POLITECNICO DI TORINO

Department of Mechanical and Aerospace Engineering

Master's thesis for the Master of Science in Aerospace and Astronautical Engineering

Certification process and operations of innovative hybrid STOL aircraft within the UAM scenario

Application to the Alérion M1h case

Supervisors:

Prof. Giorgio Guglieri
Politecnico di Torino

Marc Chouffot
École Nationale de l'Aviation Civile

David Gallezot
Avions Mauboussin

Fabrice Claudel
Avions Mauboussin

Candidate:

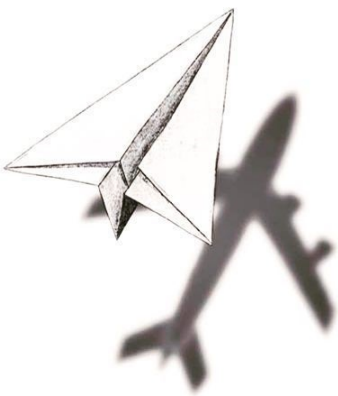
Rocco Nannavecchia

Accademic Year 2019/2020

Page intentionally left blank

”*Il faut bien que je supporte deux ou trois chenilles*
si je veux connaître les papillons”.

Antoine Saint-Exupéry, Le Petit Prince (1943).



Page intentionally left blank

Acknowledgement

[EN] Before to present the topic analysed and developed in this thesis it is fair to thank the people who helped me out in this path of growth.
A word has to be spent for Monsieur Fabrice Claudel, an inexhaustible source of knowledge and support. His passion for his work is unspeakable but, nevertheless, it can be considered inferior to his pleasure in passing all his passion to others. To him, I owe the discovery of the true meaning of flying as well as my personal growth and not only in the world of work. He will continue to be a reference point.
Thanks also to Monsieur David Gallezot, whose perseverance and experience have taught me a lot, and will always make him as an example to be followed.
I cannot fail to thank also Monsieur Marc Chouffot and Professor Giorgio Guglieri, as very kind people who followed me in this thesis path with their wise advice. Thank you.
Another special thanks also goes to the Avions Mauboussin team, namely Guille, Baptiste, Sebastien, Pierre, Alix, Lauriane, Paul, Benjamin and Paul Lemoine, who made this path lighter and decidedly more enjoyable, confirming the importance of a good friendship.
Finally, thanks to my friend Sam, a pleasant discovery of this course of study, who has always been present and to Sofia, a source of constant support who together with my family, my dad Leonardo, my mom Francesca and my brother Mino have represented my safe place in the world, even hundreds of miles away. I owe everything to you.

[FR] Avant de présenter le sujet analysé et développé dans cette thèse, il est juste de remercier les personnes qui m'ont aidé durant cette période.
Tout d'abord, je remercie Monsieur Fabrice Claudel, qui est pour moi une source inépuisable de connaissances ainsi qu'un soutien indéfectible. Son affection pour son travail est sans nom mais n'égale pas son plaisir de transmettre sa passion pour les avions aux autres. C'est à lui que je dois la découverte du vrai sens du vol ainsi que mon épanouissement personnel et pas seulement dans le monde du travail. Il continuera à être un point de référence.
Merci aussi à Monsieur David Gallezot, dont la persévérance et l'expérience m'ont beaucoup ensigné et feront toujours de lui un exemple à suivre. Je ne peux pas manquer de remercier également Monsieur Marc Chouffot et le Professeur Giorgio Guglieri, qui m'ont suivi et encadré tout au long de ma thèse avec leurs conseils avisés. Je vous remercie. Un autre remerciement particulier va également à l'équipe d'Avions Mauboussin, Guille, Baptiste, Sébastien, Pierre, Alix, Lauriane, Paul, Benjamin et Paul Lemoine, qui ont rendu ce parcours plus léger et décidément plus agréable, confirmant l'importance d'une bonne amitié.
Enfin, merci à mon ami Sam, une agréable découverte de parcours qui a toujours été présent. A Sofia, ainsi qu'à ma famille, mon père Leonardo, ma mère Francesca et mon frère Mino qui sont des soutiens indéfectibles, mes attaches dans ce monde, même à des centaines de kilomètres. C'est à vous que je dois tout.

[IT] Prima di presentare l'oggetto di questa tesi è necessario ringraziare tutti coloro che hanno reso possibile questo percorso di crescita. Una parola deve essere spesa per il Signor Fabrice Claudel, fonte inesauribile di conoscenza e supporto. La sua passione per il suo lavoro è inesplicabile, ma che, tuttavia, può essere considerata inferiore al suo piacere nel passare tutto il suo sapere ai suoi allievi. A lui devo la scoperta del vero significato del volo, così come la mia crescita personale non sono in ambito lavorativo. Continuerà ad essere il mio punto di riferimento nei prossimi anni.
Un ringraziamento va anche al Signor David Gallezot, la cui perseveranza e esperienza mi hanno insegnato tanto, rendendolo un esempio da seguire.
Non posso, inoltre, non ringraziare il Signor Marc Chouffot e il Professore Giorgio Guglieri, persone gentilissime che mi hanno seguito in questo percorso di tesi, migliorandolo grazie ai loro saggi consigli. Grazie.
Un altro ringraziamento speciale va, invece, al team di Avions Mauboussin, ovvero Guille, Baptiste, Sebastien, Pierre, Alix, Lauriane, Paul, Benjamin e Paul Lemoine, che hanno reso questo percorso più leggero e decisamente più piacevole, confermando, ancora una volta, l'importanza dell'amicizia.
Infine, un grazie al mio amico Sam, una piacevola scoperta in questo percorso di studi che è stato sempre presente e a Sofia, fonte di costante supporto che insieme alla mia famiglia, a mio papà Leonardo, mia madre Francesca e mio fratello Mino, hanno rappresentato il mio posto sicuro nel mondo, anche a centinaia di chilometri di distanza. Vi devo tutto.

Page intentionally left blank

Abstract

[EN] The following master's thesis, has, as its main objective, to represent the case study analysed during the last 6 months at Avions Mauboussin. An analysis of the current scenario of the product and technologies offered, the engineering and non-engineering challenges, the perplexities, the difficulties encountered and the technical solutions proposed to satisfy the technical problems and needs of the company, will be, therefore, shown in the following paper.

The scientific problem faced and studied in this thesis, is the determination of the operations of the design product of Avions Mauboussin, namely Alérion M1h. The latter, is an aircraft with eSTOL (extremely Short-Take-Off and Landing) performance, which operations have been made extreme and delicate by the operational challenges to which the aircraft is about to perform. The aircraft is, in fact, designed to perform urban operations, with take-offs and landings in less than 100 metres, being one of the main characters of the ever-closer Urban Air Mobility scenario. A feasibility analysis of these operations, taking into account the current characteristics and performance of this aircraft, has been, therefore, carried out, showing that the plane is suitable to perform 1 out of 3 operations within the UAM scenario and that the operational performance desired, are not still feasible with the current performance of the plane.

In this technical feasibility analysis, finally, the challenges in the certification of such extreme operations and of the unusual technologies implemented on a small aircraft, such as Alérion M1h, will be shown and analysed as well. The perfect solution for this type of plane, the perplexities and the ever-present lacks of the current certification scenario will be, therefore, shown as results. The thesis will be concluded, finally, with the presentation of the tool License to fly, realized with the aims to facilitate the laborious certification process.

Keywords: STOL, VTOL, eVTOL, UAM, Urban Air Mobility, Certification Basis, CS-23, License to Fly, Avions Mauboussin, Alérion M1h.

[FR] Le présent mémoire de fin d'étude, a pour objectif principal de représenter l'étude de cas analysée au cours des six derniers mois chez Avions Mauboussin. Une analyse du scénario actuel du produit et des technologies offertes, des défis d'ingénierie et de non-ingénierie, des perplexités, des difficultés rencontrées et des solutions techniques proposées pour satisfaire les problèmes techniques et les besoins de l'entreprise, sera donc présentée dans le document suivant.

Le problème scientifique rencontré et étudié dans cette thèse, est la détermination des opérations du produit de conception d'Avions Mauboussin, ou Alérion M1h. Ce dernier, est un avion aux performances eSTOL (extremely Short-Take-Off and Landing), dont les opérations ont été rendues extrêmes et délicates par les défis opérationnels auxquels l'avion s'apprête à faire face. L'avion est en fait conçu pour effectuer des opérations urbaines, avec des décollages et des atterrissages en moins de 100 mètres, ce qui constitue l'un des principaux personnages du scénario de l'Urban Air Mobility toujours plus proche. Une analyse de faisabilité de ces opérations, prenant en compte les caractéristiques et performances actuelles de cet avion, a donc été réalisée, montrant que l'avion est apte à effectuer une opération sur trois dans le cadre du scénario UAM et que les performances opérationnelles souhaitées ne sont pas encore réalisables avec les performances actuelles de l'avion.

Dans cette analyse de faisabilité technique, enfin, les défis de la certification d'opérations extrêmes et des technologies inhabituelles mises en œuvre sur un petit avion comme l'Alérion M1h, seront montrées et analysées également, montrant comme résultats la solution parfaite pour ce type d'avion, les perplexités et les lacunes toujours présentes dans le scénario de certification actuel. La thèse sera conclue, enfin, par la présentation de l'outil License to fly, réalisé dans le but de faciliter le processus laborieux de certification.

Mots clés: STOL, VTOL, eVTOL, UAM, Urban Air Mobility, Certification de Base, CS-23, License to Fly, Avions Mauboussin, Alérion M1h.

Contents

List of Figures

List of Tables

Introduction

This master's thesis is the final paper that will sanction the completion of a master's degree course at the Italian university, Politecnico di Torino, which has been enriched by various challenges and experiences through the recent years. Above all, the 12-month Erasmus project at the French Ecole Nationale de l'Aviation Civile, which has monitored this thesis project carried out on-site at the small French company, Avions Mauboussin. The latter works in the aeronautic domain as designer of a new generation of light aircraft provided with new technologies and a green footprint. Alérion M1h will be the first plane of Avions Mauboussin's range, designed with a hybrid propulsion system, to perform eSTOL performance, a natural wooden structure and a fighter configuration to make it aerodynamically efficient and comfortable.
Alongside experts in every field of engineering, several interns are contributing to the realization of the project dreaming of making a contribution to what could be, other than a new aircraft, a new concept of mobility. Alérion, in fact, with the performance desired will try to fit into a decidedly urban scenario, allowing a connection between cities, with direct access to the heart of the cities and to the major points of interest.
This kind of concept and this type of operations are an integral part of a future scenario, called Urban Air Mobility, destined to change the world of mobility by adding a new level. This new level of mobility aims to significantly reduce the complexity of urban transport, offering an alternative solution to that of current means of transport to reach a point B from point A.
In this scenario, several figures are already working hard to offer the best possible solution, taking 3 aspects as a common factors: respect for the environment, safety and comfort.
The ideal solution for this type of operations today seems to be the use of aircraft with eVTOL capabilities: fully electric, a high level of safety guaranteed by a distributed propulsion and comfort provided by their urban operations directly in the heart of the cities, on-demand flights bookable via an App. To these solutions, Avions Mauboussin wants to add that of an eSTOL aircraft, such as Alérion, capable of landing and take-off in very short distances, less than 100 meters, and even on unprepared and rough surfaces like a football pitch, former airfields and airparks, with, finally, the advantage of an extend range and a higher cruise speed.
At the date, few are the projects which could compete with Alérion M1h in this last scenario:

Table 1: Direct competitors of Alérion M1h

Project	**Developer**	**Architecture**	**Seats**	**Vcruise**	**Range**	**T/O**	**Stage**
Alérion M1h	Avions Mauboussin	Hybrid	2	220 km/h	600km	100m	TC in 2024
Cassio	VoltAero	Hybrid	4-10	360 km/h	1200 km	600 m	Ready for 2022
Ampère	Onera	Electric distrib. propulsion	4-6	≅250km/h	500 km	/	Ongoing project
Velis Electro	Pipistrel	Electric	2	167km/h	≅130km	≅ 450m	EASA certified
X 57 Maxwell	NASA	Electric distrib. propulsion	2	277km/h	160km	/	Flight test soon
Kodiak	Quest A/C Daher	Gas turbine	10	339km/h	2096km	285 m	Certified in 2007
CH 801	Zenith	Piston engine	4	170km/h	600km	122m	Homebuilt

Chapter 1

Introduction to V/STOL aircraft

After the middle of 20^{th} century, the possibility of providing air service into urban or industrial activity centres had already received considerable attention. However, vertical and/or short take-off and landing (V/STOL) aircraft studies to develop this service concept had been largely oriented toward large commercial airline applications since there was no applicability of V/STOL concepts to the needs of general aviation. Historically, in fact, general aviation acceptance of new aircraft concepts has, with some exceptions, followed military and commercial applications. [1]
According to a NASA's study, carried out by engineer Franklin D. Harris, the number of V / STOL aircraft in the U.S.A, that had demonstrated at least a hint of flight worthiness before the end of the 20^{th} century was very low. It was estimated that only 100 V / STOL aircraft had become technologically and historically significant. Of these 100, only 64 were VTOL machines, and out of the 64, only 2 have gone into production. Of the 36 STOLs, only a very few reached production status and only a few STOLs had obtained a FAA Type Certificate [2].
The situation in Europe could not be considered better.

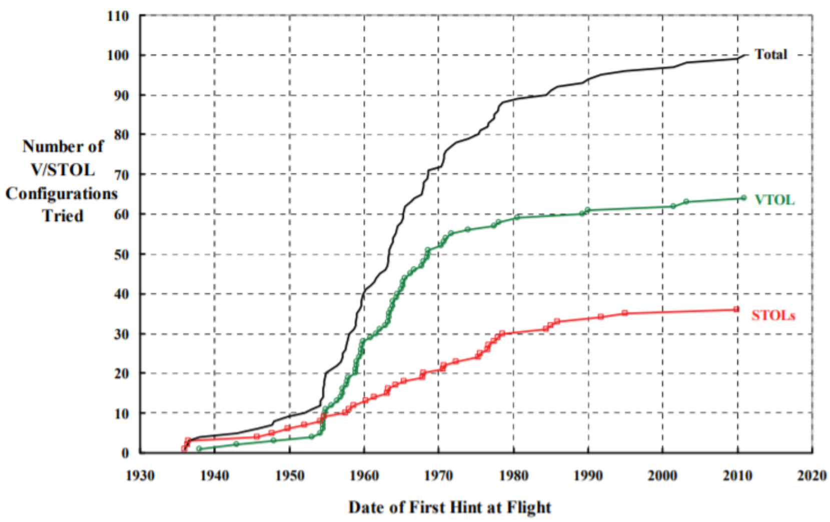


Figure 1.1: The number of V/STOL aircraft that have demonstrated at least a hint of flight worthiness in the U.S.A [2]

Mr. D. Harris kept track of VTOLs and STOLs for this study, keeping in mind the following classification:

1. A VTOL aircraft can take off and land vertically at a quite respectable operational weight, which includes operationally useful payload and fuel. At an overload weight, it can also take off and land over a 50-feet obstacle in 1,000 feet or less [2];

2. A STOL aircraft cannot take off and land vertically, but it meets the U.S. Air Force 1,000-feet criteria (take off and land over a 50-feet obstacle in 1,000 feet or less). While a STOL aircraft may have the power to perform as a VTOL, it does not have an adequate flight control system for flight at zero, or even very low speeds [2].

Of course, the intent of Mr D.Harris was not to include helicopters within the VTOL classification nor every light aeroplane and glider ever made, whether it had flaps and other high-lift devices or not, within the STOL classification.

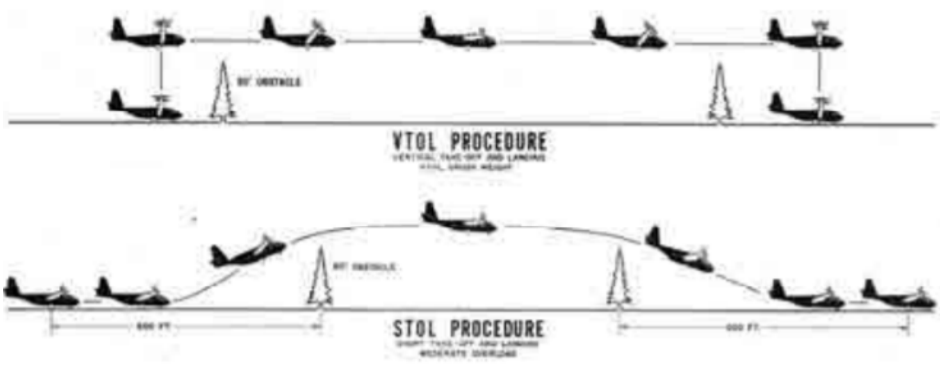


Figure 1.2: Take-off and landing variations [2]

The operational capabilities issues and restraints, the ground-based infrastructure required, the effort for a solid research programme on new technologies and the political environment seemed did not justify the overall cost of the project, orienting the studies toward other applications.
An extraordinary persistence, therefore, has been necessary for operational V/STOL aircraft to become a reality.

Since the 1970s, a period representing the earliest availability of advanced technology aircraft, however, the VTOL capability was the one which appeared most desirable from the standpoint of easy access to locations not served by, or not conveniently accessible to, scheduled airlines [1].
Feeling that hasn't changed over the years. Today, in fact, the desire to enable highly automated, cooperative, passenger or cargo-carrying air transportation services in and around urban areas identifies as the most viable solution, the VTOL capability.
The latter seems exactly the perfect solution to supersede the conventional helicopter transportation within the urban-centred air transportation scenario, always limited due to the negative public response to noise and pollution but not only, the high operational expense and service costs for the customer, in fact, were not considered acceptable.

However, the market is not closing its doors to the STOL solutions. Several companies, as Avions Mauboussin, are working to provide the current demanding market with innovative STOL aircraft capable to satisfy the public demands on noise and pollution.

1.1 VTOL aircraft

An official definition of VTOL aircraft, where VTOL stands for Vertical Take-Off and Landing, is somewhat difficult to find since the ICAO, International Civil Aviation Organization, has not released any definition. However, for VTOL aircraft it is intended, based on the definition of VTOL capability given by the NATO STANDARDIZATION OFFICE (NSO), "*an aircraft that has the capability to take-off and land vertically and to transfer to or from forward motion at heights required to clear surrounding obstacles*" [3]. This classification can include a variety of types of aircraft including fixed-wing aircraft as well as helicopters and other aircraft with powered rotors, such as cyclogyros/cyclocopters and tiltrotors.

Reading that, immediately a doubt comes to mind. If the study carried out by Mr D. Harris in 2015 did not involve helicopters, which are the main means of transport that exploit the Vertical and Take-off Landing capability, within the VTOL aircraft classification, what aircraft was he talking about?

After the development of the helicopter, a great research study has been carried out to develop a machine able to fly as fast as an aeroplane and able to take off and land vertically like a helicopter. Several configurations were tested through the years, even with two different power plants for hover and cruise. At that time, the power plants configuration available were piston engines and jets. With the latter has been realized the only truly successful V/STOL design of the many attempted during that era, the Harrier.
Before to be conceived as aircraft carriers, the Harrier, was conceived to operate from improvised bases, such as parking lots, forest clearings, without requiring permanent large air bases.
Mr D.Harris from NASA, therefore, took configurations as the one of the Harrier into account for his studies.

Figure 1.3: AV-8B Harrier landing aboard Principe de Asturias, LEONARDO CARRILLO, 2007

However, as the aviation World, today is on the brink of some major transformations, with innovative companies that are pushing to a new concept of mobility, developing breathtaking technologies and solutions for this World, EASA has felt the need to clarify the concept of the new emerging VTOL aircraft.
The Agency, through a document called 'Special Condition for small-category VTOL aircraft [4]' which will be discussed later, has defined all vehicles with a Certification Basis based on the VTOL Special Condition, or person-carrying vertical take-off and landing (VTOL) heavier-than-air aircraft in the small category, with lift/thrust units used to generate powered lift and control, which differ from conventional rotorcraft or fixed-wing aircraft, as “Special Category” aircraft.

1.1.1 Main VTOL architectures

Through the years, several configurations have been tested to perform such performance: tiltjets, tiltrotors and even tiltwings for the single-power plant configuration. Other configurations, instead, included one set of engines for lift only and another set of engines for both lift and cruise. The Soviet Yak 38 is one of these VTOLs, it vectored the thrust of the main engine and used two additional engines behind the cockpit for hover [5].
However, the configurations that will be taken into account into the critical study of this thesis are the current configurations of electric VTOL aircraft, namely eVTOLs. In the last decade, several innovative companies have proposed breathtaking solutions to carry people from a point A to the point B in busy metropolitan areas giving a valid response to the exigencies of the Urban Air Mobility. The eVTOL solution is on of those.
An article, published by the scientific website www.mdpi.com, shows the study carried out by the full professor at the Politecnico di Torino, Cestino E. and the PhD A. Bacchini about the current

architectures of eVTOLs vehicles .
Within the article mentioned here above, the Electical VTOLs, or eVTOLs, are classified in the following categories:

- Vectored Thrust;
- Lift + cruise;
- Wingless;
- Hoverbikes;
- eHelos [5].

The **vectored thrust** eVTOLs are designed with 2 particularities: an unique propulsion system for both hover and cruise, and a wing for an efficient cruise. The **Lilium Jet** project, designed by a Germany-based start-up co-founded in 2015 'Lilium GmbH', which has already raised up million dollars in financing, falls into this category.
The Lilium jet has been provided with two fixed wings, one main wing at the rear of the aircraft and a 'canard' wing at the front of the aircraft. The jet has, furthermore, 36 electric engines to make the aircraft more safer, efficient and more manoeuvrable. Why?
As defined by the company, the 36 engines give to the aircraft a strong level of redundancy which prevent catastrophic events in the case of an engine failure, increasing, therefore, the safety.
Furthermore, the engines nacelles, provided with a tilt duct solution, are part of the wing which help the performance of the aircraft increasing the efficiency as a result of an increase of lift and a reduction of drag.
Finally, the use of smaller engines increases the manoeuvrability of the aircraft, even without requiring the use of ailerons and/or elevator, because the time taken to increase power ('spin up') or decrease power ('spin down') in a small engine is much less than that in a typical aircraft engine. This makes the Lilium Jet able to respond much more rapidly to a control input [6].

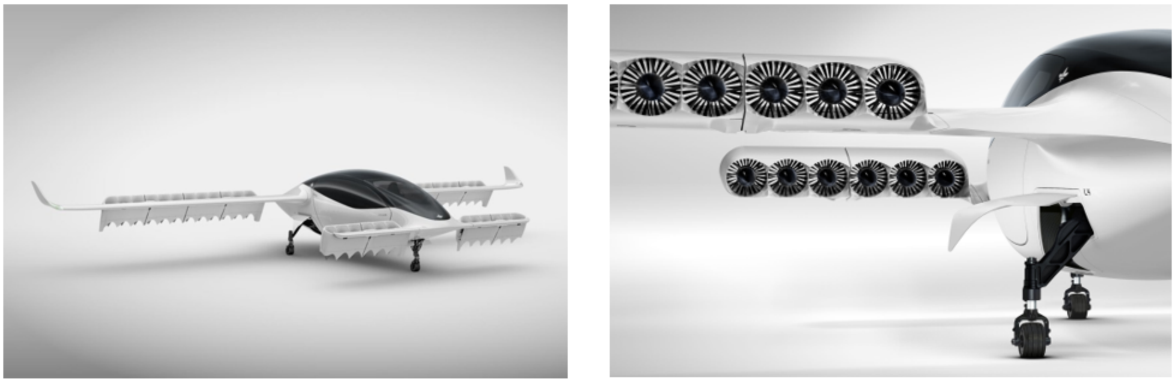


Figure 1.4: Lilium 5 seat eVTOL Jet, hover configuration of the distributed propulsion system

Table 1.1: Specifications Lilium 5 seat eVTOL Jet

	Lilium
Aircraft type	eVTOL jet
Capacity	5 seats
Cruising speed	300 km/h (186 mph)
Range	300 km (186 statute miles)
Maximum flight time	60 minutes
Propulsion	36 electric ducted fans and 36 electric motors
Power	Batteries
Noise	6 to 7 times quieter than a helicopter at take off

Lift + cruise eVTOLs differ from vectored thrust eVTOLs because instead of using a single propulsion system for hover and cruise they use two. However, wing are used to increase lift as well as in the vectored thrust eVTOLs configuration.
Among all the aircraft which fall into this category, a noteworthy project is the **Wisk (Kitty Hawk) Cora**, made by Wisk, a new company formed by a joint venture between Boeing and Kitty Hawk Corporation.
Cora, unlike Lilium Jet, uses two different propulsion systems for hover and cruise, uses propellers and has place only for 2 passengers. Cora, in fact, is an autonomous aircraft which, therefore, does not involve the presence of a pilot. Concerning the propulsion, instead, 12 independent electric-powered lifting propellers mounted on its 11 m long wings are used for vertical take-offs and landings and one three-bladed pusher propeller has been added to provide thrust for forward flight [7].

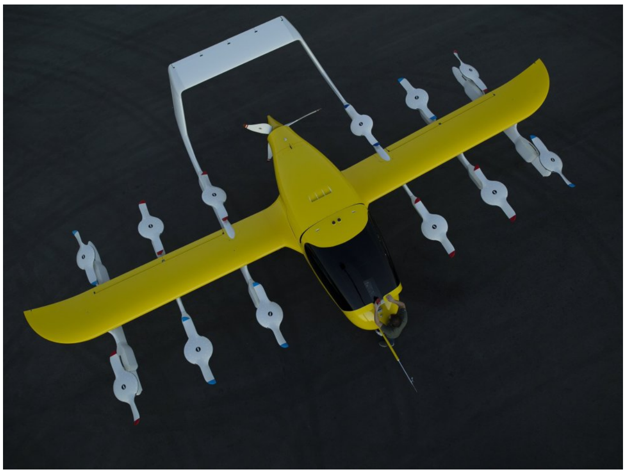


Figure 1.5: Wisk (Kitty Hawk) Cora, electric-powered lifting propellers for vertical take-offs and landings

Table 1.2: Specifications Wisk Cora eVTOL

	Wisk Cora
Aircraft type	eVTOL
Capacity	2 seats
Cruising speed	110 mph (180 km/h)
Range	62 miles (100 km)
Maximum flight time	19 minutes with a 10 minute reserve
Propulsion	12 independent electric-powered lifting propellers + 1 three-bladed pusher propeller
Power	Total electric, Lithium-ion batteries

A different solution from the last two is the **wingless** solution proposed by two companies: the German Volocopter GmbH with its VoloCity project, and the Chinese Ehang with its Ehang 216 project, which are already in the certification process.
The particularity of these wingless eVTOLs solutions is that they are multicopter aircraft and they don't have any wing. This make their use suitable only for short-range operations in city offering anyway a good solution to the new and flexible operational concept of the UAM.
The **VoloCity eVTOL** structure is simple and robust. It is provided with 18 small fixed-pitched propellers having no tilting mechanisms and 18 electric motors on the top of the beam structure that can be used independently. Furthermore, VoloCity has multi-redundant systems including, propellers, motors, batteries, electronics, displays and more, to ensure the highest degree of reliability and safety [8].

Figure 1.6: VoloCity 4th generation, Volocopter GmbH website

The VoloCIty's capacities here above shown, are coherent with the Volocopter's idea of UAM, which foresees a higher demand for inner-city air taxi service than any other services .

Table 1.3: Specifications VoloCity 4^{th} generation

	VoloCity
Aircraft type	eVTOL multicopter
Capacity	1 pilot + 1 passenger and his luggage
Cruising speed	100 km/h (62 mph)
Range	35 km (22 miles)
Propulsion	18 fixed-pitch rotors + 18 brushless DC electric motor
Power	Lithium-ion Batteries
Noise	65 dB(A) at 75 meters (246 ft)

Furthermore, there are the **Hoverbikes** that are multirotors that can be flown like a motorbike. Some projects have already failed as the Kitty Hawk Flyer but however there are companies that are still working to propose such solution for the future mobility. A noteworthy project is **Hoversurf**, an American company which has thought to design a carbon fiber bike able to fly at 5 meters above the ground with a maximum speed limited to 96 km / h.

Figure 1.7: Hoverbike S3 2019, Hoversurf

Table 1.4: Specifications Hoverbike S3 2019

	Hoverbike S3 2019
Aircraft type	eVTOL multicopter
Capacity	1 seat
Cruising speed	96 km/h
Flight time	10 to 25 minutes with the pilot
Propellers	4 three-bladed carbon propellers
Power	LiNiMnCoO2 Batteries

Finally, there are **eHelos** solutions that are nothing else than electrical conventional helicopters. An example is the **Aquinea Volta** designed by the French company Aquinea and the university 'École Nationale de l'Aviation Civile' (ENAC).
Volta is an helicopter with a main rotor and a variable blade pitch designed for one passenger although a two seat trainer has been envisioned. It's a totally electric helicopter whose motors have been provided by EMRAX, a company which has given its contribute to provided the first electric plane certified by EASA, the Pipistrel Velis Electro, with electric motors as well as it will do with Avions Mauboussin for the project Alérion M1h. A 15 minutes of battery powered manned flight has been already achieved but the team is working to expand the flight time up to 40 minute [9].

Figure 1.8: Volta side view, Aquinea/ENAC

Table 1.5: Aquinea VOLTA

	Aquinea VOLTA
Aircraft type	eHELOS
Capacity	1 passenger
Flight time	4 minutes
Propulsion	1 main rotor powered by an EMRAX motor
Power	Batteries + EMRAX motor

All these solutions proposed aim to offer a green reliable solution as response to the exigencies of the Urban Air Mobility without upsetting the urban planning of the cities, as these aircraft could use the heliports or helipads already present. I use the conditional because companies in this sector will not limit themselves to poor surfaces like some of the helipads already present, but they will present projects for **cutting-edge vertiports**, as done by the German company Lilium, able to minimize waiting times.

1.2 STOL aircraft

As well as seen for VTOLs aircraft, an official definition of STOL aircraft, where STOL is the acronym of Short Take-Off and Landing, is somewhat difficult to find since the ICAO, International Civil Aviation Organization, has not released any definition. However, agencies as the US Federal Aviation Administration and the NATO STANDARDIZATION OFFICE (NSO) have threaten the topic issuing a definition. The US Federal Aviation Administration defines STOL aircraft, as explained by John Kern, FAA's Deputy Director of Flight Operations in 1984, in the document 'Aircraft Navigation and Landing Technology: Status of Implementation',U.S Government Printing Office, 1984, "*an aircraft with a certified performance capability to execute approaches along a glideslope of 6 degrees or steeper and to execute missed approaches at a climb gradient sufficient to clear a 15:1 missed approach surface at sea level*" [10].
The NSO, instead, defines STOL aircraft as "*an aircraft capable of clearing a 15-metre (50-feet) obstacle within 450 metres (1,500 feet) of commencing take-off or, in landing, of stopping within 450 metres (1,500 feet) after passing over a 15-metre(50-feet) obstacle*" [3].
An example of performance of a STOL plane is shown in the following figure which precisely depicts the performance of the Viking DHC-6 Twin Otter Series 400.

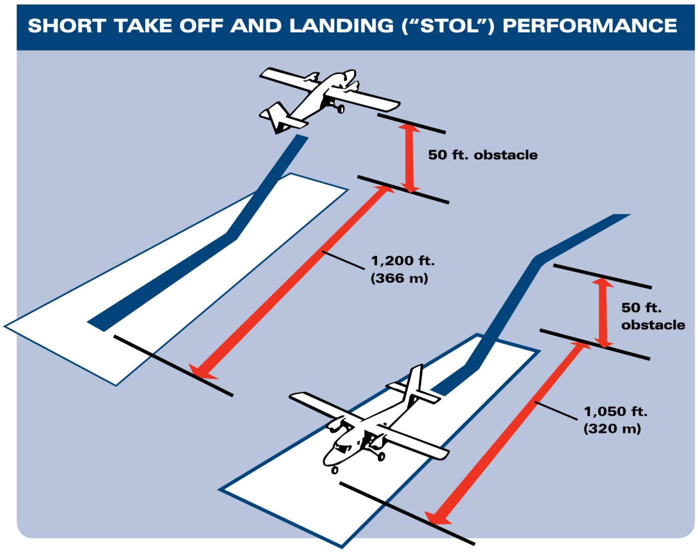


Figure 1.9: Viking DHC-6 Twin Otter Series 400 STOL performance, Viking Air website

With a good approximation, therefore, it is correct to say that the overall STOL performance of an aeroplane is represented by the measure of the length of the runway necessary for the aeroplane itself to land or take off becoming, within the UAM scenario, a subject of competition.

1.2.1 STOLport

Many STOLs aircraft are specially designed to operate even on runways, that are, poorly or semi-prepared or with a surface other than asphalt as grass, potting soil, snowy or frozen surfaces.
However, there is a concept of airports suitable for STOL operations. These airports are distinguished by their short runways and are called **STOLports**.

STOLports are also defined by the International Civil Aviation Organization, ICAO, in the document "STOLport Manual", the latest version of which was released in 1991, as "*airports whose physical characteristics, visual and non-visual aids and total infrastructure are create to support safe and effective public air transport in and out of densely populated urban areas as well as to and from rural areas with difficult terrain*" [11].
ICAO, therefore, defines STOLports as a viable alternative to conventional airports in areas where

would be prohibit the establishment of the latter.

In the here above mentioned document, ICAO draws up a series of guidelines and requirements to be followed for the creation of a STOLport suitable for the characteristics of the aircraft that will use it: In the point 1.3.2, for example, ICAO suggests to locate the STOLport as near as possible to the market it is intended to serve, in order to maximize the advantages offered by it [11]. Thanks to its favourable characteristics as the short runway and the practicality of steep obstacle limitation surfaces, in fact, it allows greater flexibility in locating the site [11].
To determine the length of the runway, several factors have to be taken into account. First of all, of course, it is necessary to know the reference field length of the aeroplane, without underestimating factors as the elevation of the site, temperature and humidity of the site and the nature of the runway desired.
An example of STOLport for a plane which has a reference field length of 800 m, a wingspan up to 26 m and a main landing gear measurement of up to 9 m, is the following one:

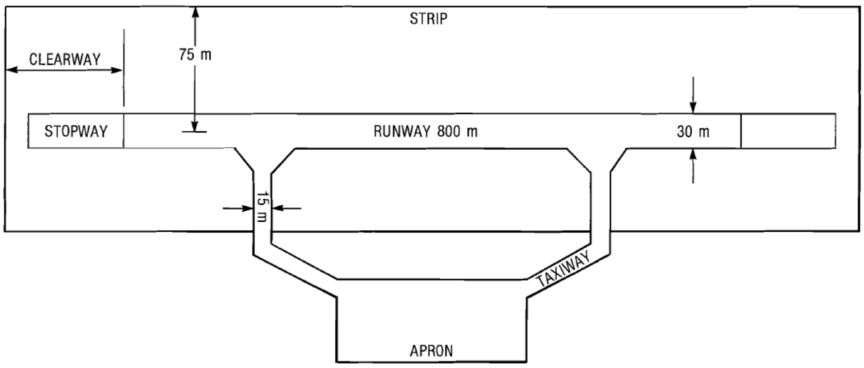


Figure 1.10: STOLport suitable for an aeroplane with a reference field length of 800 m, ICAO doc9150

Several STOLports, actually, have been realized and face with an improving market. The constant increase in the number of flights in recent years has led to a clogging of airports, even the large ones, which are most of the time unable to accommodate the new flights offered by the airlines. In cases like these, STOLports are an invaluable source capable of unraveling traffic and freeing airports from small capacity aircraft, allowing more passengers to fly. A vivid example in Europe, is the **London City Airport (LCY)**, the city's most central airport at just five miles from the City of London and close to the dynamic and fast-growing East London.

Figure 1.11: London City Airport's location in the London airports system, London City Airport Draft Master Plan 2020-2035

A small airport like that, allows much faster operations, great for businessmen who have to deal with their business and leave immediately afterwards. LCY, in fact, is the UK's most punctual airport with only 20 minutes spent by a passenger to go from the front door to the departure lounge. Currently, the airport is used by 12 airlines which serve 46 domestic, European and U.S. routes. As said before, therefore, small airports like this, deal with a good market playing a central part in contributing to the prosperity of the UK's capital city, through an annual economic contribution of more than £750m [12].

