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BLOCKCHAIN

AIRCRAFT SPARE PART MANAGEMENT



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M.Sc. Management of Technology

Blockchain for aircraft spare part management: Evaluating the robustness of the Maintenance, Repair and Overhaul business model

Master thesis submitted to Delft University of Technology in partial fulfilment of the requirements for the degree of

Master of Science

in Management of Technology

Faculty of Technology, Policy and Management

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To be defended in public on September 20, 2018

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Project duration	February 2018 – July 2018
University	Delft University of Technology
Faculty	Faculty of Technology, Policy and Management
Master Program	M.Sc. Management of Technology
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Key words	Aircraft Spare Part Management, Inter-Organisational Information Sharing, Blockchain Technology, Track and Trace, Business Model

TABLE OF CONTENTS

APPENDIX I	CONSULTING 1 – INTERVIEW 1	1
APPENDIX II	CONSULTING 1 – INTERVIEW 2	7
APPENDIX III	CONSULTING 1 – INTERVIEW 3	12
APPENDIX IV	CONSULTING 1 – INTERVIEW 4	17
APPENDIX V	CONSULTING 2 – INTERVIEW 5	23
APPENDIX VI	CONSULTING 2 – INTERVIEW 6	27
APPENDIX VII	CONSULTING 2 – INTERVIEW 7	32
APPENDIX VIII	CONSULTING 2 – INTERVIEW 8	37
APPENDIX IX	MRO 1 – INTERVIEW 9	42
APPENDIX X	MRO 1 – INTERVIEW 10	47
APPENDIX XI	MRO 1 – INTERVIEW 11	52
APPENDIX XII	MRO 1 – INTERVIEW 12	56
APPENDIX XIII	MRO 2 – INTERVIEW 13	58
APPENDIX XIV	MRO 2 – INTERVIEW 14	73
APPENDIX XV	OEM – INTERVIEW 15	74
APPENDIX XVI	OEM – INTERVIEW 16	81
APPENDIX XVII	HEAT MAP JUSTIFICATION	86
APPENDIX XVIII	LITERATURE REVIEW JUSTIFICATION	92

Appendix I CONSULTING 1 – INTERVIEW 1

CHARACTERISTICS

Function: Management Consulting Analyst

Expertise: MRO aircraft spare part management

TRANSCRIPTION

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the relationships between an MRO and its key partners?*

Interviewee: If you look at Boeing, for example, at a moment that a new aircraft (e.g. Boeing 787) enters service, then there is a X number of components that will enter the market. This also relates to the configuration of an aircraft. An aircraft operator that acquires the aircraft does not completely understand which part and serial number is located in which section of the aircraft. To get this clear, it is necessary to engage in extensive interaction with Boeing. As an aircraft operator, you are obligated at all times to fully understand the aircraft configuration. If you can improve this relationship and work together through the Blockchain, you can shorten up the communication lines between the MRO and OEM.

Interviewer: *You mention that it is possible to shorten up the communication lines by using Blockchain. How could this benefit an MRO?*

Interviewee: Considering the Profit-Loss balance, it is always directed on time, capital and compliancy. Compliancy is an interesting issue, since it is difficult to develop a business case until you get caught. The fact is, when you do not operate in compliancy, you face risk. This is an area that you can improve with Blockchain by acquiring the actual part number much quickly. In that sense, you can improve compliancy. Moreover, I think you can save up a lot of time. When you get a new aircraft, engineering must form an opinion (e.g. about the configuration slots, the maintenance requirements, the parts, and which parts can be exchanged). This is an enormous task to process, since you expect an OEM to do this work during the manufacturing and design process of its aircraft. If you draw this throughout the fleet, there is a lot of data entries involved that must at some point be processed in legacy systems. At different MROs they use different legacy systems to process the data. If this can be processed and communicated automatically, it can save up a lot of labour and time.

Interviewer: *To what extent do you think MROs currently focus on reducing the manual data labour? Is this a critical issue?*

Interviewee: Definitely. We currently focus on a tool in which aircraft maintenance is planned and see what the actual aircraft configuration is. This tool would be leading in compliancy checks. In this tool all the information is kept and currently we try to link this with legacy systems (e.g. SAP). It should be possible to purchase the spare part and immediately receive the data (e.g. OEM/usage data). In fact, I think we are already including and building Blockchain-like principles in the tool. However, I have a difficult time seeing how Blockchain can exchange data with legacy systems. For example, MRO X uses a certain maintenance software program for aircraft maintenance and uses it to purchase aircraft spare parts. When I purchase this part, I want to know if I have it and if it is compliant. When I acquire this part, I need all the information and data that is available on the component. This, of course, is connected with existing logistics and its processes. Therefore, I have a difficult time seeing how Blockchain could be aligned with these systems.

Interviewer: *How is information currently exchanged between an MRO legacy system (e.g. SAP) to a different party (e.g. OEM/repair vendor), since there is a lot of processes involved?*

Interviewee: Currently a lot of this information is exchanged manually. Not all lists are maintained in a prehistorical fashion. It is possible to script Excel and load the data on to the system of a different party. However, a lot of the work to exchange information from one system to the other is still done manually.

Interviewer: *What if Blockchain is used to make this information accessible by different parties?*

Interviewee: What you never want is that a different party fully understands your aircraft configuration. At least, I cannot imagine when that is desirable. However, what you do want is that to work together with other airlines in spare part pools. For example, there might be a warehouse in Singapore that contains various aircraft spare parts that is shared between an X number of aircraft operators. For such hubs, it would be amazing to fully understand where each component is and can source it at any moment. There is a lot of capital involved to move the spare part around the world in a short time, which is a huge capital problem for MROs. If you know at all time where a tracked spare part is (e.g. typically more expensive components), you can change your sourcing and purchase strategy. What if you could source and purchase the component from a warehouse in San Francisco. There is a chance this is less expensive than to acquire the component from the standard warehouse in Miami. In this way, you become more flexible in sourcing opportunities.

Interviewer: *How do you think they could use Blockchain to improve maintenance activities?*

Interviewee: A major part of Aircraft Maintenance results from non-routine repairs (e.g. sudden failure). However, the real overhaul/maintenance program is driven by the usage of the spare part. Normally, MRO should have insight on this data and drives when an aircraft will enter maintenance. Based on these due dates, the maintenance planner must ensure that the material arrives before maintenance occurs. If the MRO is not capable to ensure that the material is available, an Aircraft-on-Ground situation develops. This is something you want to prevent. In such situations, MROs have a special department that can source the component from any part in the world, regardless of the financial costs. This is to ensure that aircraft can be released back to service. There are airworthiness directives that state when an aircraft spare part must be modified or maintained. Sometimes the OEM is responsible for part modification. In the situation when trivial information on the components must be sent between parties, it is possible to quickly make errors and here Blockchain could be of great use.

Interviewer: *What if we solve this with Blockchain and RFID tags that automatically process the information? How could this impact the costs of an MRO?*

Interviewee: In theory that seems great, if it is actually used. At some point someone must stick a barcode on the spare part. A few years ago, they tried to do this at an MRO. However, it did not work. In these MRO firms, these engineers work for 40 to 50 years and fully understand how an aircraft works. They have no interest to rely upon IT to tell them how an aircraft must be maintained, since they know everything. Therefore, they did not consistently work with RFID. This could also apply for Blockchain. The quality of Blockchain depends on whether the information is entered consistently. An MRO might have problems to do this consistently. It is an extensive operation, since there are thousands of components that move through the supply chain or enter maintenance each week. The fact that there is a huge quantity of components makes it difficult to integrate Blockchain over an entire aircraft and fleet.

Interviewer: *Why do you think it is difficult to integrate Blockchain?*

Interviewee: We currently face a lot of effort to couple two data models. Excel sheets must be coupled and mapped. There must be a common understanding to make it work. That is the difficulty with Blockchain in this situation. If you maintain the supply chain of beer, it would be easier. An MRO does not manufacture its aircraft. They purchase an aircraft with all the parts and must ensure that equivalent, interchangeable parts are purchased based on predetermined lists.

Interviewer: *So basically, there is a potential positive impact of Blockchain on the MRO partnerships in some situations. However, in other situations, it might not be desirable to expose this information to participants outside of this network?*

Interviewee: MROs typically have a lot of clients, such as aircraft operators. When another aircraft operator suddenly faces a failure in Amsterdam, they can become a new client of the MROs in Amsterdam. What if they need to change or source a component – at such moments it is possible to extend the value proposition if RFID and Blockchain is used. When the client receives the component, it also receives all the data from RFID and Blockchain. This is different from a phone call with a representative, where it is necessary to check whether the part can actually be installed on the aircraft and whether the part actually matches the aircraft configuration. We currently help MROs to develop a stronger value proposition for different partners and clients. Currently it is too difficult and too time-consuming to find the right component that involves a lot of phone calls about where does the component exactly comes from and whether they can use it. With turnaround times, it is about minutes and seconds. If you can improve this in such a way they already know where the component is, it would be possible to limit the communication to one phone call to purchase the part. I am not sure if you can purchase the part through the Blockchain. If you know the traceability of each part and purchase it through the Blockchain, it would be possible to open up a larger market.

Interviewer: *(Explanation of how Blockchain hypothetically allows asset exchange)*

Interviewee: I then wonder, as long as they not all trade with cryptocurrencies, how the IT alignment is realised. From an administrative perspective, I understand how the Blockchain can allow this exchange. However, there should be a trigger from e.g. SAP or a different order system to logistics that a person must physically pick up to deliver a certain part and actually send out the invoice.

Interviewer: *Therefore, you believe it is necessary to invest a lot of time and capital in order to align Blockchain with these existing ERP systems?*

Interviewee: Yes, definitely. This is not an operation that you can realise in two years, since it is a very complex procedure. It is already very difficult for an MRO to automate simple order procedures for these spare parts throughout the entire logistic chain. It requires a lot of effort.

Interviewer: *Could you tell me a reason why it may be difficult for them to track or follow such a part through the chain?*

Interviewee: It is such a complex situation at these MROs. There is scarcity of capital. What this means is that an IT organisation often does not have the necessary capacity to tackle the problems within a normal turnaround time. Therefore, IT projects are typically really time consuming. And as previously mentioned, the average age of an MRO employee is very high. Because of this, every change you want to incorporate faces a lot of resistance and they sometimes refuse to adopt the new method. That makes it very difficult to implement change. It can definitely be done technically, but you definitely need the right manpower and capital

allocated to it. Finding this manpower and capital relies on a strong business case. It would be interesting to identify the unused potential (in terms of speed, quality) of when an MRO would be able to gather new clients if they actually incorporated these IT solutions.

Interviewer: *If I reflect upon the model and focus on key partners: in which scenarios do you think Blockchain can improve or deteriorate MRO relationships?*

Interviewee: In most situations it can definitely improve the situations. However, for example, when the Blockchain is not secure enough and can leak information it might deteriorate relationships. In theory it is still a great idea, since every participant can immediately see what happens with the parts. It should be a win for everyone. I do see a huge issue though. What you want is real-time insight – where is the part, what is the status and when does it arrive. However, everyone throughout the entire value chain should, at all times, be able to sync the ERP system with the Blockchain. A more important question is how much server capacity it requires. What if Airbus updates the systems once per week while a Boeing would update it daily? These logistic issues can still lead to discrepancies in the Blockchain, unless everyone actually uses a real-time tracking mechanic (e.g. RFID).

Interviewer: *Therefore, does this mean that the value of Blockchain does not extend beyond a communication platform for supply chain participants to share information?*

Interviewee: Yes, I think so. If Boeing updates its systems on part number A and changes it to A1 that will immediately be updated in the Blockchain. If an MRO has integrated Blockchain with its IT systems and updates its ERP systems with changes in the Blockchain, without any requirement for manual labour, then it could lead to real benefits.

Interviewer: *If we move onward to the cost structure, we basically notice from the discussion that Blockchain might not necessarily impact the model in general. Transaction costs, personnel costs and inventory cost might reduce in some scenarios, while increasing the cost of IT projects and infrastructures.*

Interviewee: Yes, definitely. I am not sure how these costs relate to each other though.

Interviewer: *Do MROs still send out-of-control components back to OEMs for status verification?*

Interviewee: Well, you would hope not. I am not entirely sure. What this means is that you purchase an unserviceable component, because you do not know if this component is serviceable. If you make it serviceable, it involves certification procedures. I cannot imagine that someone would invest thousands of euros for a component without knowing whether it is serviceable, because you would still need to overhaul it. It seems not plausible. However, a lot that happens seems not plausible, so you might never know.

Interviewer: *If we look at the key resources that we recently discussed, there are different barriers from IT systems and human capacity that make Blockchain adoption a difficult procedure. From a different perspective, what if we use Blockchain – it could potentially result in reduced manual labour as you mentioned. How do you see Blockchain functioning as a key resource or contribute to existing key resources?*

Interviewee: This contribution depends on how you define the functions. You must identify which administrative roles there is and which ones would omit. From an IT perspective, I am not sure yet. I think Blockchain currently is a visual tool that does not necessarily trigger where you would send an order to, reserve a part and actually send someone to physically acquire the part. Not yet at least.

I think it is still a shared logbook that contains information on the spare parts. However, it is important that you can act on this information. It is not a surprise why MROs use specific maintenance tools that shows information on the work scope of the whole fleet and plan maintenance. This will always be a necessary resource, unless the Blockchain could transcend these systems. However, I cannot imagine this. Until this is possible, it is necessary to assure some form of integration between Blockchain and all these legacy systems. As a result, Blockchain will more adopt a dashboard- rather than an acting function. Therefore, I am not sure if Blockchain can improve the decision-making processes. It depends on if you can search on the Blockchain where a spare part with part number X is located. If this is the case, it might be different. However, as an MRO you want to be able to still install this part on your aircraft. In the end, this must still be recorded in the maintenance system. This is because the system must know what you build in the aircraft and whether it is compliant. It must still happen.

Interviewer: *If we look at the value proposition, how do you think Blockchain could solidify and extend the existing MRO value proposition?*

Interviewee: In theory, it is possible. The value proposition is that I offer you something in exchange for something else. In this case, the proposition must also mean that if you also participate with the Blockchain network that we already use, then it can lead to several benefits for the clients. These benefits, however, do not represent the initial value proposition. You must first convince these participants to enable Blockchain and then it is possible to develop the value proposition. I think it is very difficult to develop a business case for a Blockchain network with only one participant. This business case only has right to exist when a party engages in the Blockchain network and receive benefits because other parties also engage in the network (network effect).

Interviewer: *If there are benefits for a party to engage in the Blockchain (e.g. to make parts visible), why would a party not engage in a Blockchain network?*

Interviewee: I think in first case it relates to time and capital. I think it is great if *you* know where all parts are and how you can acquire it cost efficiently. However, if everyone has that same knowledge, people may become more restrained to this idea. If everyone knows where you store your parts, how expensive it is and for what price it has been procured throughout the market – if all information is available, you might lose bargaining position.

Interviewer: *Therefore, you believe that it is a problem for MROs to expose their operations?*

Interviewee: Yes, exactly. If an aircraft operator from Timbuktu enters Amsterdam and suddenly need a part – if they know they can acquire this part for 30 euros and call a local MRO who offers it for 100 euro, then they will decline the offer since the Blockchain could provide them insight on historical transactions. A lot of items and services are overpriced, since there is a high need for it. This is a typical aspect of the airline industry. However, in general this can reduce the overall operational costs. If all the information is available, the market will stabilise itself.

SURVEY

How do you think Blockchain as an aircraft spare part capability could impact the MRO business model?					
Component	Very poor (1)	Poor (2)	Neutral (3)	Good (4)	Excellent (5)
Key partnerships				X	
Key activities				X	
Key resources			X		
Value proposition			X		
Cost structure			X		
Revenue structure			X		
Customer relationships				X	
Customer channels				X	
Customer segments			X		

Appendix II CONSULTING 1 – INTERVIEW 2

CHARACTERISTICS

Function: Management Consultant

Expertise: MRO aircraft spare part management

TRANSCRIPTION

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the relationships between an MRO and its key partners?*

Interviewee: I think that it could potentially be very positive. You will exchange information with partners, which currently already happens. However, MROs has customers for whom they do maintenance. Sometimes these maintenance activities are outsourced to third parties, during which information exchange can occur in the field of spare parts. If all of this can be managed centrally, each party can optimise based on this information exchange. OEMs exchange data with operators and MROs with pool partners. The importance is to maintain aircraft airworthiness, so it is important to have insight on what is available at the partners in order to improve aircraft availability. If you have transparent insight on 1) how much stock anyone has; 2) at which location; 3) what they have; 4) what they could use, this could be provide more insight and security for operators and MROs. As a result, it may be possible for them to reduce their own stock. Basically, it can optimise order and inventory management. OEMs can further optimise their parts database and MROs can improve their maintenance planning, which could impact the underlying costs. If you have improved insight on when something breaks, it is possible to improve maintenance planning. If I stay practical, you notice that MROs engage in contracts with different customers. Based on costs and capabilities, they could determine whether to engage in maintenance or outsource it. If they often outsource the maintenance or acquire customers from other external MRO providers, a lot of information exchange occurs. A lot of flexibility can be acquired if all of this is exchanged through a central platform. Airlines use different systems and databases and struggle a lot to ensure that a lot of data is properly entered and extracted from a maintenance program. In that field I see a lot of short term potential.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO revenue structure?*

Interviewee: The potential problem is that when I have understanding about your inventory stock, where you normally tell me the part is the last one in stock and sold at the highest price, would be no longer be sold at premium price since it is possible to see that you actually have ten more extra parts in stock. You can exchange the information and become transparent, but you lose your negotiation position. You show all your cards and no longer pay the premium price. However, there may also be financial benefits involved. I can imagine that at the moment you engage in adequate inventory management, you could get more demand from the market. When you are transparent, you become more accessible for clients who look for a specific part number and arrives at your place through a search. In that sense, the system can be viewed as a market place in which all this traceability data is provided. If you can manage your demand, you can potentially engage in more contracts with clients. You sacrifice leverage, but as a result of being transparent you can still reap benefits. Not in terms of profit margin, but in terms of volume. Considering the revenue streams of an MRO, they do maintenance for aircraft operators and airlines. MROs typically engage in specific maintenance contracts with its clients. Most planning and preparation is done in-house, but sometimes execution can be outsourced to the client. This engagement is contract based. When you have more insight on the parts that they accept and allow on their fleet, the time that the part is installed on an aircraft, or the parts they include on line maintenance – if you receive all of that in a structured way, it can save a lot of labour for MROs who are required to engage in their client's

maintenance program. As a customer, the maintenance program means that they want to know about everything that is involved in maintenance. If an MRO does their client's maintenance, the process is transparent. However, if the customer changes these components themselves or engages in base maintenance, then it is necessary for MROs to understand what happens through the procedure. Blockchain can help make this visible. Currently this happens through Excel sheets, which must be filled in a maintenance planning software. In terms of volume it can be positive, which could outweigh the loss in profit margin. It is more transparent, you might lose a negotiating position since clients see what you stock. However, you must not forget that time is an important aspect. If you have a failure somewhere with passengers waiting for take-off, the MRO provider still has a negotiating position to put up a premium price regardless of transparency. I think that for routine work, you lose the negotiating position to influence the price due to increased transparency. For emergencies, you maintain this position. The possibilities might outweigh the losses.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO cost structure?*

Interviewee: I think inventory costs can reduce, because of improved order and inventory management. With Blockchain, you have insight on what part lies where for all parties, not just your own inventory. This means that you can optimise over an integral stock instead of optimising it over your own stock. On a high-level the inventory should reduce, since you can optimise over a larger pool. Otherwise, you sub-optimize with only your own MRO spare part inventory and in the new situation you can extend this perspective to an ecosystem. Furthermore, I think IT costs will increase and administrative costs would decrease. Transport costs could decrease, since you have further insight on the location of a spare part (assuming the usage of a RFID tracking system). When you use RFID, visibility of the spare part stream would increase. This means that it is possible to get more insight on this process and manage it. Personnel costs could increase, since the system requires maintenance. I think it is important to mention that reduction of the MRO part purchase can contribute a lot for even a few parts and reduce inventory capital costs. I do not see immediately how maintenance costs itself could be reduced. In the long-term, OEM will provide and feed more data to improve spare part optimisation. They may provide more feedback on how to further optimise the part management. This could result in reduced maintenance costs. Partially, this is the trend of technology in general. The data that is available for OEMs can be used to improve components and maintenance. MROs can base decisions on this data to improve maintenance planning in order to ensure as profitable as possible maintenance. Predictive maintenance is an area in which there is a lot of data available, where the data is sent from the components itself. There are a lot of sensors installed that send the data from the aircraft to a ground station, with which operators and MROs work. However, there is still a lot of potential. If you use Blockchain for these parts, it may be possible to find a connection to Big Data from these (IoT) sensors. If you receive an unserviceable part, it enters the maintenance repair cycle. The more you receive data on the component failure and reason of its removal, the better it is possible to coordinate maintenance. Throughout the process MROs engage in analysis and conclude whether they can engage in maintenance or not. If you, based on location, can already determine what happens, you can reduce transportation costs and time by understanding what locally happens with the part. Through this it is possible to identify to which repair station the part must go to. Secondly, the more information is available of a component, the better it is possible to engage in troubleshooting processes. This has an efficiency benefit, since sometimes it is necessary to disassemble the entire part from the aircraft and start with blank knowledge in the analysis.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO key activities?*

Interviewee: I think there is potential in the acquisition repair process when you know in advance what is wrong with the component, as fast as possible, then you can identify where to send the component and what to do with it. This decision can be done faster and more efficiently. If at the other side you want to provide components to the clients, it starts with a test. You get the request for a part. If I received this request and I have insight on what is available and where, it is possible to ask more focused questions. The Blockchain, where some participants are involved, understand the request for part at a specific location, time interval and scope, then it is possible to determine which part numbers must be used or not. For example: Part A and B is desired by MRO 1, but part C is not. Another MRO may be indifferent whether they receive part A, B or C. In the future, there will still be differences in demand for specific parts. Every operator has their own requirements on what is important for their fleet. For dispatch, the fact that someone has a demand for a part, this can be dedicated to someone who has insight on its availability. For this purpose, Blockchain could provide a positive impact. If we assume that Blockchain can provide more insight on the part demand based on location X, then we can at some stations (e.g. runway Y has a long runway length), these stations might have a higher demand for brakes and tires. This means that the supply of brakes and tires must meet this part. If you can capture this demand through the Blockchain, it can improve the inventory at certain location.

Interviewer: *Ownership is important for people. To what extent is ownership currently important for MROs?*

Interviewee: I think that ownership is an important element in the sense that there is strict control. Authority want insight on how the parts are maintained and its process. MROs want to comply with the regulations set by an MRO. In that sense is data ownership important. If this is not present, then it is difficult to guarantee any failure. This is a data risk. For example: Company X from country Y must maintain this information in country Y, while they keep this information in country Z with service B. From the authority this is even a problem. The data must always be maintained in country Y. With the Blockchain, this might become an issue, where all the data is duplicated everywhere. If they already are strict about data control and where it is stored, it becomes a real issue who becomes owner of the Blockchain. From my point of view, they do not want this information in a different country. If country Y, for example, enters a conflict with country Z. Then country Z can hack service B and request all sensitive information of an airline or MRO in country Y. I think this is one of the largest challenges of Blockchain. You cannot make any mistakes in this business and is punished immediately. It is important that the data upon which you make the decisions is correct. At the moment you keep the data to yourself, you gain direct control and ownership of the data. If any mistake is made, you assume responsibility. If you share this information and make it transparent, it may raise the question who is responsible of maintaining the data quality and integrity in the Blockchain. The data is shared between different parties, starting at an OEM, where an MRO eventually interacts with. An independent party, such as a regulator, should maintain oversight over the ecosystem. They should 1) determine who should enter the system, 2) assure that no party would pollute the system, 3) assure that each party follow the right processes, 4) assure that each party have the right capabilities to participate. The central party must not provide input to the Blockchain network, but it can benefit from a network that is well structured and have full insight on whether any component related action is done in a compliant manner.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO key resources?*

Interviewee: In terms of human capacity, the Blockchain might result in few required administrative capabilities where people are focused on what to do with the data. At that moment it is possible to focus more on tasks that contribute to the business. However, it is necessary to have Blockchain capabilities. Currently, people understand traditional ERP and IT system. It is necessary to develop the necessary capabilities to establish and maintain the systems required for Blockchain, which requires a lot of time and effort. Blockchain would probably not replace any existing system. It would be necessary to connect the Blockchain with existing IT systems. The MRO landscape is very complex and vary per company. Some have a huge number of business units (e.g. supply chain, aircraft maintenance). Some choose for one system, others choose for two and others for three. There is a lot of difficult integration between these legacy systems. But, it would be a real challenge to actually fit the Blockchain somewhere in such an architecture. It is necessary to start such an endeavour small, show that it actually works and then slowly extend it out.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO customer relationship?*

Interviewee: It can be more focused on the contract and the strategic future. It takes away noise when it is not necessary to focus on parts and how information should be exchanged, since the Blockchain could improve this engagement. Otherwise, in the field of parts you know exactly what you can offer to another party and what they can offer you. There is less bargaining. It might be good for relationship when there is more transparency. Long-term there might be benefits. Short-term it might be difficult to get accustomed to sharing data with other parties. You do not know if they can use the data to make analysis and improve their fleet. You could sacrifice your competitive position. However, I think we have not spoken about the compliancy of the entire fleet of an operator. This can improve at the moment you are more transparent with the data. If I loan the part or receive a part from a vendor, if I know exactly what data is involved and exchanged with each part, the total compliance and control of the fleet will increase through Blockchain. At the moment you simply do not know exactly what the origin of each component is – you know the part, part number and part serial number and that is all you know. I think this is an important benefit of Blockchain usage and can yield positive impact. Exchange and loan services can benefit from Blockchain. In Asia MROs use different tires (and thus different part numbers) than in Europe. At the moment we have insight in that, we can appropriately register it at the moment we use a tire from an Asian airline. That means you are more in control over the configuration of your aircraft.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO customer channels?*

Interviewee: In the end there might be a new web-based portal. It would be great if it is possible to show a pilot or demo of the Blockchain to the clients. It may be easier for customer representative to establish contracts.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO customer segments?*

Interviewee: There are aircraft operators who require part maintenance. It is important to realise that partners and customer segments are intertwined. An MRO client could also be a different MRO. Key partners could also act as clients. MRO X might have a capability that MRO B might not have, and therefore outsource their activity to MRO X. When you use Blockchain to group data, what you could maybe do is – if you maintain it as a group you could maybe provide advice based on the whole Blockchain and use it to optimise maintenance. You may have a capability that another MRO may not have that help you acquire more data. Based on that, there may be opportunities for new business models.

