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Master Thesis

Topic: Beyond financial metrics, the place and role of technical and other additional due diligence in the process of Mergers & Acquisitions transactions. Case study in the Engineering Services Industry.

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Abstract: This paper aims at complementing the literature on Mergers & Acquisitions (M&A) with a case study to provide the lecturer with a full insight on the diversity of the challenges inherent to M&A transactions.

Especially, a strong emphasis will be made on extra-financial analysis of the target. Indeed, a M&A process always includes a very formal and standardized financial analysis of the target, called the Financial Due Diligences, very often including also a similar Tax & Legal Due Diligences process. However, the collection and analysis of other information relative to the business and its specificities are much less standardized. As regards to the technical capabilities of the target or economic and operational considerations, the level of information available to the purchaser might be significantly variable from an acquisition to another, depending on the availability of the info first, but also on the quality of the analysis of them.

This case study will provide concrete examples of what additional analysis to the financial ones can be performed on the target and its environment. It will be then discussed how crucial they might be in the decision-making process of pursuing with the acquisition or not. The discussion will be extended to the place that take each of those analysis (financial and extra-financial ones) in the valuation of the target and the consistency of current valuation methods as regard to the importance of each element.

Key words: M&A, Due Diligence, Technical Capabilities, Valuation

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Glossary:

Vocabulary relative to the financial domain:

EBIT: Earnings Before Interest and Taxes

EBITDA: Earnings Before Interest, Taxes, Depreciation and Amortization

HR: Human Resources

LOI: Letter of Intent

M&A: Merger & Acquisition

SPA: Share Purchase Agreement

Vocabulary relative to the engineering domain:

ADG: Aircraft Data Gateway

API: Application Programming Interface

BES: Batch Execution System

CI: Condition Indicators

E/E: Electrical and Electronic

FPGA: Field Programmable Gate Array

HIL: Hardware in the loop

HUMS: Health and Usage Monitoring System

IoT: Internet of Things

IP: Intellectual Property

MIMO: multiple input – multiple output

R&D: Research & Development

SIL: Software in the loop

STEM: Science, Technology, Engineering and Mathematics

Introduction

In the life of a company, an operation of Merger and Acquisition (M&A) is always an event of high importance, regardless of the size of the company or the sector. Such operations consist of a transfer in ownership of the company, or part of a company. A portion or the totality of the capital of the *target* company will be acquired by the *acquirer,* or *purchaser* which becomes shareholder of the company. The reasons for a company to acquire another can vary from strategic opportunity, financial opportunity, diversification of activities, growth accelerator to many others. In any case, such operations are risky, and their realization is subordinated to an extensive review of the target by the acquirer to ensure its shareholders that the acquisition will not lead to the bearing of unreasonable risks in comparison to the benefits expected from the operation. The review of the target is called the due diligence. Historically, due diligences consisted essentially of a "mechanical verification" of legal, accounting and tax matters (Harvey & Lusch, 1995). Harvey & Lusch (1995) underlined at that time the limits of such due diligences and introduced the need to extend the audit to the intangible assets[1] to have a chance to get a "more fully developed picture of the potential benefits and liabilities" of the target. According to them, "the intangible dimension may [even] have greater impact on the long-run success of the partnership than the tangible assets". Therefore, the extended scope of due diligence provides a better understanding of the current and future value of the target and allows a more informed decision-making.

With globalization becoming more and more present in every business operation, an increase in M&A complexity has been observed in the recent years, especially with cross-borders acquisitions (Carbonara & Caiazza 2013). This increase in complexity in the M&A market supported the need for extended due diligences. Sacek, A (2016) proposes for instance to include the evaluation of critical factors in terms of business capabilities, technological competences, human resources knowledge, strategic relatedness or cash-flow oriented parameters. McGrady (2005) also suggests that "more focus on the less tangible factors such as culture, leadership and change might increase the chances of success". Whatever is added to the due diligences, it seems that it is the entire approach that is challenged, Shimizu at al. (2004) proposes that the learning process during the due diligence must be of an "exploratory" nature.

[1] An intangible asset is an asset that is not physical in nature but has a value for a business (a brand name for instance)

They encourage the pursue of answers to question raised during the process, even if it requires movement outside of the original structure. They describe "good due diligence (…) as semi-structured, containing both primary and exploratory inquiries". A similar approach is shared by Ahammad & Glaister (2008), indeed they emphasized the need of the explorative function of due diligence in order to provide the acquirer the most complete understanding of what is being purchased.

However, extensive literature relates the high rates of failures in M&A; also referred to as destruction of value for shareholders. Schoenberg (2006) gives a mean acquisition success rate of between 44%-56%, within a sample of British cross-border acquisitions, this range matches the typical 50% rate given in literature and press articles and still accurate nowadays (Cullinan et al., 2004; Koi-Akrofi, Godfred., 2016).

The article from Cullinan et al. (2004) starting with the statement "Deal making is glamorous; due diligence is not" suggests pretty clearly the role that the quality of due diligence plays in the success or failure of a M&A operation. It would probably be incorrect to say that the interest of due diligence is questioned by companies intending to make an acquisition. Indeed, acquirers know the due diligence will provide them with a stronger base to define the acquisition price they are willing to pay. However, what is suggested in Cullinan's article is that due diligence keep focusing on "essentials" elements, especially the financial metrics and tend to limit the investigations performed beyond that. Therefore, the level of information available to the purchaser might be significantly variable from an acquisition to another, depending on the quantity of information collected first, but also on the quality of the analysis conducted afterwards. Harvey and Lusch (1995) analyzed the issues impacting directly the level of due diligence and listed time restrictions, cost constraints and situational factors as reasons for "effective examination of the target acquisition - beyond the major financial, legal, tax, and future sales projection - to not occur". However, the main reason for investigations beyond the financial metrics that remain very high-level is probably the fact that the "intangible" is by definition much harder to assess and measure than the tangible.

As a result, the financial, tax and legal due diligences are much easier to perform and are much more standardized. Specific firms have specialized on those audits, the most famous ones being KPMG, Deloitte, PwC, Ernst & Young, or Mazars. In almost every M&A operation the potential acquirer mandate one of them (or one for each topic) to carry out the financial tax and legal review of the target company. For all additional investigations the processes are much less standardized. If the acquirer wishes to perform more advanced diligence on marketing, operational, technical, cultural, or other aspects of the target's business it will be limited to

public information, market studies and/or experts from the target's industry that he is in position to have access to (Sacek, A., 2016), and lastly to insightful discussion he might have with the target itself. Obviously, the last source of information being the most biased and subjective one of the list.

Aims of the study:

This paper aims at complementing the literature on due diligences performed in M&A with a case study to provide the lecturer with a real insight on the diversity of elements that can be raised during pre-acquisition investigations and the interest they can represent for the acquirer.

Especially, a strong emphasis will be given to extra-financial analysis of the target. A first part will be entirely dedicated to in-depth analysis of the technical capabilities of the target, its positioning among its competitive environment and the strategic rationale for the acquisition considering the perspective of evolutions on the market(s) served. A second part will propose a review of additional due diligence, still belonging to extra-financial domains, which can have a potential significant economic impact on the target. Topics such as legal, regulatory, political, human resources or even the nature of customer and supplier relationships will be addressed.
A third and last part will then discuss how crucial, each of the elements raised in the sections 1 and 2, might be in the decision-making process of pursuing with the acquisition or not. The discussion will be extended to the place that take each of those elements, in comparison to financial ones, in the valuation of the target and the consistency of current valuation methods as regard to the relative importance of each element.

Methodology & Data:

The research method is a qualitative single case study. The M&A transaction will be approached through the perspective of the potential acquirer.

An immersion inside the acquirer M&A team allowed for observations to be made as close as possible from the deal and the decision-making process. In addition, the role in the acquisition process of each element of due diligence addressed in this paper, has been discussed with members of the top management and M&A experts from the acquirer's staff, based on their past and current experience. Although the data collected remains essentially qualitative, it has been confronted with literature and articles redacted by other M&A experts.

Both the acquirer and the target serving as case study for this paper, operate in the engineering services industry. Their respective characteristics are provided in table 1 below.
The engineering services industry consists of providing services to commercial and industrial companies looking to externalize part of their research and development (R&D). Indeed, the need to innovate always faster on technologies always more complex led to the need for companies to have access to the right resource at the right time for a short or longer period of time, without bearing the risk of an internal recruitment, neither dedicating the time for the recruitment process; in other words the need for flexibility. This is the role of engineering service providers. They play the role of interface between: on the one hand the human resources (essentially engineers) they recruit to constitute a pool of the best resources to fit the current market needs, and on the other hand, the industrials who needs people to work on missions and projects they have. Their business model relies on the difference between the salaries paid to the engineers and the price billed to the customer for the same engineers.

Characteristics of the companies	**Target**	**Acquirer**
Listed/Non listed	Non listed	Listed
National/International operations	National	International (25+ countries)
Size (number of employees)	240	37 000+ (with 32 500+ engineers)
Avg. annual revenue (in USD)	30 M	2 600 M
Verticals served (& revenue breakdown associated)	Airspace & Defense: 70% Medical devices: 20% Other: 10%	Airspace & Defense: 20% Automotive: 20% Rail & Naval: 4% Energy & Life Science: 18% Telecom: 8% Media: 8% Banking Financial services & insurance (BFSI): 18% Others: 4%

Table 1: Main profile characteristics of the target and the acquirer used in the case study

The target is headquarted in a different country than the acquirer. Therefore, this case study will offer a chance to apprehend, in addition to typical challenges inherent to M&A, an overview of the specificities when realizing cross-borders M&A operations.

Results:

It appears from the immersion inside the M&A team of the acquirer under study that investigations prior to an acquisition transaction are not at all limited to financial elements, it is actually crucial for companies to dig into the technical aspect of the business, as well as performing legal, economic, HR, political and furthermore analysis of the target and its environment.

However, as regard to the valuation phase of the target, i.e. assessing its price, the results of the extra-financial analyses have little impact on the price. Extra-financial elements consist essentially of potential deal-breaker or deal-enhancer. Nonetheless, they have a significant role in the anticipation of the integration and the organization of the target strategy if the acquisition is concretized, considering the future opportunities or risks revealed by the due diligence.

I. Technical due diligence

This section focuses on the investigation of the technical capabilities of the target, its positioning among its competitive environment and finally the trends on the market(s) addressed.

On the technical capabilities first, it is often very difficult for the acquirer to assess the quality of the product or service proposed by the target. In the case of an engineering service provider like the acquirer under study, the skill level of the consultants might be variable, and this information will impact the nature of the missions that can be targeted, therefore the revenue associated with them, and so on. However, the level of information provided during the regular due diligence – financial, tax and legal – is usually limited to their name, age, salary, tenure and current position they serve in the company (e.g., electrical engineer, software engineer, etc.). Another source of information for determining precisely the technical capabilities of the target would be to review the past project it worked on, but such projects are not rarely disclosable and if the target accept to share some information it is necessarily biased in addition to remaining generally high-level data.