Figure 1.12: Current airlines which serve the LCY with European and U.S routes,London City Airport Draft Master Plan 2020-2035

Looking at the figures of this market, the question arises spontaneously: why are similar solutions so rare in Europe and worldwide?
As said before, it is true that a STOLport allows greater flexibility in locating the site but, however, in the other hand, for a solution like the LCY, which is located just 5 miles from the City of London, within the inhabited area, the noise and pollution sensitivity of the nearby residents result as invincible resistance making an otherwise suitable location politically infeasible.
To face that, the LCY, for example, has solid and convincing pollution and noise policy, which includes limitations of each type, steep slope approach (5.5°),8 hours-ban on night flights, a wide package of noise controls, a defined contour area limit, sound isolation of the airport and economic wellness packages for the isolation of the apartments of the nearby residents.

Figure 1.13: London City Airport, Michael Tomas, London City Airport Draft Master Plan 2020-2035

1.2.2 Main STOL architectures

Through the years, several configurations of STOL aircraft have been designed and realized for each type of use: utility, civil and military transport, artillery observer,airliner and research. Despite this, however, an official classification of this category of aircraft has not been drawn up, also due to the need to respond to the needs of a market that asks and asks for aircraft with ever greater autonomy and payload transport capacity.

The main classification of STOL aircraft can be based, as well as for conventional aircraft, on their main use purposes. This means:

- Commercial STOL aircraft:
- General aviation STOL aircraft:
  - Bush Flying operations aircraft.

1.2.2.1 Commercial STOL aircraft

Several small airlines have found as an interesting market the one which helps big airlines to gather all the passengers in big airports, namely hub-airports, for them, since the impossibility for those airlines to move big planes to small regional airports due to the significant operating costs they would get through otherwise. To provide big airlines with this service, these satellite companies have thought, as the best solution, to the STOL commercial aircraft, capable to use STOLports as the ones mentioned in section 1.1.4.

Among these types of aeroplanes, there is the historical **de Havilland Canada DHC-7** (Dash 7), designed by the Canadian Company 'de Havilland Canada' with the purpose to offer a low-noise performant aeroplane STOL with higher capacity to the market. The Dash 7 met with limited commercial success as the features on offer were not considered as so attractive by the big airlines. In fact, only 113 aircraft were sold all around the World and only 19 are still flying nowadays. However, this plane matched exactly the exigencies of the London City Airport, in fact, the London City Airlines, the airline of the homonym airport in London, built its entire fleet of DHC 7 only.
Concerning its specifications, the plane was provided with four turboprops engine, a wingspan of 28m, a MTOM of 20000 kg and a capacity of around 50 passengers. With these specifications, the plane was, therefore, able to fly for 1280 km at a speed of 428 km/h. Looking at these data the plane looks not so attractive, but what made it special was its capability to take-off and land in around 600 m, allowing operations in those places awkward to the conventional planes.
The DHC-7 was essentially a larger, four-engine version of the Twin Otter, in which, due to weight and complexity, unlike the Twin Otter, flaperons were not included, the ailerons were reduced in size to allow more flap area, and were augmented with two sets of roll spoilers, or "spoiler", with the outboard one which operated at speeds less than 130 KIAS to allow for more roll control at slower speeds. Upon touchdown, both the inboard and outboard roll spoilers extend in unison to aid in destroying lift created by the wing. The goal of a STOL aircraft is, in fact, to create high lift in the less time possible, so most of the trailing edge of the DHC 7 was spanned by a complex, double fowler flap arrangement which increases the area of the wing by extending out on rails or tracks. [13]

The fowler flap allows in the first stages of its extension, a large increase in lift, but little increase in drag, making the setting ideal for STOL aircraft. By opening a slot between the wing and the flap, in fact, high pressure air from the bottom of the wing flows through the slot into the upper surface, energizing the wing's boundary layer, delaying airflow separation, and producing so less drag. In the second stages, instead, the surface continues to extend, this means that the flaps move downward more and more, creating a little more lift, but a lot more drag [14].

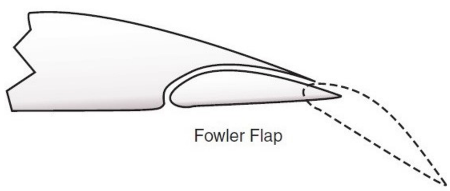


Figure 1.14: Fowler flap

During a typical STOL landing, therefore, flaps are selected to the 45° position, generating more lift and drag, thus allowing for steeper descents and slower approach speeds. On touchdown, the flaps automatically retract to the 25° position, thus reducing lift once on the runway and producing better braking performance. The flaps also retract to 25° when engine power is increased during a go-around procedure. A substantial aid during the landing phase is also given by the four-engine layout that when reverse thrust is selected on landing, the props reverse pitch, push air forward, and slow the aircraft very effectively along with the antiskid wheel brakes.

Figure 1.15: de Havilland Canada DHC-7, Airline.net

De Havilland Canada ceased production of the Dash 7 in 1988 when it was purchased by Boeing and was later sold to Bombardier. Bombardier before to sold the type certificate for the aircraft design to Victoria-based manufacturer Viking Air, in 2006 it has designed a more conventional twin-engine plane based on the design of the Dash 7 and called Dash 8 which still continues to operate today with exceptional success [13].

1.2.2.2 General aviation STOL aircraft

Among the several architectures of STOL aircraft within the general aviation classification, there is an architecture rather simple but which performs operations into truly hostile environments requiring a lot more care and observation from the pilot. The operations here above mentioned are known as **Bush Flying operations** and are performed by aircraft provided with abnormally large tires, floats, skis or any other equipment necessary for unpaved runway operations. These operations are usually carried out in the bush, rough terrain where there are often no prepared landing strips or runways.
This architecture and these operations were born in Canada, where, they are still performed to reach hostile environments of the aforementioned Country.

A famous STOL aircraft which is used to performs such as operations is the **Zenith CH 701 STOL**. The Zenith CH 701, first introduced in 1986 by the designer Chris Heintz has been through many significant improvements over the years, but its goal has been always kept. As mentioned into the website of the company, the Zenith CH 701 was not designed to be just another 'pretty' light aircraft, but was engineered to offer outstanding short take-off and landing performance, all-metal durability, unparalleled ease of construction, off-airport operations, fulfilling the demanding requirements of both sport pilots and first-time builders. The plane can land in less than 120 feet of unprepared grass, or 90 feet of hard surface [15].

Figure 1.16: Zenith CH 701 STOL, zenithair.net

Although the Zenith CH 701 is a sport utility kit aircraft, that had to be design for easy assembly and maintenance, it shows some highly and researched features:

STOL aerodynamics To perform STOL operations, STOL aircraft have as main goals, as already said, to achieve very high lift and low stall speed. These goals led the Zenith aircraft's engineers to think about a special airfoil design: a thick wing, full length leading-edge slats and trailing edge Junker type flaperons which develop a maximum wing coefficient of 3.10, while maintaining a short wing-span.

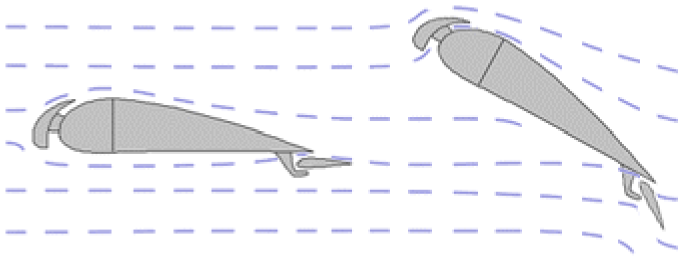


Figure 1.17: Special airfoil design of the Zenith CH 701 STOL, zenithair.net

Furthermore, even the tail design has to be carefully studied because an excellent controllability at very low flying speeds is required by STOL performance. This is achieved by the Zenith CH 701 thanks to large control surfaces with an all-moving rudder tail section and an horizontal tail which features a unique inverted stabilizer to achieve adequate negative lift for sustained high angle of attack climb attitudes [16].

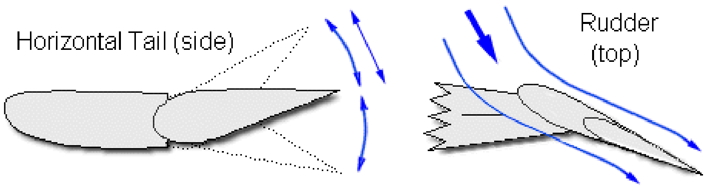


Figure 1.18: Tail design of the Zenith CH 701 STOL, zenithair.net

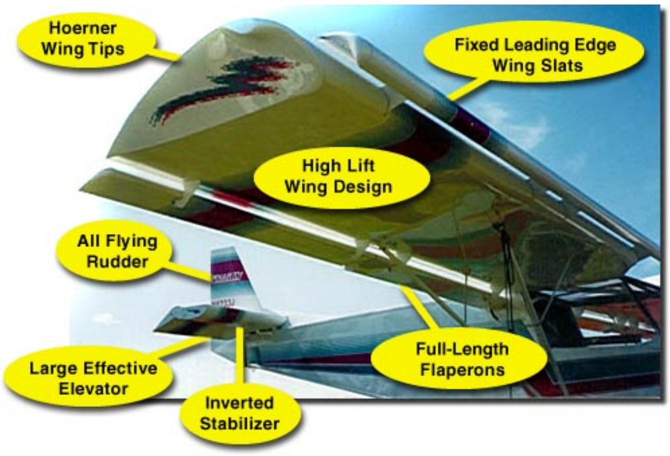


Figure 1.19: Wing and tail design of the Zenith CH 701 STOL, zenithair.net

STOL performance The performance of the Zenith CH 701 STOL, as mentioned in the name of the plane, have to be STOL. This means that the plane has to land and take-off in a very short distance. Other than the aerodynamics, even the choice of the engine has to be carefully studied which is strongly conditioned from the take-off requirements here above mentioned. The 'liaison' powerful engine-short take-off in this case could be rather useless and ineffective not only because it would provide the plane with a high increase of weight but also because the STOL planes don't require high-speeds.
The Zenith CH 701 has been, for example, provided with a Rotax engine in the version Rotax 912 (80hp) or 912S (100hp)[17].

Table 1.6: Performance of the Zenith CH 701 STOL

Performance	**Rotax 912(80hp)**	**Rotax 912S(100hp)**
Top Speed (MPH)	136 km/h	152 km/h
Max Cruise (Sea Level)	128 km/h	136 km/h
75 Cruise 8000 ft (TAS)	148 km/h	157 km/h
VS1 Stall Speed	45 km/h	45 km/h
Rate of Climb	1100 fpm	1200 fpm
Take-off Roll	60 ft	50 ft
Landing Distance	80 ft	80 ft
Range	598 km	563 km
Endurance	4.6 hours	4.1 hours

Chapter 2

Alérion M1h

2.1 Avions Mauboussin

In 2011, David Gallezot, a recognized consulting engineer in the field of high level safety on-board systems, design certification and organization approvals as well as a pilot and enthusiast of aviation in all its shapes, created a company called Avions Mauboussin with the dream of reviving a famous brand of French light aircraft from the 1930s and, at the same time, applying new technologies and green processes to general aviation.
Avions Mauboussin, in fact, is based on a company founded by Pierre Mauboussin, a jeweller with the passion for general aviation, who developed with the engineer Louis Peyret several high-wing monoplanes. However, after Louis Peyret's death, Pierre Maubousisn decided to show his idea of plane. The design thought by Pierre Mauboussin was simple, a performing low-wing plane with a wooden structure, aerodynamically efficient, economical, comfortable and affordable for everyone.
A plane realized on this design was the M123 Corsaire [18] [19].

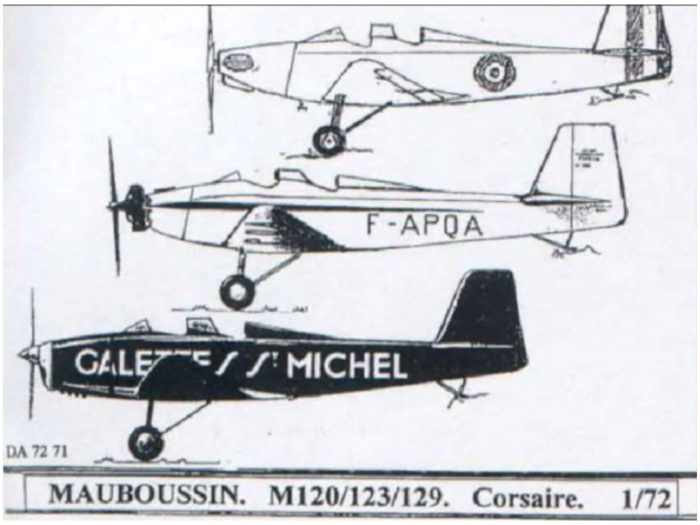


Figure 2.1: Mauboussin M120/123/129 Corsaire, unknown source

In the first place, David Gallezot thought about a fully electric aircraft since one of the cornerstones of the company's philosophy is the environmental sustainability of its aircraft. However, due to the slow development of electric technologies, the activities quickly moved toward a hybrid propulsion aircraft.

The company, located in Belfort, has several partners, which collaborate with Avions Mauboussin in its activities, as UTBM, ESTACA, ISAE SUPAERO, ENAC, ELISA Aerospace, INSA and IPSA, and has received several accreditation by entities of national and international importance as SAE

International, RTCA, ASTM International, EUROCAE, Dassault Systèmes and 3AF among others. The company is composed, other than David Gallezot, by several experienced members, and recruits interns for the design and engineering studies. Six interns have been hired during my internship at Avions Mauboussin:

- Operations and certification intern;
- Structures intern;
- Avionics intern;
- Propulsion intern;
- Aerodynamics intern;
- Communication intern.

Figure 2.2: Avions Mauboussin presentation image in the news "Mauboussin redécolle à Belfort" of the magazine L'Est Républicain

The goal of the company is to design powerful and sustainable aircraft and has already developed several ideas and solid projects. Among these, there are a tandem and a six-place plane, but the company aims to design also aerobatic planes and drones in order to have a complete range of aircraft suitable for each scenario.

2.2 Alérion M1h - The urban fighter

Keeping in mind the design idea of Pierre Mauboussin, the modern Avions Mauboussin has developed as first plane of its range of aircraft, an innovative light aircraft that aims at offering to private pilots and air-taxi companies a quiet, comfortable and high-performance aircraft, namely Alérion M1h.

Alérion M1h is a 600 kg single-engine tandem two-seater aeroplane made of natural composites (wood and natural fibres), fitted with a low wing, a conventional empennage and a hybrid propulsion system, able to land in less than 100 m without any carbon emission and with a considerably reduced noise level, thus offering itself as a solid and valid solution to the requests of the Urban Air Mobility scenario.

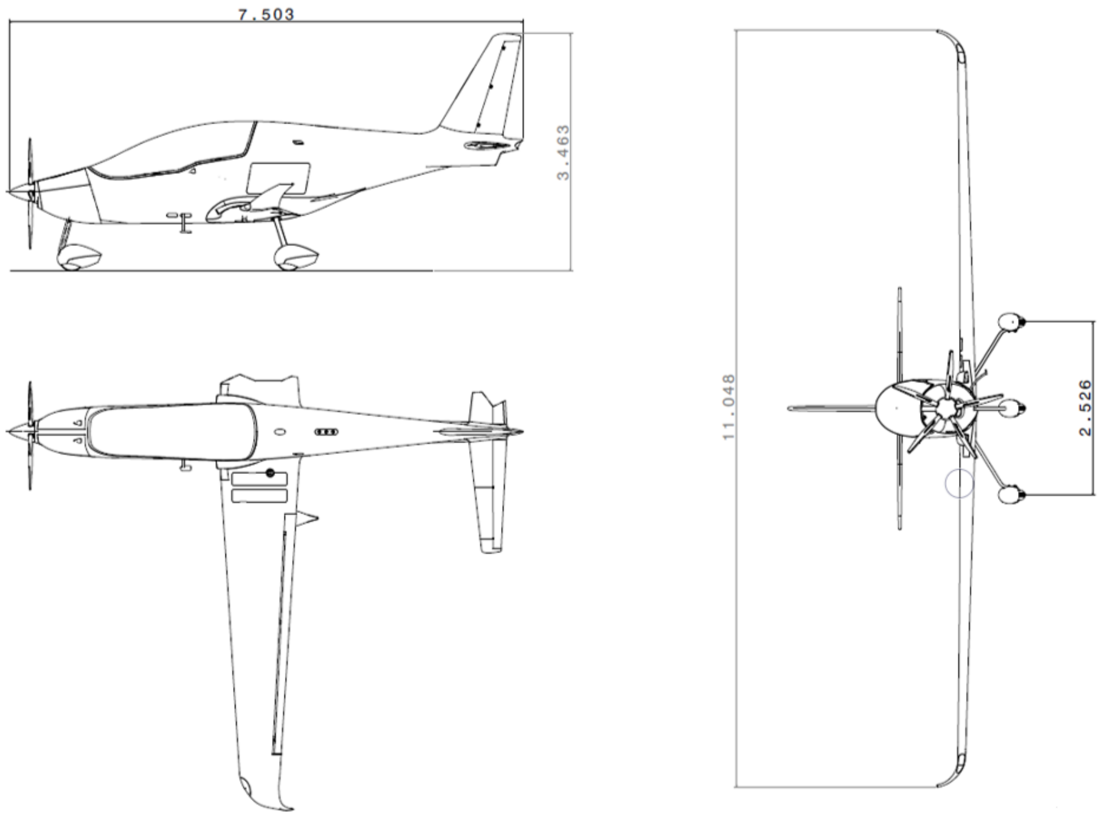


Figure 2.3: Alèrion M1h 3 views drawing, Avions Mauboussin website

Table 2.1: Technical data of the Alérion M1h

MTOM	600kg
Maximum payload	200 kg
Wingspan (w/o winglets)	11 m
Wing area	9 m^2
Stall speed	35 kts
Range	600 km
Cruise speed	220 km/h
Endurance	3h

Figure 2.4: Alèrion M1h "Le chasseur trés urbain", Avions Mauboussin website

Alérion M1h, in fact, is meant for use as a conventional aeroplane from classical aerodromes as well as an urban means of transportation to/from small airparks. Airparks are small aerodromes or surfaces dedicated to ESTOL (Extremely Short Take-Off and Landing) aeroplanes, located inside cities or close to their periphery, to prove quick and easy access to passengers and cargo.
Alérion M1h can be operated privately by its pilot-owner or a flying club or commercially by an airline as air taxi service, in Day and Night VFR, IFR, and FIKI meteorological conditions. It flies at low heights above inhabited areas as well as at high altitude in cruise and can clear obstacles usually associated with helicopter operations (up to 20 % climb and approach slopes). The aircraft can be classified as a STOL aircraft and it is currently is in the process of CS-23 certification in VFR and VFR night, with the possibility of eventually offering soon the IFR certification (according to the developments in the certification of hybrid and electric engines).

Combining STOL performance, silent operations, and safety of a certified aircraft, Alérion M1h has new arguments for negotiating with the authorities a return of the aircraft closer to urban areas: less nuisance, lower consumption, low footprint, high level of security.

2.2.1 Innovations carried out by Alérion M1h

Avions Mauboussin aims to offer a product able to give satisfactions to its pilots-owners other than comfort, efficiency, effectiveness and a high safety-level despite the introduction of new technologies.

Alérion M1h, in fact, other than conventional design features as winglets, fixed tricycle landing gear and flaperons which are getting more common, shows features that we can define innovative and not because of their novelty (some of them are already on the market) but more because the mix of these features in a light aircraft is rather uncommon. Among these, we can mention a **hybrid propulsion system** which will be able to use hydrogen as the main fuel; a **very light composite structure** made of natural composite materials as wood, natural fibres and bio-based resins, combining strength and lightness marking at the same time the green footprint of the company; a **pilot-centred avionics** interface as a fighter thanks to the Head-Up Display, which offers control in incidence and trajectory and the HOTAS controls which let the pilot to look outside and enjoying the flight, without having to bend over any buttons or levers in the cockpit. The fully digital and connected avionics, in fact, supports the pilot in all phases of flight.

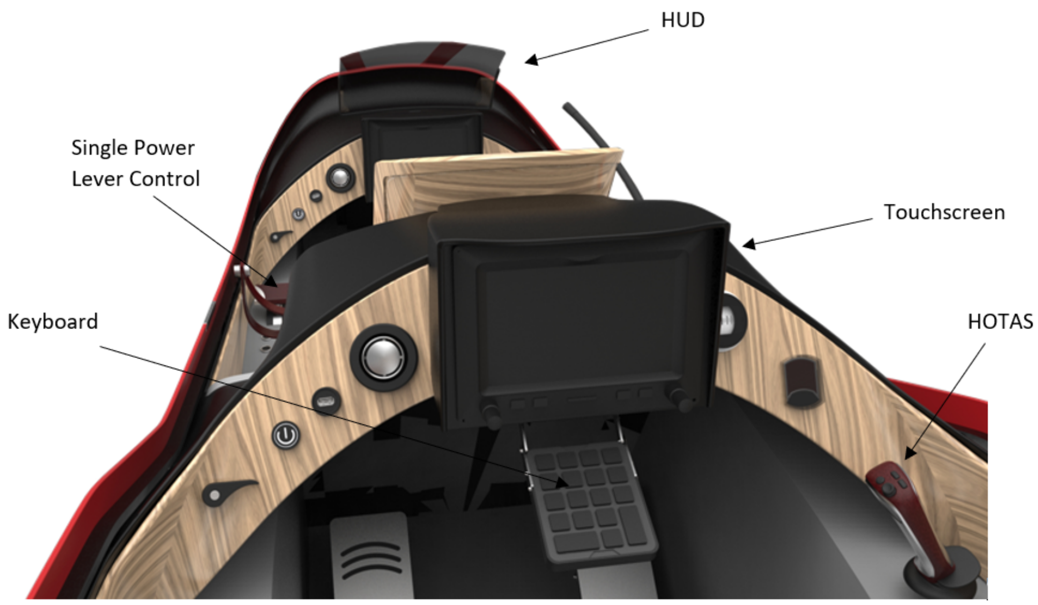


Figure 2.5: Alérion M1h's cockpit, Avions Mauboussin website

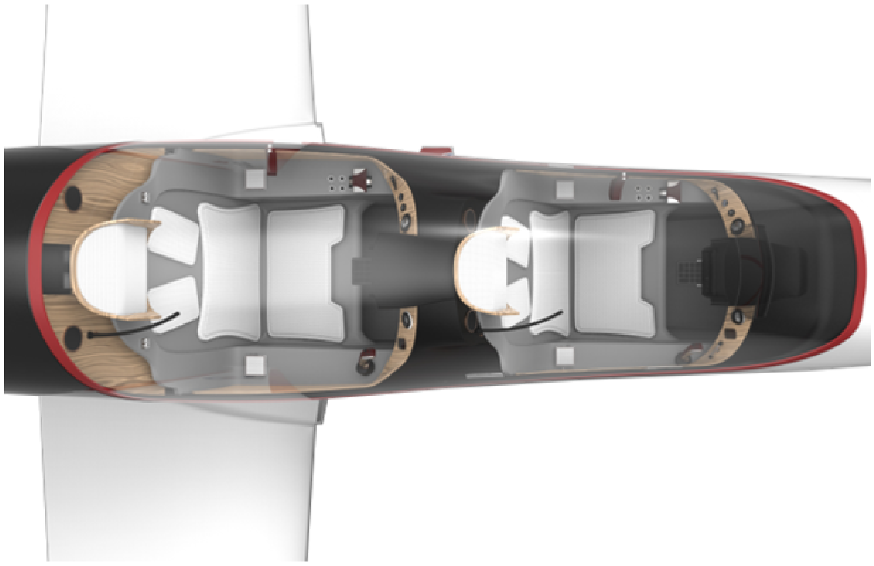


Figure 2.6: Alérion M1h's cockpit, Avions Mauboussin website

Finally, Alérion M1h offers a **STOL aerodynamics** with the wings that are fitted with advanced high-lift devices as slats and double-slotted flaps, allowing the plane to land in 100 m and take-off in short distances.

The footprint of Pierre Mauboussin's planes is still clearly visible.

2.2.1.1 Electric/Hybrid propulsion

Since one of the cornerstones of Avions Mauboussin has always been the environmental sustainability, Alérion M1h has been conceived to reduce to 0 the emissions of CO2 within the urban areas. This means that the plane has been designed to taxis, takes-off, moves away from the aerodrome, approaches it and lands in pure electric mode.
In the other hand, however, the company wanted to realize a plane able to sustain long ranges. These points led the company to the choice of a hybrid propulsion system, that can be considered as the main innovation of this plane, composed of an electric engine which drives a five-blade propeller designed to limit noise pollution, and a thermal engine which acts as a range extender and works only during the cruise phase, recharging the batteries and supplying the electric engine. This solution has the name of Zéphyr and comes up from a partnership recently unveiled by Avions Mauboussin with the University of Technology of Belfort-Montbéliard (UTBM). This solution foresees even the use of Hydrogen which should allow Alérion to free itself from fossil fuels and reduce its noise footprint. Through this model, the company wishes to develop a range of motors of various powers, EASA certified [20].
This innovation benefits from the highly developed ecosystem of the hydrogen sector in the Bourgogne Franche-Comtè region and will integrate the full cycle of green production and distribution of hydrogen [21].

ZÉPHYR

Figure 2.7: Logo Zéphyr, Avions Mauboussin Designs a New Hydrogen Propulsion System for Aircraft, FuelCellsWorks

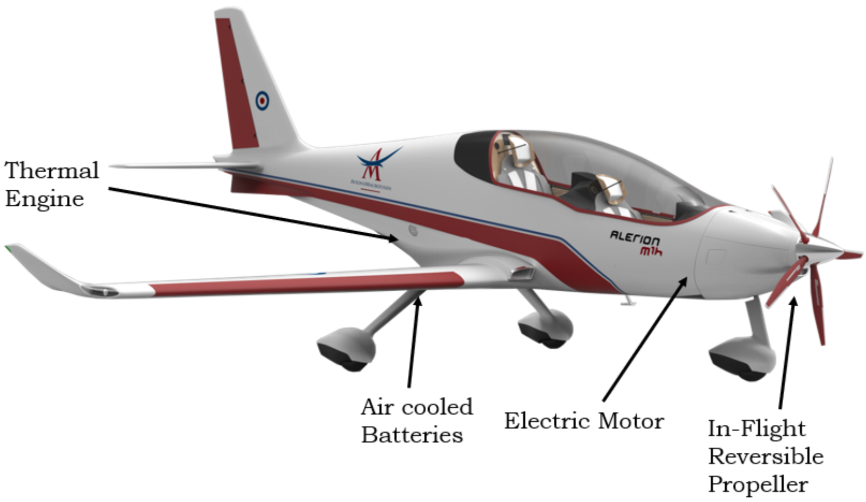


Figure 2.8: Propulsion layout of Alérion M1h

As development of this solution, the company Avions Mauboussin will use as electric engine the Slovenian EMRAX 268, as well as done by Pipistrel for the first fully electric aircraft ever certified by EASA, the Velis electro.

Figure 2.9: EMRAX 268, EMRAX innovative E-Motors website

Table 2.2: Technical data of the E268

Type	Axial flux motor / generator
Dry mass	20 kg
Stator cooling	air (IP21 Spec)
Peak power	200 KW
Continuous power	up to 107 KW
Peak torque	500Nm
Continuous torque	up to 250 Nm
Efficiency	92-98 %

As thermal engine, instead, the company opted for the Turbogenerator TG-R55 made by the

French company Turbotech, which offers high-performance propulsion systems. The TG-R55 generates electric power on-board and paves the way to hybrid-electric architectures. Used in conjunction with batteries, it can offer up to 10 times more range than a full-electric plane [22]

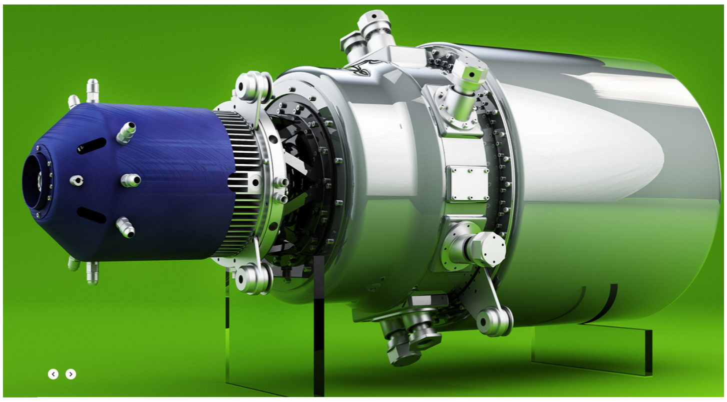


Figure 2.10: Turbogenerator TG-R55, Turbotech-aero website

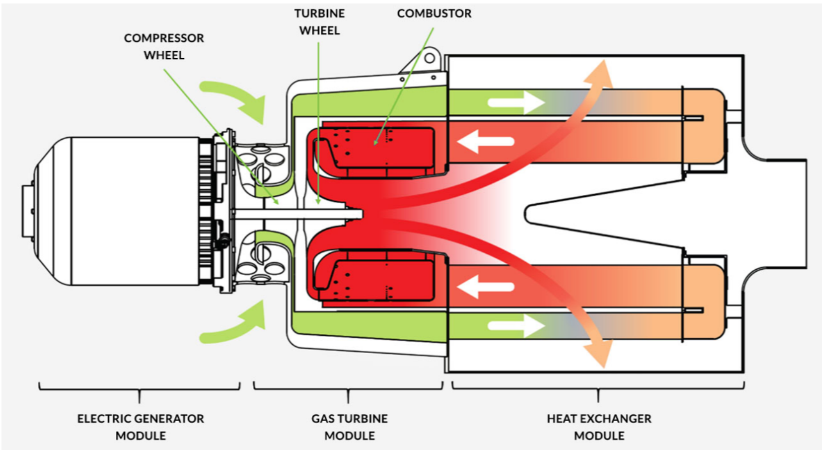


Figure 2.11: Drawing project TG-R55, Turbotech-aero website

Table 2.3: Technical data of the TG-R55

Fuel	Jet-A1/Diesel/Bio-Fuel/H2
Dry mass	55 kg
Peak power	200 KW
Continuous power	up to 55 KW
T.B.O	3000 hours
Acoustic signature	Ultra Quiet

The lithium batteries previously mentioned, finally, will be foreseen and will be charged in several ways:

- during flight, for an immediate take-off without long recharge on the ground, or in the event of a go-around;
- by the electric engine during the descent phase thanks to the five-bladed propeller that is an In-Flight Reversible Propeller;

- on the ground from the mains without external equipment.

In this way, the pilot can choose to land with the full battery or else discharged if he prefers to recharge it on the ground.

2.2.1.2 Hydrogen as the main fuel

Why Avions Mauboussin, and the aviation industry in general, is moving towards the use of Hydrogen as main fuel? What does it make so special?

The aviation industry even if it is currently considered as responsible for 3% of global CO2 emissions, is committed to reduce this percentage looking for more sustainable solutions. Several solutions came up through the years but actually the most renowned today, as said by the German consulting company Roland Berger, are sustainable aviation fuels (SAFs), electric aircraft and hydrogen propulsion.
Among these solutions, the German company, has been able to explain in three points why the hydrogen is better than the others:

1. The Hydrogen can be considered better than the conventional fuels and SAFs because it is able to remove carbon dioxide emissions entirely and to reduce other GHG emissions;
2. The Hydrogen has a higher energy density, both in gravimetric and volumetric measures, than batteries;
3. Finally, Hydrogen has already penetrated into other industries, which could speed up the development of fuel cells and storage systems, promote downstream infrastructure and push down supply chain costs [23].

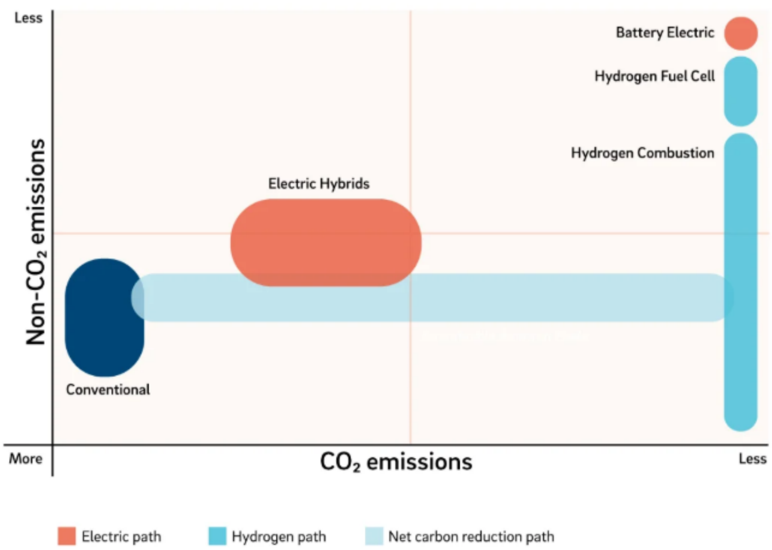


Figure 2.12: Potential solutions by intensity of CO_2 and non-CO_2 emission, Roland Berger

The figure 2.14 shows how the hydrogen has a very limited CO_2 emissions although the best solution in this figure seems to be the battery due to the less Non-CO_2 emissions. What makes the hydrogen better than the batteries then?

Hydrogen (H_2) is the most abundant element in the universe, but also the simplest and lightest fuel which presents greater transportation and storage capabilities than the current fuels. It is non-toxic, colourless, odourless and presents a specific energy, or stored energy by weight, that is the highest of any practical fuel: 142 MJ/kg. This allows aircraft propelled by hydrogen to fly continuously for up to 4 hours or more instead of less than a half an hour as allowed by batteries.

However, even the hydrogen has a flaw,it does not exist naturally as fuel and it has to be produced through one of the two current methods:

1. Electrolysis;
2. Synthesis gas production from steam reforming or partial oxidation.

Even if the first method is the most environmental sustainable as it uses electrical energy, which comes from renewable fuels or from the sun, to split water molecules into hydrogen and oxygen, the predominant method nowadays is the second one, which is not sustainable at all due to the use of fossil fuels [24].

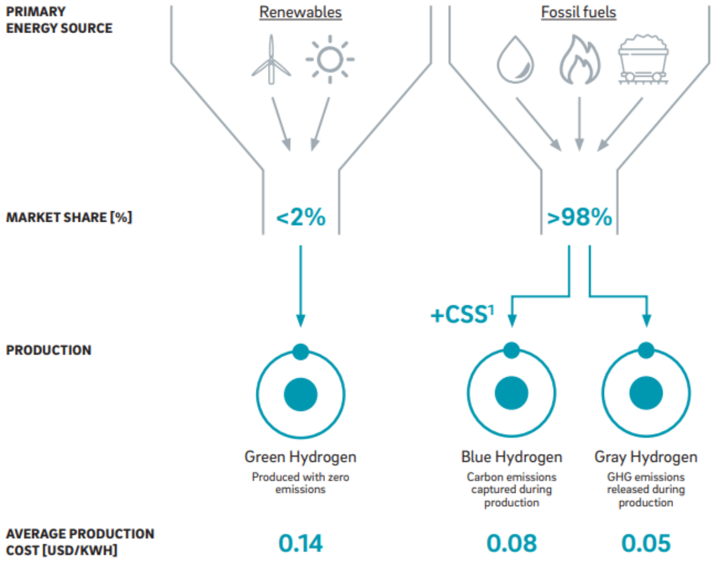


Figure 2.13: Hydrogen production methods, "Hydrogen: a future fuel for aviation?", Roland Berger

When the Hydrogen has been produced, it can be used to produce thrust by its *combustion*, which eliminates most but not all GHG emissions, or using fuel cells which offer a “true-zero” solution for GHG emissions, but the latter requires a heavy redesign of engine and aircraft itself.