SURVEY

How do you think Blockchain as an aircraft spare part capability could impact the MRO business model?					
Component	Very poor (1)	Poor (2)	Neutral (3)	Good (4)	Excellent (5)
Key partnerships				X	
Key activities				X	
Key resources		X			
Value proposition					X
Cost structure				X	
Revenue structure				X	
Customer relationships			X		
Customer channels			X		
Customer segments				X	

Appendix III CONSULTING 1 – INTERVIEW 3

CHARACTERISTICS

Function: Technology Architecture Delivery Senior Manager

Expertise: Blockchain technology

TRANSCRIPTION

Interviewer: *Do you think it is a feasible solution to use Blockchain to not only track and trace aircraft spare parts, but also the documents?*

Interviewee: I do think at the moment it is a little bit difficult to realise. Nowadays there is no production or enterprise level solution that allow you to store large documents on the Blockchain, which means that you have to store it off-chain. This creates an issue, because it is really important for the network and business case to enforce the presence of the paper documents. It is necessary to make a connection to the real world. MROs recognise the importance of document presence, which is why we were looking at how the Blockchain could store the large documentation. Although there are white papers, there are technical solutions to provide this functionality, I never heard about the production of it. Basically, for now, at least what I know, is that the storage of large documents on the chain is currently the largest technological challenge.

Interviewer: *Looking at the function of the smart contracts, could we use the smart contract to use the Blockchain data to create certificates?*

Interviewee: I believe that in terms of smart contracts and complexity, I do not expect issues now. So far, the functionality of the smart contract is not great, but you can program almost everything. We were able to do the pre-implicate of pretty complex calculations and logic. I do not think you need any innovation there. The real focus and challenge is on storing the documentation. For the business case, the airline stores the document. For them it is important to enforce the presence of the document when they are asked. They will actually store the documents and want to be able to retrieve the documents from the past upon request. For now, as I mentioned, I do not know the technology or production solution that will allow you to store the document, since you need to scan it. I currently know no solution that supports it.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the relationships between an MRO and its key partners?*

Interviewee: I believe that Blockchain can significantly improve the relationship, because nowadays airlines are focused on the history of the spare part. There are fake spare parts or parts with unknown history, which can make it difficult and troublesome for airlines to acquire certificates to fly. When they send an aircraft to the MRO for repair, they want to be 100% sure that all the history of all spare parts is in sync in order to acquire the certificates and licenses. Basically, if the whole ecosystem would be able to confirm and track the history of expensive spare parts (e.g. engines), it can significantly improve speed of the process to obtaining the certificates to fly, and therefore the trust and relationships through the ecosystem. Through the whole ecosystem, the history of all the (good) parts will be visible. This will eliminate all invalid spare parts, since you can track the history. In some case, it is not clear if it will directly reduce the cost. It will increase the speed and probably result in associated cost reduction. For the whole ecosystem, it is beneficial since it keeps the supply chain clean and transparent. However, this transparency might not be beneficial for all parties. There are still grey spare parts in the market, which means that transparency would drive out the competition that rely on these parts. It is not a total win-win for all participants. Some may lose their business.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact MRO key activities?*

Interviewee: I believe maintenance could be done faster, since it is easier to find a spare part with a good history. If you will manage a certain coverage of the network, there will be a lot of participants that will bring their spare parts in. It covers the holistic view, result in ability to trade and exchange information. It might improve the speed of maintenance and provide better overview of what is possible. When you have the trusted information shared between the parties, it should be easier to find out when to meet, deliver and it would be easier to predict and develop timelines. Overall, you must keep in mind that there might be less spare parts. For airlines, they will get a clear history and it should be faster for maintenance and improve prediction. They will have an overview of the spare parts that are available and they can be more flexible. Instead of relying upon one MRO, they can rely upon a network of MROs to decide where to do repair. I do have some doubts though. Based on previous history, airlines prefer to have an internal MRO and try to establish the business processes already to mitigate the risks. By introducing the Blockchain solution for them, we actually try to remove the risks for them. As a result, it is necessary to engage in changes for these established business processes, which is normally a painful process in a large organisation. We can support them with this change, since we have a lot of materials and point of views on how to establish and maintain the consortium, how to overcome the change, and how to scale the production solution to an enterprise version. For airlines it will mean that we will assist them in the process. Currently we are trying to design and quantify the benefits. I do not think the work is already done, but we should come up soon with a quantification model for a consortium. Ultimately, I do believe it has more impact on the MRO relationship. The MRO who does their maintenance with clear spare parts will probably get more trust and work. This means that it would be beneficial for MROs to be more transparent if they get more demand, which depends on the ecosystem and support for Blockchain. I can imagine if there is a strange case where a company prefer a grey part that might be cheaper. If everything is done at a high quality, which I doubt on the current maturity state of technology, it should also significantly reduce the paperwork. This is the clear benefit for all the parties. MROs should get more business due to their trustworthiness.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact MRO key resources?*

Interviewee: I believe MROs have enough people, since it should not require more than those supporting the IT systems. With regards to understanding, we are doing a lot of education now. It can take some time to understand that and make clear all the legal parts and changes in the business process. But on technology level they are getting there quickly. They are also educating themselves, and at least large airlines have been active for the past few years. There are a lot of talks. The innovation departments of the airlines are preparing themselves.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact MRO value proposition?*

Interviewee: Logically, having more and structured information, they should be able to recognise new ways of opportunities and activities. They should be able to streamline the business, since they are more trusted than others. What is missing is a holistic view. If we have one ecosystems where there are multiple airlines and MROs, the data set would be much bigger. This will provide a broader view. I can imagine there would be maintenance service providers who analyse the data set as a business in order to provide the prediction as advice on what parts are more reliable. I believe if everyone will do the same, it will improve the overall quality. Unreliable parts and parties should get pushed out of the market. I think this would happen.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact MRO revenue structure?*

Interviewee: There would be increased competition, which airlines should benefit from. It is not beneficial for MROs. This rebalances the market, since we will make information clear and visible. We do not push the business into a peer-to-peer situation but push it into market-based consumption. This will rebalance the market, which means that some will lose and others will win. This might be a scary situation for MROs, because they have a certain position now and might lose it in the future. This also gives the possibility for smaller organisations to enter the picture. If previously only big MROs with clean history with a good name were in the market, nowadays you could have the trust of the network and obtain the spare parts and easily enter the business. This will open doors for the smaller organisation. When they say about the disruptive nature of the Blockchain, that is normally the number one point: the smaller organisations can enter the market segment.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact MRO cost structure?*

Interviewee: The maintenance costs will stay the same, since the process will be digitalised. IT costs should also be the same, since the Blockchain solution is light. Increased speed to market and decreased time to find the necessary part and find the certificate can also reduce the overall MRO costs. In the end, we can see the whole cost of MROs reduce.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact MRO customer channels?*

Interviewee: They would try to put their name high in the list of potential clients. In terms of reaching the customer, I do not think the Blockchain will change anything. I do not think it will create any new channels. The Blockchain will probably be a web or mobile based application. It will only have an impact if MROs do not already use these digital channels.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact MRO customer relationship?*

Interviewee: If everything is digital with enforced trust, it is likely that less people and human interaction is required especially when you rely on the whole history.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact MRO customer segments?*

Interviewee: I think it may unlock new potential ways to do business. They will get new clients and provide new ways to provide services to these clients. There is information you can rely upon and engage in better analytics for clients, prediction, future management of spare parts, pool of spare parts, and different types of repairs. The presence of reliable information and sharing this across the ecosystem should allow the participants to boost their creative thinking of what new services they can provide. The core of the change is that they will have core reliable data set, which they never had before. The presence of this should unlock new business opportunities. The leverage of the data set can enable analytics on terms of which spare parts are more reliable. By tying AI to this granular and analytical information, it should be possible to predict the maintenance and allow airlines to opt for maintenance or data. However, they can find out that an area code is not reliable and change their relationship with the OEM.

Interviewer: *How would you personally convince these parties to participate in such a Blockchain ecosystem?*

Interviewee: It is difficult to convince airlines, MROs and OEMs to participate in the Blockchain consortium. The doubts they have lay in multiple levels. There is fear about the new technology, it is difficult to get the enterprise architecture and IT aligned, and there are unclear benefits for them. This is challenging, since they can see risks in all types, such as IT and business. I believe that the way to overcome that is by leaning on different layers. We are educating them and we bring readiness of the technology to the minimum. Through Proof of Concepts and cocreation, we try to remove the doubts in IT. At the same time, we explore the business benefits with them. We try to quantify the benefits for them and together with them. I think it is important to raise awareness that with Blockchain, the party who initiates it might obtain most of the market. In terms of trust, the party who is longer in the Blockchain network has more trust. When they become aware, they understand they do not want to be the first or third adopter. If there is a party that will be the first adopter, there would be an avalanche of others who want to be the second adopter. The key is to find a partner (e.g. airline) who is able to understand that there is no way back when Blockchain is taking over all parts of the current technology. I believe that in five years, the internet will work on the Blockchain solutions. For technical solutions, a decentralised system is more stable and reliable. If you start with Blockchain, you will face barriers related to technology availability and maturity. But, the first adopter should win the most.

Interviewer: *Who do you think should initiate the Blockchain? To what extent do you think it is possible for a regulator to initiate the Blockchain and invite airlines/MROs/OEMs to participate in it when they company with regulation and standards?*

Interviewee: I have a very strong opinion on that, because I believe if there is someone who owns the solution, you do not need the Blockchain. Basically, the true potential of Blockchain is that nobody wants the ownership. It is the ecosystem that is an owner. The true benefit of Blockchain is that nobody owns it. As soon as you have an owning partner, you can switch to a centralized solution. If the owning party is trustworthy, you do not need the Blockchain anymore. The whole business case lies in decentralisation. Nobody wants to charge others to participate. The true potential is reached when you have an open system. You have the protocol for exchanging the data, information and process. But the client application (node code) can be created by being a participant. That is the necessary level of competition and makes it fear. Basically, I could imagine if you have one owning party that charges the transaction, all participants are vulnerable to what the owner could do. This eliminates the purpose of the Blockchain. The party who is trying to resolve the question which party owns the Blockchain, would be doing it in their own false way or understanding. Basically, if you have a trust party, it is not necessary to set up a Blockchain and rather use a centralised solution that would be more effective. The beauty of the blockchain is for the ecosystem where nobody really trusts each other, but the whole set up is shared. So, nobody pays to somebody to maintain the system and nobody is vulnerable to a central party who decides. This is also the most misunderstood part, because you cannot start coding the Blockchain and sell it to others. You cannot agree with others to participate in such an ecosystem and charge others for transaction. That is not a true Blockchain solution. The true Blockchain solution is that you create a white paper, define the protocol and data set. Then you let participants develop their code and test it against the protocol. This means that you can be sure that the parties satisfy the initial demand purpose, but they have their own code that is competing. New joining parties can choose between adopting these competing codes or develop their own solution, which creates flexibility and trust throughout the ecosystem.

Interviewer: *I understand your opinion on that it would be difficult for a regulator to participate in the Blockchain solution. However, I have a difficult time seeing how this can translate to the Aviation industry. Within the industry, you need an authority regardless of whether a Blockchain solution is present or not. You still have to prove to these authorities what you have done with the spare parts. Given this situation, how do you think the regulator can still be involved in the Blockchain solution?*

Interviewee: Regulators will connect to the network and see everything that happens, from which the network can benefit. The whole data set and process should be created with the regulator in mind in order to provide the necessary data and functionality. This also opens new ways for new types of regulating activities for new organisations. So far, the regulator is the monopolist. Once the presence of the information is available, there might also be competition on this side. If the data is available, the party who does the data analytics better can become the new regulator. They can opt for this and trade their services cheaper to the government. To the certain extreme, when the size of the network would be big enough, there would be no need for a regulator and exchange it with AI. You basically need to check that the information is correct, which is possible to do by computer and you do not necessary to pay or need humans for this. If it is reliable and tamper proof, you do not need the regulator anymore who produce the certificates. You do not even need AI to check whether the data is correct and conditions are approved within limits to produce the certificate. You can code that on the smart contracts, which is not a problem. You basically need AI to improve those roles. No process is absolutely perfect. You need a regulator to improve the process, not to provide certificates. They change the regulators from time to time, and for that you need AI who can adapt to these changes. But to provide the certificates, you can already do that right now. If the logic exists, and if this logic is strict, you can just code it with the smart contract.

SURVEY

How do you think Blockchain as an aircraft spare part capability could impact the MRO business model?					
Component	Very poor (1)	Poor (2)	Neutral (3)	Good (4)	Excellent (5)
Key partnerships				X	
Key activities				X	
Key resources					X
Value proposition			X		
Cost structure				X	
Revenue structure		X			
Customer relationships			X		
Customer channels			X		
Customer segments				X	

Appendix IV CONSULTING 1 – INTERVIEW 4

CHARACTERISTICS

Function: Technology Consulting Senior Manager

Expertise: Overall MRO industry

TRANSCRIPTION

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the relationships between an MRO and its key partners?*

Interviewee: At a certain moment, they need to start exchanging information. When you receive a component from a different provider and you want to install this on an aircraft, you need to be entirely sure that all the data about (e.g. number of cycles/repairs) the component is correct. At the moment, you exchange this information in a one-by-one setting, where everybody uses their own information systems. Whether this will improve the relationship is one question, but it will improve the interaction between these partners.

Interviewer: *What do you think this improved interaction means for an MRO?*

Interviewee: At the moment I receive a component and I have to check whether that information is correct. I already have to conduct activities in order to process this data into the systems. That will be much easier since everyone will provide the data through the Blockchain, which can save a lot of labour to keep the information and data up to date. If the information is correct, it can further prevent other problems: regardless, you must be able to communicate to the authorities that the aircraft is airworthy. This means that you must prove that the components operate within specified limits. On one hand, you will assure that the information is correct. On the other hand, at some point you might get a component that has gone through more cycles than recorded that results in an unserviceable condition. As a result, you might do maintenance too late and is beyond the limits that are specified by the maintenance manual.

Interviewer: *Do you think other parties, such as an OEM, may perceive this improved interaction with the MRO?*

Interviewee: It is difficult. I think that the supply will be more transparent. For example, if you want to purchase a part from the market, you will be more confident about what you will receive. Of course, I can believe someone on his word, I still purchase a part and believe that the data and information is correct. If this information is provided through the Blockchain, which cannot be hacked, then you know the data always correct. You can select more appropriately – for example on price. At the moment you might think it might be better to purchase parts at OEM X over OEM Y. In the Blockchain environment, since you are sure the data is correct, you can start selecting the parts based on other factors (e.g. price) – effectively increasing the options of parts from which you can choose.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO revenue structure?*

Interviewee: In any case, you know that if you are offered an aircraft spare part, then you must be able to check the history of that component through the Blockchain – that is positive. What you often see, if you fly with an aircraft around the entire world and you end up in a location where there is no pool and your component fail – then you must quickly purchase or rent a component in the market and you will be subject to the market conditions. At some point you want to continue with your aircraft, you will quickly pay too much for these components. The parties that currently offer these components will lose some of this advantage, since through the Blockchain you may have more options between components – which ultimately may reduce the market price. It will be difficult to ask a premium price, since at that moment you have better insight on what other parties price the same part or service.

Interviewer: *So, based on what I hear you saying, reduced information asymmetry could result in reduced negotiating position for MROs in certain scenarios?*

Interviewee: It works in two directions. As an MRO you might have to acquire a component from the market. There is always the supply and demand dynamics. Maybe that some MRO that does maintenance in Timbuktu but has no pool, they may have to acquire parts from another MRO. It works two ways. It has its advantages and disadvantages. Through transparency, I think you might avoid these types of scenarios.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO cost structure?*

Interviewee: Considering the part inventory, you must have a certain degree of inventory. On one hand, you do not want to have a too low inventory, since that can result in a needed component not being available. On the other hand, you do not want to have a too high inventory, since that means that capital is invested in your inventory that can also be spent elsewhere. Topics such as predictive maintenance can contribute to this, since you predict when components will break and this can influence the part inventory. With Blockchain I do not immediately see this relation, except that you are always sure that the aircraft is in the correct configuration. As a result, you might encounter fewer problems with a component in the aircraft. MROs currently already use maintenance programs in order to manage and set the allowable and actual aircraft configuration. The actual configuration is what you actually receive from the component. At the moment when a mechanic installs the component onto an aircraft, then you must couple the component (and its associated data) to the aircraft in the maintenance program. The component is coupled to certain data (e.g. number of cycles). The maintenance program will help you develop the airworthiness report – for example by highlighting that an operator is installing a part that does not comply with the specifications or that it is soon reaching operational limits (e.g. a part is soon reaching 100 cycles and also must be repaired every 50 cycles). In terms of cost structure, I think the IT will take over a lot of this work. You may reduce the complexity of IT systems, since in the current situation everybody works with their own IT systems and databases. At the moment the component is exchanged from one organisation to another, the information must also be exchanged. This process will be simplified, which will reduce the costs associated with this process.

Interviewer: *I do think it would be really difficult to replace existing IT maintenance systems by Blockchain. What is your perception on this?*

Interviewee: That will of course not happen. What you do have to assure is that the information that is stored on the Blockchain can be extracted and forwarded to the maintenance programs. For example, maintenance program X might have an integration with other IT systems with the actual configuration of an aircraft spare part that is installed on an aircraft. I must then acquire this information through Blockchain. Regardless of the amount of system integration, whether manual or not, the complexity of the systems will still reduce. The information is still stored on some system. For example, MRO X has stored this information in their own system. Later this information will be saved on the Blockchain. Ultimately, you also have an aircraft management system that must access this information in order to realise the aircraft airworthiness. It is important to realise the integration of the IT systems. However, instead of dealing with more inputs, you will rely upon one input.

Interviewer: *What kind of data do you think an MRO should share with its partners or industry? Is it only traceability data or also condition data?*

Interviewee: It is important to share data primarily that describes (for example) what type of maintenance or modification occurred on the components and how much cycles these components are subject to. This is the typical data that you need as an aircraft operator in order to prove and set up your airworthiness.

Interviewer: *To what extent do you believe that Blockchain could impact the MRO inventory management?*

Interviewee: For me, inventory optimisation relates to the amount of stock you manage. For example, you may need 10 wheels to assure that if a wheel fails you have some wheels ready on stock. But you also do not want too much so that you own wheels that will never be used. I do not immediately see how Blockchain can contribute to this. For me, Blockchain relates more to the presence of information about these components. The part inventory is a different area, since you use optimisation models with historical data in order to predict when and which components must be required. That is more related to predictive maintenance. Example: from the maintenance plan you know that every x days the wheels of an aircraft must be replaced. This is input for you to know how much inventory you need. The same applies if you can already see that an air conditioning system (which are expensive components and you do not want to have too much on stock) will fail soon through predictive maintenance, then you also know exactly when you need something on stock. I personally do not see immediately how Blockchain can contribute to inventory management.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO key activities?*

Interviewee: There are two elements: 1) component repair – making sure that unserviceable components are conditioned to serviceable state; 2) component provision – ensuring that when there is demand for a component from the client (e.g. MRO/pool partner) then you must ensure that the components are available for these clients. However, for Blockchain in the supply chain, you also have the Continuing Airworthiness Organisations (CAMO). They must prove that your aircraft complies with regulations and guidelines. For that the Blockchain can provide a real value. Looking at the MRO planning – for example: the maintenance manual for an aircraft states that an air conditioning system must be inspected every 100 cycles. For that reason, within the maintenance program, you need a tool that shows the actual configuration of the aircraft. It shows for each component how much cycles it has and shows that maintenance must be planned and conducted between now and X amount of cycles.

This ultimately has impact on the maintenance planning. Somewhere on the A-check or on the line, this must be addressed. The entire MRO process is connected and integrated with each other. I do think, if you have all this information, it is important to ensure that the aircraft complies with the right configuration. This is related to the component must be repaired based on the amount of cycles. I do see more impact on the airworthiness side. The point is, everything is connected with each other. If you remove a component from an aircraft, and it is sent to the component shop for repair, it will change the configuration of a component. This has impact on the overall aircraft configuration, as we discussed previously. If I think about Blockchain, where we want to be sure that the information of a component is correct, then we find the value proposition in the CAMO organisation. But that is merely my perception.

Interviewer: *To what extent do you think airlines and MROs are RFID capable and do you see any problems in that regard?*

Interviewee: I see a lot of airlines that work with RFID to localise an asset. When you disassemble an engine, which contains a lot of components, you want to be sure that you can find these components together. At some point these components are put on a table, which raises the challenge on identifying the right components for the right engines. They used an RFID in order to quickly identify the right component for the right engine. This relates more to localising rather than forwarding data. The MRO industry is quite conservative due to all the regulations. What you see is that they still work with old mainframes. Now you see a first step of switching from these old mainframes to industry standard applications (e.g. SAP). At that moment you have one tool to work with. In the past they had various tools for various parts of a maintenance process with various integration between it. And now they use a standard tool, which allows data standardisation and digitalisation on the scope of one organisation. At MRO X they use two industry applications: e.g. maintenance program 1 for CAMO, planning and line/base maintenance; maintenance program 2 for supply chain management, component and engine maintenance. I cannot count how many applications were previously used for these areas. For this scenario, the Blockchain will have the impact of integration on industry level where industry standard applications such as SAP had that impact of integration on company level. Aircraft spare part management is a typical example where you want to search cooperation between all these companies, especially since everyone holds their own copy of the same information and you want to assure that these copies match.

Interviewer: *Who do you think should initiate the Blockchain? To what extent do you think it is possible for a regulator to initiate the Blockchain and invite airlines/MROs/OEMs to participate in it when they company with regulation and standards?*

Interviewee: Ultimately, what you saw with the whole airline ticketing system – everyone has their own systems. Eventually, the industry has designed these systems in collaboration. I think this initiative should come from the industry, where a few parties sit together that collaborate the construction of an industry standard. The industry can benefit from this. I do not see this initiative happening from the authorities. This involves everyone: OEM, OAM, MRO. They can benefit when all the information is in sync. Someone must eventually take the initiative, similar to how someone take the initiative to collaborate in the design and establishment of an industry wide ticketing system. So that will eventually happen. What you now see is that digitalisation is disrupting the MRO industry. You see that OEM 1 and 2 emerge with their own platforms to which you can provide all your data. Aircraft operator X is also working on a similar initiative. So, the question is – is there demand for an industry wide platform? So not something that is established by OEM 1 or 2, aircraft operators typically clash against OEMs.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO key resources? Do you think the MRO industry possesses the right resources to support Blockchain adoption?*

Interviewee: There will be a number of integrations. There will be an industry standard, for example Spec 2000, that highlights if you want to link each tool with the Blockchain, it must comply with a specific format. Any industry participant that wants to engage in Blockchain must be able to use a tool within its maintenance programs so it can read data from the Blockchain. At some point you are going to synchronise the component. In the Blockchain you will have data on the cycles of the components and you want to be able to forward this data to the maintenance programs. If an industry standard emerges, then the industry standard will propagate to all the tools and applications with the purpose that they can communicate with Blockchain. I think that an MRO by itself cannot implement the Blockchain. You need to do this in collaboration with partners. If you do this by yourself, you might as well use your own organisation standard application. It is important to acquire as much parties and partners around you as possible to engage in this Blockchain network and establish this initiative from the industry. And then you must assure that everyone will follow. Later the capabilities will just automatically emerge.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO value proposition?*

Interviewee: An important thing to consider is that an MRO provides its services for airlines. The important goal for an airline is to ensure that an aircraft flies as much as possible. Every time the aircraft is on ground, airlines sacrifice revenue. We want to ensure that the aircraft availability is as high as possible. The MRO provides the value to the airlines by ensuring that repair is done in an as short time as possible to ensure the maximum availability for the airlines. An MRO can repair, but sometimes pool contracts are also established. An airline can establish these contracts together with an MRO, where they pay a certain price per flight hour. The MRO then ensures that if a failure occurs, they will solve it. I assume that even with Blockchain, they will provide the same value. At most you can probably reduce the internal costs, through which you might be able to offer a lower price. Looking at predictive maintenance, for example, we see that MROs can provide pool contracts. By applying predictive maintenance, we can know upfront that a component will fail. This can help reduce the internal costs. This will allow you to differentiate yourself in the market, by reducing the price and improving your competitive position. Moreover, when the Blockchain is available, it is accessible for everyone. It is difficult to offer the Blockchain, since it is an industry standard. Ultimately, it can affect your efficiency, but I do not see new value propositions emerging for MROs.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO customer relationships?*

Interviewee: What you see is that customers are often engaged by mail and post. And there you can see a consolidation, where industry members see if it is possible to find a uniform approach to digitalising these relationships (e.g. through portals). Ultimately, you provide specific services to your clients. I think that the Blockchain could optimise your internal processes. I do not think it has real impact on the services you provide to your customers or how you maintain these relationships. The clients will go on the Blockchain to see what components are offered and see what its underlying information and data is. I do not personally immediately see how this could improve the customer relationship. You still offer services to the customers and you are not suddenly going to offer Blockchain services. At most, you might establish a customer portal through which you can acquire information on the relevant components instead of your own systems.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO customer channel?*

Interviewee: If you look at how customers are currently contacted – exactly for different aircraft types and channels. Sometimes a package from an airline is sent to an MRO with the request for repair. They figure they might not have the capabilities, so they send the component to a different MRO provider. By creating a personal portal, you might provide an overview of MRO capabilities and offerings on component repair aspect. And they could perhaps acquire this information through the Blockchain. In any case, something must happen in order to ensure the robustness of the Business-to-Business channel. Currently these channels are outdated within the MRO industry. And with that, the Blockchain can help as input in the back-end towards the portal. If you really want to show something to the customer, you do not show the Blockchain but your portal with information from your own systems that you can also expect on the Blockchain.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO customer segments?*

Interviewee: There is a chance of gain and loss. In the end, depending on how the Blockchain is deployed, if next to the fact that the information can be acquired, you also have insight on what components are offered on the market, then it can improve the transparency of the industry. It can offer new opportunities and treats. For example, if you are in Timbuktu, and you have a repair station there, anyone who is stuck on ground there must acquire parts from you. Maybe there are other suppliers who might be able to quickly deliver the desired spare part. I think that will not change too much. But the entire ecosystem will become more transparent. But I am not sure which parties will gain or lose.