Regarding the positioning of the target among its environment and its ability to continue performing considering the future evolution on its market(s), it is also difficult for the acquirer to get a fair vision. This area of investigation is not standardized at all in M&A processes. Actually, the level of investigation will depend highly on the knowledge of the acquirer as regard to the target's business. In some M&A cases, for instance if the purpose of the acquisition is the diversification of a portfolio of activities, the acquirer will probably be very unfamiliar with it. In the case under study, both the acquirer and the target operate in the engineering services industry and the verticals served by the target are also part of the large portfolio of verticals served by the acquirer. However, the size of the acquirer - more than 35 000 employees - and the wide variety of services proposed implies that the top management cannot reasonably be fully familiar with the technical aspects of every domain of expertise of its own company. Especially, as the people involved in the M&A discussions are only constituted of top management who left the technique a long ago in most cases, and the M&A team composed essentially of people with a financial background. Therefore, the need for more in-depth investigations might be highly relevant. When the acquirer estimates it to be necessary it can require a "technical" due diligence. This due diligence can be performed internally by people experts on the various domains part of the target's business or even be mandated to an external agency. In the case under study, an expert from one of the acquirer's subsidies operating on a

very similar scope was even mandated to go at the target premises for a few days to provide a better understanding of the target's activities and allow a more informed decision-making.

The following section provides a summary of the technical due diligence that served as a basis for decision-making in the case under study. The technical due diligence is not entirely presented in this paper since elements have been removed for confidentiality reasons.

It was identified that the target's main domain of expertise was the testing and verification processes of software and hardware materials, the collection and management of data within the airspace industry, and lastly the domain of Internet of Things (IoT). In each domain the investigation aimed at better understanding the service provided by the target and the technology associated with it and more precisely their expertise level on the domain. For each of the three domains, the future market trends are also discussed.

I. 1 Hardware and software testing stations

One of the major expertise of the target consists in the testing of hardware and software thanks to dedicated testing stations they develop. The overall functioning of these testing stations will be described hereafter, then the positioning of the target company as regards to these techniques will be discussed.

When building a hardware device or developing a software, being able to perform various test as early as possible in the process has become crucial with the increasing complexity of the systems. It is the case with systems developed for the airspace industry. Indeed, detecting a functional bug or defect becomes significantly more complex, and consequently costlier, when the development is well engaged, and the number and complexity of component integration is greater. The sooner the testing phase is performed the easier and the cheaper the whole process will be. Therefore, specific techniques have been elaborated for testing various complex systems, the most notable ones being Hardware-in-the-loop (HIL) for complex embedded systems, software-in-the-loop (SIL) for complex software, and respectively PIL and MIL for processor-in-the-loop and model-in-the-loop.
The target essentially focuses on the development and sale of HIL and SIL test stations.

(i) Introduction to HIL/SIL systems:

Basically, HIL and SIL techniques consists in building a virtual simulation environment to extensively test the solution in real-time before going any further in the development.

In the case of HIL simulations, a piece of hardware, the embedded system, will be tested in a virtual simulation environment, with mathematical model representing the dynamic systems of the embedded system's future environment (see Fig. 1). The embedded system outputs are fed directly to the simulation, where they are sampled and used as input variables. A dynamic simulation model, acting on these input variables, is evaluated (normally in real-time, but this is not always the case). The outputs from the simulation, which are synthesized from the dynamic model(s), are then fed back into the system under test as outputs, thus closing the control loop (Short M., Pont M. J., 2005).

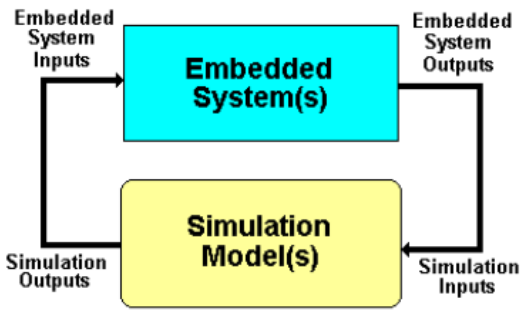

Figure 1: HIL simulation principle

(Source: Short M., Pont M. J., 2005)

In the case of SIL simulation a piece of software will again substitute to a physical environment to allow the testing and early detection of bugs in a source code destined to middleware of software application. The source code will replace the embedded system(s) present in the Figure 1 above.

(ii) Positioning of the target company in the domain of HIL/SIL testing:

The target developed its own HIL and SIL test stations using a semi-custom software that allows them to work with simulation models developed with Simulink[2], or written in C++ or Python[3]. Then, the signal is sent into parallel paths to be run on multiple processor cores. The board they built is designed with 4 Central Processing Units (CPU) sockets, each capable of having 90 cores, so theoretically they could run up to 360 cores in a single simulation. This type of arrangement allows an increased speed; according to sources from the target company they recorded real time performance frame rate of 1 millisecond. In order to get same speeds or even faster simulations, most competitors utilize Field-Programmable Gate Arrays (FPGA) in the HIL or SIL installation. However, the addition of a FGPA in the system comes at a higher cost and longer time of development.

Moreover, the target also developed its own scheduling software, the Batch Execution System (BES). This proprietary software allows them, or their customers, to automate and optimize the scheduling of HIL and SIL test sessions. The BES calculates running times, hardware availability and generates an optimized schedule for usage. This is particularly useful for customers who uses the HIL and SIL stations continuously.

The BES can be deployed independently of testing equipment, providing greater flexibility and reliability over other systems. It is entirely customizable for each implementation, modifying how it executes the test, as well as the post-processing and data collection.

(iii) Perspectives on the HIL/SIL market and conclusion on the target's positioning:

As mentioned in introduction of the section, the need for extensive testing during the development phase becomes crucial with the increasing complexity of the systems. According to Austin Consultants[4], "the number of embedded applications is increasing exponentially". In addition, it is also observed "the evolution of an increasingly complex embedded ecosystem of converging areas including machine-to-machine solutions, Internet of Things (IoT), cloud-

[2] Simulink is a graphical programming environment for modeling, simulating and analyzing multidomain dynamical systems.
[3] C++ and Python are two computer programming languages
[4] Austin Consulting (austinconsultants.com), engineering service provider, specialized in testing technologies.

based apps, sensors, fault detection, security and risk management. (…) The quality challenge is growing but development timelines and budgets not increasing proportionally."
Therefore, the diversity of applications potentially requiring HIL/SIL testing are expected to keep exploding.

The fact that the target has already completed the development of a complete testing line (HIL/SIL testing stations + BES), that is fully customizable, is extremely positive since it offers numerous sales opportunities; either through the sale of stand-alone elements or through the offering of testing services. So far, the target company proposed essentially its services to customers from the airspace industry. However, the acquirer can imagine to leverage this asset by expending the scope of applications of the testing services. In particular, HIL and SIL testing are well adapted for testing in the automotive industry. Indeed, vehicles have become more and more connected and the number of electrical and electronic (E/E) embedded systems have increased exponentially for a few years. But the context is even more favorable now that the automotive sector is heading towards Advanced Driver-Assistance Systems (ADAS) and eventually to autonomous vehicles. The Global Technical Director in the Technology & Innovation Center from a leader in engineering services, explains "the complexity of the driving environment, and the complexity of an autonomous vehicle, lead [them] to demand extensive testing with large data sets" (Altran, 2019). Therefore, the developments to come are numerous before autonomous cars are ready to go on the roads and HIL/SIL testing have a large role to play in their success. They are actually, already in use on many development programs, for instance on real-time simulators for electric vehicles (Silloway T., et al., 2012) or electric powertrain testing (Vasiliu, C., Vasile, N, 2011).

The transfer of HIL/SIL capabilities of the target from the airspace to the automotive industry represent a tremendous opportunity. If the acquisition were to be realized, this transfer would be highly facilitated by the strong presence of the acquirer in the automotive industry. This type of mutual benefits - the target providing expertise on a technology and the acquirer providing its valuable customer portfolio and privileged relationships - are typically the type of synergies that are sought out in every M&A opportunity. In this specific case, the acquirer already identified internally potential customers implanted near the target's location that might benefit from its HIL/SIL testing facilities. These capabilities are even perceived as a potential entry door for approaching new customers and gain contracts for other types of services later on.

I.2 Internet of Things (IoT)

Another important field that the target progressively addressed based on its strong expertise in electrical and electronic (E/E), is the Internet of Things (IoT) domain.

(i) Introduction to the IoT field:

The domain of IoT is gaining increasingly high interest since a few years. Indeed, the decrease in the cost of microcontrollers and wireless communication chips allows nowadays incalculable numbers of daily or professional life objects to get connected and interact with one another.

The development of smart devices requires a good understanding of the various technologies that can be involved in IoT in order to select the one(s) that will best serve the device's application.

This section will provide an overview of IoT technologies that constituted a basis to apprehend the positioning of the target company on the IoT sector and their level of expertise. Finally, based on the capabilities of the target in the IoT domain, the interest of the acquisition will be discussed according to the perspectives of evolution on this specific market.

Various technologies have emerged to serve a multitude of IoT applications from domotics (domestic and home automation), to healthcare, smart cities, supply chain management and many more (*Bhuvaneswari V., Porkodi R., (2014)*). A schematic representation of the interactions of all types of IoT devices with Internet is given in Figure 2 below.

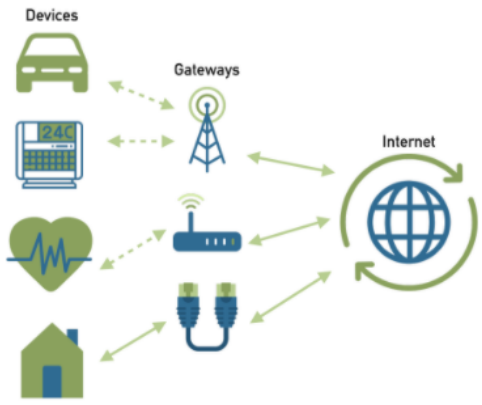

Figure 2: A multitude of devices connected to Internet via various IoT technologies.

The development of a smart device requires first of all, the integration of the right technologies together in order to properly fit the numerous device's requirements. Those requirements include:

- The computational capacity required locally in the device
- The storage capacity needed locally
- The type of interactions with the physical world (type of sensors, actuators involved along with the distance of communication)
- The communication protocols involved (standards or dedicated, wired or wireless)
- The energetic autonomy required (and the power sources accessible)
- Potential cost limitations

Characteristics of an IoT infrastructure:

A smart device is typically equipped with one (or more) sensor(s) to detect or measure a physical stimulus or one (or more) actuator(s) to act upon the physical environment. It comprises at least a microprocessor, analogue-to-digital converters (ADCs), data transceivers, and controllers to convert the data into a digital signal and process it.

There can be a single device or a full network of them to interact with a relay point, or gateway, connected to Internet. Their hierarchical organization is called *topology*. The main topologies encountered in IoT networks are represented in Figure 3.

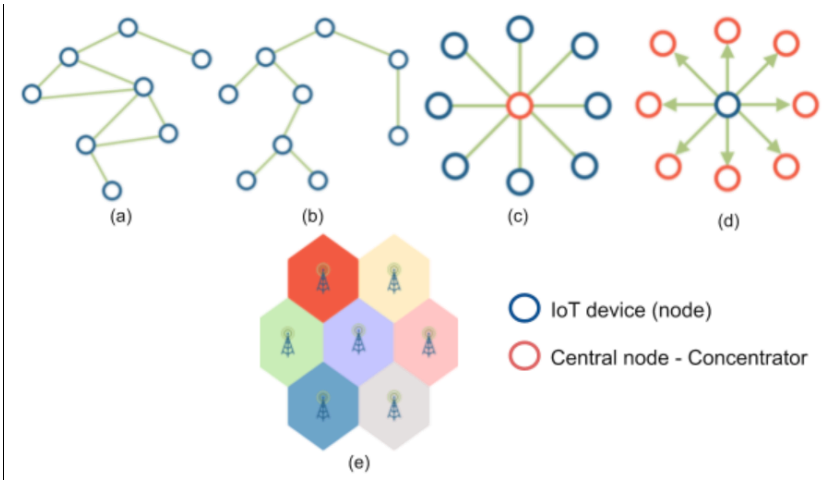

Figure 3: Different topologies used in IoT: (a) Mesh – classical; (b) Mesh – hierarchical; (c) Star; (d) Broadcast; (e) Cellular.