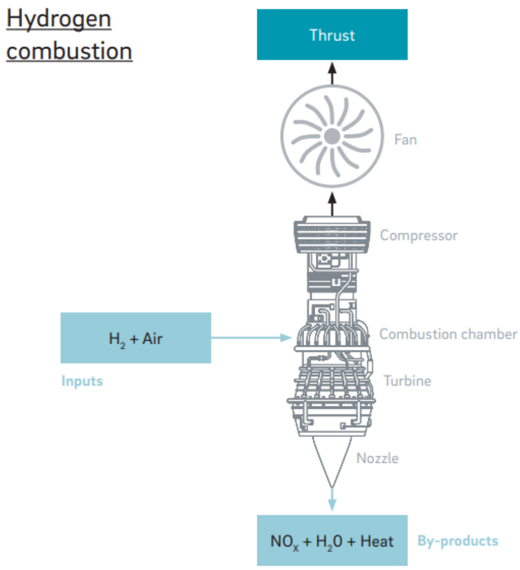


Figure 2.14: Hydrogen combustion architecture, "Hydrogen: a future fuel for aviation?", Roland Berger

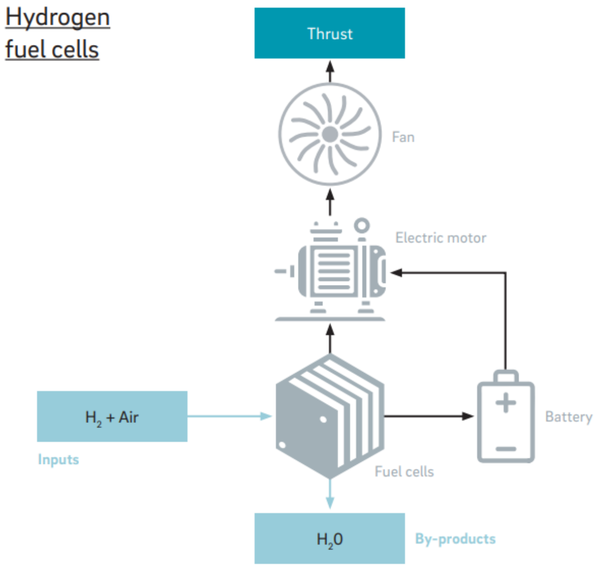


Figure 2.15: Hydrogen fuel cell architecture, "Hydrogen: a future fuel for aviation?", Roland Berger

The Roland Berger's study reported in the magazine "Hydrogen: a future for aviation?", published in March 2020, listed the five key barriers to hydrogen technology:

1. A redesign of much of the aircraft, from the propulsion system to fuel storage;
2. Advancements in light-weighting storage tanks and cryogenic cooling systems, in order to take advantage of hydrogen's high energy density;
3. A significant ramp-up in "green" hydrogen and/or carbon capture and storage (CCS) to increase the share of emissions-free hydrogen production;
4. Hydrogen infrastructure improvements in fuel delivery to airports and airport refuelling.;
5. A reduction in the price of production methods for "green" hydrogen in order to compete with kerosene on a cost basis [23].

From these points we can understand as the hydrogen World has to prove as soon as possible that the hydrogen is a solution more viable than SAFs and hybrid-electric solutions.

However, Avions Mauboussin thrusts in the hydrogen and is working hard to use it in the second version of Alérion M1h as cutting-edge technology for the aviation World.

Chapter 3

Urban Air Mobility

3.1 UAM - Urban Air Mobility

3.1.1 What is UAM?

UAM is an acronym which stands for Urban Air Mobility, a term that has been echoing in the aviation world for quite a while now and which identifies, we can say, a new mode of transportation.

The sky has always been seen as the solution to the direct consequence of the inevitable population increase, the traffic congestion. However, the lack of technology, pollution and safety stakes have never led to more than a hint of the use of the sky as a means of alleviating road congestion in large metropolitan areas. Today, however, things have changed. Through the years, in fact, the astounding technological progress and the convergence of seemingly unrelated technologies in electric propulsion, supervised automation, autonomous flight technology, new communication networks and navigation are pushing the aviation World to challenge even the most unthinkable new challenges as the Urban Air Mobility.
The latter, as said by the brilliant consulting company Roland Berger into the study "Urban air mobility -The rise of a new mode of transportation", published in November 2018, adds a third dimension to the urban transportation matrix creating new opportunities for travellers for whom personal comfort and speed are at a premium[25].
The company made an estimation of the market potential based on bottom-up calculation of the number of urban aircraft required to offer viable services in major cities. Among the "urban archetypes" in terms of population density and surface area chosen by Roland Berger for the study, let's analyse the Munich case. For Munich, after a careful study of the urban architecture, potential UAM routes linking key traffic nodes (such as airports) to points of interest (city centres, shopping malls etc.) have been identified. They, therefore, have assumed the number of passengers for urban air mobility services based on the available data on commuters and the percentages for switching to this new service based on their interviews. This led them to determine the number of UAM aircraft required to make it possible.

Table 3.1: Potential UAM routes - Greater Munich metropolitan area [25]

Potential UAM routes	**Distance**	**Commuter demand [Nb of commuter outbound/inbound]**
Munich - Augsburg	80 km	2000 per day/9100 per day
Munich - Ingolstadt	80 km	1800 per day/2300 per day
Munich - Landshut	73 km	450 per day/3900 per day
Munich - Rosenheim	67 km	1100 per day/8400 per day
Augsburg - Ingolstadt	78 km	170 per day/170 per day

Table 3.2: Potential UAM airport shuttle - Greater Munich metropolitan area [25]

Potential UAM airport shuttle	**Distance**	**Potential demand per route per day [Nb of travelers]**
MUC - Munich	40 km	34000 per day
MUC - Augsburg	85 km	6600 per day
MUC - Ingolstadt	71 km	3300 per day
MUC - Landshut	41 km	1600 per day
MUC - Rosenheim	100 km	1400 per day

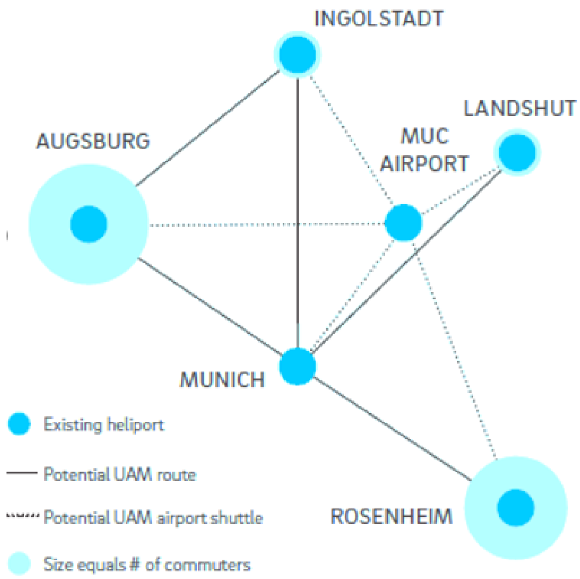


Figure 3.1: Greater Munich metropolitan area - Example of estimated passenger demand based on available commuter data, source Roland Berger "Urban air mobility - The rise of a new mode of transportation", published in November 2018 [25]

The data is impressive and the Urban Air Mobility has a great market potential but, of course, it will not be suddenly totally integrated within the current mobility scenario given the huge impact it is having to those that are the current modes of transportation and their regulations. Several countries, in fact, are still scared of the substantial change the UAM would bring to their main metropolitan areas.
It will enter our daily life step by step, in a very gradual way, until it will seem to us something extremely consolidated, part of everyday life, and its need will be felt more and more as it will bring a safe time-efficient mode of travel and a sensational flight experience decreasing even the cost.

3.1.2 Operational challenges

Goal of a transportation mean is to get from point A to point B, goal of the Urban Air Mobility is to get from point A to point B in busy metropolitan areas in the fastest and more pleasant way. UAM is not only about passenger transport, a cargo delivery service is also envisioned by several companies which have found this challenge attractive. For this, UAM is envisioned to take several shapes in the future, in order to accomplish and support a broad range of operations.
Four use cases:

3.1.2.1 Air Taxi

As reminded by the title, Air Taxi will be a service offered as the conventional car taxi service, with the difference that the service will use airways to get from point A to point B.
This type of service will be mainly exploited within the big metropolitan cities as Munich, Paris, London and Madrid, with on-demand flights between any available landing pads. The aircraft intended for this type of operations, or air taxi service, must be able to transport one / two people with their luggages over a distance not exceeding 50 km, obviously respecting all the operational challenges required by the Urban Air Mobility with a very high level of safety.
Small aircraft with a distributed propulsion as VoloCity might become the solutions of choice for this use case due to their redundancy and low speed which offers a good level of safety.

Figure 3.2: Multiple UAM corridors within the urban area, FAA Concept of Operations - UAM

As said, this concept of operations will be based on on-demand flights simply bookable via App.

Figure 3.3: Volocopter App, Volocopter website

3.1.2.2 Airport shuttles

Airport shuttles will provide a service similar to that of air taxis, covering, however, longer distances and carrying more than 2 people and their related suitcases. Therefore, the design of the aircraft could not be the same, it will change, not so much from the technological point of view as from the geometric and structural one, allowing this type of aircraft to carry a considerably higher weight than the one faced by the air taxis.

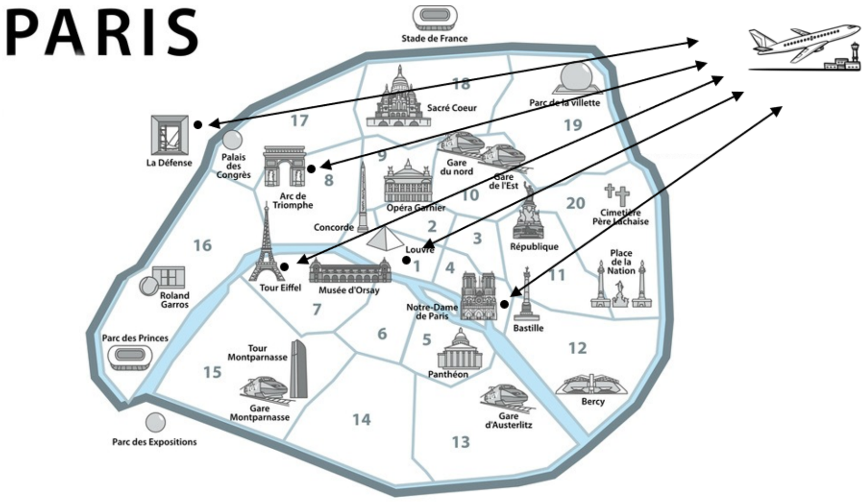


Figure 3.4: Airport shuttles operations in Paris, images source 'Paris here and there' and 'VectorStock'

Another difference that is not so subtle between the two services is that unlike air taxis, airport shuttles will not offer an on-demand service but a scheduled service given the large influx of people. The connections, instead, as expected, will be between the landing pads at the airport, which will most likely be better structured and complete, and landing pads in the major points of interest within the city.

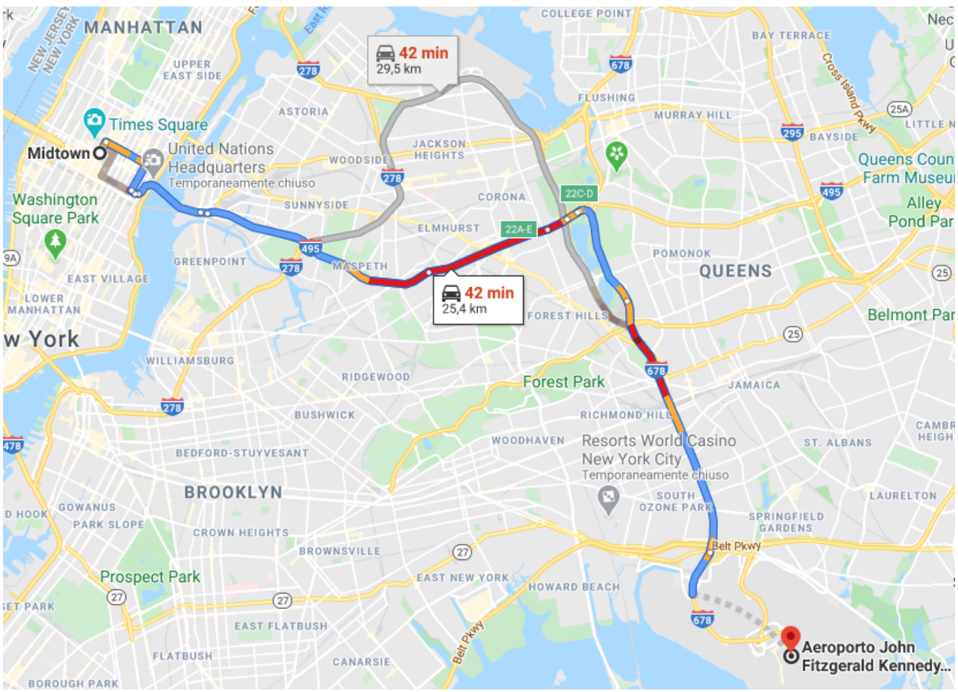


Figure 3.5: Example of a taxi route for New York (JFK-Manhatten)

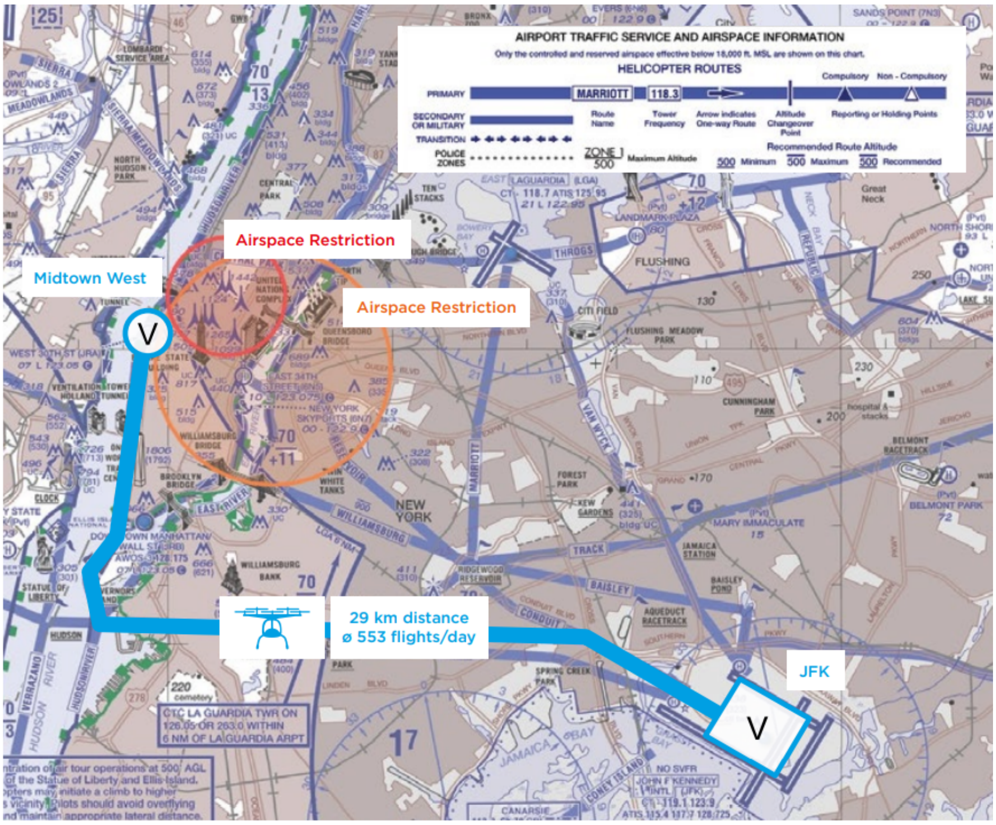


Figure 3.6: Example of an urban air taxi route for New York (JFK-Manhatten), Pioneering the urban air taxi revolution, Volocopter [26]

The figure 3.5 shows the 25 km ground route that taxis take every day to get passengers from point A, situated in Midtown Manhattan, to point B, JFK airport, while the figure 3.6 shows the 29 km airway that would be taken by VoloCity to get passengers from point A to point B. It is immediately clear that the route taken by the taxi is shorter than the airway taken by VoloCity and therefore there should be chances that a car can reach JFK airport in a shorter time than that taken by VoloCity. However, as underlined by Volocopter, even without traffic jams, would be rare to travel within megacities at an average speed of more than 50 km/h. It is even rarer to find a direct straight-line connection between two major locations inside such a city. This means that whatever is the ground transport used, the trip will last at least 35-40 minutes. With the Volocity's performance,taking into account all the limitations like noise, collision-damage and bird strike damage that operating at low altitudes over densely populated areas entails, instead, the same trip would last around 18 minutes, with a time saving of at least 50 % [26].

3.1.2.3 Intercity flights

UAM will not only cover flights within a single metropolitan area but will also make it possible to connect different metropolitan areas, even those that are at such a distance that they cannot even be reached by regional aircraft. As well as the previous cases, we are talking about a service that will be mostly scheduled and not on-demand, with an expected range of action of about 300 km and with a more complex architecture than the others as it must not only allow the transport of a higher weight, but also to have higher performance in order to guarantee, even in this case, a faster and more efficient service than traditional ones.

The German company Lilium, with its simple and performing Lilium jet and the incredible project of the modular design vertiports, aims at this market, hoping to become the pioneer of the air regional mobility.

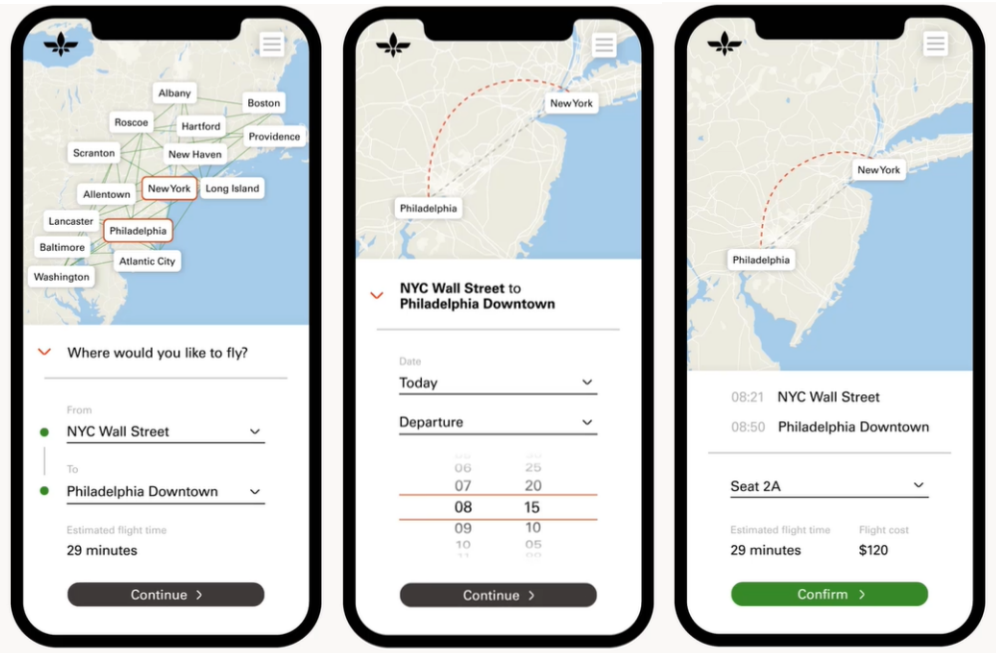


Figure 3.7: Plan your journey with the Lilium App, lilium.com

3.1.2.4 Cargo delivery

The continuous exponential growth of e-commerce has led the medium-short range logistics sector to become more and more complex given the excessive demand for goods with the time factor which turns out to be the real aspect on which the various shipping companies are fighting, trying to prevail. Lately, however, the time factor has been joined by another big aspect that shipping companies have to cope with, the environmental impact.

The e-commerce giant, Amazon, as part of the climate change plan that the company has launched in support of green mobility and which, according to the objectives, will lead the company to be carbon neutral by 2040, has in fact ordered 100,000 electric vans to be used for their deliveries by supporting the US startup Rivian with an investment of 700 million dollars.
In my opinion, however, the American start-up AirFlow has thought of something more ingenious that responds to both the needs listed above. In fact, AirFlow has recently proposed to the UAM market an aircraft to be included in an air logistics network capable of reducing road congestion, cost, time and increasing transport efficiency.
In particular, AirFlow, proposes the first electric Short Take Off and Landing (eSTOL) aircraft for middle-mile logistics able to move cargo directly between warehouses without the use of airports [26].

Figure 3.8: AirFlow aeroplane project, AirFlow.com

In my opinion, the solution proposed by the American start-up is perfectly suited to the needs of today's logistics as an increase in trucks directly related to the increase in e-commerce does nothing but increase road congestion and slowing down time. The choice then, of a fully electric aircraft with eSTOL performance, allows goods to be moved between the different warehouses even in the same metropolitan area, requiring a meagre landing surface.

The diagrams below show as Airflow would change the cargo delivery services:

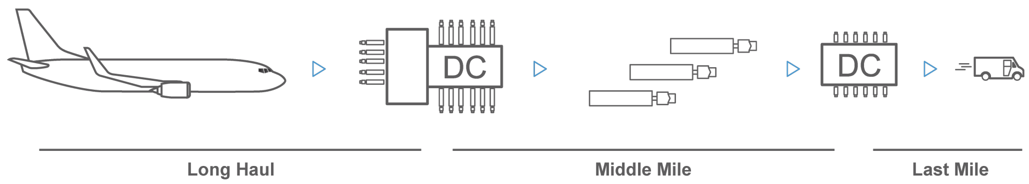


Figure 3.9: How cargo moves today between warehouses (distribution centers) using trucks, Airflow.aero [27]

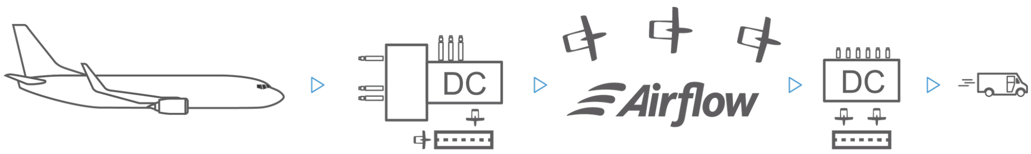


Figure 3.10: How Airflow would move cargo quickly and inexpensively between warehouses, Airflow.aero [27]

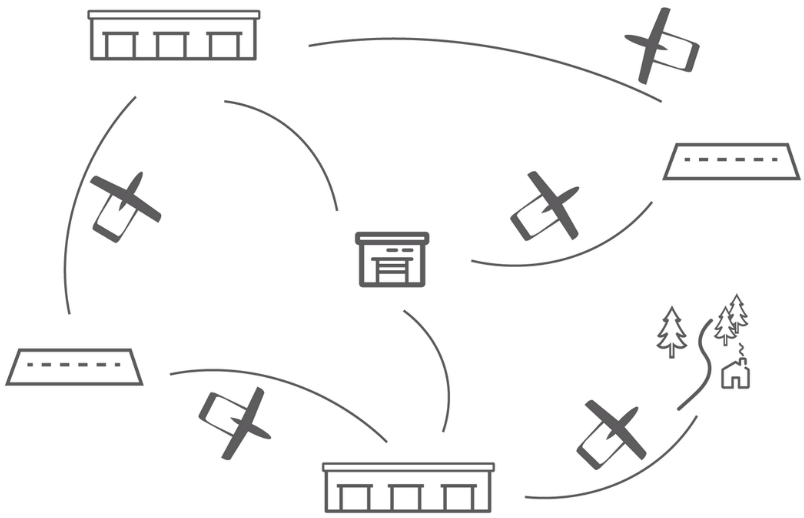


Figure 3.11: Airflow network, Airflow.aero [27]

3.2 What is the position of Alérion M1h as STOL aircraft within this scenario?

One of the main goals of this thesis was to understand what position Alérion M1h could cover within the Urban Air Mobility scenario, studying and defining in detail the regulatory environment of the various European countries. As Avions Mauboussin, in the last few years, had made only a regulatory framework of France and given, furthermore, the unclearness of some European countries regulations, this study has involved exchanges with various civil aviation authorities figures, engineers, aviation lawyers and industry experts who helped me not only to have a regulatory framework of their country but also to understand how their country was evolving in this scenario.
It has been surprising to discover that some countries were presenting such different regulations, as well as to discover that some of them are not even planning to adapt them to the operations foreseen by the future scenario of the UAM. This is the case of Germany, for example, whose flight regulations are rigid and which, as said by some German aviation experts, are not close to lightening despite two of the most successful protagonists of the Urban Air Mobility, such as Lilium and Volocopter, were born there and are developing themselves there. The company born in Bruchsal, namely Volocopter, in fact, had to complete its first ever public test flight over Singapore's Marina Bay. What has been said, however, did not aim to classify Singapore's regulation weak and not serious, on the contrary, to praise its open-mindedness towards a World that is evolving more and more. Volocopter and Civil Aviation Authority of Singapore (CAAS), in fact, have been working for more than 1 year to ensure that all the necessary safety requirements were met before the first ever VoloCity's flight in the city.
In such an environment, like the one of Germany, which, however, it is not alone, looks difficult to find a position for Alérion M1h. Other European countries, in fact, are still rather hostile towards air-taxi and air airport shuttle operations, although it seems they would come to terms in the event of a high level of safety demonstrated. This, therefore, led the study to consider that those two first categories of operations are not right at the moment for the Alérion's operations in which the eVTOLs seem to prevail in terms of type of surface needed and performance. Avions Mauboussin should, then, keep focusing on the intercity flights or, anyway, connections between secondary/regional airports and airport hubs or between cities and holiday resort/point of interest weakly to moderately urbanized. It is in this scenario that Alérion prevails over the other projects and in particular over the eVTOLs. Alérion, in fact, unlike its direct competitor in this scenario, namely Lilium Jet, has a range of 600 km and a lift-to-drag ratio, $E = \frac{L}{D}$, way higher thank its clean wing configuration. A high lift-to-drag ratio will allow, in fact, the plane to have a better fuel economy, better climb performance and a good glide ratio.
Therefore, in the following sections, the stakes of regulations and certification needs will be listed and analysed.

3.3 Regulations and certification needs

The main issue Urban Air Mobility has to face right now, if it wants to take-off, is the total absence or very immature status of regulations worldwide about those kind of operations foreseen by the UAM. As raised by the Roland Berger company, this scenario urgently needs a regulatory framework to guarantee the safety of people, infrastructure facilities and third-party property. The company, has exposed into the journal Urban Air Mobility - The rise of a new mode of transportation, issued on November 2018, an interesting opinion: "*Such a regulatory framework should, in our opinion, address four key safety concerns: avoidance of possible mid-air collisions, prevention of injuries to people and damage to properties as an outcome of possible crashes, and avoidance of privacy breaches*"[25].
The key safety factors raised by Roland Berger, are essential but, in my opinion, they are not the only that should be covered. During an interview to the prestigious air law lawyer Dr Stefan Krauss, in fact, he underlined as the main issue of German authorities, in his opinion, is the safety to which noise, so tranquillity of the neighbourhood, and air quality are connected. Therefore, to the 4 key safety factors listed by Roland Berger, the regulatory framework should address what we call environment too: level of noise and air quality.
To date, what brings everyone together is assuring a high level of safety.

3.3.1 Flight Rules regulating the airspace

To assure a high level of safety, flight rules have to established and have to be as clear as possible to avoid conflicts and, potentially, collisions between all the aircraft using the same airspace. Air traffic, therefore, has to be monitored.

3.3.1.1 U.S

The Federal Aviation Administration (FAA) NextGen Office has recently issued a document called "Concept of Operations", shortly ConOps 1.0, about the foundational principles, roles and responsibilities, scenarios and operational threads of the Urban Air Mobility. The scope of this document is to establish a framework able to support the expected growth of flight operations in and around urban areas. In particular, the document will present the ATM vision to support initial UAM operations. FAA in the ConOps 1.0, defines UAM Corridors as "airspace volumes defining a three-dimensional route segment with performance requirements to operate within or cross where tactical ATC separation services are not provided". Air corridors that with aerodromes will support UAM operations. As reported into the document, inside UAM Corridors:

- All aircraft operate under UAM specific rules, procedures, and performance requirements;
- Fixed wing aircraft and UTM aircraft cross UAM Corridors;
- Helicopters and UAM aircraft operate within or cross UAM Corridors;
- Operations do not vary with airspace class.

While, outside of UAM Corridors, operations adhere to relevant ATM and UTM rules based on operation type, airspace class, and altitude [28]. With ATM rules, FAA intends an operating environment which refers to "Current regulations for all other manned and unmanned aircraft operations including UAM aircraft operating outside of the UAM environment" [28] and with UTM, another operating environment which refers to "Unmanned Aircraft System operating at or below 400 ft AGL" [28].

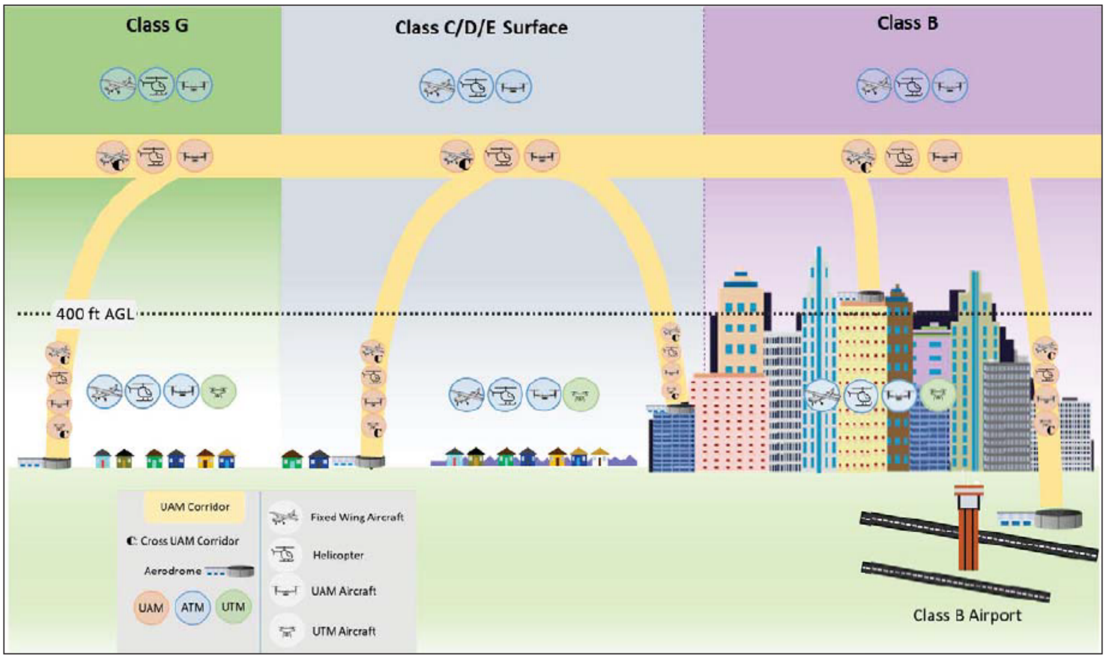


Figure 3.12: UAM, UTM, and ATM Operating Environments, ConOps v1.0 [28]

UAM Corridors will enable safe and efficient operations without tactical ATC separation services which, however, will be aware of those corridors through flight plan. The design of UAM Corridors will be based on several aspects as the public needs as environment, noise, safety and security, customer

needs and will aim to minimize the impact on the existing operations as the UTM and ATM operations. The latter will be essential for those UAM corridors nearby airports.
Initially, UAM Corridors will support point-to-point UAM operations but with its improvement, UAM Corridors may be segmented creating a network more and more complex. This, in the FAA's opinion, will be possible with the definition of tracks, or air ways as part of an internal structure which will require increased performance to the aircraft that will use them, to reduce the operational tempo and to respond to the increasing demand of use without overcome the corridors' capacity.

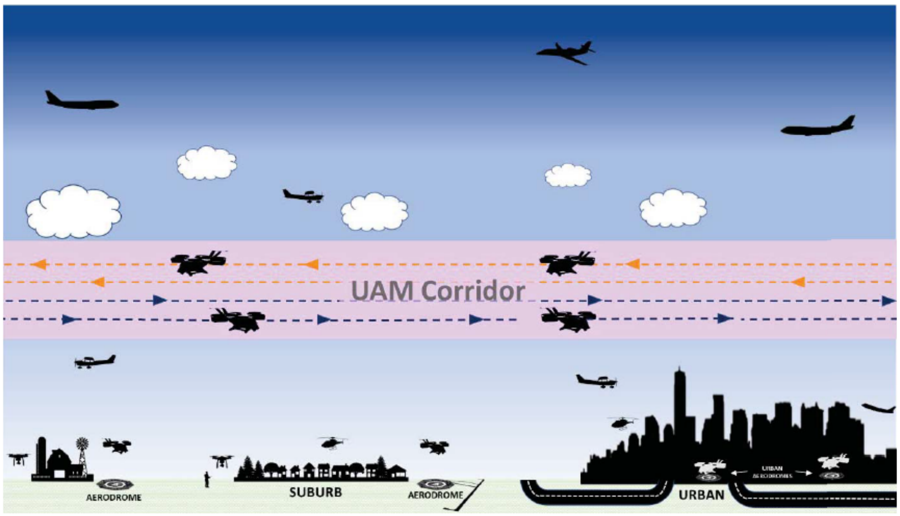


Figure 3.13: UAM Corridors with tracks, ConOps v1.0 [28]

The separation within the UAM Corridors will be assured in two ways:

1. Strategic deconfliction based on collaborative flight intent sharing;
2. Tactical separation allocated to the UAM operators supported by the PSU network that I will explain soon.

To make it possible, as all the other modes of transportation, FAA had to define the main figures of this scenario and their responsibilities.

The **FAA** as the federal authority over aircraft operations in all airspace and as oversight authority for civil operations in the Nation Airspace System (NSA), will perform regulatory, ATC and NAS data exchange for UAM.

Since for UAM operations the tactical separation within the UAM Corridors is allocated to UAM operators and not to ATC, the main responsibilities of the **FAA for the ATC services** will be: set UAM Corridor availability, provide advisories regarding UAM operations to other aircraft and respond to UAM off-nominal operations as needed.
The **FAA NAS**, furthermore, will provide UAM operations with data source via FAA-industry in order to allow authorized data flow between the UAM community and FAA operational systems.

The FAA has defined, furthermore, the figure of the **UAM operator** who conducts scheduled or on-demand services within the UAM corridors and who is responsible for regulatory compliance and all aspects of UAM operation execution. UAM operators enable strategic deconfliction, identification and distribution of constraints and restrictions for the intended area of operation and a communication with the other operators of the UAM Corridors thanks the information got from PSU and Supplemental Data Service Provider (SDSP) services. As well, UAM operators must provide flight intent and operational data to a PSU to operate within or cross UAM Corridors.

The figure of the **Pilot in Command (PIC)** has been defined too as the person on-board the

UAM aircraft who is ultimately responsible for the operation and safety during flight.

Furthermore, an entity called **Provider of Services for UAM (PSU)** that supports UAM operators to meet the regulatory and operational requirements for UAM operations, determines UAM Corridor use status, supports cooperative separation management services and distributes notifications as operational data advisories and weather, has been defined. It can also provide supplemental data to FAA through the PSU network, which is a network with all the PSUs and other entities as FAA and public interest stakeholders.

UAM operators and PSUs, finally, use **Supplemental Data Service Providers (SDSPs)** to access supporting data including, but not limited to, terrain, obstacle, aerodrome availability, and specialized weather [28].

