actual path of manufacturing in a nutshell, ranging from the processing of raw materials to the Final Assembly Line. To include these aspects, a graphic chart had to be created in the course of the thesis. Finally, expert interviews were conducted in order to give strategic inputs on this issue. This was done by means of a SWOT analysis.

In the end, many ideas for further investigations were brought to light. The bottom line is that there indeed exists a great amount of potential in Austria and Switzerland. Nevertheless, some risk factors have to be considered.

Symbols, Designations and frequently used Abbreviations

AT-CH	Austria-Switzerland, Austro-Swiss
BMVIT	Austrian Federal Ministry for Transport, Innovation and Technology
BOM	Bill Of Material
CC	Core Competences
DOA	Design Organization Approval
DS	Drive System
EASA	European Aviation Safety Agency
EMI	Electro-Magnetic Interference
EMS	Emergency Medical Service
FAA	Federal Aviation Administration (U.S.)
FADEC	Full Authority Digital Electronics Controller
FAR	Federal Aviation Regulations (U.S.)
IFR	Instrument Flight Rules
JAR	Joint Aviation Authorities (U.S.)
JIT	Just in Time
LUH	Light Utility Helicopter
MDHI	MD Helicopters Inc.
MOB	Make or Buy
MRO	Maintenance, Repair and Overhaul
MTOW	Maximum Take Off Weight
NACA	National Advisory Committee for Aeronautics (U.S.)
NOTAR®	No-Tail-Rotor (invented by Hughes)
NVIS	Night Vision
ÖAMTC	Austrian Automobile Motorbike and Touring Club
ÖBH	Austrian Armed Forces

OEM	Original Equipment Manufacturer
PC	Poly Carbonate
POA	Production Organization Approval
R&D	Research and Development
R-BOM	Relational BOM
SOP	Start Of Production
SWOT (Analysis)	Strengths, Weaknesses, Opportunities and Threats (Analysis)
TC	Type Certificate
VCM	Value Chain Model
VFR	Visual Flight Rules
VTOL	Vertical Take-Off and Landing
WKO	Austrian Federal Economic Chamber

Table of Content

1. Introduction

"QUI AUDET, ADIPISCITUR - WHO DARES, WINS"

– Latin proverb

1.1. Motivational Background

For a neutral country like Austria, production and procurement of military equipment has not been an easy task since the re-establishment of the Austrian Armed Forces (ÖBH) in the 1950ies. According to the CIA World Factbook, their financial resources for investments, as well as the overall budget for the army, are amongst the lowest in comparison to other Western-European nations, amounting only up to 0.57% of the GDP in 2019 (globally ranked on 141th place between Nicaragua and Mexico, 2nd lowest in EU after Malta).[1]

Nevertheless, the helicopter fleet is aging quite fast and parts of it, in particular the light multi-role helicopters of the types Alouette 3 (see Figure 1) and Bell OH-58 Kiowa, need to seek replacement by the early 2020ies, because of their maximum life expectancy of respectively 40 to50 years.[2]

Figure 1: Alouette 3 and S-70 "Black Hawk" in mountain training, Source: Bundesheer (n.y.), online source [28.1.2019].

In 2017, marking the start of the electoral campaign in Austria, new approaches to solve the problem were subject to political debate. Besides the conventional way of purchasing such a system on the

[1] Conf. CIA (2019), online source [30.01.2019].

[2] Conf. Tögel (2018), online source [16.08.2018].

market, other innovative paths have been subject to discussions all over the mass media, such as the daily newsletter "Kurier", which provided the following information: [3]

In a recent article, a statement was published, in which the former Austrian minister of defence, **Hans-Peter Doskozil**, presented an innovative idea. His proposal was to build an "all-Austrian" helicopter, according to detailed military specifications, assuming that domestic companies and organizations had the knowledge and resources to do so. He further stated that this goal could be achieved via an industrial cluster consisting of Austrian suppliers to the aerospace and automotive market, which would be formed especially for this matter. According to him and other experts, such a cluster should contain many well-known companies, such as Pankl, Zoerkler and the, now Chinese-owned, Diamond Aircraft, which produces light aircraft. The projected time horizon would have been estimated between **four to five years**, which could be made possible with the support of government agencies, at a budget of approx. **€ 100 million**. However, an example by a Swiss company (**Kopter**) showed that it would take at least **15 years** from the idea to SOP. In this article, the WKO supported his idea, claiming that it could be theoretically possible, as Austria had the expertise, which is spread across several companies throughout the country. Zoerkler added, that they could see the necessary competences within the local industry to proceed a project like that, but only if companies provided the necessary capacities, and the purchaser provided the budget. Finally, the article also stated that, despite the lack of a full-blown local helicopter manufacturer, there is the drone manufacturer Schiebel, which produces helicopter-drones for the international market, and **Diamond Aircraft** is already developing a helicopter, called the **Dart 280**.

The idea itself of having an indigenous military aircraft development is quite common amongst many greater industry nations (e.g. USA, Russia, China, France, Great Britain and Germany) and remained a popular solution since the end of World War II. For political and economic reasons, some countries focused on their own innovation and production capabilities (e.g. Boeing in the USA); whilst others implemented a policy of producing their aircraft locally under a license agreement or via joint ventures (e.g. Helibras S.A. as a subsidiary of Airbus in Brazil, see Figure 2)[4]. The reason for the last option is that fully developing and manufacturing of a helicopter requires a long-time horizon (more than 10 years), longer than the local end-customer can wait. In the case of Switzerland, despite of being neutral and not part of EU, it is proven possible that a small neutral country can produce reliable systems beyond small training aircraft. Besides the well-known company Pilatus, from whom the Austrian Air Force has purchased military aircraft of the type PC-6 and PC-7, there is also the Swiss-based helicopter manufacturer Kopter, formerly known as Marenco-Swisscopter, which develops and produces light utility helicopters (LUH) for civilian use as well as for law enforcement. [5]

[3] Conf. Möchel/Schreiber (2017), online source [05.06.2018].

[4] Conf. Duran (2013), online source [12.11.2018].

[5] Conf. Van der Wall (2015), p. 31–68.

Figure 2: Helibras manufacturing facility in Itajubá, Source: Ricardo (2013), online source [30.1.2019].

Despite the fact that the aerospace market shows an upwards trend, the OEMs, maintain their strict supply-chain hierarchies with their suppliers and generally, do not share or outsource their internal knowledge in order to preserve competitive advantages.[6] Consequently, all the main competences to fully develop and build a helicopter remain at a handful of firms, a phenomenon that can be observed at Airbus, for instance. A hypothetical Austrian enterprise of this kind would face many challenges from the technical and production point of view. The big question in the beginning can be stated similar like this: **Who could be capable of producing the necessary parts? Are there enough local suppliers? Who could be responsible for development, production and the product lifecycle of a helicopter?** Despite a broad discussion with lots of opinions regarding this dicey topic, there has not been any known publications of academic background concerning it, so far. There is also no working concept for a unified strategy on the table just yet. However, the analysis of the current state of research in literature gave some academic inputs regarding general frameworks of manufacturing systems in aerospace industry, such as Pradeep Fernandez from MIT (2001). Nevertheless, this source was dealing in a great level of detail with the organizational environment and implementing lean management in an already existing aerospace company, which did not help with the specific problem of this thesis. Consequently, the focus will be directed on figuring out a more individual approach, as described in the consecutive chapters.

[6] Conf. Fernandes (2001), p. 21–33.

1.2. Assignment- and problem formulation

Based on the situation depicted above, the proposal of hypothesis, which also represents the statement of this thesis and subject to the testing bench, could be stated as the following:

"It is reasonable to build up an indigenous network of manufacturers, which is able to locally produce a helicopter for the military, within the economic zone of the closely related neutral countries Austria and Switzerland (AT-CH)."

The thesis should consist of qualified statements about **reasonableness (i.e. to clarify if there is a demand)** and in **which strategic way** such an enterprise could be **feasible**. Furthermore, we need to know, how the line-up for a **value-chain for a complex product** could look like; in this case, for a helicopter and therefore, **how much** of the necessary components **can currently be built in the economic region of Austria-Switzerland (AT-CH)**. Furthermore, the idea was to get the value chain model approved, so that it could serve as a basis for similar complex products. Finally, the thesis aims to investigate on **problems, risk factors,** and **strategic possibilities** for the specific helicopter enterprise. In order to be able to obtain also the knowledge from the industry for academic purpose, the research will include the points of view from different **stakeholders**, which also gives **insight** into their way of internal thinking about this matter.

Derived from our hypothesis and the statements made, the research question and its sub-questions (see Table 1) formulate themselves as following:

"How does an adequate indigenous (AT-CH) production network for a helicopter look like and to what extent can a light utility helicopter for the military be built, taking into consideration the current (2018) requirements and specifications of the ÖBH?"

Sub-questions:	Goals:
• Break down **complexity**: What main components are necessary in order to build a helicopter, what is the structure of the **helicopter** as well as the **value chain**? • How would such a **local manufacturing network** fit to the value chain and what would it ideally look like? • How far is **company "XYZ"** suited to be a **player** in that network? • Which **components**/firms are missing and **have to be procured** from somewhere else? What further problems may occur? • **Strategic view**: Requirements for OEM, Purchasing, Strengths Weaknesses Opportunities Threats (SWOT)? • **Restrictions** and **Costs**? • How reasonable/feasible is such an enterprise in undertaking?	• Strategic estimate of the actual problem stated. • Conception of an optimized manufacturing-network along the value-chain for the most important main-components of the LUH • Develop a stylized depiction of firms corresponding to a simplified helicopter-model. • To bring up a new topic for academic research. For people in industry as well as for aerospace enthusiasts.

Table 1: Sub-questions and thesis goals

1.3. Approach and Methods: *"The Thesis Cockpit"*

The following part describes the assignment derived from problem statement and the used approach. The upper definitions already give a very clear picture, of what the outcome should be:

- To develop a **visual concept for integration of different firms**, which are situated as locally as possible, into a working industry cluster or consortium. This network should be able to manufacture a helicopter "made in Austria/Switzerland" and according to aerospace standards; in this way, the focus of the value chain will lie on the product and production itself.
- To have an **estimation** about **who** can be a supplier and **what** and **how much** of the components can be manufactured by **local suppliers**.
- To find out about **strategic players**, and who could form an **OEM consortium** through joint ventures etc.
- To investigate on possible **SWOTs** in the point of view of an OEM.

Upper statements imply one very important **assumption**: **The product and its production are in the focus.** Consequently, forging an aggregated and simplified model around the helicopter will be the main method used in this thesis.

The thesis starts with a research in literature about the current state of art, relevant helicopter types, components and requirements, producing companies, SWOT methods, interview methods and methods for network modelling. This research will be done first within the range of the TU Graz Library and secondary with the help of Mr. Puffing from FH Joanneum (Institute of Aviation). Other sources will be investigated through the internet. However, there is no known unified value-chain-mapping approach in existence, which can help to give a clear picture to the problem. Therefore, for developing a supply-chain-network on an aerospace (i.e. helicopter) Greenfield a handy solution had to be developed. Consequently, there was used a more individual and intuitive "try-and-error" approach with a very steep learning curve. This means that many assumptions had to be made in the beginning and throughout the course of the thesis, which have to be critically reviewed and discussed in the end internally and by the experts.

To save time and effort, the number, properties and types of **the usual parts a helicopter contains** is limited by **focusing on a set of main components** only. In the beginning, an adequate LUH type will serve as a platform for the analysis and research on the structure. Consequently, the model will use as an already **existing helicopter, which will be chosen with the help of initial interviews in the pre-phase. However, it <u>is not</u> the purpose to simulate** as if the expertise was bought externally from a company and the product will be built under **license**. This should only compensate for the missing part of research and development on a completely new product from scratch because it is not the focus of this thesis. An analysis of requirements will therefore serve the selection process useful to find the right type. A technological comparison of design features between a purely **Austrian-Swiss (AT-CH)** helicopter version and the chosen type is subject to the expert interviews.

As many details of production itself remain more or less a company secret, only the most common manufacturing techniques will be applied. Even though the focus of the thesis lies on the manufacturing, the important value chain activities of research and development will be noted down in the process of the company investigation. Hence, they will find their way onto the R-BOM.

The companies will be at first filtered, and then added to the process and the sourced components. To visualize the locality, supply chain and value chain position in some form, suppliers and production companies will be categorized as the following:[7]

- AT-CH, EU and non-EU.
- OEM Partner vs. Supplier (no Tier hierarchy is ignored in the first attempt)
- Possible involvement of the company in the research phase, development phase and/or production phase

The outcome of this part will be a **preliminary, theoretical model**, which will provide a first approximation.

The inputs for the final discussion will be sampled by means of qualitative interviews. For answering the strategic questions, the SWOT Analysis was chosen to be the most practicable tool, which will also be done with the interview inputs. The **expert interviews** and **SWOT** analysis, which will then represent the aviation experts' opinion in the perspective of the companies, will be completed in order to answer the **questions** regarding feasibility etc. and to find possible execution strategies. All aspects of **costs** will be covered in this section. For the interview setting, experts will be confronted with two sections of questions:

- a general section, which will be common to all interviewees and deal with **strategic implications/SWOT**, and
- a specific section, which will be tailor-made to specific aspects of **assumptions and problem details** of the **preliminary model**.

Possible interview partners could be an agent or a manufacturer's representative of any stakeholder to the local aviation industry. Depending on situation, the form of the interviews will be adaptable. Therefore, different formats will be possible, such as:

- open discussions (if more than one experts attend);
- classical guided interview with question and answering parts (dialogue style);
- or unguided free discussion, if the expert only has a limited timeframe for a single phone call;

The inputs of the interviews will be collected by means of **minutes of meeting**, **audio files** or by **memory minutes**, depending on the situation. After sampling and transcription of notes/files, the inputs are summarized, anonymized (if requested), ordered, and finally put into the appendix section.

The final depiction of the model (**Value Chain Model, or VCM**) will contain the right kind of suppliers on the main components and manufacturing steps to answer the questions: Who can be a player? What does procurement look like in our case? How much can be produced throughout the competences within the local industry? How to organize production? Iterations and analysis of shortcomings of the model will be subject to discussion afterwards with the help of the experts. The following Figure 3 sums up the strategic approach in detail.

[7] Conf. Chapter 6.2.

Figure 3: Approach for the Thesis.

2. The term “manufacturing network”: more than a value- or supply chain model

The first challenge is to define and explain what the term “manufacturing network” means and how it relates to the other common terms like supply chain and value chain. The goal of this chapter is to elaborate a usable definition of it and to investigate it in order to elaborate a strategic planning tool for the thesis out of it.

2.1. Theoretical Background and Terminology

The terms value chain and supply chain often depend on company intern terminology and, as people often use them interchangeably. Basic concepts and explanations for purchasing and its role within the management of supply chains are usually material found in standard textbooks, such as in Van Weele’s 2018 edition of “Purchasing and Supply Chain Management”, from which the basic information retrieved is the main subject of the following subchapters.

2.1.1. Value Chain

The term value chain quite recently has become increasingly a central part in many business strategies in order to improve a company’s value position to its end customers. According to Van Weele, it was first described by Michael E. Porter in 1985 and is described in the following paragraphs:[8]

The value chain is composed of several horizontal activities by stakeholders, which create value, and a margin, which is the aim of those activities. The position, where a company should place itself in a value chain in order to sustain superior performance to competitors has become a main topic in top management. By definition, a value chain is the sum of all value activities plus a margin achieved by the activities, reflecting the rewards of the risks. A positive margin means that the total value generated, as perceived by the customer, is more than the sum of its costs. Porter’s famous value chain model (see Figure 4) is most widely used to explain these activities, which consist of primary (add directly to the value) - and secondary activities (support primary process). Porter categorizes a company’s **primary activities** into the following parts:

1. **Inbound logistics**: All activities related to material handling and warehousing, like receiving, internal logistics and storing of raw materials.
2. **Operations:** The input is transformed into the output. This transformation is referring to the **manufacturing processes**, which can be characterized as following:
    a. Make to Stock (MTS): Standard products are manufactured and stocked while customers are serviced from an end-product inventory. The planning is based on forecasts.
    b. Make to Order (MTO): Customer-specific products are produced to specifications from raw materials or the purchased components inventory after a customer order has been received.
    c. Engineer to Order (ETO): All activities from design to assembly plus procurement of all required components and raw materials are related to a specific customer order.
3. **Outbound logistics:** Physically distribution of the final product to the customers.
4. **Marketing and Sales:** Advertising, promotion, sales, pricing, distribution channel selection.

[8] Conf. Porter (1985), n.p., quoted from Van Weele (2018), p. 2–28.

5. **Services:** Provide life cycle support to customers (e.g. maintenance, repairs, installation etc.).

Support activities are:

1. **Procurement:** This function is directly related to logistics and the manufacturing processes. Should be able to meet material requirements. It also relates to the sum of a company's external resources. Supplying under most favourable conditions is the overall goal. Crucial for procurement is TCO (Total Cost of Ownership), a way of thinking which focuses on the total costs that a company will incur over the lifetime of the product that is purchased.
2. **Technology development:** Every activity requires expertise or certain procedures. The design of processes, systems and products falls also into this category.
3. **Human resources management:** Includes all actions directed at recruiting, hiring, training, developing and compensation of personnel, active in both sets of activities.
4. **Firm infrastructure:** Thinking beyond the processes in the primary activities, the infrastructure serves rather the whole company processes. This includes management, planning, quality management, finance, legal, and facilities management. In large corporations, one sees these activities divided among the main company and its business units (division of tasks).

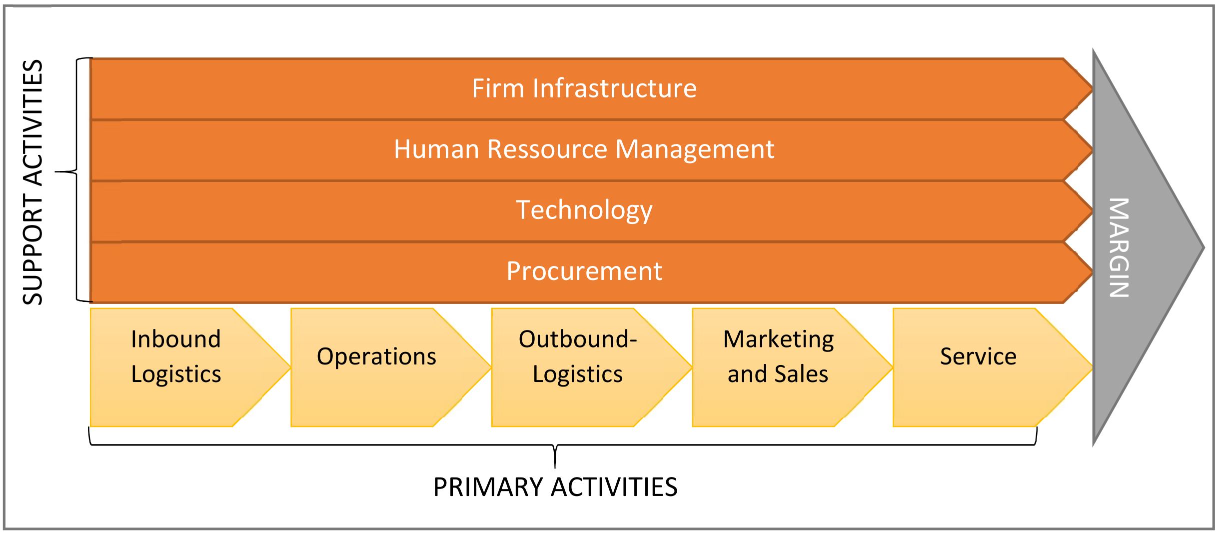

Figure 4: Value Chain, Source: Porter (1985), quoted from Van Weele (2018), p.2 (modified).

This general model applies consequently to the helicopter OEM as well; aspects of these activities will be subject to our discussion in the further course of this thesis. One has to keep in mind, that the **value** a company can **add** to the value chain is actually defined by the **core competences (CCs)**, hence the market area where it is most effective in [9].

2.1.2. Supply Chain

Nowadays companies struggling with the issue on how to become more competitive are starting to think about which activities from the value chain are considered core or non-core. Non-core activities or competences are usually primary targets for outsourcing, which is one aspect of the procurement activity. This function puts the supply chain into the spotlight. The supply chain refers to the vertical integration of suppliers and involves all activities, information, knowledge and financial resources associated with the flow and transformation of goods and services from the raw materials suppliers,

[9] Conf. Chapter 2.1.4.

component suppliers and others in a way that the expectations of the customers are met or exceeded. The terms supply chain and value chain are often used interchangeably. Nevertheless, all of them have one important thing in common: that "supplying" includes the aspect of purchasing and materials management, incoming inspection, receiving and materials handling.[10]

The supply chain is often depicted as a vertical relationship between the core company and its suppliers. The following paragraphs, based on Wallentowitz, will highlight this aspect:[11]

The supply chain is often associated with the automotive industry and the very popular "suppliers pyramid" (Figure 5). OEMs coordinate the market through this relationship. The grade of vertical integration goes from non-existent (no attachment to the OEM) up to fully integrated, for instance, when an OEM buys a supplier. Between those extremes lies the area of obligations, defined through a contract relationship. Well- maintained relationships with the suppliers ensure the organization of a flexible production and this is by itself a very complex management topic. Suppliers usually fall into different categories, depending on their specific value-added step, illustrated as following:

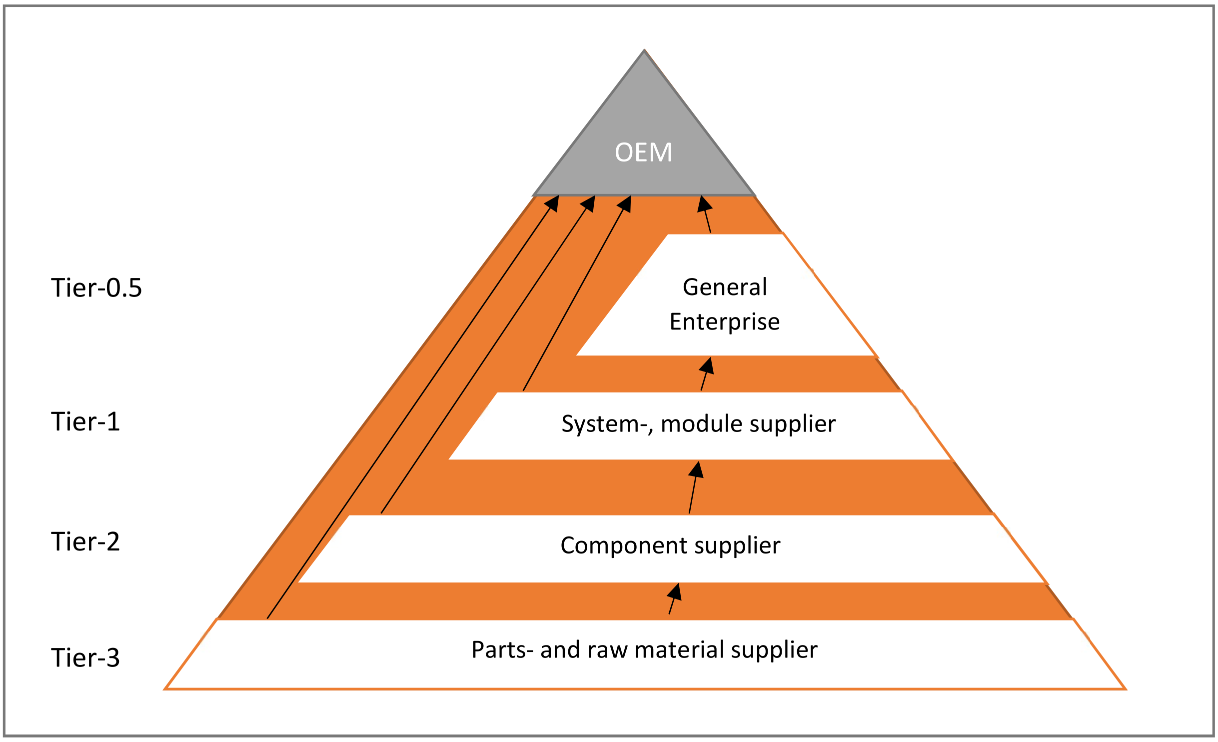

Figure 5: Supplier Pyramid, Source: O Wallentowitz (2009), p.40 (modified).

Tier 3 (Raw Material- or Parts-Supplier) delivers parts/raw materials to OEM and all other suppliers. **Tier 2 (Component-Supplier)** is responsible for **component** production and transport of components to OEM and Tier 1 supplier. **Tier 1 (System- or Module-Supplier)** is Responsible for **R&D (Research and Development)** and production of complex systems and modules and deliver those **JIT (Just-in-Time)**

[10] Conf. Van Weele (2018), p. 185.

[11] Conf. Wallentowitz/Freialdenhoven/Olschewski (2009), p. 40.

to the OEM. Finally, the **Tier 0.5 (General-Supplier)** is to be considered an optional category depending on source in literature. Those suppliers are responsible for R&D and production of whole vehicles[12].

Nowadays' commentaries on this hierarchical vertical structure regard it as out-dated, because the increasing degree of inter-relations and communication in the age of digitalisation and Industry 4.0 consequently are breaking up the linearity within the automotive industry, which leads to a more cooperative network or alliances type of structure[13]. The role of the suppliers becomes even more important, as many activities are subject to outsourcing, because of a handful of increasing factors: cost pressure, proliferation by competitors, innovation potential through new technologies and complexities. Therefore, OEMs can save fixed costs and make production more flexible.[14]

2.1.3. Sourcing Scenarios

Overall, the costs of supply and procurement can be described using the so-called TCO approach, which relates to the total costs that a company would incur over lifetime of a purchased product[15]. In order to keep costs low, competitive businesses need a good sourcing- (esp. for final components, assemblies) and procurement strategy (raw materials). Many Challenges in general due to fast IT developments, increasing consumer demands and international competition, for instance global sourcing and corporate social responsibility. Types of purchased goods are listed below:[16]

- Raw materials
- Supplementary materials
- Semi manufactured products
- Components
- Finished products
- Investment goods
- Indirect materials
- Services

Moreover, the buying process itself is affected by the following variables:

- Characteristics of the product
- Strategic importance of the purchase
- Sums of money involved in the purchases
- Characteristics of purchasing market
- Degree of risk related to the purchase
- Degree to which the purchased product affects existing routines in organization

There are several strategies (scenarios) for sourcing, which identify for a certain category from how many suppliers to buy, from whom, and the type of relationship under the aspects of regionality:[17]

- **Single Sourcing:** OEM receives a commodity from only one supplier. This is mostly applied to Tier 1 or Tier 0.5 like suppliers for electronics or systems that are more complex. The provision of tailor-made solutions for the OEM requires a very strong relationship. Consequently, a change of supplier is very difficult. For best quality, one should choose an experienced firm with a lot on process and product knowledge.
- **Multiple Sourcing:** In this scenario, the OEM gets its commodity from several suppliers in smaller batch sizes, in order to have an uninterrupted flow of material. Suppliers see each

[12] Conf. Heigl/Rennhark (2008), p. 8.

[13] Conf. Heigl/Rennhark (2008), p. 12 et seq.

[14] Conf. Schade et al. (2012), p. 31 et seq.

[15] Conf. Van Weele (2018), p. 9.

[16] Conf. Van Weele (2018), p. 15–16.

[17] Conf. Van Weele (2018), p. 9 et seq.

other as competitors, which leads to lower prices for the OEM, as dependency from single suppliers is low.

- **Local Sourcing:** Here the focus lies on local suppliers. Advantages are the high flexibility, less logistical interruptions and lowest transport costs. Domestic sourcing refers to buying the goods within a country.
- **Global Sourcing:** This strategy is commonly used by global enterprises and aims for purchasing goods globally, mostly in low-cost countries. Therefore, exhaustive analysis of global suppliers is necessary. This strategy is applicable for raw materials, parts and smaller components, but comes at the risks of price fluctuations, logistic problems and eventually a loss in quality.
- **Modular Sourcing:** This term is used, when an OEM purchases more-complex goods or systems from a few module and system suppliers, which by themselves have their own supply chain (e.g. a supplier buys raw materials and produces the cockpit or the drive train). The problem here is the potential loss of knowledge for an OEM, if a module gets completely outsourced, and the growing dependency from a supplier.

To sum it up, favourable strategies can also be applied to the supplier pyramid from before in respect to each category, as depicted in Table 2:[18]

Sourcing Strategy	Supplier Tier
Partner relationship: • **Modular-** • **Single-** • **Local-Sourcing**	**Tier 0.5** (General-Supplier) **Tier 1** (System- or Module-Supplier)
Quality, Costs, Time: • **Multiple-** • **Domestic/Local-Sourcing**	**Tier 2** (Component-Supplier)
Costs: • **Multiple-** • **Global Sourcing**	**Tier 3** (Raw Material- or Parts-Supplier)

Table 2: Sourcing strategies on each supplier tier, Source: Own illustration, based on Wannenwetsch (2009), p. 164-173.

In respect to purchasing and sourcing there are some aspects based on industrial market setting that need consideration. Many persons are usually involved in the decision making process. The purchase prices often show an inelastic behaviour, while the number of customers is limited. In addition to that, there is a high proportion of derived demand (companies selling to other companies, rather than to the end customer), which can fluctuate with an increasing amplitude, because of delivery uncertainties, from the OEM towards the suppliers ("bullwhip-effect") and from a geographic point of view, OEMs and suppliers tend to appear in close distances to each other.[19]

The sourcing scenarios outlined could form a basis for further investigations and discussions, as soon as the VCM has been finished[20]. For now, the locality of firms matters only in relation to the value they can add. However, it will be tried to find a decent amount of local suppliers for most helicopter components. If a competence cannot be fulfilled by an AT-CH company, the supplier has to be found in EU. If no EU firm is available, it will be allowed to switch on to the global level. The Tier hierarchy

[18] Conf. Wannenwetsch (2009), p. 164–173.

[19] Conf. van Weele (2018), p. 23.

[20] Conf. Appendix, Part II, Drawing no 2.

naming depicted will be left out intentionally in the first attempt in order to maintain a certain amount of freedom when designing the VCM. However, this can be added in a later stage.

2.1.4. Outsourcing: Make or Buy?

The subject in the next paragraphs are the three basic concepts of outsourcing. Afterwards, some rationales for **Make or Buy (MOB)** will be summed up. The following outsourcing concepts could be derived from literature, as described in the following:[21]

1. **Offshoring:** this business concept relates to the commissioning of former in-house activities to a provider in a low-cost country. This is often concerned with outsourcing of services (e.g. IT) and manufacturing (e.g. to eastern Asia).
2. **Turnkey outsourcing:** The responsibility for the execution and coordination of the entire outsourced activity lies with the external provider. The buyer has minimal responsibility. The project goes more smoothly and the buyer does not have to have experience with similar projects. The downside comes through limited influence on prices and no insight on the suppliers cost structure, as well as technology, quality and staff. The great dependence can also become risky in a commercial, technical and performance sense.
3. **Partial outsourcing:** Only a part of an integrated function or activity is outsourced, while coordination of those still remains at the client/buyer. The buyer has more influence on prices, staff, technology and quality. However, at the same time the buyer needs to have the knowledge of the outsourced function and parts. Delays can also happen through coordination problems.

In addition to the section above, general reasons for MOB could be identified and put into Table 3:[22]

Some general reasons for make:	Some general reasons for buy (outsource):
• To keep production in-house • Company has significant competitive advantage • Quality in company's control • To remain independent from suppliers • Less supplier relationship problems • Knowledge (secret or strategic etc.) stays within the company • Trade barriers, political reasons • No transport costs, toll etc.	• To utilize the skills and knowledge of external companies • Lower costs (e.g. labour costs) • Get rid of expensive and time consuming non-core activities and functions, products etc. which are difficult to manage • To free up internal ressources • Gain external knowledge/ressources, which would otherwise not be available • Minimize risk

Table 3: Reasons for make and buy, Source: Van Weele (2018), p.193 (modified).

A MOB decision's objective is to improve the performance of the outsourcing firm. Very often, the so-called **core competence approach** is used. Therefore, a company should always concentrate on its CCs, hence keep skills in-house, whilst outsourcing all those activities, that are non-core, i.e. do not have a

[21] Conf. van Weele (2018), p. 189 et seq.

[22] Conf. van Weele (2018), p. 193.

competitive advantage, hence were the value-added is very minimal. These important skills develop over time as a result of continuous improvement and are not rigid. The **strategic phase of outsourcing** begins with **characterisation of CCs**, which are defined as:

- **Skills, knowledge sets**, not products or functions
- **Flexible long term platforms** that are capable of adaption or evolution
- Unique **sources of leverage** in the value chain
- **Limited** in number, generally 2 or 3
- Areas, where **company can dominate**
- Elements **important to the customer** in a long run
- **embedded** in the organization's systems

A company should not outsource this set of CCs. Another option is collaboration with other companies, when the competence is important but the knowledge of other firms is better. These rationales are explained in the following matrix illustrated in Figure 6:

Level of competitiveness relative to suppliers	Low (non-core)	High (core)
High	MAINTAIN/INVEST (opportunistically) Non-strategic competencies, that offer great advantages; Can be kept in-house	IN-HOUSE/INVEST Strategic competencies, that are "world-class"; Must be kept in-house, invest in ressources, maximize scale and maintain leadership
Low	OUTSOURCE Competencies have no competitive advantages;	COLLABORATE/ MAINTAIN CONTROL Strategic competencies, but no competitive advantages; Form partnerships, alliances, joint ventures etc.

Strategic importance of competence

Figure 6: The outsourcing matrix, Source: Savelkoul (2008), quoted from Van Weele (2018), p. 192 (modified).

Innovation strategy and management of competences often interact. Mc Kinsey and Boston Consulting Group suggested that in order to ensure profitability it is also important to **be the first on market**. According to them, performance does not only depend on innovation or products, but the key to it rather lies in the **resource-based view** of the firm. Hence, it is an imperative to deploy and use a company's resources well to **fulfil the needs of customer**. Also **good supplier relationships** can be seen as resource. The issue on how to serve customer best could be solved by the focus on CCs as it is defined as an activity, through which the company achieves its sustainable competitive advantages. Therefore, it is always recommended to differentiate between core and non-core competences, which should be outsourced anyway.[23]

This sub-chapter's purpose was to illustrate some basic understanding about the rationales behind the topic on how and where to draw the borderlines as a function of competences in between the responsibilities of the different companies (OEM vs. supplier). This separation should consider their

[23] Conf. van Weele (2018), p. 164-165.

specific market segment, which will be matched onto the different helicopter components. In the next chapters, CCs will be identified and applied accordingly as a set of skills to produce certain parts of the helicopter to the OEM and the supplier respectively.

2.2. Definition of the term „manufacturing network"

One possible definition is the so-called "industry-cluster". A cluster is a kind of company eco-system of high-level suppliers, which is formed around an existing OEM in a geographic proximity to each other. Prominent examples in this thesis are ACstyria ("Auto-Cluster") and the Swiss Aerospace Cluster. [24]

According to Table 2, this can be classified as a kind of partner relationship. Having Tier 0.5, Tier 1, and maybe also Tier 2 in one geographic region offers advantages, such as less lead times (increased efficiency), less transportation costs, JIT delivery. In addition, the value-added and the bundled knowledge would also stay in the region, resulting in huge R&D potential. However, this would also result in huge dependencies on each other and it can be assumed that there would be many uncertainties in the case one supplier (for whatever reason) drops out of this system.

Nevertheless, the manufacturing network should have a cluster-like structure, as it fulfils the requirement of a local value/supply-chain. As there is no OEM yet, possible candidates have to be investigated, who could form an internal OEM cluster (or OEM consortium) to fill this gap. Hence, a manufacturing network can be defined for this thesis as **"A complex cluster of clusters, focusing on accomplishing one or more specific targets"**. In this case, the target is the production of a helicopter.

2.3. Proposal for the first draft of the Manufacturing Network

Based on the complex issues of the value and supply chain characteristics in combination with the considerations from the helicopter market environment, it will now be tried to use the information given above to enhance the approach for the thesis, in order to map different capabilities of Austrian and Swiss companies. A critical review of this preliminary model will be a main topic in the verification stage of the project (Chapter 5).

As mentioned earlier, the first focus lies on the product itself. Therefore, it is important to know how the complex structure of a helicopter, which components it consists of and how it looks like on the interior. Components will be derived from an existing helicopter as a result of analysing technical descriptions. When the analysis is complete, a list of parts (Bill of Material or BOM) will be used to fix the range of components. Afterwards a model has to be generated, where the product and the way it is assembled is in the focus. As a first proposal, this can be realized using an adaption of the straightforward **GOZINTO ("Goes-into") chart method**. This method is currently taught at the TU Graz in the lecture and exercise of Production Planning & Control (Department of Engineering and Business Informatics) as a pre step of **MRP**. The original method can be investigated in the cross-reference[25]. The adapted version of this approach, which is brought forward to experts in the form of interviews for further enhancements, would work as following:

1. Divide all components into categories: Raw Materials, Parts, Assemblies, Systems, Modules and Final Product.

[24] Conf. Appendix, Part I, Chapter 1.3; Chapter 1.5.

[25] Conf. Furian/Neubacher/Mösl (2018), p. 2–11.

2. Make a hierarchical BOM Diagram: Begin with the final product (helicopter), then attach the Modules and Systems, then the Assemblies and Subassemblies and finally the parts and its raw materials. Clearly show, which component(s) goes into which upper component(s)
3. Simplification: Focus on the main Systems and modules, instead of the smaller parts. If a component appears more than one time, merge them together.

Based on personal experience, the main advantage lies in its compatibility to the original mathematical concept of GOZINTO models. Consequently, it can be further developed into a complete MRP approach. Prerequisites for a mathematical model would be, of course, a fully known BOM and exact amount of items, given manufacturing capacities, lead times and a fully known production process. This could give us a full picture on how efficient manufacturing would work. Since efficiency is not the research goal and for simplicity reasons, all numbers will be avoided in our first model proposal. However, when more information and resources to conduct further research are available, these figures can be added in a later stage.