The interest of mesh topology is the extension of the distance between the emitting device and the nearest gateway since the device can transmit data through other devices located around it, each of the connected devices of the network being called a *node*. The star architecture, on the contrary, ensure a direct connection of any device with the gateway, one device can be easily removed without impacting the functioning of the system.
Cellular topologies are very well known since they are used for mobile networks, for instance in connecting smartphones to internet.
Lastly, broadcasted topologies are characterized by the communication of a message to any gateway around, indifferently.

The *communication* with the gateway can be *wired* or *wireless*. Typical physical support for both types of communication are provided below:

- Wired: Ethernet (twisted-pair cable), Optic fiber
- Wireless: Radiofrequency (with different range of bandwidth possible) or luminous

The communication relies on various *data format*, the standard ones being:

- XML: text-based, very heavy because too wordy
- JSON/ BSON: similar to XML but lighter
- CBOR: binary, particularly suited for IoT applications

To allow the transfer of data, each device of the network must integrate the appropriate *communication protocol* defining the way to encrypt or decrypt a message and modify it if necessary. The standard communication protocols are:

- HTTP (Hypertext Transfer Protocol): Binary, allows multiple request & responses.
- CoAP (Constrained Application Protocol): HTTP version optimized for IoT applications (binary, compressed)
- MQTT (Message Queuing Telemetry Transport)

Lastly, according to the technology involved, the *flow rate* and the *transmission range* can be different.
In terms of power supply, many options exist depending on the application. Smart devices require often to be mobile, in that case the need for extended autonomy becomes crucial. In most cases a low-power battery is used, but other power supply systems can be envisaged

depending on the environment, such as the possibility to connect to a small solar panel. Otherwise, the device is directly connected to an electrical outlet.

A summary of the major technologies used in IoT is provided in Table 2 and Figure 4 below with their characteristic's parameters:

Technology	Physical support	Topology	Transmission range	Flow rate	Energy consump-tion	Cost	Comments
3G, 4G	Wireless	Cellular	Entire cellular area	3G: 200 kb/s 4G: 0.1–1 Gb/s	Medium	Medium	Standards for mobile telephony worldwide
SIgfox	Wireless	Broadcast.	30-50 km (rural areas) 3-10 km (urban areas)	10-1 000 bits/s	Very low	-	Adapted to very small data packets
LoRaWAN (Low Power Wide Area Networks)	Wireless	Broadcast.	<30 Km	0.3–50 kb/s	Very low	High	Became a reference for IoT applications
Wifi	Wireless	Star	20–100 m	1 Mb/s–6.75 Gb/s	High	High	Too consuming for most IoT applications
Zigbee	Wireless	Mesh, or star	10-100 m	250 kb/s	Very low	Low	65 000+ nodes possible
Z-Wave	Wireless	Mesh	30 m	9,6 / 40 / 100 kb/s	Low	-	Adapted for domotic applications (lighting, sensors...) especially devices using battery. Max 232 circuits (full mesh)
Bluetooth /BLE[5]	Wireless	Star	8–10 m	1–24 Mb/s	Bluetooth: Medium BLE: Very Low	Low	Adapted to small data packets. Protocol implemented in most smartphones.
NFC (Near Field Communication)	Wireless	Star	<0,2 m	100–420 kb/s	Low	-	Adapted to bi-directional, simple and safe interactions (widely used for contactless payment)
Ethernet	Wired	Star, Broadcast	na	10 Mb/s – 400 Gb/s	na	-	

Table 2: Summary of the major technologies used for IoT applications.

Author's creation using work of Bhuvaneswari V., Porkodi R., (2014); Ray P.P, (2018).

[5] BLE for Bluetooth Low Energy (or Bluetooth Smart), is the last ultra-low power, low-cost version of Bluetooth technology.

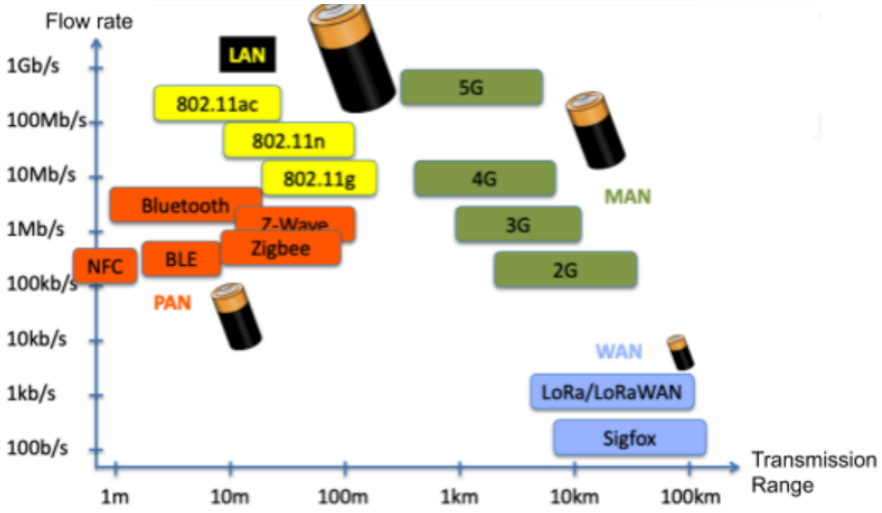

Figure 4: Visual mapping of the major technologies used for IoT applications.

(Source: Extract from a course "Communication protocols for the IoT", by Samir Medjiah, Associate professor at University Paul Sabatier and researcher at the LAAS-CNRS[6])

(ii) Capabilities of the target in the IoT field:

The target company under study worked in particular on two projects aiming at enhancing capabilities of IoT systems.

The first project consisted of overcoming power access limitations preventing some IoT applications to be fully adopted in some areas with limited or absence of power access, poor signal or other physical barriers.

For the purpose of one of its customers looking for implementing a leak detection system in an environment with poor signal quality, the target company elaborated a system using a series of wireless bridges connected by ethernet to a local core server uploading the data in real-time to the cloud. Each wireless bridge consisted of the hardware with embedded processors able to connect four sensors at once to the core server (see Fig. 5).

[6] LAAS (Laboratoire d'Analyse et d'Architecture des Systèmes) : *Laboratory of analysis and system architecture*

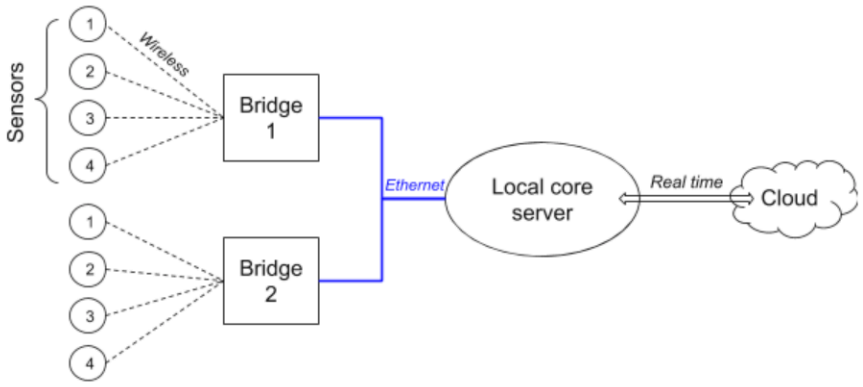

Figure 5: Schematic representation of the first IoT system developed by the target.

Author's creation based on technical due diligence work

The second project, consisted of an IoT platform, constituted of many smart devices, capable of interpolating the location of various users and their requests in real-time. However, during the development phase, the target company realized the standard voice recognition system they were using was insufficient. The sound quality received and transmitted by the connected device's microphones required to be improved. Maintaining sufficient sound quality within a device whose size must be as small as possible is challenging due to the multiple physical phenomena that can appear when sound enter small enclosures. The target company initiated a R&D process to try to solve this issue. First of all, several characterization experimentations measuring the air velocity and velocity profiles at the entrance and within the device enclosure revealed parameters such as the total air velocity, the surface area within the device or the speaker's diameter had a crucial impact on the quality of the sound transmitted. Further design investigations permitted to identify a design with port holes and reduced speaker diameter that showed enhanced sound quality and better voice assistance performance.

In order to free the system from the inherent delay generated by traditional horizontal beamforming methods, the engineers also proposed a vertical configuration of the microphones and the speakers. This configuration required the implementation of a vertical beamforming method, which is not the standard on the market since horizontal beamforming is much widely used.

The final prototype demonstrated enhanced voice recognition without signal delay which suppresses the need for a digital signal processor, as required in horizontal configurations. The target company claimed this was the first vertical beamforming method to be as fast and accurate as traditional horizontal beamforming method. This point was not verified by the acquirer's M&A team.

(iii) Perspectives in the IoT field:

The IoT domain observes a fast-growing rate, however technical limitations remain and prevent from its full adoption.

One of the major limitations is the question of interoperability of the systems considering the wide variety of architectures and protocols (Ray P.P., 2018; Wang et al., 2013). Wang et al., (2013) suggests that particular architecture, middleware-type solutions, shall be devised to leverage the facilitation of heterogenous protocols.

A second common challenge mentioned in literature is the security and privacy of data exchanged (Li L., 2013; Ray P.P., 2018; Roman et al. 2011; Ting S.L., Ip W.H., 2013). Roman et al. (2011) reminds us the large number of presences of attack vectors on IoT entities and the risk it generates when IoT is deployed in medical applications for instance.

Although those interoperability and security challenges remain under work, an explosion of IoT is expected with the deployment of the 5G technology. This technology will rely on new generation radio base stations, the massive multiple input – multiple output (MIMO), constating of a large number of smart transmitting antennas (from dozens to more than 100), each of them equipped with space-division multiple access (SDMA) technology to allow beam focusing between the antenna emitter and the mobile user (the receiver).

The improvements resulting from the combination of these advanced technologies are significant. First, SDMA data to not be broadcasted in all directions of space anymore but only in the space division where the mobile user is located (see Fig. 6, left). This contributes to the quality of the communications by considerably reducing the overall interferences in the area, and at the same time it reduces health and safety concerns. In addition, it allows to serve simultaneously multiple users over the same radio channel, which multiply the connections capacity without requiring more spectrum.

Secondly, massive MIMO increases significantly the quality of the communication by allowing enhanced beamforming. Beamforming is typically used to maximize the fraction of energy transmitted that will reach the targeted receiver in addition to reducing the unintended interferences. With the architecture of massive MIMO, beamforming becomes 3-Directional and increases horizontal and vertical coverage capabilities (see Fig. 6, right).