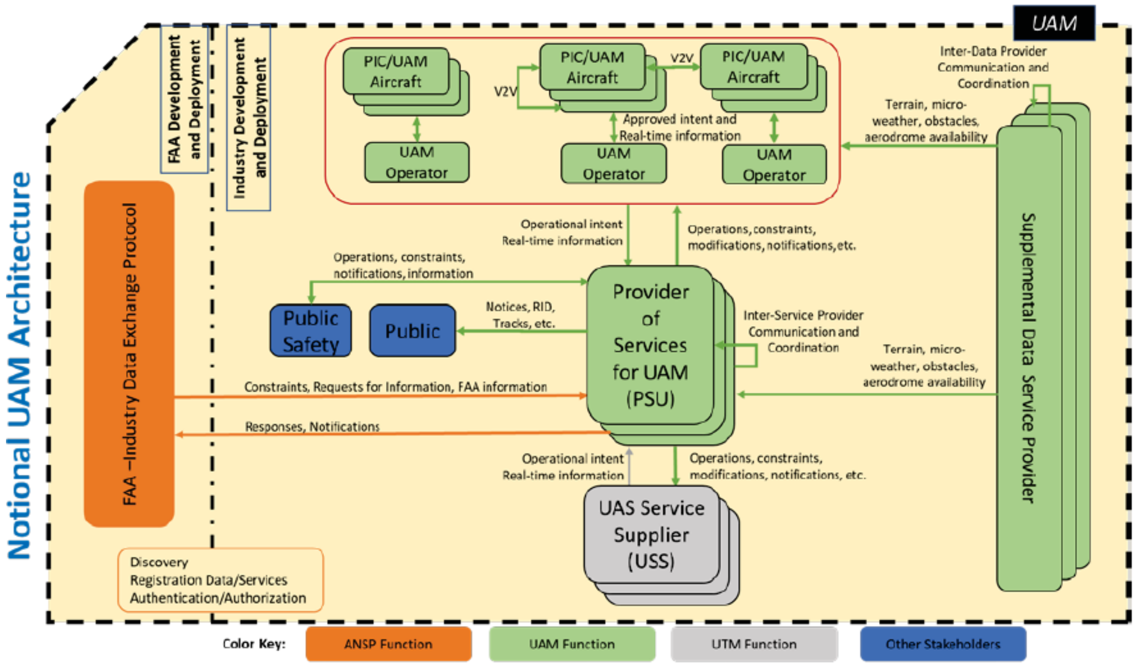


Figure 5-1: Notional UAM Architecture

Figure 3.14: Notional UAM architecture, ConOps v1.0 [28]

The architecture as defined by the FAA looks quite complex but it makes sense and could work, enabling a system efficient and protected by external threats with, therefore, a high level of safety.

3.3.1.2 Europe

Unfortunately, the European Commission did not publish yet a detailed concept of operations as the one issued by the FAA but we are waiting it hopefully because it would clarify several aspects that before the American's document were totally unknown and would finally allows us to step in this scenario.
To date, the only regulation we can take seriously into consideration is the Regulation (EU) No 923/2012 - "Standardised European Rules of the Air (SERA)", which has the scope to establish the common rules of the air.
During my studies of the European regulations, I discovered that almost all the Countries don't deviate from the standards of this document but almost they all stick to the document equally.
In particular, to understand the operations that could fit best to Alérion M1h, I focused on the limitations, showed within the document, about the flight over urban areas. Until now, the document states that the air-travel over urban areas has been limited to very special operations, such as police

operations or helicopter emergency medical services (HEMS) but now new aviation partners are seeking new business models to provide more services to citizens. The European Commission and EASA know that they have a key role to play in this area and they are working to guarantee to allows these new operations keeping the confidence that citizens have in the air transport system.
However, waiting the new European instructions, I took a look at the minimum flight heights established within the document SERA. The standards to be considered, among the others, are SERA.5005 (c)(f) for Visual Flight Rules (VFR) and SERA.5015 (b) for Instrument Flight Rules (IFR):

SERA.5005 (c)(5)
Except when necessary for take-off or landing, or except when specifically authorised by the competent authority, a VFR flight at night shall be flown at a level which is not below the minimum flight altitude established by the State whose territory is overflown, or, where no such minimum flight altitude has been established:

1. over high terrain or in mountainous areas, at a level which is at least 600 m (2 000 ft) above the highest obstacle located within 8 km of the estimated position of the aircraft;
2. elsewhere than as specified in i), at a level which is at least 300 m (1 000 ft) above the highest obstacle located within 8 km of the estimated position of the aircraft[29].

SERA.5005 (f)
Except when necessary for take-off or landing, or except by permission from the competent authority, a VFR flight shall not be flown:

1. over the congested areas of cities, towns or settlements or over an open-air assembly of persons at a height less than 300 m (1 000 ft) above the highest obstacle within a radius of 600 m from the aircraft;
2. elsewhere than as specified in (1), at a height less than 150 m (500 ft) above the ground or water, or 150 m (500 ft) above the highest obstacle within a radius of 150 m (500 ft) from the aircraft [29].

SERA.5015 (b)
Minimum levels except when necessary for take-off or landing, or except when specifically authorised by the competent authority, an IFR flight shall be flown at a level which is not below the minimum flight altitude established by the State whose territory is overflown, or, where no such minimum flight altitude has been established:

1. over high terrain or in mountainous areas, at a level which is at least 600 m (2 000 ft) above the highest obstacle located within 8 km of the estimated position of the aircraft;
2. elsewhere than as specified in (1), at a level which is at least 300 m (1 000 ft) above the highest obstacle located within 8 km of the estimated position of the aircraft[29].

However, as specified in the standard SERA.3105, the permission from the competent authority to fly at lower levels than those stipulated in SERA.5005(f) and SERA.5015(b) may be granted either as a general exception for an unlimited number of cases or for a specific flight upon specific request[29].

In **France**, however, the standard SERA 5005 f)is supplemented by the decree of October 10, 1957 (revised in December 2018) which is related to the flight over agglomerations and gatherings of people or animals. According to the size of the agglomeration or of the gathering of people as well as the engine of the aircraft, in fact, the heights allowed are different [30]:

A - For flights over isolated factories, all other industrial installations, hospitals, rest centres or any other establishment or operation bearing a distinctive mark,as well as for flights following a direction parallel to a highway and close to it, the minimum height is:

- 300 meters for aircraft equipped with a piston engine;
- 1000 meters for aircraft equipped with several piston engines or with one or more turbo-machines [31].

B - For flights over any built-up area with an average width that does not exceed 1200 meters, as well as for the overflight of any gathering of people or animals (beaches, stadiums, public meetings, racetracks, stockyards, etc.):

- 500 meters for aircraft equipped with a piston engine;
- 1000 meters for aircraft equipped with several piston engines or with one or more turbo-machines [31].

C - For overflight of any city with an average width between 1200 and 3600 meters as well as for overflight of any gathering greater than approximately 10000 people:

- 1000 meters for all powered aircraft (except helicopters)[31].

D - For the overflight of any city whose average width is greater than 3600 meters as well as for the overflight of any gathering of over 100000 people:

- 1500 meters for all powered aircraft (except helicopters)[31].

However, France allows "**Vols Agglos**" or flights over high-density areas, cities or other agglomerations, or gatherings of people in the open air. The issuance of an "Agglos Flights" authorization is under the responsibility of the Prefect of the department in which the operation is carried out. This authorization is issued taking into account the opinion sent by the Border Police (PAF) and the technical opinion delivered by the DSAC service in the territory of which the operation takes place. Furthermore, whatever is the altitude to which the authorization allows to descend, the operator must always ensure that the aircraft can in an emergency (in particular in the event of engine failure) leave the agglomeration, or reach collection areas allowing to land in congested areas without endangering people and property on the surface. If this is not the case, the operation of this aircraft is classified as high risk [30].

Table 3.3: Vols Agglos [30]

	Height to fly over agglomeration with an average width < 1200 **m and** < 10000 **people**	**Height to fly over agglomeration with an average width between 1200 and 3600 m and between 10000 and 100000 people**	**Height to fly over agglomeration with an average width** > 3600**m and** > 10000 **people**
Single-engine aircraft	300 m	400 m	500 m
Multi-engine aircraft	200 m	200 m	200 m

The table here above shows the minimum heights to fly over agglomeration as well as the number of engine of the aircraft. Those heights are valid for commercial operations (AIROPS SPO), non-commercial operations of complex aircraft and non-commercial operations of non complex aircraft (AIROPS NCO). However, these height reductions do not apply to the overflight of the beaches and the 300 m coastal strip measured from the seafront (if there are gatherings of people), hospitals, rest centres, penitentiary establishments or any other establishment or operation with a distinctive mark prohibiting low-altitude flights.

Alérion in the exploitation of its operations must, until new ordinances by the European Commission and EASA, take into consideration these flight rules aforementioned.

3.3.1.3 Off-airport landing

Concerning the possibility of landing in areas other than the airport, all the countries have adopted different measures allowing different operations. While Germany strictly forbids off-airport landing, Italy and Spain have adopted an approach softer than the German one.

In **Italy**, for example, the possibility of landing in areas other than the airport owes its existence to the law 21 April 1968 n ° 518, which notwithstanding the articles n. 799 and 804 of the Navigation Code, which requires the use of airports for landing and taking off, has introduced the concept of liberalization of landing areas into the national regulatory environment. This liberalization, which was first regulated by the Ministerial Decree 27.12.1971, have contributed significantly to the development of general aviation by promoting the spread of an increasing number of airfields and heliports. After being through a path of changes and innovations, a new regulatory framework has been designed by the decree 1 February 2006: 'Norme di attuazione della legge 2 aprile 1968, n. 518, concernente la liberalizzazione dell'uso delle aree di atterraggio'. This, therefore, is the decree I took into consideration to understand the Italian point of view about the off-airport operations.
The aforementioned decree defines as surfaces other than an airport:

- Airfields;
- Occasional airfields;
- Helipads;
- Occasional helipads;
- Hydro-surfaces;
- Sloping airfield (AP);
- Non-sloping airfield (ANP);
- Elevated helipads.

Among these surfaces, we will focus, in particular, on the second one and third one: occasional airfields and occasional helipads. The decree 1 February 2006 defines occasional airfields as '*any area of dimensions suitable to allow occasional take-off and landing operations*' and occasional helipads as '*any area of dimensions suitable to allow, in the pilot's opinion, occasional take-off and landing operations*'[32].
For both the surfaces, the articles 7 and 8 of the decree 1 February 2006 states that, in order to determine the adequacy of the occasional surface, the pilot performs an in-flight reconnaissance in which ensures compliance with the following conditions:

1. The minimum size of the landing and take-off area must be at least one and a half times the distance between the points extremes of the helicopter with the rotors in motion for the occasional helipads, and the dimensions of the airfield must be suitable for carrying out the landing run and take-off run of the aircraft for which use is envisaged, for occasional airfields;
2. The Plano-altimetric trend and the bottom surface resistance must be suitable for carrying out the operations of landing, take-off and manoeuvres on the surface;
3. Existence of a sufficient surrounding area free of obstacles to perform take-off and landing manoeuvres in safe conditions;
4. The obstacles that may be present along take-off and landing paths must be such that they can be overcome with the margins envisaged by the general rules, both during the landing and take-off phase;
5. The area must be clear of people, animals or objects that could hinder operations;
6. The take-off and landing phases must not involve the overflight of inhabited centres, of agglomerations of houses and gatherings of people [32].

The use of occasional surfaces is allowed in the following cases:

- carrying out occasional aerial work activities, not exceeding 100 movements per year, in daytime VFR conditions;

- emergency interventions as defined by ENAC.

The use of occasional helipads is also allowed for the private air activities and limited to flights with origin and destination in the national territory without intermediate stops in the territory of another state.
Furthermore,the use of occasional helipads doesn't require the manager figure, the signs and fire prevention assistance, and the pilot is the solely responsible for the choice of the area and for conducting operations. However, the use of occasional helipads located on a private property area is subject to the consent of the owner of the area. If the occasional helipads, instead, are located in an area owned by the State or by public bodies, instead, the use is subject to the authorization or the granting of use by the competent administrative authority [32].

In any case, the article 9 adds, to the previous ones, that before starting a transfer flight on an occasional helipad or an occasional airfield, the pilot must transmit to the airport management and public safety authority competent territorially, several data as: airfield or departure helipad, geographic coordinates of the helipad or airfield of destination, type and name of the aircraft, expected time of take-off and landing, name of the pilot responsible for the flight, number of people transported and type of the eventual air activity.

As for aerial work is meant air-taxi services too, these surfaces could be a starting point for future agreements between Avions Mauboussin and ENAC for the exploitation of the operations of Alérion M1h. This should not be difficult as, in an interview with the ENAC engineer Davide Drago, Italy is working hard on the development of the Urban Air Mobility, revaluing several regional airports, airfields and helipads in order to improve connections between points of interest.

Surfaces like these, furthermore, exist in **Spain** too. The 'Agencia Estatal de Seguridad Aérea' (AESA) defines, in fact, in a document issued by BOE (Agencia Estatal Boletín Oficial del Estado), **occasional aerodrome** as a '*surface suitable for use by one or more aircraft, excluding helicopters, whose use is limited in time to a maximum of 30 days a year and which does not have a permanent infrastructure for the operation of aircraft*' [33]. More specifically, as found in another definition, the occasional aerodrome is '*a surface suitable for the use of aircraft that, in the judgment of the operator, meets the minimum conditions for the safety of operations and whose use does not exceed 40 operations per year, without exceeding 15 per month*' [34].
While **occasional heliports**, are those surfaces used by helicopters on a temporary basis upon the permission of the landowner and the AESA and a maximum of three monthly landing and takeoff operations, except for aircraft in special operations. To land on these occasional surfaces it is necessary to obtain the permit by the landowner and contact the AESA or competent body in the Community if they have assumed competences in this matter like Madrid, Catalonia, Valencia and Aragon.

As said for Italy, even with Spain will not be difficult to find an agreement for the exploitation of the operations of Alérion M1h, as some Spanish cities have already agreement for the development of the UAM. An example is Sevilla, whose mayor has signed an agreement with the Chinese start-up EHang, that is designing a two-seat autonomous air taxi, to work together to develop urban air mobility solutions for the city.

3.4 Alérion M1h's operational framework

Once the regulatory framework of the main countries have been made, a clear idea of what kind of surfaces, from an operational point of view, would make fit most the operations of Alérion M1h at this moment came up: the occasional surfaces. However, Avions Mauboussin hopes and aims at a more fluid, efficient service with an unlimited number of operations than the current one allowed by the regulations, which would allow Alérion M1h operators to carry out their intercity connection activities.
For this, Avions Mauboussin will support and look carefully at the developments of the Urban Air Moblity both on operations and infrastructure side. This because, even if Alérion M1h has extraordinary performances, it will not be able to use a small helipad but will need a runway longer than that required by a VTOL aircraft.
Most of the helipads present within the city centre, in fact, are very small and suitable for only a helicopter, while, the heliports, which are definitely bigger, are mostly in the suburb areas of the cities, namely far from points of interest. Same story for all the airfields.
Since the intercity flights market, which will provide connections between points of interest of different cities, in fact, is the most interesting one for Alérion, Avions Mauboussin, before my arrival, has had already identified in the most visited city in Europe, namely Paris, an area that could be suitable for the Alérion M1h's operations: the heliport of **Issy-les-Moulineaux**.

Figure 3.15: Heliport of Issy-les -Moulineaux, Source: Aéroports de Paris - Laboratoire

The heliport of Issy-les-Moulineaux is located in the 15th 'arrondissement' of Paris, an ideal location to serve the capital of France. This heliport, is an historic heliport which the birth is strictly connected with the erection of the Eiffel Tower and therefore is in the heart of all the French aviation enthusiasts. However, despite this, the heliport is subject to many restrictions, politicians are always trying to reduce the activities on it.
Being a very sensitive heliport from the environmental point of view, it is, therefore, imperative to respect the published trajectories and the restrictions like: departures or arrivals from heliport are prohibited for school and training flights; departure from heliport is prohibited for circular flights with passengers and without stopover or with a tourist stopover of less than one hour; the transponder use

is compulsory and the operations are limited to helicopters able to climb on a 20 % slope all engines running. At the same time, the traffic is quite limited. Daily traffic on Saturday, Sunday and public holidays is limited to 70 movements excluding humanitarian or medical flights.
This has led, therefore, to a situation under tension and the operations dropped sharply.
Avions Mauboussin then is pushing the DGAC to allow STOL operations on the Issy-les-Moulineaux heliport which presents a FATO 350 m long and a width of 50 m.

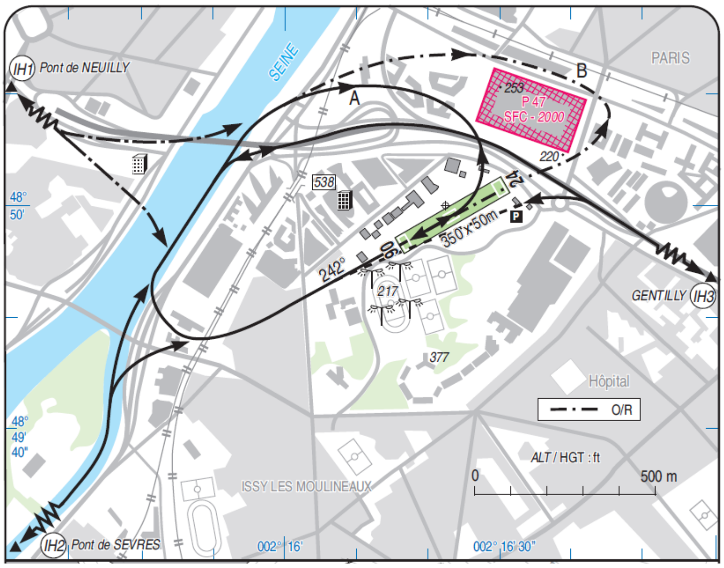
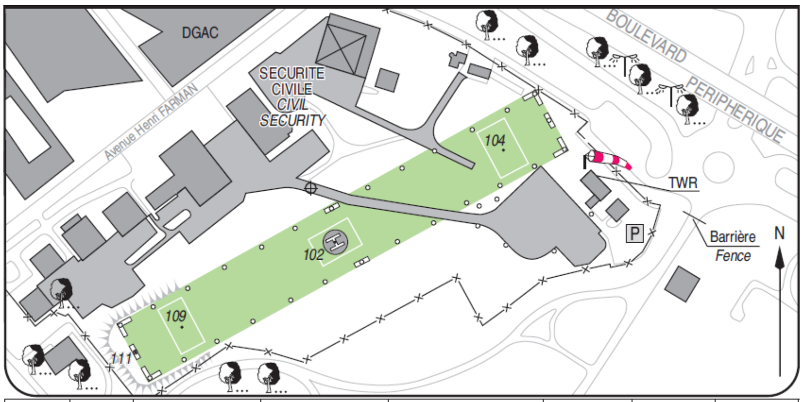


Figure 3.16: Heliport of Issy-les -Moulineaux, Source: Service de l'Information Aéronautique, France

At Issy-les-Moulineaux there are two routes to go. The route A is the nominal route and a minimal climbing slope of 20 % is requested. A second route, B, can only be used upon request by the crew, by twin engine helicopters if required by weather conditions and performances. For these specifics routes, the minimal climb gradient at QFU 062° is 10 %, but a careful monitoring is required to avoid entry into restricted areas of Paris city. Take-off is preferential on QFU 242° and landing on QFU 062°. [35].



RWY	QFU	Dimensions *Dimension*	Nature *Surface*	Force portante *Strength*	TODAH*	RTODAH	LDAH
06 24	062 242	350 x 50	Non revêtue *Unpaved*	-	350 350	270 270	350 350

Aides lumineuses :
BI bande accélération/arrêt
feux blancs

Lighting aids :
LIL : acceleration/stop strip
white lights

* Pente MNM au décollage/*MNM take off slope*
RWY 06 : 20 %
RWY 24 : 10 %

Figure 3.17: Heliport of Issy-les -Moulineaux, Source: Service de l'Information Aéronautique, France

The heliport with its 350 m of runway looks like the perfect solution for the operations of an aircraft, over the French capital, which performs STOL operations like Alérion M1h. A proposal of trajectory of Alérion to operate at Issy-les-Moulineaux could be, in fact, the following one:

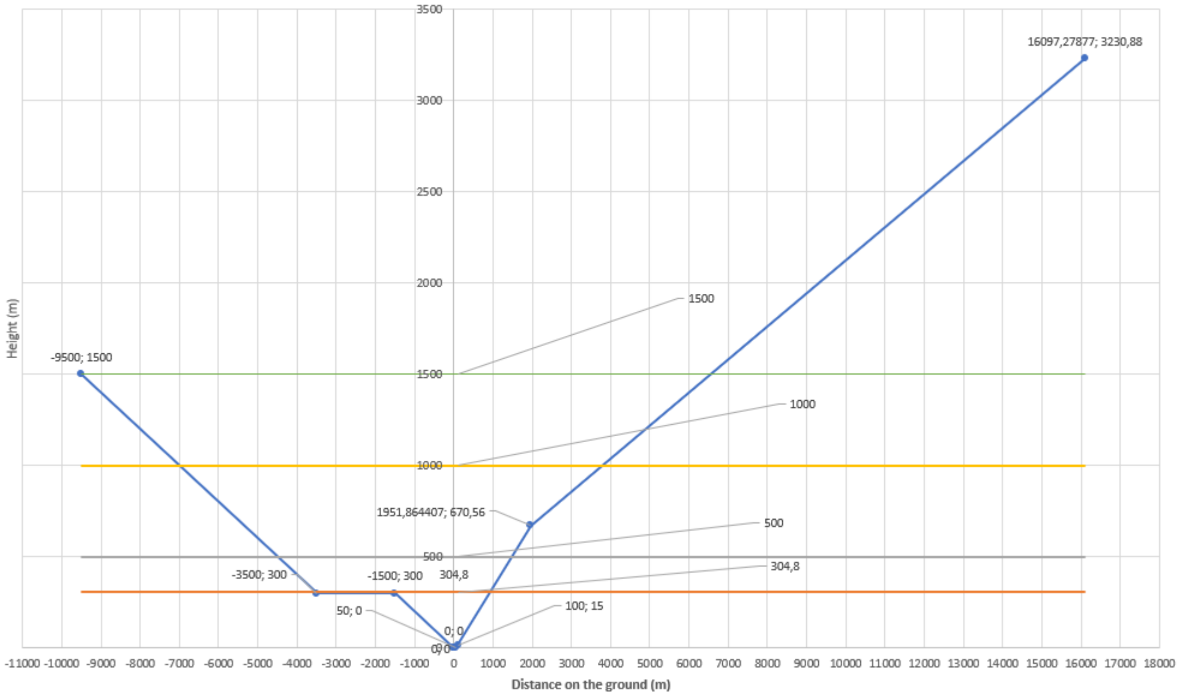


Figure 3.18: Proposal trajectory of Alérion M1h

Where the three straight lines shown in figure 3.18 have been drawn in accordance with the flight rules. The orange line drawn at 1000 ft indicates the height at which the so-called 'tour de piste' takes place while waiting to have the runway free to land; the grey line, on the other hand, has been drawn at the level 1640 ft and indicates the minimum flight height over built-up areas with a width $\leq$ 1200 m; while, the yellow line was drawn at 3280 ft, which is the minimum flight height allowed for flights over built-up areas with a width less than 3600 m and higher than 1200 m and $\leq$ 10000 people. Finally, the light blue one, drawn at 4921 ft, represents the minimum flight height allowed for flights over built-up areas with a width higher than 3600 m and $\leq$ 100000 people
Concerning the approach, instead, a slope approach of 20% has been considered for both the descents, before and after the "tour de piste". To determine the take-off and climbing trajectory, finally,it has been a little bit more complicated. After the overcome of the obstacle, supposed with a height of 15 m, or the so-called end of the take-off, the climbing has been split in two phases: the first phase just after the take-off is a climb at the maximum slope with the maximum power, while the second one is a climb at the maximum $V_{z_{max}}$, or best rate of climb speed, with less power to cool down the engine. The trajectory fully respects the environmental conditions established by EASA, as the plane can reach an altitude of 5000ft in full electric mode.

Once the possible trajectory has been determined, the performances of Alérion M1h have been studied, which it is still in an initial phase design, to understand if it could perform those operations. In particular the study carried out focuses on which could be, at the current stage of the project, the real take-off runway length and the landing runway length required for its operations.

3.4.1 Operational performance

3.4.1.1 Take-off

As a first step to determine the take-off runway length needed by Alérion for the exploitation of its operations, the runway has been split into 3 parts according to the 3 phases of the take-off phase: taxiing, rotation and in-flight phase.

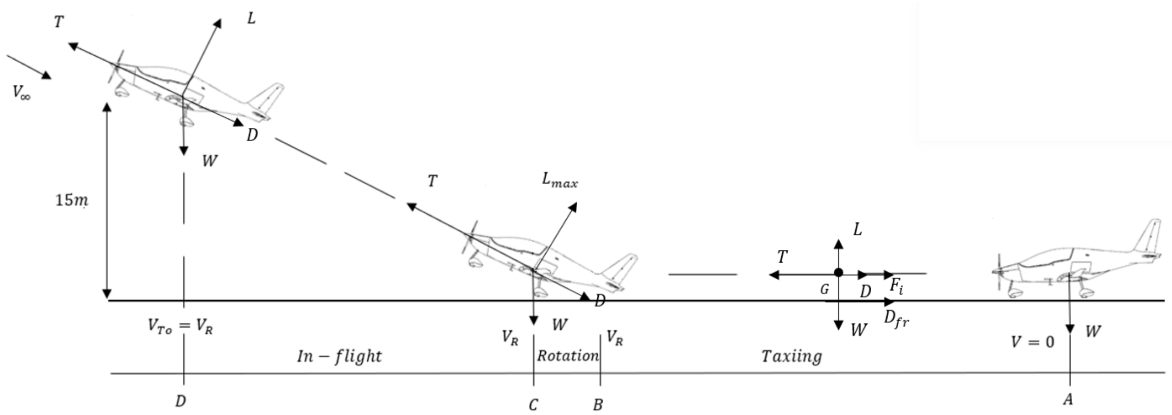


Figure 3.19: Take-off steps

A-B Taxiing

The dynamic equilibrium equation of the motion in the taxiing phase can be written as follows:

$$T_{max} - D_{tg} = \frac{W}{g} \cdot a \tag{3.4.1}$$

Where T_{max} is the maximum available thrust that we will assume, for simplicity, constant and acting parallel to the ground, (W/g)* a is the force of inertia F_i and D_{tg} is the total drag on the ground given by the sum of two components, aerodynamics drag D_{aero} and friction resistance D_{fr}:

$$\begin{aligned} D_{tg} &= \frac{1}{2}\rho V^2 S C_D + f(W - L) = \\ &= \frac{1}{2}\rho V^2 S C_D + f(W - \frac{1}{2}\rho V^2 S C_L) = \\ &= \frac{1}{2}\rho V^2 S C_D + f \cdot W - f\frac{1}{2}\rho V^2 S C_L) = \\ &= f \cdot W + \frac{1}{2}\rho V^2 S(C_D - fC_L) \end{aligned} \tag{3.4.2}$$

In the previous equation, f stands for rolling friction coefficient and V stands for V_{stall} .
A very simplified representation of the forces acting on the aircraft during the taxiing is the following one:

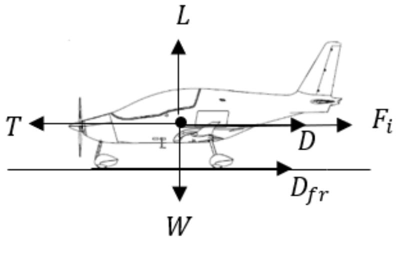


Figure 3.20: Simplified representation of the forces acting on the aircraft during the taxiing at t

The total drag on the ground that the aircraft will meet, is in function of the speed and it will increase reaching the maximum value at V_R. This because the D_{tg} is composed of an aerodynamics drag D_{aero}, which increases with the square of the speed reaching the maximum value with the activation of the flaps at the take-off speeds, and of a friction resistance D_{fr} which will decrease as

the weight on the wheels will reduce.
Alérion, however, will start the take-off with deflected flaps to limit two major drawbacks: the increase of drag, as aforementioned, that would slow down the plane, and the increase of the pitch moment due to the retreat of the aerodynamics load, consequent to its greater curvature.

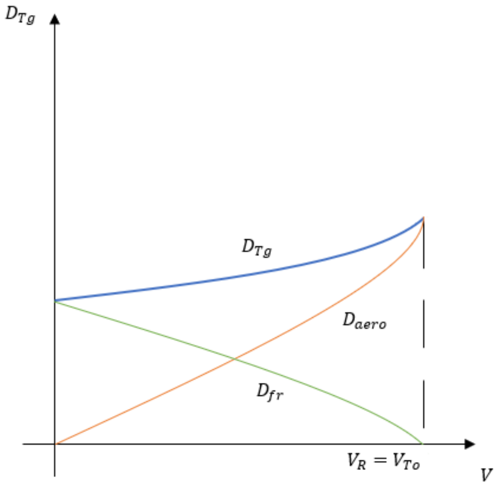


Figure 3.21: Approximative trend resistance on the ground

Another aspect of the taxiing, that should be considered is the attitude that should minimize the total resistance to advancement. This could be found by deriving the total drag in the function of the coefficient of lift, setting it equal to zero and then using the polar of the aircraft. This would allow us to find an optimal coefficient of lift to minimize drag during the taxiing phase.

$$\frac{dD_{tg}}{dC_L} = 0 \tag{3.4.3}$$

Assuming the Prandtl Polar:

$$D_{tg} = f \cdot W + \frac{1}{2}\rho S V^2 (C_{D_0} + \frac{C_L^2}{\pi\lambda\varepsilon} - f \cdot C_L) \tag{3.4.4}$$

$$\frac{d}{dC_L}(C_{D_0} + \frac{C_L^2}{\pi\lambda\varepsilon} - f \cdot C_L) = 0 \tag{3.4.5}$$

Which leads to:

$$C_{Lopt} = \frac{\pi\lambda\varepsilon f}{2} \tag{3.4.6}$$

$$C_{Dopt} = C_{D_0} + \frac{C_{Lpot}^2}{\pi\lambda\varepsilon} \tag{3.4.7}$$

From the 3.4.1 we can determine the acceleration:

$$\begin{aligned} a &= \frac{(T - D_{tg}) \cdot g}{W} = \\ &= g \cdot (\frac{T}{W} - f) - \frac{1}{2}\rho \frac{S}{W} g V^2 (C_{Dopt} - f \cdot C_{Lopt}) = \\ &= A - BV^2 \end{aligned} \tag{3.4.8}$$

where:

$$A = g \cdot (\frac{T}{W} - f) \tag{3.4.9}$$

$$B = \frac{1}{2} g\rho \frac{S}{W} V^2 (C_{Dopt} - f \cdot C_{Lopt}) \tag{3.4.10}$$

To find the taxiing distance we have to resort to the use of integrals. In particular, as first assumption, the term B will be considered negligible in comparison to A:

$$dt = \frac{dV}{a} \rightarrow a = \frac{dV}{dt} = \frac{dx}{dt} \cdot \frac{dV}{dx} = V \cdot \frac{dV}{dx} \rightarrow dx = \frac{V}{a} \cdot dV$$

$$\begin{aligned} X_t &= \int_0^{V_{Stall}} \frac{V}{a} dV = \\ &= \int_0^{V_{Stall}} \frac{V}{A} dV = \\ &= \frac{1}{2} \cdot \frac{(V_{Stall}^2)}{g \cdot (\frac{Tmax}{W} - f)} \end{aligned} \tag{3.4.11}$$

[Hp] For the calculation of this distance, the influence of the wind on the taxiing has not been considered but the calm air, ISA conditions and runway at sea level have been, therefore, used as a hypothesis and will be used in all the following phases.

B-C Rotation

This is the phase that marks the passage of the aircraft from the taxiing phase to the take-off phase in which the pilot operates the flaps and where the C_L has to be considered maximum. The operation time of this phase is established by the regulations according to the size of the aircraft used.
Even in this phase, the effect of the wind, being carried out in a very short time, will be considered negligible.

$$X_R = V_R \cdot t_R + \frac{1}{2} \cdot a_R \cdot t_R^2 \tag{3.4.12}$$

where:

$t_R = 1$ s $\rightarrow$ small-size aircraft
$t_R = 2$ s $\rightarrow$ medium-size aircraft
$t_R = 3$ s $\rightarrow$ big-size aircraft

The speed at the end of this phase, instead, will be:

$$V_{R_{fin}} = V_R + a_R * t_R \tag{3.4.13}$$

C-D In-flight

Once the aircraft has reached the maximum lift, it is capable of taking off leaving totally the ground. The motion in this phase will still be accelerated, but since it is no longer parallel to the ground, the acceleration, as well as the speed, will have two components: a vertical one, w', and a horizontal one, u'.

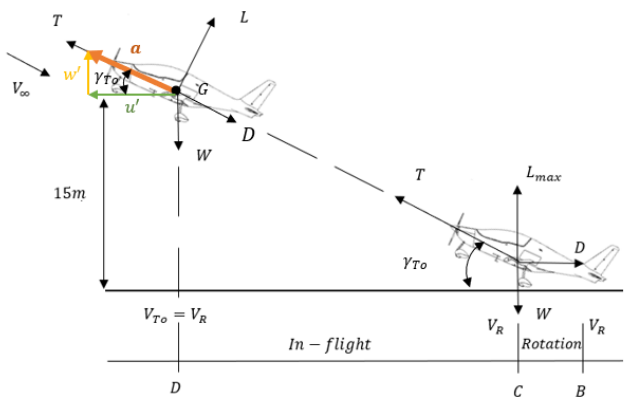


Figure 3.22: Acceleration components u' and w'

$$u' = \frac{du}{dt} \tag{3.4.14}$$
$$w' = \frac{dw}{dt} \tag{3.4.15}$$

During the in-flight phase, the equations of motion can be expressed as follows:

$$x) : T \cdot cos(\gamma_{To}) - D \cdot cos(\gamma_{To}) - L \cdot sin(\gamma_{To}) = \frac{W}{g} \cdot u' \tag{3.4.16}$$
$$z) : L \cdot cos(\gamma_{To}) - W - D \cdot sin(\gamma_{To}) + T \cdot sin(\gamma_{To}) = \frac{W}{g} \cdot w' \tag{3.4.17}$$

A graphic representation of the forces acting on the aircraft in the actual take-off phase is the following:

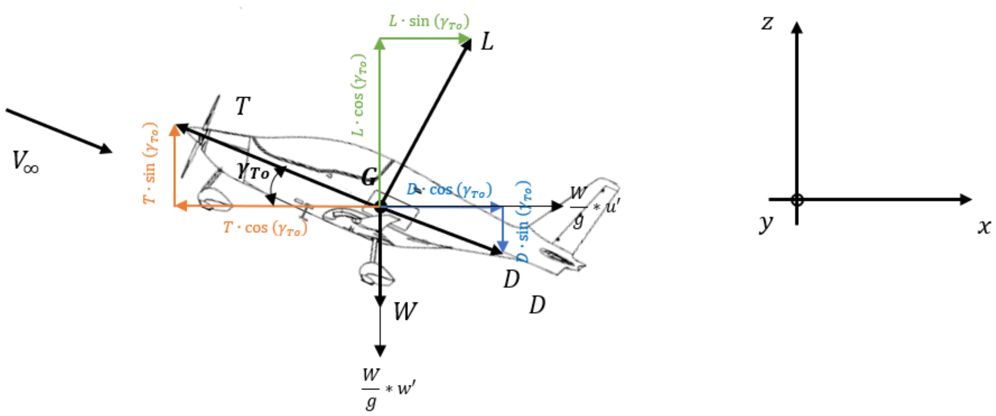


Figure 3.23: Approximative graphic representation of the forces acting on the aircraft during the in-flight phase

From the 3.4.16 and 3.4.17 we can extrapolate u' and w':

$$u' = \frac{T - D}{W} \cdot g \cdot cos(\gamma_{To}) - \frac{L}{W} \cdot g \cdot sin(\gamma_{To}) \tag{3.4.18}$$
$$w' = \frac{L}{W} \cdot g \cdot cos(\gamma_{To}) + \frac{T - D}{W} \cdot g \cdot sin(\gamma_{To}) - g \tag{3.4.19}$$

Knowing that

$$tg(\gamma_{To}) = \frac{w}{u}$$

solving these equations becomes quite complicated. However, an approximate method can be used, which still leads to appreciable results. This method consists to follow for at least all the take-off phase or overcoming of the obstacle, the following hypotheses:

- negligible climbing angle γ_{To};
- the average horizontal component of acceleration, u', equal to zero → u= V_R=constant;
- the vertical component of acceleration equal to a value slightly lower than the initial maximum w'< w'_{max} [36]

With these hypothesis, according to the kinematics equations, the trajectory of the plane can be expressed as:

$$z = \frac{1}{2} \cdot a \cdot t^2 = \frac{1}{2} \cdot \epsilon w' \cdot t^2 \tag{3.4.20}$$
$$x = v \cdot t = u \cdot t = V_i \cdot t \tag{3.4.21}$$

Where for the equation 3.4.20 the kinematic equation for uniformly accelerated motion has been used, for the equation 3.4.21 the kinematic equation for uniform rectilinear motion has been used. Furthermore, the constant ϵ in the 3.4.20 is a corrective factor of the acceleration w' and is variable between 0.9 and 0.95.
The in-flight distance, Xi, can be found setting z = h and solving for x (that is our Xi):

$$X_i = V_i \cdot \sqrt{\frac{2hW}{\epsilon g(L-W)}} \tag{3.4.22}$$

Where V_i can be determined as the average speed at the beginning of the in-flight phase, which is the same of the speed at the end of the rotation $V_{R_{fin}}$ and the speed once the plane has reached the height of 15 m, $V_D = 1.2 \cdot V_{stall}$:

$$V_i = \frac{V_{R_{fin}} + V_D}{2} \tag{3.4.23}$$

With these assumptions the take-off distance has been determined and the results are shown in the following table:

Table 3.4: Take-off distance

Distance	**Value**	**Unit of measurement**
X_T	62,93124372	m
X_R	25,79766895	m
X_i	70,4860872	m
X_{tot}	159,2149999	m

Suggestions: The determination of the take-off distance for Alérion M1h's performances, has been performed with several assumptions and simplified equations to obviate the inaccuracy and completeness of the aircraft's aerodynamics data being still in a premature phase of the project. The accurate data should not lead us to a massive difference in the results, however, the take-off distance is still not the one desired by the company, which aims to a shorter runway. My main advice is to work on the 3D airfoil of the wing to determine exactly the lift coefficient and trying to increase it. An increase in the lift coefficient, would, in fact, lead to a higher (S$\cdot$ C_{Lmax}) and, therefore, a lower stall speed, thus allowing to decrease all the three distances seen. Brainstorming with the aerodynamics engineer of the company, he agreed with my suggestion of reducing the stall speed but we realized that an increase of the surface would be easier than an increase of the C_L, acting, anyway, on the factor (S$\cdot$ C_{Lmax}). We arrived, therefore, at the conclusion that a feasible solution could be an extension of the surface of the flaps. The team has now taken into account this suggestion as one of the solution to face to reach the goal. Further evaluations will be carried out before to proceed.
A second improvement could concern the propulsion. In particular, the first thought goes to an increase of the maximum take-off power. As the electric engine EMRAX 268 provides a continuous power up to 170 KW and a peak power of 200 KW, the use of an increased T/O power could be possible but brainstorming with the propulsion intern of the company, we realized that an increase of the propulsion power would not lead anyway to reach our goal but would only lead to higher temperature and higher stress to the batteries making them unsuitable.