After all the necessary components have been mapped, the next applicable features of the value chain are applied to the model in form of:

- Primary activity “operation”: In this thesis, it refers to common manufacturing practices in aerospace industry. The manufacturing operations are divided into general process steps, which unify certain characteristics (e.g. Final Assembly Line, FAL).
- Secondary activities “technology” and “procurement”: Sourcing scenarios are applied to the different components and processes of the chart resulting into a framework for the supplier network.

The next phase is the **selection** of suppliers. In this context, assumed Make-or-Buy decisions is made for each component in the point of view of the OEM. The purpose of this is to find out which **core-competences**, hence **strategic knowledge and process abilities to research, develop or produce certain components**, would be convenient to keep at OEM level and what other competences can be outsourced to suppliers. The OEM is viewed as an aggregated firm i.e. a consortium, which in reality could consist of top level aerospace companies in AT-CH, assuming they would act as strategic partners. Hence, this strategic OEM-consortium then inherits most of a helicopter manufacturer’s CCs. As the same company might be in different tier levels, tier numbering is not to be used. Providers of **turnkey** solutions (referring to turnkey outsourcing, p.13) will be prioritized. There will be a balanced view between the worldwide supplier market and local production capabilities. Therefore, a database with coherent data is needed, from where companies can be evaluated by same set of **criteria**. The competences are then **matched individually** by hand to the helicopter components, respectively its manufacturing processes. A more detailed description of the procedure is subject to discussion in the course of Chapter 4.

Afterwards, a verification process with help of external experts investigates on the flaws of this approach and highlights, what aspects need further enhancement. Although the finalized model will depend strongly on the outcome of discussion and the afterwards chosen perspective, it still provides an answer to the research question. Eventually, it also serves as a tool well suited for a beneficial early supplier involvement in product development to secure long-term relationships (rather strategic than operational).

3. Breakdown of Complexity of the Product/Production

The overall goal of this chapter, as the title already indicates, is to break down the complex issues regarding design and production of the right type of helicopter. Therefore, a requirement analysis filters out the right model, the case analysis levers out a sufficient range of components and the production sequence will highlight, in which steps a rotorcraft is manufactured. The amalgam of this information will succeed in a preliminary network model, which will be the base line for the company research and the final expert discussions.

3.1. Pre-Study: Specific implications for the helicopter market environment

This subchapter is based on Bittner (2009), who used it himself in his book about rotor dynamics as a kind of introduction chapter. In this thesis, this section serves similar purposes. First, it should provide an introduction or "warm-up" for the helicopter topic, summing up relevant issues specific to the market environment of rotorcrafts. This should also help readers, who are new to the topic. However, the second purpose is to have a sort of anchor or reference point for the later results of the thesis, whenever needed. This "pre-study is" now summarized in the following sections:[26]

According to Bittner, surviving on the helicopter market depends on the capability of the OEM to master the complete system of a helicopter in its full depth. Real superiority is characterized by the optimum of all relevant qualities of an aircraft, but also by abilities to be adapted to any special mission scenario (e.g. rescue operations, transport, etc.). The following Table 4 gives an overview of possible scenarios (adapted for Austria):

Civilian mission scenarios	Military mission scenarios
Private piloting (heli-skiing etc.)	Transport of soldiers and equipment
Sight-seeing, VIP applications	Reconnaissance missions
Forestry	Liaison and surveillance
Air transport	Blackout scenarios
Infrastructure surveillance (power grid etc.)	Fire support
Special Assembly (e.g. wind turbines)	Counter terrorism
Air rescue and ambulance services (EMS)	Search and Rescue operations
Fire fighting	Training
Civil protection	
Police & counter terrorism	

Table 4: Helicopter mission scenarios, Source: Bittner (2009), p.20 (modified).

Therefore, the overall mission reliability of a helicopter is the critical performance indicator, because manufacturer's **specifications are not consistent** throughout the industry. For example, the specifications regarding maximum speed, as a rule, do not include all atmospheric conditions or momentary vehicle weight. Reliability is often measured by the **experience, i.e. system capability**, of a specific helicopter company. Consequently, **newcomers have a hard time** in trying to establish themselves. Therefore, a market entry is often tried by **licenced production**. The quickest way is to cooperate with a system-capable company. In both cases, there have to be obvious benefits for the knowhow supplier:

[26] Conf. Bittner (2009), p. 19–30.

1. Exploitation of a market, which is hard to enter.
2. Having a potent first customer.
3. Financial or capacitive contributions by the partner during development.
4. Sharing the risk in respect to the product development, production and marketing.
5. Special distribution rights reserved.

Some companies have the benefit of a completely sealed off market, in particular eastern Europe, Russia and especially the military sector United States, which is the largest market segment in the world. Nowadays, there is a cutthroat competition between all major companies, and American firms have the advantage because of the military and the deducted helicopter variants for the large civilian market. On the contrary, European companies have to form strategic partnerships or alliances and coordinate their actions in order to prevail. In 2009 the market spanned 25000 civilian helicopters in 160 countries. Many machines have already reached a critical phase in their aging process, where maintenance costs are becoming higher than the costs for new acquisitions. Spare parts, in some cases, are not even available anymore and further machine updates become equivalent to complete new product developments.

The biggest markets consist of of USA, Canada and the ex-USSR countries, which cover a large landmass; therefore, it is mandatory for European firms to have subsidiaries abroad. Piston engines are only available for small helicopters, and new regulations **(JAR OPS3)** will result in a shift from one-turbine aircrafts towards two-turbine-machines. The need for more military applications comes because of increased mobility requirements of many units, while at the same time the number of active personnel is declining.

The prices per machine and the costs of maintenance are in general higher than for conventional aircrafts of comparable performance. Helicopters only come to use, if **VTOL (Vertical Take OFF and Landing)** and hovering capabilities are mission-critical. A huge fraction of the overall production costs is induced by supplier systems, like engines, avionics, transmission and hydraulics in particular, and not so much through the manufacturing itself. Therefore, the value added margin is very small for the OEM and possibilities for design-to-cost are very limited. In addition, retained development costs have to be added onto the price. Therefore, advantages from the manufacturing learning curve result in fewer savings, compared to other industries.

Before the start of a new product development, it is critical for success of the company to consult potential end users and operators. The purpose is to see what features/improvements can be made beyond competitors. Next step is making the list of requirements given by those customers. This list can include detailed specifications, for example such as an aerodynamically optimized fuselage, panoramic cockpit view, extra storage space, two Turboshaft engines, rotor system with lower maintenance costs, and many more.

Finally, current technology has to be evaluated and decisions have to be made on what is appropriate for the aircraft (e.g. for a two-seated small rotorcraft, it could be a disadvantage to use very expensive avionics). The focus of the civilian market segment lies mostly in the area of 5 tons of **maximum take-off weight (MTOW)**, whereas the military segment lies at 15 tons with a 2.5-fold increased market value of those products, because of special equipment requirements. Most revenue is generated with multi turbine helicopters (82% and increasing). The rest applies to helicopters with piston engines and mono turbine configurations respectively.

3.2. Requirement Analysis

As described earlier, the requirements are depending on the environment of different market segments, their necessary capabilities and the end customers themselves. This chapter lays out the special requirements for Austria and applies them to the LUH that has to be built for government and emergency services. The first step is to define the customer. The main assumption here is **state procurement**, for instance by the Austrian Armed Forces or Federal police. However, civilian or private organizations and customers should be considered too as current users like the ÖAMTC "Christopherus" fleet, Austrian Federal Police or mountain rescue operators. The requirements were derived from expert interviews with a general from the Austrian Air Force and a private company and online sources. The goal is to the **best value-added for the end-customer**, so an orientation on current **public proposal requests** is a good option to begin with.

One such procedure is currently undergoing with the ÖBH, as stated by a recent article, which leaked into publicity in 2018. According to the article, the army has been looking for a successor of the **Alouette 3 and Bell OH-58 KIOWA**. The requested candidate should lie in the category of **Light Utility Helicopters** (around **2.5 tons of MTOW**). A basic **requirement** for the next generation helicopter is **two turbines** instead of one. This in corresponds to newest standards for rescue operations over built-up area (JAR OPS3, EU regulation 965/2012) and to laws of third countries such as Switzerland, where only helicopters with two engines are allowed to operate at night. This is in respect to possible transfer flights for troops. Speaking of which, the **transport capacity should be at least eight persons (incl. pilots)**. The helicopter should also feature **rigid skids** instead of retractable landing gears, which would come beneficial for high alpine missions and in connection to Special Forces (additional footsteps needed!). Another requirement is full **IFR (Instrument Flight Rules)** ability with one pilot being able to fly under lowest visibility by help of instruments. This should enhance capacities regarding night missions and all-weather serviceability compared to the older models in use. Finally, **retrofitting capability** (for light machine guns is needed), as the Bell OH-58 becomes decommissioned. A **RFI (request for Information)** went to a number of OEMs concerning their helicopter types. One candidate is Bell-Textron, which produces the **429 Global Ranger**, a derivative of the KIOWA. However, this type needs a conversion to military specifications by other companies. Second on the list is Leonardo Helicopters with the **AW109 Trekker M**, a recent development for military operators, based on a 70ies design. Finally, Airbus Helicopters makes an appearance with the **H135M and H145M**. Despite current lawsuits regarding the Eurofighter scandals, experts see good chances for Airbus because of the SPÖ exit from the cabinet due to the elections. The civilian H135 type is already in use with the Federal Police and the Austrian automobile club (ÖAMTC). A characteristic of the Airbus design is the use of the shrouded Fenestron® tail rotor. However, the results of the RFI still remain non-public to this day. In fact, if no decision is made on a budget for the procurement of a successor, the army will lose a total number of **33 LUHs** in capacity. [27]

Nevertheless, Major general Karl Gruber pointed out, that the future helicopter needs to be compatible with the current military communication system (NATO standards). In addition, it needs to be able to be fitted with extra armour, FLIR (Forward Looking Infrared), thermal imaging modules, light weaponry such as small calibre machine guns for close fire support, EMS equipment (rope windlasses), and cargo hooks. The helicopter should be designed to allow for lower maintenance costs (providing self-maintenance capability within the organization of the ÖBH). Moreover, the OEM should also be

[27] Conf. Tögel (2018), online source [16.08.2018].

able to provide a stable in-flow concerning spare parts logistics as well as an optimal training- and maintenance service. From Mr. Grubers point of view, the Dart 280 mentioned earlier is not capable of being an emergency helicopter, as it is specified as a light training aircraft. [28]

In addition to the helicopter types listed on the RFI the MD 902 Explorer was introduced during another interview with Mr. Stefan Ganahl from Wucher Helicopters in Tyrol. This unique design features a NOTAR® (No Tail Rotor) anti torque system, where compressed air goes through the tail boom and exits through slits in the end, which produces torque due to the so-called Coanda-effect (see Figure 8).[29]

The following Table 5 compares those types with the Alouette 3, including reference values such as standard ranges, maximum take-off weight (MTOW, internal), crew and passenger capacities in transport configuration etc. Unfulfilled requirements are highlighted in red. The information was retrieved from many different sources and product catalogues of notable producers[30].

Type	Crew	Passengers	Engine	Continuous Engine Power [kw]	Max. speed [km/h]	Max. range [km]	MTOW [kg]	MTOW w. external load [kg]	Empty weight [kg]
Aluoette III	1+1	5	1 x Turbomeca Artouste 3B turboshaft	1 x 649	210	540	2200	600 (hook load only)	1100
Bell 429 Global Ranger	1+1	6	2 x Pratt & Whitney Canada PW207D1	2 x 455	278	761	3180	3629	1900
Leonardo AW109 Trekker M	1+1	6	2 x Pratt& Whitney Canada PW207C	2 x 426	296	824	3175	3350	1670
Airbus H135M	1+1	6	2 x Safran Arrius 2B2 OR Pratt & Whitney Canada PW206B2	2 x 432 or 321	278	609	2950	n.s.	1462
Airbus H145M	1+1	10	2 x Safran Arriel 2E	2 x 575	250	662	3585	3700	1792
MD 902 Explorer	1+1	6	2 x Pratt& Whitney Canada PW207E	2x 426	259	542	2900	3129	1531
KOPTER SH09	1+1	0-7	1 x Honeywell HTS900	1 x 761	269	800	2650	2800	1300
Dart 280	1+1	2	1 x Safran SMA 4 cyl. TDI	1 x 205	240	1600	1350	n.s.	800

Table 5: Helicopter Comparison Table with unfulfilled requirements marked red, Source: Own illustration, based on information retrieved from footnote 30.30

[28] Conf. Appendix, Part I, Chapter 1.1.

[29] Conf. Appendix, Part I, Chapter 1.2.

[30] Conf. Bell Textron Inc. (2018), online source [7.8.2018]; EASA (2015), p.8; (2018a), p.9; (2018b), p.7; Leonardo S.A. (n. y.), p.7; Air Force Technology (n. y.), online source [7.8.2018]; Airbus Helicopters (2016), p.15; Air Force Technology (2018), online source [7.8.2018]; Hinz (2017), online source [7.8.2018]; Kopter (2019), online source [29.1.2018].

The flaws of the Dart 280 become obvious, when comparing its engine powers to the other models. MTOW shows that it is definitely not designed to be a LUH category aircraft, concluding that Diamond Aircraft designed this helicopter less for multi-purpose operations and more as a competitor to light training rotorcrafts like the Robinson R44. However, the data given above are not consistent between different OEMs. Therefore, additional information from the **EASA (European Aviation Safety Agency) type-certifications** (also known as **TC**), especially for the engines, had to be considered and are included in the literature list. The remaining five options are very similar to each other. Deeper investigation of the brochures and data sheets shows, that all of them would fulfil the known customer requirements. Nevertheless, only the Sales and Marketing from MD Helicopters Inc. provided enough data in their technical description for the MD 902 Explorer, which is available for the public and shows many details of the systems and components, allowing for a complete evaluation of the design. As standards and design rules are heavily regulated and LUH structures seem to be very similar to each other, the MD 902 Explorer, in representing also the other helicopter types, will serve as the basis case for the model of the manufacturing network. This seems to be a very reasonable approach in the beginning, as an OEM license production can be simulated (even though it is not intended!). Besides, the structure of the fuselage is very similar to the other competing LUHs, despite using the NOTAR-system. Hence, to gain a more holistic view, a conventional tail rotor can replace the anti-torque system (by just adding a configuration element in the design of the VCM). Moreover, this LUH fulfils the basic requirements, and is already certified for EMS in Austria[31] and because more information is available for the public, it is easier to analyse the helicopter's components up to a decent level.

3.3. Case Analysis: MD 902 Explorer

This sub-chapter deals with important systems and components of the MD 902 Explorer. The information was derived from **MD Helicopters Inc. (MDHI)**. publication of the technical description.[32]

Figure 7: MD 902 Explorer, as operated by Heli Austria, Source: Giptner (2015), online source [31.1.2019].

[31] The MD 902 is currently in use at Heli Austria (see Figure 7).

[32] Conf. MD Helicopters Inc. (2014), p. 1–59.

3.3.1. General Information

MD Helicopters, a subsidiary of Boeing, developed the twin-turbine-engine MD 902 Explorer in their attempt to penetrate the European market environment with a multi-purpose LUH. Because of EU regulations concerning sound emissions and safety, it features a patented and damage resistant NOTAR system (depicted in Figure 8), which was developed by Hughes and reduces the noise profile tremendously. A fan low-pressurizes the tail boom and the airflow is then expelled through two slots on the right side of the boom. The emerging boundary layer results in the tail boom acting as a wing, flying in the downwash of the main rotor system. Up to 60% of the required anti-torque is produced this way. A rotating jet thruster on the end of the boom then balances the direction control, actuated by the foot pedals in the cockpit, which also control the fan blades. In this way, a tail rotor and its mechanical parts become obsolete, eliminating the disadvantages of tail boom like vibrations, tail rotor strikes and wind sensitivity, for example. The resulting noise emission amounts to 86.2 dB, thus rated clearly amongst the lowest compared to its competitors. Besides, statistic show that 21% of helicopter accidents are attributable to conventional tail rotors.

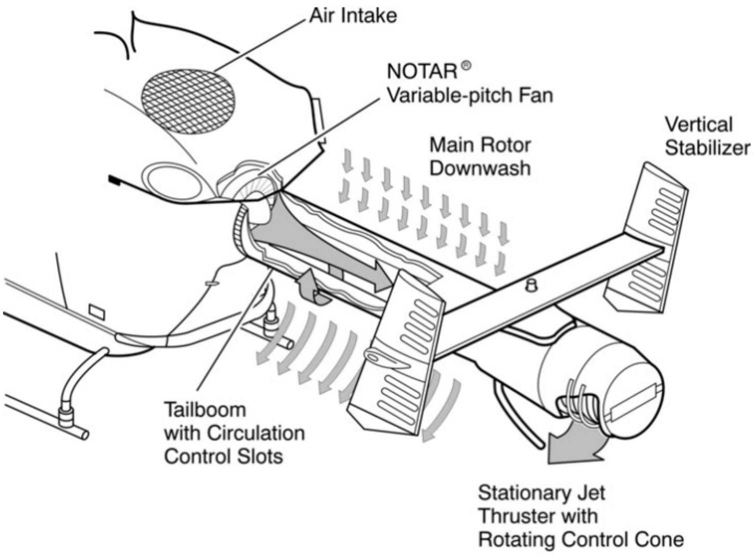

Figure 8: How the NOTAR Anti-Torque System works, Source: MD Helicopters Inc. (2014), p.36.

Another important feature are the bearing-less and fully articulated composite main rotor system, fly-by-wire controls and crashworthy fuselage and seats according to FAR/JAR 27.562 emergency landing requirements. The design is certified for single pilot **visual flight rules (VFR)** and capable for instrument flight rules (IFR) and JAR OPS- 3 as well as for operation in high-intensity radiated fields. It is approved for use in over 50 countries (including Austria) and configurable for EMS as well as VIP and military applications. Until 2014, a total number of **130 helicopters of this type were in operation worldwide**. In order to support maintenance, the aircraft is designed in a modular way, thus most built-in components, e.g. engines, NOTAR, rotor system, transmission, avionics, canopies, doors seats, tail boom etc., are fully access- and replaceable. The total direct operating costs, rated in the year 2014 US dollars, amount to $951.30 per flight hour and are among the lowest in the category of twin-engine helicopters. However, as Mr. Ganahl pointed out in the interview[33], the supply with spare parts is quite

[33] Conf. Appendix, Part I, Chapter 1.2.

difficult and the purchase price of the helicopter is higher compared to competitors. The **main components** of the helicopter are illustrated in the explosive drawing in Figure 9.

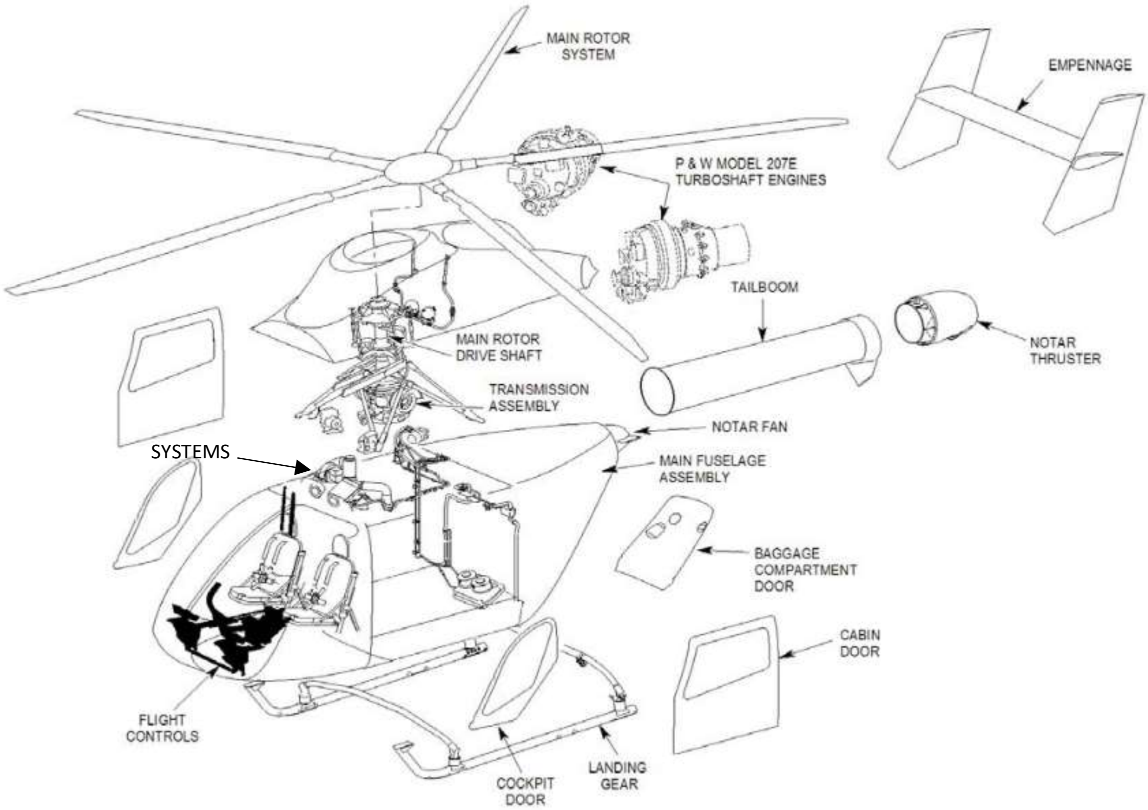

Figure 9: MD 902 Explorer System/Component Details with Systems added in, Source: MD Helicopters Inc. (2014), p. 16.

3.3.2. Airframe and Fuselage

Total inner cabin volume is 4.9 m³. The outer shell of the fuselage is a one-piece semi-monocoque composite structure, which hosts a fine aluminium mesh for HIRF and lightning protection. The energy absorbing A-frame structure and composite tail boom carry the flight loads. Five major sections compart the semi-monocoque construction (see Figure 10). Table 6 shows the external dimensions.

Parameter	Dimension [m]
Fuselage width (aft top)	1.8
Fuselage length	5.56
Horizontal Stabilizer width	2.84
Landing skid width	2.23
Ground to rotor height	3.33
Ground to fuselage bottom height	0.38
Main rotor diameter	10.31

Table 6: External dimensions, Source: MDHI, p.11 (modified).

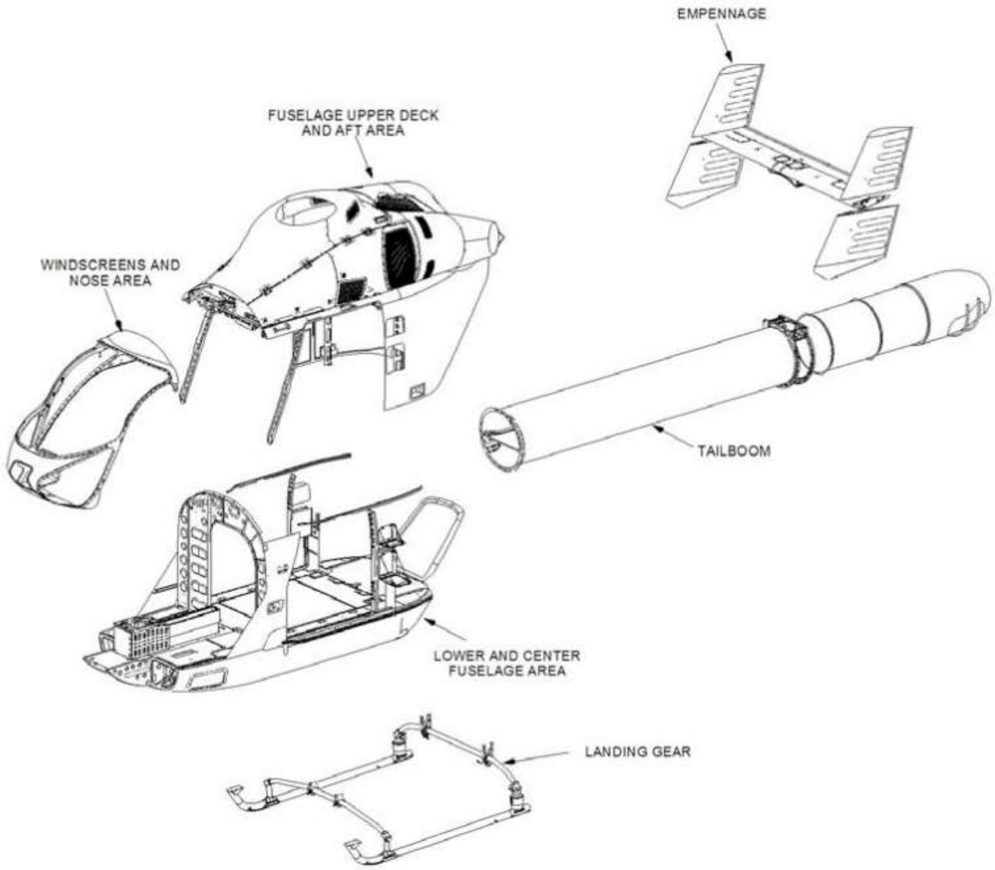

Figure 10: MD 902 Explorer Main Fuselage Assembly Sections, Source: MDHI, p.22.

Based on Figure 9 and Figure 10, one can now name the main components, which will form the first levels of the BOM. These components are summarized in the following Table 7.

Level 0	Level 1	Level 2
Helicopter (MD 902 Explorer)		
	Main Fuselage Assembly	
		Windscreen an Nose Area
		Lower/Centre Fuselage Area
		Landing Gear
		Fuselage and Upper Deck Area
		Empennage
	Cockpit Doors	
	Cabin Doors	
	Baggage Compartment Doors	
	Tail Boom	
	NOTAR Thruster	
	NOTAR Fan	
	Transmission Assembly	
	Main Rotor System	
	Turboshaft Engines (PW 207E)	
	Flight controls	
	Systems (not referenced)	

Table 7: Basic BOM

Table 8 explains some basic characteristics of the individual compartments of the fuselage.

Windscreen and nose area (including cockpit)	The construction of the front section consists of the windshield (could be made from **PC or Acrylic glass**[34]), which features air ducts for defogging, canopy parts and the front structure made from composites.
Lower and centre fuselage (including doors, cabin and landing gear)	From an engineering point of view, this sensitive region inherits the **critical loading path** and needs to **withstand crashes** to a certain amount of deformation. The construction of the aircraft starts around the critical loading path, which starts at the base of the mast and goes down through the framework into the bottom section[35]. The framework is made from **aluminium** and the outer structure and skin panels is **composite**. All aluminium parts have to be **anodized/coated** during assembly for protection. The skin parts and framework are joint together using **wet-riveting techniques** and integral **fiberglass barrier strips** to prevent galvanic corrosion. **No magnesium parts** are used. The structure also hosts built-in steps and handholds for maintenance activities. Cabin interior trim consists of panels, carpeting and insulation material. Seats inherit an energy attenuating tube-frame construction. The cabin has a flat **composite floor** with cargo tie-downs and two sliding doors on each side, crew doors and baggage doors are hinged. **Doors are composite manufactured** and incorporate jettison mechanisms for emergency exit of the vehicle. The **elastomeric fuel bladder** has a holding capacity of 602 l and is enclosed by two crash resistant deep keel beams. The landing gear, which needs testing and certification for crashworthiness as well, consists of a set of elastomeric-damped, non-retractable **aluminium skid tubes** with **carbide skid shoes** for protection. The skids also feature crew- and passenger steps in addition.
Fuselage upper deck and aft area	This area mainly consists of the drive train mounting deck and the engine bay. The walls and structure surrounding the engine compartment (see Figure 11) have to be **fireproof** and can be made from either high temperature resistant **stainless steel or titanium sheet metal parts**, the latter one being very work-intensive considering maintenance[36]. The **canopies and engine cowlings** are also made from **composite**, and have pneumatic actuators to access the engine compartment for maintenance. **Air inlets are triangular shaped** according to **NACA (U.S. National Advisory Committee for Aeronautics)** geometry, which provides extra ram air for the engines.
Tail boom	This component consists mainly of **aluminium and composite**. It is connected to the aft top end of the aircraft and hosts the NOTAR® system.
Empennage assembly	This assembly contains the **horizontal and vertical stabilizers** and is made from **composite**. It is mounted on the tail boom with **elastomeric vibration absorbers**, which minimize vibrations to the fuselage due to wake turbulence. The stabilizers are controlled (in conjunction with collective pitch) by a dual redundant fly-by-wire control system.

Table 8: MD 902 Explorer fuselage compartments, Source: Own depiction based on MDHI, p. 22-26.

[34] Conf. Mecaplex (2019), online source [29.01.2019].

[35] Conf. Appendix, Part I, Chapter 1.4.

[36] Conf. Malaysian Institute of Aviation Technology (2014b), p. 2–8.

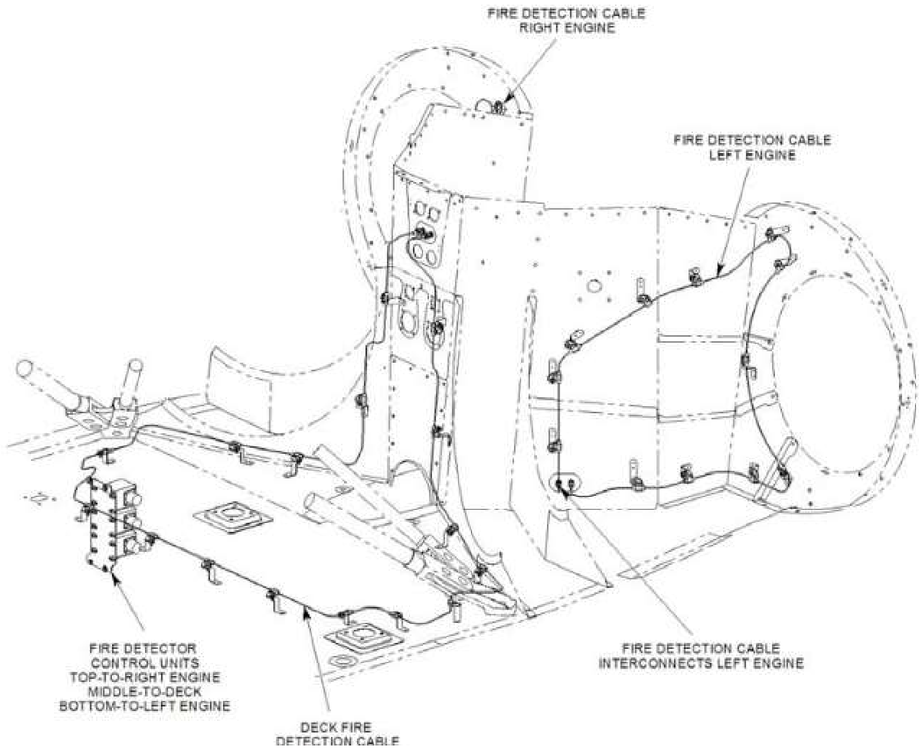

Figure 11: Engine Compartment with Fire Detection System, Source: MDHI, 38.

3.3.3. Engine

The twin **P&W Canada 207E engines with 530 kW on each output shaft** are mounted directly behind the main transmission and provide direct input to it, without any combining gearbox in between. The fuel flow for turboshaft engines is controlled via a **full-authority-digital-electronics-controller (FADEC)**. FADEC is backed up by a hydro-mechanical fuel control line, which is controlled manually and operates in the case of a failure. An automatic **engine-fire-suppression-system** is also included. The battery bus, which also provides power for the starter/generator, provides the necessary start-up energy for ignition. The engine also hosts the **accessory gearbox** and the **power output (i.e. transmission input) shaft**.

3.3.4. Main Rotor System and Drive System

The **main rotor system** (see Figure 12), located **over the centre of gravity**, is **bearing-less, fully articulated** and supported via the hollow static mast. The transmission provides the torque. The system is made from hardened **aluminium alloy, steel and composite materials**. According to Table 9, it consists of:

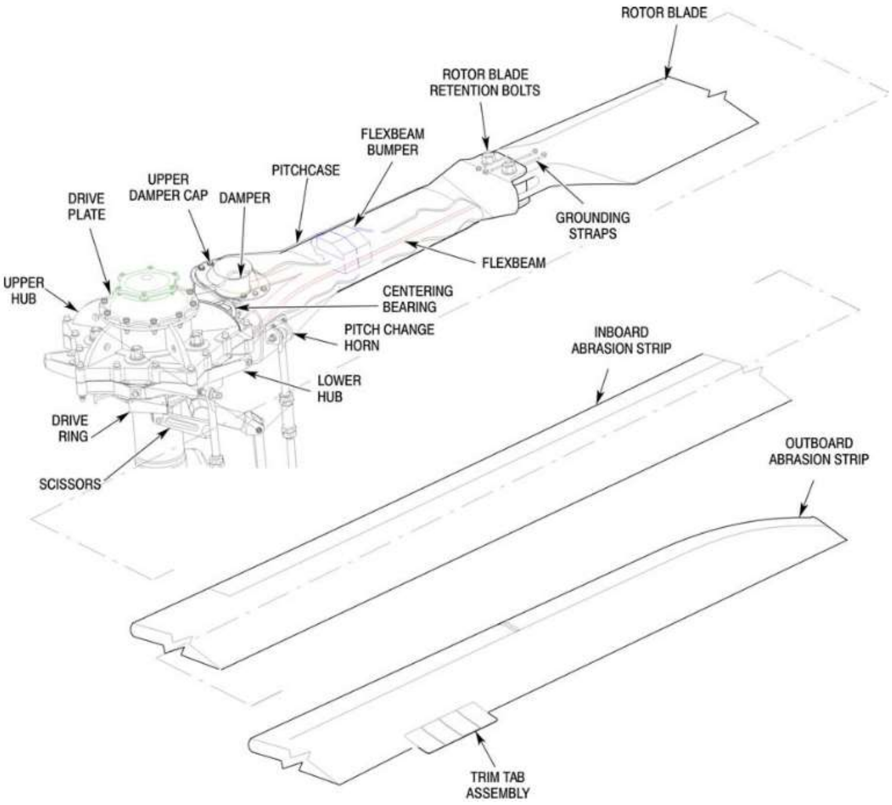

Figure 12: Bearing-less, fully-articulated main rotor system, Source: MDHI, p.34.

Rotor blades	The five blades provide **lift** through **collective pitch** changes, and **lateral and longitudinal control** through **cyclic pitch** changes. The **fiberglass/epoxy** blades host a hollow leading edge spar (**composite**) and a **Nomex®-** (a brand of aramid produced by Du Pont**) honeycomb**-filled trailing edge. Bearing-less and fully articulated refers to way the blades are attached to the hub. It means, that the design does not have any hinges or bearings that would usually allow for lead/lag- (move backward/forward), flap- (move up and down) and feather- (rotate about pitch axis to change lift) movements; instead design relies on the structure of blades to absorb the stresses.[37] Therefore, blades are attached to a so-called flex beam. The flex beams have a stiff cuffing (i.e. pitch case) that provide stiffness in all directions to the inboard end of the blades. The pitch case is twisted by the action of the pitch change horns. It also transmits feathering control motions to the blade. It is attached to the hub via **elastomeric dampers**.
Rotor hub assembly	This rotating component is attached on the drive shaft and mounts the rotor system to the static mast. The hub is made of **fibre-composite material**.

Table 9: Main Rotor System, Source: MDHI, p.34-35.

The **drive system (DS)** transmits the torque from the engines to the rotor hub. According to Table 10, the DS consists of:

[37] Conf. Federal Aviation Administration (2012), p. 4–5.

Main rotor static mast/base	This component is **non-rotating** and rigidly mounted to the mast **support struts** of the primary structure and **absorbs all the lifting loads** of the vehicle. The rotor hub transfers all the loads directly into the mast via tapered roller bearings. The mast also provides the support for transmission, rotor and rotor drive shaft.
V-shaped support struts	The struts are mainly made of **titanium** and **transfer the flight loads** from the mast into the airframe structure.
Main rotor drive shaft	Drives the main rotor by transmitting the **torque**. The drive shaft does not carry or transmit the lifting loads.
Main rotor transmission	The transmission is mounted to the bottom of the static mast and has its own **air cooled lubrication system** and **internal sensors/chip detectors**. According to Holger Friehmelt, this is also a very sensitive piece of equipment, which needs a lot of construction effort due to the **dynamic and complex force situation**[38].
Overrunning clutch	This clutch is attached between the engines and transmission input shafts. It **disengages** automatically during auto-rotation and engine shutdown.
Main rotor transmission input drive shaft	These shafts transmit the **torque** produced by the engine to the main transmission. They are connected to the overrunning clutch with flexible diaphragm couplings at each end.
Fan drive shafts	They also have flexible **diaphragm coupling** and **transmit torque** to the NOTAR® fans.
Oil-cooler with blower	**Cools** both the engine and transmission lubrication oils. An **air blower**, driven by the transmission, provides ambient cooling air.
Rotor brake	Is mounted onto the fan drive shaft flange and consists of a **caliper** that clamps onto the rotor and the whole **transmission system is interrupted**.

Table 10: Components of the Drive System, Source: Own depiction, based on MDHI, p. 31-33.

[38] Conf. Appendix, Part I, Chapter 1.4.

3.3.5. Systems

Flight control system

This mechanical system integrates all pilot inputs (control stick, pedals) from the cyclic, collective and anti-torque systems. It is dual redundant, hydraulic boosted and mechanically linked to the upper flight controls (e.g. swash plate assembly). According to Table 11 consists of:

Cyclic control	The cyclic is controlled manually via a control stick. The mechanical parts of the cyclic are hinged below the cabin floor. This component controls the attitude of the helicopter, by manipulating the location of the lift force. Therefore, the feathering angle of each blade, which is proportional to its lifting force, changes as it rotates with the rotor. The steering inputs control the severity a rotor blade flaps. As a result the CG changes, which changes the local inertia of the blade. The effect is that the blade tends to speed up or slow down (lead/lag). Therefore, the most force is located on the upward flapped and leading side of the rotor in motion. Because the rotor acts like a huge gyroscope, the actual effect of control inputs is realized on a position of 90° in rotation axis prior to the control input.[39]
Collective control	Controlled by the pilot via a second throttle control stick, it controls the magnitude of lift force (vertical movement of the helicopter), by changing the pitch on all blades at the same time. As lift increases, the blades tend to flap upwards. This control hosts a magnetic clutch, which holds the last commanded position. This control is able to override the FADEC manually.
Internal control rod linkages	These rod linkages are contained in a closet behind the pilot seat and connect cyclic/collective control to the upper controls.
Upper flight controls	Connected to the cyclic and collective control and translates the commands from the cockpit into movement of the control rods. They consist of the swash plate assembly and the blade-pitch control rods. The swash plate is mounted around the rotor mast and converts stationary inputs from the pilot into rotating inputs. The lower half of the swash plate is not able to rotate, but can tilt in all directions and move vertically. The upper half is mounted to the lower half by means of a uniball sleeve and it rotates alongside the drive shaft. Both halves tilt and move as one unit. The rods link the inputs to the control surfaces. [40]
Anti-torque control	Transmit the pedal inputs to the NOTAR® fan and thruster for directional (yaw) control.