Interviewer: *Do you have a final remark?*

Interviewee: I think it is interesting to also focus on who will become the owner of the Blockchain. At some point some party has to initiate this network. Eventually, such platforms can also generate revenues. The owner of this platform can consider to develop a new business model. It is important to involve as many industry partners as possible and ensure that you are one of the founders in order to reap the benefits.

SURVEY

How do you think Blockchain as an aircraft spare part capability could impact the MRO business model?					
Component	Very poor (1)	Poor (2)	Neutral (3)	Good (4)	Excellent (5)
Key partnerships				X	
Key activities			X		
Key resources			X		
Value proposition			X		
Cost structure			X		
Revenue structure			X (user)		X (founder)
Customer relationships			X		
Customer channels			X		
Customer segments				X	

Appendix V CONSULTING 2 – INTERVIEW 5

CHARACTERISTICS

Function: Senior Management Consulting Executive

Expertise: Overall MRO industry

TRANSCRIPTION

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the relationships between an MRO and its key partners?*

Interviewee: It would limit and reduce the interfaces most probably. With this it is possible to enhance accuracy in such limited interfaces. And last, but not least, I think the most important on the spare part side is traceability back-to-birth. If all of this is digitally available, it would save a lot of paperwork. However, an important partnership is the one with authorities. You get audited from the authorities and based on that you achieve approval to issue certificates. So, based on your work processes on your adhering to the component maintenance manual, you then get the authority to issue IATA or FAA forms (depending on how you are authorised). The issue with all this is, if you look on digitalising the airframe or data that goes with the aircraft, it is currently always a copy. You must always have to keep the physical paperwork and then you have a scanned copy of it. And that is still what the authorities require. Just to get a digital signature, I think IATA needed about six or seven years for approval. So, the authorities are a key player. Even if everybody says it is a great idea, without getting the authority behind it, it is just a good idea.

Interviewer: *What if we convince the authority to establish or participate in the Blockchain network and access the relevant certificates and information in a transparent web portal? How do you think it could improve the relationship between an MRO and these authorities?*

Interviewee: The frustration of lack of innovation on IATA towards authorities is significant. However, there are a lot of power political issues in the set up. I started working in the industry in the mid-90s and RFID came up early 2000s. Everyone was enthusiastic, since you can track components. The case was made and then the authorities impose changes in the design of the parts with attaching RFID. With this, we are still talking about RFID 18 years later. The only use was then to put it in the transportation cases. Potentially, today the manufacturers can put RFID in the design, but still it must be certified and approved. However, the advantage for the OEM is too limited, because for them it is a cost in the design. They do not see a return. A lot of people in different industries (whether rail/life science), typically underestimate the issues that authorities have with something lifting off the ground. Everything around Aviation is double and triple checked. To get innovation into the authorities is difficult, especially with having these two large blocks of FAA and IATA.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO key resources?*

Interviewee: I would say that MRO have the right people, since it is an engineering environment. The people got educated in engineering and are interested in moving this forward. I think from a people perspective, that is not an issue. However, I think it is heavily regulated. And then you have also other industry dynamics, which makes it a difficult environment. You have the airframe manufacturers, the airlines as the customers and the MROs. Nobody knows who owns the data in this equation. The MRO believes, whatever repairs they do it is theirs. The OEM believes it is theirs, since they are the manufacturer, does the warranties, guarantees, etc. The airlines believe it is theirs, since they have the ultimate responsibility to be airworthy. That is not necessarily solved. With that, the interchange and interaction between airlines, OEMs and MROs is very limited and political.

Interviewer: *And you do not believe that Blockchain could really solve the political nature of this interaction?*

Interviewee: I think the advantage has to be shown in real value. Then you could convince people entering into this. Most probably the easiest for that is the airline, because they have the biggest interests. Looking at an average MRO, their only IP is their knowledge about supply chain, fixing parts and aircraft in the best way and they are hesitant to share it.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO key activities?*

Interviewee: Right now, if you talk to someone in an MRO, which is in a very narrow, niche industry, most of the people working there did their career there. You have very little people in the whole industry who have moved around. You have some in the C suits of airlines, but in general the outside-in view they have is very limited.

Interviewer: *Do you think an MRO who does not engage in Blockchain could have a competitive disadvantage to their competitor who does share data?*

Interviewee: I would say that they definitely would have a disadvantage, just because they have limited data. If I take reliability data, availability data, hardware – it is a question if they see a threat to their overall business model by that. Or, if they feel they have a competitive advantage because of special procedures, higher productivity, and would not like to share that with someone else.

Interviewer: *How do you think the MRO business model could be threatened by a competitor that does share the data with the partners? Do you think their business model is not sustainable for the future in that sense?*

Interviewee: Most probably not. The demand is growing constantly. The MRO pretty much has a hard time keeping up to provide the service. Looking at engines, for example, I think the engine shops have never been fuller than today. On the component supply chain, we see the same thing. I doubt that the business or the existence of the business would be under pressure. But most probably, the threat is that someone else is outpacing. The question is whether you can build capacity in the same form.

Interviewer: *To what extent do you think MROs are able to build up these capacity and resources?*

Interviewee: There is a shortage of engineers worldwide. I read the other day in the US 40% of the mechanics are going to retire in the next eight to ten years. On one side, this is a threat and on the other side an opportunity. This means that MROs have to change their business model in order to cope with this. So, if they can save time and effort with all the things Blockchain could bring in, it would be an advantage. It is a very complex matter, sine in the end it comes back with the authorities. If you have the innovation and have a track to go on, in the moment it is just duplicative to have something you have to do anyway. You need the physical paper and do a parallel Blockchain. Not sure that I can bring the savings it could bring.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO cost structure?*

Interviewee: If we talk spare parts – it is a very specific area and there it can certainly improve the quality assurance process. The logistics can track and trace the parts with reliability and predictivity. I think there are savings there. However, fixing the part is the actual work of the MRO, impact there is most likely limited.

Interviewer: *How do you think Blockchain could improve the prediction capabilities of an MRO organisation?*

Interviewee: The aviation industry is doing the reliability engineering since ages. The reliability of the aircraft, if you go back into the 60s, has improved significantly, also with the amount of flying. It is a combination of the original system and maintenance. So, the engineers are trained to do root cause analysis to do predictions, removal planning, etc. Predictive maintenance capabilities can further improve the technical dispatch reliability. This has to be considered throughout the whole industry, and in the cost and value to the industry.

Interviewer: *To what extent do you believe that data exposure can make you vulnerable as an MRO organization?*

Interviewee: It can go two ways. It can impact negatively when you show to the market that you are still a profitable organization at the end of the day. If you chose to be a great organization, someone can mimic it and take some of your competitive advantage. Looking at the negotiation position, I can give an example from the car manufacturing industry. Tier two and tier three people have to give full visibility to tier one, who then decides what margin is adequate. This is something that does not exist in the aviation industry – potentially on the OEM side, definitely not on the MRO side. Within aviation, we helped a group purchase an aircraft. The OEMs have a very limited understanding and know-how of what the aircraft actually costs in operation. But, coming back to the very beginning: the ecosystem is imbalanced. OEMs, airlines and MROs believe that they have a unique position in it. That is why airlines do not necessarily know what MROs are doing for the money they pay. The MROs try to hide as much as they can of what they are doing and protect the real cost transparency. Even if you take collaboration between an internal MRO as the subsidiary to an aircraft operator, I doubt that this operator really knows what the aircraft maintenance actually costs. In the end these companies will be impacted, whether negatively or positively. If also the MROs would have more transparency on what their target is to repair component, they could potentially take more educated make or buy decisions.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO value proposition?*

Interviewee: I am certain that the value proposition would change. Coming to what we just said, if you take the make-buy decisions – most of the MROs in the world came from airline (state-owned) monopolies in countries. With this, they had a wide range of capabilities to serve their airlines. Was it the right economic decision to do things this way? Most probably not. Could they, with the transparency, make that make-buy set up much better? I am one hundred percent sure. Do they need to fill medic kits, as an example, with labour costs in Amsterdam? Or could they do this somewhere else with much lower costs? But it was always done this way. We have the capability and do not have to do the investment to get it. To give an example with the bankruptcy of Swiss Air in Switzerland, we had a review after the bankruptcy of all the capabilities of SR Technics. There was one guy reading out all the black boxes from aircraft. These services were needed once every four years. We did not even know that it was needed and that it existed. Certainly, it was a capability that the monopolized airline

in Switzerland needed. Nobody wanted to give it out to competitor, because of confidentiality. So, you had that one guy. What I mean: transparency will definitely provide it. If I do my check or repair of a component, I do it in two hours. I see from data that someone does it an hour. I have a different target. Before, I would never even have looked into that if I would not have had that comparable data.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO customer relationship and channels?*

Interviewee: At the end of the day, the customer (airline) needs all the information around what and how MROs do its maintenance to take an informed decision to declare the aircraft airworthy. The ultimate responsibility for airworthiness lies with the AOC holder, so with the airline. All that certainly right now is done on paperwork. I think the ability to have uncorrupted data, if approved by the authorities, then it would help airlines to quicker do that process most probably. The other thing is that very little airlines and MROs are currently really integrated from an IT perspective. Mostly: MRO provide information on a web portal and on the other side you have someone sitting and writing the data into its own system. There is a good opportunity to reduce mistakes (e.g. human error). With transparency, for airlines it would be very valuable to know what was done to the component, how long it took, what the failure was, etc.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO customer segment?*

Interviewee: At the end of the day, if the value proposition and competitiveness improve, then they can definitely approach new clients.

Interviewer: *Do you have any final remarks?*

Interviewee: I think this subject is very interesting and relevant for the industry. My reservation is the whole authority part, I think that is a big item. The other is the protective nature of the aviation industry, which is a historical thing: everybody comes from a monopolistic point of view into that industry. Everybody believes that sharing data on the engineering side, is something that they like or are more open to do. But, in the moment it becomes commercially relevant, it is a very closed world.

SURVEY

How do you think Blockchain as an aircraft spare part capability could impact the MRO business model?					
Component	Very poor (1)	Poor (2)	Neutral (3)	Good (4)	Excellent (5)
Key partnerships				X	
Key activities				X	
Key resources			X		
Value proposition				X	
Cost structure				X	
Revenue structure		X			
Customer relationships				X	
Customer channels				X	
Customer segments			X		

Appendix VI CONSULTING 2 – INTERVIEW 6

CHARACTERISTICS

Function: Management Consulting Principal Director

Expertise: Overall MRO industry

TRANSCRIPTION

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the relationships between an MRO and its key partners?*

Interviewee: To be clear, when you are talking about MROs, I assume you are including all types of MROs. There are independent MROs, MROs that act as a department of an airline and primarily serve them, MROs within an OEM, to name a few examples. But, the tricky thing about the relationship between MROs and OEMs is that they can often be competitors, particularly on the engine side. Engine OEMs, as you probably know, make a lot of money selling the service contracts with the engines upfront. Often times they even make a loss on the sale price of the engine in order to make it up on the service contract over time. So, on the engine side, in particular, they have a very strong incentive to avoid or limit the amount that other MROs can do with the engine. They have taken steps to control more over the spare parts and more of the IP in the engine to make it harder for MROs to serve that space. An independent MRO trying to compete in that space would be happy for anything that would give them better connection to the IP of the OEM – which could be facilitated by Blockchain or any number of other ways that they might have more access. But, the OEM themselves probably is not incentivised to make that available to others.

In other parts of the MRO that could also be more or less true. On basic airframes MRO work, where they are doing a heavy check on an airplane – that part of the work is commoditized. Any MRO can do that. But, as you get into repairing specific components, there is potentially more and more incentive for the OEM to try to control the aftermarket of their components. They will do what is required of them, from a regulatory and basic customer service perspective, to make it possible for others to maintain the parts. In many cases, they are definitely trying to control the aftermarket itself. Then it becomes interesting if you are talking about an airline-controlled MRO, because they then have potentially more negotiating power with the OEMs to be able to get access to more IP. The OEMs obviously want to sell their products to the airline. So, some airlines may be more sophisticated at having access to IP and ability to repair the parts in their MROs and be part of the negotiation over purchasing the products in the first place. But, an independent MRO that is not part of an airline is not directly a customer of the OEM, other than buying spare parts in certain cases. Those costs will be passed through to their airline customers. So, they are in a tricky position in terms of the power they have to make demands of the OEM. I think the biggest question there is the following: the OEM is really the one in most cases who has the most powers. So, what is their incentive to participate in this Blockchain ecosystem? Then, I am not sure if they do have that incentive.

Interviewer: (..) – *Short dialogue where insight from an OEM interview is shared*

Interviewee: Boeing and Airbus are in a funny position in this whole conversation, because their name is on the end product and they are large companies that have the primary responsibility of selling the airplanes. At the same time, they do not control a lot of valuable IP. Things like avionics system, APU or engine – any of the large systems on the aircraft are made by other companies. They definitely are interested in having access to this information, because they do not actually have access to this information.

They are kind on the outside of the details of the workings of the parts that go on the airplanes. Boeing and Airbus, on a number of occasions, made the effort to get more into the aftermarket of their aircraft as a growth opportunity for them. They constantly run into the problem to do this. So, Boeing is almost in the same position as an independent MRO. However, currently OEMs do not have the information nor expertise needed to do repairs.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO revenue structure and negotiation position?*

Interviewee: The benefits of Blockchain accrue probably primarily to airlines at the end of the day. Aircraft owners are a beneficiary of this system, because it gives them closer visibility to the maintenance status of their aircraft, which is particularly interesting to aircraft owners who are not operating their aircraft – primarily meaning leasing companies. There could also be some benefits in easier tracking of historical maintenance on an aircraft during the sale of an aircraft, especially in cases where historical maintenance records might otherwise be patchy, for example if a previous operator of an aircraft is no longer in business. If they try to sell their airplanes to the other part of the world, then they are not going to have the paperwork on all of the components (e.g. maintenance history). That is bad for that airline, because a client that wants to purchase the airplane cannot do it. So, if there is an industry standard that made it easier for all of us to track the parts along the way and took it out of the hands of the airline, it would just make life easier for managing and selling aircraft – particularly for smaller, less sophisticated airlines. In turn, MROs would potentially lose business on its margin. Potentially, when this happens the airline might have to pay the MRO to do a whole bunch of extra work. But frankly, that is not a lot of business and does not happen that often. There might also be situations where such an airline is paying an MRO to do a comprehensive management of the maintenance of the aircraft. Again, that would be inferior to this Blockchain format. Although, I would guess that if the airline does not have the capability to do it now, they probably will not have the capability to give proper oversight to what happened through the Blockchain. I think from the MRO perspective, there might be more competition in the MRO space. MROs will be more confident that all the parts will be tracked, and providers have access to the system and are easily able to get in. On the other hand, if it requires new kind of IT capabilities and new levels of sophistication to even get into the Blockchain in the first place as an MRO, then that might actually create higher barriers for entry for the MRO industry – if it makes it harder for some small company that does not have a lot of IT capability then Blockchain becomes less likely.

Interviewer: *To what extent do you think MROs actually have the necessary key resources and capabilities in order to engage in such a Blockchain ecosystem?*

Interviewee: The largest airline-owned MROs (e.g. Lufthansa Technik) are truly sophisticated in managing their business. So, they might have the capabilities to do this. There is a lot of other MROs, especially for airframe maintenance, that are just focused on low labour costs since it is a labour-intensive process to do a check on the airplane. A lot of that is happening in the developed world with competent providers. Certainly ones that focus their business on low labour costs have not invested a lot in complicated system capabilities. So, this might be a real challenge for them to support that.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO cost structure?*

Interviewee: I think Blockchain does not inherently improve an MRO's supply chain performance; most improvements to inventory levels, parts tracking should be possible with or without moving to the Blockchain. I suppose Blockchain might have some benefits for parts tracking if it encourages easier/more open tracking as parts move from one vendor to another. That benefit is only possible if every player along the way participates in the Blockchain though, which might not happen for a while. I think if you already are doing a bad job of managing your supply chain or have too many parts on the shelf now, I do not know the way that Blockchain could improve this. I do not know how large the IT requirements are to participate in this. Obviously, there is at least some sort of transition from what you are currently doing. I think there is at least a one-time cost or maybe an ongoing cost to support this. I think it is an increasing cost on that.

However, if this becomes an industry standard that is required for MROs to participate, then presumably this is affecting all players equally. So, it would not necessarily be a loss of competitive position. But, if it is a voluntary thing, especially in the short term – and airframe MRO in particular is a very cost competitive industry where low costs is very important – then you are going to have a problem getting players to want to participate in this and raise their costs. If the airlines are the ones benefiting from this and are going to say that they require their MROs to have this capability, then the obvious response to that is to put in extra costs to meet this requirement.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO key activities?*

Interviewee: I would not think it is going to affect the core of each of those activities. It will obviously affect how you record the outcome of those activities. But I would not think the component repair and logistics processes will directly change, other than that every change is recorded.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO value proposition?*

Interviewee: I would think that the real beneficiaries of moving to Blockchain are airlines, and I guess I did not mention it before: leasing companies. Basically, any aircraft owners and managers who care about how the tracking of their aircraft component are handled. I think it is ultimately the aircraft owners: airlines, employees and companies that are going to perceive the value out of this. Meaning, they are presumably going to be requiring that MROs participate in this ecosystem. MROs would presumably see this an imposition from their customers than anything else. It is not clear to me that there is a significant benefit to the MRO here. Other than that, they may participate only because they have to.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO customer engagement?*

Interviewee: Not majorly I think. If it started to be something that customers ask for, they have to react to that and demonstrate they have the capabilities to meet that requirements. This may result in bigger MROs having something of an advantage, since they are more likely to be able to build the capabilities to do this. But the core value proposition or offering around whether or not they could repair components and at what costs they could do that, I think that would not be affected.

Interviewer: *How do you think Blockchain could affect the MRO value of component exchange and logistic services?*

Interviewee: Essentially, I have not thought of that side of things. Something like an MRO component pooling or exchange services – at that point MRO are the ones with the interest in seeing that all the paperwork around that component is tracked appropriately to make sure the value of their investment is retained. To the extent that they are owning components, leasing out or sharing with airlines for various periods of time – they benefit just like the airline does in that the Blockchain could make sure that all the paperwork is covered.

Interviewer: *So, if you think that the industry and regulator could benefit from the usage of Blockchain to track and trace these parts – where do you think the initiative should come from?*

Interviewee: What we tend to see in many places across the airline industry: it is still a relatively fragmented industry and there are a lot of players who depend on mutual access to a lot of the same platforms – including: MRO as a platform, airports as a platform, ways of selling tickets as a platform. All that stuff is standardised across the industry, so that multiple players have access to it. A lot of that stuff is ultimately driven, typically by IATA as a trade group and/or by regulators to make sure the standardization is in place. I think in the medium term; some combination of IATA and regulatory authorities have to be driving this. As a starting point for the first mover, it could start smaller than that – whether it is one particular big airline setting up something and encouraging or forcing their vendors to move on to it. But obviously, we have to be a big airline in order to have a sufficient leverage over their vendors to make that happen. So that might be one way it starts. One OEM maybe could even try to make this happen. Although, I think only an OEM have the ability to force airline onto this without a regulatory push then airlines would have to push their vendors onto it.

Interviewer: *To what extent should regulators have the right to establish who enters the Blockchain and who does not?*

Interviewee: If you had an airline that started this own their own, it is not going to be interoperable necessarily with other airlines. Essentially: if an airline did this on their own, it would essentially be a different way of them storing the data that they already store. But it would not have the broader implications in terms of being valuable to future purchases of used aircraft or other things like that. I think it would be a fairly limited application. And yes, I think ultimately this is going to become an industry-wide standard. We would need a regulator or trade group like IATA or some other entity to set some standards that make this mutually work for everybody.

Interviewer: *But how do we convince the regulator to actually go into this direction and next step with Blockchain?*

Interviewee: It may not be regulators, because regulators are almost as fragmented as airline are. The FAA and EASA have significant sway over what the rest of the world does. Regulators and small countries themselves may not have the technical capabilities to support this platform and are not going to want to force themselves into it. Even for the FAA and EASA there is a lot of austerity and government budget issues where they do not want to make a big push. I would think that, IATA – the industry trade group – is probably the most likely place where it could happen. IATA manages a lot of other industry standards that exists as well. Possibly ICAO, which an UN agency that manages certain industry standards. If the airlines benefit from this, they are ultimately the shareholders and directors of IATA. They are the ones that can push IATA to make this happen. Essentially, the authority, regulatory bodies are not even part of this conversation upfront. All the regulatory bodies care about is that if they go to an airline, that an airline should be able to show the paperwork on its airplanes.

So, if the airlines start storing that data on the Blockchain, the airline can presumably still go into the Blockchain and print out all the relevant paperwork and present it to the regulator. Then the regulator does not necessarily care that much about how it is stored, as long as they are convinced by the airlines that they have a rigorous tracking mechanism and the parts are being tracked appropriately. So, the regulator having a direct connection into this Blockchain may not be something that happens until sometime after it is established as an industry standard.

Interviewer: *It seems like a cumbersome process if regulators still request for printed documents if they could just access these documents themselves through the Blockchain.*

Interviewee: Remember, even the Blockchain makes it difficult, if not possible, to tamper with the database, there are still other failures that could occur here. You could put a record into the Blockchain that says you did a check, but you did not actually do – just like you could add in your database today and there would be a record that you put that in there – but there is no way to tie that physically to having done that check. The regulator is going to care about that, just like they would today. Going in and looking at the records may have some value to them, but it is not going to meet all of their requirements to make sure that the aircraft is being properly maintained.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO customer segments?*

Interviewee: I would think that is probably not very likely. It is a very cost competitive industry. There is definitely an element of trustworthiness that is required to be able to play in the industry. So, you cannot just start up an MRO anywhere and out of nowhere expect to get business. People want to know that you are trustworthy, because it is the safety of their airplanes that they put on the line. There is potentially some marginal improvement to the perception of your trustworthiness that comes from having Blockchain. But, I would think that is just one factor out of many – in terms of what your facilities look like, your reputation and all other things that play into how trustworthy and sophisticated you are perceived by people.

SURVEY

How do you think Blockchain as an aircraft spare part capability could impact the MRO business model?					
Component	Very poor (1)	Poor (2)	Neutral (3)	Good (4)	Excellent (5)
Key partnerships			X		
Key activities			X		
Key resources		X			
Value proposition		X			
Cost structure		X			
Revenue structure				X	
Customer relationships			X		
Customer channels			X		
Customer segments			X		

Appendix VII CONSULTING 2 – INTERVIEW 7

CHARACTERISTICS

Function: Management Consulting Executive

Expertise: Overall MRO industry

TRANSCRIPTION

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the relationships between an MRO and its key partners?*

Interviewee: First, I would like to add a few partners on that list. I would include the regulatory bodies, which might not be as important for the MRO as the airline itself. But both MROs and airlines have to report data to the regulatory bodies at some point or another on the component. Another one I would add are aircraft lessors, who are always looking for data on the aircraft that they have out there – especially when the time comes to take an aircraft back for another placement. From what I have seen in the market, getting detailed component data, especially when you are talking about back-to-birth type records, it is a very manual process with a lot of mails back and forth. I call this labour intensive. So, if there was a way to remove that piece of labour using the Blockchain and make it easy to access, rather than having a bunch of redundant communication. I think that takes costs out of both MROs and its partners, which should make it run a whole lot smoother and actually could give first mover MRO competitive advantage. But I also think the whole industry will run a whole lot smoother. The nature of interactions between these participants would change. To give an example: the interaction between the airlines and MROs when it comes to this data. You have MROs building web portals, which have all the data. But, it is difficult to ask access and you are pulling this data one at the time and not following or automating transactions. Whereas the airline would like to plug some of that data and directly feed into its maintenance systems. But nobody got that right, since there is no real good data exchange or someplace where there is live data. That would make everyone's life a bit easier if that exchange is automated. Airlines are pushing hard for it, but nobody gotten it right yet.

Interviewer: *Why do you think nobody got it right yet? Do you think they lack the right capabilities or resources to establish Blockchain?*

Interviewee: I am not sure if it has to be Blockchain. I think Blockchain is great once you are trying to cover everything - even just an interaction where it could just be two databases interacting to each other (from MROs and airlines). I think the technology has evolved. Where MROs was spending their money five years ago was on developing web portals. They start reinvesting in the API infrastructure so they can share data more seamlessly.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO key activities?*

Interviewee: I think for the most part they have a lot of the data that they put on the Blockchain anyway, and they are running it in their own system in traditional operations. They have to know the history of the component, where it is, who owns it, where it is deployed, etcetera. They focus on the transactions of changing ownership once things are installed out of the pool. What I think would really be helpful, is once you get global coverage of the Blockchain – when they go out and source a new component or source customers, rather than trying to go and track all the history of those parts that they are sourcing for, the part from the customers are coming in - it would already be available in a centralised place. It does not take a long time to roll up a new customer and parts into the system.

Interviewer: *To what extent do you think they could optimise their inventory management because of Blockchain?*

Interviewee: I think they are doing that already. But I am not sure how much Blockchain itself changes that. They have the data that would be in it, at least for their own components already. I do think it would help them in the sourcing process when they go and buy something new, because they will have full transparency on who used the part, where it has been, whether it had issues and how often it has not been removed. If all of that was on the Blockchain when they acquire a new component, it could give them better judgement on the quality of the component and decide whether they want it in their pool. They can start doing some analytics around that.