Table 3.5: Take-off distance with the highest max T/O power provided by the engine EMRAX 268

Distance	**Value**	**Unit of measurement**
X_T	39,464243	m
X_R	26,92850228	m
X_i	65,4506518	m
X_{tot}	131,8433971	m

To get an acceptable results, the power is supposed to be considerably higher than the current one. A solution that would totally upset the project and therefore it has been set aside for the moment.

Finally, the determination of the balanced take-off distance has not been carried out because Alérion M1h is a single-engine aircraft.

3.4.1.2 Landing

As well as seen for the take-off, for the landing the landing phase has been split in 3 parts according to the 3 phases of the landing phase: approach, flare and taxiing or ground roll.

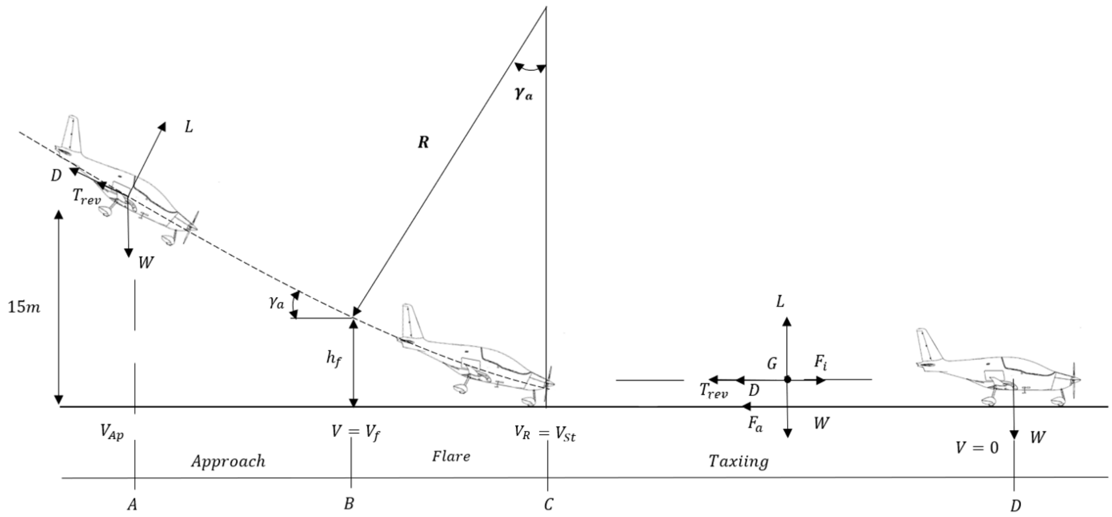


Figure 3.24: Approximative graphic representation of the forces acting on the aircraft during the landing phase

A-B Approach

To determine the landing distance we will consider several important hypothesis:

- Slope = constant;
- Calm air, ISA conditions and sea level(valid for all the phases of the landing);
- The use of the reverse thrust since the beginning of the approach phase.

These hypothesis have allowed me to find the approach distance with a simple trigonometric formula. Considering the triangle ABH and a slope of 20 %, that is the slope required for the approach at Issy-les-Moulineaux, X_a can be determined as follows:

$$20\% slope \rightarrow \gamma_a = 11.31[deg]$$

$$X_a = \frac{15 - h_f}{tan(\gamma a)} \tag{3.4.24}$$

Where, h_f should be determined with the flare equations, that, therefore, can be determined knowing the flare speed V_f. The speed of the plane during the flare can be determined with an average of the two coefficients of the approach speed and touchdown speed. The approach speed V_{app} according to the standards is $1.3 \cdot V_{Stall}$, while, the touchdown speed foreseen for the approach with flare, according to the standards too, is $1.15 \cdot V_{Stall}$ but the latter can be approximate to V_{Stall} since Alérion will use the reverse thrust since the beginning of the approach. Therefore:

$$V_{approach} = 1.3 \cdot V_{Stall}$$

$$V_{touchdown} = 1 \cdot V_{Stall}$$

$$\downarrow$$

$$V_{flare} = \frac{1.3+1}{2} \cdot V_{Stall} \tag{3.4.25}$$

$$h_f = R \cdot (1 - cos(\gamma a)) \tag{3.4.26}$$

The only data missing is R, or the radius of the trajectory, that could be found with the equation of the motion according to the flight mechanics.

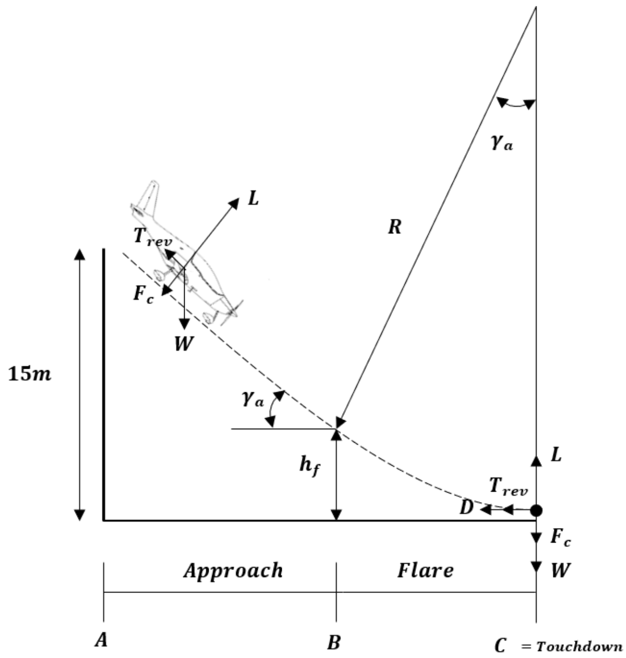


Figure 3.25: Approach and flare

The equations of the motion are:

$$L - Wcos(\gamma a) - F_c = 0 \tag{3.4.27}$$
$$D + Wsin(\gamma a) + T_{rev} = 0 \tag{3.4.28}$$

that become:

$$L = Wcos(\gamma a) + \frac{W}{g} \cdot \frac{V^2}{R} \tag{3.4.29}$$
$$D + Wsin(\gamma a) + T_{rev} = 0 \tag{3.4.30}$$

The radius R can be then determined by the definition of load coefficient n:

$$n = \frac{L}{W} = \tag{3.4.31}$$
$$= cos(\gamma a) + \frac{1}{g} \cdot \frac{V^2}{R}$$
$$\rightarrow R = \frac{V^2}{g} \cdot \frac{1}{n \cdot cos(\gamma a)} \tag{3.4.32}$$

B-C Flare

As the last part of the approach, there is the phase called flare. In this phase, in which we assume the rotation takes place too, the plane gradually decreases the slope angle of the trajectory and the speed, with an increase of the angle of attack and, therefore, of the lift which stops the plane during the descent [34].

$$X_{flare} = R \cdot sin(\gamma a) \tag{3.4.33}$$

C-D Taxiing

In this phase, the braking begins which will lead to the stopping of the aircraft. During taxiing the forces acting on the aircraft are the following:

- Lift, variable over time as such is the speed during the taxiing, L;
- Total drag on the ground, variable over time as well, D;
- The weight on the wheels, W;
- Reverse thrust T_{rev}, considered 20% of the T_{max};
- Force of inertia, F_i= (W/g)· a.

Looking at the figure 3.24, the equation of the motion can be established as follows:

$$D_{tg} + T_{Rev} = \frac{W}{g} \cdot a \tag{3.4.34}$$

In the previous equation, the term D_{tg} is the total drag on the ground which is composed, as seen in the take-off phase, of an aerodynamics resistance, or simply drag, D_{aero}, and a friction resistance, D_{fr}, as the result of the contact of the wheels with the ground. Furthermore, the term f' present in D_{fr}, is the rolling friction coefficient, different from the one mentioned in the take-off phase, and a is the deceleration.

$$\begin{aligned} D_{tg} &= \frac{1}{2}\rho V^2 S C_D + f'(W - L) = \\ &= \frac{1}{2}\rho V^2 S C_D + f'(W - \frac{1}{2}\rho V^2 S C_L) = \\ &= \frac{1}{2}\rho V^2 S C_D + f' \cdot W - f'\frac{1}{2}\rho V^2 S C_L = \\ &= f' \cdot W + \frac{1}{2}\rho V^2 S(C_D - f' C_L) \end{aligned} \tag{3.4.35}$$

Defined the forces which act on the aircraft, with the 3.4.34 and the 3.4.35, it's possible to find the deceleration a:

$$\begin{aligned} a &= \frac{(T + R_{Dg}) \cdot g}{W} = \\ &= g \cdot (\frac{T}{W} + f') + \frac{1}{2}\rho\frac{S}{W} g V^2 (C_D - f' \cdot C_L) = \\ &= A + BV^2 \end{aligned} \tag{3.4.36}$$

where:

$$A = g \cdot (\frac{T}{W} + f') \tag{3.4.37}$$

$$B = \frac{1}{2} g\rho \frac{S}{W} V^2 (C_D - f' \cdot C_L) \tag{3.4.38}$$

To find the taxiing distance we have to resort to the use of integrals:

$$dt = \frac{dV}{a} \rightarrow a = \frac{dV}{dt} = \frac{dx}{dt} \cdot \frac{dV}{dx} = V \cdot \frac{dV}{dx} \rightarrow dx = \frac{V}{a} \cdot dV$$

$$\begin{aligned} X_t &= \int_0^{V_R} \frac{V}{a}\, dV = \\ &= \int_0^{V_R} \frac{V}{A + B \cdot V^2}\, dV = \\ &= \frac{1}{2B} \int_0^{V_R} \frac{2BV}{A + B \cdot V^2}\, dV = \\ &= \frac{1}{2B} \cdot ln(A + BV^2)\Big|_0^{V_R} = \\ &= \frac{1}{2B} \cdot ln(A + B{V_R}^2) - \frac{1}{2B} \cdot ln(A) = \\ &= \frac{1}{2B} \cdot ln(\frac{A + B{V_R}^2}{A}) = \\ &= \frac{1}{2B} \cdot ln(1 + \frac{B}{A} \cdot {V_R}^2) \end{aligned} \tag{3.4.39}$$

However, since the coefficient of drag and the coefficient of lift during the taxiing are still under study and then undetermined, I chose to use an approximation to find the final taxiing distance. In particular, I noticed that the second term of the 3.4.36, B, is very small in comparison with the first term, A, then B has been considered negligible leading the 3.4.39 to be:

$$X_t = \frac{1}{2} \cdot \frac{V_R^2}{g \cdot (\frac{T_{rev}}{W} + f')} \tag{3.4.40}$$

A further consideration made by me on the determination of the taxiing phase, is that when the plane lands there is still lift, so the weight on the wheels can be considered 1/3. After a while, however, the lift will decrease till to 0 N. Therefore, the weight is all on the wheels at the end of the taxiing. Taking this into account I will use an average value of the weight, called:

$$W_m = \frac{\frac{W}{3} + W}{2} \tag{3.4.41}$$

Finally, using W_m within the formula 3.4.40, the taxiing distance is determined.

Table 3.6: Landing distance

Distance	**Value**	**Unit of measurement**
X_a	65,73473051	m
X_R	18,71310133	m
X_t	31,156842	m
X_{tot}	115,6046738	m

Suggestions: The total landing distance found is not the one desired by Avions Mauboussin for the operations of Alérion M1h. The company, in fact, for its first plane, aims at a landing distance fewer than 100 m, marking the plane as a real urban mean. Therefore, considerations have been taken and will be taken in the future. The parameters on which the engineers can, currently, work, in my opinion, are two:

1. T_{rev};
2. V_{St}.

For the first one, T_{rev}, a study should be carried out on the propulsion system and on the propeller. A bigger propeller could perform a greater reverse thrust able to stop the plane before, but in the other hand could flip the plane backwards, so it should be foreseen only on the ground.
For the second one, V_{St}, instead, as said for the take-off, the team should work also on the design of

the wing, trying to increase the surface of the flaps, and, therefore, the surface of the wing acting on the factor (S $\cdot C_L$). A decrease of less than 4 m/s of the V_{Stall}, for example, would allow the plane to reach the goal:

Table 3.7: Landing distance with a lower V_{Stall}

Distance	**Value**	**Unit of measurement**
X_a	69,39490231	m
X_R	11,32027117	m
X_t	18,84796615	m
X_{tot}	99,56313963	m

However, acting only on the wing area, reaching this V_{Stall} would mean increase the wing area of 4 m^2, looking rather infeasible. An increase of the two parameters of (S $\cdot C_L$) should therefore be performed.
Another way to reduce the runway length required is to increase the angle of approach, γa, of a few degrees. An approach with a slope around 27 %, in fact, would allow the plane to stop in less than 100 m, reducing X_a and then X_{tot}, as desired by Avions Mauboussin:

Table 3.8: Landing distance with a higher γa

Distance	**Value**	**Unit of measurement**
X_a	43,68257405	m
X_R	24,16781296	m
X_t	31,156842	m
X_{tot}	99,00722901	m

Indeed, an approach higher than the current one foreseen by Avions Mauboussin, would just complicate more and more an operation that already looks like quite difficult for a pilot. Further evaluations should be carried out on the pilot preparations side.

Finally, another suggestion concerns the design of the runway. As Avions Mauboussin wants to design an ideal airpark for the operations of Alérion M1h, a sloping runway has been thought to help the plane stopping because of the increase of the deceleration. It is estimated, in fact, that a runway with a 6% slope could decrease the landing distance required by a plane of 30%. However, EASA limits the longitudinal slopes of runways up to 2%, where the code number is 1 or 2, with the safety objective to enable stabilized and safe use of runway by an aircraft. In our case, anyway, even a 2% of slope could help to get closer to our goal. In fact, the landing distance required of 115 m on a 0% slope runway, will decrease down to 102 m for a runway with a longitudinal slope of 2%.

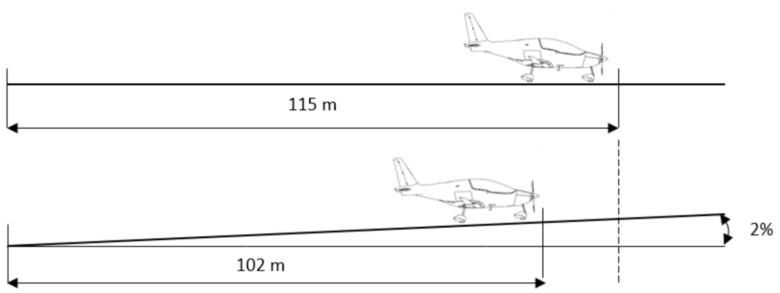


Figure 3.26: Approximative landing distance with a sloping runway

Indeed, this scenario is not always possible as the landing and take-off are performed according to the wind conditions and most of the time this could be suitable only for one of the two operations. Furthermore, it does not respect the scenario of most airports or airfields which should modify the features of their own runway to comply with what has been said, so this solution could come in help only in certain scenarios. However it could be a point of inspiration, or starting point, for the realization of future eSTOLports.

3.4.2 Opportunities in Europe in terms of surfaces and operations

With the performances here above shown, Alérion M1h is able to operate on surfaces like the one at Issy-les-Moulineaux or even shorter, allowing intercity flights between cities not well connected. This led the study to a more focused search across Europe of other surfaces suitable for the operations of the plane. The research, however, was focused not only on current existing surfaces but also on former or abandoned airfields.
Furthermore, all the surfaces recognized as commercial airports, have been avoided, as the price for the operations at an airport is quite high and this is, therefore, not compatible with the ideals of the company that wants to offer an aircraft accessible to everyone. Airfields within the city centre or, anyway, close to it, have been, instead, considered.
The research and innovation programme Mahepa (Modular Approach to Hybrid-Electric Propulsion Architecture), during a webinar held in collaboration with EASA, has shown, among other topics covered, all the European aerodromes identified in one image and their types of surface.

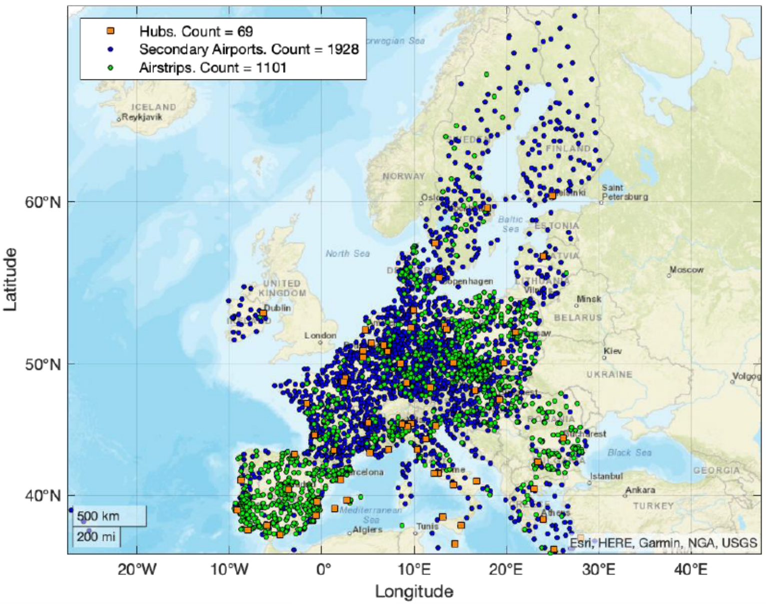


Figure 3.27: European aerodromes, Mahepa-EASA Webinar [37]

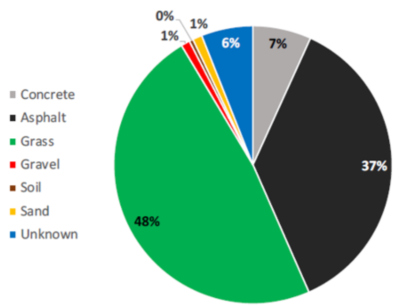


Figure 3.28: European aerodromes type of surface, Mahepa-EASA Webinar

In **France**, although the number of airfields is huge, nothing has been found for the moment that could compete with the characteristics of Issy-les-Moulineaux. However, in the other hand, Avions Mauboussin could take advantage of the presence of these airfields to improve the connection between medium-small cities and large metropolitan centres, leading to a great gain in terms of time and comfort for the passengers.
A study has been carried out, therefore, to show the advantages of using Alérion M1h, or any eSTOL aircraft, for two routes:

1. **Belfort - Toulouse**

   The connection between the two cities is weak making complicate journeys for businessmen. Belfort, in fact, does not have an airport, and the closest one is the EuroAirport Basel Mulhouse Freiburg (IATA: BSL, ICAO:LFSB), situated in Saint-Louis, 3 km away from Basel and around 68 km from Belfort. Toulouse and Belfort are connected three times per week with a direct flight served by EasyJet. Other airlines, like KLM, offer, instead, this connection but with several stopovers.
   The current scenario offers to a businessman, who wants to move from Belfort to Toulouse, several possibilities: flights, car trips, bus trips and train trips.
   Flights: As said before, the two cities are served by three flights per week by EasyJet and everyday by KLM with at least one transfer. The fastest option is, indeed, the aerial connection which, anyway, presents several issues:

Figure 3.29: Belfort-Toulouse flight connection served by KLM

   Every traveller when moves from a city to another, keeps in mind 3 things: comfort, time and costs. A businessman, or any person who has to move for working, in particular keeps in mind the first two points: comfort and time. Important to them, in fact, is to close a deal with all possible comfort and without wasting time.
   The solution offered by **KLM**,shown in figure 3.29 , even if it allows the businessman to deal his meeting in Toulouse and come back home in the same work-day , does not match at all the 2 points here above mentioned as the total travel time is more than 11 hours. The total travel time, in fact, has to consider the 40 minutes driving to get at the airport BSL from Belfort, and the 30 minutes to get from TLS, situated in Blagnac, to Toulouse city, and the lack of comfort due to transfers, stopovers and queue at the airports which would make the day endless.
   Having discarded the KLM option, all that remains is to analyse the EasyJet solution. **EasyJet**, as already said, offers 3 direct flights per week, on Monday, on Friday and on Sunday and the flights-planning of the airline does not allow a round trip within the day leading the passenger to stay in the city for 4 nights if he excludes a premature Sunday departure as an option. Even an intermodal journey would not make a round trip within the day possible.

The three other solutions: car trip, train trip and bus trip will be here under analysed but their complexity can already be predicted:

Table 3.9: Belfort-Toulouse possible journeys

	Car	**Bus**	**Train**
Accessibility	Easy	Easy	Easy
Travel time (one way)	> 8h	> 14h	> 7h
Stopovers	0	1	1/2
Frequency (days per week)	/	5	7
Round trip within the day	No	No	No

It is in this scenario that Alérion M1h will operate, in order to overcome these problems and offer a more advantageous solution from all points of view: comfort, time and costs which are not taken into account in this study being variable.

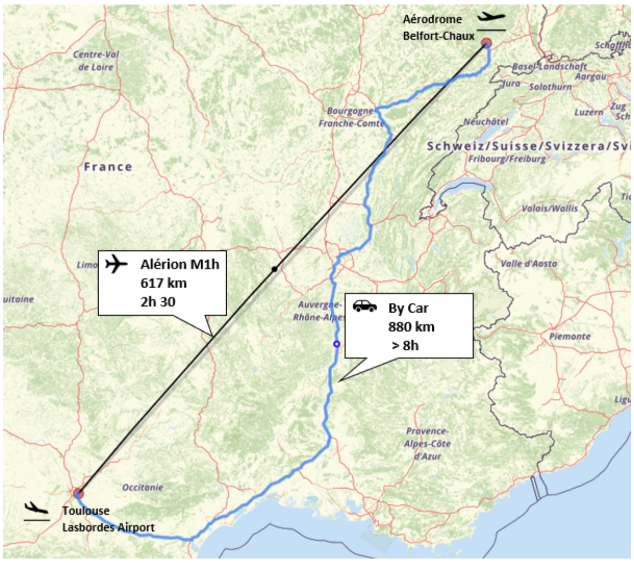


Figure 3.30: Belfort-Toulouse flight connection served by Alérion M1h

Alérion M1h, with its performances, will allow passengers to move from Belfort to Toulouse in around 2 hours and 30 minutes in totally comfort, because the plane will be accessible to the closest airfields to the city, Aérodrome Belfort Chaux for Belfort, and Toulouse – Lasbordes Airport (ICAO: LFCL) for Toulouse. Both closer than the major airports of the cities.
Alérion M1h will allow then a round trip within the day saving time and avoiding the annoying transfers, stopovers and long waits at the airport.

Table 3.10: Belfort-Toulouse journey with Alérion M1h

	Alérion M1h
Accessibility	Easy
Flight time (one way)	2h 30
Stopovers	0
Frequency (days per week)	/
Round trip within the day	Yes

A comparison, instead of the total travel time, including then transfers, stopovers, airports queue, to move from one city to another is shown below:

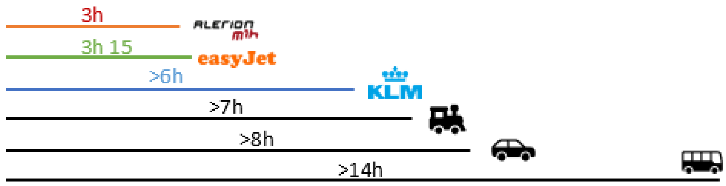


Figure 3.31: Belfort-Toulouse total travels times in comparison

It is wise to think that the connection between two cities such as Belfort and Toulouse, does not lead to an exorbitant demand but, first, offers a valid solution to the needs of inhabitants of Belfort, second, if we think of the use of Alérion M1h between two of the largest cities in Europe such as Paris and London, beating hearts of the European economy, the scenario is undoubtedly indifferent.

2. **Paris - London**

London and Paris, have the busiest airports in Europe, and their connection has been one of the busiest European routes to/from Paris Charles de Gaulle International Airport (2019). 1,255,227 passengers, in fact, moved between London-Heathrow and the French airport, according to the studies of Eurostat, "Air passenger transport between the main airports of France and their main partner airports (routes data)", updated to July 2020 [38], stating how busy is this route.
Although the two cities are very well connected with dozens of flights per day scheduled by several airlines, the airports are faraway from the city centres. The London-Heathrow Airport is, in fact, 22 km away from the City of London while Paris Charles-de-Gaulle Airport is located twenty-five kilometres north-east of Paris in Zone 5.
Since the London City Airport, which is the most centred airport in London, is not served by any airport in Paris, Alérion could put itself as a means of connection between the two cities, or rather between the two city centres thanks to LCY, on the English side, but also to the Issy-les-Moulineaux heliport, on the French side.

Figure 3.32: Issy-les-Moulineaux - LCY flight connection served by Alérion M1h

Alérion M1h would allow a trip time of 1 hour and 25 minutes, taking probably more time than an airliner but saving time in airports waits, as LCY has been classified as one of the most efficient airports in Europe, allowing passengers to leave the airport in a few of minutes.
A comparison between the operations offered by Alérion M1h and the other transport means has been made and is shown here under:

Table 3.11: Paris - London possible journeys

	Car	**Bus**	**Train**	**Airline**	**Alérion M1h**
Accessibility	Easy	Easy	Easy	25 km away	Easy
Travel time (one way)	> 5h	> 8h	> 2h	< 1h 5	1h 25
Stopovers	0	0/1	0	0	0
Frequency (days per week)	/	7	7	7	7
Round trip within the day	No	No	Yes	Yes	Yes

As it is possible to see in the table 3.11, Alèrion M1h looks like it does not offer a more advantageous solution than airliners, but, however, the scenario changes considering the time to get at the airport, the time spent for the airports' procedures and operations, and again the time to get at the meeting place. If we consider a scenario that a Parisian businessman has to deal with every time he has a meeting in London, currently he would look like as follows:

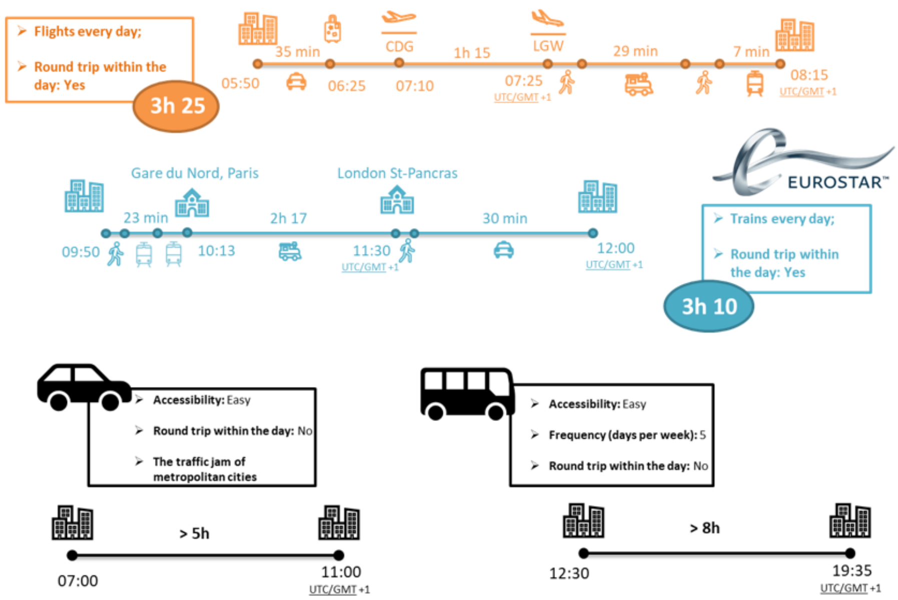


Figure 3.33: La Défense(Paris) - Canary Wharf(London) current scenario

With these considerations, the times have been lengthened considerably, but not only that, the stress factor will also be considerable given the reluctance of passengers to constantly change means and waiting in the queues. Alérion M1h would offer then a faster and greener way to reach Canary Wharf with a considerable level of comfort as it can approach at London City Airport, just 6 km away from Canary Wharf:

Figure 3.34: Paris-London total travels times in comparison

Italy Similar operations could be required in Italy too, where the connections between major hubs and small airports are weak, as seen for the route Belfort-Toulouse. In particular, in Italy, the study focused on the airfields as much as possible close to the city centre of those cities that are a source of worldwide attraction. These airfields could be the easiest gates to the city for STOL planes which serve secondary airports allowing a save of time for commuters or businessmen.
At the top of the list, of course, there is **Milan**, the backbone of the Italian economy where thousands of commuters work and where international businessmen arrive every day from all over the World. Unfortunately, a solution as the one offered by the heliport of Issy-les-Moulineaux has not been found. In Milan, in fact, other than the Milan Linate Airport, only an airfield has been found in the countryside of the city, Bresso Airport, which is however 12 km away from the business center of the city. However, Milan is a city in continuous development and always open to new opportunities, so an interesting area which is not yet fully set up for a plane landing, has been identified. Since the two football clubs of Milan have exhibited their will to build a new stadium in the centre of a large sports park in the San Siro area, a small airfield could be, therefore, installed there given the easy accessibility to the city centre from this area and to the several attractions of the area like the stadium, the hyppodrome and the golf course.
An interesting scenario in Italy, also, is the one offered by the close XXV Olympic Winter Games, that are scheduled to take place from 6 to 22 February 2026 in the Italian cities of Milan and Cortina d'Ampezzo. This led ENAC to think on how to improve the connection between the two cities as Cortina d'Ampezzo is not provided with an airport or an airfield large enough for the operational performance of current aircraft. eSTOL aircraft could consequently allow a good connection between these two cities.

In **Turin**, where the FIAT headquarter is based, instead, a very interesting surface is the Turin-Aeritalia Airport (ICAO: LIMA). This airfield, with a runway 821x29 m, is located on Corso Marche, around 5 km (3 mi) away from the city centre. While the commercial flights arrive at Turin Caselle Airport, the Torino-Aeritalia Airport is used for tourist flights and as a flying school, both for gliding and powered flight. There is also a helipad for the use of air ambulances.

Figure 3.35: Turin-Aeritalia Airport, source: turismotorino.org

In **Rome**, capital of Italy, furthermore, two surfaces are quite interesting. These surfaces are Roma Urbe airport and Centocelle Airport (ICAO: LIRC). The first one, is situated only a few minutes drive away to the city centre by taxi, with its north/south oriented 1084 meters runway, Urbe Airport is the ideal gateway to the eternal city. The second one, is, instead, a former civil airfield, currently used for military activities. It is situated in Centocelle, a quarter of Rome in Italy, and its 350 m runway has been closed and converted into a park (Parco di Centocelle), but the grounds remain a base of the Italian Air Force, including active helipads.

Figure 3.36: Roma Urbe Airport, source: mapio.net

Figure 3.37: Military Airport F. Baracca (Centocelle Airport), source: google Earth

Finally, in Italy, an airfield that ENAC aims to enhance given its position between the various islands, is the fantastic **Venice**-Lido Airport (ICAO: LIPV), located 3.5 km east of Venice. It has one runway designated 05/23, with a grass surface measuring 994 by 45 metres and an elevation of 13 m above the sea level. For ENAC, as understood during the interview with the engineer Mr Drago, improve the connection between these islands could be very interesting.

Figure 3.38: Venice-Lido Airport, source: vfr-pilote.fr

Those shown, are the most interesting surfaces in Italy but certainly surfaces like those are present all over Europe. In **Germany**, for example, Mr Krauss, an air law lawyer, said during an interview, intended for the study of German regulation, that in the suburbs of all the big cities there are airfields well equipped and efficient but after a research none of them is close to the city centre. However, a solid opportunity in Germany, with the help of the LBA-Luftfahrt-Bundesamt, German Civil Aviation Authority, could be the re-valorization of the already closed Berlin Tempelhof Airport, often called the "City Airport" due its proximity to the city centre. A chance to see this airport open would be possible if Germany would start to support UAM operations.

3.4.3 Ideal Airpark within the city centre

Avions Mauboussin in the next years will define a concept of airpark suitable for the operations of Alérion M1h, that will be added to the current surfaces solutions. In this thesis, some concept ideas are already represented.
The airpark will be designed according to the ASTM standard F2507-15 "Recretional Airpark Design", and this section will be based on that document.
A recreational airpark is intended as an area which may provide commercial daylight services operations from 60 min before official sunrise to 60 min after official sunset, in support of the recreational operation of any aircraft with stall speeds of 45 knots or less. Commercial services can include, but not limited to flight instruction, introductory flights, aircraft rental, glider towing, and maintenance services[39]. Two examples of airpark concept design, not as a result of the ideation of Avions Mauboussin but only as an example, are shown below.

Figure 3.39: Airpark concept design - Development of a Methodology for Parametric Analysis of STOL Airpark Geo-Density, Joseph Nathaniel Robinson

Figure 3.40: Airpark concept design - Development of a Methodology for Parametric Analysis of STOL Airpark Geo-Density, Joseph Nathaniel Robinson

The standard F2507-15 states that the minimum runway length, measured from the landing threshold to the threshold at the end of the landing distance available, has to be twice the demonstrated or published minimum landing and take-off distance requirements of the aircraft to be served or 275 m (902 ft) at sea level, whichever is greater. Airparks which are, instead, located at elevations above sea level, in the absence of a more rational calculation, an increase of 25 m (82 ft) per 300 m (984 ft) of elevation may be used. The width shall, finally, be a minimum of 10 m (33 ft) for unpaved runways and a minimum of 6 m (19.7 ft) for paved runways. [39].

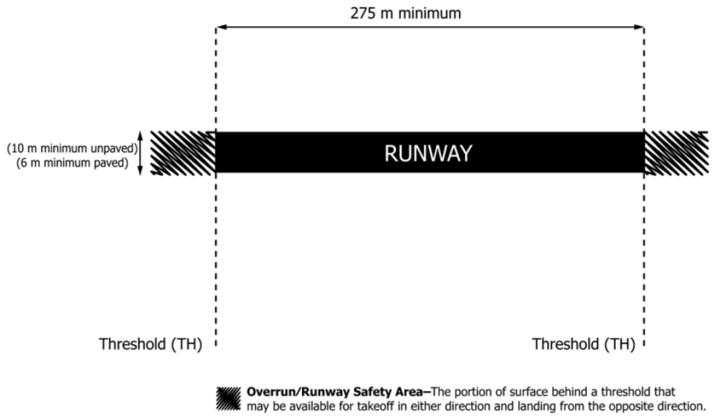


Figure 3.41: Runway Length—Threshold, Not to scale, ASTM F2507-15

A minimum runway safety area (RSA), or a surface surrounding the runway to reduce the risk of damage to aircraft in the event of an undershoot, overshoot or excursion from the runway, shall be established as well as a runway protection zone (RPZ).