Table 11: Flight Controls, Source: Own illustration, based on MDHI, p. 25, 34, 54-55.

Hydraulic system

This system supplies the flight control actuators with pressurized fluid. It is dual redundant and incorporates hydraulic pumps, reservoirs, servicing connectors, hydraulic hand pump and plumbing lines. All fittings are frangible.

Electrical system

The electrical system, which operates on **24-28 V DC** in this case, generates and distributes all the necessary power for operation and control of the aircraft. It consists of a power generation subsystem and a power distribution subsystem. **Two methods** are responsible for **power generation/distribution**. The first one to mention is the **battery bus**. This bus system is located in the electrical load centre on

[39] Conf. Federal Aviation Administration (2012), p. 5.

[40] Conf. Federal Aviation Administration (2012), p. 6.

the baggage compartment ceiling. It relies on battery power (Nickel Cadmium batteries, located in the nose of the helicopter) and is responsible for energy provision during start (runs the FADEC) and backup power during flight. The second important system is the so-called **essential bus:** The second bus, located in the cockpit centre console, is powered by a starter/generator, which is by itself powered by the engines. The actuation happens after the start-up by a manual switch. This system charges the battery during the flight. The **EMI (electro-magnetic interference)** shielded **wiring harnesses** distribute the power to the electrical buses. Separate harnesses and connectors power the redundant systems.

Cockpit systems

In referring to the **cockpit** (Figure 13), which is digital and configurable for optional IFR equipment (e.g. additional instruments, pitot tubes, particle separator, night vision lights etc.), the final systems in consideration is the **EFIS** (electronic flight instrument system). This system hosts the cockpit displays for monitoring the flight attitude and **aircraft system performance** (e.g. critical engine parameters, hydraulics, vibrations, power plant etc.) and serves as a **HMI** (human-machine interface). **Transponder** and customer-identified **communication equipment** sit in the **centre console**. The pilot/co-pilot's primary **flight displays** sit in within the **instrument panel** in the front and indicate fight attitude, speeds, altitude etc. The display panels consist of state of the art LCD (liquid-crystal-display) displays. The EFIS can also provide expanded **situational awareness** functions such as navigation, weather, mapping, terrain and is certified for single pilot operation. For the manual input, a cursor control is located on the grip of the cyclic control stick. The company **Genesys Aerosystems** has recently been selected to upgrade the cockpit systems for MDHI[41] to newest standards, including night vision (NVIS) upgrades, IFR software and hardware and state of the art digital flight indication systems.

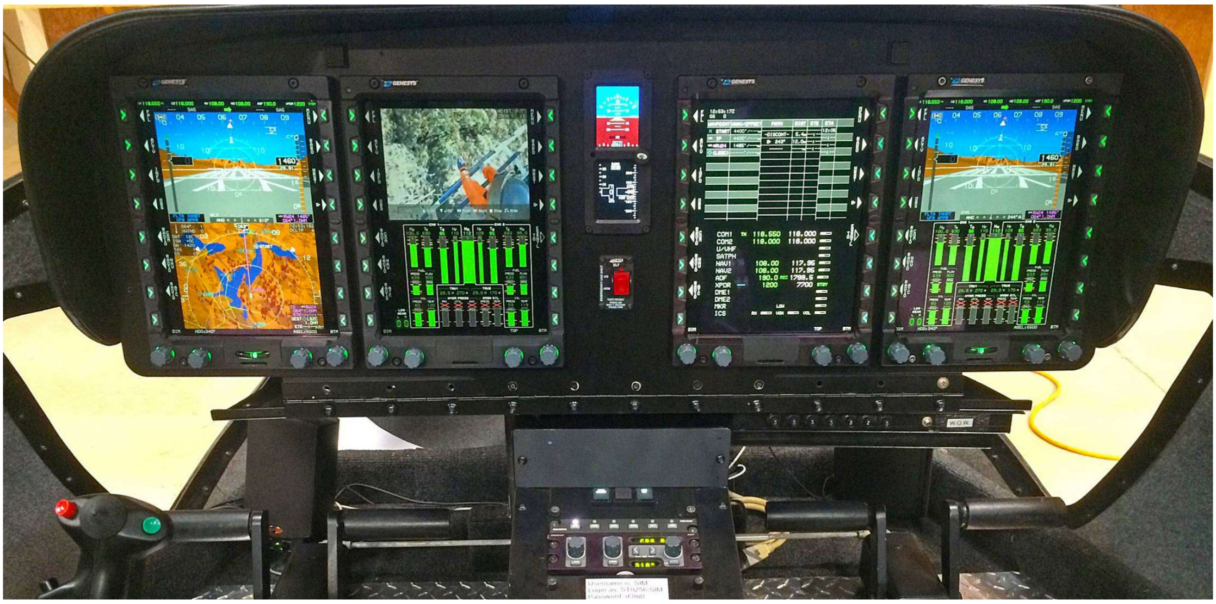

Figure 13: MD 902 Cockpit Upgrade by Genesys Aerosystems, Source: Thurber (2017), online source [31.01.2019].

Environmental Control System

The **environmental control system** consists of three subsystems. The **heat/defog system** is responsible for heat-up of the cockpit and defogging the windscreen by heated up air. Next is the **fresh air vent system:** This system provides fresh air from outside and ducts it into the cockpit/cabin area. Finally,

[41] Conf. Thurber (2017), online source [31.01.2019].

there is the **air conditioning system**, which is supplied by the fresh air vent system. The air conditioning system (vapour-cycle type) conditions and cools the air inside the aircraft.

3.3.6. Summary

This chapter focused on the components of a typical LUH helicopter design. What stands out regarding this type in particular is the NOTAR® feature, which can enhance safety and lowers noise emissions. Of course, an AT-CH helicopter could also use a conventional tail rotor or other systems as alternative. Due to the patent, this could be a very likely scenario. Otherwise, the rest of the components are aerospace state of the art and used amongst other LUH types as well. For example, the bearing less rotor system is also a main feature of the H135 from Airbus. Alternative rotor constructions are the semi-rigid rotor system (e.g. Bell 212 or Bell OH-58 KIOWA) or the articulated system (with hinges and bearings)[42].

The components listed were extracted to a excel sheet and in later stages integrated into the final R-BOM in the appendix. **Important note:** *For reasons of space, only the R-BOM is printed out, which already includes the separation of core competences and the matched companies[43].* At this stage, the components of a helicopter that meet the customers' requirements have now been analysed and explained. In order to connect them to the value chain, a question emerges:

"How does an OEM manufacture and put together a helicopter?"

3.4. OEM-Consortium Core Competences: Production Aspects

This sub chapter serves as beacon to enter the topic of OEM related CCs. These one can understand as necessary expertise/knowledge and a set of skills in a production technology setting in order to manufacture a product in a way that it fulfils quality requirements and matches the customers' expectations, thus gaining a competitive advantage.

3.4.1. Basic Manufacturing Sequences of a Helicopter Production

The overall aim of this sub chapter is to display an empirically useful vertical range of manufacture in a classical sense, which will be used for the AT-CH manufacturing network model. However, the level of detail will be subject to simplification in a later stage, as not all information of the BOM as well as production of the MD 902 Explorer are available and the this thesis would break its mould when attempting to propose a full scale routing plan. The focus here is to identify the classical CCs of a company related to manufacturing of a helicopter. The basic production sequence, which is in the beginning assumed quite similar amongst all LUH OEMs, can be described as following:[44]

Sequence A: Manufacturing of Airframe parts

The design and development of the airframe, i.e. the fundamental structure, encompasses the disciplines of engineering, aerodynamics, materials technology and manufacturing methods to achieve a favourable output[45]. The airframe is a semi monocoque construction, which essentially means that it consists of a framework of horizontal and vertical members covered with a rigid skin. Vertical members are called bulkheads/formers. They are the components that shape the fuselage. Heavy

[42] Conf. Federal Aviation Administration (2012), p. 2-5.

[43] Conf. Chapter 3.5.4 and 4.2.

[44] Conf. Advameg (2006), online source [8.8.2018].

[45] Conf. Federal Aviation Administration (2012), p. 1.

Longitudinal members (longerons) provide the necessary strength of the construction, while light longitudinal members (stringers) stiffen the skin. The primary material used is aluminium.[46]

Titanium, or alternatively stainless steel, is mainly used for the drive train deck and the engine bay[47]. The skin is made of composite material[48]. Airframe parts of the MD 902 Explorer are shown in Figure 15 below.

Sub-sequence A.1: Preparation of tubular substructure parts

In the case of the MD 902 Explorer, the airframe by itself hardly contains any tubular parts, except for hydraulic plumbing. Therefore, this stage will refer more towards the landing gear, which is made of aluminium tubes, as shown in Figure 14 below. Table 12 shows the steps of tube manufacturing:

Step 1	**Cut tubular raw material** using a length adjustable tube-cutting machine.
Step 2	**Shape bends** to proper angle in a bending machine, which should utilize interchangeable tools for different diameters and sizes.
Step 3	**Stretch forming** of those tubing parts that must match precise contours.
Step 4	**Machining** the part-ends to required angle and shape while holding the parts within clamps
Step 5	**Deburring and crack Inspection** as final step by means of a fluorescent liquid penetrant that seeps into cracks and surface flaws. The excess fluid is wiped off and the tube is then dusted with a fine powder that interacts with the fluid and renders any defects visible.

Table 12: Steps of Sub-Sequence A.1, Source: Own depiction, based on Advameg Inc. (2006), online source [8.8.2018].

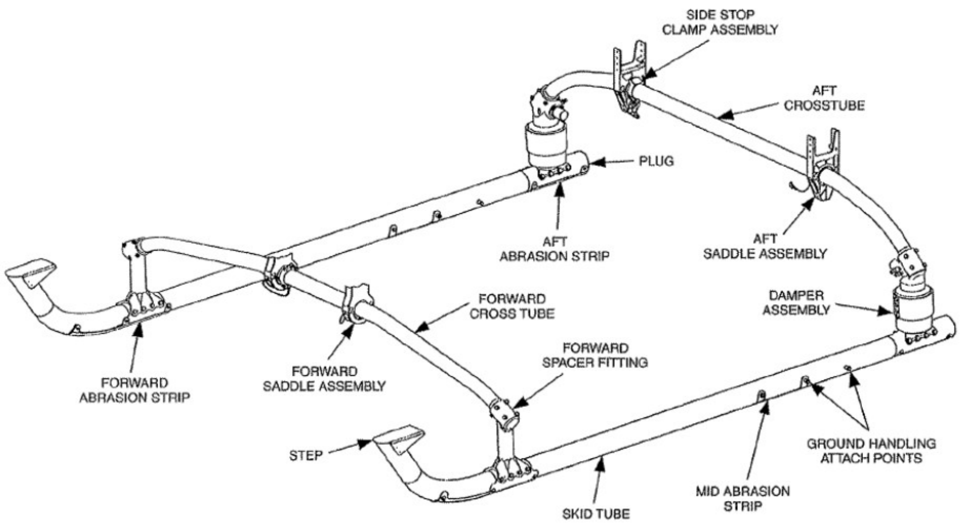

Figure 14: MD 902 Explorer Landing Gear (Skids), Source: Diman (2014), p. 13.

Sub-sequence A.2: Preparation of gussets

These refer to all reinforcing parts, details or brackets used in the airframe. They are made of aluminium wrought-material and are either machined or casted/forged. Table 13 shows the chronological order of this sub-sequence.

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[46] Conf. Malaysian Institute of Aviation Technology, p.9-20.

[47] Conf. Diman (2014), p. 13–20.

[48] Conf. MDHI (2014), p. 22.

Step 1	**Machining of gussets:** Raw materials are plates, angles or extruded profile stock. These parts are machined by routing, shearing, blanking or sawing.
Step 2	**Investment casting or forging of gussets** that provide more complex or critical details. This step is followed by a cool-down interval.
Step 3	**Finish machining** and deburring once again.

Table 13: Steps of Sub-sequence A.2, Source: Own depiction, based on Advameg Inc. (2006), online source [8.8.2018].

Sub-sequence A.3: Sheet metal parts and details

These details make up other parts of the airframe. For most parts, aluminium is used. However, if some components must be heat or stress resistant (e.g. drive train deck or engine bay etc.) titanium or stainless steel is a better choice.

Step 1	**Blank cutting** of pieces to predetermined size by abrasive water jet, blanking dies or routing.
Step 2	**Heat treatment** of aluminium blanks to anneal them (homogenize structure) in order to improve malleability. The blanks are then refrigerated until the next step.
Step 3	**Forming (die pressing)** into the proper shape.
Step 4	**Aging** of metal sheets to full strength.
Step 5	**Trimming** by routing as a final step.

Table 14: Steps of Sub-sequence A.3, Source: Own depiction, based on Advameg Inc. (2006), online source [8.8.2018].

Sub-sequence A.4: Subassembly of airframe parts

Assembling of the inner bottom structure with boat tail and A-frame (see Figure 15). This is the main structural member of the fuselage, which carries all loads and supports all other sections of the fuselage directly or indirectly[49]. Airframe part assembly goes according to the following order (Table 15):

Step 1	**Chemical cleaning** of surfaces of the parts to remove any contaminants, before they are fitted into a subassembly fixture.
Step 2	**Joining of aluminium tubes or gussets through MIG (metal-inert-gas) welding**, for example. The parts are joined through the melting of the electrode wire.
Step 3	**Stress relieving** through heating, so that the metal can recover any elasticity lost during previous welding processes.
Step 4	**Joining of metal sheets** by means of **riveting** or **adhesive bonding**
Step 5	**Inspection** for any deviations, welding quality or major flaws. Welding quality is inspected either by fluorescent penetrants or by X-ray imaging technique. Sheet metals are checked against form templates and then hand worked if necessary.
Step 6	**Coating:** Aluminium parts and welded subassemblies may be **anodized** to thicken the protective oxide layer. All metal parts have to be chemically cleaned and primer-painted. Most also receive a durable coating (e.g. **epoxy**) by spraying.

Table 15: Steps of Sub-sequence A.4, Source: Own depiction, based on Advameg Inc. (2006), online source [8.8.2018].

49 Conf. Malaysian Institute of Aviation Technology (2014), p. 34.

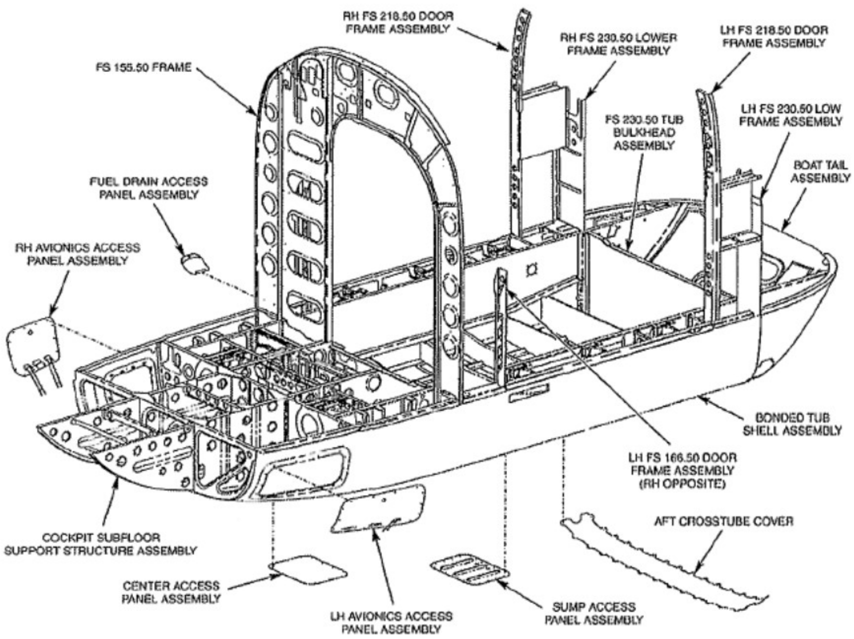

Figure 15: MD 902 Explorer Bottom Structure, Source: Malaysian Institute of Aviation Technology (2014), p.13.

Sequence C: Manufacturing of Composite fuselage, rotor blades and other parts

Composite is often the primary choice for aircraft designers due to it its high strength-to weight-ratio. As already seen in the earlier discussion, this also applies to the MD 902 Explorer to a large extend.

Sub-sequence C.1: Shaping of composite components

The central part of a composite is called “core” and is often made of Nomex® or aluminium honeycomb. A component may uses multiple cores. The build-up material is called “pre-preg ply”, which are layers of oriented fibres (e.g. epoxy or polyimide) that have been impregnated with resin.

Step 1	**Cutting:** As a first step, the core is cut to size by a band saw or other means.
Step 2	**Trimming:** Then, a machine trims and bevels the edges.
Step 3	**Sandwiching the layups:** Under direction, workers now create highly contoured skin panels or other elements by setting individually cut plies on bond mould tools and sandwiching cores between additional plies.

Table 16: Steps of Sub-sequence C.1, Source: Own depiction, based on Advameg Inc. (2006), online source [8.8.2018].

Sub-sequence C.2: Alternative automated shaping method

As automation improves quality and lowers labour costs the use of roving robots to wind filament, wrap tape and place fibre permits the fuselage structure to be made of fewer, larger and more integrated pieces (e.g. tail boom). In terms of materials, high strength thermoplastic resins could improve the overall impact resistance in comparison to epoxy or polyimide.

Sub-sequence C.3: Laminating (Autoclave curing)

The shaped layups now have to be cured. Therefore, a so-called **autoclave** is used, which is a special plant that resembles a sort of oven. The composite components are put into the autoclave and then exposed to a pressurized saturated steam for some time. Through this sort-of cooking process, the plastic is laminated together, thus the resin layers are cured.

Sub-sequence C.4: After treatment

The bond-mould tools mould trim lines into the panels, which are then followed by a band saw or water-jet robot to remove excess material around the edges. The components are the inspected ultrasonically, cleaned and painted. All surfaces must be well sealed to prevent any metal corrosion or water absorption. Wet rivets are used to join the composite skin to the aluminium framework[50]. Sheet metal strips are adhesively bonded onto the main rotor blades in order to protect the leading edges.

Sequence W: Windshield canopies and Windows

For usual, these special components are formed (Table 17) of a durable polycarbonate (PC) sheeting. However, acrylic glass can also be used.

Sub-sequence W.1	**Cutting:** The PC blank is cut to the proper (oversized) contoured shape.
Sub-sequence W.2	**Forming:** A fixture holds the shaped blanks in place during heating. A free blowing process, where no tool surface touches (distorts!) the optical surface, then forms the required curvature by use of air pressure. Front panels, which are subject to impacts such as bird strike, may be laminated of two sheets of greater thickness.

Table 17: Sub-sequences of Sequence W, Source: Own depiction, based on Advameg Inc. (2006), online source [8.8.2018].

Sequence R: Rotor system manufacturing

Rotor assembly parts, made of specially selected **high strength metals (e.g. titanium)**, are either machine shop produced or purchased from external suppliers.

Sequence S: Preparation of wirings and tubing

These installations are necessary for connecting the systems and controls. Alternatively, these parts can also be sourced from external suppliers. They are prepared according to Table 18 in the following:

Sub-sequence S.1	**Manufacturing of wiring harnesses:** Wires are laid-out and provided with protective looms on special boards that serve as templates to define the length and path to connectors. The wire bundles are then soldered by hand onto the connectors.
Sub-sequence S.2	**Manufacturing of hydraulic tubing:** In contrast to the first sequence, the small hydraulic tubes are cut and formed by hand by skilled craftsmen. After the ends have been flared, the tubes are inspected for accuracy and cracks.

Table 18: Sub-sequences of Sequence S, Source: Own depiction, based on Advameg Inc. (2006), online source [8.8.2018].

Sequence FAL: Final Assembly Line

In this final sequence, all components of the helicopter, which have either been produced in the upper sequences or purchased, are merged together to form the finalized product.

Sub-sequence FAL.1: Airframe subassemblies and inspections

After quality inspections, the airframe parts are delivered to subassembly jigs (shown below in Figure 16). These jigs are simple fixtures that shall hold the parts in place while they are assembled. Parts are joined by either bolting or riveting by pneumatic powered tools. The joining process is sequenced in drilling (countersunk holes for aerodynamic smoothness), reaming/deburring and applying the rivets or screws (together with a sealant). In many cases, semi-automated machines are used. The subassemblies are then closely inspected and move to the next step.

[50] Conf. MDHI (2014), p. 22.

Figure 16: Example for a subassembly jig of the Bell 412, Source: Malaysian Institute of Aviation Technology (2014), p. 16.

Sub-sequence FAL.2: Final assembly and integration

After "top-level" acceptance, the subassemblies are then delivered to the Final Assembly Line (FAL, see exemplary depiction below), where they can be further integrated (see Figure 17). As finalisation of the structure proceeds, the assembly follows a bottom-up principle. At first, landing gear and centre fuselage are merged together. Then the nose section with windshield is attached and wirings and tubing are prepared, installed and tested. Engines, Drive Train, NOTAR, and Tail Boom are also added. To complete the vehicle rotor with rotor hub, doors, interior elements and instruments are then installed. Finish painting also takes place.

Figure 17: Example for a Final Assembly Line of the H135 in Germany, Source: Airbus S.A.S. (2015), online source [31.10.2018].

Sub-sequence FAL.3: After-assembly activities

The finalized helicopter now has to undergo a series of tests (see Figure 32), after it has been properly examined by inspectors. At first, the propulsion system is tested by using an adequate set of testing equipment. Rework effort is then checked and filed for reference. After overall inspection, the vehicle is flight-tested and the complete documentation of materials, processes and inspection is prepared.

3.4.2. Summary

In conclusion, the basic principle of the helicopter production at a typical **OEM** is now explained. This manufacturing process is outlining the necessary **skills and know how**, which should bring a competitive advantage to the company in terms of operational manufacturing. However, as stated in the chapter about the helicopter market, it has to be considered that the bigger fraction of the margin is achieved in the sense of purchasing, because of major components like the engines that have to be supplied, rather than produced in-house. This is the reason why this thesis focuses strongly on this topic, as it is of strategical importance. Based on this chapter and on the previous ones the following observation can be made:

From the point of view of an OEM, there may are a few **strategies** on how the manufacturing can look like. First, it is possible to **outsource all** the production and only keep marketing and sales in-house, secondly, it is possible to manufacture simpler parts like the **airframe and the fuselage in-house** and to outsource turbine, transmission and rotors. A clear definition of OEM versus supplier core competences has to be made before the company selection, and those core competences are closely connected to the manufacturing process stated above. Another point here is that the closer the "tier" suppliers are to the top of the pyramid, i.e. the OEM, the **closer** they also need to be in a geographical sense, which is underlining the goal of the thesis to build a local network. Besides, it has to be mentioned that the helicopter assembly itself can follow different layouts, for example by means of **project manufacturing** production, if the OEM assumes a rather small batch size, or by means of a complete **Final Assembly Line**.

In an effort to enhance the GOZINTO Chart, the steps of the manufacturing sequence were summed up and ID-categorized in an MS Excel table[51]. They are treated as **"gates"** for raw materials, parts and components. This evolution will be the base layer illustration of the later manufacturing network.

For further thoughts on the topic of aerospace materials and manufacturing and beyond, the reader may refer to the Interview with **Professor Sergio Amancio** in the Appendix section.[52]

[51] Conf. Appendix, Part I, Chapter 2.

[52] Conf. Appendix, Part I, Chapter 1.6.

3.5. Description of the first draft of the network chart

3.5.1. Hierarchical BOM

The design process of the network chart is based on the first considerations made before. At first, the components of the BOM are listed and separated into **BOM levels** similar to Table 7 as following**:**

- level 1: system/ main-assembly
- level 2: subsystem/ subassembly
- level 3: part
- etc.

After the BOM is finished (for reference, see R-BOM[53]), raw materials, which can be derived from the manufacturing sequence and technical handbooks, are then categorized separately as well as the steps from the manufacturing sequence. Next, the hierarchy of the different levels is translated into a graphical representation (**hierarchical BOM**), which could look like in the following example:

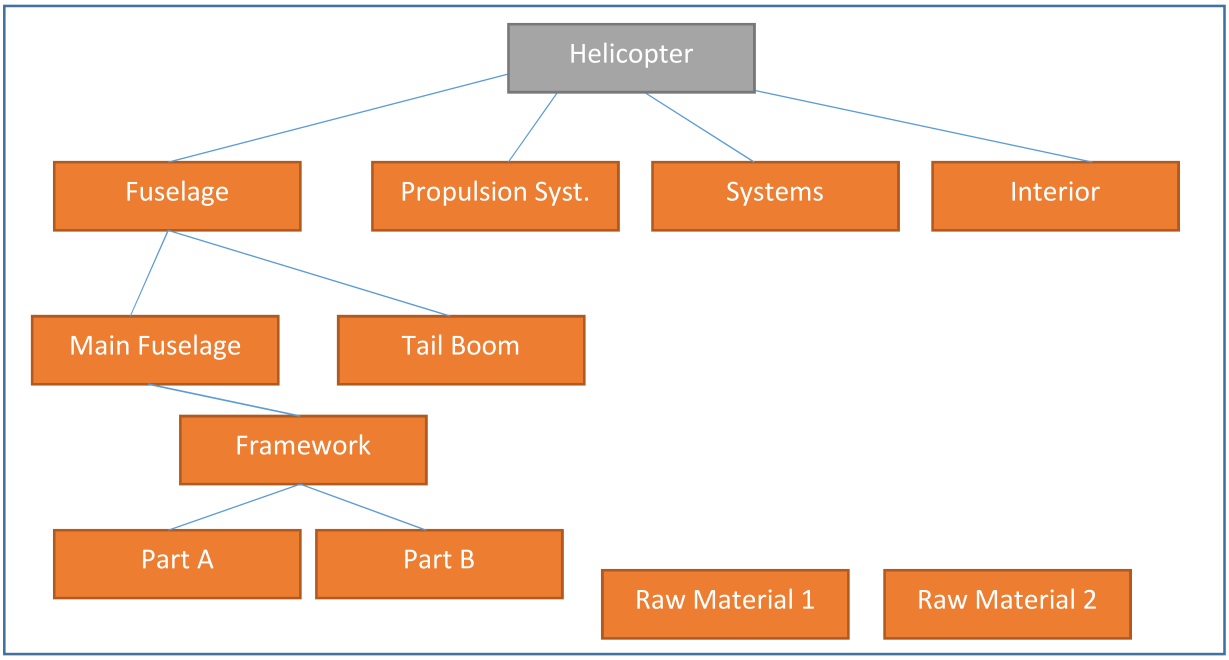

Figure 18: Example for a hierarchical BOM

This model is then expanded from top to down and component by component until the level of the parts is reached and the sum of all necessary systems has been included. Upon competition, the raw materials can already be classified as purchase items and are put to the bottom, yet without any connector lines, in preparation for the next step.

3.5.2. GOZINTO Chart

After the hierarchical BOM is drafted, it is transferred into a **GOZINTO Chart**. Raw materials are now attached to the components. If two or more components use the same raw material, the raw materials

[53] Conf. Appendix, Part I, Chapter 3.

are merged together. As a “no-redundancy” design rule[54] for this type of chart, there cannot be two times the same raw material (see depiction below).

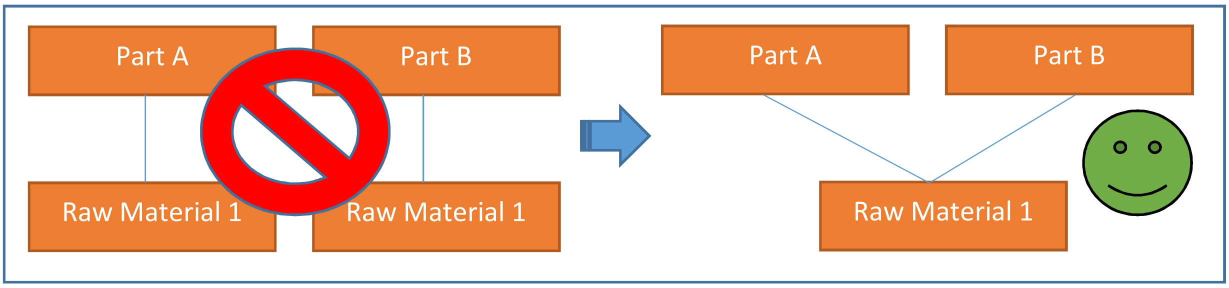

Figure 19: Rule: Merge raw materials, Source: Own illustration, based on Conf. Furian/Neubacher/Mösl (2018), p. 7.

3.5.3. GOZINTO Chart with production sequence

In the next stage the right **production sequence** has to be applied (depicted as **coloured hexagons**). This works by matching the IDs of the sequence in between the right components, using the information given in the previous subchapters and the technical description of the helicopter, from airframe production to FAL (an example is shown below). In this depiction, the core competences can already be divided (see next sub-chapter) between the OEM and the suppliers, as the highlighted blue components refer to purchased ones. All components critical (from strategic importance) to the OEM are highlighted in a different colour (white, grey). If an assembly is outsourced, all the processes also become a domain of the supplier (they would be deleted from the chart). Hence, every remaining process knowledge is a core competence of the OEM. If a system or assembly is insourced, the BOM tree grows and additional processes are inserted until a level of raw material or outsourced component is reached.

[54] Conf. Furian/Neubacher/Mösl (2018), p. 7.

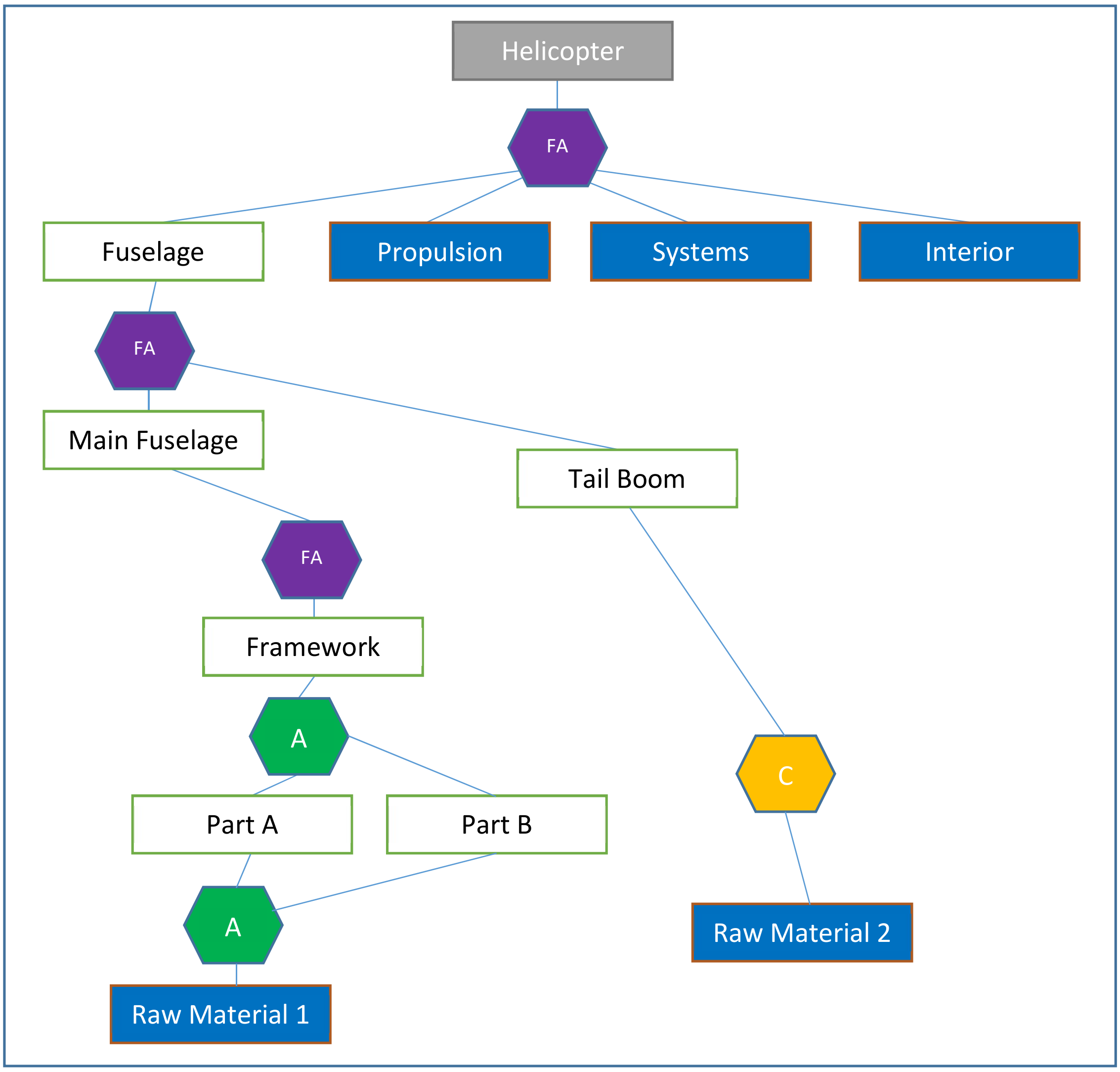

Figure 20: Example for the network base layer, Source: Own illustration

3.5.4. Separation of Core Competences and Summary

A very important feature is the assumption of separate core competences in between the OEM and the suppliers. Considering the topics of value chain and production sequence, the CCs would split themselves up as following depiction shows (Figure 21):

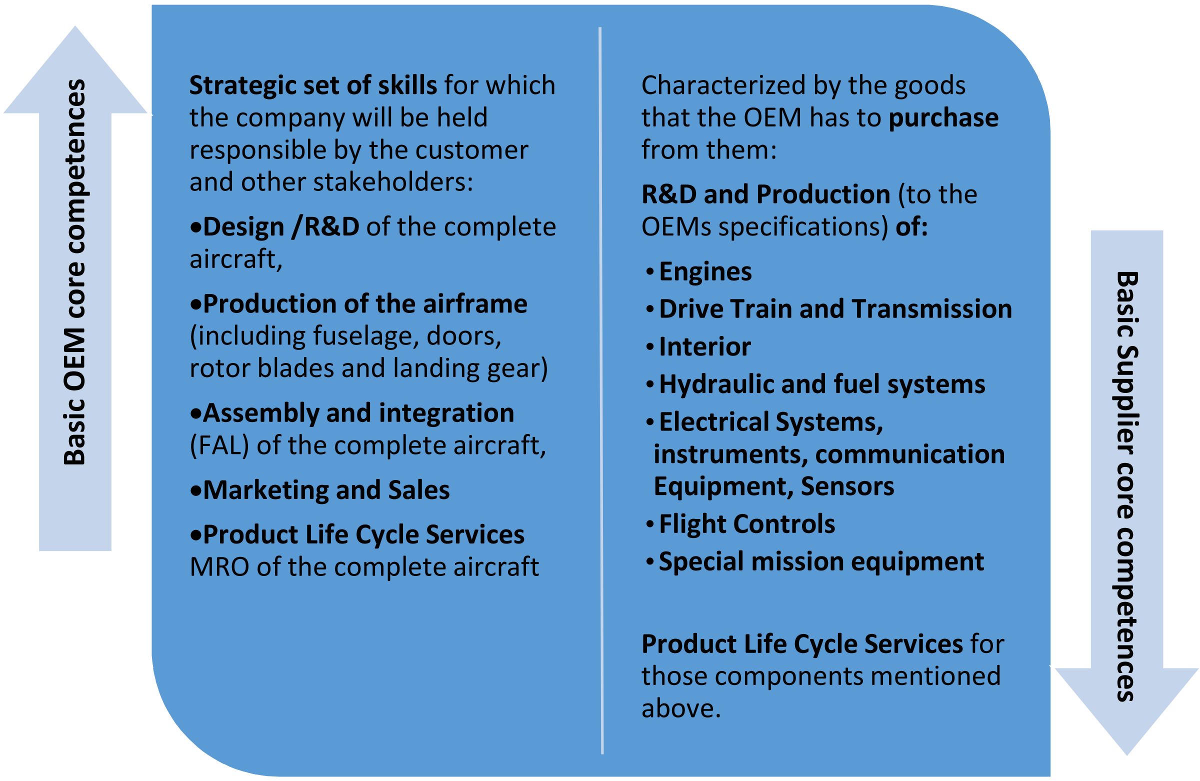

Figure 21: Distribution of CCs

As already described earlier, a huge fraction of the overall production costs is induced by supplier systems, like engines, avionics, transmission and hydraulics in particular, and not so much through the manufacturing at the OEM itself, which consequently leads to a very small value added for the OEM. The manufacturing learning curve savings remain low because of retained development costs. This argument also matches the skill separation above, taking the sheer number of purchased parts and their development efforts into account. Nevertheless, these skills are not set as fixed to the components and processes. If a turnkey-solution is available from a certain supplier (e.g. complete R&D of a complete helicopter), it will be included in the discussion of the optimized model as an outsourcing option. At this stage the draft of the first base layer model of the network, based on the BOM of the MD 902 Explorer, common manufacturing technology and competence separation has been finished and depicted[55]. Together with help of aerospace experts, an iteration will be done in a later stage.

[55] Conf. Appendix, Part II, Drawing no. 1.