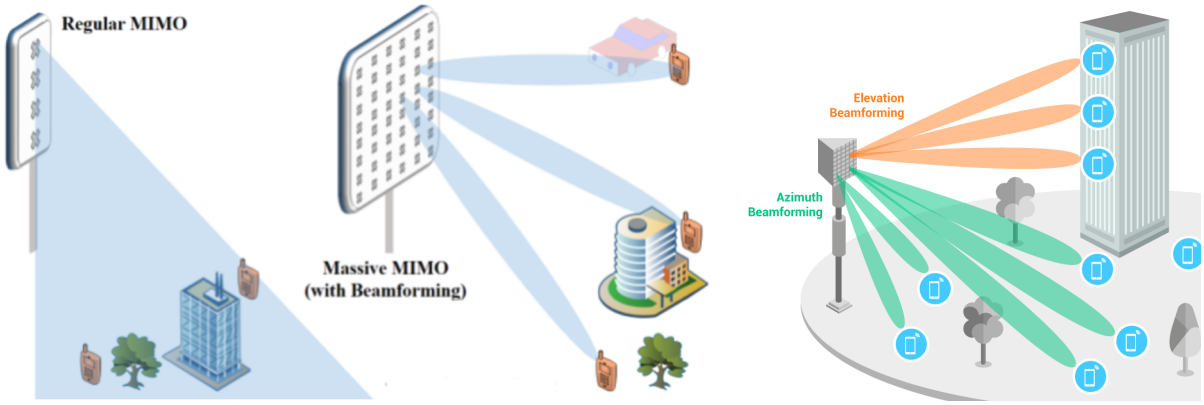

Figure 6: Comparison of the space coverage during transmission with MIMO technologies and Massive MIMO technologies (left); representation of the 3D beamforming capabilities with massive MIMO (right).

(iv) Conclusion on the target positioning in the IoT field:

First of all, the technical due diligence on the IoT capabilities of the target revealed that they master combinations of IoT technologies together along with embedded systems and cloud computing. Compared to other engineering services companies whose services are limited to the picking and assembling of the right IoT technologies, the target demonstrated an advanced positioning.

The successful research work on sound quality enhancement in smart devices is interesting since the work is scalable and can be transferred to many different devices and projects.

Although their pioneer position in term of mastery of vertical beamforming method can be questioned, their successful experience on a project involving new beamforming methods is promising, and one can expect they will be in good position to be mandated on future projects requiring advanced beamforming methods. This is positive considering the number of such projects that can be expected in the years to come to follow the market trend, initiated by major ongoing developments such as the 5G.

Therefore, it can be concluded that the target demonstrates strong capabilities is the IoT domain, which is very likely to benefit for them on a medium-term horizon since this market is expected to explode.

I. 3 Data collection and processing tools for the airspace industry

Engineering services companies are organized to provide services to their customers; however, it doesn't exclude to propose also a few products. On the contrary, it is pretty common to see this type of business model combination. It is common that service companies are asked by clients to develop a hard- or soft-ware that they the client will purchase as a product. It is also frequent that many customers feel the need to develop a similar tool at the same time and that the service provider decides to develop it internally and sell it as a customizable product to its various customers, ideally with a subscription model to guarantee a revenue flow on the long-run.

The acquirer under study is not particularly used to the "product" business model, it historically tended to avoid it. However, the target company under study had recently started working on two products after their top customer initiated a call for tender and they answered to it because of the strategic size of the contract. In that case it becomes even more necessary for the acquirer to investigate with a specific attention this aspect of the business.

It must be highlighted here that in some cases an acquirer may ask the seller to separate the services from the product business in order to acquire only the division of interest for him and leave to the seller the option to close the left division, sell it to someone else or keep it active. This process will not be further detailed here since a carve-out of the product division was not considered in this specific case, the main reason for that being that the services and products were difficult to separate since they involved a same customer, that the seller might have lost interest in the acquirer's offer if he had to deal with a carve-out pre-acquisition while he was looking for a total exit of its activity.

The interest for the acquirer to purchase the target considering its product division will be further discussed in section II of this report dedicated to other type of due diligence, including legal, regulatory or operational investigations.

Therefore, this section will focus on the investigation of the two products developed by the target from a technical perspective, in order to apprehend the interest it represents for the acquirer.

The target is developing since 2017 two boxes, an Aircraft Data Gateway (ADG) box and a Health and Usage Monitoring System (HUMS) box. Both boxes are due to the same customer operating in the aerospace industry.

A. Aircraft Data Gateway (ADG) boxes

(i) Introduction to Aircraft Data Gateways

ADG, or Aircraft Interface Device (AID), are systems that equip aircrafts and act as the central interface for all data flowing into and from the aircraft. Data transiting through the ADG are typically flight operation information, manuals or maintenance data. As represented on the schema (Fig. 7 below) the ADG ensure the real-time connection between pilots, flight crew and ground personnel at any time and any location of the aircraft. Data can be transferred between any of those three actors automatically and in real-time or be stored for downloading after landing

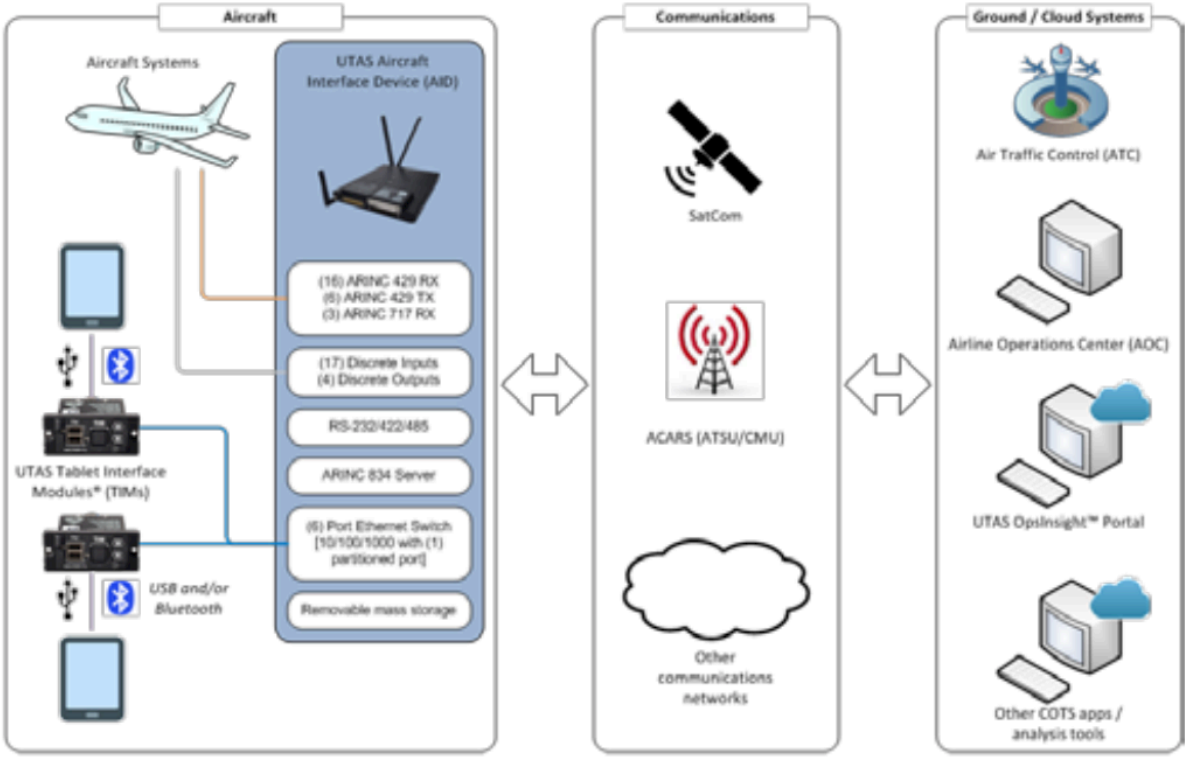

Figure 7: Representation of an Aircraft Data Gateway system and its connections with the ground.

(ii) Capabilities and achievements of the target in the field of Aircraft Data Gateways

First of all, the target company managed to keep the size and the weight of the device to a minimal small form factor. For instance, they equipped the system with a next-generation CPU, smaller and with lower thermal output, in order to meet the strict spatial, power, and heat requirements of the system.

However, when working on the miniaturization of the device they faced overheating issues once in operation. These issues are not acceptable for airspace applications and had to be solved. Indeed, all electronic devices embedded in an aircraft must fulfill strict behavioral criterion while ongoing critical environmental situations. These criteria are defined by international aerospace industry guideline. This topic will be further addressed in Part III.II of this paper.

Therefore, the target company developed both hardware and software aiming at better dissipate the temperature, including designing application programming interfaces (APIs), integrated circuits, field-programmable gate arrays (FPGAs) and a set of controls to allow functioning in environments up to 85 °C (conform to regulations).

In addition, the target company worked at developing a solution that allows airlines to save time when transferring data compared to traditional transfer methods that typically uses multiple data-loading and/or interface units. Indeed, the target company developed a system able to incorporate into a single control box, data coming from various onboard systems. This achievement requires to incorporate in the same device the protocol converter corresponding to each type of data to transfer. Indeed, to ensure the transfer of data from one device to another, the protocol of the first device must be converted and adapted to the protocol of the second device. The protocol converter is the software that allows this interoperability (see Fig. 8 (a) below).

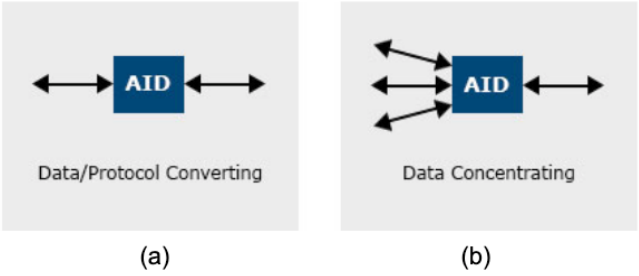

Figure 8: Schematic representation of the role of an Aircraft Interface Device, or Aircraft Data Gateway.
(Source: Astronics.com)

Lastly, the target company worked at the integration of all communications protocols and in particular legacy protocols that are no longer in standard use but still functional.
This achievement is the result of various challenges. For instance, some off-shelf components associated to legacy equipment suffered from overheating failures between 70°C and 80°C when going through the critical environmental tests. Especially, 10BASE-2 protocol caused overheating at 70°C. The company had to design and integrate in the prototype a circuit with a power regulation system to control the temperature that finally successfully passed the multi-drop scenario test for all configurations, including the 10BASE-2 protocol.

To summarize, the target managed to include all the avionics sub-systems, including legacy systems, into one single ADG box, while reaching a miniature size that meets the thermal, regulatory and power requirements under critical environment.

The ADG box developed by the target seem to gather similar features as systems developed by competitors (see Appendix 2 for full datasheet from the target company and three of its competitors) and shows advanced capabilities in term of connectivity since it allows to incorporate wireless communications technology into existing avionics systems.

B. Health and Usage Monitoring System (HUMS) boxes

(i) Introduction to Health and Usage Monitoring Systems

Since the 1980s, Health and Usage Monitoring Systems became increasingly popular to enhance safety of rotorcrafts. Their initial application on helicopters progressively entered the aircraft industry. Nowadays, the use of HUMS is no more limited to flight safety improvements, it also allows predictive maintenance and therefore reduce the time spent on the ground allowing cost savings and a better management of the fleet deployment along with enhanced performances and fuel consumption reduction.
HUMS are devices measuring the health and on-flight performances of mission-critical components in the helicopter (or airplane today). The device is alimented by data collected in specific points of the apparatus through a set of sensors. Typically, in a rotorcraft, HUMS will monitor vibrations in the rotors, and specific health indicators in the drivetrain or the engine.

A HUMS box does not only comprise the hardware to ensure the connection of all the sensors onboard, but it is also constituted of software in charge of converting and analyzing the data flowing in to produce and communicate to ground controls actionable information and advanced prognostics for maintenance (see Fig. 9).