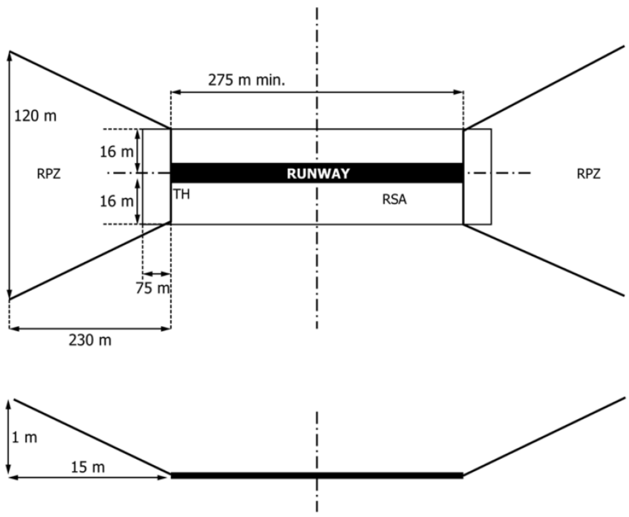


Figure 3.42: Runway safety area (RSA) and runway protection zone (RPZ), Not to scale, ASTM F2507-15

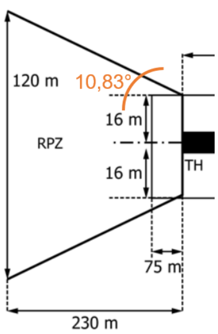


Figure 3.43: RPZ extension, Not to scale, ASTM F2507-15

An airpark is not required to have taxiways. If taxiways are established, then each taxiway shall

be at least 3 m wide and shall have a taxiway safety area as well, with a width of 15 m centred over the taxiway centerline without overlap the runway safety area. No obstacles and blue marker on the taxiways edges are requirements to comply with too.
Furthermore, all the buildings and parking areas are to be placed a minimum of 45 m from the runway centerline. An aspect that should not be under evaluate during the design of an airpark is the runway location and orientation, important for the airport safety, efficiency, economics, and environmental impact. As them are strongly influenced by the wind, an accurate analysis of wind has to be done to determine the orientation and number of runways. Two aspects have to be studied with accuracy: crosswinds and the wind coverage.
The most desirable runway orientation based on wind, in fact, is the one that has the largest wind coverage and minimum crosswind components. Where, wind coverage is that per cent of the time when crosswind components are below an acceptable velocity while crosswind is a component of wind direction.

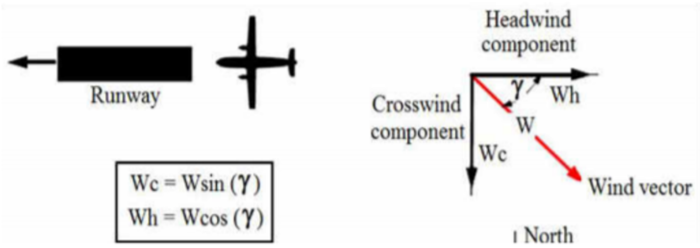


Figure 3.44: The optimum airport runway orientation for different regions in Egypt, 19 November 2013 [40]

The ASTM F2507-15 suggests, therefore, to use a record which covers the last 10 consecutive years of wind observations to make the studies.
Finally, if fuel is provided at the airpark, all local fire, environmental, and zoning regulations should be followed. As Alérion M1h is a hybrid aeroplane with an electrical engine, Avions Mauboussin will include probably a fueling facility for aviation fuel and hydrogen and a means for recharging the batteries of the plane.
Concerning the operations side, instead, a traffic pattern has to be established in accordance with the civil aviation authorities. The pattern altitude is defined by the standard and will typically be 152.4 m (500 ft) or greater above the altitude of the airport but may be lower. A typical traffic pattern for light planes is the rectangular one as the the one shown in the following figure.

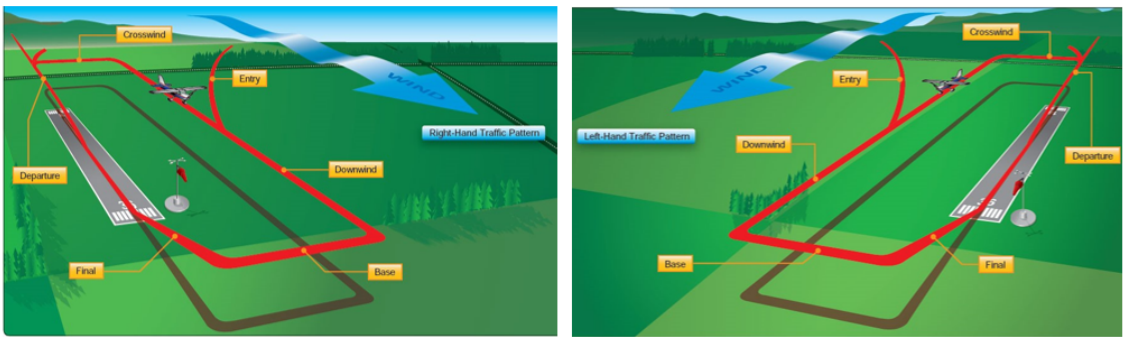


Figure 3.45: Rectangular traffic pattern,fly8ma.com

3.4.3.1 IFR approach

The next version of Alérion will operate under IFR conditions. Therefore, a study of how to design and approve an IFR procedure for an airpark has been carried out and has involved METEO France. The study brought up that in France, for an approach IFR on an airfield, the use of an automatic parameter transmission system or STAP (Système de transmission automatique de paramètres sur un aérodrome, in French) is required. As written into the Annex 1 of the document "Arrêté du 30 juillet 2009" the meteorological parameters that can be provided by a STAP are the following ones:

- direction and speed of the wind at the surface;
- ground visibility;
- height of cloud base;
- air temperature;
- dew point temperature;
- QNH;
- QFE [41].

The connection between the STAP and the aircraft is carried out on a VHF air-ground frequency of the aerodrome, which is published on the visual approach and landing charts (VAC) and the instrument approach charts (IAC). In addition to the meteorological parameters, local information concerning the restrictions and special conditions of use of the platform (works, operation of the installations, access restrictions, etc.) can be broadcast. STAP broadcasts in French but an additional program in English can be set up if needed [41].
Avions Mauboussin in particular, designing an airpark has to take into account that to perform IFR approaches on that, a STAP level N2 or N1+ must be implemented.

3.4.3.2 Authorization process to open an airpark

A preliminary study of the authorization process to open an airpark in Europe and U.S.A has been carried out by me as well. This has helped the company to a first approach to the regulatory framework that will face in the next months or years.
The authorization process for the construction of an airfield in the **U.S.A** is clearly explained into the document: "FAA Form 7480-1, Notice for Construction, Alteration and Deactivation of Airports" issued by the FAA. Title 14 Code of Federal Regulations Part 157, in particular, requires all persons to notify the FAA at least 90 days before construction, alteration, activation, deactivation, or change to the status or use of a civil or joint-use (civil/military) aerodrome [42].

To open a new airfield in **Italy**, instead, it is necessary to communicate it to ENAC with a copy of authorization issued by the municipality and by the public security. The manager of the airfield must, first of all, obtain the clearance from public security in order to check that there are no criminal records and clarify the uses of these airfields (in order to avoid drug trafficking). The manager is therefore responsible for the airfield. He must check that everything is ok with the current standards. ENAC authority will intervene only in the presence of third parties (such as in the case of public transport or flight school). What is fundamental, therefore, is the permission from the municipality on which the airfield will be built.

In **France**, finally, the construction of a new airpark is rather complex and must take into account the document: 'Demande de création d'aérodrome privé ou d'utilisation d' une aérosurface'. Permanent platforms for remunerated activities are authorized by order of the prefect of the department, after a favourable opinion of the head of the aeronautical district, the head of the air and border police, the regional customs director with territorial jurisdiction and the chairman of the regional military air traffic control committee and, within the limits of its powers, after consulting the mayor of the city concerned. The prefect has a 30-day response time (60 in the area of a priority defence installation) and in the absence of a decision, the authorization is deemed to be granted. The authorization may be refused in particular if significant noise disturbances will affect the neighbourhood [43].

3.4.4 Required pilot licenses for Alérion M1h

In summary, the typical operations of Alérion within the UAM scenario are those of intercity flights, namely connections between centres of interest and between secondary airports and hubs. However, it aims at, pilot-owner operations and flight-school operations too. For the latter, both positions will be equipped with commands but only the pilot in command will be responsible for all the operations of the plane. In the case of operations such as flight school, the pilot in command, as well as responsible for operations, will be the instructor.
Therefore, the pilot license requested for the use of Alérion M1h for private operations will be the PPL, or private pilot license, which does not present particular limitation or difficulties to keep it going. In fact, only 12 flight hours (which includes 1h with the instructor) in the 12 months preceding the end of the validity of the class qualification are required.
For the commercial operations of Alérion M1h, instead, the pilot license required is the CPL, or commercial pilot license.

However, to perform steep slope approaches, that are those operations using glideslope angles of 4,5° or more, according to the regulation (EU) No 965/2012, other than the prior approval by the competent authority, the pilot needs flight training, including briefing for competency in conducting steep approach landing operations. The briefing before the simulator session, should include limitations, normal and abnormal procedures, performance with special emphasis on landing distances and brake cooling. While for the stages of the steep slope approach, the crew should be trained on stabilized approach concept, appropriate slats/flaps configuration, approach speed, and flare initiation. The EASA Operational Evaluation Board (OEB) will define in the Operational Evaluation Board Report, the specifics requirements for initial training and recurrent training for the pilot of a specific plane and for a specific airport.
An example of airport where the sleep slope approach must be performed, other than Issy-les-Moulineaux, is the London City Airport, where the requirements to land are rather strictly according to the "Certification requirements for London City Airport", document which states that acceptable steep approaches are only those that are 5.5 degrees or steeper and '*any flight crew training (navigational or procedural), before to land at LCY, that is undertaken in a synthetic flight-training device, can only be conducted in a Level D or Level C simulator. The simulator, furthermore, must reproduce the London City environment and the handling characteristics and performance of the aircraft proposed for approval*'[44].
The specifics for the approval of steep approach operations, as well as for the approval of short landing operations, are explained by the regulation (EU) No 965/2012.
Alérion M1h's pilots will be trained and evaluated on a simulator able to reproduce exactly the operational performances of the plane.

Chapter 4

Certification process

4.1 Introduction to the certification World

In parallel with the work on the operations of Alérion M1h at Avions Mauboussin, a strong commitment has been made on the certification part of the project. In particular, the source of this huge commitment has been the complexity of the Alérion M1h project and the lack and/or incompleteness of the current EASA standards on hybrid aircraft and on the latest technologies. This thesis will, therefore, show an in-depth and careful study of the current standards governing the various technologies that will be presented by Alérion M1h.
A top-down approach has been chosen, therefore, for the development of this chapter. An introduction of what is the complex and intriguing world of certification today, the concept, main actors, state of art and future challenges, will be shown. It will allow the reader to immerse himself into the certification environment, knowing the main players and the main procedures for the certification of an aircraft and its operations. A state of the art of the situation prior to the beginning of this study will be, therefore, shown highlighting the salient points at the basis of the certification work carried out by the company to pursue its goal. Finally, following the top-down approach, the chapter will definitively enter into the "detail", that is the Alérion M1h project, showing and analysing the challenges to face for the certification of a hybrid aircraft, with extreme operations and the avionics of a fighter. Doubts and proposals aroused during the study, furthermore, will be shown as support work for the development of the clearest and most complete certification framework possible by EASA, able to face the latest aviation technologies.

4.1.1 Certification's meaning

The certification of an aircraft is a complex process that requires the definition of a very well-structured and an accurate planning. Every step, since the initial design of an aircraft to its end-life point shall lie to the standards, which are established by mutual agreement by the various bodies within their field of competence, to regulate, organize and guarantee a level of safety that is not a threat to things or people.
Certification can be defined, therefore, as the result of two operations: verification that something or somebody complies with the requirements established beforehand, and attestation of the verification issuing a formal approval.
In Europe, a product design is assumed to comply with the requirements only if both the design of the product and the organisation hold a certification. In this way, both the design and the production are covered by the certification. It's competence of the competent authority then, to verify the compliance with the standards of an applicant and to issue a certification.
In the aviation, therefore, the objective of the certification was and is still today, to ensure an acceptable level of safety for passengers, crew and people on the ground. To ensure that, however, the standards face a continuous evolutionary trend to regulate the ever-present technological innovations.

4.1.2 Aviation Authorities

The need for a common basic standardization all over the world has led the norms to evolve more and more towards an international standardization, without, however, totally depriving states of their

power, allowing them to modify these standards only in a more restrictive way. Over the time, this led to several differences over the countries so Bilateral Agreements came up to facilitate the reciprocal airworthiness certification of civil aeronautical products between two signatory countries. With these BAs, a bilateral cooperation in areas like maintenance, flight operations and environmental certification have been provided too.
At the base of the aviation certification, there is, therefore, a body which defines the minimum international standards defining the regulatory framework that has to be followed by all the 193 members of this body around the World. This body, is the International Civil Aviation Organization (ICAO).

4.1.2.1 ICAO

The International Civil Aviation Organization (ICAO) has been created on the "Convention on International Civil Aviation", or Chicago Convention, on December 7, 1944. The latter, signed in the first place by 52 states, had as main goal to establish rules of airspace, safety, security and aircraft registration. The Convention has been then revised several times and as March 2019, it had 193 parties. As aroused in the previous chapter, one of the most important article of the Chicago Convention is the Article 12: "*Each contracting State undertakes to adopt measures to insure that every aircraft flying over or maneuvering within its territory and that every aircraft carrying its nationality mark, wherever such aircraft may be, shall comply with the rules and regulations relating to the flight and maneuver of aircraft there in force. Each contracting State undertakes to keep its own regulations in these respects uniform, to the greatest possible extent, with those established from time to time under this Convention. Over the high seas, the rules in force shall be those established under this Convention. Each contracting State undertakes to insure the prosecution of all persons violating the regulations applicable.*[45]", which highlights that each state shall keep its own rules of the air as uniform as possible with those established under the convention.

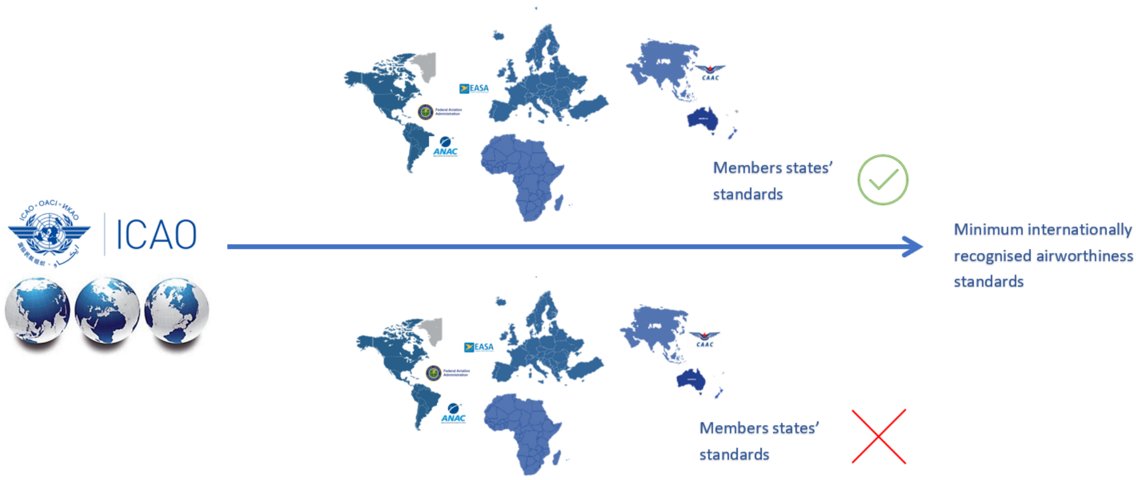


Figure 4.1: ICAO at the base of the airworthiness standards (Only a few of CAA shown)

The Convention is supported by nineteen annexes containing standards and recommended practices (SARPs) amended regularly by ICAO. The latter is, therefore, a specialized agency of the United Nations, located in Montreal, in charge of the coordination and regulation of the air travel, developing the principles and techniques of air navigation and facilitating international relations to ensure the safe and orderly growth of the international air transport.
ICAO mainly issues, as said before, Standards and Recommended Practices (SARPS) as Annexes of the Chicago Convention. The standards represent rules that all the signatory states must follow, while the recommended practices, are instead desirable recommendations, not mandatory, which failure to comply with does not threaten the safety of the international air navigation. The annexes issued by ICAO are continuing evolving in order to face the latests aviation technologies. Today the 19 annexes

issued are:

Table 4.1: ICAO Annexes

Annex	**Title**
1	Personnel Licensing
2	Rules of the Air
3	Meteorological services for international air navigation
4	Aeronautical charts
5	Units of measurement used in air
6	Operation of aircraft
7	Aircraft nationality and registration marks
8	Airworthiness of aircraft
9	Facilitation
10	Aeronautical telecommunications
11	Air traffic services
12	Search and rescue
13	Aircraft accident and incident investigation
14	Aerodromes
15	Aeronautical Information services
16	Environmental protection
17	Security & safeguarding
18	Transport of dangerous goods
19	Safety management

Among the others, important for the purpose of the definition of a type certificate is the Annex 8. The latter, includes broad standards which define the minimum basis for the recognition by States of Certificates of Airworthiness for the purpose of flight of aircraft of other States into and over their territories, thereby achieving, among other things, protection of other aircraft, third parties and property[46]. In addition to the annexes, ICAO produces DOCS, whose contents are guidelines for the Member States to modify the standards in a manner consistent with their own operational needs. Based on the Annex 8,therefore, each State can define its own code of airworthiness which must be respected by applicant for obtaining the type certificate of a design product.

4.1.2.2 The States

In the previous section the figure of the states have been mentioned several times. It's time to define those bodies and their responsibility within the certification environment.
The term state means the civil aviation authority which has the power to establish, on their own territory, the minimum standards to be followed for the design, production, maintenance and certification of any aircraft, also managing the renewal of airworthiness, the standards regulating airports and air traffic based on the minimum international requirements set by ICAO.
Among the various Civil Aviation Authorities there are:

- **FAA** - Federal Aviation Administration, in America;
- **EASA** - European Aviation Safety Agency, in Europe;
- **ANAC** - Agência Nacional de Aviação Civil, in Brazil;
- **CAAC** - Civil Aviation Administration of China, in China;
- **FATA** - Federal Air Transport Agency, in the Russian Federation;
- **JCAB** - Japan Civil Aviation Bureau, in Japan;
- **TC** - Transport Canada, in Canada;
- **CASA** - Civil Aviation Safety Authority (CASA Airworthiness Directives), in Australia.

As already mentioned above, in order to obviate the regulatory differences between the various states, Bilateral Agreements have been stipulated to ensure free circulation in intercontinental territory of an aircraft certified in another country under the competent Authority of the country itself.

To pursue the goal of my thesis a brief description will be made of the American FAA, already mentioned in the Urban Air Mobility section, while a more detailed description of the organization and responsibilities of the European EASA body, to which Avions Mauboussin must refer for the release of the type certificate for Alérion M1h, it will be carried out.

FAA The Federal Aviation Administration (FAA), born on August 23, 1958, is defined as "*the agency of the United States Department of Transportation responsible for the regulation and oversight of civil aviation within the U.S., as well as operation and development of the National Airspace System*"[47].
Along with the European Aviation Safety Agency (EASA) the FAA is one of the two main agencies world-wide responsible for the certification of aircraft and its major roles and responsibilities are several, from the commitment to ensure aviation safety, to construction and operation of airports, air traffic management, development of air navigation facilities, the certification of personnel and aircraft, and the regulation of the commercial space transportation industry. The FAA is, therefore, divided into four lines of business:

- Airports (ARP);
- Air Traffic Organization (ATO);
- Aviation Safety (AVS);
- Commercial Space Transportation (AST).

The FAA governs all the aviation activities issuing rules under the name of Federal Aviation Regulations (FARs). The FARs, however, are part of the Code of Federal Regulations (CFR) which is the codification of the general and permanent rules and regulations issued by the executive departments and agencies of the federal government of the United States. The CFR is divided into 50 titles regulating several areas, among these, the one which regulates the aviation area is the title 14 - Aeronautics and Space, where the FARs are organized into sections called parts. Each part regulates a specific type of activity. Among the others, the ones we will deal to, are, for example:

- **Part 21** – Certification Procedures for Products and Parts;
- **Part 23** – Airworthiness Standards: Normal, Utility, Acrobatic and Commuter Airplanes;
- **Part 34** – Fuel Venting and Exhaust Emission Requirements for Turbine Engine Powered Airplanes;
- **Part 36** – Noise Standards: Aircraft Type and Airworthiness Certification.

Finally, the FAA issues 'Advisory Circulars' whose contents are guidelines to give a unique interpretation to the reader for those regulations or requirements unclear.

EASA On the European continent, in the other hand, the authority that has powers similar to those of the FAA is EASA, which, however, unlike the American body, is made up of several national authorities which, based on EASA standards can issue standards more restrictive according to their own operational and safety needs.
As expressed by the agency itself on its website, EASA is an Agency of the European Union. As an EU Agency, EASA is a body governed by European public law. It is distinct from the Community Institutions (Council, Parliament, Commission, etc.) and has its own legal personality. Based in Cologne, Germany, the agency, created on 15 July 2002, has specific regulatory and executive tasks in the field of civil aviation safety and environmental protection. The agency works closely with the national authorities, that today are 28 plus 4 non EU States, still able to carry out tasks as certification of individual aircraft or licensing of pilots.
The main tasks of the Agency currently include:

- Rulemaking;
- Inspections, training and standardisation programmes to ensure uniform implementation of European aviation safety legislation in all Member States;
- Safety and environmental type-certification of aircraft, engines and parts;
- Approval of aircraft design organisations world-wide as and of production and maintenance organisations outside the EU;
- Authorization of third-country (non EU) operators;
- Coordination of the European Community programme SAFA (Safety Assessment of Foreign Aircraft) regarding the safety of foreign aircraft using Community airports;
- Data collection, analysis and research to improve aviation safety through the 19 EASA panels or areas of expertise.

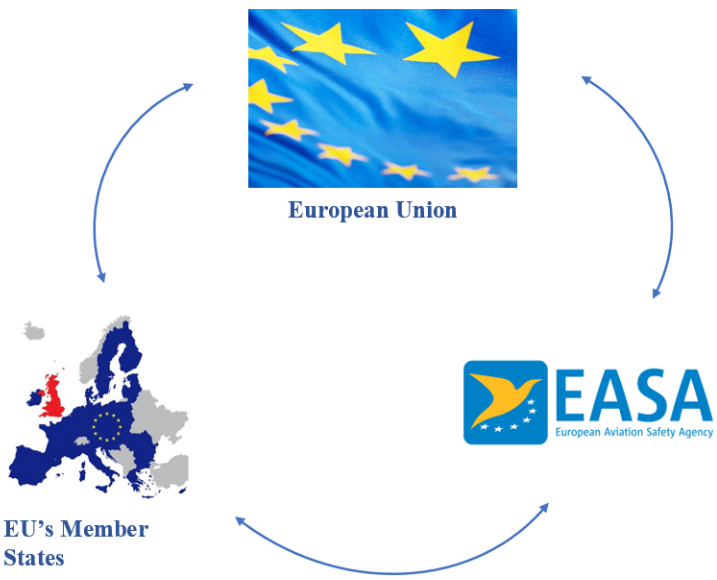


Figure 4.2: EASA partnership

The regulation which has set the legal basis for the creation of EASA, defining its competences and its powers, is the 'Basic Regulation' or Regulation (EU) 2018/1139 of the European Parliament and of the Council of 4 July 2018 on common rules in the field of civil aviation. The Regulation (EU) 2018/1139, therefore, can be classified as the first level of requirements, or **Essential Requirement (ER)**.
The so-called **Implementing Rules (IR)**, instead, can be classified as the second level of requirements. EASA defines the Implementing Rules (IR) as '*binding rules in their entirety and used to specify a high and uniform level of safety and uniform conformity and compliance*'[48]. They are adopted by the European Commission in the form of Regulations. To these regulations, Annexes are associated, containing the different Parts as seen for the FAA standards. An example of the latest EASA regulation structure can be found in Appendix 1 of this thesis.
At the third level, finally, there are the **Certification Specifications (CS)** that are non-binding technical standards adopted by EASA to meet the essential requirements of the Basic Regulation. Non-binding means that if applicants do not meet the recommendation of the CS, they may propose an Equivalent Level of Safety (ELOS) that demonstrates how they meet the intent of the CS. Certification Specifications are used to the establishment of the Certification Basis(CB) that once agreed with the applicant makes the CSs binding on an individual basis to the applicant.

However, EASA, other than these three levels of requirements, issues other non-binding documents as:

- **Special Conditions (SC)**, useful for the certification of Alérion M1h, are non-binding special detailed technical specifications that EASA provides if the certification specifications established by EASA are not adequate or are inappropriate for the product design the applicant is applying for. As well as for the Certification Specifications, the Special Conditions become binding on an individual basis to the applicant as part of an agreed CB;
- **Acceptable Means of Compliance (AMC)**that illustrate a means by which a requirement of an implementing rule can be met. However, National Aviation Authorities and organisations may decide to show compliance with the requirements using other means proposing alternative means of compliance (AltMoCs). Therefore, the Acceptable Means of Compliance (AMC) are non-binding;
- **Guidance Material (GM)** that is a non-binding explanatory on how to achieve the requirements contained in the Basic Regulation, the IRs, the AMCs and the CSs providing information, and examples [48].
- **Delegated Regulations (DR)** that are regulations used to supplement existing legislation on non-essential parts or amend specific and non-essential elements of a legislative act[49].

4.1.2.3 Who is certifying in EU other than EASA?

In Europe other than EASA, as mentioned before, there are other authorities that still have some responsibilities recognized by EASA. These authorities are:

- **National Aviation Authorities, NAA**:
  - DGAC, France;
  - ENAC, Italy,
  - CAA, United Kingdom;
  - LBA, Germany;
  - AESA, Spain;
- **Approved Organisations**:
  - DOA - Design Organisation Approval holder;
  - POA - Product Organisation Approval holder;
  - Part 145 - Maintenance Organisation Approval holder;
  - Continuing Airworthiness Management Organisation, Part M, CAMO.
- **Qualified Entities**.

Starting from the top, **National Aviation Authorities**, or NAAs, remain responsible for approving production, maintenance, and maintenance training organizations within their country as well as airworthiness certification of individual products coming into their registry without deviating from EASA procedures and EU implementing rules. Therefore, a National Aviation Authority can :

1. Issue Product Organisation Approval (POA);
2. Issues airworthiness certificates for individual aircraft registered in their country;
3. Issues mandatory corrective actions when unsafe condition relates to production or maintenance;
4. Issues noise certificates for individual aircraft registered in their country;
5. Approves and oversees all aircraft and related parts and appliances that are not under EASA's authority. The products excluded from EASA's responsibility are listed into the Annex I of the Regulation (EU) 2108-1139, which generally covers small fleets of historically relevant aircraft, such as the Concorde, as well as other aircraft such as ultra-lights and amateur-built.

EASA, therefore, on behalf of the EU will be responsible for certification and oversight of all civil aviation products of Member States except for those mentioned into the Annex I [50].

The **Design Organisation Approval**, **DOA**, is an approval granted by a Design Organisation which has been recognised to comply with the requirements of Part 21 Subpart J. A DOA holder gets the confidence of EASA showing the necessary knowledge and means to develop certification demonstration. Granted the DOA, an applicant has several privileges like:

- Perform design activities within the scope of approval;
- Have compliance documents accepted by the Agency without further verification;
- Perform activities independently from the Agency like:
  - Classify changes/repairs;
  - Approve minor changes/minor repairs;
  - Approve certain major repairs/changes;
  - Issue information or instructions for continued airworthiness.

Even EASA has several advantages with the issue of a DOA, because, the latter allows EASA to be more efficient and to direct the resources where needed.
A Design Organisation can apply for a Design Organisation Approval by submitting an application form to EASA. After acceptance of an application, EASA will assign a DOA Team Leader who will perform some quality investigations on the organisational structure, procedures, resources and performance [51].
The process to grant a DOA is shown below:

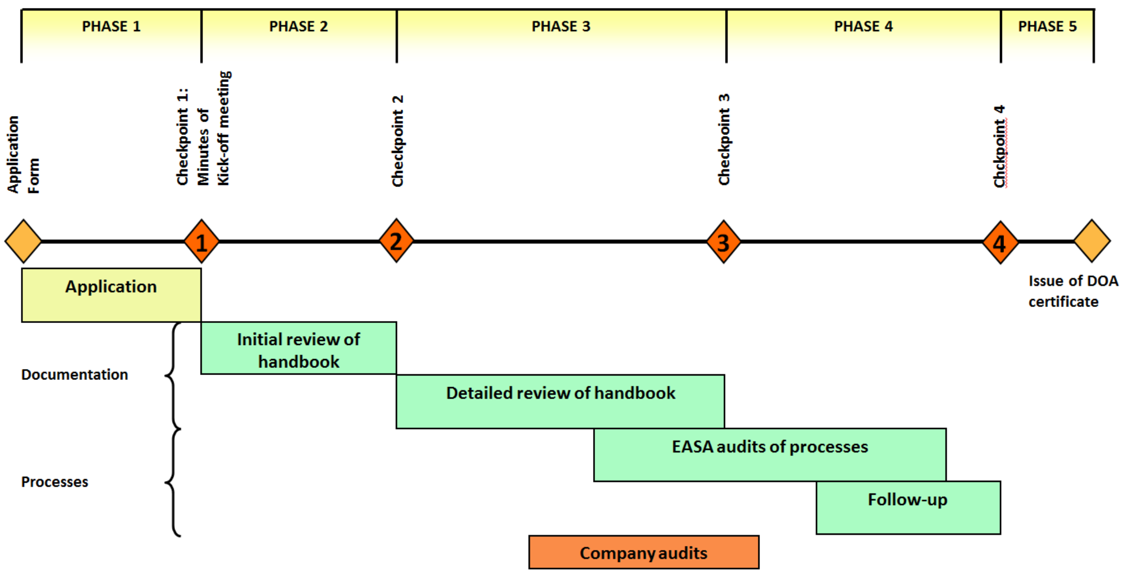


Figure 4.3: DOA process

The **Production Organisation Approval**, **POA**, is an approval to gets EASA's confidence in the conformity. The approvals are managed by EASA in accordance with Subpart G of Regulation (EU) No 748/2012, Part-21, for production organisations which principal place of business is located outside of the EU / EU Member State, while for production organisations having their principal place of business in an EU Member State, the competent authority is the one designated by that Member State [52].

A POA allows several privileges like, among the others:

- Obtain without further showing a Certificate of Airworthiness;

- Issue a Permit to Fly.

Both **Part 145** and **Part M**, unlike DOA and POA which are part of the Regulation (EU) No 748/2012 for the Initial Airworthiness, they are part of the Commission Regulation (EU) No. 1321/2014 for the Continuing Airworthiness that will be explained later.

Part 145, in particular, is specified in Annex II of the Commission Regulation (EU) No. 1321/2014, and addresses the conditions for an organisation to be approved as a maintenance organisation, where for '*maintenance*' is meant, as defined in the Article 2 of the Regulation (EU) No. 1321/2014: '*any one or combination of overhaul, repair, inspection, replacement, modification or defect rectification of an aircraft or component, with the exception of pre-flight inspection*' [53].
As described in 145.A.75 of the Regulation (EU) No. 1321/2014, the organisation, which has granted the Part 145, shall be entitled to carry out, among the other activities, the following tasks:

- Maintain any aircraft and/or component for which it is approved at the locations identified in the approval certificate and in the exposition;
- Arrange for maintenance of any aircraft or component for which it is approved at another organisation that is working under the quality system of the organisation;
- Issue certificates of release to service in respect of completion of maintenance in accordance with point 145.A.50.

Part M, unlike the Part 145, is specified in Annex 1 of the Regulation (EU) No. 1321/2014. EASA Part M specifies the rules for the continuing airworthiness of the aircraft and its parts. Its subpart G focuses on the continuing airworthiness management organisation, or CAMO, which are responsible for the airworthiness of the aircraft that means the monitoring of the aircraft, of the engines, of the components and the planning of maintenance activities to ensure the aircraft airworthy. According to the M.A.708 Continuing airworthiness management of the Regulation (EU) 2020/270, for every aircraft managed, the approved continuing airworthiness management organisation shall, among the other activities:

- Ensure that an aircraft maintenance programme including any applicable reliability programme is developed and controlled;
- Provide a copy of the aircraft maintenance programme to the owner or operator responsible where required;
- Manage the approval of modification and repairs;
- Ensure that all the maintenance is carried out in accordance with the approved maintenance programme and released in accordance with Section A, Subpart H of this Annex (Part-M);
- Ensure that all defects discovered during scheduled maintenance or reported are corrected by an appropriately approved maintenance organisation;
- Coordinate scheduled maintenance, the application of airworthiness directives, the replacement of service life limited parts, and component inspection to ensure the work is carried out properly;
- Manage and archive all continuing airworthiness records and/or operator's technical log[54].

Finally, there are the **Qualified Entities**, or bodies born to provide support to EASA. In particular, the Article 3 of the Basic Regulation (EU) 2018/1139, defines *qualified entity* as '*an accredited legal or natural person who may be charged with certain certification or oversight tasks under this Regulation by and under the control and the responsibility of the Agency or a national competent authority* [55]'.
A Qualified Entity , however, cannot issue certificates or legal approvals but can only provides support that will enable EASA to issue the required certificates or approvals. An example of Qualified Entity is the OSAC, Organisme pour la Sécurité de l'Aviation Civile, in France.

4.1.2.4 Volunteer bodies

To complete the framework of bodies acting within the certification World, volunteer companies like ASTM-International and Radio Technical Commission for Aeronautics, or RTCA, have to be mentioned.
In particular, the **ASTM**, or **American Society for Testing and Materials International**, is one of the largest voluntary standards developing organizations in the world that provides consensus standards for materials, products, systems and services. To date, the means of compliance for obtaining the airworthiness of the CS-23, as for Alérion M1h for example, are identifiable in the standards developed by the committee F44 of the ASTM. The latter, was born with the decision of the FAA and EASA to adopt consensus standards, updated frequently to face the technological progress, as a means of compliance in an attempt to update Part 23 in 2016, now CS-23 Amendment 5 to EASA.

Another volunteer body is the **Radio Technical Commission for Aeronautics**, or **RTCA**, which develops technical guidance for use by government regulatory authorities and by industry. RTCA, in particular, develops standards and guidelines for tests of aeronautical equipment. An example is the DO-160G, Environmental Conditions and Test Procedures for Airborne Equipment, which specifies the standards for the environmental testing of avionics hardware.

4.2 A/C airworthiness

There are several definitions and interpretations of airworthiness. ICAO, in particular, within the Annex 8, defines '*airworthy*', '*the status of an aircraft, engine, propeller or part when it conforms to its approved and is in a condition for safe operation*' [46]. Airworthiness, therefore, can be considered as the ability of an aircraft, equipment or system, to be operated in flight and on the ground without being a threat to aircrew, ground crew, passengers or to third parties.
The term airworthiness is then strictly connected with the safety one. A shortage of airworthiness could be the cause of an in-service incident or accident. Certification authorities, therefore, must examine all aspects of the design and construction of an aircraft, even when the changes don't deviate so much from the standards.

4.2.1 A/C airworthiness activities

To obtain and keep the airworthy status of an aircraft and its part, two main activities have to be carried out:

1. Initial Airworthiness;
2. Continuing Airworthiness.

4.2.1.1 Initial airworthiness (Part 21)

The Initial Airworthiness activities is defined by the Annex I of the the Regulation (EU) No 748/2012, which has been revised several times since 2012.
The Annex I of this regulation, or Part 21, is structured as follows:

- Section A in which technical requirements are shown;
- Section B in which, instead, the procedure for competent authorities have been defined;
- Appendices to Annex I, finally, in which the EASA's forms are attached.