4. Investigation on suitable companies

This chapter deals with the filtering and selection process of the relevant aerospace firms, which would be suitable for the AT-CH helicopter. In the course of the thesis, this process could be enhanced with through interviews.

4.1. Databases

Where does someone get a sufficient amount of company data? That can be a very tricky question, if one has never been deeply involved in aerospace industry at all. As this branch is heavily regulated, the first approach is to conduct investigation at the homepages of competent authorities in Europe, most notable the EASA. Luckily, there also exists a second solution, at least for Austria, namely the homepage "aeronautics.at" published by the **WKO (Austrian Federal Economic Chamber)** in cooperation with the **BMVIT (Austrian Federal Ministry for Transport, Innovation and Technology)**. In addition, relevant information was extracted from the **interview with ACstyria**[56] and added into the R-BOM.

4.1.1. How to use the EASA Document Library as a Database

The **EASA homepage** features its own set of information for every single branch within the aerospace sector in its **document library**, which is produced and published by the agency. Besides legal catalogues, manuals, information for operators and other files it also hosts manufacturing relevant company data based on the **subparts G and J of EASA regulation Part 21**, which is highlighted in the **list of approved production organizations** (inheriting companies with POA certificates) and in the **list of approved design organizations** (inheriting companies with DOA certificates).

Production Organisation Approval (POA) certificate:

The POA (Part 21, subpart G) is a license issued by EASA. It considers every aspect of the manufacture and assembly of aircraft production. Besides processes relating to manufacture and assembly, this certificate also covers supply chain management as well as the production facility itself. Each POA issued to a specific company also comes with a scope of work, which marks the maximum extend of the approval.[57]

In the POA-list, the scope of work is referenced to as codes[58]. Figure 22 shows the excerpt for Diamond Aircraft. In this case, the company would be production certified for: D1 (Maintenance), A2 (Small Aeroplanes), A7 (Motor Gliders), A11 (Very Light Aeroplanes, C2 (Parts), D2 (Issue for permit to fly), and C1 (Appliances)[59].

[56] Conf. Appendix, Part I, Chapter 1.3.

[57] Conf. Bentley (2016), online source [6.1.2019].

[58] Conf. EASA (2007), p.1.

[59] Conf. Appendix, Part I, Chapter 4.

Diamond Aircraft Industries GmbH

AT.21G.0001	Previous JAR 21 Nbr/MOT.G.01		
N.A. Otto Straße 5 2700 Wiener Neustadt Austria Phone: +43 2622 267 00 Fax: +43 2622 267 80	*Scope of work:*	D1 A2 A7 A11 C2 D2 C1	*Competent authority:* Austro Control GmbH

Figure 22: EASA POA excerpt for Diamond Aircraft, Source: EASA (2018c), p. 9.

Design Organisation Approval (DOA) certificate:

A DOA is the recognition that a company (design organization) complies with the requirements of the regulation Part 21 (J). This one considers mainly design activities and flight test. This approval is more detailed, as it not only shows the scope of work, but also on which category of product it is applicable (e.g. small airplane). Besides, it also shows the list of products for which the license holder is also a Type Certificate holder or applicant.[60]

Beyond some scope descriptions similar to the ones presented before in the POA section (e.g. small aircraft, rotorcraft, engine etc.), a typical example one can find for a scope of work is the following quote:[61]

"Minor and/or major changes to…	-	In Part 21 "minor change" is defined as a modification that has no appreciable effect on: • the weight, • balance, • structural strength, • reliability, • operational characteristics, or • other characteristics affecting the airworthiness of the product. All other modifications are referred to as "major changes").
…aircraft/rotorcraft…	-	referring to the type of air vehicle the scope is considering
…related to structures, cabin interiors […]."	-	referring to the components a company is approved to work on

Table 19: Scope of work explanation, Source: own illustration, based on EASA (2018d), online source [20.8.2018].

[60] Conf. Bentley (2016), online source [6.1.2019].

[61] Conf. EASA (2018d), online source [20.8.2018].

Country	DOA Id	Organisation Name	Initial Issue	Scope Description	Scope Ptf
Austria	052	Diamond Aircraft Industries GmbH	27/09/2004	Small Aeroplanes	Privilege to approve the flight conditions supporting permits to fly, within technical capability defined in the scope; privilege to issue permits to fly.
Austria	276	FACC Operations GmbH	05/12/2014	minor changes and minor repairs to aircraft related to structures, cabin interiors, galleys and other interior equipment	

Table 20: EASA DOA excerpt showing Diamond Aircraft and FACC, Source: EASA (2018d), online source [20.8.2018].

Both the DOA and the POA are usually required to move forward into a so-called type certification programme with the production of a specific aircraft[62]. However, in the case of a licensed production, a DOA for design activities can be left out, saving a lot of time and effort[63].

According to Thomas Leitner, obtaining these certificates can be very problematic for an Austro-Swiss helicopter, because it takes a long time to get them as the example of Kopter shows, which has been developing its machine since 2009 and due to the lack of POA no helicopter could be delivered yet up to this day. This lead-time can also bear a high financial risk for the OEM in the end.[64]

The two separate lists (available in MS excel and pdf format) for each approval can be downloaded from the EASA homepage, featuring all DOA and POA qualified companies across the globe. As the thesis goal is to build a network of primarily companies in Austria and Switzerland, the listed Austrian and Swiss firms will be prioritized.

4.1.2. The WKO/BMVIT Database - „aeronautics.at“

This online-platform was initiated to provide stakeholders from all over the world with an overview of Austrian aeronautics technologies. It lists all registered companies and research centres from A to Z and features an advanced search engine for products and services such as R&D, manufacturing or maintenance as well as a structured search for competences in Austrian aeronautics technologies. In addition to the structured search, an elaborated 3D plugin, depicting a generic A-380 style aircraft, was designed for this particular homepage. The 3D model allows an interactive search for aircraft components produced by Austrian companies. The year 2009 marked the start of the project, when BMVIT initiated the commission of a survey. The purpose was to acquire a comprehensive database in order to list all Austrian companies involved in aeronautical engineering and technologies. In this phase, a total number of 241 companies were identified, and 87 of them volunteered to present their competences in a brochure and on the website. Today 198 companies and research centres are registered and listed on aeronautics.at of which 156 are presented in FRESH VIEW magazine on aviation technologies, which is available for the public and can be downloaded directly. The ministry states that all Austrian companies, research organisations, universities and competence centres involved in aeronautics technologies, which are not yet listed on aeronautics.at, are invited to register and present themselves on the website.[65]

[62] Bentley (2016), online source [6.1.2019].

[63] Conf. Appendix, Part I, Chapter 1.4.

[64] Conf. Appendix, Part I, Chapter 1.3.

[65] Aeronautics.at (n.y.), online source [5.8.2018].

Since registration is not mandatory, it is not likely that 100% of all Austrian aerospace companies or other companies that would be capable are listed. Besides, there are also a lot on young and inexperienced companies, as well as companies that may misuse the tool to promote themselves or other firms that published flawed data. For this reason, also the original homepages had to be checked as well as the EASA database to acquire knowledge about actual certificates. Nevertheless, this homepage gives an extraordinary huge overview, compared to the EASA database, and 198 companies is a sufficient amount to begin with. The interactive 3D-model is shown in Figure 23 below.

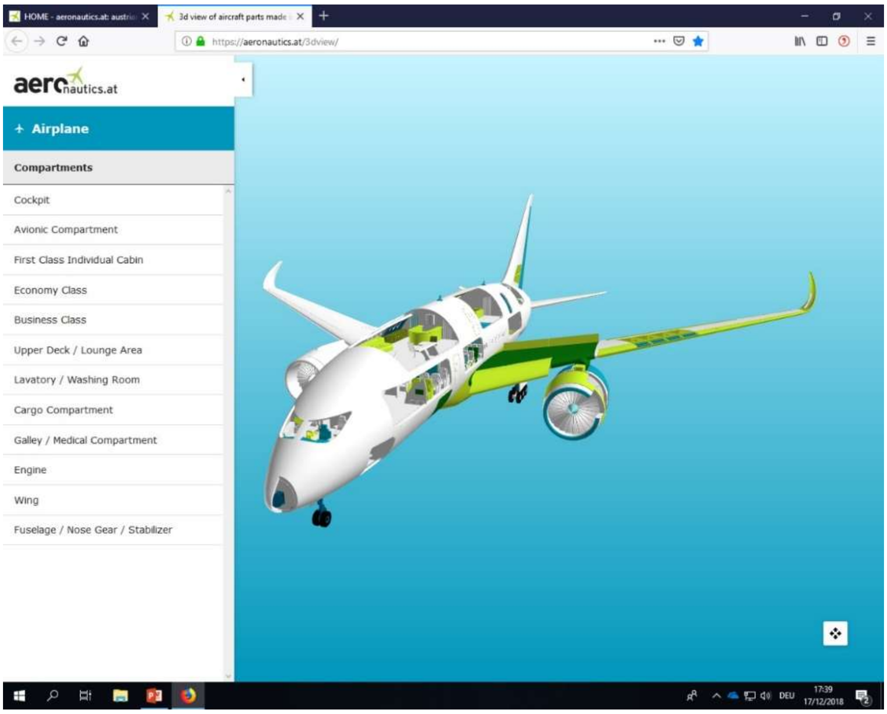

Figure 23: Generic 3D aircraft model, Source: Own screenshot from Aeronautics.at (2018).

With help of the coherently structured company data, companies can be evaluated individually. The components and the companies were tried to match. If a firm appears on a searched component/competence, the information presents itself in the following format (compare to Figure 24 below):[66]

1. **Company name** e.g. FACC
2. **Short description** representing the firm and its goals
3. **Technologies and** competences, explaining what their main focus is on and what kind of tools they use
4. **Fields of activity** (e.g. Aircraft, structures, engines, interiors, manufacturing technologies, cockpit components, systems) are presented in a table, which is divided into research, development and production. This classification was also introduced into the BOM in order to try providing this information on every single listed helicopter component or value chain operation as detailed as possible.
5. **Products and services in aviation**; even though the 3D model is an airplane, many of them are transferable to rotorcrafts as well (e.g. structure parts, fuselage, control rods). This served as the basis for the match.

[66] Conf. Aeronautics.at (2018), online source [5.8.2018].

6. **Aviation standards and certifications** is a very significant section. Besides EASA certificates (e.g. POA, DOA, Part 21), it also features other manufacturing and quality standards, which are important for aircraft OEMs or suppliers to have. The most notable **EN/AS9100** is a standard, which appears quite frequently amongst producing firms. It is the common **Quality Management System (QMS)** standard for the aerospace industry, which also includes the widely known ISO 9001. Hence, it is accepted worldwide and implemented by organizations designing, developing and manufacturing aerospace products. The main benefit for manufacturing companies is the market and customer acceptance, as it is endorsed by many authorities such as FAA and NASA.[67]
7. **Additional information:** Address, contact, number of employees and annual turnover;

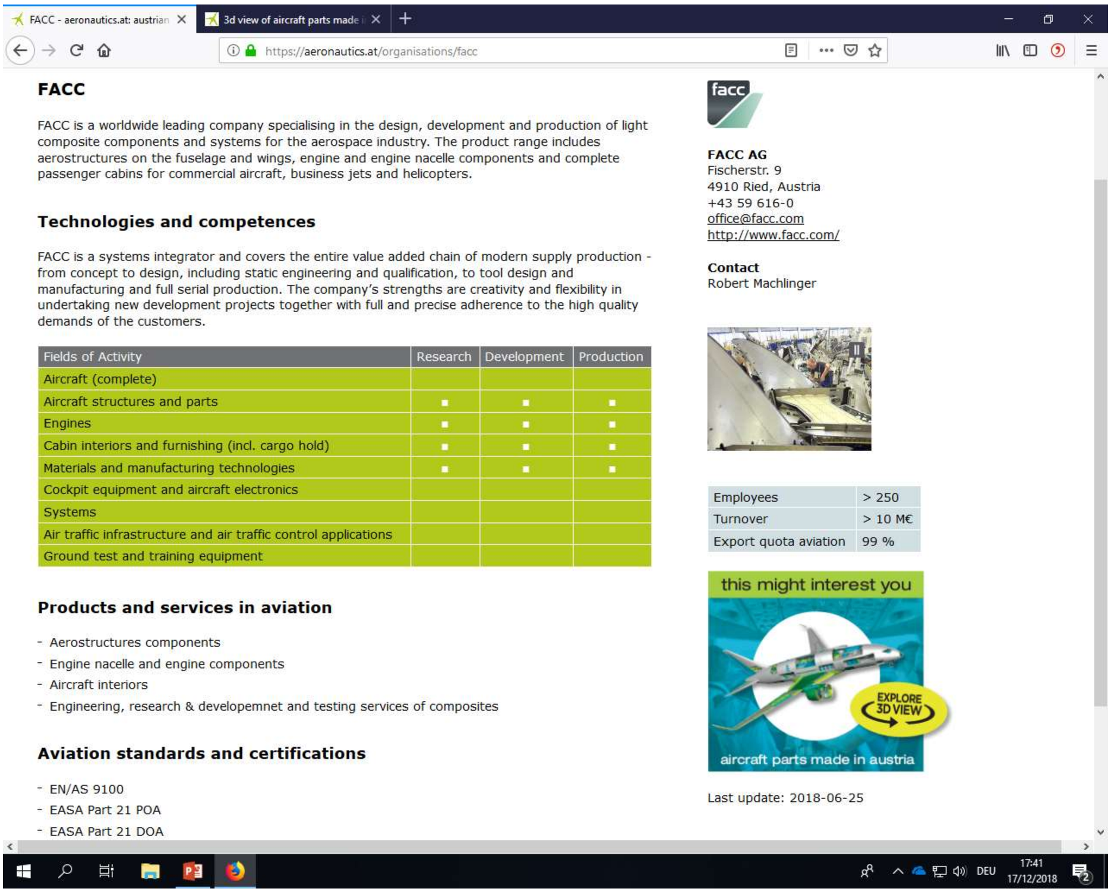

Figure 24: Example from the company register (FACC), Source: Own screenshot from aeronautics.at (2018).

4.2. Workflow (Investigation strategy) and Selection Criteria

In order to achieve an optimal solution for the industry cluster, which will be applied to the base layer model, the companies have to be investigated and selected according to the required skills. The information used in this procedure is derived from the GOZINTO Chart V1, where the entities (components and manufacturing processes) are depicted.

As a first measure, individual entities are analysed and compared to company CCs in the databases. According to earlier discussions, a decision is made on whether the entity falls into the field of CCs of

[67] Conf. AS9100 Store (2019), online source [2.1.2019].

the OEM or the suppliers. If both entities match, the company enters a filtering procedure. Important criteria for the filtering are stated as following:

- **Component/Process matching:** Assuming CCs and components correlate through design, development and production, it is investigated, if the company's CCs fit to the considered component or process.
- **Certificates and approvals:** Having a certificate is not mandatory in order to appear on the list. However, an assumption is made that if a company already has acquired a number of certificates shows that it has an aerospace focus and already gathered experience in the field of certification and quality standards (POA, DOA, EN/AS 9100). This comes in handy, if there is a lack of helicopter specific approvals that need to be obtained. Therefore, this company becomes prioritized in the end.
- **Locality:** As mentioned earlier, depending on the place of a company's production facility an additional ranking of firms is done. First priority will be **Austria and Switzerland**, followed by the **EU** as second and final priority will be **non-EU** countries.

Afterwards, the company becomes listed next to the considered entity. The process is repeatedly applied for each BOM-component and process listed until the list is completely perused. In the end, the result of this procedure is the R-BOM, which is the final evolution of the original BOM. Finally, in the course of the next chapters an evaluation needs to be done, to make this depiction feasible in order to answer the **sub questions of the scientific hypothesis**:

- **Conception** of the **value-chain for a complex product** (LUH) will happen **by means of** an evolved version of the simple **base layer model**, using the information synthesized in the **R-BOM**. Optimization of this manufacturing network will be the aim of the verification section[68].
- It will be clear, **how much** of the necessary components **can currently be built in AT-CH**, and which components need to be sourced from other areas, or put in another way which **firms are missing** in AT-CH. There should also be the answer to the question, which companies would be **important players** within the network. [69]

Summing up everything stated above, following flowchart (Figure 25) features the main steps of this procedure, which are repeated repeatedly for each listed component. The final product of the summarized R-BOM comes in form of a detailed excel sheet[70]. A possible example. Is also provided in Figure 26.

[68] Conf. Chapter 6.

[69] Conf. Chapter 7.

[70] Conf. Appendix, Part I, Chapter 3.

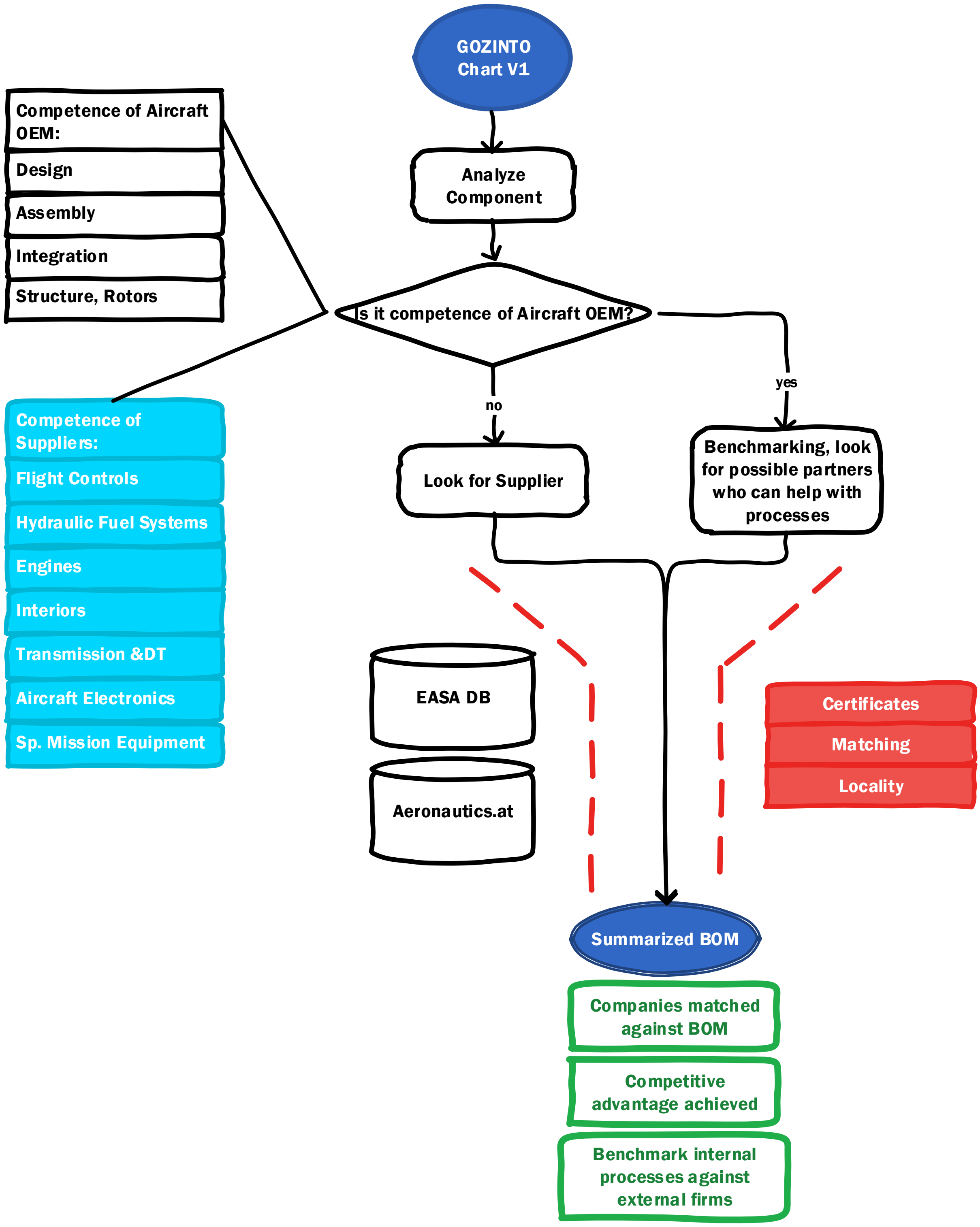

Figure 25: Flowchart of the company investigation process, Source: Own illustration (MS Visio).

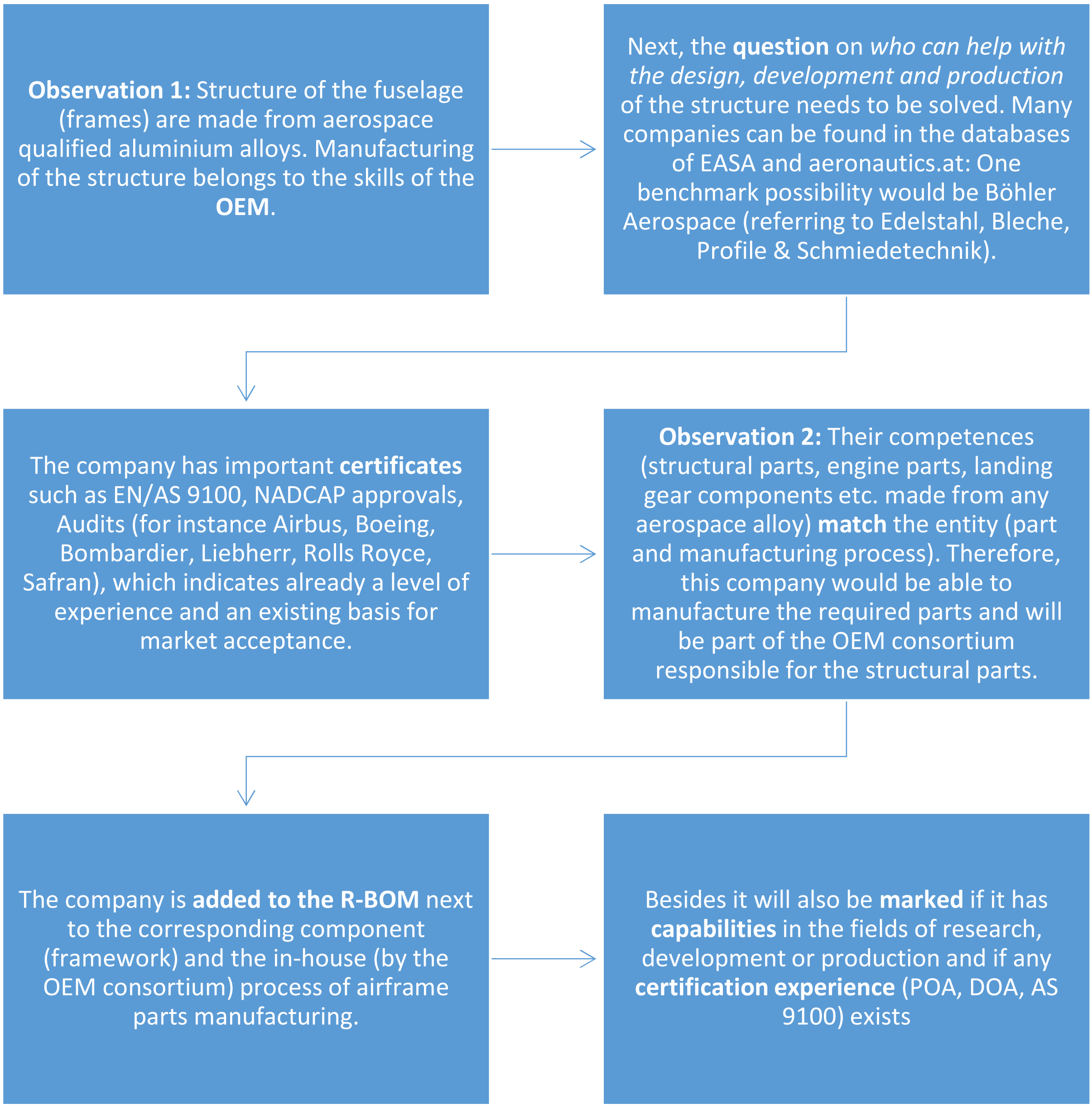

Figure 26: Example for the selection process

5. Expert Inputs: SWOT Analysis for the hypothetical OEM

"IF YOU KNOW THE ENEMY AND KNOW YOURSELF, YOU NEED NOT FEAR THE RESULT OF A HUNDRED BATTLES. IF YOU KNOW YOURSELF BUT NOT THE ENEMY, FOR EVERY VICTORY GAINED YOU WILL ALSO SUFFER A DEFEAT. IF YOU KNOW NEITHER THE ENEMY NOR YOURSELF, YOU WILL SUCCUMB IN EVERY BATTLE."

–Sun Tzu, The Art of War

This chapter depicts the final synthesis of the assumptions made in the previous chapters with the expert inputs. Consequently, some changes, iterations and further ideas for re-work will be the final output. A secondary focus will be the strategic SWOT Analysis from the point of view of the AT-CH OEM-consortium.

5.1. Expert Interviews

The main idea was to use a qualitative approach, asking a few amount of stakeholders specific questions corresponding to the individual expertize and field of work. The interviews were conducted both in personal meetings as well as via telephone and online messengers (primarily Skype). Although the set of question was tailor-made to the interviewee, the questions in general can be grouped into different categories:

A. Questions based on personal experience
B. Questions considering the SWOT Analysis
C. Questions regarding the assumptions made in the thesis for validation and verification/falsification purposes

The experts' inputs were then synthesised and transferred into this chapter in order to check the groundwork (e.g. assumptions, charts etc.) and to get a conclusion for the strategy and the thesis itself in accordance with the research question. Table 21 names the experts that have been consulted/interviewed on behalf of this topic and in regards of their individual emphasis the in the overall course of the thesis. The table is listed in chronologic order, starting in June/July 2018 until January 2019.

EXPERT NAME	JOB DESCRIPTION	INTERVIEW TOPICS
DI Stefan Oschkera	Affiliated Lecturer at TU Graz, TU Wien and FH Joanneum in the fields of aerospace engineering, systems engineering and launch systems; CEO of **SYENTEC GmbH**	Education for Aerospace Engineers in Austria[71]
Generalmajor Mag. Karl Gruber	former Chief of the **Austrian Airforce** until December 2018;	Customer requirements of the ÖBH, SWOT, Strategy[72]
Stefan Ganahl	chief pilot and head of flight operations at **Wucher Helicopters** in Tyrol	Customer requirements EMS/Transport, SWOT, Strategy[73]
Mag. Thomas Leitner	Area Manager Aerospace at **ACstyria** Mobility Cluster	Clusters, Austrian Aerospace Industry, SWOT, Component Suppliers, OEM candidates, GOZINTO-Chart evaluation[74]
DI (FH) Reinhard Puffing, PhD	Senior Lecturer and expert in the field of fluid dynamics and de-icing systems at **FH Joanneum**	Thesis discussion & Critique[75]
DI (FH) Lukas Andracher	lecturer and expert in the field of aeronautics at **FH Joanneum**	Thesis discussion & Critique[76]
Dr. Ing. Holger Friehmelt	Head of Aviation Institute at **FH Joanneum** and expert on rotorcrafts	Thesis discussion & Critique, SWOT, Rotorcraft Construction and design[77]
Erik Linden, M.A.(HSG), MBA	Research assistant at the Center for Aviation Competence, **University of St.Gallen**	Clusters in Switzerland, SWOT, general thesis ideas[78]
Univ.-Prof. Dr.-Ing. Sergio Amancio	Endowed Professorship for Aviation at **TU Graz, IMAT**; expert on aerospace materials	Manufacturing & joining of aerospace materials, new material developments[79]

Table 21: Experts & topics.

5.2. SWOT Analysis

[71] Conf. Appendix, Part I, Chapter 1.7.

[72] Conf. Appendix, Part I, Chapter 1.1.

[73] Conf. Appendix, Part I, Chapter 1.2.

[74] Conf. Appendix, Part I, Chapter 1.3.

[75] Conf. Appendix, Part I, Chapter 1.4.

[76] Conf. Appendix, Part I, Chapter 1.4.

[77] Conf. Appendix, Part I, Chapter 1.4.

[78] Conf. Appendix, Part I, Chapter 1.5.

[79] Conf. Appendix, Part I, Chapter 1.6.

Before the experts inputs are presented by means of a SWOT matrix, a short introduction of the SWOT analysis tool and its major aspects is done. This approach should help with the other parts of the research question, which could not be answered sufficiently in the course of the previous chapters, such as:

- Strategic view: Requirements for OEM, Strengths Weaknesses Opportunities Threats (SWOT)?
- Restrictions and Costs?
- How reasonable/feasible is such an enterprise in undertaking?
- Strategic estimate of the actual problem stated.

5.2.1. SWOT Analysis in Theory

In the following paragraphs, the basic theory behind this tool is stated:[80]

The **SWOT** analysis is a common strategic marketing tool, but also used across many different disciplines. It serves the purpose of understanding and identifying possible **S**trengths **W**eaknesses **O**pportunity and **T**hreats that anyone (person, company, project) can face openly. Therefore, it can be used in a business context, where it helps to find a market niche, as well as in a personal context for career development.

A main advantage is that the effort for the analysis is very little and the tool is easy to use. It can also help uncovering opportunities that a company is well placed to exploit. Furthermore, it offers an understanding of weaknesses and enables companies for a strategic management or elimination of threats. Highlighting risks prevents one of being unaware of them and increases the chance of early discoveries, which moreover prevents cascading complications. Finally, this tool serves as a starting point for strategy design in consideration of possible competitors in order to achieve a competitive advantage.

SWOT can be divided into **interna**l and **external** factors, hence its second name IE-matrix. While strengths and weaknesses are considered internal to an organization, opportunities and threats are viewed under an external aspect. In order to provide a well-suited template, the following Figure 27 explains the imperatives and questions that should be considered for each aspect.

[80] Conf. Mind Tools (n.y.), online source [17.1.2019].

SWOT-Matrix: What to consider?

Strengths (internal)

- Should be considered from internal perspective as well as stakeholders and customers view. They also have to be thought about in relation to competitors.
  - **What major advantages can you name for the organization?**
  - **Where do you perform better than anyone else?**
  - **Which key or low-cost resources does the company inherit in comparison to others?**
  - **What do stakeholders see as your market strengths?**
  - **What are the factors that contribute to success?**

Weaknesses (internal)

- The view should be again mainly internal but on the other hand also include external perceptions from market stakeholders. It is very important to face any unpleasant truths too.
  - **In which areas can the company improve?**
  - **What should be avoided?**
  - **What do stakeholders and customers perceive as weaknesses?**
  - **What are the factors that result in bad developments/sales?**

Opportunities (external)

- They can emerge from new technology and market trends on a broad and narrow scale, as well as changes in government policy related to the companies field or socio-economic changes and life-style trends or local events. A useful approach is to look at the strengths first and to ask oneself if they open up any opportunities. The same can be applied to the weaknesses while asking if new opportunities can be opened up by eliminating them.
  - **Which easy-to-gain opportunities can be spotted?**
  - **Are there any interesting trends?**

Threats (external)

- At this aspect, it is important to capture all-important external factors. Government regulations or technological changes in industry should not be overlooked.
  - **What obstacles or barriers does the company face?**
  - **What are direct/indirect competitors doing?**
  - **Are there any changes in quality standards or specifications?**
  - **Is the company’s position challenged by new technologies?**
  - **Are there any financial problems?**
  - **Could any of those threats substantially threaten the business as a whole?**

Figure 27: SWOT considerations, Source: Own depiction, based on Mindtools (2019), online source [17.1.2019].

SWOT can be used for both vague "warm-up" strategy formulations as well as for serious discussions in project management. For the later one it is also important to consider that only precise verifiable statements are used, factors are prioritized, analysis is done at the right level (e.g. product level vs. company level) et. It is also recommended to use the tool together with core competence analysis in order to get a comprehensive picture of the situation.

For the sake of completeness an in consideration of later works, other strategic planning tools, which despite being compatible with SWOT would otherwise be excluded in this thesis, will be briefly suggested in the following paragraphs: [81]

One famous tool is the **BCG (Boston Consulting Group) Market Growth Market Share** Matrix, which is often used for the development of new products and markets. The goal is to spread financial risks evenly across these two entities. The matrix consists of the four fields of "Stars" (high market growth rate, high relative market share), "Cash cows" (low market growth rate & high relative market share), "Poor dogs" (low market growth rate & low relative market share) and "Question marks" (high market growth rate & low relative market share). Stars and Cash cows should be able to finance the Question marks and Poor dogs. Dogs should be eliminated, if possible.

The second one to mention is **Porter's five Forces model** for competitive strategy. As the name indicates, it consists of the analysis of five forces that could harm the companies' ability to compete on the market, namely direct competitors, new entrants, substitute products, customers, and suppliers.

Finally, **Ansoff's strategic growth matrix** not only considers the impact of economies of scale, but also economies of focus. The assumption is that only focused companies are able to produce very good financial results. A company can either prevail through the strategies of cost leadership (beat the competition by being cheaper), differentiation (not cheap, but offer advanced customer benefits e.g. Apple iPhone) or focus strategy (niche businesses). As a rule a company should never be stuck in the middle (i.e. use a mix of these strategies).

In the following subchapters, the information and inputs retrieved from the interviews and discussions was subject to synthesis, context interpretation and summary and made in an order for the SWOT analysis of the Austrian-Swiss internal and external environment considering a helicopter production.

5.2.2. Strengths – What has to be boosted?

According to Mr. Leitner:

Austrian companies are doing very well throughout the different Tiers. OEMs would be Diamond Aircraft (general aviation) and SCHIEBEL (helicopter drones). Key assets are special mission equipment, drive trains and transmissions, complete interior, composite parts (e.g. FACC, Peak Technology) and metal works. Many Austrian firms provided the SH09 project of the Swiss Kopter company with major key components. Switzerland has the experience and expertise to produce helicopters. They also have experience in doing elaborated customer requirement analysis, which can help finding a proper market niche (e.g. aircraft for missions in alpine terrain). Both countries have a lot of engineering knowledge and manufacturing expertise.

[81] Conf. BCG (n.y.), Ansoff (1980), Porter (1980), quoted from Van Weele (2018), p. 164–165.

According to Mr. Ganahl:
Austria is doing very good on structure parts, engine parts, composite components and interior.

According to Mr. Gruber:
Despite being also neutral, Switzerland has the better framework conditions (laws) to export military equipment, for example small airplanes like the PC-7 from PILATUS. This offers new channels for international sales and distribution. Even though not able to utilize for the Austrian Armed Forces, Austria is on the way to develop and produce light training helicopters (Diamond DART 280) that can compete on an international scale.

According to experts from FH Joanneum:
A major strength is the Austrian mind-set. There is more freedom of movement and fewer prescriptions by NATO. Austrians also show more courage than other countries when it comes to the procurement of older or used aircrafts. A German Lufthansa would never do such thing.

According to Mr. Linden:
Austria and Switzerland can act very independent from other countries (both are neutral and not part of NATO). Moreover, a possible knowledge transfer between AT-CH could bear a great potential, since there are a lot of competences in both countries regarding the aerospace area.

According to Mr. Amancio:
There are a number of companies in AT-CH, which are have some knowledge:
Voestalpine/Böhler Edelstahl/Böhler Aerospace make metallic components, which are already flying at most aerospace OEMs. These are very strong and capable firms. FACC makes composite parts for Boeing, Airbus and for Embraer, so they would be very important too.

5.2.3. Weaknesses – What should be reduced/improved?

According to Mr. Leitner:
There is a lack of focus on helicopters in Austria in comparison to general aviation. Moreover, we do not have a risk-taking culture and tend to keep a lower profile. Few companies have certificates to design parts for helicopters from scratch. Another flaw is that the necessary helicopter-knowledge and expertise is spread-out across the firm landscape (no central organization).

According to Mr. Ganahl:
Even though we manufacture important engine parts (shafts, nacelles, turbine blades) there is not yet a company in Austria that can develop or produce the required turboshaft engines. A purely Austrian helicopter design would be also very difficult to develop, as a lot of external/foreign knowledge would be necessary.

According to Mr. Gruber:
There is a lack of knowledge in R&D, Quality Assurance and certification. For a project like this, we would depend largely on global partners. In regards of military use and export, we are also very dependent on NATO and the norms they require an OEM and helicopter design to fulfil. In addition to that, there is no strong lobby in the government to support this. Besides the helicopter itself, there are no turboshaft-engines available in Austria.

According to experts from FH Joanneum:
The crash requirements are most important, as regulations are very harsh. Therefore, landing gear and fuselage have to be designed and constructed in a special way. The same applies considering the critical loading path of the helicopter, which is much different from airplanes and needs to be built from high

strength titanium. Considering this, there is hardly any firm in Europe that has the expertise to design and develop such a structure accordingly. In Addition to that, there is almost no knowledge of rotor-dynamics in Austria (lack of education). No company holds the necessary certificates to design a helicopter and therefore the "Level-of-Involvement" (certificates - experience) needs to enhance throughout the industry.

According to Mr. Linden:

AT-CH are both very small countries, hence there is not a developed helicopter sector yet. Even though Switzerland has Kopter, there is no established OEM for helicopters. In the area of engineering, Kopter does not have a sufficient amount of co-workers (100 positions are currently open). Few firms are involved/available in the moment. Besides, a general overview of the market is missing (Who builds what? Certificates? Who is an expert for Certification? R&D?). In fact, component suppliers are very hard to track. This has been also a hard task for Kopter.

According to Mr. Amancio:

No comment on this topic.