Interviewer: *To what extent do you think it is desirable for MROs to even openly share data throughout a Blockchain on ecosystem level?*

Interviewee: I think it is very desirable to have your reliability for the global pool, rather than just the MROs pool of parts. This should allow them to do a bit more predictive analytics and maintenance. You get into a lot of challenges with how much data the people want to share. If I am an American, why would I want to share the pool of data that I can be predictive on and essentially change my cost structure with Delta? I do think there are some challenges there. But, we have to remember that this is not the largest cost structure change in the world, but it could have a large impact on time operations. That is where MROs want to develop competitive advantage.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO cost structure?*

Interviewee: Blockchain is a new technology. It is going to be an investment, take up a lot of time to set up and get people to roll into it globally. From an airline standpoint on the benefit side, if this were in place – what is it really saving me on the cost side? Yes, you will do some predictive analytics and maybe take a bucket of components per flight hour of 80 bucks to 75. But in the grand scheme of airline operations, that is a small savings when you talk over 1000 bucks per flight hour for operating an airline. To think about: is the payback worth the challenge?

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO administrative processes, if we use smart contracts?*

Interviewee: When you get to the smaller airlines that 1) do not have fleet management teams, 2) are leasing aircraft, 3) and are not capturing all the data and preparing for when they have to return the aircraft – sometimes they will hit with extra maintenance checks or they have to pull some components off and do a huge overhaul just because they do not have the right records available, and that costs them a lot. I have seen happen in terms of the repair costs to get the random parts back, because they do not have the data. But it also happened in terms of extending the leases, because they could not return it because they did not have the data. There are big costs there, and think it is more valuable for smaller airlines than for some large airlines. Then the challenge becomes whether the small airlines have the time and money to invest in something like this, rather than if it were in place would they use it.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the way MROs purchase their parts?*

Interviewee: Definitely on the used and trading market. I think it would influence whether they would purchase the market, since they have the full history on it. They ask if it is worth the risk and price. In terms of total volume, I am not sure. If I had a global view on where all the spare components are around the world, which I think the Blockchain would do - I have spares sitting in X location or my partners have spares sitting in Y location. I would have less inventory risk on my side – so buy fewer parts, knowing that you know something with a low failure rate, I just pay above-market rate if I need it, because someone has it there rather than going out and buying it myself and holding it in my inventory. It will reduce the capital costs and increase the usage costs if you are trying to buy or lease a part when you need it and you do not have it. You will run in challenges there, since you are using someone as a partner that is actually a competitor.

Interviewer: *What kind of challenges do you think might occur if you want to use Blockchain on a global scale and for what reason?*

Interviewee: Data is value. Everyone wants to own this. The MRO and bigger airlines want to own and monetize their own data. The OEMs already start playing in that space. Especially with more sensors and connectivity, they try to own those data feeds so they can do the predictive analytics and sell that back as a service. So, how much of that are they going to open up on the Blockchain and allow it to be on there?

Interviewer: *How do you think data ownership should be allocated and who do you think should be the Blockchain owner and initiator?*

Interviewee: That is the million-dollar question. I think that is why something like this has not happened with either Blockchain or any database technology. If I thought this was a good idea, they could have been suggesting it to their airlines and help them manage that 10 years ago with different technology. What do I think is necessary? I think it must be driven by the regulators who 1) state that we must improve data visibility on components, because that would improve safety and operational performance and 2) provide the structure that will be mandating. Do I see the FAA ever investing in this? No. They love paper records, love hard signatures and greasy fingerprints. To get to electronic signatures, I think it is close to a ten-year process – it was driven by airlines. But I think they evolve, if they can find a way to improve safety management since they would force airlines to comply with that process, then they will get there. It would be a good starting point. I have no idea what a Blockchain cost to design, set up and operate. It would be difficult for me to make a call on whether it will happen. But, I think you need the regulator and one big airline to partner with them. You could find a large airline, OEM and FAA to define this together, that works. But you must say: what is the return for each party to do this rather than the systems they have today. To do that, you must start with: 1) what data and processes are we going to manage in the Blockchain? 2) Are we still controlling our data and our IP and control who sees it? 3) What do I get in terms of operational efficiency by doing this? – Why does it have to be Blockchain? If somebody, an MRO, airline or OEM find the benefits of having all the data in one place valuable and set it up in any technology, run it, be the operating partner and then charge people for access to the data. OEMs are an interesting one. If they design repair and test processes the right way that are then signed off by the regulators, they could almost be forced to report some of that data to the Blockchain.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO revenue structure?*

Interviewee: There may be, but it is going to take a lot of proof, fail and marketing to get it right. From a revenue side, I am not going to assume it is a different service – and basically bake it into the component services, which is repair and ownership type of approach. If I am going to the market and say: the component services for this bucket of parts is 80 bucks per flight hours. What then happens: I can charge you more, since I have better data. This is tough, unless you can show that their cost of managing this contract is lower to the airline. You could state you do some predictive removal and turn up KPIs and say that parts are always going to be available when you need them, because you are more predictive and know where everything is. This is good, but then the airline says: this idea is great with predictive analysis using our data, but you actually lowered the costs, so we want a lower rate. So, there is going to be some trade-offs there. If you are the first one, you get it right – then it works really well. But, if we are talking Blockchain – once it hits the whole market and everyone has access to the same data – they should be doing the same analytics. This would mean you have just commoditised the analytics and lose the ability for MROs to monetise it.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO negotiation position?*

Interviewee: I am not sure it changes a ton. The smaller airlines, who typically go into these comprehensive PBH agreements, do not want to build that capability anyway. When you are doing one-off repairs, depending on what information is in that Blockchain, you will have better view of what the repair should cost, what should be done and how many hours should go against that repair. You can then question the amount of time the cost that an MRO is putting into any single repair.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO value proposition?*

Interviewee: Depends on what data ends up on the Blockchain. If it is operational data (e.g. cycles to failure, why it failed, etc), it does not threaten the value proposition. A lot of airlines do not want to do that math and take on the challenges. It threatens it if one MRO is doing something with the data and the other is not. Then, if you are adding even more operational information on the Blockchain (e.g. what I did to the repair, what sub components I replaced and added in, how many hours it took me to do the repair work) then you starting to put pressure on the value proposition if an airline really wanted to manage a contract tightly. If you are taking advantage of the data and optimising your business with that, you should be able to take more calculated risk on performance and inventory levels. I could manage my contract at a cheaper cost, because I am better. I could put more guarantees and put more financial penalties against them, for inventory availability or on-wing performance. Right now, airlines are viewing these elements qualitatively and put no numbers against them when they are evaluating these proposals. But, if you could go in with a strong financial tie-back regarding where you meet or miss the performance guarantees, it could be a game changer.

Interviewer: *What if an MRO analyses global Blockchain data and establishes themselves as a Blockchain consultant to the regulator – what do you think that could mean for the overall industry?*

Interviewee: I think that is an interesting one. Regulators always need coaching on what is important, where they should be going next and what they should be thinking about. They are not the ones that are going to spent a lot of money with an OEM on a consultant for this. They get all the information they need today.

But if you could make the reporting process for an airline to get that data cheaper, then that might be the right way to do it. Right now, you have a team that is building all your reliability reports and answering inquiries. If they had the Blockchain available and all the data was just sitting there, it would be a lot easier to meet the needs of the regulator.

Interviewer: *What if we used smart contracts to establish those reports and what would that mean for the industry?*

Interviewee: I think once you have all the data in one place, they can essentially be more effective at their job. Right now, they are not covering every component to make sure it is within regulation. They would be able to use computers to do that, and then they will try to be better at their job and adhere to their policies.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO customer engagement?*

Interviewee: Sure, we talked about this a little bit before. The cost of servicing a contract of doing business should be able to go down if that data is centralised and available – rather than having to get different channels, people and customer reports involved. I think it is a positive impact. People get frustrated when they cannot get information, whether it is their information or other – they want it as fast as possible. The second you put a different channel or person in the mix, it just takes longer and people get frustrated. The more I can have things available at my fingertips, or even before I asked them because I used AI – then it should be valuable. I do think end-customers would put a value on that. But again, you have to worry about the commoditization problem. If everybody has this, then what is the upside from me for having it and why did I just spend a bunch of money on it? Now, if I build and control it, then it is a different story. Then we go back: we pay for this and who needs this? Whether it is Blockchain or another technology, if I control the structure and I can see all the data and I am sharing only some of the data back – that is where you can get some value out of it as the owner.

SURVEY

How do you think Blockchain as an aircraft spare part capability could impact the MRO business model?					
Component	Very poor (1)	Poor (2)	Neutral (3)	Good (4)	Excellent (5)
Key partnerships			X		
Key activities				X	
Key resources				X	
Value proposition		X (standard)			X (control)
Cost structure				X	
Revenue structure			X		
Customer relationships				X	
Customer channels					X
Customer segments				X	

Appendix VIII CONSULTING 2 – INTERVIEW 8

CHARACTERISTICS

Function: Management Consulting Senior Manager

Expertise: Overall MRO industry

TRANSCRIPTION

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the relationships between an MRO and its key partners?*

Interviewee: It is about data availability, and this is very important for the MRO industry. Usually you share data with your MRO provider, OEM or operators. There is data sharing, specifically between the agreed partners per contract. But of course, if there is a decision to centralise and be collaborative in data sharing, no matter if there is a contract or not between the partners – it has two aspects: 1) it is positive, in case you need assistance – you can engage with opportunities of repair or spare part availability, which you probably normally would not have if you do not share the data; 2) on the other hand, you are also exposing the data to the industry. Basically, the business decision of sharing data can improve maintenance KPIs (in terms of repair, reliability and other KPIs). However, I am not sure if operators would be really willing to share, for example, reliability data with competition.

Interviewer: *Are there any scenarios where the operator would be willing to share their reliability data? Or do you think it is an improbable scenario?*

Interviewee: I am not sure that full transparency of data in the industry is going to be possible in the near future. I believe that if there is the possibility to filter who is able to see what data, there would be value on that. As an operator, I do not want my competitors or a group to see my sensitive data. But these groups to share data with premium MRO partner or certain closed OEMs – that is something I see as possible. It is already happening today, but in a more rudimentary way.

Interviewer: *What type of information is typically shared and what type of information would be beneficial to be shared throughout the MRO industry?*

Interviewee: I believe in terms of component availability, it is something that almost all operators would be willing to share. You can then do business with it – for example if you have an overstock of wheels, if someone is in need of a component then sharing the data is something that is attractive. Sharing reliability or cycle data of different component is quite sensitive: 1) from an operator point of view I do not want my competitors to look at my data and compare it with their data; 2) from an MRO point of view it can have an impact on the pricing. For example, when an MRO knows that a component is exchanged every 100 landings. It happens that its exchange is actually done every 84 landings for airline one – MROs do not want to share that the actual exchange is every 100 landings, since they are doing to profit on that with airline one. There is a commercial point of view, where I believe that data sharing in this business model is part of a commercial thought – it is not only about availability. There are some certain topics that have no effect on any critical profit and loss of the players, but there are certain topics that can impact the profit and loss of some players.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO negotiation position?*

Interviewee: When there is transparency in terms of cycles – which from a philosophical point of view, it would make sense – but the MROs play a little bit with their expertise. Let us say they have 100 airlines in their portfolio, they play on the price aspect. Some small operators are not able to leverage data knowledge, so there is a thought on the pricing. When it comes to the Aircraft-on-Ground time of an operator: as we discussed, in terms of spare part availability and transparency it is something that could be positive from an operator and MRO point of view. But it can be negative in terms of an OEM point of view, because people would reduce the minimum stock on all operators and MROs. It is part of the triangle: it will benefit the operator in terms of aircraft availability, it would benefit the MRO in terms of maintenance support for that operator – but this could mean that these operators could reduce their stock of its components by 10%.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO revenue structure?*

Interviewee: From an MRO perspective there might be a reduction. From an OEM and airline perspective, it could improve their efficiency. I do think the revenue structure can also improve. It depends on where you look – for instance, stock availability or parts from an MRO – it could be very positive. Then there is availability, real-time worldwide data with all operators and everyone could have access to parts. So, you can increase your revenue there. Also, from an MRO and operator perspective, you can reduce your stock so it has an effect on the parts investment costs and minimum stock that you have available. This plays against the OEMs, since you reduce the overall stock available in the industry. It is like a puzzle of OEM, MRO and operator. The whole revenue is shared between these three players. So, if you take out revenue from one or two of them, it goes at the cost of the efficiency of the other. There is an amount of revenue available between these players. And eventually it is just a shift between them.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO cost structure?*

Interviewee: There are two aspects to this: 1) the business decision of sharing more information in the industry; 2) the technology sustaining business decision (which can be Blockchain or anything else). Regarding the technology decision, I have no idea what the Blockchain would cost compared to other IT systems. Regarding MRO costs: if there is increased transparency in terms of spare part availability, it is something that can make the MRO more efficient. We could build a virtual network of available parts for this MRO, instead of their own. It can reduce the parts investment costs and depreciation of parts. In the end, the workforce costs would probably stay constant, because you need to do the same maintenance. It is not that you reduce the manhours or the change engineering part of it. It may have some impact on overhead type of administrative costs. It would increase the cost in procurement, because airlines have access to all information so procurement cost of an MRO would be higher since you have to invest more time. I believe the biggest bucket of cost reduction would be the stock of the part (capital costs). From my opinion this would be the biggest part.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO key activities?*

Interviewee: It could maybe impact the maintenance process. In the Aviation industry, especially maintenance, it is something that is very process oriented and regulated. To go into this part of producing the maintenance cost in terms of how we do it, it is something we need to go via long approval process. Of course, if you think about components – you have a certain cycle, which is done with certain conservative ways. For example, you exchange a part a percentage before it is actually should be changed. So, you do not use the whole cycle of that part. If you have real-time availability of data and transparency, you can increase the cycles to the maximum. But this is something that requires lots of cultural change in the MRO.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO key resources?*

Interviewee: In terms of the core maintenance, there are people that are both open and closed to new technology -but: on a very strict, process regulated way. This means that: it has to be well proven and explained what the technology is about, how it is used, how it is checked. It is possible, but it requires a large cultural change. This is about the business decision of having complete real time data across all industry players – this is one part of it. When it comes to impact on their key resources: there are two angles: 1) in theory, information transparency and data availability is something that should improve the decision making of technicians, troubleshooting and decision of exchanging a component or not; 2) Aviation and especially maintenance is a highly regulated arena. It is also an area where safety plays the biggest role in terms of decision making. This would mean that the regulatory processes – if they are not adapted to this amount of information and mindset change, nothing will happen. It is not about only technology, it is technology together with regulatory, process and cultural change. If you just implement the technology without these other changes, nothing will change.

Interviewer: *If Blockchain could become a new industry standard, do you think it is something that should be initiated by the regulator?*

Interviewee: I am not sure initiated, but at least supported. The regulator should be involved and go in together. Initiated? I am not sure. Often regulators react to technology, so probably from a speed implementation perspective it would make sense if the big players of the industry come together to do that. If you think, for example distribution systems, those were big things happening in the airline industry. Large airlines were joining and working together to develop the technology. If it is initiated by the industry, it is the most suitable way to success. But, regulators should be involved in the development. It is not about Blockchain, it is about change in the way data is available and exchanged.

Interviewer: *If these big players work together to establish the new technology, who do you think should be the owner of such a technology that is established in a partnership?*

Interviewee: It is a very difficult question. In the end, it is about very sensitive data sharing that could change the revenues of the three different players in the arena – change in cost, perception of the different brands – there is so much sensitive things there. I am not sure that the big players, or any player would be willing to do that. First, the sensitivity of the data exchange or maybe a restricted amount of data – but this is already happening in a very rudimentary way. I am not sure if the willingness is there yet. But, if the willingness would be there, it is probably the most appropriate when some organisation above the different players initiates. I am a little bit sceptical there that this could happen. There are already tools exchanging data around. OEMs have tools, the big players have tools in terms of predictive maintenance. It is something that has been in the industry forever. But, it depends on the

methods that it was used. But, there are tools available. But if you look at it, the tools of OEMs – operators are fighting back: the data is my ownership, so I do not want to share the operating data of my aircraft with the OEM. So, there is fighting against the OEM tools. On the other hand, if you think about MRO or operator tools – the big players are reluctant and not happy to player there. This is not in a Blockchain area, but in terms in general data sharing in the industry. If you look at the different power maps between the different players of the industry, it is not very successful because of the very sensitive nature of the data.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO predictive maintenance?*

Interviewee: It is about data sharing. Of course, from an operator point of view, with the preferred partners, they would be happy to share the data. To improve reliability, improve cost with the MRO – there are lots of positive aspects from data sharing between the operator and preferred MRO. The MRO on the other hand, they are more sceptical of the level of data sharing - then the cycles are optimised from a cost perspective – everything is more transparent. Today, they have (example) 20% profit on a contract. This would make it more transparent. The negotiation power of the operator is stronger. On the other hand, the operator does not want to exchange this level of data with everybody in the industry. It would probably be one or two preferred MROs and that is it.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO value proposition?*

Interviewee: Data sharing in the industry can be positive from an ROI perspective in terms of reducing their cost, so they can put more competitive prices into the industry for the operators. If it is accompanied with process, regulatory and cultural changes – it could also reduce ongoing costs and manpower in the end, it would be a way of reducing their costs, then the question is: they would not transfer the whole cost reduction to the operator. They can optimise and be transparent to the client in terms of pricing reduction. It is not only the ownership of the MRO, but also the availability of aircraft improvement as there is more transparency in parts availability. Mostly it is about costs and aircraft availability.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO customer engagement?*

Interviewee: In the end, it is about the front end of the maintenance process. If you have real-time industry information, you can also adapt your front-end to make it more efficient in terms of contracting instantly – you do not have to request and wait for reply for part availability and maintenance process. The whole front-end maintenance contract process can be more real-time; and when accompanied with regulatory and cultural changes – the actual maintenance process can be more fast and real time. If the industry would agree to go this way – I am sceptical - the whole process of contracting and performing the maintenance and building KPIs as a final of the cycle → you can be very transparent, very real-time and more efficient. You can take out all the iterations that are happening today in the maintenance process contracting and you could reduce also a little bit on-ground time of the aircraft if you follow the right change process.

SURVEY

How do you think Blockchain as an aircraft spare part capability could impact the MRO business model?					
Component	Very poor (1)	Poor (2)	Neutral (3)	Good (4)	Excellent (5)
Key partnerships			X		
Key activities				X	
Key resources			X		
Value proposition				X	
Cost structure				X	
Revenue structure		X			
Customer relationships			X		
Customer channels				X	
Customer segments			X		

Appendix IX MRO 1 – INTERVIEW 9

CHARACTERISTICS

Function: Enterprise Architect

Expertise: Blockchain and MRO expertise

TRANSCRIPTION

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the relationships between an MRO and its key partners?*

Interviewee: That can vary a lot, which is due to social acceptance. If only one or two partners participate, there is no or only limited impact. If a majority decides that Blockchain is a great idea, then it will result in higher impact. It can vary a lot, depending on acceptance grade and where the community as a whole believes it will go to. The most important reason why the community would not accept Blockchain: perfection. At the moment there already is a lot of rules that establishes how information must be shared between parties. If the data is perceived good enough by each participant, then they will not invest in a Blockchain. Even though Blockchain could have technical and business benefits, if the current situation is deemed good enough by people, then you are done. At the moment, interaction between various parties occur one-on-one. But later this interaction would occur through a central Blockchain platform. This would change the communication pattern. This means that the one-on-one relationships may focus on Service Level Agreements and exceptions. The regular process will be supported by the Blockchain, thus affecting the communication pattern. That means that it can affect the administrative processes. I am not sure how this will be affected, but I am certain that this will no longer remain the same.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO key activities?*

Interviewee: I think it can have impact. At this moment a lot of knowledge about spare parts is exchanged through paper and one-on-one relationship. If there is more clarity, facilitated by a Blockchain for example, then it is possible to use this information to predict maintenance and improve inventory management.

Interviewer: *Do you think there are alternative technologies (e.g. AI/RFID) besides Blockchain that can facilitate increased clarity?*

Interviewee: I think IoT/RFID/AI can help, but they are not dependent on each other. I think these technologies can make a contribution or change on how the process currently is organised. It is not that you necessary need Blockchain in this process, but I think it can supplement these other technologies.

Interviewer: If we look at smart contracts (e.g. for the establishment of airworthiness certificates), to what extent do you think this could impact the maintenance process?

Interviewee: It depends on the extent to which you want to delegate responsibility to the Blockchain. At the moment there are Blockchain enthusiasts that want to code away the entire maintenance process through these smart contracts. I am not sure if this is a good idea. My perspective is to actually keep it as light as possible. The maintenance processes you code away might turn out to not become the right process and might not cater to the use cases and things that could happen throughout the maintenance process.

Blockchain certainly has the disadvantage that once contracts are deployed or released, it will be difficult to change it. This lack of flexibility can be problematic. To give an example: for each component you must record it's the amount of flight cycles or hours. Now you can code away in the smart contract that the amount of flight cycles or hours must never go below a certain threshold, which is a very simple business rule. However, imagine if you have loaned a component to another airline and someone from that airline made an incorrect entry (for example, included a zero too much in the amount of flight hours). Then, based on this incorrect entry, someone wants to repair/maintain the component. They then find out that this entry is incorrect and wish to correct it on the Blockchain. However, the immutability of Blockchain and the smart contract business rules prevent this from happening. So, you may have a problem. I think in the initial versions of your smart contracts, you do not want to include these cases where people can make mistakes or the process does not occur how it should.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO key resources?*

Interviewee: I think it depends on how you approach Blockchain. The current image I have of how we can deploy Blockchain is that there is not one Blockchain, but many Blockchains with their own consortiums of participants. The Blockchain for engines could be different from the Blockchain for Auxiliary Power Units. I think it also depends on who are the key participants of such a Blockchain network, which could include us as the MRO, but also Boeing as the OEM. There will be many Blockchains, especially in the beginning. I think this could standardise into some direction, but we are nowhere near ready for that yet. So, initially I think the Blockchain itself can be seen as a hidden database behind your normal applications in your architecture. I cannot imagine that you want your employees to access each separate Blockchain web/mobile application for each type or brand of aircraft. That is definitely not going to happen.

Interviewer: *And what your employees do not use separate Blockchain applications, but one application where they have access to information of all spare parts and to a spare part exchange service?*

Interviewee: I think that could have a lot of impact, since you can really work with that. But I sincerely wonder if that could be a realistic outcome in the MRO industry. It will not only involve participants of the industry, but also service providers (e.g. consultancy) that are ready to promote their own Blockchain as the right solution. It will take a lot of time before this competition results in a winner that is seen as the standardised solution.

Interviewer: *If we approach this from a regulator perspective – where we 1) consider the interactions between an MRO and the regulating party; 2) the driver that establishes the Blockchain – what is your opinion about this?*

Interviewee: First of all, there is not one regulator. There are many regulators that all have their own ideas and opinions about how Blockchain should be established. I expect from the regulators that they might not even be too enthusiastic about the idea. They have no interest to engage with 30 Blockchain consortiums, which only complicates their lives. At the same time, if they do want to engage in a Blockchain consortium, they want to direct the design of the network. Since there are not be one or two, but 30 to 40 regulators, they all have a different opinion about it. It still takes a lot of time before this converges. You must not underestimate the stubbornness of these regulators. You have the European Aviation Safety Agency and the Federal Aviation Administration. You must not believe that these parties are related to each other. Party 1 might think the contract must look like A, while party 2 might think that the contract must look like B. One party might be directed by the decision of the US congress and the other party might be directed by guidelines of the European Commission.

Interviewer: *I hear that data ownership is currently a large issue within the MRO industry, concerning where the data is located and who owns it. This discussion might not even be solved by the Blockchain, where the data will be duplicated by all nodes. What is your perception about Blockchain and ownership?*

Interviewee: Per definition, ownership and Blockchain is a complicated matter. I am not sure how this will develop over time. However, ownership and the associated responsibilities are especially for regulators an important concept. You are responsible for the damage that you cause with your car, because it is your car. If you arrive with the Blockchain, where nobody owns the data, I really start wondering how regulators will deal with it. I have no clue, but I think that it will be a struggle within their legal boundaries.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO cost structure?*

Interviewee: We have already discussed about optimising your inventory management, which can have a major impact. If you require less spare engines to meet the same service level, it could impact the capital costs of the MRO organisation. I also think that there is potential in the running costs – where administrative costs are an important part of the MRO cost structure. Then, it really depends on what you want to do with AI based solutions that work with Blockchain-based data. That really can go far. You could semi-automate aircraft spare part maintenance. There is a lot we could come up with. However, these opportunities are not completely reliant on the presence of Blockchain.