Each section is, therefore, subdivided in sub-parts from A to Q.
According to Part 21 requirements, then, the Initial Airworthiness can be defined and developed in two main activities:

1. The issuance of a type certificate;
2. The Continued Airworthiness with the issuance of a certificate of airworthiness.

The latter involves the approval of the Type design, and its changes, issuing the TC, the verification of the conformity of the product with an approved Type Design, the issuance of the Individual Certificate of Airworthiness (CofA) which states the Entry into Service (EIS) of the aircraft. The Continuing Airworthiness is, instead, as will be possible to see later, the process by which an aircraft is kept airworthy throughout its operational life.

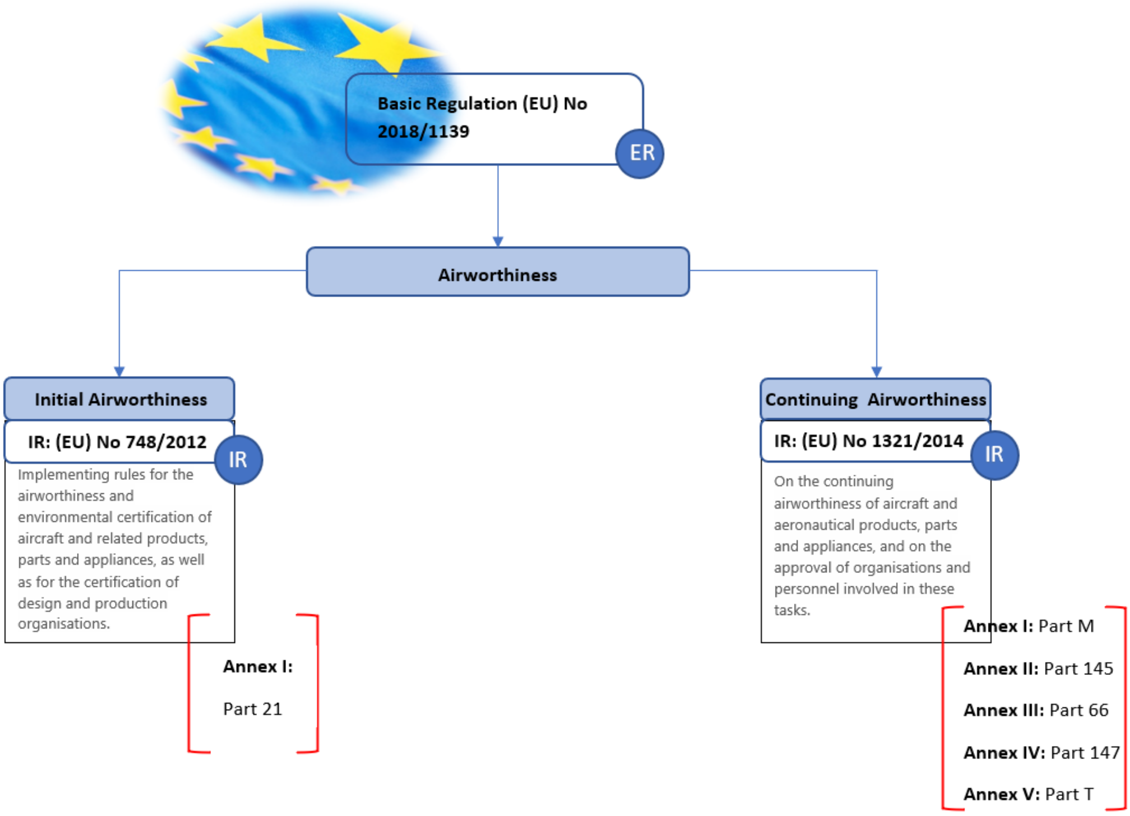


Figure 4.4: Airworthiness activities

Part of the Initial Airworthiness are the Certification Specifications above mentioned. As defined in the CS 23.200 (a) , in fact, the Certification Specifications prescribe airworthiness standards for the issuance of type certificates, and changes to those certificates, for aeroplanes in the normal category [56].
In particular, the CSs that are noteworthy for our purpose are:

- CS-LSA which regulates Light Sport Aircraft;
- CS-23 which regulates Normal, Utility, Aerobatic and Commuter Category Aeroplanes;
- CS-34, Aircraft Engine Emissions and Fuel Venting;
- CS-36, Aircraft Noise;
- CS-E, Engine;
- CS-P, Propeller.

Type Certification The goal of the type certification process is the issuance of a Type Certificate (TC) which is a document by which the authority attests that an applicant, or a company in charge of the production of an aircraft, an engine or a propeller, has demonstrated the compliance of type design to all applicable technical airworthiness requirements. As said in the previous sections, however, an applicant can apply for a type-certificate or restricted type-certificate only if it can demonstrate its capability by holding a design organisation approval (DOA), issued by the Agency in accordance

with Subpart J, or by way of derogation for certain products as an ELA 1 aircraft like Alérion M1h, according to the points (b) and (c) of the 21.A.14 [57].
This type certificate, however, is not an authorisation for the enter in service of the aircraft, which, instead, is given by an airworthiness certificate that will be explained later. A TC once issued has an unlimited duration and remains valid all along the holder remaining in compliance with Part 21, or the agency has not issued a notification for its revocation.
The issuance of the Type Certificate is a process quite long: 5 years for CS-25 (Large Aeroplanes) and CS-29 (Large Rotorcraft), while, 3 years for others TCs [58].
The main steps for the obtaining of a Type Certificate are the following shown in the figure:

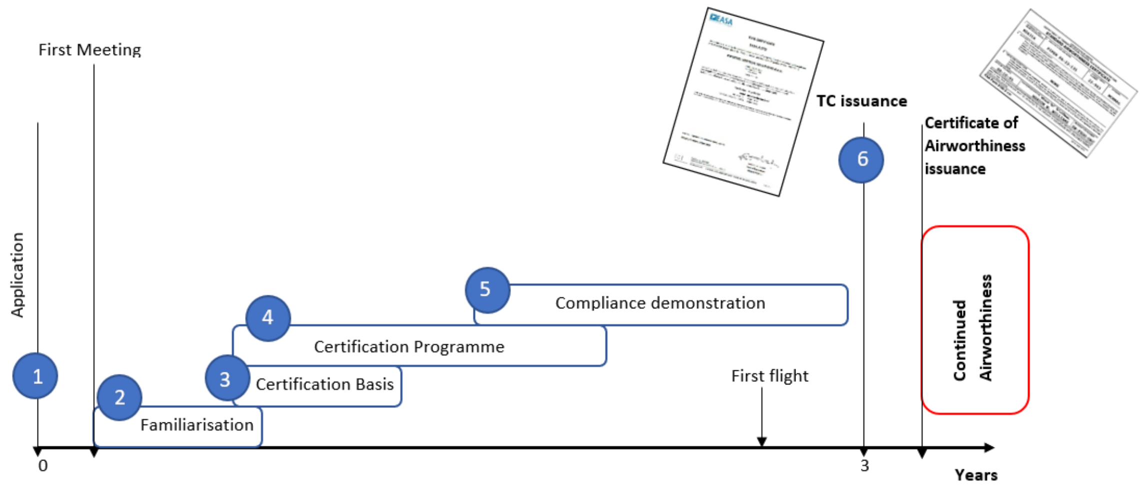


Figure 4.5: Type Certification process

Step 1 - Application The application is the first step of the type certification process which activates EASA and therefore the certification mechanism. The application shall be made in a form and manner established by the Agency and shall include,according to 21.A.15, as a minimum, preliminary descriptive data of the product, the intended use of the product and the kind of operations for which certification is requested. Once the application form has been received by the Agency, the latter, through the certification director, defines the certification team composed of a program certification manager and a team of experts for each panel of the agency.

Step 2 - Familiarisation The second step, is the familiarisation between the company and the agency. The familiarisation starts with a meeting which foresees a presentation, held by the applicant, whose contents are the general presentation of the product intended to be certified, a detailed presentation of the system's subjects and the certification objectives. The Agency, furthermore, in case of a complex project, identifies the possible issues of the certification process and suggests several ways to face it, as the proposition of special conditions. A first step, then, towards the establishment of the certification basis, which is step number 3, can be done.

Step 3 - Certification Basis With the establishment of the certification basis, the applicant definitely shows officially his certification needs and the applicable requirements to his product. The applicant with the certification basis establishes the applicable airworthiness code established by the Agency that is effective on the date of application, the special conditions that will be part of the certification and will cover the unconventional or unusual design features, Equivalent Safety Finding (ESF), for those points which don't directly comply with the requirements, and the Operational Suitability Data (OSD), described in 21.B.82, necessary for the safe operation of the aircraft and which includes among the others aspects like the pilot type rating training and the qualification of the simulator.

Step 4 - Certification Programme The certification programme is defined by AMC 21.A.15(b) as '*a document that allows the applicant and EASA to manage and control the evolving product type*

design or OSD, as well as the process of compliance demonstration by the applicant and its verification by EASA when required'[57].
In the certification programme, in the first place, then, the applicant must show several aspects which do not concern only the product but the project and the decisional process of the organisation too. In particular, according to 21.A.15(b), the following information should typically be expected:

- Identification of the relevant personnel who make decisions affecting airworthiness, operational suitability and environmental protection, and who will interface with EASA;
- Major milestones;
- An overview of the architecture, functions, systems, materials, technologies and noise/emissions level;
- Operating characteristics and limitations;
- The intended use of the product and the kind of operations desired.

In second place, the applicant shall identify the industry standards, or consensus standards, technical documents, specifications and guidance material to comply with. To each requirements, the applicant shall provide the proposed means of compliance and the related compliance documents. To respond to the latter, the applicant shall use the '**Means of compliance**', or the means to show to the Authority the conformity of the proposed design to the applicable requirements. The appendix A to AMC 21.A.15(b) shows the means here above mentioned:

Type of compliance	Means of compliance	Associated compliance documents
Engineering evaluation	MC0: (a) compliance statement (b) reference to design data (c) election of methods, factors, etc. (d) definitions	(a) Design data (b) Recorded statements
	MC1: design review	(c) Descriptions (d) Drawings
	MC2: calculation/analysis	(e) Substantiation reports
	MC3: safety assessment	(f) Safety analysis
Tests	MC4: laboratory tests	(g) Test programmes (h) Test reports (i) Test interpretations
	MC5: ground tests on related product(s)	
	MC6: flight tests	
	MC8: simulation	
Inspection	MC7: design inspection/audit	(j) Inspection or audit reports
Equipment qualification	MC9: equipment qualification	Note: Equipment qualification is a process that may include all previous means of compliance at equipment level.

Figure 4.6: Means of compliance codes, Appendix A to AMC 21.A.15(b), EASA

The last two aspects to be covered by the applicant within the certification programme are the organisation of the certification work per ATA chapters, which is a common referencing standard for commercial aircraft documentation, and the creation of grouping of compliance demonstration activities and data, or CDI, to facilitate the risk assessment which allows EASA to determine its level of involvement (LoI).

Step 5 - Compliance Demonstration The compliance demonstration is the last step before the issuance of the type certificate (TC). Once obtained the acceptance of the certification programme by the Agency, or EASA, the applicant, as described in 21.A.20, shall demonstrate compliance with the type certification basis, operational suitability data and environmental protection requirements. The applicant, furthermore, shall provide the Agency with the means by which such compliance has been demonstrated, reporting all the difficulties or events encountered during the process of demonstration. Authority's teams could join the applicant in this process other than set periodic meetings to check the progress.

Step 6 - TC issuance Once all the compliance demonstration documents including analyses and test have been issued by the applicant, the latter has to provide EASA with the Aircraft Flight Manual (AFM) and the instructions for Continued Airworthiness. The EASA will evaluate and approve, then, all the documents provided by the applicant, which will be followed by the applicant statement of compliance. Once everyone is satisfied the PCM will provide a statement of compliance and will issue a Certification Report. The final status of the document is then, reviewed by both, the Authority and the applicant, before the final report is presented to the certification director. EASA, finally, will issue the type certificate and a type certificate data sheet, with the main design data and certifications records, the aircraft flight manual, the type design and the Instructions for Continued Airworthiness which includes recommended maintenance tasks, airworthiness and life limitation.
An example of TC signed by the certification director is shown in the Appendix 2 of this thesis.

Continued airworthiness In case of an aircraft, however, the Type Certificate, does not sanction the entry into service of the aircraft which is, instead, sanctioned by the issuance of the 'Certificate of Airworthiness' which establishes the so-called phase of continued airworthiness.
The Certificate of Airworthiness is defined by 21.B.326, and differs by certificate for new or used aircraft. For the purposes of this thesis, everything that concerns only the certification of a new aircraft will be taken into consideration without considering any major or minor change of the TC. Therefore, only the issuance of a Certificate of Airworthiness for a new aircraft will be explained.
The Certificate of Airworthiness for a new aircraft is issued by the competent authority of the Member State of registry to an applicant which applies according to the form and manner established by the authority itself. As stated by the point 21.A.172, each application for a certificate of airworthiness shall include:

- the class of airworthiness certificate applied for;
- a statement of conformity, an EASA Form 52, for complete aircraft, or EASA Form 1, for other products, parts or appliances, validated by the competent authority;
- for an imported aircraft, a statement signed by the exporting authority that the aircraft conforms to a design approved by the Agency;
- a weight and balance report with a loading schedule and;
- the flight manual, when required by the applicable certification specifications for the particular aircraft[57].

Once the applicant has obtained the Certificate of Airworthiness, which has unlimited validity subject to the maintenance of the airworthy status, the aircraft is therefore allowed to the exploitation of its flight operations.
It is now that the concept of continued airworthiness takes place. A definition of continued airworthiness has not been issued by any competent authority as sometimes, with the continuing airworthiness, are used interchangeably. However, Continued Airworthiness, or Type Airworthiness, can be intended as defined by the Defence Safety Authority of the United Kingdom, in the Military Aviation Authority Master Glossary, MAA02: '*all the actions associated with the upkeep of a Type Design and the associated Approved Data through life*' [59].

4.2.1.2 Continuing airworthiness

The Continuing Airworthiness, although it goes hand in hand with the continued airworthiness, unlike the latter which is defined within the Regulation (EU) No 748/2012 as Initial Airworthiness, it is regulated and defined by the Regulation (EU) 1321/2014 as: '*all of the processes ensuring that, at any time in its operating life, the aircraft complies with the airworthiness requirements in force and is in a condition for safe operation*' [53].
Responsible of the continuing airworthiness are the approved organisation CAMO, or Continuing Airworthiness Management Organisation, regulated by the Annex I of the Regulation (EU) No 748/2012, and which responsibilities have been listed in the section 4.1.2.3 of this thesis. To what has already been said, all that remains is to add that for all the operators based in Europe, a Continuing Airworthiness Management Organisation (CAMO) must be in place and even for those based outside

Europe, the continuing airworthiness has to be verified.
Finally, concerning the responsibilities of continuing airworthiness, they are explained within the section M.A.201, which states that the responsibility of the continuing airworthiness is on the owner of the aircraft that, sometimes, according to the operational uses, involve lessees or aircraft operators.

4.3 Certification Exercise for Alérion M1h

In this section of the thesis, the certification process currently underway for Alérion M1h aircraft, made by Avions Mauboussin, will be described in detail. In particular, all the choices that have allowed the company to fully define the complex certification programme of this aircraft will be shown, covering its difficult operations and unusual innovations for a light aviation aircraft.
The top-down approach will be used for this section too. In the first place, the certification scenario adopted by the company for the aircraft before the beginning of this study will be shown and analysed. In the second place, on this basis, the representation of the work done at Avions Mauboussin will follow, digging more and more into the detail and touching on all the topics covered during the definition of the certification programme.

4.3.1 Certification Basis: The CS-LSA or CS-23 dilemma

Before the beginning of this thesis, Avions Mauboussin has spent time and resources trying to understand under which certification specification the aircraft could fit best. The certification specification was, in fact, the first step towards the definition of the 'Certification Basis' which has been partially defined by the previous interns.
In particular, the company and the certification intern, in 2018, have been carrying out for several months a comparison study between the certification specification for very light sport aircraft, or CS-LSA, and the current CS-23 Amendment 5, at the time, just issued by EASA.
For the final decision, several aspects have been considered and have been explained by Hadrienne Guerin, previous certification intern, in her report 'Study of the EASA initial certification process changes for small aeroplanes through the certification exercise of Alérion M1h', made in September 2018, which has been at the basis of this work, as starting point. The report exhorts, in fact, as the performances and design features of Alérion M1h, despite had been set to fall in the LSA category, presented some points that were at the upper limit of the category aforementioned, forcing the company to consider the next category, or CS-23 for normal category aircraft. This consideration has been wisely taken into consideration to avoid the possible problems of a possible modification of the project with consequent weight increase that, in case of the choice of the CS-LSA would have not been allowed. The choice to consider the next category was then forced, because an aeroplane in its premature state of design could face several changes, some of them even major changes. Alérion M1h, in fact, at the time, it still lacked a defined propulsion system which, being electric, could have brought an huge increase of weight.
However, even the CS-23 did not fit exactly to the extreme performance and unusual design features of Alérion M1h. Therefore, was not possible for the company to ensure the safety objectives using the existing requirements and the discussion with the authorities about special conditions and/or equivalent safety findings were already foreseen.
The company, therefore, had identified, in a first overview, the characteristics and the main technical constraints of the two certification categories. A summary of the work done before my arrival, which highlights the specifications of Alérion M1h missing in the CSs, is shown in the following table:

Table 4.2: CS-LSA and CS-23 highlights

	CS-LSA	**CS-23**
MTOM	$\leq$ 600 kg	$\leq$ 8618 kg
Seating capacity (pilot included)	$\leq$ 2	$\leq$ 2 (Level 1)
Cabin	Non-pressurised	/
Propulsion	A single, non-turbine engine fitted with a propeller	/
Missing	Single Lever Power Control Flaperons No whiskey compass Steep slope approach In-flight propeller reverse Variable pitch propeller Hybrid propulsion Twin engine Natural fiber secondary structure Winglets Head Up Display VFR Night	Single Lever Power Control Flaperons No whiskey Compass Steep slope approach

Other than the technical constraints, the company had to understand before to go ahead what were its planes and its resources, so a study on the feasibility of the two certifications, then, has been carried out carefully.
Three points have been considered, therefore, to end up to a final choice:

1. Target market;
2. Evolution of the design;
3. Readiness of the organization to face a specific certification process.

The **target market**, or the potential customers to whom the company wants to sell the plane, is, in fact, a crucial point on the choice of the certification specification. A target market which involves countries outside of Europe, in fact, would lead the company to respect and face the applicability requirements of several certification authorities. Therefore, a certification which would allow an easier approval by other authorities, as FAA at the top of the list, other than EASA could be crucial for the overall certification time. On the latter point, the CS-23 helps thank to the full harmonisation with the CFR Part 23 of the American FAA, which allows a faster process of validation. On the other hand, instead, the CS-LSA does not present a full harmonisation with the FAA regulation, in particular for unusual design features and performances as the ones of Alérion M1h. Therefore, a product design certified under the CS-LSA requirements cannot get a directly validation by foreign authorities which would like to perform studies and audits on the product design, on the organisation and its procedures for continuing airworthiness.

The **evolution of the design**, instead, is another point that companies sometimes do not take into account seriously, or at least they are not far-sighted. Being far-sighted in fact, could really help in the choice of a certification specification because it could justify the effort for a more complicate certification process done in the first place. Avions Mauboussin has thought about this and, in fact, this has led the company a step closer to the CS-23. Avions Mauboussin, in fact, sees Alérion M1h as the first basic component of a family of innovative and urban aeroplanes which could involve an increase of the seating capacity and the use of a new propulsion system for the use of the hydrogen, element on which the company focuses a lot.
Undergo a certification under the CS-23 for Alérion M1h would help, then, thank to its flexibility, for the certification of the further performing versions even with lower costs.

The last point to consider, not in order of importance, is the **readiness of the organization to**

face a specific certification process. The company must be aware of what it is facing and must ask itself if it has the experience and financial resources to go through with it. The CS-23, unlike the CS-LSA, is, in fact, more complex and this means, in a few words, a higher cost, to manage suppliers which provides certified products, and a higher amount of work which leads to lengthening the times.

Table 4.3: CS-LSA and CS-23 advantages and disadvantages

	CS-LSA	**CS-23**
Advantages	- Low cost - Simple - Not frequently updated	- Wide range of performances covered - Flexible - Easier consideration of unusual design features - Full harmonisation with FAA's requirements - Detailed Means of Compliance
Disadvantages	- Stringent requirements - Not adapted for unusual design features - No harmonisation with the FAA's requirements - VFR Night to be discussed - Too many technical aspects to be discussed with the authorities	- Complex certification process - Big amount of standards - Huge experience required - Certified products by the suppliers - High certification cost - Continuing updates

Reference Standards As mentioned in the previous chapter, furthermore, with the part 23, EASA and FAA have decided to use consensus standards as reference standards. This standards are made by ASTM International which are then accepted and used by EASA through an AMC document. After an evaluation study, as mentioned within the Hadrienne's Report, the ASTM standards for the CS-23 are the most appropriate to be used as means of compliance, because most of the design features were already covered, consider emerging technologies and show a better structure.

Finally, decided the Certification Specification and the Referenced Standards, the company has been able to define a first version of the certification basis which is shown here under:

Table 4.4: Certification Basis on September 2018

CS	**Title**	**Version**
CS-23	Normal-Category Aeroplanes	Amdt 5
CS-P	Propellers	Amdt 1
CS-E	Engines	Amdt 4
CS-22 Subpart H	Sailplanes and Powered Sailplanes	Amdt 2
CS-34	Aircraft Engine Emissions and Fuel Venting	Amdt 2
CS-36	Aircraft Noise	Amdt 4

Based on this foundation my work at Avions Mauboussin began.

4.3.2 Certification Basis update

Since then EASA has worked hard to keep up with new technologies and unique aircraft configurations, such as eVTOLs, realizing that in fact, neither the current certification specifications nor a combination of them allowed EASA to properly regulate these new aircraft and new technologies in their support. As part of this thesis study then, a study of the new recommendations and regulations has been carried out in order to understand if they could be useful to the Alérion M1h's certification basis. In particular, the authority has faced this continuous technological development with the establishment of a common set of conditions within Special Conditions (SC), as a clarification for future potential applicants and to provide greater flexibility in the Operational regulatory framework. In particular, the SC VTOL and SC E-19, have been considered useful for the certification process of Alérion M1h. The first one as, in absence of SC for STOL aircraft, it presents the requirements and safety levels for the operations over and in congested area, while the second, because cover mostly all the aspects of the hybrid propulsion of Alérion M1h.

4.3.2.1 SC VTOL

The Special Conditions, as already said in the section 4.1.2.2, are non-binding special detailed technical specifications that the authority provides if the certification specifications already existing do not cover completely the product design the applicant is applying for.

Why the need of a SC VTOL? The scenario aforementioned has been exactly the scenario faced by the applicants who are developing hybrid and electrical vertical take-off and landing aircraft, or simply eVTOL. Despite eVTOls have, in fact, design features close to the ones of aeroplanes, or rotorcraft or both, in most of the 150 cases studied, EASA has not been able to classify these new vehicles as being either a conventional aeroplane or a rotorcraft.
The European authority has carried out several proposition before to issue the SC VTOL. Among these, it has been thought to provide the certification specification for aeroplane or rotorcraft already existing with some modifications and then applying either the CS-23 or CS-27 depending on whether they were rather an aeroplane or rather a rotorcraft. A feeling of unfairness of this solution early came up which would have treated different solution without equity.
EASA, therefore, has decided to develop the SC VTOL to establish a common set of conditions for the certification of these new concepts with innovative state-of-the-art designs and technologies.

Applicability The SC VTOL is foreseen for all the aircraft which differs from conventional aeroplane for the VTOL capability and from conventional rotorcraft for the distributed propulsion. The SC VTOL is set up to the CS-27 limits for an easier alignment with the levels 1,2 and 3 of the CS-23 and UAS specifications, which is not yet covered by this SC:

- Passenger seating configuration: ≤ 9;
- Maximum certified take-off mass: ≤ 3175 kg;

Certification categories To identify the nature of risk and safety level needed by the operations conducted by VTOL aircraft, the SC VTOL defines certification categories linked, as said, to the type of operations. The two categories introduced are:

- **Category Enhanced**: the aircraft under this category will perform operations which correspond to the highest operational risk to third parties and/or to passengers transport for remuneration which leads to safety objectives assigned regardless of the number of occupants. Continued safe flight and landing and the ability to continue to the originally intended destination or veer to an alternate vertiport in case of failure are, therefore, the requirements to be met by the aircraft in this category.
  It is this category that Avions Mauboussin will consider for the certification of Alérion M1h.
- **Category Basic**: for the aircraft certified under this category, unlike the category enhanced, only controlled emergency landing requirements have to be met, in a similar manner to a controlled glide or autorotation. The safety objectives, therefore, are assigned and linked to maximum number of passenger seats for a given configuration. It is an approach similar to the one of the CS-23 but which has been through an increase of one level due to the higher dependency on systems that are associated with distributed propulsion that has led this category to be aligned with the current upper level of the CS-27.

Structure The SC VTOL is structured in 7 sub-parts:

- Subpart A - General;
- Subpart B - Flight;

- Subpart C - Structures;
- Subpart D - Design and Construction;
- Subpart E - Lift/Thrust system installation;
- Subpart F - Systems and equipment;
- Subpart G - Flight crew interface and other information.

Each sub-part contains certification requirements identified by the referenced special condition, number of the requirements and title. Each requirements can be, therefore, structured in two sub-levels.

VTOL.2120 Climb requirements

The design must comply with minimum climb performance out of ground effect:

(a) in the normal flight envelope.

(b) for Category Enhanced:

(1) in the operational envelope;

(2) reserved.

(c) reserved.

Figure 4.7: VTOL.2120 Climb requirements, Subpart B, SC VTOL, EASA [4]

In addition to this document, EASA has issued on May 25, 2020, '*Proposed Means of Compliance with the Special Condition VTOL*' which contains the Means of Compliance (MOC) addressed to the applicants as guidance material to assist them with an understanding of the objective rather than providing a definitive means of compliance in order to drive basic design choices.

4.3.2.2 SC E-19 EHPS

The development of eVTOLs has carried out, as said before, new technologies mostly for the propulsion system, that are foreseen to be electric or hybrid. The eVTOLS World, in fact, is moving hand in hand with the respect of the environment, and this could not have been otherwise given the urban operational scenario of eVTOL aircraft.
However, even for these new technologies EASA was not ready at all as none of the certification specifications already existing, like the CS-E Amendment 5 or CS-22 subpart H, considered Electric and / or Hybrid Propulsion Systems. The closest document issued by the agency for this scope was the SC-LSA-15-01 - Electric Powerplant Installation for CS LSA aeroplanes, used by Pipistrel Aircraft for the certification of the Velis Electro, which provided requirements about electric powerplants. However, this was not enough for the current needs.
To run for cover, the European agency has published the document 'Proposed special conditions for Electric/Hybrid Propulsion System', or SC E-19, to set commons requirements for all Electric and / or Hybrid Propulsion Systems used to produce lift/thrust/power for flight in any manned and unmanned aircraft, both during normal and emergency operations. Propellers, propulsion systems for large aircraft and all the Electric / Hybrid Propulsion Systems that are not used to produce lift/thrust/power in flight are outside the scope of this Special Condition.
The final document is still under development by the working group of Mr Régis Rossotto, who I had the pleasure to talk with and who assured me that the final document with the Acceptable Means of Compliance will be issued officially by EASA before the end of the year. The document, however, already assists the applicants with an understanding of the requirements set by EASA for the basic design of the propulsion system and proposes Associated Interpretative Material / Means of Compliance to ease the reading of the Special Conditions and give an idea of the future MOCs.

The development of documents like these aforementioned, caught our attention and awareness that the certification basis defined in the first place for Alérion M1h had to be redefined. This led me and the company to remove some documents from our certification basis such as CS-E, CS-P and CS-22

Subpart H, as they are not obsolete but further away from our needs and our products, which, instead, fall more under the special conditions for VTOL and for Electric / Hybrid propulsion system.

Table 4.5: Certification Basis updated

CS	Title	Version
CS-23	Normal-Category Aeroplanes	Amdt 5
CS-34	Aircraft Engine Emissions and Fuel Venting	Amdt 2
CS-36	Aircraft Noise	Amdt 4
SC-VTOL-01	Special Condition for small-category VTOL aircraft	Issue 1
SC E-19	Proposed Special Condition for Electric / Hybrid Propulsion System	Issue 1

Do these SC cover all the aspects of these new vehicles concepts? The issuance of these documents certainly paved the way for Avions Mauboussin to certify its Alérion M1h hybrid aircraft, but in the implementation of the certification programme a question aroused: 'Do these SCs cover all the aspects of these new vehicles concepts ? '.
In particular, the question aimed to understand if all the points within the SCs were first clear, then if they were relevant for Alérion M1h, in line with the other documents such as the CS-23, and if all the aspects of a complex aircraft such as that of the French company were covered by these common rules established by the European authority. An analysis of the contents of the SCs and of the added value to the regulatory process, with a gap analysis with the CS-23, has been, therefore, carried out to answer to all these questions.

4.3.2.3 Gap analysis CS-23 - SC VTOL

EASA has practically developed the Special Condition VTOL based on CS-23 Amendment 5, full harmonised with the FAAs Part 23, integrating, however, elements of CS-27 and defining new elements when deemed appropriate cause the lack in the aforementioned certification specifications.
Almost all the special conditions previously issued by the Authority were in line with their true meaning and purpose, namely provide small changes to requirements based on something that was not regulated by the existing regulations in order to regularize the use of latest technologies in the aviation world. The SC-VTOL, instead, has had a rather different purpose, in fact, with its issuance, it has literally defined a new category of aircraft that is neither an aeroplane nor a rotorcraft, consequently defining a new type of certification.
This has been the first point which has raised several controversies not only among applicants but even among aviation leading authorities. Several, have been the comments of aviation authorities calling for a harmonisation of EASA rules with those envisaged by other authorities such as the FAA, which consider eVTOL aircraft as special categories of existing Part 23 or Part 27 regulations, managing the operational differences under the operational procedure already defined. The FAA, in fact, has written, within the EASA SC-VTOL-01 Comment Response Document, made available by EASA following the publication of the proposed SC VTOL, a comment that underlined the problem and aroused a bit of fear for the eVTOL developers. It states: '*It appears that this Special Condition and EASA definition of VTOL will dramatically de-harmonize our regulatory requirements as well as our Means of Compliance (MOCs)*'. A de-harmonisation between the two aviation leading authorities would be , in fact, a serious problem for the market of European eVTOLs, which would lose the possibility to be part of the considerably US eVTOL market.

Furthermore, another point raised by Mike Hirschberg, Vertical Flight Society Executive Director, in the article '*EASA Takes the First Shot at eVTOL Regulations. Did They Miss the Mark?* ', published on The vertical flight commentary on October 2019, is that since EASA has not the authority to write operating procedures, which is the task of the European Commission, this new kind of aircraft does not fall in the Regulation (EU) No 965/2012, thus remaining without well-defined operational procedures [61].
The lack of defined operational procedure for VTOL aircraft leaves the VTOL developer to deal with the National Aviation Authorities (NAA) of each individual EASA member state, leading, therefore,

the developers to a huge amount of work definitely complex for the definition of a common framework satisfactory for everyone.
The levels of safety required, therefore, follow the CS-25 and CS-29 requirements for the category enhanced, and the CS-23 requirements for the category basic, which however have been increased by one level compared to CS-23.

	Maximum Passenger Seating Configuration	Failure Condition Classifications: Minor	Major	Hazardous	Catastrophic
Category Enhanced	-	≤ 10^{-3} FDAL D	≤ 10^{-5} FDAL C	≤ 10^{-7} FDAL B	≤ 10^{-9} FDAL A
Category Basic	7 to 9 passengers	≤ 10^{-3} FDAL D	≤ 10^{-5} FDAL C	≤ 10^{-7} FDAL B	≤ 10^{-9} FDAL A
	2 to 6 passengers (see note A)	≤ 10^{-3} FDAL D	≤ 10^{-5} FDAL C	≤ 10^{-7} FDAL C	≤ 10^{-8} FDAL B
	0 to 1 passenger (see note A)	≤ 10^{-3} FDAL D	≤ 10^{-5} FDAL C	≤ 10^{-6} FDAL C	≤ 10^{-7} FDAL C
[Quantitative safety objectives are expressed per flight hour]					

Figure 4.8: Safety objectives - SC VTOL 01

This means that any aircraft which falls in the category enhanced, in order to operate over cities or for commercial purposes, must have the same level of safety for a catastrophic failure as a commercial airliner. Same story for any aircraft with more than 7 passengers, which falls in the category basic, under which flights over congested areas and commercial operations are forbidden.
These safety levels can be considered very strict and could affect the design and the market of these aircraft. Mike Hirschberg, furthermore, adds that in this way, the eVTOL developers will focus on a pilot-centred design which, well, relies on the pilot which at the date, is still the most common cause of accidents. EASA, should, therefore, focus more on the man-machine relationship, in order to reduce the recurrence of accidents caused by human factors.

Several US companies, furthermore, are pushing the Civil Aviation Authorities to allow the use of non-steerable parachutes for achieving safety standards. While the FAA has not yet commented on the use of parachutes, EASA has, instead, rejected this solution a priori, deeming the non-steerable parachutes ineffective to perform a controlled emergency landing. This has been officially stated within the Proposed Means of Compliance issued on May 2020 with the MOC VTOL.2000 3) : '*A controlled emergency landing should be performed under control; in particular it should be possible to steer the aircraft towards a touchdown area with the remaining lift/thrust units. Therefore this objective cannot be met by the use of non-steerable parachutes*' [62]. In the other hand, however, in the same MOC, EASA has expressed a favourable opinion on the use of active systems '*if their reliability is commensurate with their criticality*' [62].

There is still a heated discussion on the points listed above that EASA will have to resolve. In my opinion, however, the European authority is right in requiring a certain level of safety, which perhaps, could be revised, with the solely basic design of the aircraft without having to require any other 'external' system/equipment. Consequently, personally, I believe that the authority should continue to maintain this judgment without being conditioned by the wishes of the companies in this sector and should, instead, focus on supporting the European Commission in the implementation of the new operational procedures trying to harmonize them as much as possible with the provisions of the FAA.This would reduce the time, which could lead, if too long, to inhibit the production and the worldwide market of these eVTOL aircraft.

Avions Mauboussin Avions Mauboussin is, indeed, monitoring the evolving of this regulation, as the company wants to include within its certification basis some requirements mentioned within the SC VTOL.

Alérion M1h, furthermore, being a fixed-wing plane, would not be affected too much then by the EASA safety requirements for operations over and in congested areas, as it will be able to continue a safe flight and landing or to continue to the original intended destination or a suitable alternate vertiport after a failure. However, in the study of the SC VTOL some points have been raised. These points relies in particular on the classification of the aircraft in these special conditions and on the requirements, present in the SC VTOL, which are not mentioned in the CS-23 Amendment 5 nor in the ASTM standards or that are in conflict .

The first doubt is about the determination of the performance of Alérion M1h, as foreseen by the VTOL.2105-Performance Data. The standard requires, in fact, that the applicant to determine the performance in the normal flight envelope or in the operational envelope if category enhanced, therefore, the doubt aroused by Avions Mauboussin is if the performance should be determined by analogy with the category enhanced due to the flight over congested areas or for commercial operations only. The question is legitimate as Avions Mauboussin envisages the use of its aircraft over congested areas not only for commercial operations but also for private operations by a pilot-owner who wants to land in the heart of the cities.

The standard VTOL.2240-Structural Durability, instead, raises a further doubt for Avions Mauboussin as the standard aforementioned states: '*For Category Enhanced, the procedures developed for compliance with SC VTOL.2240(a) must be capable of detecting structural damage before the damage could result in structural failure*' [4]. This means, that the SC VTOL foresees a damage tolerance approach which traditionally is not used for wooden structure as the one of Alérion M1h. This point should be asked and clarified with the authority.