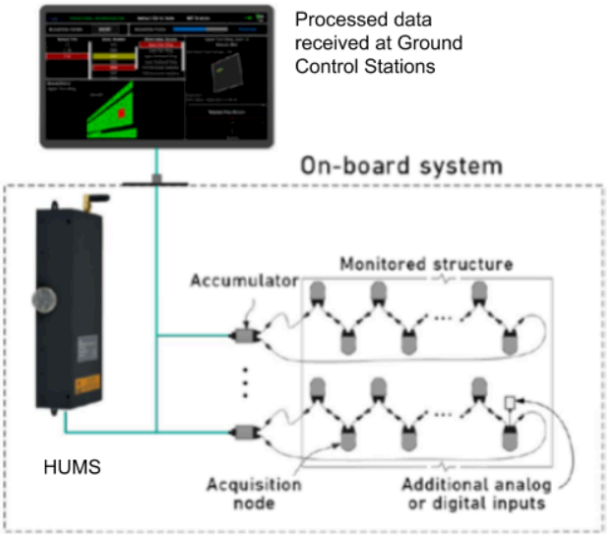

Figure 9: Different hardware elements constituting HUMS
(Source: CollinsAerospace.com)

The advanced software embedded in HUMS rely on fault specific Condition Indicators (CI) proper to each mission-critical element of the apparatus being monitored. Many researches have been conducted on gear fault diagnosis based on CI (Sharma V., Parey A., 2016; Goyal D. et al, 2018). Figure 10 provides example of typical condition monitoring techniques. Besides the large number of studies on the topic, manufacturers provide most often specific CI for the element part they designed. All these information combined are then integrated in the software embedded in HUMS. Based on the CIs, non-regular exceedances of physical quantities monitored can be identified immediately while on-flight.

However, Condition Monitoring science has now evolved to much more complex analysis relying on complicated algorithms using data fusion or even artificial neural networks (Dhamande L.S., Chaudhari M.B., 2016), along with next-generation sensing capabilities (Greaves M., 2014).

Techniques	Insulation	Stator Windin	Rotor winding	Eccentricity	Bearing Damage
Vibration	-	-	✓	✓	✓
Noise Monitoring	-	-	✓	✓	✓
Air-Gap Monitoring	-	-	-	✓	✓
MCSA	-	✓	✓	✓	✓
Temperature Monitoring	✓	✓	✓	✓	✓
Speed Fluctuations Monitoring	-	✓	✓	✓	✓
Induced Voltage	✓	✓	✓	✓	✓
Magnetic Flux Monitoring	-	✓	✓	✓	-
Oil- Monitoring Techniques	-	-	-	✓	✓

Figure 10: Comparison of different Condition Monitoring techniques

MCSA standing for Motor Current Signature Analysis*
(Source: Goyal D., et al. 2018)

(ii) Capabilities of the target in comparison to HUMS's competitors:

The target' HUMS have been developed precisely for rotorcraft applications. It collects, process and interprets data collected from critical dynamic components, including the drive train, engines, gearboxes, shafts, fans, rotor systems, etc. The strength of the product resides in the software processing and interpreting the data. In particular, CI are integrated in neural nets to enable higher analysis level for earlier detection and better maintenance. Moreover, the software offers high level of customization for the user, for instance it allows "to modify the data collection specifications, create aircraft specific thresholds, customize reports, create diagnostics, generate email alerts, and generate maintenance procedures for use at remote sites" (source: target datasheet). No specifications were given on the nature of the transmission of the data collected onboard to ground-based servers.

Since HUMS progressively generalized from rotorcrafts to all the aviation industry, both civil and military, several competitors are now sharing this market.

Among them, Safran Electronics & Defense proposes health monitoring system compatible with Boeing and Airbus aircrafts. Their Aircraft Conditions Monitoring System (ACMS) monitors and controls flight conditions of major onboard equipments. The solution is fully customizable to predict components failures on a short time basis but also to perform analysis of trends on longer time periods in order to maximize the optimization of maintenance operations on the fleet.

As regards to the specific engine monitoring, shaft vibration measurements and actuator response times analysis are carried out after landing. Once on the ground, the data collected during the flight is then compared with the signature of the shaft bearings provided by the engine manufacturer.

Recently, Safran Electronics & Defense developed an additional module allowing wireless data transfer from the ACMS to ground control stations. The Wireless Extension for ACMS (WEFA) stores the data collected and produced by the ACMS on a smart card onboard and then ensure the secure transmission of data via 3G+ connection to a WEFA ground software application installed on the airline servers. However, the data transmission is only permitted once the aircraft has landed.

On top of Safran's ACMS, Boeing designed an Airplane Health Management (AHM) which collects in-flight information provided by the ACMS (or Central Maintenance Computer on specific models) and relays it in real-time to maintenance personnel on the ground via Boeing's internal web portal (MyBoingFleet). The solution provides real-time access to the status of the airplane's current and future serviceability, a system of prioritization of relevant data to assist ground operators in their analysis and the automatic alert or notification if an issue is detected.

Another aircraft manufacturer, Bombardier, choose Pratt & Whitney to partner with him and equip its CSeries aircrafts with an advanced data management service. Bombardier CSeries aircrafts are equipped with an on-board Health Management Unit (HMU) ensuring the collect of data, the Pratt & Whitne's eFAST system will enable the near real-time transmission of data collected on-board to maintenance crew on the ground. However, it is important to note that although the Pratt & Whitney system download data automatically, the crew must transmit manually the data to the ground teams. The data is then processed and analyzed on the ground while the aircraft is still in flight.

C. Perspectives on the airspace market and conclusion on the target's positioning

(i) Perspectives on the airspace market:

ADG systems opened the way to Connected Aircrafts. This trend is definitely what is reflecting from all the website of airspace players, Collins Aerospace states for instance that "if [the enormous amount of data that is produced by all the elements of airline operations] isn't simply connected, if it's not seamless, highly accurate and in real time, then a tremendous

opportunity to make operations as intelligent as possible could be missed." Therefore, the possibility of connected aircrafts meets the changing needs of the modern airline industry.

However, aircraft manufacturers constitute a highly consolidated market worldwide with the two major actors being Boeing and Airbus. The fact that these actors already engaged in the race for connected aircrafts can represent a risk for small suppliers. Indeed, both companies already developed internally platforms with infinite data analysis and storage capabilities, that they propose to their customers (international airlines) on a "platform as a service"[7] model. The two platforms are AnalytX and Skywise, respectively from Boeing and Airbus. Moreover, Airbus already identified its partner for the collect of onboard data to feed the Skywise platform, this partner will be Rockwell Collins. The system developed by Rockwell Collins, FOMAX, consist of an onboard super-router that allows to "[keep] crews better informed while providing better data collection and improved analytics to drive operational efficiency and reduced maintenance", according to Steve Timm, vice president and general manager of Air Transport Systems, a subsidiary of Rockwell Collins.

Therefore, the first major evolution on the airspace market, is the infinite possibilities for airlines to collect and process amount of data accessible onboard.

The second transformation concerns the passengers of the modern airlines, which are expecting now to have access to internet all along their journey, including at 30 000 feet in the air.

Those two evolutions towards fully connected aircrafts raises important challenges, and concerns, in terms of security and accessibility of the data. Indeed, by connecting all the avionics systems and the information coming in and out of the cockpit in real-time, any intrusion in the system becomes a critical safety threat for the flight.

[7] "Platform as a service" (PaaS) is a category of cloud computing services that provides a platform allowing customers to develop, run, and manage applications without the complexity of building and maintaining the infrastructure (source: Wikipedia)

(ii) Conclusion on the positioning of target in terms of data collection and processing for the airspace industry

First of all, the wireless communication of the ADG implies the integration of high-level security firewall. This aspect of the product might require additional investigations on the regulations applying and the verification that the system is protected from external attacks.

Regarding the features of the ADG, the product is in line with the market and the features proposed by competitors. Its efforts to include all legacy systems might become a strength in the 2020 context and the future. Indeed, considering the severe impact of the crisis (initiated by the Covid-19 pandemic) that is expected in particular in the airspace industry, it makes sense to allow the integration of legacy systems in new technologies already being implemented on some aircrafts. Indeed, one can consider that during a time, airlines will prefer to extend the lifetime of their old systems, still in order of work, instead of renewing the entire avionics systems. This strategy of "retrofit" is expected to be the trend in the airspace industry on a medium-term period.

This remark can be extended to the topic of predictive maintenance. Indeed, in this crisis context predictive maintenance becomes a powerful mean to reduce to the maximum the costs generated by flight delays, estimated at over $26 million worldwide per year (Honeywell, 2018). The tools developed by the target in this domain of predictive maintenance have been dedicated so far to military applications exclusively. Considering the momentum for predictive maintenance, the acquirer can consider transferring this technology to the civil aviation industry and increase the sales. Again, the target could benefit from the strong positioning worldwide of the acquirer in the airspace vertical to operate successfully this transfer; this is called operational synergies.

It has been identified in the previous paragraph that the future aircrafts manufactured by the leaders of the market, Boeing and Airbus, will be equipped with systems of collection of data that will feed powerful platforms of data analysis and visualization, namely AnalytX and Skywise. However, with a severe decrease in purchase of new aircrafts by airlines worldwide, the goal will be to implement advanced predictive maintenance systems on older aircrafts, already in service and/or on existing platforms of data analysis. Therefore, the objective for the target consists in making possible to adapt its technology and its advanced predictive maintenance software to any existing system and exist as a stand-alone brick that could even be implemented on the two major platforms AnalytX and/or Skywise.

II. Legal – Regulatory - Operational due diligence

An overview of the type of investigations that can be made in order to have a better vision of the technical abilities of the target company, has been provided in Part II.

The following section focuses now on other analysis that can be performed in order to identify elements that might be of high interest in the perspective of the realization of the M&A transaction. Again, the case study will serve as a guide and provide concrete examples of topics of significant importance raised during extra-financial due diligences. However, most of the topics addressed are relevant in many M&A operations, regardless of the nature of the target, its size, its sector or any other variable parameter. For instance, this includes topics related to intellectual property, human resources, customer relationships or branding.

Some of the elements raised in this section can be revealed by "Tax & Legal" due diligence, which are very common to perform in order to identify potential tax or legal risks incurred by the target along with the evolution of tax and legal situations of both companies if the transaction had to happen.

However, most elements raised is this section are not the result of financial or tax & legal due diligence scope. Indeed, elements belonging to operational aspects of the business or to specific regulations applying to the business, are not part of any formalized type of due diligence (financial – tax – legal). The chances that the potential acquirer has the biggest picture of the target's situation highly depends on its original knowledge of the sector and its own specificities, and/or its willingness to further investigate.

II.1 Transfer of legal and contractual responsibilities

In case of realization of the acquisition, the assets, and contracts associated to them, which are included in the scope of acquisition will be transferred to the purchaser on the date of signature of the acquisition contract, *the closing*. Since all the legal responsibilities of the target will be transferred to the purchaser on the closing date, it is crucial for him to clearly know the risks associated with each asset and each activity of the target.

Therefore, the first step of the legal analysis consists of properly identifying the elements included in the scope of acquisition. This can typically raise intellectual properties issues, or the need for a detailed review of the contracts tight to the target.

(iv) Intellectual property:

Intellectual property (IP) matters are particularly sensitive in the field of engineering. Being the owner of a patent can have a tremendous impact on the future activity of a company. It must be highlighted here that IP matters does not only apply to products but are also a common matter in the engineering services industry. Every time consultants are developing a tool (software, hardware, etc.) for a customer, a contract between the two companies involved specifies clearly the ownership of the IP. In most cases, it is agreed that the customer will retain the IP.