Interviewer: *So, if we look at the inventory costs that might reduce with the usage of Blockchain and compare it against the required IT costs to establish a Blockchain – how do you think these relate to each other?*

Interviewee: I think the increased IT costs associated with Blockchain would be significantly less in comparison to reduced inventory costs. However, I have no insight on the following: for Blockchain you must establish and maintain a consortium. I have no clue what the costs and impact is of these long-term costs. The short-term IT costs only play a marginal role. But establishing and maintaining the consortium – with all the agreements and responsibilities that must be arranged through conversations – that is what could really result in costs beyond IT. It is difficult to value how these costs weight against each other, since I have never established a consortium. I do know that the capital costs of spare parts are enormous. To make any concrete statements, I do think it is necessary to involve statistics in order to properly evaluate the cost differences.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO revenue structure?*

Interviewee: I do not think on the structure, but on the execution. The MRO manages aircraft spare parts for a group of airlines, where they receive revenues from using these parts, membership of the MRO partner. When you have better insight on what happens with these components, then you could invoice much more pristine. Maybe you could then sharpen up your paper-use policy. I actually think there will be less negotiation in general, for the very simple reason that the Blockchain would tell that an airline has used a specific component or broke it. There is less negotiation regarding the quantity of the invoice, where you normally dispute about the usage of the component. For example, one would state that you have used 10 components while the other states that you have used only nine components. You will remove that dispute. Therefore, you start focusing on the price and value of these components. The discussion will change. However, to call it an enormous impact, I am not sure.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO value proposition?*

Interviewee: MROs will still provide the value of optimal aircraft spare part availability and will not change, because you share these components. Some components are too expensive in order to stock a number of spare parts, especially when you are a smaller airline. When you have two Boeing 777's in your fleet, it is not useful to have two spare engines to ensure that these planes can still fly. For that, these components are just too expensive. Regarding component sale, loan and exchange services – I believe that this value will be diminished in a Blockchain-based environment. Based on Blockchain data, you should be able to do this yourself in a marketplace or exchange. In that regard, you could lose some value as an MRO. Component management and support services will remain the same, since you remain ownership of the knowledge. Component maintenance and logistics coordination services will also remain. Except for exchange service, I think the impact of Blockchain on the value proposition is quite limited.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO customer engagement?*

Interviewee: For us, we make no immediate distinction between partners and clients. The relationship between our MRO and our operator, which is also applicable for many airlines, is much more complex than just categorising them as client. In that regard we do have a few airlines that are merely just clients of our MRO activities. However, with most of our clients that is not the case. You could really see the ecosystem in which the responsibilities and tasks are divided and delegated among the partners and clients. That is a much better description of the reality. To give an example, operator 1 and operator 2 both fly with Boeing and Airbus aircraft. You could make an agreement: if you as operator 1 could provide us with Airbus aircraft spare parts, since you act as MRO for the Airbus fleet; we as operator 2 could provide you with Boeing aircraft spare parts, since we act as the MRO for the Boeing fleet. In that way, we can optimise together. That is much more a realistic representation of the relationship between partners than just a simple MRO-customer relationship. Customers and partners cannot really be separated in this industry. But to say whether Blockchain really has impact on the core of this relationship, I doubt it.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO competitive position relative to other MROs?*

Interviewee: The most important element that you can provide your customer is an increased transparency in the origin and availability of components. Unless you already really have managed all your inventory adequately, it will be easier with Blockchain. If you purely look at the customer-supplier relationship, I think you can really extract a competitive advantage. If you are less capital intensive, you can provide a lower price. Capital costs are one of the major costs of the MRO industry. In that regard there might be an impact.

SURVEY

How do you think Blockchain as an aircraft spare part capability could impact the MRO business model?					
Component	Very poor (1)	Poor (2)	Neutral (3)	Good (4)	Excellent (5)
Key partnerships				X	
Key activities			X		
Key resources			X		
Value proposition				X	
Cost structure				X	
Revenue structure				X	
Customer relationships			X		
Customer channels			X		
Customer segments			X		

Appendix X MRO 1 – INTERVIEW 10

CHARACTERISTICS

Function: Blockchain Program Manager

Expertise: Blockchain technology

TRANSCRIPTION

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the relationships between an MRO and its key partners?*

Interviewee: Well, I think the overall impact is more trust within the different parties. That is the key thing when you use Blockchain. Why do you get this? It is because when you get full traceability (back-to-birth) on each and every component, you can make sure what happened to every part throughout its lifecycle. If you have a component where the manufacturer provides flight hour recommendations, today it is difficult to quantify. However, when you have everything on the Blockchain where airlines join as participants, then you have also a way to leverage around what the manufacturer was telling you – which is something you are not able to do today.

Interviewer: *To what extent do you think it is more logical to establish Blockchain consortium only between an MRO and its partners, or on an industry-wide level?*

Interviewee: For me, it does not make sense if it is a Blockchain consortium with only a couple of actors. It needs to be industry-wide, because otherwise you are losing the track of some parts. It can happen that some part is put on another aircraft that is not part of the consortium and you would have no idea what is happening there. The idea is that you really get a transfer-view of everything. However, if not all actors are present the idea does not really make sense.

Interviewer: *How do you think we can convince each of these parties (MRO, airline operator, OEM, regulator) to participate in the Blockchain consortium?*

Interviewee: For me, the start would be that a large MRO would partner with another MRO. If we would partner with another SkyTeam MRO or airline, the Blockchain would be branded as a SkyTeam consortium – which would make it difficult to get others to join. Where would start from the beginning is to engage in a partnership with a competitor. We would send a different message to the industry: we are establishing a standard. If we would start this, we could easily get an OEM (e.g. Boeing) on board. That will not be a problem, because they are extremely interested with the data. With OEMs, we will need to start with the one that is our best partner today. That is how we would build: we will start small with a large partner that is not from our alliance and then set up an example from the industry and get others to join. Through this we hope to be the one being able to establish a standard.

Interviewer: *If we look at how MROs interact with their direct partners, how does this interaction change with Blockchain? Does it change the nature of the relationship itself?*

Interviewee: In an ideal world where all data are present on the Blockchain, everybody is updating everything in it, and assure that the data is correct – in this ideal version world, I think you do need to call each other, because you have all the data you need. You know who has what and you can query directly from the Blockchain. I think this world is far away. Until then, I think the Blockchain will be the application where you cross-check with the data you already have and get through. I think it will take a bit of time before you are sure that all the data is the right data and version and be sure you do not have to call someone.

Interviewer: *To what extent do you think it is necessary to use alternative technologies (e.g. IoT/RFID) to assure high quality data on the Blockchain?*

Interviewee: I think it is very important, even more with Blockchain than any other technology. If you put wrong data onto the Blockchain, they are in and it is impossible to take them out. So, you have to update them. Blockchain is called the truth. But, as long as you put something manually on the Blockchain, you can put anything in and you do not have any verification. So, we are facing this type of problem with a project, where there was wrong information coming from an outside API and we are still stuck with that wrong information. We need to shape things around and cheat the Blockchain to update and correct the false data that came from an API from the outside world. So, it is very important that all the information you put on the Blockchain is from a verifiable source, that must be correct for sure. However, it is very complicated to ensure whether the source is actually correct. So, IoT and any type of sensors is definitely one of the key elements. But even there, someone can hack the IoT and change the data. With RFID, someone can remove it and put another tag. So, in any type of Blockchain projects, one of the largest problems we face is ensuring that the data we put is the right data.

Interviewer: *To what extent have you considered the usage of editable Blockchain architectures?*

Interviewee: We are looking at different options. We face the same problem with smart contracts. If there is anything wrong in the way you coded the smart contract, and you cannot change it – then wrong things will be applied. So, for us, immutability is great, but it causes problems. We need to have a door open, and for me this is the part of when you set up the consensus when you create the Blockchain consortium. We must have a way to modify things when they are not correct.

Interviewer: *So, you mention an important element: smart contracts. One hypothesis discussed with other interviewees is the usage of smart contracts to automatically generate airworthiness certificates that must be provided to the regulators. Do you think it is possible for smart contracts to use data from the Blockchain to develop those certificates?*

Interviewee: I have never thought about it, because I have always thought about smart contract from a finance perspective. But, I think it would be possible. Those certificates are linked to flight security, which involves a lot of regulation. You will need to create the smart contracts jointly with the parties that must agree with those certificates. That will be the most complicated part. You need to make to sure, as we just said: the input data must be correct and there must be no way that anyone could have cheated. If it is a smart contract, it means that once I get something, everything is done automatically. I need to make sure that all the data must be correct and that the person that is going to validate the certificate also agrees on the way we operate. It must be a joint work with the party.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO key activities?*

Interviewee: There will be less paper than there is today. Today, their job involves a lot of paper. I think you might ease anything related to the payment process. However, I am not an MRO business expert, I do not really see how this will impact the day-to-day jobs of the mechanics that are fixing airplanes and parts. However, I do really see it as a helpful tool for a back-office job rather than something that can help the day-to-day job of the mechanics.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the way MRO do analysis?*

Interviewee: There is one thing, which is predictive maintenance that might be supported with a Blockchain. If you are just tracking parts, it will not help with predictive maintenance. But, once you start sharing more data, such as engine behaviour – where you get a lot of data coming from all parties, and not only your own aircraft, I think you can start building interesting predictive maintenance models. I think this comes into play with having a data sharing platform for maintenance across the industry and I think in the end of the day all participants will benefit from that. The only thing is: everybody believes that they are sitting on a gold mine with their data. Do you want to share them with other parties? Or do you think they should say inside? I personally believe that the more you share, the more you will get. I think this is something that is very complicated today. Around data, everybody indeed believes they sit on a gold mine. It is difficult for them share, since they can take the risk that someone can benefit from the data – even though they themselves can benefit from it in the end. I think such a platform can help, but I do not know if the actors are willing to share the data.

Interviewer: *Taking this idea forward, do you believe that this increased analysis capabilities only affect predictive maintenance? Or do you think there are other applications?*

Interviewee: The first idea was around predictive maintenance. I am sure this is not it. It might give an idea of how other parties are handling their stocks. This might make you realise that you may have too much inventory compared to your needs. You might get inspired by what your competitors are doing. Then you are able to see what parts everyone has and you can try to do something that differentiates yourself from others. I am not sure if this is something where airlines are willing to share this type of data.

Interviewer: *Another hypothesis is using the widely available Blockchain data to engage in a new business, where MROs can engage in analysis in order to provide regulatory consultancy. What is your opinion about this?*

Interviewee: I think when you are the one showing that you do everything by the book, especially in an environment like ours where security is the key. I think it is something extremely interesting, but it will be interesting for those that do not have anything to be waiting for. The ones that are not perfectly honest might not be willing to then join the Blockchain. It will also make you select your providers in this way: when you do not want to be transparent and you want to hide something, then you are not interesting for me.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the way MRO key resources?*

Interviewee: Well, I believe to be able to build a Blockchain consortium, you need IT Blockchain experts. However, what you really need is business experts. They are the ones that will say how the process works today and what data is relevant to put on the Blockchain. It is the combination between the people who know their business: MRO expert and IT Blockchain experts. There are IT Blockchain experts on the market that can guide you through the process. I think the key element we have as an MRO is that we really understand our business, so we know exactly where it would make sense to get the right tracker to get the data on the Blockchain. The impact for them - if we move forward to something that is automated and where all the processes (e.g. billing) will be automated through smart contract – then potentially on the back office there might be people that are not needed anymore. You will not change the jobs of the mechanics, but it will definitely change the job of the people that are in the back office today (e.g. invoicing).

Interviewer: *Could this be a reason or incentive for people to oppose Blockchain?*

Interviewee: Well, it is possible. However, everybody reacts that way to any kind of new technology. I think it is just one of the new technologies, like robots and AI. The way we perceive it: we are going to make people focus on more interesting tasks than the ones that can be automated. They will lose their job and do a different job. That is valid for anyone today – all the jobs will change. It is not just coming from me, where it is estimated that half or 70% of the jobs that exist today will no longer exist tomorrow. It is very important that we are able to transform ourselves and that we do not try to resist. The way I see it is that if we want to be the actor that is not being eaten by other ones, we have to be the first mover. But, we have to be able to accompany the people through this change.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the way MRO cost structure?*

Interviewee: I do not have a clear view today of how much it costs to run a Blockchain. Let us say this cost will come on top of everything – I think it will not replace their current IT system, but that it will be something on top – so there will be additional costs. We should make it very clear: putting all the data on the Blockchain and becoming the only information system we have is not realistic. It is going to be on top of everything else that requires additional resources and additional costs. I think where we will gain is when we start automating stuff that is done manually. But, this is difficult to further quantify.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the way MRO revenue structure?*

Interviewee: Well, I think they might be able to sell new business and services. Let us say that they are able to get cross-data on the Blockchain and build predictive maintenance. An example is that they could sell predictive maintenance based on data that comes from other parties. This means: you provide me your data on the Blockchain, I run my predictive maintenance algorithm, and I give you the information when I believe that your parts must be changed.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the way MRO negotiation position?*

Interviewee: I think it might be very helpful, since you are able to compare a lot of things that you are not able to do today (except by having bilateral talks). I also believe that it might leverage the quality to the top. When you are able to compare the quality of one OEM/MRO to another one, you can improve your negotiation position since you have insight on the quality of the services. You can ask them to improve the quality of their services or reduce their prices – otherwise you can move to their competitors. You might be able to cross-check a couple of data that might give you a ranking on the different actors. Some MROs will gain and some will lose. You have to make sure you are not the ones that lose. What I mean is that the quality will increase. If you look at TripAdvisor, for example, where you can read what the customers are thinking about your services – then you react normally and improve the services. Here, it is not about what people think about you, it is more about: it becomes a transparent world, where we are able to see what we and others are doing – based on this, we should improve or react to how they do it.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the way MRO value proposition?*

Interviewee: For me, it would really be that you are able to prove that you are better than the other ones. You are able to sell your services at a higher price, or on the other way: you can see what others are charging so you can make cheaper by reducing the price.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the way MRO customer segments?*

Interviewee: It is possible that they could get new customers. It is possible, because you could use it as a selling pitch where you compare your own performance to competitors. I do not know if this only would help you get new customers. Everything is based on a trust relationship – so at the end, that is what Blockchain is bringing. But I am not sure that this only would help you generate a lot of additional revenues.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the way MRO customer relationship?*

Interviewee: I guess today, MROs exchange a lot of Service Level of Agreements, upon which parties can dispute. Having all the data at one spot might change these disputes. It might ensure that there is no discussion needed: the truth is delivered by the Blockchain – we know that the data is correct, because the way the inputs are validated in the blockchain – so we know there is no discussion needed. There is no dispute possible.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the way MRO customer channels?*

Interviewee: I would say that Blockchain could be seen as complementary information, because you are not going to store all types of the data on the Blockchain. It will not replace everything.

SURVEY

How do you think Blockchain as an aircraft spare part capability could impact the MRO business model?					
Component	Very poor (1)	Poor (2)	Neutral (3)	Good (4)	Excellent (5)
Key partnerships				X	
Key activities			X		
Key resources				X	
Value proposition				X	
Cost structure		X			
Revenue structure			X		
Customer relationships				X	
Customer channels			X		
Customer segments			X		

Appendix XI MRO 1 – INTERVIEW 11

CHARACTERISTICS

Function: B787 Supply Chain Specialist

Expertise: Supply chain expertise

TRANSCRIPTION

Interviewer: *To what extent do you think it is possible to use Blockchain in order to use smart contracts to automatically establish Certificate of Airworthiness that could be accessed by regulators?*

Interviewee: I think in an ideal scenario there will be a connection with regulators, such as CARC – the Chinese authorities. A connection with these authorities would be desirable. However, I am afraid that if you will include this in your solution, the development of your systems will be much more complex and difficult. It might be a nice add-on for the future, but not something that you want to include now. It would make the system too complex.

Interviewer: *What has motivated you to consider Blockchain as an aircraft spare part track and trace capability?*

Interviewee: We often have limited information on specific components. We have components in pools, our operators have installed our components in their aircraft with their own pools – and we do not have a consistent set of serial numbers in our inventory. We are offered new offers from component shops or we must acquire new components elsewhere – so new units keep entering and leaving our supply chain. We do not always have all the data (e.g. lifecycle) of these components. We do not know what the previous shop findings were, we do not know what all happened in terms of maintenance, how long these components have been installed in an aircraft – from that point of view, interest emerged for Blockchain to actually create an overview of all data we get of each component that we acquire.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the relationships between an MRO and its key partners?*

Interviewee: For that, a lot of trust is needed to establish the Blockchain. You need a certain level of trust with involved parties in order to initiate the network, since everyone will have insight on each other's data. But, I do think it can have some potential benefits. Once you have installed the platform, you save up a lot of communication – less mail and phone calls. There is more transparency about certain components and processes can be more standardised. Currently, when maintenance is due, the OEM is responsible to guarantee a certain turnaround time for a component. If the OEM is not able to meet this turnaround time, it must provide an exchange unit. This is now a manual process: accept the unit, analyse the unit, check whether the unit is good enough, check whether the unit has the same configuration as our aircraft spare part, then you can accept it. If you put all of this in a digital network, you can automate this process since you can set parameters (e.g. when component meets condition X, and Y then you can send it). That could be done easier. But, I am mostly focused on the usage of Blockchain for components through repair: the repair findings that you can digitalise. Currently, shop findings (e.g. what was replaced, what broke) are scanned into PDFs. Analysis in general could be improved, especially if we can have insight on all components of all Boeing 787's of the whole world instead of just our own fleet and access (performance) data. I am not sure if this will be there in the final product, but it can definitely help us with our own analyses.

Interviewer: *To what extent do you believe that this data accessibility and transparency could threaten your competitive position within the MRO industry?*

Interviewee: An important point of discussion relates to the extent other parties can view our data: do we give access to only data that is their proprietary or do we provide access to all data? This is a difficult challenge. If we look at smaller competitors that may have only ten planes in their fleet, if they could access your data, you might indeed lose that advantage you have as largest MRO. I do not think this will be the end scenario of the end product, but it will rather go into a scenario where you can only access the specific data if you are a special owner of that unit.

Interviewer: *To what extent do you believe that this use case could impact the actual MRO maintenance process?*

Interviewee: Each airline has QA – Quality Assurance department that checks every component before it is installed on an aircraft. I think a Blockchain - where all certificates and component data are accessible – could significantly improve QA compared to now, where they now must go through paperwork in order to determine whether the unit is good enough for installation and meets the configuration criteria. I think a Blockchain format with all available information could make it easier, but that is also an assumption.

Interviewer: *If we assume this is the case, to what extent do you think that this could impact how MROs could manage or optimise their inventories?*

Interviewee: I think personally that Blockchain will not immediately impact your inventory stocks. You still need an equal number of units in order to meet your client's demand. I think the benefit is more with component data, not the number of components. Perhaps this could be an indirect consequence. If you have more information about specific components (e.g. you know which failure caused a component removal), you could maybe help clients with certain failure codes. With some components, we receive a *No failure found* message – which means that once a component had been removed, it turned out that nothing was wrong. This means that there was a failure message and according to some manual it was necessary to remove and install a new component – which is another component replacement. With the available data on the Blockchain, you could maybe indirectly assure that this component replacement does not have to occur. Then you have less component usage, but that is just an assumption.

Interviewer: *To what extent do you believe that Blockchain can contribute to predictive maintenance, for example when you use industry-wide component data?*

Interviewee: It depends on what type of data is used on the Blockchain. Blockchain by itself will not contribute to predictive maintenance. However, if you also include aircraft sensor data on the Blockchain, then it could contribute to predictive maintenance. I do not expect us to put this data on the Blockchain. It will stay intern. At least at this moment. But, if it is possible to check the data of other operators, for example our pool partners and clients, it could be possible.

Interviewer: *To what extent do you have the necessary resources in order to deploy Blockchain throughout MRO?*

Interviewee: The finances are there. Interest is there. Knowledge is limited. I had a meeting with people who did not know what Blockchain was. But the interest is there. We do not have the right human capabilities to establish the system. But, we have approached external companies to establish it. An MRO could organise the project, but not only internally. Considering the IT structure, I think Blockchain would act as a complementary system. It would not act as a system that replaces legacy systems. I would see it as a web-based IT system, where you could check the Blockchain and hook it up with your own systems – but it would not replace existing systems. Some MROs might work with old mainframe systems, which will be difficult to replace. It is difficult with both change management with employees and with IT systems that rely on each other and cannot just be disconnected.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO cost structure?*

Interviewee: I think it could impact repair costs. You could improve repair analysis, based upon which you can set out actions. It could optimise the unit exchange process, not in terms of costs but in terms of manhours – since you could automate this process. Perhaps there might be indirect cost reductions, but that is only speculation. I do not think it is too expensive to set up a Blockchain. It could only be expensive, because it is a new technology and firms will ask a higher price for its products and services. I think if you have your own people and capabilities, it should not be too expensive to establish Blockchain. It will be nothing more than a web-based platform in which people can feed their data.

Interviewer: *Who do you think could be the owner of the Blockchain platform and is responsible of the integrity of the data that is in it?*

Interviewee: The whole idea of the Blockchain is that everyone is owner. It is still difficult. I would assign ownership and responsibility of data integrity to a neutral party. This could be an external company that builds the network for you and maintains the data itself. But, this responsibility should not be allocated with a party that is involved in this project. In our case, I can see us building the business case and setting up the network. However, when it comes to maintaining and assuring data integrity, I cannot see us taking that role. Initially, I would think we should put this responsibility with an OEM when they do not offer an MRO product or service themselves. It would also not be fair if our competitors assume responsibility.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO revenue structure?*

Interviewee: I think Blockchain can be something that will differentiate you from other MRO companies. We notice that our clients become enthusiastic when we mention Blockchain. In that regard, it could be something that sets us apart. If competitors provide this and could provide more insight in their component – Blockchain is then used as a term, even though few people know what it really is. I think that Blockchain will not necessary improve the revenues, but it could improve your competitive position and promotes innovation.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO customer engagement?*

Interviewee: A customer that sends its components to us for maintenance want to receive the shop findings. Usually they do not receive the exact same component, they typically receive another component from our pool. They still want to know what exactly happened with their component in the repair shop (e.g. what was the error, what was replaced). Currently, the customer support manager must manually retrieve all PDFs and sends it monthly to the clients. This is something that could be automated and make it transparent for the client through something like a web-based platform. This should be an option for client, who should then be able to extract data that is valuable for them.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO value proposition?*

Interviewee: It depends. You can access a lot of information, based upon which you can do other analysis. Besides the service related to providing a new component when clients need it, you could also focus on maximising efficient operation. For example: you could improve or finetune their maintenance program based on Blockchain data. It is very important: who can see what data? If you have Blockchain and everyone has access to the same data, then it will be difficult for you to differentiate yourself. Everyone has the same benefit. However, if you are owner of the Blockchain, you could monetise the Blockchain by asking a subscription fee for external partners and clients who wish to join the Blockchain network. I think the Blockchain can be built in such ways that everyone can join and participate – when you do not create a complex system but keep it web-based.

SURVEY

How do you think Blockchain as an aircraft spare part capability could impact the MRO business model?					
Component	Very poor (1)	Poor (2)	Neutral (3)	Good (4)	Excellent (5)
Key partnerships					X
Key activities				X	
Key resources			X		
Value proposition			X		
Cost structure				X	
Revenue structure		X			
Customer relationships					X
Customer channels				X	
Customer segments			X		

Appendix XII MRO 1 – INTERVIEW 12

CHARACTERISTICS

Function: Change manager

Expertise: Blockchain and MRO expertise

TRANSCRIPTION

The recorder captured only the remaining 10 minutes out of a 30 minutes discussion, which resulted in loss of qualitative data. The main arguments are summarised below (with the exception of the value proposition and cost structure).

Key partnerships:

- Blockchain might improve the relationships between MROs;
- However, Blockchain might not always improve this between an MRO and OEM.

Key activities:

- Blockchain could directly contribute to predictive maintenance, indirectly to inventory management.

Key resources:

- It is still necessary to acquire the right human capabilities that could set up the Blockchain and take advantage of its full potential.

Transcription is available of the following business model components: revenue structure, customer channels and customer segments.

Interviewer: *How do you think Blockchain as an aircraft spare part capability could impact the MRO revenue structure?*

Interviewee: I think there is an opportunity to increase revenues. There will be a moment where customers ask to do maintenance only for components with full back-to-birth historical records.

Interviewer: *How do you think Blockchain as an aircraft spare part capability could impact the MRO customer channels?*

Interviewee: It depends on the extent to which you look towards the future. You could state that in 5-6 years we may have a Blockchain-based component marketplace. Through this marketplace clients could inform the network that their components require maintenance or overhaul. Long-term, this could absolutely be an additional channel.

Interviewer: *How do you think Blockchain as an aircraft spare part capability could impact the MRO customer segments?*

Interviewee: I think neutral, but I think there might be new segments that we could approach. Currently, there are MROs that always acquire their spare parts from the same component providers. So, with Blockchain, they could start considering different providers.

Interviewer: Which party do you think should initiate and own the Blockchain network?

Interviewee: That is a difficult problem. If MROs, OEMs and operators engage in this network, then you have the chance that they all see themselves as system owner. One of the key elements of Blockchain is transparency. This means that you want to establish an independent network that is established by an independent party that could safeguard the core principles of Blockchain.

Interviewer: Any final remarks?

Interviewee: I am convinced it is not a matter of if but when we use Blockchain, especially when considering high-value spare parts, it is a very useful use case for the MRO business.

SURVEY

How do you think Blockchain as an aircraft spare part capability could impact the MRO business model?					
Component	Very poor (1)	Poor (2)	Neutral (3)	Good (4)	Excellent (5)
Key partnerships			X		
Key activities				X	
Key resources			X		
Value proposition				X	
Cost structure			X		
Revenue structure				X	
Customer relationships					X
Customer channels				X	
Customer segments			X		

Appendix XIII MRO 2 – INTERVIEW 13

CHARACTERISTICS

Function: Maintenance Manager (13) and Maintenance Controller (14)

Expertise: Overall MRO industry

TRANSCRIPTION

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the relationships between an MRO and its key partners?*

Interviewee 14: First, if you consider OEMs, which is typically one party that manufacture components – the experience I have is that if you require overhaul or maintenance on a component, you do not depend in a one-on-one relationship on these OEMs. Typically, there are often other shops that undertake these activities. This also means that there are different parties with whom you interact. These parties often do not know of each other what the history of a component is. This also means that if you have one central information carrier that is matched with a component, regardless of its position, then everyone always has insight on the same information. You know the entire history, especially items that must be maintained based on intervals. Not components that are on-condition, but items with a logbook – that is where the most opportunity is. With that you can derive whether component A) actually had the maintenance it had to and B) what the maintenance was for what problems occurred in the past. If you have one central information carrier, which would be a digital version of a paper logbook, then you can have certain benefits: the paper logbook can A) lose easily and B) the information that is recorded in the logbook is not often clear.

Interviewer: *What is the consequence of information that is not recorded clearly? Does it impact your maintenance?*

Interviewee 14: Definitely. At the moment you have no clear insight (e.g. on wheel) then the maintenance you must do is always the most difficult one. Normally, you receive a wheel with an X amount of cycles and must be replaced when it is due for overhaul. If the historical information is not clear, then it automatically means that you must do the highest category of maintenance, which means that you must do complete overhaul.