5.2.4. Opportunities – What trends/chances can be utilized?

According to Mr. Leitner:

According to information from Airbus, a growing trend in the aerospace sector can be expected, despite sinking oil prices. Governments across Europe also started programs of re-armament due to politics shifts within the NATO alliance. In addition, Austria can be expected to purchase new equipment for law enforcement and maybe the army (counting in the 33 potential machines) eventually. Besides traditional helicopters, there can also be other options to enter or disrupt the aerospace market. For example, there is now a trend in China for so-called "passenger drones", autonomous air taxis that do not require the users to have a piloting license[82]. The Austrian FACC recently made a joint venture with the Chinese drone manufacturer EHANG, in which they took over the responsibility for producing structural composite components and fuselage for the EHANG 184 drone. Another option could be to compete in certain niches. For example, an Austrian OEM could try to develop a pendant to the RACER concept of Airbus. This would mean to design a helicopter with two additional propellers for propulsion, which in theory results in increased speeds, and offers other benefits to the customer such as lower noise levels and fewer costs. Austria has some companies, which have POA, DOA and type certificate experience ("level-of-involvement"), which can be very helpful in any regards. Moreover, Switzerland, of course, has already Kopter, a helicopter producer, and Pilatus, as well as other companies, which have a lot of experience. Finally yet importantly, there is also the possibility to produce a helicopter under a license agreement or strategic partnership with an OEM. This activity could involve, for example, to buy up an old TC (Type Certificate) for an older model, which has a low sales potential for the licenser (the Alouette 3 for instance), and to upgrade it to current state of the art (modern materials, safety features etc.) with the help of Austrian firms. In this case, POA certificates are only required. These can be easily obtained by companies such as Diamond, which already have a certain level-of-involvement.

According to Mr. Ganahl:

It would be an advantage, if we can develop a good and modular main platform that fits our needs for transportation and emergency services and allows us to cut maintenance costs.

[82] Conf. EHANG (publ.) (2019), online source [22.12.2018].

According to Mr. Gruber:
The best solution would be a modular machine that besides fulfilling the main requirements also has certain retrofitting capabilities (modularity) to install or uninstall special equipment (rope windlasses, cameras, light weaponry etc.), as the mission requires it. In addition to that, the helicopter should be designed in a way that it allows for quick and easy maintenance.

According to experts from FH Joanneum:
To build a helicopter under a sort of license contract would be easier to achieve. The TC of an older machine could be purchased and consequently a manufacturer would not have to develop an own helicopter DOA as well as sophisticated design capabilities. That would mean just producing a machine, which only requires a POA (less effort). A TC can be bought, out-dated parts can be replaced and the improved machine could be sold. Utilization of opportunities is mainly a political question. In theory, the army could also assemble a helicopter, as they have their own certification requirements, but this machine would never be approved for any civilian mission scenario.

According to Mr. Linden:
AT-CH could gain more independence and from a macro-economic standpoint there could be a high volume (selling/export potential).

According to Mr. Amancio:
Speaking from materials science point of view: A future chance would be the use of innovative materials, such as fireproof and durable magnesium alloys. There are also intelligent structures currently under development, which can change their shape or appearance by an external stimulus (they could be used instead of mechanical actuators). Research is also done for smart composites, which have integrated sensors for temperature or health monitoring and can provide self-healing features. Moreover, an increasing amount of additive-manufactured metal components. There are also technologies under development, which enable to print thermoplastic composites in 3D, also combined with metallic structural components.

5.2.5. Threats – What risks have to be managed/eliminated?

According to Mr. Leitner:
Sinking oil prices could threaten the market development, which is very fragile now. The aerospace industry has shown a downwards trend in the last years. The military sector is too small to have a sufficient impact, and politic situation is not clear. For an own indigenous helicopter design, there do not exist any DOA approved firms in Austria, so we would be dependent on other countries. In addition to that, any certification process (DOA, POA, TC, etc.) takes a long time, even longer if you do not build under licence agreement. Kopter started in 2009 and still has not acquired a POA since then, although over 200 machines have been ordered. This bears a huge financial risk. If no one can be found that would finance the project in the prophase, such a project will be doomed. Moreover, if no sales were possible in that time, there is a risk that equity capital would decline as investors pull themselves out. Other aspects are the lack of organizational expertize for a project of such a scale as well as the missing quality knowledge. This would take additional time to develop. A pre requirement would also be to have financially stable customers and suppliers. Beyond production and finance, there are also operational risks. They often bear an effort that usually is not seen in the beginning, such as the organization of aftermarket services, provision of maintenance and repairs, documentation and handbooks for the specific helicopter.

According to Mr. Ganahl:

If you look at the market, you can see a steady grow in customer expectations and requirements, where even the bigger companies struggle. Another point would be the establishment of a stable spare parts logistics.

According to Mr. Gruber:

A problem would be to organize responsibility for maintenance, training and other services. There is also the question, who can be a reliable partner to supply operators like the Army with critical rotables and spare parts. Critical for the survivability of an OEM would be a proper company size, workload and utilization, an innovative marketing and sales strategy and barrier free ways of distribution. If the helicopter would be a pure military machine, Austrian laws would make export very hard.

According to experts from FH Joanneum:

A Break-Even-Point is extremely hard to achieve. There can be assumed that just a low number of machines, counting in the 33 potentially required ones by the military and even the 200 of Kopter, would be produced and sold in the end. This would not be enough for a company to cover all costs. In addition, demand on civilian market is uncertain. Finally, the overall success also somewhat depends on politics.

According to Mr. Linden:

There is a high risk for an OEM, since the project is a Greenfield from both technological and economic standpoint. Besides, as the controversial Brexit issue is currently a hot topic in the news and some Austrian politicians talked about an "Öxit" in addition, there is no estimate on far how such an event would harm the value/supply chain or what other effects could be provoked. This by itself could be another idea for a whole thesis.

According to Mr. Amancio:

No comment on this topic.

6. Validation and Proposal of an optimized model/concept and strategies

In the course of the thesis the complexity was broken down, a helicopter type analysed, a production sequence applied, core competences split, a set of companies investigated and sourcing scenarios applied. As the basic mind-set of the thesis was to use a straightforward approach, progress without failing in some points is very unlikely. In this sub-chapter, the assumptions are put to the test bench. Summed up, the chosen perspective was rather optimistic, but model vas validated and some flaws or potential for later improvements could be discovered.

6.1. Discussion: Thesis Shortcomings and suggested Changes

As stated in all the previous chapters, in making of the preliminary model for the value chain mapping, a lot of simplifications and optimistic assumptions were used. Finally, these were subject to critical self-reflection and foreign reflection in the course of the expert interviews. A certain amount of flaws was identified. Some of them could be easily fixed. Other flaws, which would require a larger reworking effort, should be considered in the way of a detailed long-term study.

The **theoretical assumptions** made in the progress of this work can be summed up as following:

1. It is reasonable to produce a helicopter in Austria-Switzerland (main hypothesis, can be falsified).
2. In this thesis, firms in Austria and Switzerland form a single consortium; there is no competition in between.
3. Competition only exists with companies outside of this common economic sphere, named Austria-Switzerland (AT-CH), which is formed by both mutual neutral countries.
4. The bundled forces of AT-CH have the expertise to: Design & Develop, Manufacture, Test and certify, Sale, Maintain & service a typical rotorcraft of the LUH class;
5. If designing and developing is taking too long, an alternative approach could be a license-manufactured helicopter type.
6. Modern LUH types are very similar in both construction and production and essentially share the same manufacturing process (on a macro level).
7. The MD 902 Explorer is a good representation of a typical LUH, despite having the NOTAR system.
8. The simplification of the components can be done according to the BOM shown (referring to the R-BOM).
9. The manufacturing sequence is comprehensible and shows a reasonable depth of value added. The synthesized individual steps, layout, stations and technologies fit to the model and are state of the art.
10. The GOZINTO chart was the best mean for answering the key questions.
11. The depiction (GOZINTO-Chart V1) of the arrangement and hierarchy of the components is reasonable and understandable. It mentions every important component and system.
12. Using a split of core competences in between the OEM and Suppliers is the way to go.
13. The core competences were distributed in a reasonable way. Hence, outsourcing and insourcing depictions work in an optimal way.
14. The procedure shown in the flowchart for company investigation works and is reasonable and practical.

15. Important databases were considered.
16. Idealizing the resources as well as capacities of the companies was a good idea in an optimistic sense, as the focus is only on the set of skills that they can provide.
17. Within the R-BOM, the list of companies gives an idea of the research & development potential within AT-CH.
18. The final illustration (GOZINTO-Chart V2/VCM) gives an educated guess about who amongst the companies would be a "big player" and how much of the components are producible in AT-CH realistically.
19. There is no practical way to calculate the full scale of costs in this early stage, as their structure remains unknown. Consequently, there is no point in answering the question about costs.
20. The expert always know best.

Naturally, those optimistic and simplifying assumptions come with certain flaws. In the course of the external and internal reflection, some critical points were discovered. The discussion with the experts resulted into the following **statements of positive as well as negative critique**:

1. As the idea itself emerged by politicians during election campaign, the true motivation for the idea is not very reflective.
2. The knowledge and expertise as such is highly questionable for Austria, as no specific education in the field of helicopters exist. However, in an optimistic approach, Kopter could assist in this regard.
3. In the thesis, individual interests of companies and politicians are not considered.
4. Crashworthiness is a basic requirement. This applies to the whole fuselage, as well as the landing gear and the seats. In addition to that, the layout of the critical loading path is important for construction.
5. Information on helicopters is very rare, so it was a good choice to consider the one with the most detailed information. However, it does not mean that it necessarily represents a genuine AT-CH design. How the AT-CH solution would look like depends strongly on the strategy (customer requirements as well as the question of doing an own design development versus license manufacturing).
6. A simplified model like this does and cannot consider individual company capacities. However, that would become important as one may speaks about optimizing the manufacturing network and its effectiveness.
7. The GOZINTO-Chart-method seems to be a suiting method for the mapping of the value chain. However, whilst attaching the companies to the components, it could be helpful to consider their hierarchies (Tier1, 2 etc.) as well. According to both Mr. Linden and Mr. Leitner, tracking of suppliers is a very complex task. Therefore, a thesis like this could help in finding some versatile approaches.
8. Even though the technical description of the MD 902 Explorer appeals to be the best solution to understand the necessary details of a LUH, the component hierarchy shown may be too simple and to detailed in other parts. It is highly recommended, to use the numbering and designation of the ATA 100 chapters for the BOM. According to interviewees, ATA designations are a sort of Koiné language spoken by the civilian aircraft industry. The advantage is that it would enhance the mutual attribution of companies to the individual ATA named components. Therefore, the R-BOM would become more significant. The same applies to the GOZINTO-Charts. In addition, the competences would be easier to split up.

9. Another nice-to-have would be the inclusion of raw material providers, as well as MRO (Maintenance Repair and Overhaul) companies as such. However, MRO firms were included in the R-BOM as possible suppliers for the OEM. For example, if a company can refurbish the whole interior (requires at least a minor changes DOA certificate), it potentially would be able to supply a OEM also in the later stages of manufacturing. This is, of course, a very optimistic estimate.
10. The production sequence depicted could be approved to some extend for the composite manufacturing of fuselage and rotor parts as well as for the tail boom[83]. Despite the fact that some variations, such as additive manufacturing of metal parts, adhesive bonding were also shortly discussed, no further inputs for validation could be generated.
11. Other lecturers stated that there is no curriculum for aerospace students in Austria. University education of talented junior-engineers would be a prerequisite for building up the necessary expertise. Therefore, an estimate of the knowledge situation and distribution in Austria would be very important.
12. Costs: A huge question mark as well as the question on how many helicopters have to be produced in order to break even. However, it was found that there indeed exist empirical formulas for the evaluation of costs (using kg, kW, number of rotor blades etc.), which are accurate enough to do at least a base price calculation.
13. Experts can also be biased.

For now, some of the suggested improvements will be implemented. Based on the GOZINTO-Chart V1 and the R-BOM a GOZINTO Chart V2[84] was designed to depict and describe a full-blown value-chain mapping. It was tried to take as many recommendations of the interviewees into account as possible. For example, the R-BOM list was reviewed critically and only a fraction of the firms was picked for the final Chart. It was attempted to pick those firms, which showed the highest "level-of-involvement" within AT-CH. However, the original R-BOM was not changed to leave the door open for different opinions and readers view, as some expert opinions contradicted each other. The same also applies to the terms and designations of the different components and systems. In the preparatory work, the MD 902 was analysed for relevant components and in this process some parts were grouped together that would not be there according to some experts. A much safer way would be to use the ATA 100 numberings definitions and designations, which would enhance the validity of the BOM to some extent. On the other hand, it was also seen that the GOZINTO V1 chart already showed a great level of detail to work with for answering the scientific question, so the ATA chapters were not included in this thesis. However, for academic follow-up works on more detailed supply-chains, it would be highly recommended to use this form of designation from the beginning onwards. Considering costs, a formula for the base price calculation is described in the course of the next sub-chapters.

6.2. Final Design Iteration of the Value Chain Map and further Recommendations

This sub-chapter highlights the relevant aspects for the evolution from the GOZINTO-Chart V1 into the GOZINTO Chart V2, which will from now on simply be referred to as the **VCM or "Value-Chain-Map"**.

[83] Conf. Appendix, Part I, Chapter 1.6.

[84] Conf. Appendix, Part II, Drawing no. 2.

In order to get a sort of diagram that really deserves that name, some adaptions on the original design were done. Following steps illustrate the procedure:

1. A classical tail rotor configuration was added as a choose-able alternative in order to provide a more general solution. Alternative paths are marked as dashed lines.
2. In order to highlight the importance of the fuselage section (crash worthiness, critical loading path, bottom up assembly), its development path was horizontalized.
3. The process octagons were directly attached to their output components, forming a single entity. If more than one part are produced in the step, conventional connection lines are used in between.
4. Next, a new symbol (shaped as a divided diamond) was designed in order to mark the direct border (decoupling point) in between the OEM (orange side) and the Suppliers (blue side) (Figure 28).

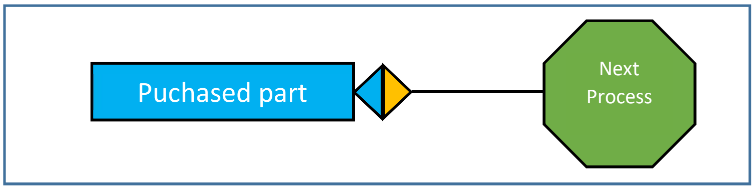

Figure 28: Decoupling point supplier side (blue) and OEM side (orange).

5. In the next sequence, the companies are designed. Each entity is equipped with a coloured arrowhead, indication orange for an OEM consortium member and blue for a Supplier. In addition, a country indication is displayed as both flag symbol and background colour (green for AT-CH, yellow for EU and red for non-EU). Non-investigated or unknown companies are marked with a question mark on a white background and an X instead of a flag. In the following Figure 29 some possibilities are displayed:

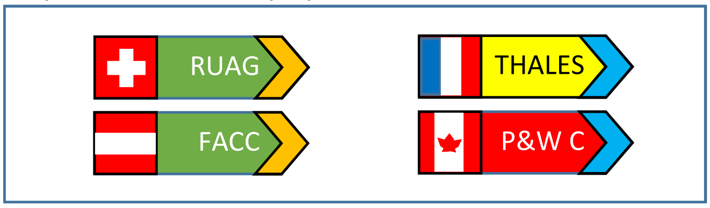

Figure 29: Suppliers and OEM-members (blue/orange tip) from AT-CH, EU, non-EU (green/yellow/red).

6. As companies can either refer to purchased parts and both processes/processed parts, it has to be explained what area a company can cover in particular. Therefore, a dashed covering frame is introduced, which is dragged around the relevant entities. The company's marker is then connected by an angled reference line to the relevant entity.
7. For the sake of completeness, a table for the production sequences[85] is added onto the sheet, referring to the numbers placed within the octagons.
8. The final product's name was changed from MD 902 to LUH AT-CH 1 for generalization purposes.

For the final VCM, the R-BOM was critically reviewed and a few number of competent companies was handpicked, which were deemed to have the best experience for the corresponding field of work.

[85] Conf. Appendix, Part I, Chapter 2.

Naturally, this depiction comes with a sense of subjectivity, as no mean for a more objective solution can be found yet. For further research, which may involves a more detailed re-doing or enhancement of the basic chart, it is highly recommended to use ATA 100 chapters. In this case, it can be speculated that the solution may also inherits subjective traits and there could be other opinions leading to different outcomes as well. Maybe, a method that goes more into the direction of MRP, including company capacities, lead times, and routing plan could give a clearer picture. In the course of the thesis, it was also made the attempt to put the company data into a database. Therefore, an Entity Relationship Model was designed. As the number of entities and data sets grew, this solution became unpractical for the scope of the thesis. To make this work, establishing a data warehouse gathering up to date company data would be very efficient, but also be the result of hard long-term research and work. Moreover, this in connection with the design from above could result in a very useful VCM software. A tool like that could work well in the context of industry 4.0 and the Internet of Things, as flexibility and faster transfer of information become increasingly important and having an detailed and up to date supply chain mapping would be an advantage for many firms. At this point, it has also to be noted that the design and the layout provided in this thesis found some resonating recognition within the group of interviewed experts.

7. Evaluations and Results

7.1. Evaluation of firms and key players

With the help of the VCM chart, it is possible to attempt an evaluation of firms, whilst answering the question on how many parts are producible in AT-CH. At first, one can distinguish between two cases: A maximum and a minimum value added in AT-CH. The later one means that the Anti Torque system is purchased in USA and the rotor head including the blades is outsourced to a Canadian firm. In doing so, the amount of total components would shrink. Next, one could also have most of the external value-chain within the EU or try to shift more of it into non-EU countries. The counting of all parts and components with exception of raw materials, as for now no companies were investigated in that level, leads to the following result (Table 22):

	AT-CH (max.)		AT-CH (min.)	
Counted Parts in AT-CH:	**66**		**52**	
Purchased parts	49		45	
Processed Parts (incl. Final Product)	33		27	
Total parts:	**82**		**72**	
Value added within AT-CH	**80%**		**72%**	
	EU (max.)	**EU (min.)**	**EU (max.)**	**EU (min.)**
Parts from EU countries	**15**	**13**	**16**	**13**
Parts from non-EU countries	**1**	**3**	**4**	**7**
Total Parts from non AT-CH	16	16	20	20
Value added within EU countries	**18%**	**16%**	**22%**	**18%**
Value added within non-EU countries	**1%**	**4%**	**6%**	**10%**
Control sum	100%	100%	100%	100%

Table 22: Counting of components and regional value-added.

In consideration of the counting made in Table 22, a **maximum value added in between 71% to 80% can be achieved within AT-CH**. However, one has to keep in mind that the raw materials have not been included. If the firm hierarchy, including all tiers accordingly, becomes better in later processes, while adapting and improving the GOZINTO-Chart and the VCM, it would probably result in a more detailed, but also more complex estimate. Consequently, the numbers calculated above should not be seen as fixed.

The next section is about the question on who would probably be a big player within an AT-CH OEM consortium. The ranking was done in the following list of companies presented in Table 23. The score was determined by simply counting how often a company appears throughout the different value chain steps, i.e. processes and components. Individual company functions as OEM or supplier were kept separate, but then summed up to get a total score.

Rank	Company	Country	OEM count	Supplier count	Total Score
1	RUAG	CH	16	0	16
2	Böhler	AT	9	5	14
3	Kopter	CH	13	0	13
4	FACC	AT	8	4	12
5	Diamond Aircraft	AT	9	0	9
6	Peak Technology	AT	5	4	9
7	Secar	AT	8	0	8
8	RO-RA	AT	4	3	7
9	Zoerkler	AT	0	6	6
10	Schiebel	AT	4	1	5
11	Mecaplex	CH	0	4	4
12	Pankl	AT	0	3	3
13	Anton Paar	AT	2	0	2
14	KTS	AT	0	2	2
15	Magna	AT	1	1	2
17	H+S	AT	0	1	1
18	Helios	AT	0	1	1
19	Kuerzi	CH	0	1	1
20	Milltec	AT	0	1	1
21	PIDSO	AT	0	1	1
22	QCM	CH	0	1	1
23	Sathom	CH	0	1	1
24	Thommen	CH	0	1	1
25	TTTech	AT	0	1	1

Table 23: Company Ranking AT-CH.

Explaining the choice of selection for each company will be done only for the top 12 firms. Furthermore, they will be introduced to the reader by means of a short description on in what business segments they are active. However, it should only be considered a recommendation for the OEM-consortium, and not necessarily a factual list, since only a few companies are currently involved in the helicopter branch or certified accordingly. Keeping this in mind, there might be a potential for the listed firms to expand their range of products and services according to their placement in the VCM.

7.1.1. RUAG

RUAG is a Swiss aerospace company, which divided into three divisions: Space, Air and Land. Air's focus lies on the aircraft sector. RUAG plays a major role worldwide as a leading supplier, support provider and integrator of systems and components for civil and military aviation. The company has also a lot of experience as an OEM, since it also manufactures the Dornier 228. Moreover, RUAG specializes in the development, manufacturing and final assembly of fuselage sections for passenger aircraft, wing and control surface components. Besides, they also are active in MRO and system upgrades of helicopters and can provide consulting on this matter. In addition, they are also able to integrate and install any kind of state-of-the-art avionics suites and special mission systems, as specified by the customer. For this purpose, due to the fact of being an EASA Part 21 J and G Approved Design

Organisation (DOA), they are also capable for the design of the necessary airframe modifications and can ensure their certification.[86]

Figure 30: On Site FAL support, Source: RUAG (2019b), online source [28.1.2019].

In the process of the VCM development, RUAG appeared most often on very critical steps of the value chain. Even though they do not produce any fuselage sections for helicopters in the moment, they would be very capable to do so due to the high amount of expertise that can be found in the company. Therefore, RUAG would play the most valuable role within a hypothetical OEM-consortium. Considering the supply chain pyramid (Figure 5), the company would also fit into the role of a Tier 0.5 supplier very well.

7.1.2. Böhler

The Austrian company Böhler is composed of the four divisions Edelstahl, Schmiedetechnik, Bleche and Profil. Their individual key assets and services (CCs) for the aerospace industry will be explained in the following paragraphs:

Böhler Edelstahl:[87]

This division provides primarily the metallurgical knowledge and supplies steel and nickel-based alloys for the aviation industry as well as high quality powder and printing know how for additive manufacturing. Key products are steel bars and nickel-based alloys as raw material for highly stressed safety components, elements of fuselage construction (such as flap & slat systems, pressure cylinders, engine mounts, and cargo systems) and engine (bearings, turbine blades, turbine shafts, etc.).

Böhler Schmiedetechnik:[88]

Böhler owns a specialized division, which is dedicated to any type of die forged and pre-machined components. Moreover, the material range for their products consists of difficult to form alloys such as titanium, nickel base alloys and high-alloyed steels. Accordingly, these factors make this division a premium supply-candidate for the provision of engine mounts and discs, landing gear parts, wing and fuselage components (tracks, fittings, etc.) and pylon parts.

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[86] Conf. RUAG (2019a), online source [28.1.2019].

[87] Conf. Austrian Federal Economic Chamber/BMVIT (2018), p.43.

[88] Conf. Austrian Federal Economic Chamber/BMVIT (2018), p.45.

Böhler Bleche:[89]

This branch of Böhler is specialized in manufacturing hot- and cold-rolled sheets, plates and blanks. They can provide OEMs with engine mounts, seat runners, wing flaps and engine parts´.

Böhler Profil:[90]

The final division plays a major role in the area of profile steel components. As such can be named the sealing sections for cargo hatches, guideway sections for the landing flaps, turbine ring sections and blade profiles for engines.

Figure 31: Böhler's divisions and products for aerospace industry, Source: Voestalpine, adapted by Held (2015), online source [28.1.2019].

In addition for each of the divisions being EN/AS 9100 certified, Böhler has become a major supplier for many aerospace companies worldwide such as Airbus, Boeing, Bombardier, Liebherr, Rolls Royce, Safran, GE, PW, MTU etc. Summed up, as Böhler shows a lot of involvement in the area of aircraft structures and parts made from any type of metal as well as materials and manufacturing technologies, they can be assigned to any part that requires special metallurgical knowledge (e.g. landing gear, tail boom mount etc.). Hence, they can be assigned for many parts in the value chain either as part of the OEM consortium or as a supplier. Thus, they would make the 2nd place in this consideration.

7.1.3. Kopter

First founded as Marenco-Swiss Helicopters in 2007 for the purpose of developing, building and supporting a new generation of turbine helicopters, this company is a rather fresh face on the LUH market. Kopter’s single product is the multirole SH 09 helicopter, which differentiates clearly from other competitors by the use of a composite fuselage with a high internal volume, weighting only 1300 kg, and a shrouded, Fenestron-like tail rotor system. The 5-bladed main rotor is controlled via an

[89] Conf. Austrian Federal Economic Chamber/BMVIT (2018), p.42.

[90] Conf. Austrian Federal Economic Chamber/BMVIT (2018), p.44.

innovative integrated system of control rods (they lie within the rotor head), reducing overall air drag to a minimum. Currently, it features only one engine (Honeywell HTS900), but other configurations are in development for the international civilian market. With an external load capability of 1500 kg, it targets customers from many branches such as law enforcement, firefighting, transportation (sky-cranes) and passenger transport.[91]

Figure 32: Test flight of the SH09, Source: Kopter (2019), online source [29.1.2019].

As described earlier and in the interviews, this company has not yet delivered a single machine due to the high EASA and FAA regulations. As audits with both authorities are still ongoing to this day, the financial balance is still in the reds and the company relies heavily on external injection of capital.

However, Kopter was chosen quite often for relevant components such as landing gear, fuselage, main rotor system and the final helicopter, due to their increasing level-of-involvement and expertise. Hence, the company would be considered a key player and responsible for the design, development, parts of production (final assembly) and quality assurance of the whole airframe.

7.1.4. FACC

Another important representative of the Austrian aerospace industry is FACC. The company's centre of activity lies mainly on both R&D and production of components/systems made of lightweight composites. Their range of composite products covers aero-structures (control surfaces, fairings, ram air inlets, skin panels) on the fuselage and wings, engine and engine nacelle components and finally complete passenger cabins and interior for commercial aircraft, business jets and helicopters. In addition, FACC can also provide engineering, research & development and testing services of various composites used throughout industry. Moreover, the company also inherits a great range of certificates and approvals such as EN/AS 9100, EASA Part 21 POA, EASA Part 21 DOA, EASA Part 145 and Nadcap Certifications AC7118, AC7114, AC7108; ISO 14001.[92]

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[91] Conf. Kopter (2019), online source [29.1.2019].

[92] Conf. Austrian Federal Economic Chamber/BMVIT (2018), p.63.

FACC has recently signed up for a strategic partnership with Chinese drone manufacturer EHang in their effort to build their Autonomous Aerial Vehicle (AAV), which is currently under development and has some prototypes flying already. EHang will therefore occur as the inventor and AAV expert, while FACC will be a key player for the high-tech-hardware in regards of development, certification, production and worldwide aftermarket-service[93]

Figure 33: EHang 184 Autonomous Aerial Vehicle (AAV), Source: FACC (2018), online source [28.1.2019].

Accordingly, FACC is well placed over any composite component (such as skin panels, flaps, empennage, interior etc.) and its processing.

7.1.5. Diamond Aircraft

As Austria's single seasoned aircraft OEM, this company is also known as an international specialist for glass and carbon fibre composite technology. Hence, their activities also cover many areas of research, development and application of lightweight materials. Diamond Aircraft produces single and twin-engine training & touring aircrafts such as DART 550, DA 40 and DA 62. Hence, their record of certificates (EASA POA, DOA etc.) show a higher level-of-involvement.[94]

As mentioned already in the introduction chapter, Diamond has also appeared in the news as they have been trying to build an ultra-light training helicopter named DART 280, which will be pitched against the Robinson R 44.[95]

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[93] Conf. FACC (2018) online source [28.1.2019].

[94] Conf. Austrian Federal Economic Chamber/BMVIT (2018), p.57.

[95] Conf. Hinz (2017), online source [7.8.2018].

Figure 34: The DART 280, Source: Hinz (2017), online source [7.8.2018].

Therefore, Diamond would also be a major player within the OEM-consortium. The firm could be involved for example as a key partner in the Final Assembly Line as well as the development of the airframe and in manufacturing of the composite fuselage.

7.1.6. Peak Technology

Peak Technology's focus lies mainly on fibre composite lightweight aircraft structures and parts, ranging from initial prototypes to production readiness. Notable products are for instance high-pressure storage tanks (up to 700 bar working pressure), actuation shafts for aircraft landing flaps, tail rotor drive shafts and tail rotor blades for helicopter industries.[96] An EASA Part 21 POA approval as well as EN 9100 has currently been achieved[97].

As recommended by Mr. Leitner, Peak Technology was assigned to the position of a possible main- and tail rotor blade and system manufacturer.

7.1.7. SECAR

SECAR is specialized in the field of reinforced composite materials and components for the aerospace industry. Their products and capabilities range from pipes, slabs and prefabs to precision 3D-composite parts, manufacturing semi-finished products as well as completely assembled modules. Very notable products are also high temperature carbon fibre jet engine parts, pull-winding carbon fibre torsion bars, carbon fibre profiles and 3D-compression moulding parts. Besides, SECAR is EN/AS 9100 certified.[98]

Figure 35: SECAR products, Source: Aeronautics.at (2019), online source [28.1.2019].

[96] Conf. Austrian Federal Economic Chamber/BMVIT (2018), p.119.

[97] Conf. Peak Technology (2019), online source [28.1.2019].

[98] Conf. Austrian Federal Economic Chamber/BMVIT (2018), p.142.

SECAR could potentially be assigned to structural composite manufacturing as well as manufacturing of the doors, as recommended by Mr. Leitner.

7.1.8. RO-RA

RO-RA products and services cover mainly the development, qualification and production of applications for interiors, structures and engine Components. Most notable services can be found in the conception/design abilities, vibration computation/simulation, compression and tension load analysis/testing, kinematic analysis, fatigue cycling and wind milling analysis and finally qualification and verification. Major products are any type of connector, air ducts, metallic rods, engine mounting rods, swaged rods, tie rods, drag links, rotary rods, rigid struts and machined metal assemblies (Aluminium, Titanium, Steel, etc.). The company is also EN/AS 9100 and EASA Part 21 POA qualified.[99]

Therefore, RO-RA was assigned to the VCM as OEM-consociate in regards of landing gear, as well as a major Austrian supplier of flight controls.

7.1.9. Zoerkler

Facing strong competition on the world market (e.g. from competitors like ZF in Germany), Austria-based Zoerkler's competences also include the building of complete drive systems for helicopters and fixed wing aircraft. The company can cover all necessary steps in-house – from engineering/R&D and prototypes to small series production, assembly, testing, certification, documentation, and MRO. In addition, they own a modern testing facility with transmission, hydraulics, shaft and fatigue test stands. The complete transmission system turnkey solution also covers the main gearbox, tail gearbox, main Shaft as well as tail shaft. Besides, Zoerkler is also capable to produce any type of high precision gears, bevel gears, landing gear components, valves, gearbox housings, pistons, rotor parts and rotor shafts as well as crank shafts. They also hold an EN/AS 9100 certificate.[100]

Figure 36: Zoerkler Drive Train for Kamov Ka-62, Source: Zoerkler (2016), online source [28.1.2019].

[99] Conf. Austrian Federal Economic Chamber/BMVIT (Eds.) (2018), p. 132.

[100] Conf. Austrian Federal Economic Chamber/BMVIT (Eds.) (2018), p.169.

One of Zoerkler's success stories is the development, production and testing of a complete drive system for the Russian KA62 helicopter, which had its first test flight on 28th of April in 2016. Certification tests also took place at the company's own test facility.[101]

Therefore, Zoerkler's main task in the VCM would also be the designing and manufacturing of the drive system for the AT-CH LUH.

7.1.10. Schiebel

Schiebel as an OEM primarily develops and produces mine detection equipment and the famous CAMCOPTER® S-100 Unmanned Air System (UAS), which is capable to operate in day and night, under adverse weather conditions, beyond line-of-sight out to 200 km, both on land and in maritime environment. The UAS navigates via pre-programmed GPS waypoints by default, but it can also be operated with a pilot control unit (produced by Schiebel). The S-100 also features a complete carbon fibre fuselage, which is in-house produced, and a MTOW of 200 kg. Moreover, Schiebel also produces their own FADEC engine and engine control.[102]

Figure 37: Schiebel's S-100 Camcopter on a maritime test flight, Source: Schiebel (2019), online source [28.1.2019].

Despite the fact of being a sort of aircraft OEM, Schiebel's role in the VCM would be rather one of an assistant for development or production of aircraft composite parts, FADEC controls, flight controls and the main rotor system. They might also be able to help with the design/layout for the final product.

7.1.11. Mecaplex

The Swiss company MECAPLEX is a supplier for mono- as well as multilayer composite-transparencies for both airplanes and helicopters, including carbon-fibre frames and heating elements. They also offer MRO services of transparencies for customers and fleet operators worldwide. Known helicopter types with Mecaplex transparencies amongst others are the already mentioned Alouette 3, AW 139, H145M, H135, and SH09. Other services include the complete production and final assembly of structural component groups (fins, rudders, pitch elevators and landing flaps) as well as the framing of

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[101] Conf. Zoerkler (2016), online source [28.1.2019].

[102] Conf. Austrian Federal Economic Chamber/BMVIT (2018), p.138.

windscreens, cabin roofs and light covers. The company was also a major supplier for the SH09, including components such as doorframes, pilot doors, sliding doors and cargo doors, which were completely manufactured by Mecaplex (incl. glass and assembly). The company is EN9100 certified.[103]

Figure 38: MECAPLEX Production Facility, Source: Mecaplex (2019), online source [29.1.2019].

The inclusion of Mecaplex provides the VCM with complete system solutions for many components, such as doors, windscreen and nose area as well as empennage. Consequently, this resulted in a huge outsourcing potential for the OEM, making the production of doors and transparencies obsolete.

7.1.12. Pankl Aerospace

Pankl Aerospace is a well-known Tier 1 supplier for flight critical transmission systems, flexible couplings, engine shafts, fuel transfer tubes (for refuelling during flight) and landing gear parts for fixed as well as rotary wing aircraft. Besides, they are also developing custom-built lightweight cabin interior (storage boxes, cabin dividers) and can provide a wide range of EASA Part 21J certified engineering services. Pankl's services and products include the engineering, production, assembly, certification of turbine- and engine Shafts, helicopter tail/main rotor shafts and radial drive shaft assemblies. The company's certificates include EN/AS 9100, EASA Part 21 POA and EASA Part 21 DOA.[104][105]

Figure 39: Products from Pankl Aerospace, Source: Pankl (2019), online source [29.1.2019].

In the VCM Pankl grouped together with Zoerkler has the task to produce the complete drive train system for the helicopter.

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[103] Conf. Mecaplex (Ed.) (2019) (online).

[104] Conf. Austrian Federal Economic Chamber/BMVIT (Eds.) (2018), p.118.

[105] Conf. Pankl (2019), online source [29.1.2019].

7.2. Costs: Base Price Calculation and Break Even Assumption

As Mr. Friehmelt pointed out[106], one can try to estimate base prices and break even by the use of empirical formulas. A reliable approximation of base prices can be given by the following Equation 5.1 (not applicable for small helicopters):[107]

$$Price = F \times H \times (\,Blades\ per\ Rotor)^{0.2045} \times mass_{empty}^{0.4854} \times performance^{0.5843} \qquad (5.1)$$

The factor F translates to $412.32, if the units kW and kg are used. A major feature of this formula is that serial production and production costs are included already. The factor H is the product of following factors, which depend on different cases (Table 24):

Engine Type: • Piston: 1 • Turbine: 1.779	Engine configuration: • Single: 1 • Multi: 1.352
Country: • US (Commercial): 1 • US (Military): 0.838 • CIS: 0.330 • Europe: 0.86	Number of main rotors: • Single: 1 • Multi: 1.046
Pressure Fuselage: • Without: 1 • With: 1.135	Landing gear: • Skids, rigid: 1 • Retractable: 1.104

Table 24: Factors of the H product, Source: Bittner (2009), p. 24.

What would the base price be for a LUH? To answer this, one can pick for example the data of the MD 902, SH09 and Alouette 3 for comparison and use a MS Excel table for calculation (shown in Table 25). At first, the individual H-factors can be calculated by multiplication of the corresponding numbers in the previous table. For the **SH09** this works as following: *(Turbine) x (Single engine) x (Europe) x (Single main rotor) x (Without pr. F.) x (Skids)*; as a result **one gets 1.53 as H-factor**. Individual empty weight and engine power can be retrieved from Table 5. Obtaining the number of rotor blades is trivial (can be counted on numerous photos). Equation 5.1 can now be calculated. As a result, one gets a base price in US Dollars. Conversion into Euro gives a base price ranging from circa **1.24 to 1.75 million Euros**. The base price for a typical helicopter in the LUH class has now been calculated. However, the structure and true amount of costs for designing, producing, selling etc. remains hidden for now. Nevertheless, a **naïve calculation** can be attempted, since the article stated in the introduction chapter projected a financial requirement of about **100 million Euros**, based on the experience of Kopter in their SH09 project. In an attempt as most formulas use the empty weight to calculate prices or costs, one could scale up/down these expenses by using the relation of empty weights as a scaling factor. Consequently, the costs for the Alouette 3 become a bit lower, and the MD 902 gets more expensive. Division of the projected costs through the base prices now gives the amount of machines that have to be sold at least to make a profit. If these costs are somewhat plausible, this would mean that a theoretical AT-CH OEM consortium would **have to sell at least between 61 and 68 machines** to break even. If the military only requires 22+10 helicopters, that a larger number has to be produced and sold either to other militaries or civilian users, provided that the certification process goes smoothly. The

[106] Conf. Appendix, Part I, Chapter 1.4.

[107] Conf. Bittner (2009), p. 23–24.

projected costs for the development of the SH09 was based on an independent design and development. Therefore, a new question would also arise: In how far would a license production have an influence on the costs? Would buying a license be cheaper than an own development? Such questions could potentially be a subject for later investigation.

	MD 902 Explorer	**Kopter SH 09**	**Alouette 3**
Turbine config.	1.779	1.779	1.779
Multi config.	1.352	1	1
Europe config.	0.86	0.86	0.86
H-factor	2.068	1.530	1.530
F-factor (for kg, kW)	412.32	412.32	412.32
Blades per main rotor:	5	5	3
empty mass (kg):	1531	1300	1100
permanent performance (kW):	746	761	649
BASE PRICE:	**$ 1,987,710.41**	**$ 1,857,488.00**	**$ 1,405,864.21**
1$=0.88€	**1,749,185.16 €**	**1,634,589.44 €**	**1,237,160.50 €**
Projected costs (scaled)	117,769,230.77 €	100,000,000.00 €	84,615,384.62 €
required machines	**67**	**61**	**68**
projected sales (ÖBH)	**32**	**32**	**32**
Overstock	**35**	**29**	**36**

Table 25: Calculation Table.