In the case of the target company under study, a few products are co-developed by the target and one of its customers. It is therefore crucial for the acquirer to determine if it will inherit at this acquisition from the IP associated to these products. In the case under study, the IP fully belongs to the target, its customer is entitled to sell the products but not to have them manufactured by another supplier or by himself.

This element revealed by the investigation constituted, in the perspective of this specific transaction, a positive element. Indeed, the acquirer will be entitled to sell the product or adapt the technology behind it for other customers. Especially, since the positioning of the products, analyzed in the Part II.3 of this report, and the outcomes were favorable. The purchaser can expect to sell the products to other customers, even to transfer the technology from the military to the commercial aviation and increase the number f potential sale opportunities.

(v) Contractual engagement:

Once the nature of the assets transferred is clearly identified and the IP matter solved, it is important to investigate the content of the contracts that are tight to the elements comprised in the scope of acquisition. Whether it is about products or services, the target might have signed contracts that engage the company on a long-term period, overlapping with the change in ownership of the company. In that case, the engagements will be transferred to the new company owner at the closing date and this last one must be in full knowledge of its responsibilities.

In the case under study, the target company engaged itself to produce and repair products to one of its clients for a 12 years period (at least 10 years will remain due at the closing date). This deal is the source of several implications for the acquirer, for instance the obligation to maintain the production line active, to be able to detach people at any time within this period from another mission to perform after-sale repairs if needed, etc.

This long-term engagement is compensated by the guaranteed purchase by the target's customer of a minimum of units per year, also settled in the contract. In addition, the price of

any repair has been fixed to 50% of the current price of sale, while the target estimates the repair cost will be significantly below. Although this information remains qualitative, the "product" business of the target seems to benefit eventually to the acquirer since most of the developments costs of the products have been enregistered already and the guaranteed revenue flow from the sales is starting in 2020.

(vi) Specific risk with the assets- *Example from the case study:*

In particular in the field of engineering, products or services sold can have a significant impact on the environment, or on the health or safety of the end customers.

In the airspace industry for instance, the role of each component on the safety of the flight must be clearly known, especially in a scenario where they were to fail. For that purpose, international regulations have been established and apply to all avionics systems. Avionics systems referring to all the electronic sub-systems installed on aircrafts for communication, navigation and numerous other purposes. Either it is hardware or software, any avionic supplier in the world is required to follow guidance at each step of the product development such as the DO-254 Design Assurance Guidance for Airborne Electronic Hardware; the same applies to software with equivalent standards. These standards are organized around 5 level of criticality: The Development Assurance Level (DAL). The definition of each level is provided in Tab. 3 below. Each level defines the criticality for the flight safety of the element considered, in case of top-level failure.

DAL-level	Top-level failure condition severity classification
DAL A	Catastrophic
DAL B	Hazardous
DAL C	Major
DAL D	Minor
DAL E	No safety effect

Table 3: Definitions of the Development Assurance Level (DAL) applying to avionic systems.

The standards are jointly developed and updated by EUROCAE* and RTCA*[8], respectively a European and US organization. Before any implementation on an aircraft, an independent

[8] European Organization for Civil Aviation Equipment (EUROCAE); Radio Technical Commission for Aeronautics (RTCA)

accredited agency must perform test and validations of the system under the specific environment conditions defined in the standards. If the product fulfills the test under the conditions corresponding to its DAL, the agency delivers a certification to the supplier and the product can go on the market.

In the case of the target under study already introduced in this paper, some of the products developed are meant to equip civil or military aircrafts. Therefore, the safety considerations described in this section enter in application. The DAL of each products became a critical element for the purchaser. Indeed, its responsibility could potentially be engaged in fatal events. This has various implications, among them the need to subscribe to specific insurances, in case of accident the exposition to legal procedures, risk of high impact on the company reputation along with following economic repercussions, etc.

The investigation revealed that the two products developed by the target company are certified DAL D, meaning under no circumstances the system can have an impact on the safety of the flight. Therefore, this element of analysis didn't lead to any additional investigation and didn't impact the pursue of the deal. However, if the products had been DAL-A the impact on the deal could have been more important, especially for an acquirer who is not used to that level of legal reliability. This could typically be a dissuasive element for the continuation of the deal, or the purchaser might require the exclusion from the deal of the concerned assets, a situation that might not be acceptable for the target and lead potentially to the deal abortion.

II.2 Challenges specific to cross-border M&A:

The case study raised specific considerations, proper to cross-border transactions. Indeed, regular M&A transactions are already highly risked operations, but the risk profile of cross-border acquisitions becomes even higher compared to domestic ones (Poushali P., 2009). Poushali P., (2009) explains that "information risk is higher as the acquirer often lacks reliable information about the target company. Hence, carrying out a thorough evaluation of critical factors, risks and potential synergies […] requires much more resources". For instance, special attention must be given to topics such as exchange rates, local taxes, local accounting standards, foreign government potential trade regulations (dividends, fees, royalties), risk of expropriation, and debt/equity ratios that might be imposed by the foreign government (Kissin and Herrera, 1990). In addition, Shimizu K. et al. (2004) highlights the need to carefully

investigate the education system, skills, and capabilities of the work force in the foreign country.

This section will focus in particular on the local regulations or specificities that are not necessarily raised during tax and legal due diligence and requires therefore specific knowledge of the market or dedicated investigations.

(v) Regulations on acquisitions:

At national and industry levels, the due diligence process must provide an understanding of the institutional environment in which the target firm is located, such as government regulations, to effectively respond to potential local constraints, particularly in specific industries such as those with high technology standards, in which regulations can be extremely sensitive (Shimizu K. et al., 2004).

This is particularly relevant with the engineering field. Some activities present a sensitive character that might be subject to specific regulations such as national security or national independency regulations. Typically, this is the case of most military and defense activities or of some programs in fields such as healthcare, energy, high technologies, etc. The state government might consider some know-hows must be retained, or research programs kept secret. In that case, the purchase of the shares of a company involved in sensitive activities by a foreign investor or company might be unauthorized by national authorities. In addition to matters of national security or independency, the success of an international acquisition can be challenged by competition authorities. They are in charge of preserving competition among each market and avoid the formation of conglomerates.

Such regulations have tended to be reinforced in a context such as the Covid-19 pandemic. During this period, various governments made public they will complete more detailed analysis of intentions of acquisitions from foreign acquirers on private companies located on their national territory. These measures intended to first, prevent foreign opportunist acquisitions in a period where companies could suffer from transiently difficulties and second, prevent the loss of national control over activities considered as strategic, a situation exacerbated by the Covid-19 crisis in domain such as medical research, medical equipment manufacturing for instance.

(vi) Regulations on business activities:

Beyond restrictions that can potentially impact the realization itself of an acquisition, the operations of the activity considered as sensitive might also be subject to specific regulations. For instance, some components of a product might not be allowed to be manufactured outside the national territory. As a consequence, this element can appear as a limitation for a potential acquirer in the choice of its future suppliers. This can for instance lead to a decrease in the level of cost optimization he was targeting.

In the case under study, this type of restrictions was contractually in place for products sold to customers operating in the military industry. However, investigations revealed that these restrictions depend actually on the product's application. For instance, no manufacturing restrictions applied to the same product if applications were civilian. This information combined with the information obtained from the intellectual property investigations (Part III.1.i) provides to the acquirer a better understanding of the future value it can expect from a product or another. Indeed, in this case the fact that the target retained the IP of the products means the purchaser will be entitled to propose the technology to other customers, even consider the possibility to transfer the technology to a different market and to increase the profitability of the sales by outsourcing the manufacturing to other regions where it has suppliers operating at lower costs. Such element has played, in this case, in favor of the deal.

(vii) Political uncertainties :

The local change in policies might also be perceived as a constraint or a potential risk. According to the context of the transaction, that might be an element the purchaser will like to investigate carefully. The impact this risk can have on the willingness of the acquirer to initiate and then pursue an operation is shown in studies revealing for instance that periods of political uncertainty in a country, such as a period preceding an important election, had a denoting impact on domestic M&A activities (Väisänen, T., 2015).

To a lesser extent, the local change in politics can also have an impact on the financial incentives which the company benefits from. Especially in the field of engineering, where it is very common that states or local administrations encourage and support research and innovation programs through various grants, loans, tax deductions or any other financial apparatus. The probability of changes the political framework of the host country may influence the business model of the acquired entity (Sacek A., 2016). Such considerations must be taken

into account on the previsions of the financial profitability of the target but can also play a more significant role on the strategy of the company and the way it operates in the future. As an example, a company specialized in a technology whose application is considered to have a strong impact on the environment might fear today the adoption of heavy taxation measures since the preservation of the environment became a central issue in many regions of the world. Sacek A. (2016) distinguishes developed markets from emerging ones, he explains that as the political institutions tend to be weak in emerging markets, and power often lies in the hands of elite, thus, the acquirer may face an even more changeable and unpredictable operating environment.

(viii) Recruitment issues

In the engineering service industry, the business model relies on the ability of the company to have the right people at the right time to fulfill the specific needs in the engineering industry. The resources are engineers. Therefore, the entire business model becomes lopsided if the company is no more able to recruit the right people. This is for instance the case in the U.S.'s market. Indeed, the USA suffers for a few years of a strong shortage of engineers, electrical and mechanical engineers are two significant examples. Indeed, according to The Business Roundtable (2013), "Fewer and fewer students are pursuing careers in science, technology, engineering and mathematics" (STEM). As a consequence, most companies have recourse to foreign engineer recruitment. According to the American Immigration Council, the number of talented foreign-born workers in the STEM workforce already amounted to 26,1% in 2012. In 2019, one of the target companies, investigated by the acquirer under study, on the US soil employed 48% of engineers under visas and still struggled to hire more people to balance the natural turnover. Their recruitment issues resulted in the loss of contracts due to lack of resources and therefore limited their growth. In addition, the need for companies based in the USA to resort to foreign engineers increases the recruitment process duration, complexity and cost. In the case of the target under study, the company had to hire a full-time immigration expert to handle all the visas procedures. The company also has to pay immigration fees, that can raise up to $8000 for each visa request.

As a conclusion, a human resource shortage can be perceived by an acquirer as an immigration risks, in addition to cultural challenges and a long-run turnover. Therefore, recruitment can consist of a decisive element in the future performance of a company and, in this regard, it must be considered with attention in the perspective of an acquisition.

Recruitment issues remain obviously local issues, STEM workers have been mentioned on the US soil, a similar situation is observed in Japan where the Japan Business Federation stated that 780,000 engineers “at least” will be needed in the country by 2025. However, India, China, or some eastern European countries such as Ukraine are on the contrary extremely strong in terms of number of students graduating each year from STEM masters and are the first ones to fulfill the vacant positions in the American market.

II.3 Operational considerations:

(i) Human resources

The Human resources (HR) knowledge factor comes as the second most mentioned ingredient of successful acquisitions in studies published by the major consulting firms in M&A (Sacek A., 2016). This topic becomes even more relevant in the case of services companies. Indeed, the unique assets of the company are its people and the way they are organized among them to deliver their services in the best way possible.

The first concerns might be of financial nature, McGrady S., (2005) recalls that “purchasing companies often anticipate fi ring workers to cut costs. However, based on existing employment contracts and union contracts, these cuts may not be possible, or could result in costly litigation and/or severance packages. Policies on pay, benefits, perquisites, holidays, vacation time, salary ranges, and employee handbooks are all ripe for litigation if appropriate due diligence is not undertaken. There could also be outstanding workers’ compensation claims, unfair labor practice charges, civil rights claims, and other labor disputes that may result in additional costs”.