Interviewee 13: What you often see in the practice is that people do not have the ability to track these components, especially not within a fleet.

Interviewer: *Why do you think MROs do not have the necessary resources to track these components?*

Interviewee 13: I think that configuration management in the current model is very limited, since they are focused on a major asset level (e.g. airframe, engines, wheels and gears). Tracing individual components is something that current programs struggle with. What you notice if you are dealing with a fleet of aircraft: for some reason it is really difficult to process and register the individual parameters of a component that are recorded by the aircraft. Operators stopped focusing on this, since it is error prone and eventually would lead up to the heaviest maintenance.

Interviewer: *What if you take advantage of Blockchain, to what extent do you think it is difficult to integrate it with your IT architecture?*

Interviewee 13: You must plug it in. You cannot replace the IT systems, especially ERP systems that already include a lot of information. One component of these systems is asset management, which is connected with a component and its digital logbooks that is recorded from production until the end of its lifecycle. Different stakeholders can plug into these logbooks.

Interviewee 14: I think it will be a web-based system. The component enters the MRO and the operator confirms that it requires maintenance. Operator grants access to MRO via a web-based system to access historical data/logbook.

Interviewer: *If it is not a web-based system, then you would probably doubt whether people would participate in these Blockchain networks?*

Interviewee 14: Then you would make the network small.

Interviewee 13: I mentioned CAMP – Continuous Airworthiness Management Program, which includes all the stock we know. Blockchain could replace CAMP for a large part, which is great: on component level we must know what happens (e.g. time since new cycle/overhaul). Next to that, if we remove a component and want to install it on another aircraft, we must know if it had been incident-free, how many hours - what we do: we have a form that we sent to the operator that they must fill in. The operator will go through their files and go through manual documentation in order to get the right data. It can easily take up a day.

Interviewee 14: If you even have the requested information.

Interviewer: *So, you believe that Blockchain can help you meet the requirements of the opposing party?*

Interviewee 13: Absolutely. You will have all the information and know where it is located. When you source components (e.g. wheel), you consider its status, part numbers and certification. When you head towards Blockchain, you can immediately have insight on what components are best. You can reduce your Product Order systems. At the moment your component will arrive, which is something that should be clarified by the Blockchain with a notification, then you can skip a majority of inspection of inbound components. We currently try to do that by requesting a copy of the paperwork on forehand.

Interviewee 14: The inbound inspection became a continuous item. Every time something was added on the Blockchain - whether the component moved from A to B, or there was maintenance or some type of action (e.g. removed or installed) – it is guaranteed data. You no longer have to analyse to check the validity of the data. At that moment you only check the packaging and whether the expected wheel is actually included.

Interviewer: *This would mean that there might be some changes in the organisation (e.g. business processes/change in tasks) – do you think this is the case and do you think this could result in additional problems (e.g. human resistance) for the MRO?*

Interviewee 14: In our case, we would not see it as a problem, but as an improvement.

Interviewee 13: However, we are user in this situation – we are at the end of the chain and it starts at the OEM and ends at the management organisations. The whole system of Continuous Airworthiness Management will be affected: the typical systems will be different; record-keeping will be done differently – then you arrive at regulation: you must refrain from Excel.

Interviewee 14: I agree with that. But, at the moment the OEM manufacturers the wheel, instead of the paper logbook, the OEM would include a digital concept and it is a central carrier of information. This manufacturer would be responsible for the maintenance data. Instead of providing a logbook, the manufacturer has a database of all components that were ever manufactured. The impact for him is not that great, yes – he must add to the process, but their basic processes will remain the same. Only, the component will include a digital information carrier instead of a component that includes a paper logbook and card.

Interviewee 13: However, if all the different OEMs have their own software with the Blockchain.

Interviewee 14: Then the solution is to use one web-based platform and that is where the challenge is: to assure that all parties look in the same direction.

Interviewee 13: At that moment you must develop a new CAMP.

Interviewee 14: That will be enormous, where every party must provide their signature. At that moment the authorities must be involved, since you must prove to them that it is a fool-proof system.

Interviewer: *You mention an important point which raises the next question: how early do you think authorities should be involved in the Blockchain initiative?*

Interviewee 13: I think the regulator must be involved from the first step. It is a conventional industry. It is also a slow industry, considering the regulatory story. We now speak about logbooks, Form 1's and 8130. Everything is certified with paper documents and that system must be included from the beginning on the Blockchain. At that moment you do not certify with paper documents with stamps, but with the Blockchain you prove that a component is airworthy.

Interviewee 14: Definitely. At that moment you have the opportunity to scope the contract agreements, which is something that definitely must be included from the very beginning.

Interviewee 13: If you can record the due monitoring on the Blockchain, for example by including component requirements on the Blockchain, and the Blockchain would be able to provide notification on the component that must be maintained.

Interviewer: *What if we use smart contracts to capture these business rules, the problem with smart contracts is that it is immutable. To what extent is this a problem for you?*

Interviewee 13: I can imagine that when we consider due monitoring, if we consider reliability data upon which we improve, if we cannot adjust the standard (e.g. every 40 cycles maintenance is necessary), it could be an issue. Imagine the problem for Airworthiness Directives and Service Bulletins.

Interviewee 14: This is why it is important to include regulatory institutions from the very beginning. At the moment you need a change – someone must provide approval.

Interviewee 13: Then you need some type of smart contract manager and this could invalidate the nature of Blockchain. You then go back to the conventional model.

Interviewee 14: However, do you need a contract manager? The contract exists and there is nobody who manages it. At the moment you want to include a change, then you need parties that are authorised to do so. In theory, you could state: you have a contract, it starts with a certain lifecycle and turnaround time or interval. At some moment this will change. You could say: this Blockchain stops and the current conditions are included as a new block in a new Blockchain with new requirements and then it continues. There must be opportunities there.

Interviewer: *Do you think that a party must attain ownership of Blockchain or do you think this ownership should be shared?*

Interviewee 13: If you want to maintain the benefits of Blockchain, the ownership must be shared across the industry. The big question: how you can incorporate these changes. These are changes that you must be able to do overnight.

Interviewee 14: That means: do you need an owning party? In my eyes, not. But do you need a party that oversees the system (e.g. regulator)? They determine the laws upon which the industry must comply with.

Interviewee 13: But you do not want an authority to participate in the Blockchain. That also does not happen now.

Interviewee 14: But in the end they do determine the rules that we must comply with. They would not actually participate in the Blockchain.

Interviewee 13: Then you go towards the following idea: what if you get an Airworthiness Directive, the regulator would be able to adjust that in the Blockchain.

Interviewer: *Why would it not be desirable for a regulator to have access to this information?*

Interviewee 13: Because I then see an operational challenge. They often cannot keep up with the operations themselves. It would be considered a disadvantage for MROs if they have this capability, unless they are involved from the very beginning of the chain. If an Airworthiness Directive or interval is released, then it would be included and adjusted in the Blockchain.

Interviewee 14: So, at the moment you receive an Airworthiness Directive, you must adjust the Blockchain contract and rules. This could have consequences: if you see you must do anything within 30 minutes, you still do it. At the end, you are responsible as an operator to assure that your Airworthiness Directives are compliant. If you have an aircraft upon which these Airworthiness Directives are applicable, then you must definitely do the action. With Blockchain, you create rigidity in the system, since an operator cannot just ignore the Airworthiness Directives.

Interviewee 13: But that means that at the moment an Airworthiness Directive is released, it means that the Blockchain is updated as well.

Interviewee 14: At that moment it is completely integrated and connected with each other.

Interviewee 13: But then you include the authorities as the Blockchain regulator?

Interviewee 14: As Blockchain supervisor. However, they are not part of the Blockchain in which they add or change steps in the component process through blocks. They only determine the rules around it.

Interviewer: *If you consider the decision to use Blockchain for an MRO and its partners, or for the industry – what would be incentives to adopt Blockchain on an industry level?*

Interviewee 13: If you want to win, you must involve the entire industry. That is the most logical approach. If you receive through Blockchain and must provide data to someone who is not part of the Blockchain, then you must still convert to the conventional system.

Interviewee 14: What I also think is equally important: one of the reasons you want to participate in the Blockchain is to reduce bogus/counterfeit parts throughout the industry and maintenance steps that are not formulated according to regulation and agreements. At the moment you have a party that does not participate in the Blockchain, but does something that is not regulated, then you lose the trust of the system. If you then have the situation where there are parties that can add information, you need the right trust between parties.

Interviewer: *If we consider the trust, how does it really impact the information exchange within the MRO industry?*

Interviewee 14: Approved supply list. We are also responsible to assure that our suppliers comply with requirements set forward by the regulations (e.g. MEL). So, we have a approved supply list: A) this is labour intensive, since you must prove that the list is still valid and B) you must maintain a file of everything that did not end up well. If you work with the Blockchain, where only parties are involved that actually have the right to be involved (since they have proven themselves to be part of the Blockchain), then the approved supply list might become invalid.

Interviewee 13: At that moment the chain will be input correctly and everyone can be part of it. A lot of efficiency can be gained from this. In the field of: component procurement: you reduce the procurement process, you reduce Product Order systems, Quality monitoring systems, intern process from storage to work floor will be easier. You can couple it to installation data, through which you can help engineers take care of the components. At the moment you state: it is released to service, you could plug it into the Part M configuration data without the engineer that must check whether the hours or inspection schedule must be changed.

Interviewer: *To what extent do you think this could contribute to predictive maintenance and inventory management?*

Interviewee 14: Inventory management, I do not think there is impact. You will not change decisions regarding the inventory itself. Predictive maintenance is also problematic, since reliability data is not included on the Blockchain. That does not mean that the Blockchain cannot tell you if the component can be trusted, since it can give information on activities, how often the failure occurred, etc.

Interviewee 13: But you can more easily see what the trends are on the component (e.g. Mean Time to Failure, removal, etc.).

Interviewee 14: The data is available. That does mean that, as MRO, OEM or operator, you must translate this data to something that can give your insight on reliability.

Interviewee 13: That is something that is possible then, but not now.

Interviewee 14: Reliability will not change. However, at the other side: if you remove all the waste of counterfeit components, it could have implications.

Interviewee 13: We recently had to replace a component and found out it had a *No Fault Found* after investing manhour and capital into this activity. If we had the ability to check the historical lifecycle and failures of this component, we might have been able to make the decision to not install the component.

Interviewee 14: However, this raises the following question: will you add this to your scope as MRO? Would you make the MRO responsible for checking this data?

Interviewee 13: We would. Smart MROs would. With that you can further help your customers. I would say this is new business. This is for the innovative MROs who want to sell aircraft and component availability to their clients.

Interviewer: *To what extent can ecosystem-based analysis contribute to predictive maintenance, where you take advantage of data on a global pool?*

Interviewee 13: With that you can manage inventory.

Interviewee 14: You can extend that with big data.

Interviewer: *What type of data do you think would end up on the Blockchain?*

Interviewee 13: You will consider your revenue model and predictive maintenance is considered new business with which we can differentiate ourselves and make a difference. We do not want to share data that makes our predictive maintenance vulnerable, since we want to sell this as a service. As soon as you provide access to other MROs, they can also engage in similar analytics. We have an aircraft type of which even the OEM does not have complete insight in its reliability. We have a lot of data on the aircraft, since we create it. We see operators around us that are not capable or structured enough to analyse this data. We can approach operators with this data to sell maintenance and inspections. With this data we can also approach regulators to reduce the overall maintenance cycle. Through this way, we can start selling data.

Interviewee 14: This is the MRO intellectual property. However, if you introduce the Blockchain from the industry, the story is different, where focus is on improving operational efficiency and aircraft safety.

Interviewee 13: We currently have an aircraft with a component that transmits data only to its OEM, who will use the data to improve their products and business model. They do not want to share this data with the industry.

Interviewee 14: At the moment you have a component, with historical data, you will not publicise all of it. You would want to keep a certain coverage of the data private.

Interviewee 13: I do think you must process all historical data. However, you must develop a converter that allows us to translate this information to reliability data.

Interviewee 14: At that point you would base your reliability on data that is transmitted from the Blockchain. Everything is related to hours and cycles.

Interviewee 13: The data is available, but we cannot go completely back to origin.

Interviewee 14: At that moment it depends on the MRO and operator to do something with this data. Is it necessary to consider confidentiality? I am not afraid that confidential data will enter the Blockchain.

Interviewee 13: I agree, but you do not want predictive data to enter the Blockchain.

Interviewee 14: That is a model you do keep intern.

Interviewer: *What if you put Mean-Time-To-Failure data? Would other participants be interested in this?*

Interviewee 13: You do not need to put the Mean-Time-To-Failure data on the Blockchain. The data is present, but it is up to the MRO or OEM to extract this data and its associated trends from the Blockchain. I would approach it that way in our business model.

Interviewer: *Do you have any last remarks regarding information exchange, trust or IP control?*

Interviewee 13: If we can include attachments on the Blockchain (e.g. manual), we can include the revision control of the documentation on the Blockchain, which currently is a task that can take up a whole day.

Interviewer: *Considering key activities (e.g. regulatory compliance), what else could you remark?*

Interviewee 13: With inventory management, in terms of component selling. At that moment you open up the data to potential buyers.

Interviewee 14: It might be less interesting for us. However, at the moment you have data on the stock of a huge number of components and you engage in reliability based on Blockchain data, then you can determine whether you need to increase or decrease your components. One problem we face is that we have a degree of stock that we do want to sell out. The first question we receive: what type of paperwork is associated with the stock? Sometimes it is even difficult for us, because: we do have the documentation, but sometimes you miss one of the documents (e.g. shop reports, attachment). At that moment, you face another problem.

Interviewer: *We just discussed selling the component. What about purchasing components? Do you think you can get more flexibility when you have more insight on components on the market?*

Interviewee 13: You can create a negotiation position. At the moment you understand the component behaviour over the recent year, you can tell the opposing party that the component does not meet the standard exchange value. Currently, we must just wait for the component and see what we will receive.

Interviewee 14: I think the component supply will be more regulated. Currently you have a few websites where you can enter the component and you will receive a number of providers. At that moment you send out a quote to all of these providers and when they tell you they have a component, then you enter the process to check the paperwork and whether these providers could become a proved supplier.

Interviewee 13: You can basically get rid of all the component brokers.

Interviewee 14: You basically destroy one market: the component broker market. At the other side, that is also the market that realises and distributes most bogus/counterfeit parts.

Interviewer: *Do you think there are MROs that take these parts in order to get a competitive advantage?*

Interviewee 14: Not of bogus or counterfeit parts. I do not think there are MROs that consciously look for cheap parts with a high risk.

Interviewee 13: Not in this EASA world.

Interviewee 14: No. But, you are looking for the most economically viable solution. If you receive three components, you consider who supplied it for what price. Then it is not necessarily the cheapest component, because you consider the reliability of the supplier and the surrounding paperwork. After that you then consider the cheapest component. You can filter out all the shady suppliers, since they do not participate in the Blockchain. Then you take a step back at the moment you involve an authority that oversees the Blockchain, who can immediately see which parties participate in the Blockchain. In the past we received components that end up originating from a supplier that did not had the capability to put a component on the market, but they still did it. These components were considered bogus/counterfeit, since the participant continued to perform activities for which they did not have the necessary capabilities. With Blockchain, you catch this in a much earlier stadium and he would be removed from the network. On the other hand, there are many parties that earn their revenues with this.

Interviewee 13: You would kill the component broker market.

Interviewee 14: This market is gigantic, especially considering the turnover of aircraft components in the USA.

Interviewer: *Do I understand it correctly that the brokers are the intermediaries between the component suppliers and demanders of the market?*

Interviewee 14: That is correct.

Interviewee 13: I think the brokers that actually have their own stocks will stay in the market. However, there are also brokers that act as intermediaries and provide what we have. We have stock, there are brokers that put it on their platform, hope that they get approached and then purchase our parts.

Interviewee 14: At the moment you have a broker that wants to participate in the Blockchain, they must comply with the regulation.

Interviewee 13: Even EASA is not completely clear about this. You have a distributor that provides the component and a supplier that actually approves the component. You can have a supplier that provides the product – However, as soon as you have a distributor between the supplier and the client, Blockchain can remove this.

Interviewer: *Do you have anything else to remark about quality assurance or maintenance troubleshooting about the Blockchain?*

Interviewee 13: Paperwork will be correct. We often have issues with paperwork. You can improve your manuals, where you always source and install the right components. To be considered a proved supplier, from EASA and ISO we must consider our supplier performance and delays. In that field you can improve management. Currently, we see that large OEMs struggle to provide the components in time. You can basically improve on your lead time, which is also an issue.

Interviewee 14: You make it more transparent. With the Blockchain you can follow the complete lifecycle of a component. You want to be sure that these components leave the manufacturer in the right state and order. You have the incoming good inspection to check whether the component is undamaged. You must assure your quality.

Interviewee 13: You still must do a visual and check whether the component statement is aligned with the data on the Blockchain.

Interviewee 14: You can remove a lot of steps. Even while you do that, you can improve the quality of your process.

Interviewer: *Do you think Blockchain could actually impact the aircraft maintenance itself?*

Interviewee 14: Labour-intensive maintenance work will not change. However, you prevent the presence of wrong components or misinterpretation. You can also consider alternative components. Sometimes you order A and receive B, without the supplier letting you know that it is approved, nor is it documented. You must contact your supplier or OEM to check whether you can actually use the component. At the moment all of this data is recorded on the Blockchain, where you can see what happens with component A and you get a notification that component B is also applicable, then you can reduce the communication and prevent wrong component installation. We have seen this happen even with major components that in retrospect turned out to be the wrong component, which forced us to remove all the other components, even though this was not really known by any of us. Basically, this improves our control over aircraft configuration.

Interviewer: *How do you think Blockchain could impact the MRO value proposition?*

Interviewee 13: We remove the red-tape: the paperwork and our speed to process it. I think the real value proposition is in the wider chain, especially when it comes to aircraft and component configuration management. There you can take advantage of predictive maintenance models from a commercial point of view. Operators have huge demand for this. However, they have no insight on how to approach it (e.g. data of fleet is too limited). If you deploy this intelligently, you can really improve your operations.

Interviewer: *They we come back to the authorities, who put importance on the red-tapes. How do you convince regulators that this is the right way to approach it over the hardcopy paperwork with the fingerprints?*

Interviewee 13: I think it is possible, since it is a fool-proof traceability system where we put the old conventional systems in a 2018 coat. It is innovative and a new way of thinking. However, it is better, safer and faster.

Interviewee 14: Indirectly, they are problem owner. Therefore, include them in the solution. Considering the downtime, this can reduce significantly – especially for Aircraft-on-Ground. At the moment you work with Blockchain, where data is digitally available in a 24-hour real-time basis – and you normally wait a night for a reaction – if you can act ad-hoc and you can determine within one hour where a component is with what paperwork, you can act immediately and contact your client. Not considering our operation, if you look at the commercial aviation, you can really improve a lot for your clients.

Interviewee 13: You provide the release-to-service, but the Part M must check whether that is correct and then provide the final release-to-service. You can basically eliminate that entire process.

Interviewer: *Considering ecosystem-based analysis: do you think you would analyse the whole Blockchain in order to provide consultancy to other parties (e.g. regulators)?*

Interviewee 13: Yes. We choose the strategy to become innovative in the MRO industry and leave our conservative mindset. We try to do this through predictive maintenance and healthcare systems. Blockchain perfectly fits with this: you innovate the industry and achieve efficiency.

Interviewer: *Would you then consider to provide Blockchain as a Service to other parties in the industry?*

Interviewee 13: At that moment you consider the revenue structure and see how you can derive revenues from being the owner. The logical answer is: yes, you want to maintain that as an MRO. However, I am not sure how you can do that. You must be able to maintain the benefit of Blockchain.

Interviewee 14: Based on what I read, the Blockchain industry is an industry on its own. There are many companies that take advantage of Blockchain. You could go to a Blockchain architect agency, who can set up the Blockchain with the information you provide them with. At that moment you can ask yourself the question whether this service will be of value to an MRO, since you have competitors that are specialised in this.

Interviewee 13: You need to keep the expertise in-house. But I think the Blockchain will be a difficult domain. However, as an MRO we must check which translators we can couple to the Blockchain through which we can acquire predictive maintenance or improve predictive maintenance.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO cost structure?*

Interviewee 14: I think the gain is in terms of the component logistics process throughout the organisation, which is from the moment the component is sourced to installation until it is regulated as an unserviceable component. At that moment you are less concerned and you can just return the component as an exchange unit or send for repair to a certified repair facility with Blockchain ID. In that regard, we can save efficiency in terms of time, labour, you can deploy your employees elsewhere. You recognise and correct faults more quickly. Your quality system will be less complex. However, when you consider the costs associated with initiating a Blockchain, those IT costs can be gigantic.

Interviewee 13: It is interesting to find out how large this investment would be.

Interviewee 14: The IT requirements actually are not too demanding. I am convinced that every MRO have the right capabilities to deal with it, especially if it is web-based.

Interviewee 13: I have heard you speak about RFID's. What is your vision on this?

(.) Discussion is focused on RFID and IoT: RFID is important, cannot send reliability data.

Interviewee 14: If we go back one step: the aircraft is one Blockchain and each component has its own Blockchain, which send their data automatically to the system without any human involvement. The aircraft will count its own hours and cycles. At that moment you lose your CAMO, since the aircraft will tell its owner that it has a brake that must be overhauled. The owner will engage with the MRO, similar to a car owner that goes to the local car garage when his brake must be replaced.

Interviewer: *That is one of the risks of Blockchain, where there is the chance you might remove not only component brokers, but also CAMOs out of the equation. Do you think CAMOs would be supporters of the Blockchain?*

Interviewee 14: I think you will not remove the CAMO. There is not one owner that really has good insight of their own aircraft. You will keep the CAMO, but their activities will reduce to a five-minute check of the aircraft.

Interviewer: *Do you think the employees of CAMO will share the same opinion?*

Interviewee 13: There might be some resistance involved. We have our own CAMO, but it would be great if Blockchain can be used there.

Interviewee 14: It is far away, at the end it already happens in a very simplified way.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO negotiation position?*

Interviewee 13: Two aspects: 1) you can improve your negotiation position against suppliers when you can see what the history and reliability is of the component you will source; 2) coupled with predictive maintenance, you can expect a certain pool volume in a certain period, so you can acquire more negotiation against your client in a certain period.

Interviewee 14: On the other hand, if you are part of the Blockchain, everyone will know you are part of this chain. To what extent does the opposing party think it is important that you are part of it? The Blockchain guarantees that the component complies with regulatory requirements. It is about the volume. If there is another MRO that can do your work, while you do not have the resources – the choice is then made. The only way you can differentiate yourself towards your client is the service that you provide: you can tell your client that he can receive his aircraft a half day later, because you found a brake with less cycles, better condition, improved history – therefore: the risk of failure is lower. And if you then vacuum the aircraft, ensure that the aircraft shines and you provide the food – that is what they are sensitive for. I think in that regard the business model will not change that much.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO competitive position? Would they differentiate themselves by using Blockchain?*

Interviewee 14: They must differentiate themselves in a different way. The shady companies will be rejected from the market. An owner or operator that wants to comply with aviation regulations will approach a company that is part of the Blockchain. At that moment, you lose your competitive advantage that you can offer components for a low price. Component competition will increase due to Blockchain. It will be more difficult to put out sharp prices on component level. At that moment you are subject to the efficiency of your labour and the small extra services you provide your clients. For example: I can provide my client a component that is better than another MRO – and they are both part of the Blockchain – but, we check the history and do reliability.

Interviewee 13: Blockchain is basically clean data. What are you going to do with this data as an MRO? If you play smart with this, you can win.

Interviewee 14: You basically extend your market, instead of being competitive by providing the lowest price. You start considering the quality and extra value you provide to your clients. This is where the real revenue structure is.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO customer interaction?*

Interviewee 14: I think focus will be more on contracting. He can reduce focus on CAMO. You do this by monitoring their components. We receive the data one-on-one, so we can tell our clients that a problem is approaching.

Interviewee 13: We think a lot about predictive maintenance, but you can also do more forecasting since you can see components throughout the whole ecosystem.

Interviewer: *Do you think in that sense that it would be desirable if the components on the Blockchain can be exchanged between parties as a token (e.g. think about Bitcoin tokens) instead of a different platform?*

Interviewee 13: Currently component exchange happens on paper. Through the Blockchain our update is their update.

Interviewee 14: The aircraft will be seen as a Blockchain. However, you must ask yourself: how do you maintain the ownership reports? If you receive a component that is part of the Blockchain, the ownership is only recorded in a digital environment.

Interviewee 13: We think about Form 1's, but they may no longer exist.

Interviewee 14: So, basically the component (e.g.) represents a Bitcoin or token on the Blockchain.

Interviewer: *Did you have anything else to remark with regards to changes in customer relationship?*

Interviewee 13: Everything will change: Part 21, Part M, Part 145.

Interviewee 14: Everything will look different: your work package, the paperwork, the maintenance statements. Normally, when you finish your maintenance you send Form 1's to the CAMO. There is not something that will not change. But this is a problem: every Blockchain participant must be organised for it.

Interviewee 13: If you design the Blockchain as a wallet where you exchange components as a token, then you can introduce it very quickly.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO customer channels?*

Interviewee 13: Blockchain will be seen as a new platform that allow you to communicate with your vendor and customer.

Interviewee 14: How does the client end up at our place? If the Blockchain is adopted industry-wide, you still have to show that you are the best on the market. You still have to find a different way to differentiate yourself. However, you could consider to change your way of communication with the client. If you have login on your MRO website, you could provide the client the right to access a part of the Blockchain. That means that you will receive a notification that this client has connected his Blockchain with yours, so you can see what his current state is and what must happen. Ultimately, you will have insight in his component: including location and ownership of the component. It is different from excessive mail and phone communication, where you will then receive temporary access to his component block.