7.3. Summary of Results

In the course of the thesis, referring back to the research question, a depiction could be achieved on how an adequate AT-CH production network for a helicopter looks like and to what extent a LUH can be built according to military and EMS specifications. One by one, the different puzzle parts now come together. The results will therefore be summarized as answers to the sub questions from the introduction chapter.

Q1: What main components are necessary in order to build a helicopter?

The basic answer can be found at in the ATA chapters, where all necessary components are listed and numbered. However, the R-BOM and the components discussed in chapter 3 already give a quite good overview. Usually it also depends on the requirements. The most critical components are landing gear (must be crash-worthy) and the fuselage, as it has to carry all the loading. Construction usually begins with the layout of the critical loading path. Next would be the drive train, which needs to be laid out to very complex machine dynamics, rotor systems and the aerodynamic lay out of the airframe. Each level of components has to fulfil certain requirements. For instance, even the seats have to absorb crash energy to some extent.

Q2: What is the structure of the helicopter as well as the value chain?

LUHs and ways of production are very similar amongst most OEMs, as the industry is heavily regulated (despite many innovations). In the value chain, there are a lot of specialized firms and suppliers. A set of CCs are kept in-house, but the heavyweight of parts comes from outer sources (e.g. engines, transparencies, and systems, interior). Unfortunately, a classical Tier hierarchy structure of suppliers could not be implemented, as the VCM is very simplified and some components were aggregated. This could be enhanced by adding in the ATA chapters.

Q3: How much can be built in AT-CH? Which components/firms are missing and have to be procured from somewhere else?

According to the VCM, the percentage of local value added would be in between 70-80%. Parts of the avionics suite, communication equipment (except for satellite communication), aircraft batteries and most notable the engines would need to be procured from other EU or non-EU countries like France, Italy and the US.

Q4: How would such a local manufacturing network fit to the value chain and what would it ideally look like?

The VCM model was developed in the process to answer this question. Taking it for reference, there are already many companies in the AT-CH region, which are specialized on different parts of the value chain. They could potentially form a form of cluster or consortium that would be able to produce the helicopter. In an ideal scenario, the 12 firms presented in the previous chapter would work together, sharing the risk and distributing responsibilities in the form of achievable work-packages. For example, Kopter could do the development, Diamond the composite parts, Mecaplex the nose section, Böhler the metal frames and RUAG could build the fuselage and the Final Assembly Line.

Q5: How far is company "XYZ" suited to be a player in that network?

To answer this question, audits with firms would probably be necessary. Nevertheless, an attempt was made in the context of "Table 23: Company Ranking AT-CH", where the most suitable players according to their individual core competences have been assigned on different entities in the VCM.

Q6: What are the Requirements for a helicopter OEM?

There are at least two possible cases: OEM as licensee or an OEM developing its own product. For the later one, more helicopter engineering knowledge is needed. There is an additional effort for certification (DOA, POA, TC), which can take a long time. As a result, such an OEM would have to have a stable funding in the beginning. On the contrary, a licensee only has to acquire a TC in this effort. Certification must only be approved for a POA on that specific TC. This would also require an adequate Quality Assurance (QA) policy.

Q7: How much would such a project cost?

Another shortcoming of this thesis is the proper assessment of costs that could occur in a project like this. The structure of costs remains unknown in the end. For now, 100 million € seems to be the most accurate estimate. In a naïve calculation, in order to break even a LUH OEM would need to produce and sell at least 61 to 68 machines.

Q8: How would an AT-CH helicopter look like?

This can only be speculated. Besides some must-haves prescript by authorities (engine number and types, crashworthiness etc.), it could may feature a shrouded Tail rotor and have internal controls on the rotor head (like Schiebel or Kopter). A new development can also come using innovative materials (smart composites) and processes (additive manufacturing).

Q7: Strengths Weaknesses Opportunities Threats (SWOT) for an OEM consortium? What could be a possible strategy?

The results are depicted in Table 26. A strategic recommendation can also be given: If one wants to build a helicopter, it could be helpful slowly building up design and certification abilities by either entering strategic partnerships, hence licence production. This would help to yield the knowledge gap in the beginning, which could potentially shrink as there would probably come knowhow and technology transfer by the licenser. Building up more expertise can also be done in a more generic way through building a completely new product (e.g. passenger drones), and then try to develop a LUH in a much later stage after the company has consolidated and achieved a stable inflow of capital.

Q9: How reasonable/feasible is such an enterprise in undertaking?

This question could not be answered, since it implicates a more business focused approach and an adequate market and cost analysis. Nevertheless, it can be concluded that building a helicopter in AT-CH for EMS and military would at least be possible from a manufacturing point of view, not including the knowledge required for design, as Kopter is the only qualified firm in this field

STRENGTHS	WEAKNESSES
• AT-CH: Many competences in the aerospace/helicopter sector (Drive Trains, Transmission, Interior, structural components, Mission equipment) • Niche products, • Manufacturing, material & engineering knowledge, • Both countries are very independent (no NATO prescriptions, use second-hand hardware can be widely used) • OEMs: KOPTER, RUAG, DIAMOND, OEM-consortium would bring a lot of knowledge transfer • Suppliers: MECAPLEX, ZOERKLER, PANKL, BÖHLER, FACC, PEAK Technology.	• AT-CH are very small countries, • Techno-economic Greenfield, • Lack of focus/development on helicopters, • High risk-averseness, • Aerospace knowledge is spread, engineering deficiencies, • Foreign know-how necessary on R&D, QA, Certificates; • Industry depends on global partners (e.g. engine suppliers, customers, NATO countries), • "level-of-involvement" (?) • Marketing/Sales and distribution ways (?) • no real helicopter OEM (Kopter is not established yet) • No market overview (no mapping/tracking of firms, certification experts etc.)
OPPORTUNITIES	**THREATS**
• More independence for AT-CH, • High macro-economic volume, • Growing market trends in industry (helicopters, drones, AAVs); • New technologies: (additive manufacturing, smart composites, self-healing structures etc.) • Niches development (helicopter for alpine terrain, "RACER"-concept); • License manufacturing (less effort, buy old TC and do some upgrades); • Chance to development of a modular and retrofit-able platform that fulfils customer needs and has low maintenance costs; • Army could do final assembly (but no civilian flights would be possible!).	• fragile market, military sector too small • increasing customer requirements, • lack of specific know-how: crash requirements, critical loading path, rotor dynamics; • EASA & FAA certification (DOA, POA, TCs etc.) can take very long, • financial risks, delivery lead time; need for financially stable customers and suppliers, • operational risks: MRO, documentation, handbooks, • ensuring continuous spare part logistics; • OEM's utilization; • export laws; • Break-even hard to achieve; • Brexit/Öxit? • No political lobby, political will (?)

Table 26: SWOT Results.

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8. Conclusion & Outlook

In the beginning of the thesis, it was hypothesized that it would be reasonable within AT-CH to build up a local OEM consortium, which is able to manufacture a helicopter for the military, within the local economic zone. This can neither be 100% corroborated, nor 100% disproved as there are too many uncertainties for instance individual company goals, politics and financial stability of a project like this. However, it can be assumed that such an enterprise would at least be possible. Both countries Switzerland and Austria already show a high level of expertise in this field. One the one hand there is Kopter, RUAG, and Mecaplex and on the other, there is Zoerkler, Pankl, Peak Technology, FACC and many others. Manufacturing would not be the big challenge. For the Austrian military, it could be investigated if leasing of already used helicopters is the economic option, at least in the short term. Nevertheless, it could also be tried to purchase an old TC and to assign a consortium to build the machines. However, this would not only require a decent financial backing, but also a sufficient amount of machines which have to be built in addition in order to break even and sold to other militaries or civilian customers, which also requires proper certification, which bears in itself a certain financial risk due to the long lead times. On a less positive note, it has to be added that there is a lack of helicopter related science and research as well as university education in the field of aerospace engineering. A major flaw of the model was the presented level of detail. This can be enhanced by re-listing the components according to the ATA 100 chapters and maybe applying a Tier Hierarchy. However, it was tried to give a strategic estimate of the actual problem stated, which was done by means of a SWOT analysis. A second goal was to deliver a conception of an optimized manufacturing-network along the value-chain for the most important main-components of the LUH. This involved the design/development of a stylized depiction of firms corresponding to a simplified helicopter-model, which resulted in the VCM. This model could help to solve similar problems in value chain or supply chain mappings. For instance:

- How would a VCM look like for a manufacturing robot assembly or an AAV?
- Which consortium could build a moon rocket in Europe?

The VCM could also be enhanced by means of digitalization. It can be tried to develop a state-of-the-art software tool for strategic value chain planning by the management, which uses databases and is connected to a company's ERP. This could also fit very well into the context of digitalization, industry 4.0. Besides, it also offers possible options for business modelling.

In the process of comparing the skills of the Austrian and Swiss companies, it was discovered that there could be also a potential on the market to provide even more turnkey solutions for OEMs, as there is almost no competition in some fields (e.g. windows, seats). Besides, it was discovered that a company providing helicopter blades or rotor heads was completely missing in this area. If there were more suppliers to choose, a helicopter OEM could then try to develop a maintenance-friendly and modular platform and could provide more configurations for the customers. Customer requirements are increasing and more modularity could therefore become a possible solution. Hence, more research can also cover a comparison of modular platforms (using building blocks) to the older integrated models and possible materials/manufacturing technologies. Beyond that there could also be investigated, how a smart production layout for a helicopter could look like.

Further ideas for investigation could also to compare a license production to a home-grown helicopter development and doing research on the advantages and disadvantages of both as well as on the capacity and individual interest of firms.

Other topics, which could not be covered in their full scale in the Master Thesis, can also be a starting point for further research. For instance: Development of an AT-CH concept for a helicopter, case study on Kopter and other OEMs, Helicopter production lines in the context of industry 4.0, market research on what types of LUH with which specifications are required on a global scale, which niches would be available etc. It seems that possibilities from here on are endless, and the interviews can give the reader many inspirations.

I hope that this thesis can inspire others to bring up new topics for academic research, for people in the industry as well as for aerospace enthusiasts.

9. Bibliography

Advameg Inc. (publ.) (2006): *How Products are made (Vol. 1): How a Helicopter is Made* http://www.madehow.com/Volume-1/Helicopter.html [accessed 8.8.2018]

Aeronautics.at (2018): *FACC*, Vienna: BMVIT https://aeronautics.at/organisations/facc [accessed 5.8.2018]

Aeronautics.at (2019): *SECAR*, Vienna: BMVIT https://aeronautics.at/organisations/secar [accessed 28.1.2019]

Aeronautics.at (n.y.): *About*, Vienna: BMVIT https://aeronautics.at/about/ [accessed 5.8.2018]

Air Force Technology (publ.) (2018): *H145M Battlefield Support Helicopter* https://www.airforce-technology.com/projects/h145m-battlefield-support-helicopter/ [accessed 7.8.2018]

Air Force Technology (publ.) (n. y.): *SA316 / SA319 Alouette III Light Utility Helicopter* https://www.airforce-technology.com/projects/a316sa319alouetteiii/ [accessed 7.8.2018]

Airbus Helicopters (publ.) (2016): *Airbus H135M Brochure*, Marseille: AIRBUS HELICOPTERS https://www.airbus.com/content/dam/corporate-topics/publications/brochures/H135M-Brochure-Presentation.pdf [accessed 7.8.2018]

Airbus S.A.S. (publ.) (2015): *First Airbus Helicopters final assembly line in China to be set up in cooperation with Sino-German Ecopark* https://www.airbus.com/newsroom/press-releases/en/2015/10/first-airbus-helicopters-final-assembly-line-in-china-to-be-set-up-in-cooperation-with-sino-german-e.html [accessed 31.10.2018]

AS9100 Store (publ.) (2019): *What is AS9100?* https://as9100store.com/aerospace-standards-explained/what-is-as9100/ [accessed 2.1. 2019]

Austrian Federal Economic Chamber; BMVIT (publ.) (2018): *Fresh View on Aviation Technologies*, Vienna: BMVIT, WKO https://aeronautics.at/downloads/fresh-view-2017-160-aviation-technologies.pdf?m=1497448954& [accessed 10.08.2018]

Bell Textron Inc. (publ.) (2018): *Bell 429 Product Specifications* http://www.bellflight.com/commercial/bell-429 [accessed 7.8.2018]

Bentley, Steven (2016): *Introduction to EASA Part 21 – Overview of Subparts* https://sassofia.com/blog/introduction-to-easa-part-21-overview-of-subparts/ [accessed 6.1.2019]

Bittner, Walter (2009): *Flugmechanik der Hubschrauber: Technologie, das flugdynamische System Hubschrauber, Flugstabilitäten, Steuerbarkeit*, 1st ed., Berlin/Heidelberg: Springer Verlag

Bundesheer (publ.) (n.y.): *"Alouette" III* http://www.bundesheer.at/waffen/waf_alouette.shtml [accessed 28.1.2019]

Central Intelligence Agency (publ.) (2019): *The World Factbook*
https://www.cia.gov/library/publications/the-world-factbook/geos/au.html [accessed 30.01.2019]

Diman, Allen Peter (2014) (2014b): *ROTORCRAFT SYSTEM , MAINTENANCE AND ROLE EQUIPMENT-Helicopter structure pt.3. (Presentation)*, Kuala Lumpur: Malaysian Institute of Aviation Technology
https://www.slideshare.net/partyrocka99/3-week-3-helicopter-structure [accessed 17.08.2018]

Duran, Rebeca (2013): *Helicopter Industries in Brazil*, The Brazil Business
http://thebrazilbusiness.com/article/helicopter-industry-in-brazil [accessed 12.11.2018]

EASA (publ.) (2007): *Explanatory note on POA list*
https://www.easa.europa.eu/easa-and-you/aircraft-products/production-organisations-approvals [accessed 20.8.2018]

EASA (publ.) (2015): *Type-Certificate Data Sheet for PW206 & PW207 Series Engines*, n.p.: EASA
https://www.easa.europa.eu/sites/default/files/dfu/TCDS%20IM.E.017_issue%2007_20151005_1.0.pdf [accessed 7.8.2018]

EASA (publ.) (2018a): *Type-Certificate Data Sheet for Arriel 2 Series Engines*, n.p.: EASA
https://www.easa.europa.eu/sites/default/files/dfu/EASA%20E.001_TCDS_issue%2011.pdf [accessed 7.8.2018]

EASA (publ.) (2018b): *Type-Certificate for Arrius 2 Series Engines*, n.p.: EASA
https://www.easa.europa.eu/sites/default/files/dfu/EASA%20TCDS%20E.029%20at%20issue%2008.pdf [accessed 7.8.2018]

EASA (publ.) (2018c): *LIST OF APPROVED PRODUCTION ORGANISATIONS - Part 21*, n.p.: EASA
https://www.easa.europa.eu/download/poa/easa-apo.pdf [accessed 20.8.2018]

EASA (publ.) (2018d): *List of all EASA DOA approvals*
http://easa.europa.eu/download/doa-adoa/List-of-Approved-DOA.xlsx [accessed 20.8.2018]

EHANG (publ.) (2019): *EHANG 184 - Autonomous Air Vehicle (AAV)*
http://www.ehang.com/ehang184/ [22.12.2018]

FACC (publ.) (2018): *Urban Air Mobility: FACC und EHang mit neuen Lösungen für autonomes Fliegen*
http://press.facc.com/news-urban-air-mobility-facc-und-ehang-mit-neuen-loesungen-fuer-autonomes-fliegen?id=75790&menueid=14307&l=deutsch [accessed 28.1.2019]

Federal Aviation Administration (publ.) (2012): *Helicopter Instructor's Handbook – Chapter 4: Helicopter Components , Sections , and Systems*, Washington: U.S. Department of Transportation
https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/helicopter_flying_handbook/media/hfh_ch04.pdf [accessed 01.07.2018]

Fernandes, Pradeep (2001): *A framework for a strategy driven manufacturing system design in an aerospace environment – design beyond factory floor*, Cambridge: Massachusetts Institute of Technology
https://pdfs.semanticscholar.org/412b/a8d0b5ffec0d417780a2f7c5e23db3c55db3.pdf [accessed 08.08.2018]

Furian, Nikolaus; Neubacher, Dietmar; Mösl, Birgit (2018): *Production Planning & Control (lecture script, chapter 5)*. Graz: Institut für Maschinenbau und Betriebsinformatik

Giptner, Julian (2015): *MD Helicopters MD-902 Explorer - Heli Austria*, Reutte
https://www.airliners.net/photo/Heli-Austria/MD-Helicopters-MD-902-Explorer/2813244 [accessed 31.1.2019]

Heigl, Katrin M.; Rennhark, Carsten (2008): *Zukünftige Wettbewerbsstrategien für Automobilzulieferer: Chancen und Risiken der dritten Revolution in der Automobilindustrie*, 1st ed. Stuttgart: ibidem-Verlag

Held, Volkmar (2015): *Die Luftfahrtgeschichte von Böhler*, n.p.: Voestalpine
https://www.voestalpine.com/blog/de/mobilitaet/luftfahrt/die-luftfahrtgeschichte-von-bohler/ [accessed 28.1.2019]

Hinz, Tashi Dolma (2017): *AERO 2017 : Diamond Aircraft präsentiert den DART-280*,n.p.: Aero Kurier
https://www.aerokurier.de/general-aviation/motorflug/aero-2017-diamond-aircraft-praesentiert-den-dart-280/719918 [accessed 7.8.2018]

Kopter (publ.) (2019): *SH 09*
http://www.marenco-swisshelicopter.ch/ [accessed 29.1.2019]

Leonardo S.A. (publ.) (n. y.): *AW 109 Trekker M Brochure*, Rome: Leonardo S.A.
https://www.leonardocompany.com/documents/63265270/69071306/body_BROCHURE_AW109Trekker.pdf [accessed 7.8.2018]

Malaysian Institute of Aviation Technology (publ.) (2014): *ROTORCRAFT SYSTEM , MAINTENANCE AND ROLE EQUIPMENT-Helicopter structure pt.1. (Presentation)*, Kuala Lumpur
https://www.slideshare.net/partyrocka99/1-week-1-helicopter-structure?qid=d99ab490-dffa-4809-a7e1-ce765bbc4d5b&v=&b=&from_search=5 [accessed 17.08.2018]

MD Helicopters, Inc. (publ.) (2014): *MD 902 Explorer Technical Description*, Mesa (AZ): MD Helicopters, Inc. Sales and Marketing
https://mdhelicopters.com/md-902-explorer.html [accessed 15.08.2018]
Mecaplex (publ.) (2019): *Mecaplex (Homepage)*
https://www.mecaplex.ch/home.html [accessed 29.01.2019]

Mind Tools (publ.) (n.y.): *SWOT Analysis - Discover New Opportunities, Manage and Eliminate Threats*
https://www.mindtools.com/pages/article/newTMC_05.htm [accessed 17.1.2019]

Möchel, Kid; Schreiber Dominik (2017): *Helikopter made in Austria: Hochgeschraubte Pläne für das Bundesheer*, Vienna: KURIER
https://kurier.at/wirtschaft/helikopter-made-in-austria-hochgeschraubte-plaene-fuer-das-bundesheer/283.107.998 [accessed 05.06.2018]

Pankl (publ.) (2019): *Pankl Aerospace*
https://www.pankl.com/products/aerospace/ [accessed 29.1.2019]

Peak Technology (publ.) (2019): *Branches*
https://www.peaktechnology.at/de/branchen/ [accessed 28.1.2019]

Ricardo, Pedro (2013): *Complexo aeronáutico ganha impulso em Minas Gerais com expansão de fábrica da Helibras*, Bairro Serra Verde*: Agência Minas* http://www.agenciaminas.noticiasantigas.mg.gov.br/multimidia/galerias/complexo-aeronautico-ganha-impulso-em-minas-gerais-com-expansao-de-fabrica-da-helibras/ [accessed 30.1.2019]

RUAG (publ.) (2019a): *RUAG Air*
https://www.ruag.com/en/products-services/air [accessed 28.1.2019]

RUAG (publ.) (2019b): *On-Site Final Assembly Support*
https://www.ruag.com/de/produkte-und-dienstleistungen/luft/flugzeugstrukturen-services/fal-support-vor-ort [accessed 28.1.2019]

Schade, Wolfgang et al. (2012): *TAB Arbeitsbericht: Zukunft der Automobilindustrie*, Berlin: TAB
https://www.tab-beim-bundestag.de/de/pdf/publikationen/berichte/TAB-Arbeitsbericht-ab152.pdf [accessed 10.10.2018]

Schiebel (publ.) (2019): *Camcopter S-100*
https://schiebel.net/products/camcopter-s-100/ [accessed 28.1.2019]

Thurber, Matt (2017): *Genesys Wins Flight Deck Upgrade for MD Explorer*, AINonline
https://www.ainonline.com/aviation-news/general-aviation/2017-03-07/genesys-wins-flight-deck-upgrade-md-explorer [accessed 31.1.2019]

Tögel, Robert C. (23.07.2018): *Leichter Mehrzweck-Hubschrauber gesucht*, DOPPELADLER
http://www.doppeladler.com/da/oebh/leichter-mehrzweckhubschrauber/ [accessed 16.08.2018]

Van der Wall, Berend G. (2015): *Grundlagen der Hubschrauber-Aerodynamik*, Berlin/Heidelberg: Springer Vieweg Verlag

Van Weele, Arjan J. (2018): *Purchasing and Supply Chain Management*, 7th ed., Andover: Cengage Learning, EMEA.

Wallentowitz, Henning; Freialdenhoven, Arndt; Olschewski, Ingo (2009): *Strategien in der Automobilindustrie - Technologietrends und Marktentwicklungen*, Wiesbaden: Vieweg + Teubner Verlag

Wannenwetsch, Helmut (2009): *Integrierte Materialwirtschaft und Logistik-Beschaffung, Logistik, Materialwirtschaft und Produktion,* Berlin/Heidelberg: Springer Verlag

Zoerkler (publ.) (2016): *28. Apr 2016: SUCCESSFUL FIRST FLIGHT OF HELICOPTER KA62*
http://www.zoerkler.at/sp/bottom/news/ [accessed 28.1.2019]

10. List of Figures

11. List of Tables

Appendix

Table Of Content:

Appendix Part I

Appendix Part II

1. Interviews and Talks

1.1. Interview with Major General Gruber

Date: 06/15/2018

Place: FH Joanneum

Position/Job description: Commanding "**Air chief**" (Commander of the Air Force) of the Austrian Armed Forces from January 2017 until the end of 2018, responsible for the management of the Air Force.

What is your general opinion on the idea and the hypothesis of the thesis?

The hypothesis and scientific question itself sound very good. It is also a very good topic for a master's thesis in general.

Can you name some of the basic requirements from the functional specification document?

As the document itself is top secret, I am not allowed to pass details out to anyone external. Even though it is not really a secret, since all specifications have been made already years ago, handing it out to private persons is prohibited. This could lead to unfair advantage and companies might sue me for that. However, from a technical standpoint I can give you some hints or explanations and find the necessary information with you together.

What hints can you give regarding general specifications?

First, the helicopter has to fulfil common standards for rescue operations, and those of course are note secret at all. For example, the helicopter has to have a minimum of **two turbines** to be able to remain in flight in the case one becomes defect.

And what is necessary for military specs?

Full **redundancy** of all important **systems**, for example a second fuel line. Very important in terms of "milspec." are IFF (identification friend or foe), governmental and NATO **compatible radio** communication systems, which are not the same used with rescue services and **FLIR** (Forward Looking Infrared) as well as **thermal imaging** modules for reconnaissance missions. What may sets us apart from other armies is our focus on **retrofitting capability**. This has become very important for us, because mission flexibility becomes increasingly important. For fire support missions, it should be able to attach LMG (light machine guns). A nice to have would also be da- and attachable **armour** systems in order to protect the crew. The helicopter does not need to be a flying tank, but at least a bottom and cockpit protection would be good. The seats could be configure able to host Kevlar plates or something similar. Of course, if we have a rescue or disaster relief situation, we need to attach rope windlasses or cargo hooks within a short time! The helicopter, that provides the best mission adaptability, would technically win in our view.

What would be important in terms of the value chain? And where could possible risks be?

Of course, we have to find out if we are capable in terms of R&D, Production, Quality Assurance and Certificates. Beyond that it is very important how to organize maintenance, training and other services. Woho could be a reliable partner for logistics of rotables and spare parts? As end-users, we had most problems in this after market fields and partners often have not been that reliable. If we do a project like this, we may need to have a committed consortium or industry cluster of some kind. There is also the question, who in Austria could fit to be the OEM. This hypothetical OEM also needs to have the right size, a sustainable workload and good utilization in order to survive. Marketing and Sales are the key here, and there you need international distribution ways. But there law and political issues might become problematic, if we want to export a purely militaristic helicopter, as we are still a neutral country. You also included Switzerland in your thesis. That is a good idea, because they have Pilatus manage export somehow, even though they are stricter on neutrality topics and not part of EU. I would be very interested in the difference between their and our juristic situation. We may would have to adapt our doctrine, but therefore we need a very strong lobby. From a technical point of view, we might be able to build most systems and components, but we will face many issues if we want to have a completely independent solution.

Why is that?

Say, if we manage to develop a helicopter, and build it up. Fuselage and interior would be for sure not a problem. Nevertheless, many systems are 100% American made. A very good example would be communication systems, which must be NATO compatible, but also GPS and navigation systems. Buying from Russia and China is not an option due to political reasons.

From all the requirements stated above: Which companies and helicopter types are now in the short list for your procurement?

Bell 429 Global Ranger, Augusta Wasteland AW109 and Airbus is also still on the list with H135M or the H145M. If you want to know our exact requirements from the functional specification document, you really can look into those systems.

Final question: Have there also been talks to Austrian firms?

Of course. We also had talks to Diamond Aircraft in regard of their new helicopter development (Dart 280), which would be quite on time. However, this helicopter is a light training helicopter, like the Robinson. That does not fit into our scheme as we are looking for a replacement for Alouette and Kiowa, which are in a heavier class.

What were the biggest shortcomings?

It is made all from composites with no option for armour or any additional equipment. The space is too small for any transport missions, as the personnel capacity is two pilots plus two people. The biggest problem would be the engines, since they use a piston engine, which are too weak for our operation requirements. Instead, we would need two turboshaft engines.

Thank you very much for the interview! Is there anything you would like to add?

Yes indeed! I think the best option here is to talk to Dr. Marak or Ing. Görlich from the WKO. They were in close contact during all the talks made with the BMLVS regarding this topic and can provide you with deeper economic knowledge. Besides, I always like to help anyone from TU or FH out in future regarding this and similar topics.

1.2. Interview with Stefan Ganahl

Date: 08/17/2018

Place: Telephone call

Position/Job description: Head of flight operations at **Wucher Helicopter**, provider of transport services and professional air ambulance services and also certified for specialized maintenance of helicopters.

What is your view of the topic?

An Austrian helicopter is not a bad idea, but it would face heavy competition. Especially against the market leaders like Airbus now. It will be a challenge to satisfy the increasing customer requirements. This is a giant leap, if you have to begin at zero. A purely Austrian design would be difficult, as you need a lot of expertise. If you look at Kopter in Switzerland: At a trade show for helicopters I was able to meet them in person. They told me that they had hired many engineers from abroad, who brought the necessary knowledge into the firm. Getting the knowhow was a major challenge. There is another thing: in emergency services you would need 2 turbine engines! By now, there is no turboshaft engine manufacturer in Austria, even though we deliver many important components. However, I would like to see the development of a versatile and adaptable platform which offers us a chance to cut maintenance costs and effort.

Where would you see Austrian strengths?

We are really good in structure parts and Interior, but also on the component level (for instance rope windlasses). However, that would already be it.

Which helicopter types are currently in use?

We currently use a broad palette of types, like EC 135 (Gallus 1 and 3 for air ambulance), Airbus AS350, and Bell 412. We also thought of purchasing the MD902 from MD Helicopters, which is used by our main competitor (Heli Tirol) and is a very good machine for rescue operations, and very good from a technical point of view, but we haven’t bought it. Our focus remains on the already existing types.

Why is that? What Are the cons regarding the MD902?

It is a very expensive system, compared to similar helicopters from the market dominator Airbus, like the EC135. The price per unit is higher, but the main disadvantage lies in the spare parts that are very expensive and hard to get and procurement has a longer lead time. Besides, adding another platform can have a lot of disadvantages (certifications etc.). But from the point of view of technology it would be a very good one.

1.3. Interview with Thomas Leitner

Date: 17.12.2018

Place: ACstyria, Raaba-Grambach

Position/Job description: Area Manager Aerospace at **ACstyria** Mobility Cluster

What is an industry cluster and how does it work? Of what kind of companies does it consist of?

This definition is quite diverse. In Europe, Porter's **triple helix model** serves as a basis for many clusters, as it is also the case with ACstyria. This consists of Industry, private enterprise and public authorities and aims to interconnect those institutions optimally, which requires an active management policy. In addition, the so-called public partnership model allows for tight collaboration in between Styrian public authorities and research institutions. However, in the US, a cluster works a bit different even though many companies do the same approach as in Europe. The formation of clusters goes either alongside or through state authorities (e.g. Ohio state). The approach of ACstyria can be described in two points:

1. We define network nodes between the three columns (primarily the private sector and research institutions).
2. We contribute the knowledge required throughout various events: Analysis of current trends, know how networking, project initiation. Finally, bring together the right people (customers, suppliers).

How is the Austrian helicopter industry structured?

The helicopter branch is organized in similar ways to the general aviation and surface aircrafts. There is not really an OEM, except for maybe Diamond Aircraft (in future). So far, full rotorcrafts are only produced by **Schiebl (UAV)**. **Zoerkler** is an important Tier 1 supplier, who provides drive trains especially for rotorcrafts. However, there are manufacturers such as **Pankl and Böhler**, which have their own aerospace department, and lot of **Tier 2 and Tier 3 suppliers**. Furthermore, there are suppliers for **special mission equipment**. Summed up, you have a rather coherent and closed-off group of companies. Nevertheless, there is **no company who identifies itself solely with the helicopter industry yet**. Considering the supply chain, there is no one who really bets on the area of rotorcrafts, not to mention in the field of procurement of parts or the direction of companies that works towards a project like this. But in the end I think we have all necessary components. Maybe an interesting side note here is that Kopter in Switzerland would not have been able to build their helicopter without Austrian help.

What does the market development for rotorcrafts look like momentarily in Europe? Which trends can be expected?

In the last five years the industry has experienced **continuous losses and decline**, due to sinking Oil prices. This also affected the civilian helicopter market. In comparison, the **military sector too small** to really make an impact, but a growth can be expected due to political paradigm shift, as there is now an armament trend in Europe. Airbus forecasts a growing trend in commercial aviation (even though the higher numbers seem to be made artificially, so one should have a scrutinizing look at their statistics). UAVs will become an important factor in the future and rotorcraft companies invest in R&D considering **"urban-air-mobility"** (autonomous air taxis, **passenger drones**). Recently, FACC has announced a joint venture with a Chinese aerospace company (EHANG) to build a passenger drone. They would be responsible for development and production of all structural parts of the aircraft, effectively becoming an OEM. These e-powered drones are already flying! It seems that the Chinese are already a step ahead. Within the range of 25 years, the economic impact of the urban-air-mobility sector could become equal to the traditional helicopter sector.

What are the market implications for Austria considering domestic helicopter manufacturing? What is needed for the success?

If you would ask me in general, whether it can be done I would say yes and no, because it depends. If finances and our existing know how meet market chances, then yes of course. Chances I would rather see in **further developments** of already existing helicopter types than starting completely new on the drawing board. Have a look into Switzerland and what Kopter did there. They were the first ones in 2009 in Switzerland to develop rotorcraft (Sky09) of a decent size, but they are still struggling, not having a POA yet, and have not delivered a single machine up to this day, even though roughly over 200 of them were already ordered in the prephase. However, you can still learn from them how important a **customer's requirement analysis** is. Because of that they had figured out that there is a niche for a special type of helicopters. In this example there was a need for a machine, which would be fit for missions in mountainous terrain, allows for quick conversions and in the end still maintains as light-weight as possible. That's for sure a very good **niche** Kopter has found there. Another idea for a niche could be the "Racer"-concept of Airbus, where they have designed one of the fastest helicopters in world (top speed: 400km/h), due to the combination of rotor and two external propellers. This machine is well suited for fast short-range missions. To sum up, I think that if you have the right thing in mind **there could be really a market for an Austrian made helicopter**. The problem is that no potential OEM would take the **necessary risk.**

What kind of risks besides market risks you stated above would you specify for an enterprise of this kind?

- **Financial risks:** Without dedicated investors a realisation would be impossible. Another problem could be that some of this people might devest if any delays emerge. It is critical to maintain the necessary equity.
- **Technological risks:** The knowhow is essential! Not only you would have to cover specific engineering knowledge, but also organizational and quality knowledge. An often underestimated topic is that of the so-called type certificates (TC). Without acquiring them you will not be able to design and produce an aircraft, hence you will not sell any product. There is a whole bunch of topics which are subject to checking and assessment. For this certificates it would be good to have companies in the cluster who have experience in that topic. They can help with all the necessary testing procedures to minimize all safety relevant risks.
- **Customers and suppliers risks:** The imperative is to find the best of them in both groups. They have to be financially stable and cooperative.
- **Operations risk:** It is crucial to think beyond manufacturing in this matter. A set-up operation also includes customers service, provision of technical handbooks and maintenance as well as after market service. There is a lot behind that!

Who would have the most experience in Austria to potentially be an OEM?

Personally, I would recommend Diamond Aircraft. I am not sure how well their latest helicopter project (Dart 280) is proceeding at the moment, since they are now Chinese owned and they currently do a lot of internal restructuring. But if someone would be able to do it in Austria you would only have to ask them. They have the most experience, as they are already doing well in general aviation. Besides, the leap from general aviation to rotorcraft OEM is easier for them than being a only a supplier. But keep in mind here that market and chances are very fragile at the moment.

How far would manufacturing under a license be an option?

That is probably a question on what is available to buy from whom. Licenses are usually bought from older aircraft types. For STOL (Short Take Off And Landing) airplanes I know two examples where this has been done: Dornier Do 28 and the DHC-6 Twin Otter. It seems to be a good option to buy an older concept and upgrade it to current state of art. However, there are some manufacturing regulations in place that have to be dealt with. For instance, if you want to upgrade this licenced machine, you have to do some changes to its design which have to be certified. These can be distinguished between certificates for minor change (they do not affect the carrying structure for example a new radar system) and major change (e.g. new wing profiles etc.), the last being more difficult to obtain. This is very reasonable, since type certificates (TC) are passed on to other firms. But still this is a problematic aspect. The aircraft industry is a very safety aware, hence heavily regulated branch. You cannot simply recreate aircrafts, like the Alouette, or even components. I think that this should be changed. Getting all the certificates can **take years** and in this time a company will be prone to **financial bankruptcy**. It would probably be better at first to gain the foothold in new developments where hardly any certificates are in place yet, like the passenger drones.

Taking OEM core competences into consideration, which companies would be suited for research, development and production in the fields of…

…airframe and fuselage?

Depends on the particular component. If it comes to composites I would recommend **FACC**, because they have production plants for larger components. They also have a lot of R&D expertise. **Diamond Aircraft** would maybe be a very reasonable choice, since besides being able for airframe R&D, they are also experts for manufacturing of composite fuselages. Metallic structure parts can be done by any **Böhler** firm (e.g. Bleche, Edelstahl etc.) and also by **Peak Technology** and **SECAR**. R&D on materials used could also be done by **AAC**. For the fire-proof engine compartment and housings I would recommend Böhler Edelstahl or Bleche, depending on the dimensions and quantitiy. In the area of metal cutting and machining there are also many possibilities. Böhler would also be able to produce any forged part or structural parts for the landing gear.

…Cockpit and windshield?

As there are not so many suppliers worldwide, so I can hardly think of an Austrian company that can produce the glass parts. But if it comes down to R&D I would suggest **Joanneum Research** and **Polymer Competence Center Leoben**.

…Main- and Tail-Rotor system?

Both can be done by **Pankl**, **Zoerkler** is also able to produce the whole drive train (as they did with the Russian Kamov Ka-62). **Peak Technology** can produce tail rotor blades and have the potential to develop and produce main rotor blades. Eventually, they can also do the rods and spars.

…Doors?

For this size and being mostly composite material: **SECAR**. In theory it could also be a field of activity for **ULTIMATE Transportation**, which produces automated doors for the railway industry. **Peak Technology** could also be a good address for the whole door as well as parts of it.

…Skids? (See airframe)

…Manufacturing of structures and composites?

Know-how on metallic components is not the problem. However, for composites you would face some difficulties, especially for the production of rotor blades and the sub assembling of structures. Getting the small parts is not the problem, but who is able to assemble everything together? Like a whole landing gear for instance? This specific knowledge is still a bit missing in Austria. But from an overall point of view, I would say the competences are there.

…Final Assembly Line?

You could also do some automation here. There is a company called **Bilfinger** from Upper or Lower Austria, which produces all sorts of industrial plants which may be needed for the processing. They are also a supplier of Airbus. All kind of services for the plant can also be provided by **Peer Automation** or **B&R (Bernecker & Rainer)**

Taking supplier core competences into consideration, which companies would be suited for research, development and production in the fields of…

…Transmission assembly?

Here you would not face any problem to get it in Austria (e.g. **Zoerkler**). You can also choose between various approved alloys. Here you have possibly a real turnkey solution.

…Glass Cockpit?

That is a more tricky one. Maybe it is better to talk to Diamond Aircraft about that. Building a cockpit and HMI panels, at least for simulators, is something we have a bit expertise in here in Styria, just thinking here of AXIS Flight Training Systems. But about actual avionics and flight controls I am not so sure.

…Systems?