However, this section focuses on the operational aspects related to HR. Especially, since literature treating failures in M&A operations is filled with studies and articles establishing the link between failures and HR issues during the integration phase, due to management, people or entire enterprise culture issues. Therefore, identifying the key people becomes crucial for the success of the operation, this is confirmed by the review of consulting studies published by top M&A specialized firms, based on their experience (Sacek A., 2016). The role of top management is often crucial in the success of the integration (post-acquisition), some might

have an extremely favorable impact on the integration, while others might be noxious on the contrary.

When key people have been identified for the success of the operation, the risk of these individuals' turnover after the acquisition becomes critical issue of concern (Shimizu K. et al., 2004). Therefore, the investigation must then concentrate on finding the appropriate leverage to retain them, at least for a certain period of time post-acquisition. Especially, since analysis have been performed on turnover patterns and showed that M&As lead to abnormally high turnover rates among target company executives for ten or more years after an acquisition (Krug, J.A., 2009).

Whether these people are shareholders or not in the target, there are means to encourage them to stay for a minimum period of time. Very often, it consists of financial incentives that will be based on the performance of the company on a pre-defined period of time after the acquisition. Although it is based only on financial results it guarantees the maintain of a good operational organization to reach the results. These types of incentives are known as earn-outs or bonuses, typically earn-outs being used with shareholders and bonuses with non-shareholders.

(ii) Customer (and/or suppliers) relationships:

In 2007, PWC revealed from a survey (not accessible publicly) it led among 53 acquisitions, that customer relationships represent 39% of the total value of the intangible assets, ahead of the branding (33%), the technologies (19%), the rights (8%). Being able to assess the value of the customer relationships of the target under considerations becomes therefore of high interest for the acquirer. Indeed, weak relationships might require higher effort in the future for the purchaser to retain the clients or to renew the customer basis more often. On the contrary, Reichheld F., (2001) explains in its study The Loyalty Effect, that in B2B[9], customers loyalty is one of the most determinant factors to explain, in a given industry, the differences in profitability among competitors. However, although the impact of the quality of customer relationships on profitability is common knowledge, the analysis of this element remains challenging from the position of the purchaser. Indeed, during the due diligence process,

[9] B2B stands for Business-to-business: it refers to trade activities led among companies

confidentiality reasons imposes a very light review of the customer portfolio. The purchaser can typically have access to the duration of the relationship and the evolution of the sales over the years, often the delay of payment they benefit from the target, but generally these information are shared only for the top customers and do not offer a real insight on the quality of the relationship. For Faulquier M., (2008), partner in a M&A consulting firm, the analysis typically performed on the customer base are too qualitative, partials and leading to too various interpretations to be helpful in the decision-making.

It must be specified, that in most acquisitions, the purchaser is entitled to finally meet the top customers of the target company at the end of the due diligences, when both parties agreed on the terms of the transaction and are ready to ratify the deal. These meetings are organized to ensure the end customers of the target company are ready to transfer the ongoing contracts to the new shareholders of the target. The meetings are not meant to provide a better insight of the quality of the relationship, they are meant to validate the transaction will not have significant impact on the ongoing operations. In most cases, they consist of a simple formality but if for any reason some top customers were not willing to work with the new shareholders, a refuse from them might consist of a deal-breaker.

As an example of difficult assessment of the target relationships with its customers (or suppliers), the acquirer under study recently suffered from important loss after acquisition of companies of which some customers didn’t pay for the services received. The bad payments happened after the transaction was conducted and therefore the due diligences fully completed. Necessarily, it can be concluded that the investigation on the quality of the customer basis was not sufficient. In addition, it must be highlighted that these considerations must be addressed even more carefully is the case of cross-border acquisitions. Indeed, the nature of customer relationships might be to a certain extent related to the business culture of the region. For instance, Deloitte's (2012) industry report concluded that managing compliance and integrity-related risks in emerging markets bear more importance than in developed markets. This is an additional element that an acquirer must have in mind when looking for targets in regions where he is not familiar with the local business environment and culture.

III. Results & Discussions:

In order to discuss the role in the M&A process of the extra-financials elements of due diligence addressed in this paper, it will be recalled first the typical chronology of the different steps of an acquisition process.

Then, the role, in the acquisition process, of the elements of due diligence introduced in the Part I and II of the paper based on the case study, will be analyzed distinctively. First, the place that can take a thorough analysis of the technical capabilities of the target, in the acquisition process. Secondly, the role of legal, regulatory, operational and other elements raised in Part II of the paper. Finally, the role of due diligences as regard as the valuation process and as regard as the entire acquisition process will be discussed from a broader perspective.

Lastly, an attention will be given to external parameters – external from the target and its environment – that can affect the due diligence process and its outcomes, including the valuation.

III.I Role of the extra-financial elements of due diligence in the acquisition process

(i) Organization of an acquisition process

In order to discuss the role in the M&A process of the extra-financial elements of due diligence, this section will recall the typical chronology of the different steps of an acquisition process. A schematic representation of the timeline is provided in Fig. 11 below. The process describe is proper to acquisition of non-listed companies. For listed companies, process are required to follow a very strict procedure defined by the market authority of the country where the target company is headquarted.

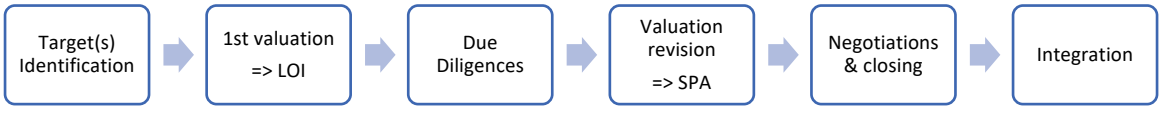

Figure 11: Typical timeline in an acquisition process (case of non-listed target company)

The target identification is the first step of the process. It is initiated in accordance with the strategic plans of the acquirer. The research of target can be mandated to a specialized firm or led internally by the acquirer (less frequent, unless the wish to make an acquisition is the result of a specific opportunity identified by the acquirer itself). The selection of the target (or of a few of them) is based on high-level criterion fixed by the acquirer, typically the positioning, the size, the location, the nature of the customer basis of the target, etc. The selection will be limited to available information, in some cases meetings between the acquirer and the target can be already organized at this stage in order for both parties to collect the minimum level of information to know if they might be interested to purchase, or sell, respectively.

If at the end of this stage the acquirer confirms his interest for acquiring the target company, it will redact a letter of intent (LOI) including an offering price based on a first valuation of the target.

If the target receives positively the offer formulated in the LOI, the acquirer can decide to move forward and engage due diligence to review different aspects of the target's business. As seen before, it will typically engage audit firms to perform financial, tax and legal review of the target. The nature and the efforts allocated to additional due diligence depends on the acquirer. The duration of this due diligence phase can vary significantly from a few weeks to several months depending on their scope and the accessibility to the target's information.

The due diligence process will be concluded by internal discussions among the acquirer's shareholders and their advisors to decide whether to do the acquisition or not. If the decision is to pursue with the acquisition, the acquirer will start the redaction of a share purchase agreement (SPA) in which it will define the detailed conditions under which he is willing to acquire the target. The conditions include the final price of acquisition, it might have been revised since the LOI based on a new valuation of the target resulting from the due diligence conclusions. The SPA also includes all the guarantees that might want to take the acquirer in case of specific risks identified during the due diligences. All the elements included in the SPA will support the negotiations.

If an agreement is reached at the end of the negotiations, it will be translated into a final SPA and the shares will be transferred from the target to the acquirer on the closing date.

Then, the integration process of the target into the acquirer's structure will be organized according to the terms defined in the acquisition contract. From the closing date, the new shareholder will be entitled to run the company's operations in its own way (in the limit of the portion of shares he acquired and the terms of the acquisition contract).

(ii) Role of in-depth analysis of the technical capabilities of the target in the acquisition process – Observations from the case study

From the observations made with the acquisition case under study and discussions with top management and members of the M&A team, the first consequence on the acquisition process of the elements revealed by the analysis of the capabilities of the target and its positioning among its environment is the ability to reinforce or not the willingness of the top management to pursue with the acquisition. However, the impact of the results of the technical due diligence on their willingness to buy remains extremely difficult to quantify.

It becomes more quantifiable if specific synergies with the acquirer's business are revealed during the due diligence. As a reminder, in the case under study, synergies have been identified in the HIL/SIL testing domain (Part I.1) and in the airspace industry (Part I.3). In that case, members of the acquirer's team or from its advisors, specialized in the technical and the commercial aspects of the business involved in the synergies, might be able to quantify the synergies more precisely. For instance, they might be able to assess the number of customers that can be shared, the number of new customers that can be approached as a result of the synergies and the sales that can be expected from that. In that case, the technical due diligence can significantly reinforce the willingness of top management to pursue with the acquisition.

Although, this is theoretically feasible it has not been done in the case study. The acquirer didn't quantify precisely the potential gain from the synergies and maintain its regular valuation method, based on current financial metrics.

Lastly, if the review of the target's positioning and the perspectives of evolution on the market(s) served is done thoroughly it might provide strong basis for the acquirer's team to challenge the financial forecasts established by the target company. In that sense, it might finally have an impact on the acquisition price. Indeed, the acquirer can propose an acquisition price organized around a down payment paid at the closing date and a system of earn-outs (for reasons mentioned in Part II.3.i). A system of earn-out is typically a bonus that will be paid during generally two- or three-years post-acquisition, pre-defined as a multiple of the financial result of the year. Metrics such as the Earnings Before Interest, Taxes, Depreciation and Amortization (EBITDA), the Earnings Before Interest and Taxes (EBIT) or the Net Result are typically considered for the calculation. Therefore, if the technical due diligence reinforce the vision of the acquirer on the future results that can be expected from the target it can adapt the portion of down payment he is willing to pay based on the current results and the multiple used

for the earn-outs he is willing to propose to the target, the duration of the ear-out or even its maintain.

(iii) Role of legal, regulatory, operational and other extra-financial analysis in the acquisition process – Observations from the case study

From the observations made with the acquisition case under study and discussions with top management and members of the M&A team it appears that elements raised in Part II of this paper (belonging to legal, regulatory, operational due diligence types) are mostly not quantifiable. None of them were included in the acquisition price discussions. However, what appeared clearly, and was confirmed by acquirer's M&A experts and top management, is their ability to constitute deal-breaker elements. Indeed, a significant legal, regulatory or operational issue can lead to the abortion of the deal. To a smaller extent, some can constitute a deal-enhancer, for instance the retention of the IP on a product that the acquirer believes it can exploit more largely or a change in regulation favorable to the target's business. But, in any case those deal-enhancers were mentioned in valuation discussions.

Besides, if an element identified during the legal, regulatory, or operational due diligence was associated with a risk, it could be integrated in the guarantees of the SPA to be covered by the target. More importantly, if the element identified in the due diligence couldn't be covered by guarantees but still represented a risk, the acquirer M&A experts and top management underlined the high importance for them to have it identified in order to anticipate a strategy to limit its risk. It appears here the crucial role of those due diligence in the anticipation of the integration phase and the smooth continuation of the activity post-acquisition or the adaptation of the strategy in consequence.

For instance, the acquirer firm shared its past experience with a company they acquired a few years ago where they left the top management, that stayed in place, continue with its regular way of running the company. The company didn't succeed to grow as expected with the acquisition. The acquirer realized after a few years that they were issues with the management, that was not really qualified for the role and they eventually sent other top managers that was part of the acquirer's group for a long time. In a very short period of time the company was back on track and showed very positive results. The analysis of the situation by the acquirer, at posteriori, consisted in acknowledging that although they identified on surface during the due diligence that they might be a few issues with the management they didn't further investigate and was not able to properly qualify the source of the problem at the end of the due diligence.