Interviewer: *Do you think this could lead to new client opportunities or loss of clients?*

Interviewee 14: I think the market will be more competitive. It will be easy to acquire many quotes, since you give many suppliers access to your component block. All these suppliers are guaranteed, since they are part of the Blockchain. At that moment you only consider two factors: price and lead time. Those are the only factors that are relevant. In the end if you have the opportunity to allow clients to approach you through a portal, how do you still offer your extra services? In that situation: you still must communicate in form of a mail or phone call.

Interviewee 13: But you still send out your quotes, I think.

Interviewee 14: I think that is an interesting one: how will your quotes look like? With Blockchain you have insight on what maintenance must happen and you can work with notifications.

Interviewer: *If we consider the establishment of the Blockchain consortium, who do you think should initiate it – industry or authority?*

Interviewee 14: I do not the authorities are considered a founder, only a supervisor.

Interviewee 13: I do think they should be involved.

Interviewee 14: From the first step. However, if you consider purely part or component maintenance, then the OEM is the one who will introduce the Blockchain, since they are the first step.

Interviewee 13: It is a chain. It involves OEM, regulator, MRO and part M.

Interviewee 14: There is no owner. However, what is important: who determines which party can access the Blockchain? You introduce another issue: how many OEMs have price agreement with component shops? A lot. That means that you introduce new competitors into the market. Ultimately, if the OEM determines which parties can access the Blockchain, they can determine which component shops can engage with maintenance. Some can be excluded from performing on maintenance. It already happens to a certain degree, since you need to be on their capability list. However, it is not as much as a problem until Blockchain is introduced. At that moment, one party must decide who participates in the chain and other participants must provide consent.

Interviewee 13: That is what happens when you provide ownership to the OEM, which is something you must not do. Currently, they can already state which components must be maintained at which MRO providers – which are those with whom they have a contract agreement with.

Interviewee 14: At some point, if the component is not part of the Blockchain it could even be considered a bogus/counterfeit part.

Interviewee 13: Not necessarily. The OEM recommendation is something that is on top of the EASA regulation and is not mandating.

Interviewee 14: That is true. However, if someone wants to add a block, and all Blockchain owners must validate – which is the power of the Blockchain – and a non-OEM partner engages with maintenance, it will not get accepted by the OEMs.

Interviewer: *To what extent should an MRO initiate the Blockchain?*

Interviewee 13: It is at the end of the chain, which would cause a challenge.

Interviewer: *So shared ownership?*

Interviewee 14: Ultimately, it is key partners who must agree to consensus. If one party disagrees, it will block the network. It is the weakness, but also the strength of the Blockchain.

Interviewee 13: I am just thinking if we will not end up in the system that we currently work in now. If you consider the logbook of an engine, there is nobody that maintains the logbook – except that it is data that can update your configuration management. Must everything be added on the Blockchain or must it be restricted?

Interviewee 14: In that situation it will only be an information carrier. Nothing more, nothing less. At that moment you only accomplish to digitalise the information. At that moment you might as well put the data on a USB that is put on the cockpit of an aircraft. However, it is not real-time compared to Blockchain.

Interviewer: *If we consider the authorities, who currently think it is important to work with paperwork with fingerprints, would they accept Blockchain?*

Interviewee 13: I think they would. They can monitor, they can audit, they can remotely manage the environment. They can stop an operation.

Interviewee 14: I think the impact on the audit industry is much greater. A lot might lose their job. What are auditors supposed to do? They will audit from the computer and sometimes attend an A-Check to check whether the component is actually installed on the aircraft. Even that is doubtful, because even the Blockchain would record when the component is installed on what aircraft. If the Blockchain is invalid, the whole power of the Blockchain is lost. However, I have a concern: all components have their own Blockchain with all their own history. Is it not a killer for the industry? From the moment you make everything public and the MRO, OEM and authorities are part of the chain that can check the data. Then I think about what happened with a car manufacturer: all small dealers were killed, because only BMW dealers had access to their facilities. You might destroy an entire industry when the smaller MROs cannot access the Blockchain. You will be destroyed and you will no longer be considered an industry player. That means that all large players can determine who can survive and who cannot. This already is one of the larger issues for us as an independent MRO, where we face these dynamics. At the moment you work with Blockchain, you create a situation where large players determine who can enter the Blockchain. As a result, you create a situation where you try to guarantee component safety and quality, you remove all the small parties from the industry that impose risk to the network. You might destroy half of the industry.

Interviewee 13: You must not evaluate it from the OEM perspective. You must evaluate it from the regulator perspective, who objectively must evaluate the capabilities of the participants.

Interviewee 14: If I consider the OEM, even if he is not owner of the Blockchain but a participant, he will also see everything. You give them more tools and capability to destroy the small service centres.

Interviewee 13: So, you come back to the fact that you need the ability to give access to anyone. But it is the owner of the Blockchain or the asset that must state: I give certain degree of access to party Y, a different degree of access to party Z. It will be fragmented.

Interviewee 14: Therefore, I think that something like this can only be realised on this scale by authorities. The technology will purely be introduced through regulation, so everyone must play by the rules. There must be no form of collusion, price agreements, unfair competition, or anything resembling that.

Interviewer: *Would the authority in that case be owner of the Blockchain? I can imagine it would be controversial to lose ownership of data you produce during maintenance.*

Interviewee 14: In that case it depends on the data you put on the Blockchain. If you include data on component failure and its findings, you will give intelligence to your competitors. However, that might be the power of the Blockchain. It depends on what perspective you approach this.

SURVEY

Interviewee 13:

How do you think Blockchain as an aircraft spare part capability could impact the MRO business model?					
Component	Very poor (1)	Poor (2)	Neutral (3)	Good (4)	Excellent (5)
Key partnerships				X	
Key activities					X
Key resources				X	
Value proposition					X
Cost structure				X	
Revenue structure			X		
Customer relationships			X		
Customer channels					X
Customer segments			X		

Interviewee 14:

How do you think Blockchain as an aircraft spare part capability could impact the MRO business model?					
Component	Very poor (1)	Poor (2)	Neutral (3)	Good (4)	Excellent (5)
Key partnerships				X	
Key activities				X	
Key resources				X	
Value proposition			X		
Cost structure					X
Revenue structure				X	
Customer relationships		X			
Customer channels					X
Customer segments				X	

Appendix XIV MRO 2 – INTERVIEW 14

CHARACTERISTICS

Since the interview was considered a group interview with two participants, this page is left intentionally blank.

TRANSCRIPTION

See previous appendix for specific quotes from interviewee 14.

SURVEY

See previous appendix for survey results from interviewee 14.

Appendix XV OEM – INTERVIEW 15

CHARACTERISTICS

Function: Senior System Engineer

Expertise: Blockchain and MRO expertise

TRANSCRIPTION

Meeting starts off with an initial dialogue. For this dialogue, only the interviewee is transcribed.

Interviewer: (..) - *Introduction*

Interviewee: What we are seeing is Blockchain, for all intensive purpose, is the first significant technology change that emerge post-cloud. And, what we are seeing is that people will take the new technology and try to implement it in an old paradigm. Does that make sense?

Interviewer: (..) – *Addresses interviewee question and discusses about resistance*

Interviewee: Human resistance to change is a classic model. It has been around forever. There is always an opportunity for innovators, the early market leaders. The challenge of the aviation industry is that it is a reluctant, very risk averse industry. It is very easy for someone to come along and say that it is not going to work. The real issue for them is that the technology is going to displace them from their current skill and they have to learn new skills and understand how to work with the technology. People do not want to do that and are happy at where they are.

Here is the nascent issue: Blockchain is not the only technology that is going to cause disruption in how we conduct business today. Now we have a baseline of understanding: we look at Blockchain in correlation with Artificial Intelligence and in correlation with 5G mobile technology. With other technologies, we wonder what the synergistic opportunity is when we meld these technologies together to disrupt, transform or reform business. Blockchain is just an enabler and we characterised it as a trust mechanism and protocol. We anticipate that smart contracts are going to be supplemented by artificial intelligence. If you have a trust mechanism and a quasi-intelligence mechanism, that is really going to cause dynamic changes in how we conduct business.

Going from left to right on the AS-IS/TO-BE diagram you sent me – it is going to a really powerful disruptor. People can continue to operate in their old paradigm as long as they can and businesses would be more than happy. But what is going to happen is that the underlying mechanisms are going to be outthinking the user – the person that is responsible. These systems will become increasingly intelligent. There will be a slow migration, which brings up another issue. When we look at Blockchain as a standalone component, I think that is just a short-term phenomenon. But, we see all of our major IP suppliers discussing and having conversations about how they incorporate the use of Blockchain within their existing systems: it could be a customer service system, an ERP system, a supply chain management system. What we are hearing is that these companies have developed these systems that we utilise now - either we buy their software or utilise their service – they are incorporating Blockchain in there.

So, they are looking at how we systematically incorporate the use of Blockchain versus having a bolt-on capability. The trust mechanism gets put into place and the artificial intelligence gets wrapped around that. So, the decisioning goes from a smart contract where people define the rules to now where we have algorithms that are determine the optimal solution relative to the problem set or event. If you take the day-to-day things: Internet of Things is providing you with the data; Blockchain is providing the trust; Artificial Intelligence is providing the prognostic decision. So what role does the human have? Someone has to monitor the machines and make sure they are making the right decision. There is going to be a new construct around auditing. How do we verify and validate that these machines are doing what we want them to do? That is going to require some thinking and training.

Interviewer: (..) – *Shares perspective on importance of data quality and validation, given the requirement to train employees*

Interviewee: If I wanted to mess up a Blockchain and they were relying on IoT-enabled devices – and all I have to do is subvert one of those devices and start putting inaccurate data into the Blockchain. Validation of data is important. So how do we fix that? The whole concept, where we are seeing, is pushed out to the edge with a greater intent to manage how things are done. So, if you look at Blockchain and how it is initiated early on in the last months and how it is being instantiated – it follows that data centre mentality where we put data in the cloud. The cloud is just a virtualization of your computer that you have in the data centre. What we dissipate is that Blockchain will move to the edge and be part of the function that occurs out there. The machines need a trust mechanism to verify and validate. Today we think about trust between human to human. Do I trust the data? The Blockchain will become a trust record for machines. It has to be in order for the machines to be able to trust each other. So there has to be some trust mechanisms put in place for the machines. So, if you move the concept of a trust record being facilitated by the Blockchain to the edge, then the machines can start to verify and validate through consensus that is accurate information. So, for somebody to overcome an IoT device that is being monitored for consensus – it can be extremely difficult for someone to overcome an IoT device and populate the Blockchain with invalid inaccurate data. That brings up the whole thing about security: information and cyber security. There is progress being made on that vector. These are some of the thoughts we are having around how Blockchain gets utilised and specifically how it could be used in an Aviation ecosystem.

Interviewer: (..) – *Agrees with interviewer regarding the importance of identifying Blockchain use cases, which was the first part of the research. Moves the discussion to understanding the impact. Mentions facts regarding supply chain counterfeit parts and the importance to prevent this within the Aviation industry.*

Interviewee: Well, yeah. So, if you think about it today: what is the propensity of imitation or unauthorised parts getting into the supply chain today? Well, it is very prominent. They have controls. But the question you have to ask is: does the introduction of Blockchain with IoT and cyber security make it safer? Well, it does. But, the question is: what is the investment and the relative value I want to realise? Then you ask yourself: what else is happening in the market place to make it more secure and safe, so we do not have fraudulent parts being introduced into the supply chain? I just think it is going to be interesting to watch how this evolved. This is personal perspective, which is in a minority of a lot of people.

Interviewer: (..) – *Raises the interest and question to understand why the interviewee believes his opinion is different from that of the majority.*

Interviewee: I run into the same resistance that you expressed, and probably a little bit more forceful. I do not share the same risk aversion as my peers do. I am more accepting of emerging technology, conditionally upon who I procure the technology from. How I found Blockchain was from a challenge we had in utilising cloud technology. We had one of the most strenuous evaluations we had to overcome in order to utilise cloud technology. Looking at Internet of Things, for example, I think this capability is never going to find its way unless there is a way of securing it. As a result, I start looking at the most secure information technology available on the market. Through research I stumbled upon a virtual coin known as Bitcoin. If that was not secure, it would not work. That is how I came across Blockchain.

A lot goes back to our earlier conversation. People talk about Blockchain from a perspective of virtual coinage (Bitcoin), which to me is the antithesis of providing confidence that a technology is secure. That is inherently the argument I have to deal with: how do we know it is going to be safe? I go to different companies who cannot afford to introduce unsafe technology into the market, since the effect can be measured in billions of dollars if they mess it up (e.g. stock price/goodwill). My efforts and understanding in researching Blockchain technology are done with major IT suppliers. They must have confidence in the technology, or they will not introduce it.

I spent a lot of time listening to what consultancies say on the technology and its capabilities, which is across the spectrum as well. We are also closely monitoring different aviation industry players and what they are doing in utilising the technology. As time goes by, confidence and technological utilisation increases. They were also monitoring what the financial and healthcare industries are doing with Blockchain.

Here is another challenge. I think I mentioned that Blockchain is one of the significant technology changes that is coming after the introduction of cloud. What we are seeing is that (small) companies that are able to acquire aviation industry subject matter experts and are rapidly able to deploy Blockchain-enabled solutions into the cloud. All you need know is subject matter expertise and some knowledge about how to implement the technology. These Blockchain services are already in place. So, you do not have to know the intricacies of the Blockchain technology, because these services are already made available. You just need your subject matter experts and some limited programmatic capability and you could build services out there. We are seeing small companies and are contacted them on a regular basis. They ask similar questions: what do you think the propensity of this solution is going to be in the market place? Generally, we confirm some of the interest that there is opportunity.

The aviation industry faces the challenge of in how to manage aircraft configuration, optimise supply chain and improve customer services. Inherently, people look at emerging technologies and see if they can use its characteristics in order to improve the business. The question then becomes: first to market – market movers. Aviation companies rely on their large market presence to facilitate confidence in moving slow and have airline customers that trust them. When we introduce the technology, we have done our due diligence. A small company is trying to penetrate the market and may be subject to more risks. The risk profile is slightly different.

Meeting then turns into an interview setting through which the impact of Blockchain as an aircraft spare part track and trace capability on the MRO business model is discussed.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the relationships between an MRO and its key partners?*

Interviewee: I think this impact will be positive, because of two vectors: there is perspective of the MRO and OEM. There is always ongoing concern about intellectual property and why I say that you must understand the relationship between the OEM, the aircraft operator and the MRO – and the licensed ability to view the intellectual properties needed or required to work on the airplane. What Blockchain facilitates is better control of the electrical property as it is utilised by the MRO. That is from an OEM perspective, which increases control over intellectual property that is utilised by the MRO. That is a key positive impact. Other members, for example pool partners, get better, more accurate information on the parts of the pool. Why is that important? Some airlines are more selective on what parts they pull out of the pool. They may participate in these pools, but they are selective on which parts they utilise. The Blockchain will help there as well. Additionally, you see disintermediation of some of the business model today. We identified key areas to see which parts of the industry are affected first. We ask ourselves how this progression look like in reality. It is not just Blockchain technology, but the synergistic perspective that those technologies have when they interplay together and how that disrupts business. This intermediation is going to occur in the aviation industry and everyone is going to be affected. There is not one company that will not be affected.

Interviewer: *How do you think MROs will be affected by this disintermediation? Do you think they could lose their business in some way?*

Interviewee: I do not think they will lose their business, since it is a hands-on labour-intensive business. When the plumbing breaks, you have to call a plumber. The robot cannot fix it. Say over the next 10-15 years, no. But then you have how airplanes are manufactured. OEMs are currently dramatically changing how airplanes are put together. That potentially could be a disruption to an MRO. We have tens of thousands of airplanes out there. But, the current technology to manufacturer them is not going to disrupt in the near term (10-15 years' timeframe). We are dealing with technology that is 20-30 years old. MROs are not going anywhere. What is going to change is the technology they utilise to manage the work and cost model of having to maintain inventory. So, if the supply chain becomes more intelligent, then what will change is how they interface with the supply chain.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO key activities?*

Interviewee: We will look at the airline operator, in conjunction with OEM and owners - where there is an owner-operator relationship. I think when maintenance must occur, the customisation of the maintenance plan is an interesting emerging opportunity: 1) it is the technology that improves the fidelity of information; 2) artificial intelligence that improve the algorithms; 3) accessibility for regulatory authority that allow for customised maintenance plans. What you are talking about is the customisation of maintenance on the airplane to be more optimised from an operational perspective and a cost reduction perspective.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO value proposition? (operational perspective)*

Interviewee: Well, this goes back to the disintermediation opportunity. It is the availability of information and the ability to apply analytics to that information. What would emerge is a partnership between the airline and the MRO as they are cooperatively analysing the data. What you must have there is an agreement in the analysis between the airline and MRO. So, this is where the real fun begins: the MRO has assets that they derive value from. They have hangars, employees and tools. The airline derives its revenue from the operational airplane.

What the airline is trying to do is minimising the time the airplane is on the ground and the MRO is trying to maximise the full utilisation of their resources (hangars, people tools). That is where these two entities, when partnered together, can optimise that problem set. Today, they do it in a distrustful or untrusted relationship. So, here is where Blockchain comes into play: Blockchain is that trust record. The MRO and airline will see the information together. Through the utilisation of artificial intelligence, the two parties are going to come to an agreed optimised plan – where the MRO resources and operator aircraft availability are optimised. So, that is where I think you are going to see the cooperative value proposition that is going to emerge. But again, that is going to require a partnership between the airline and MRO.

Interviewer: *How do you think MROs could be incentivised to engage in this partnership, from a spare part management perspective?*

Interviewee: In the ecosystem you have these spare parts, whether rotatable or expendables, that are part of the supply chain coming into the relationship between the airline and the MRO. The MRO have to manage its costs and try to minimise its inventory. So, if it has better predictability of when it is going to be performing maintenance to optimise its resources, it needs to collaboratively share that information with the supply chain. So, if the airline and MRO are cooperatively working on when to optimally perform maintenance, they can share that information with the suppliers. The suppliers can have that information and they can monitor their aircraft as well. What is really interesting is that you have collaborative analysis that takes place in the ecosystem. What you are also going to have in this ecosystem is non-collaborative analysis. The airline is maybe keeping a side book or do different analysis based on conditions that they are looking at that MRO and supply chain may not look at. Take the weather information for example, which MROs are not really worried about. Let's say a hurricane is going to hit Atlanta, which is a hub for airline X. They state that they have to shut down their hub for three to four days. So, maintenance will not be scheduled for those days, since the South East of the United States is wiped out. There will be excess capacity in airframes. That whole model, what I refer to as non-collaborative analysis, is segmented specifically to aircraft operations where MROs are not really involved with. These varying degrees of cooperative and non-cooperative analysis is going to take place in the ecosystem.

Interviewer: *In what situations do you think the MRO might not want to engage in collaborative analysis and just expose its information?*

Interviewee: In a partnership, you agreed to share certain type of information, events and analysis that will be conducted on the information. For the good of the ecosystem, you are going to facilitate that. But what might not happen: it is not going to be a complete open book on all data. Take your personal information: if you had ability to control that information within the Blockchain on your personal/private information, there is only certain individuals you will share certain types of information with. Other types of information you do want to share it. Social media is a great example of people who have varying perspectives on privacy of information. Some people just let it all hang out, yet others do not even want to be recognised or identified on social media. So, you will have the same variation in ecosystem based on partners who participate in it. But in general, for the ecosystem to have value there must be a certain level of cooperation and information sharing.

Interviewer: *Do you think MROs currently have the necessary key resources and capabilities in order to engage in such a Blockchain ecosystem?*

Interviewee: I do not think the partnering relationships have been defined between the entities that needs to be there in the ecosystem. I do not see the conversations occurring. I do think there is awareness that these conversations need to occur, but I do not think they happened yet. I think there are key entities out there that have the leverage within their ecosystem to facilitate Blockchain. That might be an easier approach vector – where an airline and their MRO could go establish the ecosystem with relative ease in contrast to companies that did not have a pre-existing relationship with MROs. It would be very easy for them to go in, from the perspective of an MRO that does not have a long-standing relationship within the industry.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO cost structure?*

Interviewee: There is the whole aspect of cost of inventory and ownership of the part. The presumption is: the information that is put in the Blockchain is transparent and immediately accessible. The model of cost of inventory and ownership of the part can change. If you have flexibility of that, there is an opportunity for an MRO to change its cost structure relative to the inventory as a whole. That also goes back to the point of how much disintermediation is going to occur in the supply chain. Today, I do not think the MRO buys a part directly from an OEM. The OEM sells its part to a part intermediary. There are some dependencies and how much cost structure an MRO will be able to achieve based on what is happening in the supply chain. That is an unknown, but it is changing rapidly.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO revenue structure?*

Interviewee: I think there some really fundamental changes that might occur in the industry. The classic model is: what is the value proposition brings to the ecosystem? How will that be disrupted today? You look at engines today – airlines do not own those parts or engines. Airlines do not own the airplane anymore. There is an opportunity for the structure of an MRO today relative to the operational performance of the airplane. How does that relationship change now that airlines act as just operators who do not own the airplane/engine and purchase services? So, I think what Blockchain might be able to do is get improved information. One example is the establishment of aircraft maintenance contracts. This model might evolve rapidly with the use of Blockchain as an enabling technology. But you might see the cost-revenue structure of an MRO change. It is an evolution of airlines that used to do maintenance, then that was consolidated and then it was contracted out. Now you can see a disintermediation of an MRO on certain types of maintenance in the near term – whether it is a heavy check, disassembly or line maintenance that occurs overnight. We have to focus on what type of maintenance we are talking about, and whether or not there is an opportunity for a revenue restructure.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO customer engagement?*

Interviewee: I think it is just an agreement with airlines. If it is a component, such as rotatable pools, then the airline is going to enable the MRO to have visibility on the component relative to cycle and time in service. So, the MRO will go to the airline and say that they have to repair this component on the airplane. You see a push from the MRO versus the pull of the OEM.

Interviewer: *Before we wrap this up, do you think your peers would disagree with your opinion on how you evaluate the business model and be more sceptical?*

Interviewee: Well, I think they would. In general, people are sceptical. We have a couple of use cases and proposed a new service based on Blockchain. The service opportunity was accepted, but the utilisation of the technology was not. The base argument is that we can use it with existing technology. It is a common, chronic response. Yes, you can do it with the old technology. However, why do you want to continue to do that? It is because it is known and safe. We can deploy it immediately and do not have to learn. That is the natural resistance, that I think you are familiar with. I would say it is rational fear. But I think the persistence of rational fear becomes irrational.

SURVEY

How do you think Blockchain as an aircraft spare part capability could impact the MRO business model?					
Component	Very poor (1)	Poor (2)	Neutral (3)	Good (4)	Excellent (5)
Key partnerships		X (short term)		X (long term)	
Key activities				X	
Key resources			X (short term)	X (long term)	
Value proposition		X (short term)		X (long term)	
Cost structure			X (short term)	X (long term)	
Revenue structure		X (short term)		X (long term)	
Customer relationships				X	
Customer channels				X	
Customer segments				X	

Appendix XVI OEM – INTERVIEW 16

CHARACTERISTICS

Function: Procurement Director

Expertise: Supply chain expertise

TRANSCRIPTION

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the relationships between an MRO and its key partners?*

Interviewee: I think it could improve the relationships based on supporting incentive alignment models, meaning I think that some of the key opportunities include: data security and aligning on why or what value drivers the partners achieved through sharing data and promoting transparency through the supply chain. I think it could act as a facilitator or technology enablement to address those key areas and concerns that would help forge closer partnerships between the participants of a Blockchain. Data can expose areas that are proprietary to a given entity and that is very closely guarded. People do not necessarily want to share their maintenance practices and/or strategies as an example. People are very guarded with how that information is used. And I would say it would come back to two elements in my mind: 1) security – the ability to demonstrate how your information is used for all transparency; 2) value drivers – we are not going to share information just because of no other reason less than the value it drives your business – whether it is better decision making and inventory optimisation or part availability. There are all kinds of examples of value drivers that could help as we promote transparency in the supply chain.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO customer relationships?*

Interviewee: Simplistically, I think it boils down two levers: 1) the value drivers and being able to support the value opportunities for the different partners, whether it is an extended partner that actually operates the equipment or entity that maintains it; 2) security – there is a lot of hesitation in today's environment to make a lot of data and information readily available. It is considered in many cases competitive information and it can drive competitive insights.

Interviewer: *If the authority decides to establish Blockchain as an industry standard, does it negatively impact the MRO organisation who does not really like to share the data or would the market stabilise itself?*

Interviewee: I think it would eventually stabilise itself. It is such a new technology and there is still a lot of unknown and possibly even unproven capabilities or uses. I think if something that dramatic were to happen, it would stabilise – people would be forced to learn and understand how the technology could be leveraged. The other dimension would be: what data? I can be an authoritarian body instituting a rule that says that you will use this technology for the purpose of our approval documentation, but there are all sorts of other information that could help the business that have to be treated differently or considered separately. I think ultimately people will see and find out that things will stabilise - they have to understand how to use the technology and rethink what they do today.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO key resources?*

Interviewee: Good question. I am a supply chain person, and not really a technology person. It is entirely subjective. I think that would vary. Certain organisations are much stronger than others in terms of their technology capabilities. What you are making me think – if we are a small organisation that does not have a lot invested in their IT infrastructure. Actually, I think this is an opportunity as much as it is a threat. By that I mean: I think there is ample opportunity to partner with technology service providers that could enable this kind of capability and even position them quicker than a big organisation that has a lot of resources but is slow to move. I think the most significant barrier is: being able to think past or rethink how we do things. I think that is the largest barriers, regardless of the size or what kind of resources you have. Matter of fact, it may even be in your benefit to not have a whole lot invested in your IT infrastructure and you are able to find and align with an effective partnership that could enable you to adopt it faster.

Interviewer: *Do you think that organisations that have invested a lot in their IT may lose their competitive positions compared to other MROs that may not have incurred these IT investments?*

Interviewee: This is my opinion only, but I am sitting in a very large organisation and that is how I feel. Because we are such a big organisation and we have invested so much in our infrastructure and how we do what we do – it becomes that much harder for us to see past that commitment and that investment and look for new ways to approach the problem. Unfortunately, we have a hard time looking truly at the problem. What we look at is where we already are and try to base our approach to the problem through that lens. People that are able to look at the problem directly, without everything else obscuring it, I think are in a better position to leverage new technology like this.