If it comes to fuel handling you can talk to Magna Steyr Aerospace. They could probably also help with hydraulic systems. Electrical systems I am not sure, but I think that you will at least get the wiring and switches done here.

…Interior?

That is easy to get. Within the Austrian area we have some specialized firms e.g. **F.List GmbH**, which do interior for private jets and can deliver a range of materials including leather seats. But there are also many others(**Antemo** etc.**)**.

What turnkey solutions besides drive trains also exist in Austria?

For communication equipment we have Scotty Group and for larger communication systems FREQUENTIS. Many companies deliver special mission equipment e.g. **Riegl** (Laser scanning devices).

What are your thoughts on the network draft of this master thesis? How could it be enhanced?

We try to do something similar next year. In the past we mostly were trying to fill gaps and found it difficult to relate on a specific product. A quick commentary on the data maybe: Depending in the aircraft we use the so-called Technical Standard Order List. From there you can retrieve the necessary components which are build into an aircraft. Of course, if you have a technical handbook that is already quite ahead. If no detailed plan exists, you can also look into the ATA-chapter and retrieve the components from there. It is internationally valid and provides a list for comparison for each system of an aircraft. Looking at your model I think it is a very good representation. Some tips maybe:

- I would also include cargo interior and special mission equipment.
- Besides the firms it would also be helpful to add another dimension: Certificates. That is a very tricky one of course. I can provide you with a company list in afterwards. If you combine the manufacturing and testing of the vehicle, I think that's already a great leap.

1.4. Interview and Discussion at FH Joanneum (in German)

Datum: 17.12.2018

Ort: FH Joanneum, Institut für Luftfahrt/Aviation (mit Audio File)

Teilnehmer an der Diskussion bzw. Interview: Holger Friehmelt **(F)**, Lukas Andracher **(A)**, Reinhard Puffing **(P)**, Markus Pfister **(M)**

Situation: Diskussion im Anschluss an Präsentation des Themas

Sinngemäße Wiedergabe der Diskussion:

M: Danke für die Aufmerksamkeit! Gibt es schon einmal Fragen vorweg, bevor wir mit dem Interview starten?

F: Ja, was sind denn eventuelle weitere Arbeiten oder wo soll das mittel-und langfristig hingehen?

M: Man könnte das mittelfristig gesehen das Supply-Chain-Mapping noch für andere Hubschrauber- oder Luftfahrzeug- Modelle durchdenken, also nicht nur für den MD902. Langfristig gesehen, gibt es für diese Art der Arbeit im Prinzip noch nicht wirklich eine klare Zieldefinition. Man müsste hier noch erwähnen, dass die Arbeit selbstständig entstanden ist, aufgrund meines Interesses und dem Interesse von Professor Haas. Ich persönlich denke, dass wir mal eine Drohne bauen könnten oder so etwas Ähnliches, dass wir in Österreich vielleicht mal eher klein anfangen sollen. Derzeit sieht es so aus, als ob wir im Bereich LUH noch nicht weiterkommen.

L: Woher kam deine bzw. Professor Haas‘ Motivation für dieses Thema?

M: Das Thema ist vorher noch nie akademisch aufgearbeitet worden. Es hat nur Diskussionen mit Politikern in den Medien gegeben. Die Frage, wie man so etwas hierzulande angehen könnte hat noch keiner genau aufgearbeitet. Professor Haas hatte eine Firma, die im Bereich der Innenausstattung Komponenten herstellt hat. Ich glaube die gibt es noch immer.

L: In Stainz oder?

M: Kann sein.

P: Die eigentliche Motivation ist von der Aussage des ehemaligen Verteidigungsministers gekommen, der gesagt hat, wir möchten einen Ersatz für die Alouette III und die Bell Kiowa, und er hätte gern ein österreichisches Produkt. Das war ein Schnellschuss in den Medien, in vollem Bewusstsein, dass es da keine Industrie gibt, die derzeit dahintersteht. Hast Du dir da am Schluss jetzt nochmal die Lage bei Kopter angeschaut? Die haben jetzt ja, glaube ich, seit letztem Jahr das Design Organisation Approval obwohl andere Zertifikate noch ausständig sind z.B. die Typenzertifizierung (leises Murmeln).

M: Danke für die Frage. Vielleicht eines noch vorweg: Andere Interviews haben ergeben, dass die Zertifizierung anscheinend ein sehr zeitintensiver Prozess ist, und folglich ist so ein Unterfangen sehr Kostenintensiv. Dahinter stand aber eine bestimmte Motivation: Ein Nischenprodukt für Schweiz zu schaffen, das einerseits gebirgstauglich ist und um andererseits zeitgleich die eigene Industrie zu fördern. Auch die entsprechende Nachfrage ist vorhanden. Laut meinen Informationen habe sie im Vorhinein schon zirka 200 Bestellungen bekommen für das Produkt, und über diesen finanziellen Vorschuss haben sie dann die Entwicklung starten können. Aber sie waren auch sehr auf externes Wissen angewiesen, welches noch kaum im Inland vorhanden war. Daher wurden einige Ingenieure aus dem Ausland reingeholt. Sehr interessant ist aber auch, dass sie es ohne österreichische Hilfe gar nicht in dieser Form geschafft hätten, das auf die Beine zu stellen. Wir haben da zum Beispiel viel geholfen, was strukturelle Komponenten betrifft. Bei der Zertifizierung ist, soweit aus der EASA Datenbank hervorgeht, das POA noch immer ausständig.

F: Aha okay. Es wird jetzt vielleicht schmerzhaft, aber an dieser Stelle muss ich Sie (M) jedoch einmal kritisieren. Aus meiner persönlichen Erfahrung im Hubschrauberbereich (Anm.: Studium, Dissertation in Deutschland) nach, möchte ich schon einmal anmerken, dass ein **Break-Even sehr unwahrscheinlich** ist. Die 200 Stück bei Kopter würden nie reichen. Eine lokale Bundesheer Nachfrage von nur 30 Stück zu decken –da habe die Politiker *„wohl nicht richtig nachgedacht" (Anm.: Original Wortlaut leicht abgeändert)*. Sind sie überhaupt schon mal im Cockpit eines Hubschraubers gesessen? Schauen sie sich vielleicht einmal selbst an, wie ein so Hubschrauber geflogen wird, dann würden sie sicher mehr Ehrfurcht hierfür an den Tag legen. Das ist viel abstrakter, als man vielleicht denken würde und als sie das hier darstellen. Das **Wissen zur Hubschrauberdynamik fehlt in Österreich komplett**, zumindest in dieser Klasse, also Drohne ala SCHIEBEL mal ausgenommen. Dasselbe gilt auch in Deutschland und ohne französische Hilfe würde Airbus das nie hinbekommen. Sehen sie sich einmal an, wie lange Airbus gebraucht hat um sich so zu etablieren: 70 Jahre! Zum Thema Zertifikate: Für jedes Teil gibt es individuelle **Typ-Zertifikate**, das heißt eine Firma darf nur diese eine bestimmte Teil für eine bestimmte Verwendung bei einem bestimmten Hubschrauber bauen. So wie es bei ihnen dargestellt ist, kann man höchstens die Erfahrung der Firma bewerten. Ob sie aber das Teil wirklich bauen darf, ist eine komplett andere Frage! Im Übrigen sind bei den Zulassungsbedingungen jene bezüglich der Notlandung am wichtigsten (Crash Requirements: 30fache der Gewichtsbelastung dynamisch, GD). Das zweitwichtigste Requirement ist der kritische Lastpfad, um welchen der Helikopter herum konstruiert wird. Dafür wird hoch-festes **Titan** benötigt und das gibt's in Österreich nicht. Selbst, wenn man es in Österreich schaffen sollte, ein kleines Flugzeug zu bauen, bedeutet das noch lange nicht, dass wir hier dann auch Kampf- oder Rettungsflugzeuge bauen könnten. Wir haben in dem Sektor einfach nicht genug Erfahrungen und schon gar nicht die Mittel.

M: Danke für ihre Einwände. Hier möchte ich aber eines einhaken: **Gilt denn das gleiche auch für den Lizenzbau?**

F: Das ist eine komplett andere Geschichte! Das läuft schon bei der bei der DOA/POA ja ganz anders. Da **würden wir nur das POA brauchen**. Das wäre weit weniger aufwendig. Eine Möglichkeit sei zum Beispiel, dass man einen **Hubschrauber** nicht von der Picke her aufbauen würde, sondern zum Beispiel einen altes TC („Type Certificate") kauft und den Hubschrauber **umbaut, etwa die alten Teile mit eigenen austauschen**. Unter diesen Voraussetzungen würde das schon gehen. Etwas möchte ich auch zum Hubschraubergetriebe anmerken: Das ist so ziemlich die schwierigste Komponente eines Hubschraubers. Alleine schon die Entwicklung ist da hochkomplex aufgrund der mechanischen, dynamischen Beanspruchungen und Wechselwirkungen. Da bekommen sie in Österreich auch schon ein großes Problem: dafür gibt es weltweit mit der Firma ZF den einzigen gescheiten Anbieter. Eines noch zum Cockpit: Da gibt es so viele Dinge, die in speziellen Nischen angesiedelt sind, z.B. Force-Feedback Steuerknüppel, was eine eigene Produktion schwierig macht; es gäbe aber eine süddeutsche Firma, Namen weiß ich jetzt nicht, die das eventuell könnte. Oder im Bereich Sitze: Da gibt es derzeit nur RECARO und das aus gutem Grund: nämlich der langen Erfahrung. Ist in ihrer Arbeit Deutschland auch dabei mit dabei?

M: JA natürlich, und zwar als möglicher Zulieferer, vor Allem, wenn es in Österreich oder der Schweiz keine Alternative gibt! Auch andere Länder wie Polen und Italien und sogar USA.

P: Ja das stimmt. Diese Annahme ist vielleicht am Anfang nicht ganz rübergekommen.

M: **Mit welchen Mitteln lassen sich die Kosten für die Produktion gut einschätzen?**

F: Man könnte ein Abschätzungsverfahren und Rechnung durch Fertigungstechniker machen lassen und dann schauen, ob diese aufginge. Eine komplette Kostenrechnung ist in einer einzelnen Arbeit nicht möglich. Allerdings kann man mithilfe empirischer Formeln eine gute Einschätzung machen. Haben sie so eine zufällig mit reingenommen?

M: Ja ist dabei, basierend auf Kilowatt, Rotorblattanzahl, Antriebstyp usw.

F: Super! Man glaubt nicht, wie genau diese empirischen Aufstellungen der Realität nahekommen. Die sind wirklich sehr genau!

M: Sehen Sie im LUH Sektor überhaupt Chancen für Österreich?

F: Im Light Utility Sektor ginge es schon, dass ist aber grundsätzlich eine politische Frage, da die Entwicklungsdauer schon mal mindestens 10, 20 Jahre und noch mehr betragen könnte. Zu ihrer Darstellung des GOZINTO-Charts bzw. der Stückliste vielleicht eine kurze Bemerkung: Es gibt für ihren Hubschraubertyp sicher auch ein Handbook mit extrem genauer Stücklistenaufzeichnung und Maintenance Manuals. Fragen sie zum Beispiel bei ihrem Interviewpartner bei Wucher Helikopters nach. Diese sind genauer und die Unterteilung ist ganz systematisch. Diese Systematik ist in sogenannten ATA-Kapiteln zusammengefasst, wo jede Komponente genau durchnummeriert ist. Nach den dort aufgeführten Begriffen wird jedes zivile Fluggerät entwickelt, gebaut, gewartet und zertifiziert. Hier könnte man sich auf Fluggeräte oder auf Komponentenebene die ersten drei Ebenen anschauen, womöglich sogar in digitaler Form! Hier bekäme man dann ein allgemeineres, verständlicheres BOM zusammen. Außerdem sollten die wirtschaftlichen Interessen der einzelnen Firmen eingebunden werden. Ich glaube kaum, dass zum Beispiel SCHIEBL ein Interesse hätte an so einem Projekt mitzuarbeiten. Die haben sicher besseres zu tun. Auch eine Seilwinde könnte man hier in Österreich zwar bauen, aber die würde man niemals zugelassen bekommen! Als Firmen mit Gesamtverantwortung als OEM gibt es in Österreich eigentlich nur Diamond.

P: Könnte nicht auch das Bundesheer als OEM bzw. verantwortliche Organisation für die Endmontage in Frage kommen?

F: Militärische Maschinen unterliegen wiederum komplett anderen Voraussetzungen für die Zertifizierung! Klar wird man das Ding zusammenbauen können, aber das Bundesheer dürfte damit niemals zivil fliegen! Bei der Zertifizierung gibt es das sogenannte **„Level of Involvement"**: Behörden prüfen alles auf 100%, gerade wenn man Anfänger ist und noch nie geprüft wurde. Bei solchen Firmen wird jeder Schritt extra getestet und bis ins Detail geprüft- laut der EASA-Länderkontrolle- auf Qualität Zeit und Fehler. Erst, wenn man ein gutes Level erreicht hat, kann man selber Berichte (Zertifikate) erstellen. Solche Lernprozesse dauern aber oft mindestens 5 Jahre! Trotzdem ist es wirklich gut, dass es sowas gibt. Nur so wird die nötige Sicherheit auch gewährleistet.

M: Welche Stärken und Chancen gibt es hierzulande generell im Bereich Luftfahrt?

F: Chancen sehe ich eher in besonderen Anwendungsbereichen wie der Bergrettung. Bei den Stärken bewundere ich vor allem das Mindset! Hier ist man im Gegensatz zu Deutschland ja neutral und lässt sich von der NATO kaum Vorschreibungen machen. Außerdem sin die Österreicher viel mutiger beim Kauf von gebrauchten Fluggeräten, wie zum Beispiel die Passagiermaschinen der AUA. Sowas würde der Lufthansa nicht im Traum einfallen.

M: Wie könnte man die Kapazität der Fertigungsbetriebe gut einschätzen?

Ein Hilfsmittel für die Einschätzung von Firmen für die Fertigung. Da wäreen sie und das Fertigungstechnikinstitut vielleicht bessere Experten. Ein Tipp wäre sicher, sich die Helikopter

Endmontage in Polen anzuschauen z.B. wie viele Arbeitsplätze dort vorhanden sind. Aber das ist eine ziemlich schwere Frage! Sonst könnte man auch schauen, ob es in Literatur etwas zu Speyer (ehem. Theiss-Flugzeugwerke) gibt. Ich könnte bei mir daheim bzgl. Büchern darüber nachschauen! Das ist sicher eine Challenge!

P: Wenn sich das für die jetzige Arbeit nicht aus geht könntest du das auf jeden Fall in den Ausblick schreiben!

M: Vielen Dank! **Möchten sie zur Arbeit noch etwas anmerken? Haben wir mit dem MD 902 Explorer ein gutes Analysemodell genommen oder wäre womöglich anderes besser gewesen?**

F: Das Kommt auf die Art des Vergleiches an. Eigentlich gibt es in diesem Bereich kaum einen Unterschied. Am besten ist immer ein Modell, wo man schon über viele Daten verfügt, dementsprechend war es in diesem Fall passend. Ich finde, ihr Mapping ist extrem gut. Man kann hier sehr gut sehen, was man in Österreich hat. Übrigens gibt es bei uns momentan etwa auch eine Bachelorarbeit zu diesem Thema an der FH Joanneum, die gerade gemeinsam mit ACstyria entsteht und von mir persönlich betreut wird. Wenn sie wollen, können wir ja in Kontakt bleiben. Diese Bachelorarbeit geht aber nur bis Tier 2 und nicht bis Tier 1. Aber man sollte definitiv nicht bei OEM aufhören! Gerade im Bereich Aftermarket gibt es noch sehr viel Darstellungspotential. Das gleiche gilt auch im Bereich der Rohmaterialien: Auch, wenn FACC oder andere Firmen wie Diamond Composite-Teile baut, Lieferanten für die Fasern gibt es weltweit nur zwei! Wenn hier alles konkreter wird, könnten wir uns gerne nochmal zusammensetzen, weil dann die genauen Arbeitsschritte noch klarer ausgearbeitet sind. Da könne wir auch unseren Bachelor-Studenten miteinbeziehen! Leider hast du dir das blödeste Teil überhaupt ausgesucht! Sogar eine Rakete wäre leichter zu bearbeiten gewesen (lacht)!

L: Habe den Namen der Firma von Hrn. Haas gefunden: Peters Engineering in Stainz. Habe mich dort schon einmal beworben.

F: Entschuldigung außerdem für meine Strenge. Das kommt daher, weil ich genau nach Lehrbuch vorgehe. Wenn nicht alle Dinge inkludiert sind, vor allem die Hubschrauber Crash Requirements fällt das einem schon mal auf. Die Konstruktion und die Fertigung gehören nun einmal zusammen. Ich habe jedenfalls ein großes Interesse an ihrer finalen Präsentation beziehungsweise an der fertigen Arbeit! Bitte übermitteln sie an Prof. Haas meine persönlichen Grüße. Es wäre wünschenswert, wenn wir wieder einmal eine eventuelle gemeinsame Einreichung mit Uni/FH machen könnten. Das letzte mal waren wir etwas zu spät dran.

1.5. Interview with Erik Linden (HSG) (in German)

Date: 30.1.2019

Place: IFT, TU Graz (Telefonat)

Position/Job description: Dissertant an der Hochschule St. Gallen, Center for Aviation Competence

Research Topic: Aviation Research Center Switzerland - Competition factors of future Aviation in Switzerland

Geschprächsnotizen:

Generelles Feedback

- Großes Arbeitspensum (Technik und Wirtschaft), schwierig alle relevanten Aspekte mit einer Arbeit allein zu Erfassen
- Daher: Potential für viele unabhängige Forschungsarbeiten
- Technischer Fokus d. Arbeit: spannende Analysemöglichkeiten

Fragen zu Kopter (Wie hat das funktioniert? Was kam aus Österreich? Wer sind die Haupt supplier und was macht Kopter selbst? etc.)

- kann im besten Fall nur Kopter selbst beantworten. Eventuell Anknüpfpunkt für weitere Arbeiten.
- Empfehlung: Kontakt herstellen.
- Man könnte eine Case Study zu Kopter machen: Firma ist aus Engineering-Begeisterung entstanden, ohne zunächst sich mal anzuschauen wie der Markt hier mitspielt. Erfolg der Firma ist noch ausständig.
- Auch Interessant: Case Studies zu anderen Herstellern (z.B Airbus, Leonardo etc.). Wie haben die das gemacht?

Wie schaut das Cluster in der Schweiz aus? Wie ist das Schweizer Aerospace Cluster zusammengesetzt?

- Verweis auf Firmenhomepage: https://swiss-aerospace-cluster.ch/
- besteht aus vielen KMUs, mehr als 100 Mitglieder aus Forschung und Industrie
- Cluster: KMUs siedeln sich rund um einen OEM an
- 1 Arbeitsgruppe für Helikopter (u.A. mit Hrn. Löwenstein, CEO von Kopter)
- Zitat von homepage: *"The working group Helicopter supports the helicopter industry in the area of production and supply of helicopter technology, helicopter business, landing places, education and further training, research of the helicopter area, CAMO and other purposes. The working group also promotes the Elaboration of the first helicopter competence center in Switzerland, based in Mollis (GL)."*
- Das Center of Competence beschäftigt sich u.A. mit der Thematik der Ansiedlung verschiedener Unternehmen rund um den OEM Kopter

Wie groß wäre das Interesse in der Schweiz, an so einem Projekt (AT-CH Entwicklung/ Produktion eines Hubschraubers) mitzumachen?

- prinzipiell eine Frage des Marktes: Zahlt sich das für die KMUs aus?
- Gibt es einen Markt? Wenn ja, welchen? Was ist überhaupt interessant? Warum soll man überhaupt? Welche Produkte kämen infrage? Wie sieht es mit potentiellen Konkurrenten aus?
- Frage stellt sich auch bei Kopter
- Es braucht jedenfalls Neuerungen!

SWOT für einen Hubschrauber "Made in Austria-Switzerland" (Klasse LUH also 2.5t) aus Schweizer Perspektive.

Stärken:

- Unabhängigkeit von anderen Ländern
- Knowledge Transfer (AT-CH)
- Viele Kompetenzen im Bereich Luftfahrt

Schwächen:

- AT, CH: kleine Länder, helikopter-technisch noch nicht weit entwickelt
- Kein Helikopter OEM vorhanden
- Engineering: Kopter hat derzeit zu wenig Mitarbeiter (100 Stellen ausgeschrieben)
- Wenig Firmen involviert/vorhanden im Moment
- Marktüberblick fehlt (Wer baut was? Zertifikate?)
- Teilehersteller schwierig zu finden. Überblick über Supplier, Zertifizierungs-Experten und Forschung ist auch eine Herausforderung für Kopter). Hier können Forschungsarbeiten sehr hilfreich sein und eventuelle Möglichkeiten aufzeigen.

Chancen:

- mehr Unabhängigkeit
- makroökonomisch gesehen gibt es ein riesen Volumen

Risiken:

- Technisches und wirtschaftliches Neuland
- Bei internationaler Supply Chain: Brexit/Öxit? Welche Auswirkungen wären denkbar? Einschätzung nötig.

1.6. Interview mit Professor Sergio Amancio (in German)

Date: 31.1.2019

Place: IMAT, TU Graz (mit Audio File)

Position/Job description: Endowed Professorship for Aviation at **TU Graz, IMAT**; expert on aerospace materials

Bezogen auf das VCM/GOZINTO-Chart: Halten Sie diese Komponenten-Wertschöpfungstiefe für sinnvoll? (Grundsätzlich meine ich die gezeigte Tiefe)

Professor Amancio: Ich glaube, dass war auf jeden Fall **eine gute Übung**. Die Darstellung bietet auf jeden Fall einen guten Überblick über die österreichischen Unternehmen, die solche Projekte abzielen können. Das ist ein guter und **erster Weg auf ein gutes Ziel**.

Hätten Sie einen anderen Ansatz gewählt oder einen Ähnlichen?

Professor Amancio: Das entspricht zwar nicht meinem Fachbereich, aber ich würde den **gleichen Ansatz aussuchen**, also mit dem Produkt, dem System und den Materialien, die hier angewendet werden anfangen. Ich glaube, so würde ich auch anfangen und nicht umgekehrt. Schon wegen der ingenieurwissenschaftlichen Ausbildung, die ich besitze und das finde ich gut.

Im Bereich Produktion. Was muss man hier beachten, wenn man Komposit Teile (Verbundwerkstoffe) und Aluminiumteile fügen will?

Professor Amancio: Das ist sehr unterschiedlich, was die Eigenschaft anbelangt. Es kommt auf die **chemischen Eigenschaften der Werkstoffe** an. Aluminium und faserverstärkte Verbundwerkstoffe sind chemisch sehr unterschiedlich. Eine große Rolle spielt das zum Beispiel beim **Fügen durch Kleben** metallischer Oberflächen anklebt, weil der Klebstoff mit Kunststoff nicht gut bindet und auch mit dem Verbundwerkstoff und mit dem Metall. Hier muss jemand vorher die Oberfläche behandeln. Es kann eine mechanische oder eine chemische Behandlung oder eine **elektro-chemische Behandlung** sein durch **Anodisieren**, damit die Oberflächenbeschaffenheit bzw. die **Oberflächenenergie** des Metalls so ausgeglichen ist wie der Klebstoff. Somit kann man bessere Verbindungen erreichen. Bei **mechanischen Verbindungen** benützt man zum Beispiel **Nietenelemente** der andere **metallische Verbinder**. Es gibt aber größere Limitationen dabei, zwar nicht die Verbindungselemente aber für die **Verbundwerkstoffbauteile**, die in der Regel sehr **kerbempfindlich** sind. Das heißt, dass die **Bohrung**, die man beim Kunststoff machen muss für Verschraubungen oder für Nietverbindungen, bei den Verbundwerkstoffen die **Faserversteifung** and der jeweiligen Stelle zerstört bzw. **schwächt**. Man kann sagen, dass die **Verarbeitung** des Verbundwerkstoffes in der Regel **sehr kompliziert** ist! Man muss hier wirklich sehr viel aufpassen, dass schon beim Bohrungsvorgang der Verbundwerkstoff an der jeweiligen Stelle nicht geschwächt wird. Ansonsten drohen erhebliche Komplikationen. Natürlich gibt es **modernere bzw. noch jüngere Technologien**, die entwickelt werden, die solche Limitationen dann verhindern bzw. verringern sollen. Aber diese sind noch in der **Qualifizierungsphase** gemäß dem **„Technical Readyness Level"**. Dieser ist in der Regel eine **Skala von 1 bis 9**, wobei 1 das niedrigste Niveau ist. **Level 1 entspricht einer Produkt-/Technologie-Idee auf dem Papier**. So wie Sie es hier in ihren Abbildungen zeigen, geht das schon in diese Richtung. **Level 9** entspricht dem bereits **gebauten Hubschrauber**, wenn er schon fertig zum Fliegen ist. Beim Technological Readyness Level 2 und 3 geht es grundsätzlich darum, eine neue Technologie zu Definieren und zu Beschrieben. Level 4 soll schon die zukünftige Funktionstüchtigkeit abbilden können (z.B. durch Versuche). Und dann geht es in diese Richtung weiter: Level 5 und 6 sind schon der detaillierte Versuchsaufbau und Prototyp, bei 7 und 8 für Komponenten- und Systemtests und in Level 9 nach der Erprobung geht es schon zum Markt.

Diese Levels bzw. Grade haben verschiedene Codes sowohl für die Entwicklung von mechanischen Verbindungen als auch für Klebestoffe oder sämtliche andere Technologien, die das Potential haben, die herkömmliche Technologie in der Zukunft zu ersetzen. Die Vorteile der neuen Fügetechnologien sind: sie sind schneller, mit weniger Vorbehandlung und mit weniger Nachbearbeitung.

Welche Verfahren könnte man sehr gut für so einen Hubschrauber (z.B. für den Rumpf aus Metall und Komposit) einsetzen? (Herstellungsverfahren und Fügeverfahren)

Professor Amancio: Es hängt davon ab, was es für ein Teil ist (abhängig von Material, Oberfläche, Struktur usw.). Heute hat man es in der Fertigung zum Teil mit vielen **metallischen Bauteilen** zu tun. Insbesondere **kleinere Bauteile** können heute schon mit Hilfe der **additiven Herstellung** (zum Beispiel Metall pulverbasierend) aktiv hergestellt werden. Heutige Flugzeuge fliegen schon mit diesen Komponenten. Für die Fertigung, zum Beispiel von Titanbauteilen, hat dieses Verfahren großes Potential und man kann damit rechnen, dass es zukünftig sicherlich häufiger und in einer bestimmten Größenordnung in Flugzeuge und vielleicht auch in Hubschrauber vermehrt eingesetzt werden wird. Hochwahrscheinlich wird es auch für Hubschrauber schon angewendet. Für die **Verbundwerkstoffe** nutzt man heutzutage häufig sogenannte **Duroplast-basierte**. Diese sind in der Regel **Epoxid**-basiert oder aus **Formaldehyd** bzw. einer **Kunstharz-Matrix**. Sie sind einfach zu verarbeiten und deswegen auch allgemein etwas **kostengünstiger** im Vergleich zu Thermoplast-basierten Verbundwerkstoffe. Ein Nachteil jedoch ist, das sie teilweise **schlechtere Eigenschaften** besitzen und im Vergleich zu den Thermoplasten **nicht recyclebar** sind. Im Gegensatz zu Thermoplasten können sie nicht wieder eingeschmolzen und geformt werden. Darüber hinaus ist die **Reparatur** von solchen Verbundwerkstoffen auch **kompliziert und aufwendig**, da man die zu ersetzenden Teile lokalisieren und herausschneiden muss und dann eine Art Pflaster darauf klebt (lacht). In der Theorie und in vielen Fällen kann ein **Thermoplast-basiertes GFK** (z.B. Polyamid) **verschweißt** werden, im Vergleich zu den herkömmlichen Verbundwerkstoffen, was einige Vorteile bringt. Allerdings, wie gesagt, sind diese immer noch etwas teurer im Vergleich zum Duroplast-basierenden Verbundwerkstoffen, weil sie eben schwerer zu bearbeiten sind. Es gibt aber einige Wissenschaftler die daran arbeiten, die Verbundwerkstoffe zu **verbessern**. Langsam wird auch an verschiedenen Stellen **geforscht**. In **meiner Arbeitsgruppe** sind wir immer noch in der Erprobung, aber wir haben schon nachgewiesen dass es möglich ist, solche **Thermoplast-basierte Verbundwerkstoffe in 3D zu drucken**. Und nicht nur das, sondern **auch in Kombination mit Metallelementen**. (steht auf und zeigt ein metallisches Profil-Bauteil, eingefasst in einer schwarzen gewebeartigen Kunststoff-Fläche). Zum Beispiel dieses hier, was für die Verstrebung eines Flugzeugs entwickelt worden ist. Das ist ein **Setup-Bauteil**, das schon gebraucht worden ist. Man sieht, dass es in diesem Fall extrudiert wurde. Die Oberfläche wurde für verschiedenen Behandlungen vorbehandelt, wobei untersucht wurde, wie man die Beschaffenheit der Oberflächen verbessern kann. Danach erfolgt der 3D Druck. Das ist etwas neues. Da gibt es **ein Patent von mir**. Es gibt auch eine Doktorarbeit zu diesem Thema. Wir wollen es auch schaffen, die Struktur mit 3D Druck zu produzieren. Das ist noch ein Traum, aber theoretisch möglich.

Der Tail-Boom (ein langer, zylindrischer Hohlkörper) ist laut Hersteller aus einem Aluminium-Komposit Gemisch. Wie könnte man so etwas effektiv herstellen?

Professor Amancio: Es gibt da so ein **„Wickel"-Verfahren**. Man nimmt im Prinzip einen **Korb aus Metall**, dessen Außendurchmesser dem Innendurchmesser entspricht. Und dann kommt man mit einem Roboter oder einer Art Strick-Maschine mit verschiedenen Spinn-Elementen, die den imprägnierte Kunststoff-Fäden von verschiedenen Seiten her um dieses Gerüst herumwickeln, genauer gesagt stricken, wie etwa bei einem Pullover. Nachdem der Zylinder vom Roboter oder einer anderen Maschine umwickelt/umstrickt wurde, stellt man das gesamte Bauteil in eine **Autoklave**, eine

Art Ofen, wo es dann bei einer bestimmten Temperatur gebacken wird, damit die Struktur aushärtet. Die Fasern halten das Bauteil dann formstabil (**Faserneffekt**). Das ist generell der Vorteil der Verbundwerkstoffe. In manchen Fällen kann aber durch den Fasern Effekt die benötigte Steifheit nicht erreicht werden. Dann greift man eher auf solche metallischen Fillings zurück. Diese Strukturen werden dann steifer.

Wie könnte man die Rotorblätter aus Titan, NOMEX und Composite usw. herstellen?

Professor Amancio: Hier kann man **Negativformen** machen. Das sind Werkzeuge mit einem negativen „Fingerprint". Dann wird ein vorbereiteter **Kern** hineingelegt und mit einem Pinsel oder einem Werkzeug das **Harz** aufgetragen, dann eine **Faserschicht**, dann Harz, dann wieder Faser, usw. Dann bäckt man das Ganze in der **Autoklave**, damit das Harz mit den Fasern eine Verbindung eingeht. So ähnlich wird das auch bei der Herstellung von Tragwerken von Flugzeugen gemacht. Bei den Rotorblättern gibt es die Möglichkeit mit Diffusion/Infusion zu Arbeiten. Das Prinzip ist das gleiche. Man nimmt ein Werkzeug mit einer Negativform und legt Fasern in verschiedene Richtungen und dann wird unter Vakuum ein Harz eingesprüht. Dann gibt man das Bauteil entweder in die Autoklave, oder das Ganze wird alternativ in einer Einfüllmaschine gemacht, also ohne Autoklaven, was aber in der Regel aufwändig und teuer ist.

Zum kritischen Lastpfad des Rumpfes: Braucht man an diesen Stellen unbedingt Titan? Welche Materialien könnte man alternativ nehmen? (Anm.: Das Support- Gestänge , „V-Struts", ist laut Hersteller aus Titan)

Professor Amancio: Ich bin zwar kein Hubschrauber Fachmann dafür, aber der Vorteil von **Titan** ist dass es grundsätzlich fester ist. Die sogenannte **„Specific-Strenght"** (Quotient zwischen Festigkeit und Dichte) ist bei Titan sehr hoch im Vergleich zu anderen Materialien. Also für höchst anspruchsvolle Anwendungen würde ich das **auf jeden Fall nehmen**. Einer der Vorteile von Titan ist es, dass wenn man es in **Kombination mit CFK** benutzt (als Verbundwerkstoff), dass es eine **bessere Korrionsbeständigkeit** aufweist als Aluminium, welches anfälliger für galvanische Korrosion ist. Das könnte von Vorteil sein. Sonst ist Titan **teurer als Aluminium**. Man muss jedenfalls **unbedingt begründen** können, weshalb man welches Material es einsetzt. Für das **Gestänge** und andere Trägerbauteile oder Verstärkungen braucht man hochfestes Material. Wahrscheinlich wird hier eine der populärsten Titanlegierungen eingesetzt: **Ti-64**.

Eine Frage betreffend Neuentwicklungen: Welche Werkstoffe neben Titan, Aluminium und Komposite könnten vielleicht in Zukunft noch groß herauskommen?

Professor Amancio: Viele neue Innovationen sind im Kommen. Manche davon werden aber derzeit noch weit unterschätzt. Neben den Aluminiumteilen gibt es da auch Neuauflagen ganz alt-bekannter Legierungen. Mittlerweile gibt es neue **feuerfeste und hitzebeständige Magnesiumlegierungen**, wo man das Problem der leichten Entflammbarkeit nicht mehr hat. Trotzdem ist die **Verfügbarkeit/Reparatur** von Magnesiumlegierungen wesentlich komplizierter und weiteres **Problem** ist die **Korrosionsbeständigkeit**, die unter der von Aluminium liegt. Magnesium hat aber verschiedene Vorteile im Vergleich; mehr als Aluminium. Deshalb wird es in Zukunft auch mehr angewandt. In Zukunft will man, das die Materialien und die **Struktur intelligenter** werden. Man will beispielsweise bei bestimmten Materialien in Zukunft mehr mit Computern kommunizieren können, die in der Lage wären durch einen **externen Stimulus die Form des Bauteils zu beeinflussen**. Zum Beispiel könnten so die Flügel/Aktuatoren aus diesen formbaren Legierungen gebaut werden. Diese Komponenten können sich auch durch bestimmte Temperaturänderungen selbständig, also automatisch ohne Motor bzw. externe Steuerung, verformen. Aber sowas ist derzeit noch weiter Ferne. Das gilt auch für

Verbundwerkstoff-Bauteile mit integrierter Sensorik. Es gibt schon heute die Möglichkeiten, mit Glasfasern Sensoren oder kleinere Sensoren, die Temperatur zu messen oder die Reaktion der Verbundwerkstoffe zu beobachten bzw. ihren Zustand zu detektieren. Das wird in Zukunft eine wichtige Rolle spielen, da sich so die Strukturen selbst überwachen können. In Zukunft wird auch die sogenannte Screening-Matrix mit bestimmten Selbstheilungseigenschaften untersucht. Wenn zum Beispiel ein Riss entsteht, wird hierbei eine Chemikalie angeregt, die dann mit der Matrix reagiert mit der diese heilt. **Smart-Structures**, **Health-Monitoring** und **Self-Healing** sind die drei wichtigsten Komponenten in dieser Entwicklung, also Formgedächtnis-Legierungen, Metall und GFK/CFK mit Self-Healing-Eigenschaften und integrierte Sensorik. Dabei können z.B. Glasfasersensoren oder andere Fasersensoren integriert werden. Das ist, woran wir hier derzeit Forschen.

SWOT-Analyse: Wie würden Sie Stärken, Schwächen, Chancen und Risiken einschätzen für einen OEM, der in Österreich/Schweiz einen Hubschrauber bauen möchte?

Professor Amancio: Leider kann ich dazu kaum etwas sagen, da ich gerade erst dabei bin die Industrie in Österreich kennenzulernen. Es gibt schon sehr viele Unternehmen, die schon gut in Österreich unterwegs sind. Voestalpine, eine **Böhler Edelstahl, Böhler Aerospace stellen Materialien/Bauteile her**, die schon bei den meisten großen Flugzeughersteller Fliegen. Das sind schon sehr starke Vertreter. Die **FACC als Hersteller von Verbundwerkstoffen** für Boeing, Airbus auch für Embrayer ist sind schon sehr gut unterwegs und auch weltweit bekannt. Soviel kann ich im Moment dazu sagen.

1.7. Talk with Stefan Oschkera (MEMO)

Date: 12.6.2018

Place: HSi5, TU Graz

Position/Job description: CEO of SYENTEC GmbH

Memory minutes:

Stefan Oschkera stated that there is no curriculum for aerospace students in Austria. The only real university option possible in Austria today is to do a so-called "studium-irregulare" (as he did at TU Vienna) on an individual basis, taking lectures in lightweight design, turbo-machinery and advanced machine dynamics. University education of talented junior-engineers would be a prerequisite for building up the necessary expertise. Therefore, an estimate of the knowledge situation and distribution in Austria would be very important.