But, most importantly, according to the acquirer, they didn't leverage what was identified during the due diligence for the purpose of the integration phase, the two phases were completely decorrelated.

(iv) Conclusion

The case under study revealed practical examples of type of due diligences performed in the perspective of a M&A transaction and the role they play respectively in the acquisition process. The case study revealed a few points that might be generalized to some extent, however one can only summarize here the major findings and consider them to be proper to the case study:

- The acquirer bases its valuation on financial metrics only and doesn't integrate the synergies in the calculation, either because it is not in position to quantify them or because it doesn't want to include uncertain elements in the valuation.
  The fact that the valuation remains essentially based on current financial results has not been discussed in this paper but it might be coherent for business that doesn't observe very high growth rate as compared to fast-growing startups where the valuation methods is, on the contrary, essentially based on forecasts of future results.
- The technical due diligence can be avoided from a theoretical point of view, however when performed it can raise important elements to the acquirer that will first, play the role of deal enhancer and second, provide a basis for anticipating the technical and commercial strategy of the target post-acquisition.
- The legal – regulatory – operational and other type of due diligence reviewed in the Part II are not integrated either in the valuation, however they can constitute deal-breakers, or deal-enhancers to a smaller extent. In addition, they might be important to prepare the integration phase
- The anticipation of the integration phase clearly appeared as a second role of the due diligence, beyond providing the elements allowing an accurate valuation of the acquisition price. However, this aspect of the due diligence remains underestimated, even the acquirer under study, who benefits from a significant historic of acquisitions performed, acknowledged it could prepare more carefully the integration phase and the future strategy of the target based on the due diligence and this could have a chance to enable him to reach higher returns on investment.

III.II External parameters affecting the due diligence process and its outcome

Although the acquirer is willing to perform thorough due diligence, it must be highlighted that a few external parameters can still affect the due diligence process and its outcome.

(iv) Natural inclination for the realization of the deal

Literature underlines the role of non-fully rational parameters influencing the decision-making, whatever the outcomes of the due diligences. In particular, senior management engaged in the decision-making have a chance to be influenced by their "affect", like in almost every decision taken by human beings because they are endowed with sensitivity. In the case of M&A, Cullinan et al. (2004) precise that "the momentum of the transaction is hard to resist once senior management has the target in its sights ». After a long and costly due diligence process, decision makers are likely to be more inclined to the realization of the deal. The example of the Sefaway case study introduced by Cullinan et al. (2004) highlights very well the crucial role that can have the opinion of one (or more) decision-maker(s) towards the interest of the deal, on the level of due diligences engaged and even the attention given to their outcomes. The authors add in that case that "Due diligence […] becomes an exercise in verifying the target's financial statements rather than conducting a fair analysis of the deal's strategic logic and the acquirer's ability to realize value from it."

(v) Impact of multiple-bidders process

A significant distinction must be made regarding the context of the acquisition. Indeed, literature largely studied the impact of the number of bidders and their distinct nature in the acquisition process and in particular in the acquisition price offered (Flanagan D., O'Shaughnessy K.C., 2003; Bessler et al., 2015). Generally, a situation with multiple-bidders is opposed to single-bidder situation. The first impact on the due diligence process is the strict timeline set up by the target that can limit the quantity of analysis performed and their quality. The second aspect is typically the pressure generated by the multiple participants on the terms of the final offer, including the acquisition price. Flanagan D., O'Shaughnessy K.C., (2003) showed the non-negligible increase in mean premium paid in the case of multiple bidders.

(vi) Acquirer's own valuation

Whatever the valuation method employed (even if method of comparable is employed), the valuation of the target is based on the target and its environment only. However, it must be reminded that in the end, the final offer might be limited to an external value: the acquirer's own valuation. In the case of a listed acquirer its valuation is completely accessible. In that case, paying the price based on the results of the due diligence and assumptions retained, if it is higher than the acquirer's current valuation, would mean for the acquirer's shareholders to lose value and contribute to their dilution.

IV. Limit of the study - Directions for future research:

The major limit of the study is the focus given to a single case study. The study could be enriched with additional case studies in order to complement the non-exhaustive review of extra-financials elements of analysis that can be of great interest for the acquirer (Part I and II of this paper). In addition, it would be highly interesting to enrich the discussion with post-acquisition vision and analysis based on returns of experience.

No literature at this stage seem to be in capacity to generalize the findings of this paper; namely the distinct role in the acquisition process of the outcomes of the various extra-financial due diligence (technical, legal, regulatory, operational, etc.); therefore, quantitative studies on this topic could contribute to the generalization of the findings. The interest of generalizing these findings would be to avoid the misinterpretation of the role of each type of due diligence and underestimate the role of extra-financial due diligence simply because they are not used right now for the right purpose. Then each type of due diligence could be employed adequately for the right step of the acquisition process. Eventually, the objective would be to increase the rate of successful M&A operations.

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APPENDICES

APPENDIX 1: **Key features of the Batch Execution System (BES) developed by the target company under study:**

- Automated test scheduling, execution, and results connection
- Easy and secure login access from anywhere with web based front end
- Simplified user interface listing all scheduled tests, users, date added, priority, available venues, and current execution time
- Deployment on existing or new systems
- Customizable venue execution and post-processing back end written in Python
- Run multiple projects on shared resources
- Supports scheduling across multiple test venues
- Batch upload and priority scheduling

APPENDIX 2: **Datasheets of Aircraft Data Gateway (or AIC, or AID) on the market**

#Target:

SPECIFICATIONS	
A615A and A615-3 data loader	• Capable of staging and loading LSAPs and databases
Drop-in replacement for airborne data loaders (through use of a mobile device for status updates)	• Same form factor and A615 connector • Mountable on DZUS rail, 28VDC or 115VAC power
Capable of connecting to a Wi-Fi or cellular (GSM and LTE compatible) source	• Configurable based on aircraft/fleet/country/airport settings
Provide a Wi-Fi access point for up to 8 clients (WPA2 enterprise)	
Record and store A717 data (QAR) and four channels of A429 data	
Provide storage and access to technical publications	
Log all access attempts and device operations	
1TB of internal storage	
ARINC 429	8 inputs and 4 outputs • Configurable – high/low speed
ARINC 717	1 input
Discretes	4 inputs & 6 outputs
8 ethernet ports	7 rear connector, 1 front panel • 10/100base T1 RS-422 port
Designed with comprehensive security risk assessments, testing, requirements validation and verification	

WIRED CONNECTIONS
Ethernet – 10/100BaseT – A615-A data loading, EPIC LAN, Satcom connection
A429 – A615-3 data loading, GPS data, avionics recording (high or low speed)
A717 – record QAR data
Discretes – weight on wheels, LRU mode selectors
RS422

WIRED DATA	
Three antennas: external client antenna, cabin WAP antenna, belly WAP antenna	• Client antenna connects to Wi-Fi or cellular based on selection
Cellular data	• GSM and LTE compatible • Two SIM card slots - configurable for which one to use based on GPS location • 4G LTE
Wi-Fi	• Client and WAP can be active simultaneously • 2.4GHz 802.11b/g • WAP - capable of connecting to 8 mobile devices at once • SSID, authentication, signal power, and channel are configurable based on settings or location

#Competitor 1:

Form Factor	Protocols	Features
Avionics Computer	ARINC 429, ARINC 717, MIL-STD-1553, CANbus 2.0, Ethernet, Serial I/O	HD Audio, DVI Video, 4GB RAM, Rugged, Up to 512GB SSD, Intel® Atom™ E3845, USB 2.0, GPIO, mPCIe (2), Configurable
Avionics Computer	ARINC 429, ARINC 717, MIL-STD-1553, CANbus 2.0, Ethernet, Serial I/O	HD Audio, 16GB RAM, Rugged, Up to 2TB SSD, VGA Video, HDMI Video, Intel® Core i5™, USB 2.0, USB 3.0, GPIO, mPCIe (2), XMC Slot, Configurable
Avionics Computer	ARINC 429, ARINC 717, MIL-STD-1553, CANbus 2.0, Ethernet, Serial I/O	2GB RAM, 30GB SSD, Lab, VGA Video, Intel® Atom™ E3845, USB 2.0, GPIO, mPCIe (2), PMC (2), Configurable
Avionics Computer	ARINC 429, MIL-STD-1553, MIL-STD-1553/1760, Ethernet	Rugged, 8GB SSD, Lab, 512MB RAM, Intel® Atom™ E640T, GPIO

Competitor 2:

Applications

- Flight tracking
- Quick Access Recording
- Aircraft Condition Monitoring System (ACMS) Lite

Connectivity

- 1x +28VDC input power
- 3x 10/100 base-t Ethernet
- 3x 10/100/1000 base-t Ethernet
- 16x ARINC 429 biploar receivers (2 receivers feature auto-detect for bipolar ARINC 717 data)
- 1x ARINC 717 hardware bi-phase receiver
- 6x ARINC 429 transmitters
- 1x RS 232/422/485
- 16x GND/open discrete inputs
- 4x GND/open discrete outputs
- 1x +28V/open discrete input

Features

- Field loadable software
- ARINC 834 STAP server
- Communicates with preferred SATCOM and ACARS providers
- 4GB RAM
- Solid state CFast SATA 32GB storage (field removable/ upgradable)
- Backwards compatible with UTC Aerospace Systems first generation AID
- Qualified to DO-160G environments
- Ability to add hosted functions

Options

- DO-178B level C software platform, including avionics-grade real-time operating system (RTOS)
- DO-254 certified to DAL C

Competitor 3:

Applications

Versatile Aircraft Interface Devices are ideal for a wide variety of mil-aero applications, including:

- Electronic Flight Bag (EFB) Integration
- In-flight entertainment systems
- Data/protocol converting
- Data concentrating
- Firewall protection for critical avionics data
- On-aircraft data loading

Specifications

Avionics Interfaces & I/O

- ARINC 429
  24 channels (16R/8T)
- ARINC 717
  4 channels (2R/2T)
- RS-232/423/422/485
  2 channels
- Ethernet (WAN)
  Independent or router function
- Ethernet Switch (LAN)
  9-port Managed Ethernet Switch
  - Eight 10/100 Mbps Ethernet ports
  - One 10/100/1000 Mbps Ethernet port
- USB 2.0 Host
  2 ports
- Avionics Discrete I/O
  4 programmable input/output

Optional Interfaces

- ARINC 708
  Up to 4 channels
- MIL-STD-1553
  Up to 4 dual-redundant channels

Standard Features

- PowerPC processor
- 64 MB SDRAM
- 16 MB Flash
- 16 MB Flash
- Real Time Clock (with 650+ hours of backup power)
- 1 Ethernet port (10/100)
- 2 RS-232/423/422/485 (selectable)
- 2 USB 2.0 host ports
- Avionics discrete I/O
- IRIG A or B, AM, PWM and PPS
- Voltage and temperature monitoring
- 8 GB Flash drive
- Power: 28 VDC nominal
- MTBF: 350,000+ hour

Environmental

- Extended Temperature
- Conduction or convection cooled
- DO-160, MIL-STD-810, MIL-STD-461

Mechanical

- Compact enclosure: 5.46 x 7.31 x 2.48 in (139 x 186 x 63 mm)
- Weight: 3.7 lb (1.7 kg)
- Horizontal mounting kit: 0.9 lb (0.4 kg)
- Vertical mounting kit: 0.5 lb (0.2 kg)
- D38999 Connectors