Interviewer: *Do you think that those firms that can leverage these new technologies better are able to innovate and revisit their business models better compared to larger incumbent organisations that are more rigid?*

Interviewee: I think so. I think the ability to look at the problem and attack it. Foremost, instead of having these intermediate considerations, like my current infrastructure, roadmap, infrastructure and partnerships – even those partnerships today can paint or influence our decision and how we navigate through this. That can, in my mind, slow us down – that is a risk. Also, there is a whole cultural aspect. When the organisation gets larger, we get used to how we do things and it is hard to rethink a process – it is difficult to reach and undo that. You have such paradigms – the change paradigm is difficult to overcome. So, I am envious of smaller companies that are looking at it fresh and do not have much invested and are looking at it with new capability sets. It is a wonderful place to incubate new technologies and truly leverage it – those are the ones I am truly worried about. With regard to cultural resistance, that right now, I am convinced in our service parts, is the largest, most significant barrier. That is really holding us back in a big way. For me, I embrace and try to find ways to pursue what Garner calls Mode Two – your folks that are working and make sure that they meet our current commitments with our current tools set, that is fine and have to respect that; but there has to be some portion of the organisation that is well position and committed to support the innovation.

Interviewer: *To what extent do you believe the regulatory nature of the Aviation industry is an issue for key players to focus on new technologies?*

Interviewee: Ultimately, I think it will help it move and underscore the need for new technologies instead of the opposite. In my opinion, when I think of regulatory requirements, I think we think of the way we manage our business – there are a lot of checks and balances and controls. There is a lot of extra scrutiny that goes into our processes, because you need it to be safe. I think what we are talking about here, the combination of security, visibility, smart contract and process flows – that would actually enforce process disciplines and streamline certain processes, I think all those elements could support those regulatory requirements in my mind. They would be a better infrastructure to ensure that you are meeting those regulatory requirements, instead of it being a reason why this could not thrive in this industry.

Let me give an example you make me think of: five years ago, we were debating the impact of additive manufacturing in aerospace. Company X is a subsidiary of Boeing and we do not manufacturer, nor have engineering authority over any parts. We buy products for OEMs and sell them to the aftermarket. Thus, this technology is very important to us. If you can print the part you need at the gate, why are you going to buy it from Company X and hold/stock it – you do not need to. The discussion went to: additive manufacturing is a long way before it will make flight critical parts. They said that this will not happen in our lifetime: there is all kinds of regulatory requirements, considerations within Aviation that preclude the ability of that technology to actually thrive in our industry. Two or three years ago Company Y introduced a flight safety part that is completely done through additive manufacturing and are on track to provide a huge number of parts on the market with that technology.

So, there is going to be a forcing function that is going to gain some traction. Regulatory considerations are what makes our industry and supply chains difficult and challenging. It does not mean that technologies will not thrive in there. I think it will once we understand it better, I think it would actually support those regulatory requirements in much a better way than we are able to today.

Interviewer: *Do you think the initiative of adopting such a technology would come from the industry key partners that work on this together, or do you think it would come more from the regulator?*

Interviewee: I think that is going to be a race between industry participants and regulatory bodies. I think what sits in between is value and safety. So, if you think about it: as we begin to understand and mystery starts to dissipate around Blockchain, what is going to happen is: the business entities are going to find the value of the technology. On the other hand, the regulatory bodies are going to begin to understand the value in terms of supporting regulatory and safety requirements. I think it is going to be a horse race between those two – which one wins. I could see the business winning – there is so much value here, just in terms of sheer dollar investments and savings – both top- and bottom-line. The business will lead regulatory bodies to promote this, but that is my guess.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO cost structure?*

Interviewee: Once we begin to understand the technology better, I think this is one of the basic building blocks alongside other digital technologies. Think about IoT platforms, additive manufacturing, AI – Blockchain is in that canvas. From a supply chain lens, there is two broad areas: 1) there is a whole series of processes and data that support decisioning, which boils down to – what products do I need, when I do need them, where do I need to place them, which are key dimensions around the supply chain; 2) then there is a whole other

layer of activity that we call the execution layer – once I understand the considerations (what, when, how many, where) then I need to execute: process my order, close my contract, negotiate a contract, support a repair order – these are all execution processes that are driven by data and process. I believe Blockchain can enable both of those broad areas. Today our business canvas, or our ecosystem is such that everybody behaves in their own world. Everybody does their own process and their portion of the process in one area. It is very siloed. The other way of describing it: you are going to read about IT (e.g. CRM, ERP – in-office tools and systems) and OT (operating technologies – the technologies we use to support our maintenance environment) conversions. Blockchain has the opportunity to thread that information together – whether it is within that decision or execution layer. The big opportunity there is for people to understand the technology in the context of bridging the information and process so you can share across and promote better decisioning and execution. The combination of those elements results in better top- and bottom-line performance. I am here broadly speaking about business performance – both supply chain and maintenance performance.

Interviewer: *Could you give me a few examples of fields in which decision making could be improved?*

Interviewee: There are several examples. One example is life limited parts, which by definition have a replacement rate or some sort of action that needs to happen at given intervals based on some sort of causal factor (whether it is hours or cycles). Today, I know that a lot of airlines track those high-dollar assets (e.g. landing gears) manually. Those are typically serial numbered components. That type of process and supply chain is a very important one. This is why for these types of components there is a lot of focus in today's current state to cover the network requirement for uptime. You cannot afford to have these parts taken care of. When they cycle out they need to be replaced or repaired. There is no exception. You have to be on top of your game to make sure that you are up to date on these components. Today, all of that is done manually. Tomorrow, I think Blockchain could help us track by serial number in an automated manner much better and promote visibility through the supply chain (from the maintenance environment → back into the supply chain → upstream into the procurement → back into supply base) to help us understand and see not only what happens but also what will happen so we can plan accordingly at a much better or more discreet level than we able to do today. This is just one example.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO value proposition?*

Interviewee: I think they can improve the experience. Underlying these types of supply chains are commitments. One example is the Power By Hour business arrangements – the business that is responsible for the asset uptime is responsible for the material and labour to support that uptime; for the recipient (operator) they get to pay one predictable fee (to which they are contracted to). So, if I am an MRO, the better I can support that business commitment with better insight and capabilities – that insight and tracking capabilities, the ability to improve tracking of those assets and ability to do corresponding analytics – helps me to perform better. This means: I may not require as much safety stock, as much investment to cover for variability (since I now start to diminish variability in the process). I can share more information readily with my partner and customer who is important, because that customer is performing the operational aspects of that assets day-to-day, so I need a way to ingest that information well and disseminate it through my process for my decisioning. So, we both see what we are working with. A lot of that is today very fragmented and not done well. I think it is a wonderful opportunity to enhance those areas and our effectiveness there.

Interviewer: *How do you think Blockchain as an aircraft spare part track and trace capability could impact the MRO revenue structure?*

Interviewee: In my mind, I think it is an increase in revenue. I think the business will be better positioned to make commitment, so it will affect risk favourably. By doing that, they would be more effective in terms of supporting and retaining current contracts and winning new contracts. I am trying to think of an example of what information I would not want to share if I am an MRO business – what kind of information exposure would compromise my business. Unless I am exposing it to my competitor, but if I am working with my customer or client, what information would hinder my ability to increase my revenue. I do not know what that would look like. In the end it does depend on what type of information you are going to expose – I am thinking of the elements I need to support my supply chain. But, what you are making me think of is: maintenance costs, hours of billing certain work, mechanics payment – I do not know if there is a need to expose that data through this channel. That would be a decision that the business makes, but I would only use this to promote effectiveness of supply chain decisioning and execution.

SURVEY

How do you think Blockchain as an aircraft spare part capability could impact the MRO business model?					
Component	Very poor (1)	Poor (2)	Neutral (3)	Good (4)	Excellent (5)
Key partnerships				X	
Key activities					X
Key resources			X		
Value proposition					X
Cost structure				X	
Revenue structure				X	
Customer relationships				X	
Customer channels				X	
Customer segments				X	

Appendix XVII HEAT MAP JUSTIFICATION

Stress factor #A: Extent of data exposure – Limited: only traceability data

1A Key partnerships

MROs can take advantage of only component logbook data to improve trust by proving component compliancy and legitimacy.

2A Key activities

MROs can take advantage of logbook data to acquire statistics on all component events, instead of not using Blockchain and face the highest category of maintenance (overhaul).

3A Key resources

MROs can improve configuration management and reduce administrative burden as they have access to component data that was previously limited (e.g. part/serial number).

4A Value proposition

MROs should be able to differentiate themselves by selling predictive maintenance if they are able to translate Blockchain logbook data to component reliability data.

5A Cost structure

Even with only component logbook data, it is possible to reduce the costs associated with component Quality and Assurance checks.

6A Revenue structure

Blockchain can be perceived as a unique selling point, through which MROs can take advantage of the component data to improve their negotiation and competitive position.

7A Customer relationships

Blockchain can help MROs show operators that they are completely transparent by reducing the problems associated with limited component data from physical logbooks.

8A Customer channels

Eventually, the aviation industry would transition towards Blockchain as a complementary Business-to-Business channel, regardless of the amount of data shared.

9A Customer segments

Blockchain can help MROs approach different segments of the component supply chain, including component vendors.

Stress factor #B: Extent of data exposure – Sensitive: Traceability and reliability data

1B Key partnerships

If sensitive component data exchange leaks from the Blockchain, it could deteriorate ecosystem partnerships and trust.

2B Key activities

When extensive component data is exchanged (e.g. reliability), it could help MROs streamline component predictive maintenance.

3B Key resources

MROs would lose their intellectual resources, since all parties can take advantage of the same component data set and commoditise the analytical IP capabilities.

4B Value proposition

MROs currently differentiate themselves with their unique data selling points, which they could lose with a Blockchain where data is shared extensively.

5B Cost structure

With increased component behaviour data, it is possible to engage in predictive maintenance and reduce associated costs with component inventory, maintenance and QA.

6B Revenue structure

The problem with extensive data exchange is that opportunistic MROs can take advantage of this IP to strengthen their negotiation and competitive position.

7B Customer relationships

With extensive component data, the MRO relationships can improve as they provide clients with the opportunity to engage in component big data analytics (e.g. wheel events).

8B Customer channels

Eventually, the aviation industry would transition towards Blockchain as a complementary Business-to-Business channel, regardless of the amount of data shared.

9B Customer segments

MROs could be able to acquire customers when limited data is available and lose these customers when they decide to expose more data on the Blockchain.

Stress factor #C: Extent of network support – Limited: Only direct MRO partners

1C Key partnerships

MROs already exchange component data with preferred and trusted partners in a rudimentary way, which would improve only marginally if only few partners participate.

2C Key activities

When few partners participate to exchange information through the Blockchain, the component logbook data might be incomplete and limit coordination opportunities.

3C Key resources

If Blockchain is only used between certain industry partners, component data and tracking capabilities diminish, limiting the ability of MROs to improve aircraft configuration control.

4C Value proposition

The few MROs that use Blockchain can take calculated risk on performance and inventory, which they can use as a unique selling point to differentiate themselves on the market.

5C Cost structure

When only few enterprises participate in the Blockchain, the MRO faces additional costs of managing not only traditional component paperwork, but also the Blockchain.

6C Revenue structure

MROs can prove to the market that they use Blockchain, but there is limited value to the market since they are one of the very few participants.

7C Customer relationships

When MROs adopt Blockchain, they can convince customers that they are innovators that are ahead of the industry and help improve their relationships.

8C Customer channels

When fewer network participants take advantage of Blockchain, its potential as an alternative Business-to-Business channel is also more limited to only those few participants.

9C Customer segments

In the situation when Blockchain only covers a limited amount of the industry, the ability for MROs to acquire new customers through Blockchain would be diminished.

Stress factor #D: Extent of network support – Widespread: Industry-wide initiative

1D Key partnerships

In the circumstance where Blockchain data is shared across a huge portion of the aviation industry, it is possible to achieve a new level of collaboration and trust across the ecosystem.

2D Key activities

MROs can improve their predictive analytics and inventory management when they are able to draw data upon a global pool of spare parts, rather than a fragmented pool.

3D Key resources

If all participants enter the Blockchain, MROs can have increased control over their aircraft configuration due to increased insight in the origin of all aircraft components.

4D Value proposition

Even though MROs can no longer differentiate themselves on the market with Blockchain, they do not sacrifice their current value proposition.

5D Cost structure

When the whole industry adopts Blockchain, all participants invest in one information exchange standard instead of many standards.

6D Revenue structure

MROs can prove to the market that they use Blockchain, but there is limited value to the market since they are one of the many participants and lose their quality differentiation.

7D Customer relationships

When every party takes advantage of Blockchain, MROs lose their unique Blockchain selling point that they can market towards their clients to improve their relationships.

8D Customer channels

In the scenario that the whole industry takes advantage of Blockchain, it could be perceived as an alternative Business-to-Business channel to the whole value chain.

9D Customer segments

When the ecosystem actually supports Blockchain, MROs could open to a larger market and gather prospective clients who look for trustworthy MROs.

Stress factor #E: Extent of regulatory support – Limited: Opposition from EASA and FAA

1E Key partnerships

With opposing regulation, Blockchain will not affect how information is exchanged nor how trust is built up in the industry.

2E Key activities

Since MROs would be expected by regulation to operate with traditional component documents, aircraft maintenance activities would remain unchanged.

3E Key resources

In order to comply with existing regulation, MROs are expected to continue to operate with traditional component documents (e.g. physical logbook/Form 1's ownership documents).

4E Value proposition

Since the underlying key partnerships, activities and resources remain unchanged, Blockchain would not contribute to the value proposition of an MRO.

5E Cost structure

Ultimately, if regulations oppose the technology, MROs would only have invested in Blockchain without any real prospect of acquiring cost reduction.

6E Revenue structure

Using Blockchain in a restricted environment does not affect any MRO negotiation or competitive position, thus they do not acquire new revenue opportunities.

7E Customer relationships

8E Customer channels

9E Customer segments

Regulators and their decisions are not allowed to affect the MRO industry business dynamics (e.g. interaction, channels, segments) between MROs and their customers.

Stress factor #F: Extent of regulatory support – Full: Involvement of EASA and FAA

1F Key partnerships

In the situation when Blockchain is seen as an industry standard guided by regulators, trust will increase even more among the participants who see robustness in the solution.

2F Key activities

MRO optimisation activities that are guided by Blockchain component data will be more trusted, as it fully complies with regulation.

3F Key resources

With regulatory support, MROs might face less requirements and a lower margin of error as they certify components with the Blockchain instead of stamps on paper documents.

4F Value proposition

MROs can provide analytical Blockchain consulting services to authorities that require guidance in these systems.

5F Cost structure

As added value is realised, MROs can expect a prospect of cost reduction in the field of component inventory management and administration.

6F Revenue structure

In the end, MROs are responsible for extracting value from the Blockchain, which could mean that some MROs might gain and others might lose competitive and negotiation position.

7F Customer relationships

8F Customer channels

9F Customer segments

Regulators and their decisions are not allowed to affect the MRO industry business dynamics (e.g. interaction, channels, segments) between MROs and their customers

Appendix XVIII LITERATURE REVIEW JUSTIFICATION

Literature group 1: Aircraft Maintenance

	Source	General insight	Research contribution
1.	(Sahay, 2012)	Discusses the regulatory nature of the MRO landscape, including the importance of assuring aircraft airworthiness by reporting each change in aircraft spare part movement, ownership and condition.	This research illustrates that Blockchain can contribute to airworthiness procedures through increased supply chain and ecosystem transparency (page 49).
2.	(Mostafa, Lee, Dumrak, & Chileshe, 2015)	Discusses different component maintenance strategies (e.g. predictive maintenance) of how aircraft spare parts are maintained, repaired and overhauled.	This research illustrates that Blockchain can contribute to predictive maintenance on the condition that ecosystem participants willingly share reliability data (page 49-50).
3.	(IATA, 2015)	Discusses the best practices of aircraft spare part management, with consideration of its purpose, complexities and type of spare parts.	This research illustrates how Blockchain can help MROs improve aircraft configuration management, especially for rotables and limited life parts (page 54).
4.	(Markou & Khomenko, 2012)	Discusses the importance and complexities of tracking and tracing aircraft spare parts within the MRO and throughout its supply chain.	This research illustrates how and why Blockchain can be considered as an aircraft spare part track and trace capability (page 22-23).

Literature group 2: Inter-organisational information sharing

	Source	General insight	Research contribution
5.	(Kumar & Pugazhendhi, 2012)	Discusses the relationship between of inter-organisational information sharing practices and supply chain agility through reduced information asymmetry.	This research illustrates how Blockchain can improve inter-organisational information sharing practices in a transparent supply chain through reduced information asymmetry (page 46).
6.	(Baihaqi & Sohal, 2013)	Discusses the relationship between inter-organisational information sharing practices and organisational performance.	This research illustrates how Blockchain can improve MRO maintenance and administrative capabilities when information sharing practices improve between MROs, OEMs and operators (page 48-51).
7.	(Baihaqi & Beaumont, 2006)	Discusses the importance to focus information sharing evaluation on information content, participants, process and requirements.	This research illustrates how Blockchain can impact MRO component data presentation (page 23), aviation ecosystem (page 24), component asset and information flow (page 25-26).

8.	(Kelepouris, Theodorou, McFarlane, Thorne, & Harrison, 2006)	Discusses 1) the relationship between aircraft spare part track and trace practices and quality of component data; 2) strategic importance to improve track and trace practices; 3) limitations of existing solutions to improve these practices; 4) requirements that must be met by any track and trace capability.	This research illustrates how Blockchain as an aircraft spare part track and trace capability 1) does not necessarily have to improve quality of component data (page 54-55); 2) can strategically impact an MRO (page 44-68); 3) can remedy the limitations of existing RFID solutions (page 22-23); 4) can meet industry and business requirements that is expected of any spare part track and trace capability (page 27).
9.	(Lee, Strong, Kahn, & Wang, 2002)	Discusses important information metrics that define the quality of spare part data: completeness, timeliness and accuracy.	This research illustrates that Blockchain does not necessarily have to improve quality of component data (page 54-55).
10.	(Cohen & Wille, 2006)	Discusses the relevancy of the problem where maintenance information is not made immediately available in traditional data sharing processes.	This research illustrates how Blockchain can contribute to real-time component data availability and how this impacts the overall ecosystem (page 22-27; page 44-77).
11.	(Ngai, Cheung, Lam, & Ng, 2014; Tajima, 2007; Abdel-Basset, Gunasekaran, & Mohamed, 2018; Ramudhin, et al., 2008)	Discusses the value and effect of RFID and IoT for aircraft spare part tracking processes through reduced costs.	This research illustrates why Blockchain must take advantage of RFID and IoT how it could contribute to MRO operations (page 23, 25, 26, 27, 28, 52, 53, 54, 56, 65).

Literature group 3: Aviation ecosystem

	Source	General insight	Research contribution
12.	(Air Transport Association, 2004) (Andresen, 2005)	Discusses the Spec 2000 B2B communication and data exchange protocol proposed by IATA.	This research illustrates how Blockchain could visually incorporate and present minimum, recommended and additional Spec 2000 component data (page 23).
13.	(MacDonnell & Clegg, 2006)	Discusses the aircraft spare part ecosystem by introducing the key parties and the relationships among them.	This research illustrates how Blockchain could impact the relationships between an MRO and its partners and clients (page 23-26; page 45-47; page 63-66).
14.	(Air Transport Association, 2000)	Discusses the aircraft spare part ecosystem and the information flows between key parties and the Spec 2000 database.	This research illustrates why Blockchain must be aligned with existing MRO IT (page 26, 53) and how information flows would occur (page 23-26).

15.	(Palma-Mendoza & Neailey, 2015)	Discusses the component information and asset exchange processes between an MRO and aircraft operator.	This research illustrates how Blockchain could impact the information and asset exchange process between an MRO and aircraft operator (page 25-26).
16.	(Lee, Ma, Thimm, & Verstraeten, 2008)	Discusses how MROs face problems when there are part and serial number discrepancies, which result in components being sent to QA for verification.	This research illustrates how Blockchain can contribute to QA by reducing part and serial number discrepancies (page 51).

Literature group 4: Blockchain technology

	Source	General insight	Research contribution
17.	(Haber & Stornetta, 1991)	Proposes the cryptographic irreversible one-way hash functions that ensure that documents can receive authentic time-stamp certification, which is used by Blockchain protocols.	This research illustrates how Blockchain's cryptographic properties and hashing capabilities can digitalise and provide unique identification to aircraft spare parts and airworthiness certificates (page 22-23).
18.	(Nakamoto, 2008)	Proposes the first large scale Blockchain solution (Bitcoin) that relies on one-way hash functions to register and confirm electronic transactions without intermediaries.	This research illustrates how Blockchain can enable trust (page 47) and disintermediation (page 60; page 62-63) in the MRO industry.
19.	(Buterin, 2013; Szabo, 1994)	Proposes the second large scale Blockchain solution (Ethereum) that enables smart contracts that embed business rules into computer-codes that are cryptographically computed.	This research illustrates how smart contracts are positioned for MROs aircraft spare part management (page 53-54).
20.	(Swan, 2015)	Proposes the development and deployment of Blockchain in three tiers and introduces the necessity to identify the impact of Blockchain adoption on business models.	This research is focused on Blockchain 3.0 with focus beyond currency and finances and provides a relationship between Blockchain as an aircraft spare part track and trace capability and the MRO business model (page 44-77).
21.	(Özsu & Valduriez, 1991; Tanenbaum & van Steen, 2001)	Discusses the importance of Blockchain to promote decentralisation and improved business economics.	This research illustrates how Blockchain can improve data accessibility, transparency, and standardisation (page 22-27).
22.	(Mougayar, 2016)	Proposes Blockchain from a technical, business and legal perspective.	This research illustrates how Blockchain can facilitate the exchange of aircraft spare parts between MROs, OEMs and operators without the presence of intermediaries (page 60; page 62-63).

Literature group 5: Blockchain technology for supply chain management

	Source	General insight	Research contribution
23.	(Morabito, 2017)	Proposes Blockchain for the use case of supply chain management, where it is possible to use the Blockchain to register and maintain details on the provenance of any asset throughout its lifecycle.	This research illustrates whether Blockchain can contribute to spare part provenance throughout its lifecycle by reducing reliance on paper documents (page 54), reducing counterfeit assets (page 54) and by encouraging IT standardisation (page 53).
24.	(Matilla, 2016) (Tian, 2016)	Discusses a practical example where Blockchain is used to track the movement, ownership and other events of laser-inscribed serial numbered diamond and food.	This research applies this concept in the aviation industry, where aircraft components can be tracked with RFID and IoT through the Blockchain (page 22-27).
25.	(Kim & Laskowski, 2016)	Proposes the importance of asset provenance in research and business, since it is often difficult to track assets that are part of a complex, international and inter-organisational supply chain network.	This research verifies the importance of asset provenance in the MRO industry, since it is difficult to track and trace components through the aviation supply chain and proposes the ability of Blockchain to remedy these problems (page 22-27).
26.	(Hua & Notland, 2016)	Proposes Blockchain as a shared IT overlay that acts as an alternative to a scenario where data is buried in legacy ERP that cannot be easily accessed by third parties.	This research verifies this concept, since Blockchain can enable MROs, OEMs and operators to elevate the barriers of information sharing (page 46; page 54-55).
27.	(Garzik & Donnelly, 2018; Crosby, Nachiappan, Pattanayak, Verma, & Kalyanaraman, 2016; Korpela, Hallikas, & Dahlberg, 2017; Pflaum, Bodendorf, Prockl, & Chen, 2017)	Proposes Blockchain as a distributed database that can improve supply chain transparency, traceability, security, trust and real-time accessibility.	This research illustrates how Blockchain can contribute to spare part component transparency, traceability, trust and real-time accessibility (page 44-77).
28.	(Kshetri, 2018)	Proposes incentives for supply chain members to participate in the Blockchain ecosystem through improved supply chain KPIs: cost, speed dependability, risk reduction, sustainability, flexibility.	This research develops incentives for MROs (page 44-77), OEMs and operators (page 75-76) to participate in the Blockchain ecosystem.

29.	(ECRIM, 2017)	Given the changes in governance of business networks and distribution of supply chain tasks, this paper raises the concern to what this impact existing business models.	This research illustrates how Blockchain for aircraft spare part management can affect the MRO business model (page 44-77).
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Literature group 6: Blockchain ecosystem

	Source	General insight	Research contribution
30.	(Baran, 1964)	Discusses that switching between ledger network can affect the interaction of the business ecosystem.	This research illustrates how the transition to Blockchain can impact the interaction between an MRO and its partners and clients (page 23-26; page 45-47; page 63-66).
31.	(Walport, 2016; Pilkington, 2015; Swanson, 2015; Baliga, 2017)	Proposes a taxonomy through which it is possible to determine whether Blockchain is public or private and permissioned or permissionless.	This research illustrates the necessity to deploy a private permissioned Blockchain consortium for a conservative MRO industry (page 22-27).
32.	(Gupta, 2017)	Proposes which parties should participate and operate in a private permissioned Blockchain consortium.	This research illustrates how each aviation industry participant assumes their role in a potential Blockchain consortium and discusses how initiation and ownership should be allocated (page 22-27; page 73-77).

Literature group 7: Business models

	Source	General insight	Research contribution
33.	(Haaker, Bouwman, Janssen, & de Reuver, 2017)	Proposes and introduces the Business Model Stress Test, a business model evaluation methodology.	This research applies the methodology to evaluate the impact of Blockchain as an aircraft spare part track and trace capability on the MRO business model (page 44-77). Furthermore, the research attempts the remedy the weakness of this methodology by incorporating mixed methods (page 37-43).
34.	(Osterwalder, The Business Model Ontology - A Proposition in a design science approach, 2004)	Proposes the Business Model Canvas, a popular business modelling ontology.	This research applies the Business Model Canvas and identified two limitations for its application in this very specific research (page 90).