2. Manufacturing Sequence with IDs and colours

Number (ID)		PROCESS DESIGNATION	Colour
A		**Manufacturing of airframe parts**	green
	A1	Preparation of tubular substructure parts	green
	A1-1	Cut tubular raw material	green
	A1-2	Shape bends	green
	A1-3	Stretch forming	green
	A1-4	Machining tube ends	green
	A1-5	Deburring and crack Inspection	green
	A2	Preparation of gussets	green
	A2-1	Machining of gussets	green
	A2-2	Investment casting or forging of gussets	green
	A2-3	Finish machining	green
	A3	Sheet metal parts and details	green
	A3-1	Blank cutting	green
	A3-2	Heat treatment	green
	A3-3	Forming (die pressing)	green
	A3-4	Aging	green
	A3-5	Trimming	green
	A4	Subassembly of airframe parts	green
	A4-1	Chemical cleaning	green
	A4-2	Joining of Al gussets/tubes (MIG)	green
	A4-3	Stress relieving	green
	A4-4	Joining of metal sheets (Riveting/Adhesive Bonding)	green
	A4-5	Inspection of parts	green
	A4-6	Coating/Anodizing	green
C		**Manufacturing of composite parts**	gold
	C1	Shaping of composite components	gold
	C1-1	Core Cutting	gold
	C1-2	Core Trimming	gold
	C1-3	Sandwiching the layups	gold
	C2	Alternative automated shaping method	gold
	C3	Laminating (Autoclave curing)	gold
	C4	After treatment	gold
W		**Windshield canopies and windows**	red
	W1	PC-Cutting	red
	W2	PC-Forming	red
R		**Rotor system manufacturing**	yellow
S		**Preperation of wirings and tubings**	blue
	S1	Manufacturing of wiring harnesses	blue
	S2	Manufacturing of hydraulic tubing	blue
FAL		**Final Assembly**	purple
	FAL1	Airframe subassemblies	purple
	FAL2	Final assembly and integration	purple
	FAL3	After-assembly activities	purple

3. Summarized Bill of Material (BOM)

RELATIONAL BILL OF MATERIAL Component/part	BOM level 1	2	3	CORE COMPETENCE OEM	Supplier	SUPPLIER COMPANIES & PARTNERS	Production	Development	Research	Country	EASA Part 21 DOA	EASA Part 21 POA	EN/AS 9100
1) AIRCRAFT STRUCTURES & PARTS													
Main Fuselage Assembly				x		HELI OEM Consortium	x	x	x	AT-CH	x	x	x
						BENCH-MARK: Airbus	x	x	x	DE	x	x	0
						Kopter	x	x	x	CH	x		0
						Diamond Aircraft	x	x	x	AT	x	x	
						FACC	x	x	x	AT	x	x	x
						ESCAD		x	x	AT			x
						AAC			x	AT			
						4a engineering		x	x	AT			
						CAE Simulation & Solutions		x	x	AT			
						TU Graz (IWS)			x	AT			
Painting						RUAG AG	x	x	x	CH	x	x	x
Landing Gear Assembly (Skids)	x			x		HELI OEM Consortium	x	x	x	AT-CH	x	x	x
						RO-RA Aviation Systems	x	x	x	AT		x	x
						Magna Steyr Aerospace	x	x		AT	x		x
						TU Graz (IME)			x	AT			
						TU Wien - Institute of Mechanics and Mechatronics			x	AT			
Skid Tubes (Aluminum)		x			x	RO-RA Aviation Systems	x	x	x	AT		x	x
Cross Tubes		x			x	Anton Paar Shape Tec	x	x		AT			
		x			x	RO-RA Aviation Systems	x	x	x	AT		x	x
Elastomeric Dampers		x			x	TU Graz (IWS)			x	AT			
		x				Hutchinson	x	x	x	FR	0	0	0
		x				ANTEMO	x	x		AT			x
Carbide Skid Shoes		x			x	TU Graz (IWS)			x	AT			
						Peak Technology	x	x	x	AT		x	
						MD-Boeing	x	x	x	USA	0	0	0
						ANTEMO	x	x		AT			x

Lower/Center Fuselage Assembly	x	x		HELI OEM Consortium	x	x	x	AT-CH	x	x	x
				FACC	x	x	x	AT	x	x	x
				Kopter				CH	x		0
				Diamond Aircraft	x	x	x	AT	x	x	
				SCHIEBEL	x	x	x	AT			
				TU Graz (IME)		x	x	AT			
Bottom Framework (incl. A-Frame & Boat Tail)	x	x		HELI OEM Consortium	x	x	x	AT-CH	x	x	x
				FACC	x	x	x	AT	x	x	x
				Kopter				CH	x		0
				Diamond Aircraft	x	x	x	AT	x	x	
				SCHIEBEL	x	x	x	AT			
				TU Graz (IME)		x	x	AT			
Longerons	x		x	Böhler Aerospace	x	x	x	AT			x
Fuselage Stringers	x		x	Böhler Aerospace	x	x	x	AT			x
Componsite support parts	x		x	SECAR	x	x		AT			x
	x			FACC	x	x	x	AT	x	x	x
Sheet metal details	x		x	System7 Metal Technology	x	x	x	AT		x	
Bulkheads	x		x	Böhler Aerospace	x	x	x	AT			x
Metal panels/plates	x		x	Böhler Aerospace	x	x	x	AT			x
Landing Gear Mount	x		x	Böhler Aerospace	x	x	x	AT			x
Cabin door rails/mounts	x		x	Böhler Aerospace	x	x	x	AT			x
Composite fuselage	x		x	FACC	x	x	x	AT	x	x	x
Maintenance Steps/Holds	x		x	Böhler Aerospace	x	x	x	AT			x
Cabin floor panels	x		x	FACC	x	x	x	AT	x	x	x
				AMTEQ	x	x		AT			x
				ISOVOLTA	x			AT			x
Center Console	x		x	FACC	x	x	x	AT	x	x	x
				SECAR	x			AT			x
				F. LIST	x	x	x	AT		x	
Fuselage strake	x		x	FACC	x	x	x	AT	x	x	x
Fuselage Upper Deck and Aft Area	x	x		HELI OEM Consortium	x	x	x	AT-CH	x	x	x
				FACC	x	x	x	AT	x	x	x
				Kopter				CH	x		0
				Diamond Aircraft	x	x	x	AT	x	x	
				SCHIEBEL	x	x	x	AT			
Upper Frame Parts (incl. Mounts/stators)	x		x	Böhler Aerospace	x	x	x	AT			x
				FACC	x	x	x	AT	x	x	x
				Pankl Aerospace	x			AT	x	x	x

				RO-RA Aviation Systems	x	x	x	AT		x	x
Drive Train mounting deck	x		x	Böhler Aerospace	x	x	x	AT			x
Engine Deck Firewalls	x		x	Böhler Aerospace	x	x	x	AT			x
				TU Graz (IWS)			x	AT			
Tail boom mount (incl. vibration absorber)	x		x	Böhler Aerospace	x	x	x	AT			x
				RO-RA Aviation Systems	x	x	x	AT		x	x
Aft Fairing	x		x	FACC	x	x	x	AT	x	x	x
Tail Boom Assembly		x		HELI OEM Consortium	x	x	x	AT-CH	x	x	x
				FACC	x	x	x	AT	x	x	x
				Kopter				CH	x		0
				Diamond Aircraft	x	x	x	AT	x	x	
				SCHIEBEL	x	x	x	AT			
				ESCAD		x		AT			x
				CAE Simulation & Solutions		x	x	AT			
Tail Boom (Aluminum-Composite)	x		x	FACC	x	x	x	AT	x	x	x
				SECAR	x	x		AT			x
Tail Skid	x		x	RO-RA Aviation Systems	x	x	x	AT		x	x
Empennage mounts	x		x	Böhler Aerospace	x	x	x	AT			x
				RO-RA Aviation Systems	x	x	x	AT		x	x
Empennage Assembly	x	x		HELI OEM Consortium	x	x	x	AT-CH	x	x	x
				Kopter				CH	x		0
				Diamond Aircraft	x	x	x	AT	x	x	
				SCHIEBEL	x	x	x	AT			
				FACC	x	x	x	AT	x	x	x
				CAE Simulation & Solutions		x	x	AT			
				Uni Linz - Institute of Fluid Mechanics and Heat Transfer			x	AT			
Horizontal Stabilizer	x		x	FACC	x	x	x	AT	x	x	x
				Böhler Aerospace	x	x	x	AT			x
				AMAG Rolling	x	x		AT			x
				RO-RA Aviation Systems	x	x	x	AT		x	x
Vertical Stabilizer	x		x	FACC	x	x	x	AT	x	x	x
				Böhler Aerospace	x	x	x	AT			x

				AMAG Rolling	x	x		AT			x
				RO-RA Aviation Systems	x	x	x	AT		x	x
Vertical Stabilizer Hinge Post	x		x	Milltec	x			AT			x
Cockpit-, Cabin & Baggage compartment doors		x		HELI OEM Consortium	x	x	x	AT-CH	x	x	x
				Kopter				CH	x		0
				Diamond Aircraft	x	x	x	AT	x	x	
				SCHIEBEL	x	x	x	AT			
Door Latches	x		x	ANTEMO	x	x		AT			x
Door Trim Panels	x		x	AMES	x	x	x	AT	x	x	
Door Fairings	x		x	FACC	x	x	x	AT	x	x	x
				Carbon-Solutions Hintsteiner	x	x	x	AT			
Door Structure Parts	x		x	Böhler Aerospace	x	x	x	AT			x
				AMAG Rolling	x	x		AT			x
				RO-RA Aviation Systems	x	x	x	AT		x	x
Cabin/Door Windows	x		x	Saint Gobain Sully	x	x	x	FR	0	0	0
				MECAPLEX	x	x	x	CH		x	
Windscreen and Nose Area (Cockpit)		x		HELI OEM Consortium	x	x	x	AT-CH	x	x	x
Windshield an glass parts (complete)				**MECAPLEX**	**x**	**x**	**x**	**CH**		**x**	
				Kopter				CH	x		0
				Diamond Aircraft	x	x	x	AT	x	x	
				SCHIEBEL	x	x	x	AT			
				Uni Leoben - Chair of Materials Science and Testing of Polymers			x	AT			
Untransparent Cannopies	x		x	Saint Gobain Sully	x	x	x	FR	0	0	0
				MECAPLEX	x	x	x	CH		x	
Windshield Canopy	x		x	Saint Gobain Sully	x	x	x	FR	0	0	0
				MECAPLEX	x	x	x	CH			
Nose Structure	x	x		HELI OEM Consortium	x	x	x	AT_CH	x	x	x
				Kopter				CH	x		0
				Diamond Aircraft	x	x	x	AT	x	x	
				SCHIEBEL	x	x	x	AT			
				FACC	x	x	x	AT	x	x	x
Inspection Panels	x		x	Saint Gobain Sully	x	x	x	FR	0	0	0
				MECAPLEX	x	x	x	CH		x	
Fairings & Panel Installations			x	FACC	x	x	x	AT	x	x	x
Upper deck fairing	x		x	FACC	x	x	x	AT	x	x	x

				Carbon-Solutions Hintsteiner	x	x	x	AT			
Side fairings	x		x	FACC	x	x	x	AT	x	x	x
				Carbon-Solutions Hintsteiner	x	x	x	AT			
Aft top fairing	x		x	FACC	x	x	x	AT	x	x	x
				Carbon-Solutions Hintsteiner	x	x	x	AT			
Rotor Head Fairing	x		x	FACC	x	x	x	AT	x	x	x
				Carbon-Solutions Hintsteiner	x	x	x	AT			
Access Doors	x		x	FACC	x	x	x	AT	x	x	x
2) TURBOSHAFT- ENGINES											
P&WC 207 E Turboshaft Engine			x	Pratt & Whitney Canada	x	x	x	CAN	0	0	0
				MTU	x	x	x	DE	x	x	0
				Pratt & Whitney Rzeszów SA.	x	x	x	PL	x	x	0
				PBS Aerospace	x	x	x	CZ	0	0	0
				Safran Helicopter Engines	x	x	x	FR	x	x	0
				ITP Aero	x	x		ESP	0	0	0
				ROLLS-ROYCE PLC	x	x	x	UK	x	x	0
				Böhler Aerospace							x
				Heldeco	x			AT			x
				Haumberger	x			AT			
				FACC	x			AT	x	x	x
				TU Graz (TTM)		x	x	AT			
				CAE Simulation & Solutions		x		AT			
				CBOne		x	x	AT			
				TU Wien - Institute for Energy Systems and Thermodynamics			x	AT			
3) TRANSMISSION & DRIVE TRAIN											
Drive System (complete)			**x**	**Zoerkler**	**x**	**x**	**x**	**AT**			**x**
				TU Graz (IME)		x	x	AT			
				TU Wien - Institute for Engineering Design and Logistics Engineering			x	AT			
Drive System Support Struts (V-struts)			x	RO-RA Aviation Systems	x	x	x	AT		x	x
Drive shafts			x	Pankl Aerospace	x	x		AT	x	x	x

				Peak Technology	x	x	x	AT		x	
Main Transmission (incl. Clutches)			x	Zoerkler	x	x	x	AT			x
				Pankl Aerospace	x	x		AT	x	x	x
				TU Graz (IME)			x				
				Peak Technology	x	x	x	AT		x	
				Pichler & Strobl	x			AT			x
Main Transmission Upper Support			x	RO-RA Aviation Systems	x	x	x	AT		x	x
4) MAIN ROTOR & ANTI TORQUE SYSTEM											
Rotor Mast			x	Pankl Aerospace	x	x	x	AT	x	x	x
Swash Plate Assembly (incl. scissors)			x	RO-RA Aviation Systems	x	x	x	AT		x	x
				Böhler Aerospace	x	x	x	AT			x
Rotor Hub (Hingeless)			x	Böhler Aerospace	x	x	x	AT			x
Control Rods (incl. pitch horns)			x	RO-RA Aviation Systems	x	x	x	AT		x	x
Rotor Blade Assembly		x		HELI OEM Consortium	x	x	x	AT-CH	x	x	x
				BENCH-MARK: Airbus	x	x	x	DE	x	x	0
				Kopter				CH	x		0
				Diamond Aircraft	x	x	x	AT	x	x	
				SCHIEBEL	x	x	x	AT			
				FACC	x	x	x	AT	x	x	x
				Uni Linz - Institute of Fluid Mechanics and Heat Transfer			x	AT			
Rotor Blade Assembly (complete)				**Kaman Aerospace**	**x**	**x**	**x**	**CAN**	**0**	**0**	**0**
				CAE Simulation & Solutions		x		AT			
				TU Graz (IWS)			x	AT			
Flexbeams (Composite)	x		x	Peak Technology	x	x	x	AT		x	
				TU Graz (IWS)			x	AT			
Dampers (Elastomere)	x		x	Hutchinson	x	x	x	FR	0	0	0
				TU Graz (IWS)			x	AT			
Pitch case (Composite)	x		x	Peak Technology	x	x	x	AT		x	
Blade tip balance pocket	x		x	HELIOS	x	x	x	AT			
				Pichler & Strobl	x			AT			x
Trim tab	x		x	FACC	x	x	x	AT	x	x	x

Trailing Edge (Nomex-honeycomb-filled)	x		x	Peak Technology	x	x	x	AT		x	
Blade abrasion strips (Ti)	x		x	CERATIZIT	x	x	x	AT			
				TU Graz (IWS)			x				
				Villinger			x	AT			
				Austrian Institute of Technology			x	AT			
Leading Edge Blade spar (Ti)	x		x	CERATIZIT	x	x	x	AT			
Rotor blade skin panel (fiberglass/epoxy)	x		x	FACC	x	x	x	AT	x	x	x
NOTAR® Fan Equipment			x	MD-Boeing	x	x	x	USA	0	0	0
NOTAR® Thruster Assembly			x	MD-Boeing	x	x	x	USA	0	0	0
5) CABIN INTERIORS & FURNISHING											
Complete Interior			**x**	**AMES**	**x**	**x**	**x**	**AT**	**x**	**x**	
				FACC	**x**	**x**	**x**	**AT**	**x**	**x**	**x**
				Swiss Aviation Interiors	**x**	**x**	**x**	**CH**	**x**	**x**	**x**
(Co-)Pilot seats			x	Greiner aerospace	x	x	x	AT		x	x
				RECARO	x	x	x	DE	0	0	0
				HDEMC	x	x	x	AT			
				ESCAD		x		AT			x
				Milltech	x			AT			x
Utility seats			x	Greiner aerospace	x	x	x	AT		x	x
				HDEMC	x	x	x	AT			
				ESCAD		x		AT			x
				Milltech	x			AT			x
Interior Trim			x	FACC	x	x	x	AT	x	x	x
				HILITECH	x	x	x	AT			
Heated cabin elements			x	Villinger	x	x	x	AT			
Glare Shields			x	Pichler & Strobl	x	x	x	AT			x
6) FCS, COCKPIT & AIRCRAFT ELECTRONICS											
Flight control system		x		HELI OEM Consortium	x	x	x	AT-CH	x	x	x
Flight controls (complete)				**MECAER**	**x**	**x**	**x**	**IT**	**x**	**x**	**x**
				FH JOANNEUM - Institute of Aviation		x	x	AT			
Fly by Wire Cockpit Controls	x		x	Ratier-Figeac	x	x	x	FR	0	0	0
Pedals	x		x	Pichler & Strobl	x			AT			x
				WFL	x	x	x	AT			
				AHC Oberflächentechnik	x			AT			x
				Milltech GmbH	x			AT			x

Collective Control	x		x	RO-RA Aviation Systems	x	x	x	AT		x	x
				Pichler & Strobl	x			AT			x
				Milltech GmbH	x			AT			x
				AHC Oberflächentechnik	x			AT			x
Cyclic Control	x		x	RO-RA Aviation Systems	x	x	x	AT		x	x
				Pichler & Strobl	x			AT			x
				Milltech GmbH	x			AT			x
				AHC Oberflächentechnik	x			AT			x
Control Rod Linkages	x		x	RO-RA Aviation Systems	x	x	x	AT		x	x
				Milltech GmbH	x			AT			x
Vertical Stabilizer Trim Actuator	x		x	TTTech	x	x	x	AT			x
				Böhler Aerospace	x	x	x	AT			x
Avionics (complete)			x	**Leonardo-Finmeccanica**	x	x	x	**IT**	**x**	**x**	**0**
				THALES	x	x	x	**FR**	**0**	**0**	**0**
				Garmin	x	x	x	**USA**	**0**	**0**	**0**
				GE Aviation Systems	x	x	x	**USA**	**0**	**0**	**0**
				RUAG AG	x	x	x	CH	x	x	0
				Kuerzi Avionics	x	x	x	CH	x	x	
				Q.C.M. design	x	x	x	CH	x		
				AIEC		x	x	CH	x		
				FH JOANNEUM - Institute of Aviation		x	x	AT			
Instrument Panel			x	FACC	x	x	x	AT	x	x	x
				SECAR	x			AT			x
				IMB	x	x		AT	x		
Instruments			x	TTTech	x	x	x	AT			x
				IMB	x	x		AT	x		
				SATHOM	x	x	x	CH	0	x	0
				Thommen Aircraft Equipment	x	x	x	CH	x	x	0
Instrument Lights			x	TTTech	x	x	x	AT			x
				Thommen Aircraft Equipment	x	x	x	CH	x	x	0
Communication equipment (TETRA)			x	Ace Aeronautics	x	x	x	USA	0	0	0
				Rohde & Schwarz	x	x	x	AT			x
				Uni Salzburg - Computer Sciences Institute		x	x	AT			

Navigation Systems				JOANNEUM RESEARCH - DIGITAL			x	AT			
			x	Garmin	x	x	x	USA	0	0	0
Cabin Electronics & MM				JOANNEUM RESEARCH - DIGITAL			x	AT			
			x	Atos Convergence Creators	x	x	x	AT			
Controllers			x	TTTech	x	x	x	AT			x
Wiring Harnesses			x	TTTech	x	x	x	AT			x
				KTS	x			AT		x	x
Wiring & BUS Systems	x		x	CCS Akatech	x	x		AT			
				F. LIST	x	x	x	AT		x	
				TTTech	x	x	x	AT			x
				KTS	x			AT		x	x
Connectors	x		x	HUBER+SUHNER	x	x	x	AT			
				TTTech	x	x	x	AT			x
				KTS	x			AT		x	x
Alternator/Generator & Starters			x	Plane-Power	x	x	x	USA	0	0	0
Battery Systems			x	Concorde Batteries	x	x	x	USA	0	0	0
Sensor Systems			x	Airborne Technologies	x	x	x	AT		x	
				TU Wien - Institute of Sensor and Actuator Systems			x	AT			
			x	MEGGIT	x	x	x	CH		x	
Anti Collision Lights			x	Oxley	x	x	x	UK	0	0	0
Antennas			x	KTS	x			AT		x	x
				PIDSO	x	x	x	AT			
FADEC Engine Control System			x	SCHIEBEL	x	x	x	AT			
7) SYSTEMS											
Exhausts & NACA Intakes			x	FACC	x	x	x	AT	x	x	x
Air Vents			x	Pall Corporation	x	x	x	USA	0	0	0
Air Ducts			x	RO-RA	x	x	x	AT		x	x
Oil Cooler & Equipment			x	Safran Ventilation Systems	x	x	x	FR	0	0	0
Filtration Systems			x	Pall Corporation	x	x	x	USA	0	0	0
Environmental Control System (complete)			**x**	**PBS Aerospace**	**x**	**x**	**x**	**CZ**	**x**	**x**	**0**
				MECAER	**x**	**x**	**x**	**IT**	**x**	**x**	**x**
De-Icing Systems				Rheologic		x	x	AT			
			x	Villinger	x	x	x	AT			
				FH JOANNEUM - Institute of Aviation		x	x	AT			
Fuel System (complete)			**x**	**Magna Steyr Aerospace**	**x**	**x**	**x**	**AT**	**x**		**x**

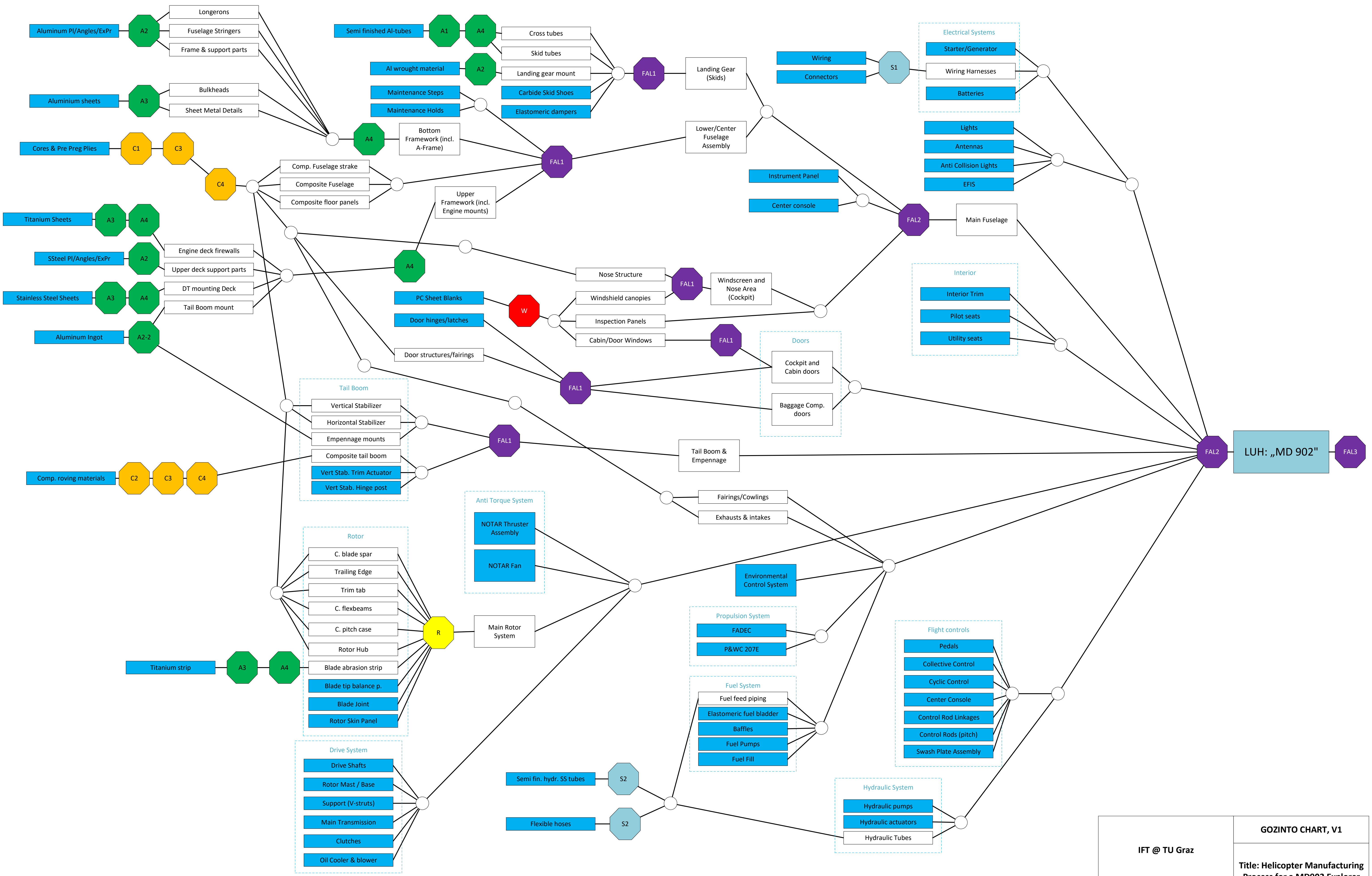
Fuel feed piping	x		x	Magna Steyr Aerospace	x	x	x	AT	x		x
Elastomeric Fuel Bladder	x		x	Magna Steyr Aerospace	x	x	x	AT	x		x
Baffles	x		x	Magna Steyr Aerospace	x	x	x	AT	x		x
Fuel pumps	x		x	Magna Steyr Aerospace	x	x	x	AT	x		x
				Uni Linz - Institute of Fluid Mechanics and Heat Transfer			x	AT			
Fuel Fill	x		x	Magna Steyr Aerospace	x	x	x	AT	x		x
				Rheologic		x	x	AT			
Hydraulic actuators	x		x	TU Wien - Institute of Sensor and Actuator Systems			x	AT			
				EATON	x	x	x	USA	0	0	0
Hydraulic pumps	x		x	EATON	x	x	x	USA	0	0	0
Hydraulic Tubes	x		x	EATON	x	x	x	USA	0	0	0
8) RAW MATERIALS											
Frame parts			x	Böhler Aerospace	x	x	x	AT			x
Aluminum Ingot	x			-	x	x	x	-			
Metal Sheets	x			-	x	x	x	-			
Extruded Profiles	x			-	x	x	x	-			
Aluminum Plates	x			-	x	x	x	-			
Titanium Plates	x			-	x	x	x	-			
Stainless Steel Plates	x				x	x	x				
Composite parts			x	FACC	x	x	x	AT	x	x	x
Cores & Pre Preg Plies	x			-	x	x	x	-			
Rovings	x			-	x	x	x	-			
Poly Carbonate Sheet Blanks				-	x	x	x	-			
Semi Finished Al-Tubes				-	x	x	x	-			
Semi finished hydraulic Stainless Steel Tubes				-	x	x	x	-			
Flexible hoses				-	x	x	x	-			
9) ALTERNATIVE CONFIGURATIONS:											
Tailrotor			x	Peak Technology	x	x	x	AT		x	
Tailshafts			x	Peak Technology	x	x	x	AT		x	
				Zoerkler	x	x	x	AT			x
Engine gearbox			x	Zoerkler	x	x	x	AT			x
				Pankl Aerospace	x	x		AT	x	x	x
				Peak Technology	x	x	x	AT		x	
				WFL	x			AT			
Tail gearboxes			x	Zoerkler	x	x	x	AT			x

Medical & Ambulance Equipment			x	Air Ambulance Technology	x	x	x	AT	x	x	
Police Mission Equipment			x	Air Ambulance Technology	x	x	x	AT	x	x	
Surveilance Euipment			x	Airborne Technologies	x	x	x	AT		x	
Cabin Communication			x	Atos Convergence Creators	x	x	x	AT			
Satellite Communication Equipment			x	SCOTTY	x	x	x	AT			x
Gyro Stabilized Cameras			x	Dynamic Perspective	x	x	x	AT			
Electromagnetic Protection			x	SCHIEBEL	x	x	x	AT			
Glass Cockpit			x	Garmin	x	x	x	USA	0	0	0
NVIS Upgrades			x	Oxley	x	x	x	UK	0	0	0
				IMB		x	x	AT	x		
10) MATERIALS & MANUFACTURING TECHNOLOGIES:											
8) PLC Services & Certification				HELI OEM Consortium	x	x	x	AT-CH	x	x	x
Independent life cycle support (complete)				**RUAG AG**	**x**	**x**	**x**	**CH**	**x**	**x**	**0**
Maintenance, Repair Airworthiness Services				HB-Flugtechnik	x	x	x	AT	x	x	
				AMES	x	x	x	AT	x	x	
				Heliair	x	x	x	AT		x	
Installation Services & Modifications				Heliair	x	x	x	AT		x	
				Urbe Aero	x	x	x	AT	x		
Avionics integration and maintenance				AIEC	x	x	x	CH	x		
PLM				TechniaTranscat		x		AT			
Structural testing				AAC	x	x	x	AT			
				TU Graz (IME)		x	x	AT			
6) Final Assembly Line				HELI OEM Consortium	x	x	x	AT-CH	x	x	x
				BENCH-MARK: Airbus	x	x	x	DE			
				AMTEQ		x	x	AT			x
Assembly Parts				System7 Metal Technology	x	x	x	AT		x	
Automation				MICADO SMART ENGINEERING	x	x	x	AT			x
Assembly Jigs & Tools				Albatros	x	x		AT			
				MICADO SMART ENGINEERING	x	x	x	AT			x
				ALPEX Technologies	x	x	x	AT			x
Material Handling Equipment				MAM Automation	x			AT			

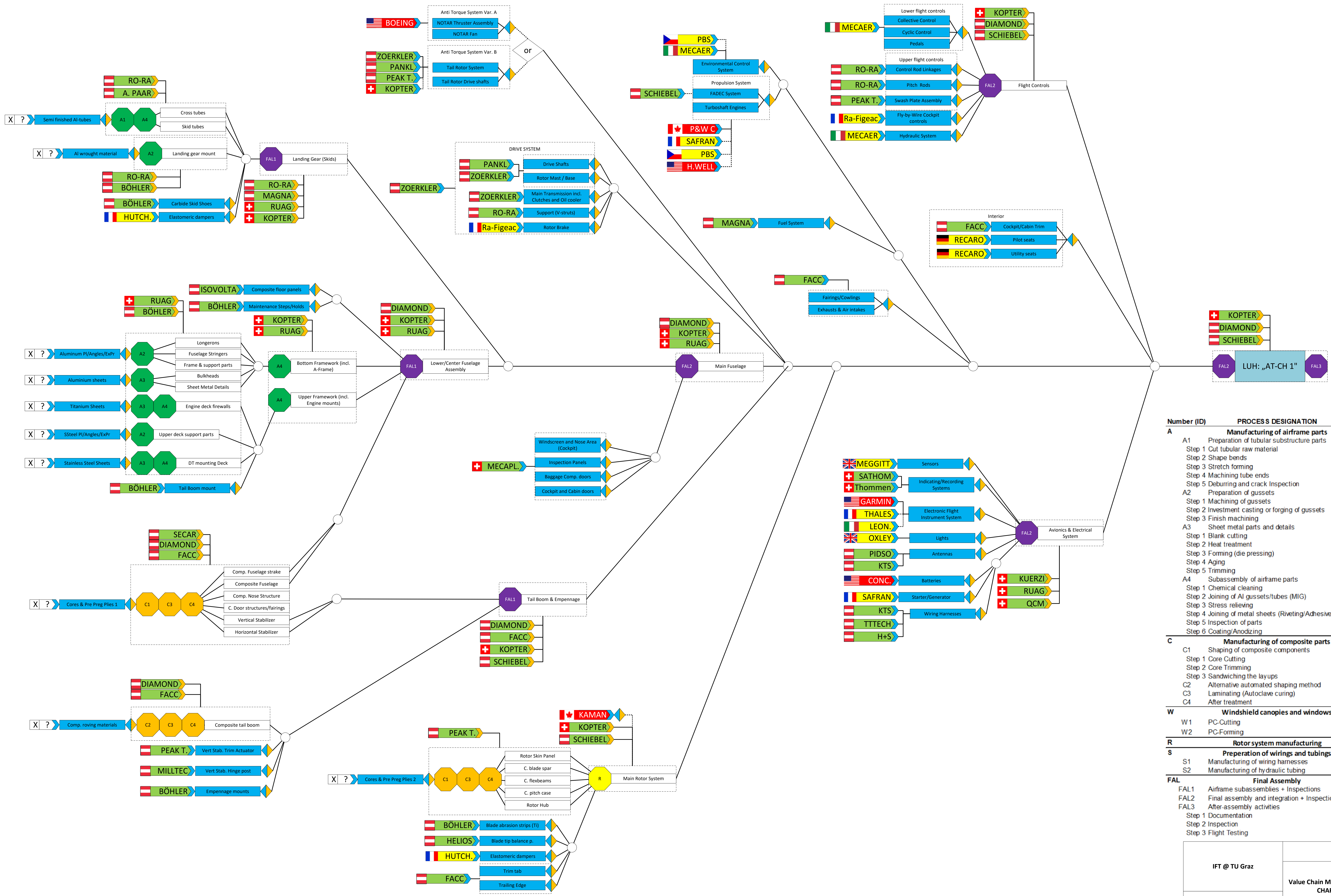
Aircraft Test Equipment	TEST-FUCHS	x	x	x	AT		x	x
	DEWETRON	x	x	x	AT			
	RECENDT		x	x	AT			
	MICADO SMART ENGINEERIN G	x	x	x	AT			x
Service & Maintenance Equipment	TEST-FUCHS	x	x	x	AT		x	x
5) Systems & Controls Manufacturing	Airborne Technologies	x	x	x	AT		x	
4) Rotor Manufacturing	HELI OEM Consortium	x	x	x	AT-CH	x	x	x
3) Poly-Carbonate Fuselage Parts	HELI OEM Consortium	x	x	x	AT-CH	x	x	x
	Saint Gobain Sully	x	x	x	FR	0	0	0
	MECAPLEX	x	x	x	CH		x	
2) Composite Manufacturing	HELI OEM Consortium	x	x	x	AT-CH	x	x	x
	ALPEX Technologies	x	x	x	AT			x
	Carbon-Solutions Hintsteiner	x	x	x	AT			
	4a manufacturing	x	x	x	AT			
	FACC	x	x	x	AT	x	x	x
Composite Handling Tools	ALPEX Technologies	x	x	x	AT			x
Curing Tools	ALPEX Technologies	x	x	x	AT			x
Preform & Layup Tools	ALPEX Technologies	x	x	x	AT			x
1) Airframe Parts	HELI OEM Consortium	x	x	x	AT-CH	x	x	x
Automated production of fuselage segments	RUAG AG	x	x	x	CH	x	x	0
	Böhler aerospace				AT			x
Anodizing	Heuberger Eloxal	x	x	x	AT			
Coating	Heuberger Eloxal	x	x	x	AT			
Heat Treatment	Härterei Michael Welser	x	x		AT			
Cutting	Anton Paar ShapeTec	x	x	x	AT			
Welding	Anton Paar ShapeTec	x	x	x	AT			
	TU Graz (IWS)			x	AT			

4. POA scope-of-work coding, based on EASA (2007), p.1.

A1: Large Aeroplanes	**A6: Sailplanes**	**A11: Very Light Sport Airplanes**	**B4: Propellers**
A2: Small Aeroplanes	**A7: Motor Gliders**	**A12: Other**	**C1: Appliances**
A3: Large Helicopters	**A8: Manned Balloons**	**B1: Turbine Engines**	**C2: Parts**
A4: Small Helicopters	**A9: Airships**	**B2: Piston Engines**	**D1: Maintenance under Part 21A.163 (d)**
A5: Gyroplanes	**A10: Light Sport Airplanes**	**B3:: APU's**	**D2 Issue of permit to fly under Part 21A.163 (e)**



IFT @ TU Graz	GOZINTO CHART, V1	
	Title: Helicopter Manufacturing Process for a MD902 Explorer from OEM Perspective	
Drawn by: Pfister, Markus		
Checked:	DWG No: 1	Rev No: 02
Approved:		
Drawn: 14.12.18	Rev Date:	Sheet No: 1 of 2



Number (ID)		PROCESS DESIGNATION	Colour
A		**Manufacturing of airframe parts**	green
	A1	Preparation of tubular substructure parts	green
	Step 1	Cut tubular raw material	green
	Step 2	Shape bends	green
	Step 3	Stretch forming	green
	Step 4	Machining tube ends	green
	Step 5	Deburring and crack Inspection	green
	A2	Preparation of gussets	green
	Step 1	Machining of gussets	green
	Step 2	Investment casting or forging of gussets	green
	Step 3	Finish machining	green
	A3	Sheet metal parts and details	green
	Step 1	Blank cutting	green
	Step 2	Heat treatment	green
	Step 3	Forming (die pressing)	green
	Step 4	Aging	green
	Step 5	Trimming	green
	A4	Subassembly of airframe parts	green
	Step 1	Chemical cleaning	green
	Step 2	Joining of Al gussets/tubes (MIG)	green
	Step 3	Stress relieving	green
	Step 4	Joining of metal sheets (Riveting/Adhesive Bon	green
	Step 5	Inspection of parts	green
	Step 6	Coating/Anodizing	green
C		**Manufacturing of composite parts**	gold
	C1	Shaping of composite components	gold
	Step 1	Core Cutting	gold
	Step 2	Core Trimming	gold
	Step 3	Sandwiching the layups	gold
	C2	Alternative automated shaping method	gold
	C3	Laminating (Autoclave curing)	gold
	C4	After treatment	gold
W		**Windshield canopies and windows**	red
	W1	PC-Cutting	red
	W2	PC-Forming	red
R		**Rotor system manufacturing**	yellow
S		**Preperation of wirings and tubings**	blue
	S1	Manufacturing of wiring harnesses	blue
	S2	Manufacturing of hydraulic tubing	blue
FAL		**Final Assembly**	purple
	FAL1	Airframe subassemblies + Inspections	purple
	FAL2	Final assembly and integration + Inspections	purple
	FAL3	After-assembly activities	purple
	Step 1	Documentation	purple
	Step 2	Inspection	purple
	Step 3	Flight Testing	purple

IFT @ TU Graz	**Value Chain Model - GOZINTO CHART, V2**	
Drawn by: Pfister, Markus		
Checked:	**DWG No: 2**	Rev No: 02
Approved:		
Drawn: 14.12.18	Rev Date:	Sheet No: 2 of 2