Furthermore, several differences in contents and details degree between the SC-VTOL and the CS-23 relevant to the certification of Alérion M1h have been found and gathered in the following table for a future discussion with EASA:

Table 4.6: Differences between the SC VTOL and the CS-23 relevant for Alérion M1h to be discussed and evaluated with EASA

SC VTOL	**CS-23 Amendment 5/ASTM**
VTOL.2245 (a) The aircraft must be free from flutter, control reversal, and divergence: [...] (4) accounting for any critical failures or malfunctions.	**F3093-20** **4.6** Freedom from flutter, control reversal, and divergence up to VD/MD must be shown as follows: **4.6.1** For aeroplanes that meet the criteria of sections 4.4.1 through 4.4.3 of this section, after the failure, malfunction, or disconnection of any single element in any tab control system.
VTOL.2250 (c) ... For Category Enhanced, a single failure must not have a catastrophic effect upon the aircraft.	No such requirement in the CS-23 Amendment 5 Level 1.
VTOL.2250 (f) (f) The aircraft must be designed to ensure that after a likely bird impact the capability remains to conduct: (2) continued safe flight and landing for Category Enhanced.	No requirements about bird impact in the CS-23 Amendment 5 for a Level 1 aircraft, but it is foreseen within the **F3114-19 4.7.6** only for a Level 4 aircraft. [63]

SC VTOL	CS-23 Amendment 5/ASTM
VTOL.2430 (a) Each system must: (1) be designed to provide independence between multiple energy storage and supply systems so that a failure, including fire, of any one component in one system will not result in the loss of energy storage or supply of another system.	The multiple energy storage and supply is not foreseen in the CS-23 Amendment 5.
VTOL.2555 Installation of recorders The aircraft must be equipped with a recorder or recorders that: [...]	CVR/DFDR is not required in the CS-23 Amendment 5 for a Level 1 aeroplane.
VTOL.2600 Flight Crew Compartment (c) For Category Enhanced, the flight crew interface design must allow for continued safe flight and landing after the loss of vision through any one of the windshield panels.	CS-23 Amendment 5 does not require redundant panels for a Level 1 aeroplane.

4.3.2.4 Gap analysis CS-23 - SC E-19

Unlike the SC VTOL, the SC E-19 is still in a very premature stage. At the date, in fact, only a proposed document has been issued by EASA. Drastically changes, therefore, could be foreseen. However, a study of the current document has been carried out to understand what are the requirements set by EASA for the basic design of the propulsion system as the type of technology used in the propulsion system will be only addressed in the further Acceptable Means of Compliance.
An aspect that stands out immediately to the eyes and that does not match with the specifics of the Alérion's propulsion is the lack of definition and standards about the Battery Management System, or BMS, which does not match with the EHPS Control System defined in the SC E-19. Since Alérion will be provided with lithium-ion battery packs as energy storage system, a battery management system (BMS) should be provided for its control. The battery management system is, in fact, an electronic system that monitors the battery state, its environment, data and operations being, therefore, responsible for its safe operation, performance and life under different charge-discharge conditions.

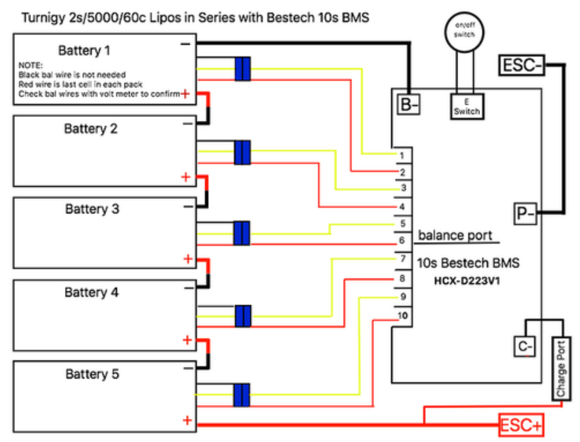


Figure 4.9: Example - BMS

The presence of a control body such as the BMS, within Alérion M1h, is, therefore, fundamental due to the limitations and undesirable phenomena related to Li-ion batteries like short circuits, thermal runaway or cold charge/discharge. The BMSs obviate to these problems having monitoring

functions on the current, voltage and temperature.
Such system should be, therefore, foreseen in the final version of the SC E-19 as well as provided in the CS-23 and in the SC-ELA.2015-01, at least. Within the latter, in fact, the standard SC-ELA.2015-01.02 Storage battery design and installation states (b) : '*A protection against overcharge and critical discharge of the batteries shall be provided including deep or unbalanced discharge if necessary for the type of battery*' [64] to which a guidance material stating '*Control Units and Battery Management Systems should be designed and manufactured following good engineering practice with consideration of electric magnetic interference, environmental and software aspects*' [64].

Therefore the standard EHPS.380 Energy Storage System should be revised as follows:

EHPS.380 Energy Storage System

(a) If the EHPS contains an energy storage device, the energy storage device and its management system must be designed and constructed so as to meet the Type-Certification basis of the intended aircraft application. [65]

(b) If the EHPS contains an electric energy storage device providing electric energy to an electric engine(s), it must be designed and constructed so as to provide the required energy for the electric engine(s) of the EHPS at all time during the flight in order for them to provide the rated powers defined in EHPS.40. [65]

(c) A protection against overcharge and critical discharge of the energy storage system shall be provided including deep or unbalanced discharge if necessary for the type of the energy storage system.

An example of standard covering the BMS specifications, instead, should look like as follow:

EHPS.XXX Battery Management System (BMS)

The BMS should be able to:

(a) Detect any overcurrent;

(b) Detect any overvoltage and undervoltage;

(c) Detect any overtemperature and undertemperature;

(d) Provide the users and the other systems the State of Charge and the State of Health of the batteries

in order to shut-down the battery operating outside its safe operating area.

4.3.3 The definition of the final Certification Basis of Alérion M1h

After the identification of the requirements relevant for Alérion M1h and the issues to be solved with the SCs, the final certification basis was able to be defined and the beginning of the certification programme, identifying the certification documents for the unusual design features and technologies of Alérion M1h.
For the certification of the innovative hybrid STOL aircraft, Avions Mauboussin will, therefore, use the following Certification Specifications and Special Conditions:

Table 4.7: Final Certification Basis

CS/SC	**Title**	**Version**
CS-23	Normal-Category Aeroplanes	Amdt 5
CS-34	Aircraft Engine Emissions and Fuel Venting	Amdt 2
CS-36	Aircraft Noise	Amdt 4
SC-VTOL-01	Special Condition for small-category VTOL aircraft	Issue 1 (revised by AMO)
SC E-19	Proposed Special Condition for Electric / Hybrid Propulsion System	Issue 1 (revised by AMO)
SC-HUD	Special Condition Head-Up Display Direction Indicator	Issue 1
SC-VLA.901-02	CS-VLA Aeroplanes with embedded aft engines and aft propeller	Issue 1
SC Steep slope approach and landing	Proposed Addition Special Condition to Steep Approach and Landing CRI replacing CS 23.1511	/

To which, as environmental protections, the CS-CO2 Issue 1, could not be added, as not applicable due to the application date.

Concerning the certification of the propeller, engine and avionics, instead, at the time of certification of Alérion M1h, Avions Mauboussin, will be an approved design organization (DOA under Part-21J) as well as an approved production organization (POA under Part-21G) but the major parts of the aeroplane, such as the propeller, engine and avionics will be certified by a TC or ETSO, and provided by suppliers with their own DOAs under Part-21J (or APDOAs under Part-21O) and approved production organizations (POA under Part-21G).
In the case of the engines, the thermal engine will be certified as E-APU TSO by Turbotech or "as part of the EHPS" while, the electric engine, designed by EMRAX, will be certified as Type Certificate by AMO or "as part of the aeroplane / EHPS" for electric motor + controller.
For the propeller, instead, a Type Certificate will be issued by Duc Hélices.

For the battery, finally, a design study is under development by the propulsion intern in collaboration with the suppliers. Being a Certification Intern, however, has been my task to identify the requirements the battery has to comply with. In particular, a study of the RTCA documents DO-160G and DO-311A has been carried out, in order to define the environmental conditions and test specifications for the future battery of the hybrid propulsion system of Alérion M1h. A summary table of this information according with the DO-160G specifications, can be found in Appendix 3.

Finally, Avions Mauboussin will use as references standards the Interpretative Material and Means of Compliance from ASTM Standards shown in the table here under that has been updated by me with new standards (bold text) relevant for the certification of Alérion M1h:

Table 4.8: Reference Standards used - ASTM International

Number	Title	Version
F3061	Systems and Equipment in Small Aircraft	20
F3062	Installation of Powerplant Installation	20
F3063	Design and Integration of Fuel/Energy Storage and Delivery System Installations for Aeroplanes	20
F3064	Control, Operational Characteristics and Installation of Instruments and Sensors of Propulsion Systems	20
F3065	Installation and Integration of Propeller Systems	19
F3066	Powerplant Systems Specific Hazard Mitigation	18
F3082	Weights and Centers of Gravity of Aircraft	17
F3083	Emergency Conditions, Occupant Safety and Accommodations	19
F3093	Aeroelasticity Requirements	20
F3114	Structures	19
F3115	Structural Durability for Small Airplanes	19
F3116	Design Loads and Conditions	18 'e1'
F3117	Crew Interface in Aircraft	19
F3120	Ice Protection for General Aviation Aircraft	19
F3173	Handling Characteristics of Aeroplanes	18
F3174	Establishing Operating Limitations and Information for Aeroplanes	19
F3179	Performance of Aeroplanes	18
F3180	Low-Speed Flight Characteristics of Aeroplanes	19
F3227	Environmental Systems in Small Aircraft	20
F3228	Flight Data and Voice Recording in Small Aircraft	17
F3229	Standard Practice for Static Pressure System Tests in Small Aircraft	17
F3230	Standard Practice for Safety Assessment of Systems and Equipment in Small Aircraft	17
F3231	Electrical Systems in Small Aircraft	19
F3232	Flight Controls in Small Aircraft	19ae1
F3233	Instrumentation in Small Aircraft	17
F3234	Exterior Lighting in Small Aircraft	17
F3235	Aircraft Storage Batteries	17a
F3236	High Intensity Radiated Field (HIRF) Protection in Small Aircraft	17
F3264	Normal Category Aeroplanes Certification	19
F3239	Standard Specification for Aircraft Electric Propulsion Systems	19
F3367	Standard Practice for Simplified Methods for Addressing High-Intensity Radiated Fields (HIRF) and Indirect Effects of Lightning on Aircraft	20
F3380	Structural Compliance of Very Light Aeroplanes	19

These 30 standards contain around 3000 lines of requirements that Alérion M1h has to comply with. To each of these requirements, the applicability to the various Aircraft Type Codes has been evaluated and an allocation to the ATA chapters has been done, continuing the work done by the previous interns.
Same work has been done for the requirements within the CS-23 Amendment 5, to which a proposition of Means of Compliance has been carried out by me. An overview of the work done is shown in Appendix 4.

In the figure 4.9, 5 Aircraft Type Codes, or ATCs, appear. The term ATC, is explained within the ASTM standard F3061, 'Standard Specification for Systems and Equipment in Small Aircraft', which states that '*an Aircraft Type Code (ATC) is defined by considering both the technical considerations regarding the design of the aircraft and the aeroplane certification level established based upon risk-based criteria*' [66]. An ATC is expressed as an alphanumeric character string where each character has its own meaning as shown in the following figure:

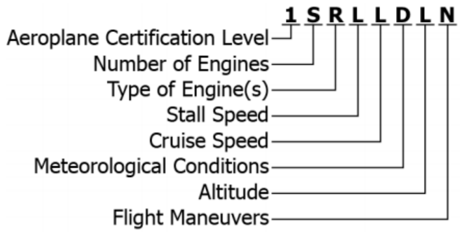


Figure 4.10: Illustration of Aircraft Type Code

Before the beginning of this thesis, the team of Avions Mauboussin had had some trouble with the definition of the ATC for Alérion M1h as the hybrid propulsion was not included as type of engine/propulsion within the F3061, which, instead, mentions the use of a reciprocating engine or turbine engine. The team has decided then to create a new ATC adapted for the specifications of Alérion M1h and to propose it to EASA.
In particular, two ATCs had been defined:

1. **1SHLLDLNP** = 1 : Aeroplane certification level 1 (two seater) – S : Single engine – H: Hybrid propulsion – L : Low stall speed (≤45 knots) – L : low cruise speed (≤ 250 knots or Mach ≤0.6) – D : Day VFR – L : Low altitude (≤ 25000 ft) – N : Non aerobatic – P : Private operations;

2. **1SHLLNLNP** = 1 : Aeroplane certification level 1 (two seater) – S : Single engine – H: Hybrid propulsion – L : Low stall speed – L : Low cruise speed – N : Night VFR – L : Low altitude – N : Non aerobatic – P : Private operations;

However, the further versions of Alérion M1h will be certified for IFR conditions, commercial operations and icing conditions, or FIKI. Therefore, within this thesis, 3 other ATCs have been proposed to cover the further operations here above mentioned:

1. **1SHLLILNP** = 1 : Aeroplane certification level 1 (two seater) – S : Single engine – H: Hybrid propulsion – L : Low stall speed – L : Low cruise speed – I : IFR operations – L : Low altitude – N : Non aerobatic – P : Private operations;

2. **1SHLLILNC** = Aeroplane certification level 1 (two seater) – S : Single engine – H: Hybrid propulsion – L : Low stall speed – L : Low cruise speed – I : IFR operations – L : Low altitude – N : Non aerobatic – C : Commercial operations;

3. **1SHLLKLNC** = Aeroplane certification level 1 (two seater) – S : Single engine – H : Hybrid propulsion – L : Low stall speed – L : Low cruise speed – K : FIKI operations – L : Low altitude – N : Non aerobatic – C : Commercial operations.

The last one, in particular, covers the operations in icing conditions which are not mentioned within the F3061 and therefore it is a proposition of Avions Mauboussin to EASA that has to be evaluated and accepted.

The introduction of the commercial operations as we can see in the last two ATCs, finally, requires the study of the requirements concerning the 'Commercial Air Transport', or CAT, issued by EASA within the Subpart D, section 1 of the Regulation (EU) No 965/2012 - Air Operations. A study of these requirements has been done as well as for the CS-23 Amendment 5 and for the ASTM standards, and it is shown in the Appendix 4.

This well defined Certification Basis allowed us to start compiling the certification programme for EASA, identifying Alérion M1h into the **phase I – Technical Familiarisation of the Type Certification Basis** of the EASA certification process as shown in Appendix 5.

4.3.4 Certification tool - License to Fly

Once the Certification Basis is established and all the CSs, SCs, ASTM standards, Certification Review Items (CRI), Certification Memorandums and all the other documents part of the certification are identified and gathered, the next step is to create an easy-to-read format which includes all the requirements relevant for the certification to be shown to the authorities.
Currently, there is a lack of innovation in this step as no tools have been made to allow the implementation of a certification programme in a faster and easier way, leading the companies to a huge hand-work on Excel.
For a plane certified under the CS-LSA, which foresees less than 1000 referenced standards, the amount of work is already considerable but when the plane is certified under the CS-23, as done for Alérion M1h, with more than 3000 referenced standards, the work becomes quite heavy and complicated. In particular, for small companies like Avions Mauboussin which don't have dedicated certification teams and which is facing the certification of its first plane, the work could not be split and has to be done by a single person strengthening considerably the total time and increasing the chance of mistakes.

The French company Dassault Systèmes, which has always been a leader in professional tools, has understood the problem and sensed the deal by creating a tool, called **License to Fly**, capable to meet these needs of the certification process.
License to Fly, is, therefore, a tool designed and thought by Dassault Systèmes to facilitate the certification process of big and small companies. The tool itself, however, is not only related for writing down the certification requirements but it helps also the company in the management of the entire project, namely time schedule, activities, costs and roles.

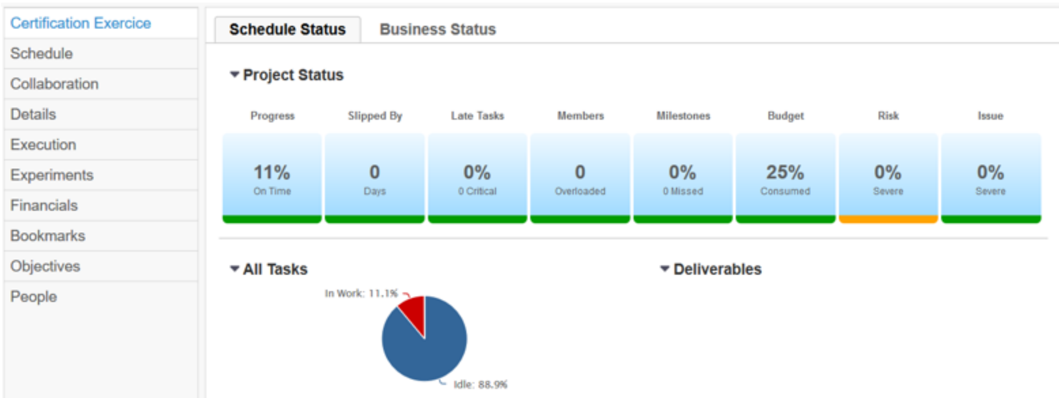


Figure 4.11: Example - Management of the project with License to Fly

On the last point, Avions Mauboussin has struggled a lot, before my arrival, to define, with Dassault Systémes, the management framework within small companies and certification process for small aeroplanes, both considerably different for what the tool had been made in the first place.
The global understanding of the management organisation of the company and the certification process the company will work with are important for the implementation and use of the tool as, for each application of the tool supporting a certification activity, a role in charge of the aforementioned application must be defined.

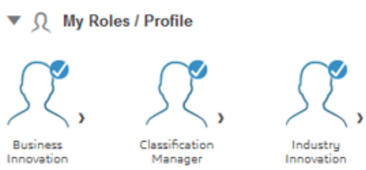


Figure 4.12: Example - Roles in License to Fly

Basically, Licence To Fly is based mostly on three applications:

1. **Reqtify**, which allows the importation of all the certification documents within the tool, avoiding the hand-work of copy and paste. The templates currently available have been structured by the company and the previous intern in according with the work done on Excel;

2. **Requirements Management**, which allows the actual implementation of the certification program thus allowing the definition of the certification basis: CSs, SCs, their requirements, their applicability to the various ATCs, the allocation of the ATA chapters, the proposition of the Means of Compliance and compliance documents;

3. **Traceability**, which enables the responsible of this activity to make a link between requirements in different documents as the traceability between the ASTM standards and CS-23.

4.3.4.1 Tool's functionalities design

During teh drafting of this thesis, several meetings have been set up with Dassaul Systémes to define the functionalities of the tool required by Avions Mauboussin.
In particular, taking into account the hand-work on Excel, the thesis proposes the functionalities which most could help the certification engineer during the drafting of the certification programme. The points raised up in this thesis, have been, therefore, presented and discussed with Dassaut Systémes, which, according to the feasibility of the requests, has constantly modified and adapted the tool according to our needs.

At the date, the following functions are offered by the tool:

1. Documents importation The tool can import documents containing certification requirements present in the Certification Basis, starting from whatever the original format of the document PDF or XML as defined by EASA, ASTM, RTCA:

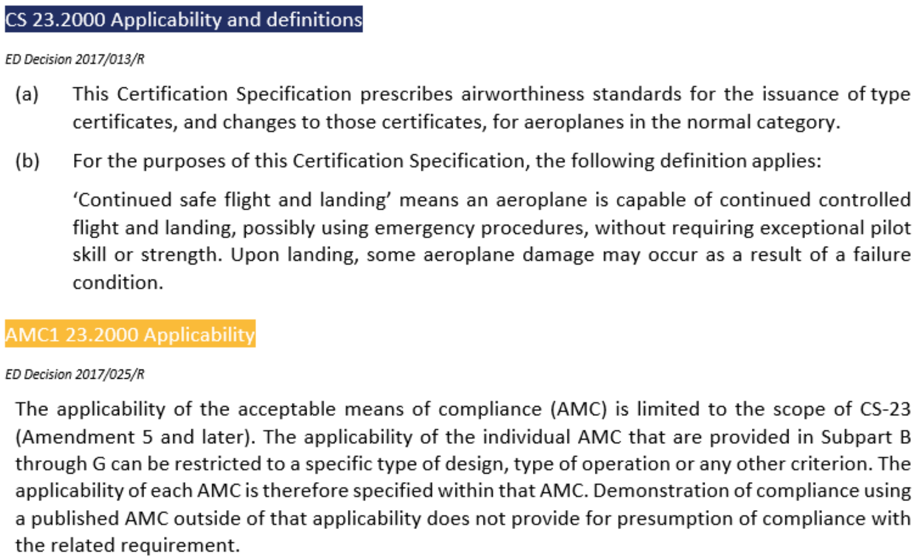
- CS-23 Amdt 5, CS-34, CS-36;
- Special Conditions: SC VTOL, SC E-19, Special Condition Head-Up Display Direction Indicator, Special Condition SC-VLA.901-02 Issue 1;
- Part 23 Commuter CRI 01 Steep Approach & Landing addition (VFE computation);
- AMC & GM to CS-23 Issue 2;
- OPS requirements for CAT and NCO operations according to EU 965/2008 - Annex IV (Part-CAT), Subpart D and Annex VII (Part-NCO), Subpart D.

Furthermore:

- ASTM: standards related to CS EASA (among others, those cited in AMC & GM of CS-23 Amdt 5);
- RTCA: specifications linked to the CSs or ETSO EASA;
- SAE: specifications linked to CS or ETSO EASA;
- EUROCAE: specifications linked to CS or ETSO EASA.

The importation will provide a breakdown into individual numbered requirements at sub-paragraph level.

For example:



CS 23.2000 Applicability and definitions

ED Decision 2017/013/R

(a) This Certification Specification prescribes airworthiness standards for the issuance of type certificates, and changes to those certificates, for aeroplanes in the normal category.

(b) For the purposes of this Certification Specification, the following definition applies:

'Continued safe flight and landing' means an aeroplane is capable of continued controlled flight and landing, possibly using emergency procedures, without requiring exceptional pilot skill or strength. Upon landing, some aeroplane damage may occur as a result of a failure condition.

AMC1 23.2000 Applicability

ED Decision 2017/025/R

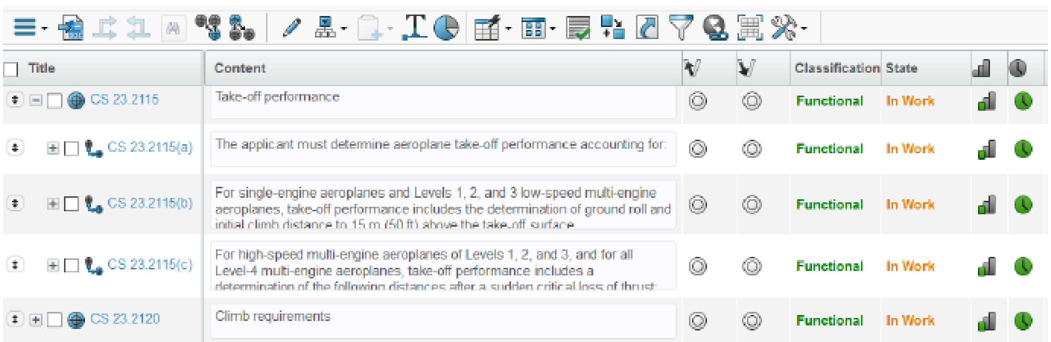
The applicability of the acceptable means of compliance (AMC) is limited to the scope of CS-23 (Amendment 5 and later). The applicability of the individual AMC that are provided in Subpart B through G can be restricted to a specific type of design, type of operation or any other criterion. The applicability of each AMC is therefore specified within that AMC. Demonstration of compliance using a published AMC outside of that applicability does not provide for presumption of compliance with the related requirement.

Figure 4.13: Example - Breakdown provided by the tool with the documents importation

The breakdown of these requirements after the importation in the tool will be as follows:

First level requirement
Number: CS 23.2000 (a);
Subpart: A - General;
Title: Applicability and definition;
Text: This Certification Specification prescribes...;
Version: 5.

Second level requirement
Number: AMC1 CS 23.2000;
Title: Applicability;
Text: The applicability of the acceptable means of ...;
Version: 1.



Title	Content	Classification	State
CS 23.2115	Take-off performance	Functional	In Work
CS 23.2115(a)	The applicant must determine aeroplane take-off performance accounting for:	Functional	In Work
CS 23.2115(b)	For single-engine aeroplanes and Levels 1, 2, and 3 low-speed multi-engine aeroplanes, take-off performance includes the determination of ground roll and initial climb distance to 15 m (50 ft) above the take-off surface	Functional	In Work
CS 23.2115(c)	For high-speed multi-engine aeroplanes of Levels 1, 2, and 3, and for all Level-4 multi-engine aeroplanes, take-off performance includes a determination of the following distances after a sudden critical loss of thrust:	Functional	In Work
CS 23.2120	Climb requirements	Functional	In Work

Figure 4.14: Example - Overview of the requirements breakdown

2. Hierarchical organization of requirements with traceability and coverage The second level requirements (AMC, GM and ASTM) are linked by the tool to the first level requirements by implementation/satisfaction links.

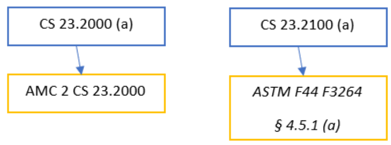


Figure 4.15: Example - Requirements traceability

The tool identifies non-stated (no lower-level requirement) or derived (no higher-level requirement) requirements for validation and calculates the coverage rate (% of requirement satisfied by a requirement of a lower level).

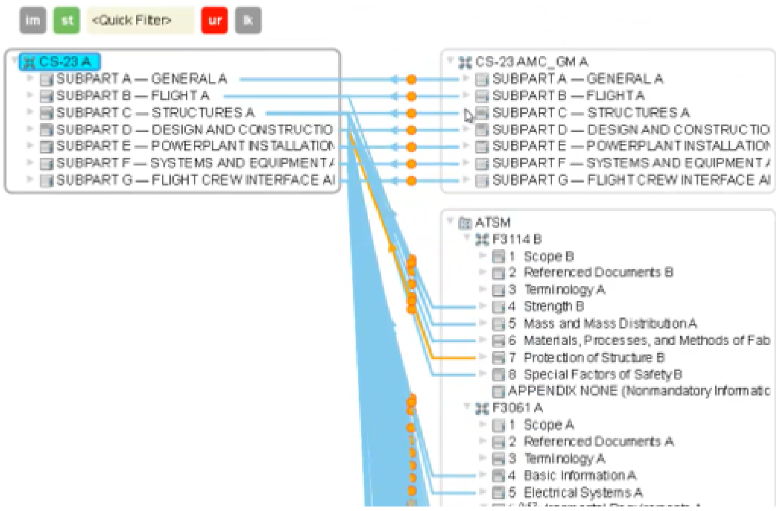


Figure 4.16: Example - Requirements traceability

3. Delta update of the documents The tool will allow the update "by delta" of the documents and certification requirements mentioned in the first paragraph with a proposal to update the traceability links and a generation of a summary table of modifications.

Standard Number	Version 06/2018	CS-23 AMC& GM Amdt 1 at 25 March 2019	CS-23 AMC&GM Amdt 2	01/04/2020	Standard's name into the CS-23 AMC&GM Amdt1	Changes from Amdt 1 to 2020	Changes from Amdt 2 to 2020
F3061	17	17	17	19a	Standard Specification for Systems and Equipment in Small Aircraft	Several changes into sections 3,4,5(Electrical system),10(Hazard Mitigation),13 (Mechanical Systems & Equipment),17(Lightning Protection),18. For most of them, it's just a 'vocabulary change'	Several changes into sections 3,4,5(Electrical system),10(Hazard Mitigation),13 (Mechanical Systems & Equipment),17(Lightning Protection),18. For most of them, it's just a 'vocabulary change'

Figure 4.17: Example of a summary table of changes for ASTM standards

4. Impact study The tool will calculate the impact of the modification, addition or deletion of a requirement on the related requirements, validation and verification activities (MOC and associated test cases), associated supporting documents.

5. Creation of the "Aircraft Type Code" (ATC) The tool allows to define the 5 modes of operation of Alérion M1h with the creation of the Aircraft Type Codes, or ATCs, according to or derived from the standard ASTM F3061.

6. Applicability of requirements For each requirement at each level, the tool will allow:

1. To define whether or not it is applicable to a Type Certificate (e.g. Alérion M1h TCDS EASA A.973);
2. To define whether or not it is applicable to a Model within a Type Certificate (e.g. A320-200neo IGW);
3. To define whether or not it is applicable to a mode of operation according to the Aircraft Type Code;

The set of requirements applicable to a Type/model/mode of operation is a "standard" or "baseline".

7. Certification Basis The tool can create a table showing the details of the certification basis for EASA.
In particular, the table will indicate the identification of the Certification Specifications (CS) and/or Special Conditions (SC), the title, the version on a given date, the version on the date of TC's request to EASA and on any other relevant date. The table will include as well, the associated observations and justifications.

CS/SC Number	CS/SC Name	Version 06/2018	Application date - 25 March 2019	Elect to Comply 01/04/2020	Remarks
CS-23	Normal-Category Aeroplanes	Amdt 5 - Aug 2017	Amdt 5 - Aug 2017	Amdt 5 - Aug 2017	

Figure 4.18: Example - Certification Basis table made by the tool

8. Table of AMC & GM and their versions The tool will make it possible to create a table of AMC & GM and their versions to be presented to EASA for the detailed definition of the certification basis and certification programme.
In particular, the table will indicate the ASTM standards, RTCA DO specifications, EUROCAE ED, SAE AS & ARP associated with the CS-23, their titles, versions on a given date, the version on the date of TC's request to EASA and on any other relevant date. The table will include as well, the associated observations and justifications.

Standard Number	Standard Name	Version 06/2018	CS-23 AMC&GM Amdt 1 Application date: 25 March 2019	CS-23 AMC& GM Amdt 2	Elect to Comply 01/04/2020
F3061	Systems and Equipment in Small Aircraft	17	17	17	19a

Figure 4.19: Example - Table of the ASTM versions on different dates

9. Requirements Allocation For each requirement at each level, the tool will allow:

1. The allocation of the requirement to the entire aircraft or;
2. The allocation of the requirement to a part of the aircraft designated by its ATA chapter or;
3. The allocation of the requirement to multiple parts of the aircraft designated by their ATA chapters.

The tool will calculate, furthermore, the coverage rate (% of requirement allocated at the time T).

10. Requirements validation For each requirement at each level, the tool allows to:

1. Define a validation method: review, analysis, mock-up;
2. Define a validation status: in progress, commented, validated;
3. Define a validation document: C / R review, analysis report, test report;
4. Calculate the coverage rate (% of requirement in progress, commented, validated at the time T).

Where the term validation is defined by the document ARP4754 Revision A, as '*The determination that the requirements for a product are correct and complete. [Are we building the right aircraft/ system/ function/ item?]*' [67];

11. Requirements implementation For each requirement at each level, the tool will allow to:

1. Define whether the requirement is implemented for a "build" or "standard": YES / NO / PARTIALLY;
2. Define any associated limitations: flight restriction, customer exemption, EASA approval, etc.
3. Calculate the coverage rate (% of requirement implemented at the time T).

12. Requirements verification For each requirement at each level, the tool allows to:

1. Define a verification method: MOC0 to MOC9 according to AMC21.A.20 (b);
2. Define a validation status: in progress, verified OK, verified KO;
3. Define a verification document: C / R review, analysis report, test report ...;
4. Calculate the coverage rate (% of the current requirement, OK or KO at time T).

Where the term verification is defined by the document ARP4754 Revision A, as '*The evaluation of an implementation of requirements to determine that they have been met. [Did we build the aircraft/ system/ function/ item right?]*' [67].

13. Control of modifications / Monitoring of non-conformities For each problem (requirement not or partially validated, implemented, verified), or modification request, the tool will allow to:

1. Define the problem or the requested modification with a reference requirement, a baseline and a standard;
2. Classify the problem or the requested modification: constraint, major or minor;
3. Carry out the analysis of the problem or modification, its impact, its solution;
4. Decide whether to correct the problem or apply the modification to a baseline or a standard;
5. Record the justification for the non-correction (exemption) or modification

14. Comparison statistics between CS-LSA / CS-23 / CS-25 The tool will make it possible to carry out a comparative study of the number of requirements necessary for the certification between the various "Certification Specifications" (CS-LSA / CS-23 / CS-25 etc.) and to display the statistics in a table.

15. Statistics of the applicability of different ASTMs to ATCs The tool will make it possible to carry out a statistic for the 'work scopes' on the number of ASTMs applicable to the different Aircraft Type Codes.
The tool also will make it possible to display the results thanks to a graphic representation on a histogram.

Requirement or Information (R,I)	R
1SHLLNLN	(Plusieurs éléments)
Number	(Tous)
Étiquettes de lignes	**Nombre de 1SHLLNLN**
Aerodynamic	493
Avionic	309
Ice	3
Operating Limitations	102
Powerplant	409
Safety Assessment	34
Structure	270
Total général	**1620**

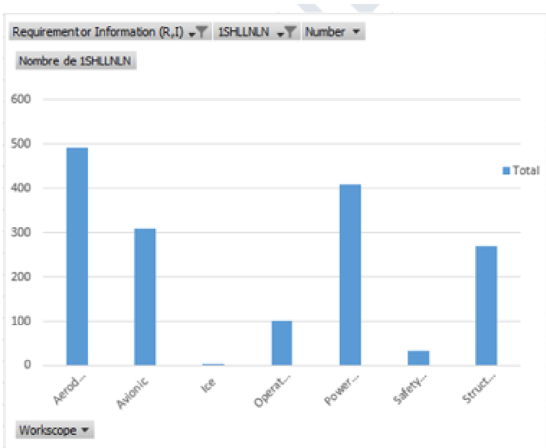


Figure 4.20: Example - Statistics of the applicability of different ASTMs to the ATC 1SHLLNLN

16. Certification programme for EASA The tool will be used to create the certification programme for EASA according to the EASA 'DOA Template Form Type Certification Programme'.

17. Linking compliance documents with the related requirements The tool will allow the linking of compliance documents to the related requirements, demonstrating, therefore, their compliance. The linkage will allow, in particular, to have:

1. Reference;
2. Archiving according to Part-21;
3. Configuration control;
4. Traceability of modifications;
5. Approval according to the authorities defined in the Certification Programme or APDOA or DOA.

18. Review and acceptance of proof documents by EASA The tool will allow EASA access, review, comment and acceptance after any changes to the compliance documents, with at least:

1. Archiving;
2. Configuration control;
3. Recording of remarks;
4. Traceability of modifications;
5. Approval according to authorities defined in the Certification Programme.

19. EASA Design Data Review The tool will allow EASA access, review, comment and acceptance after any modifications to the design data (Type Design Data), with at least:

1. Archiving;
2. Configuration control;
3. Recording of remarks;
4. Traceability of modifications;
5. Approval according to authorities defined in the Certification Programme.

All the access to the tool will be allowed by the tool guaranteeing the protection of the industrial property of Avions Mauboussin.

Chapter 5

Conclusion

[**Operations**] The main objective of this thesis was to define an operational framework suitable for a hybrid STOL aircraft carrying out several new technologies. The so-called operational framework should show the operations that this plane could perform in the Urban Air Mobility scenario according to its performance and to the regulations. The study has, therefore, analysed for instance the suitable operations foreseen by the ever closer Urban Air Mobility scenario, namely air-taxi, airport shuttle and intercity flights. This analysis revealed that among these three operations the one which Alérion M1h could fit best looks like be the third one, namely the intercity connection. Hostilities towards air-taxi and airport shuttle operations, in fact, came up by a study of the air regulations of the European countries with aviation experts who still wary of a global opening, by European countries, to these operations. The fear looks like to be the complex operational scenario which would come up in metropolitan areas and which would be difficult to manage, endangering, therefore, the safety. Alérion, however, will not give up on urban operations. The intercity connection performed by Alérion, in fact, will foresee a direct access to the heart of the cities with a net reduction of CO2 emissions, compared to conventional vehicles, given that Alérion takes off and lands in fully electric mode.

However, since Alérion M1h is not able to perform vertical take-off and landing, the thesis has been aimed at analysing the current operational performances of the aircraft and the feasibility of its use in an urban scenario. The aircraft's strength for carrying out these urban operations could be considered its ability to perform a steep slope approach to stop completely in 100 meters relying on its advanced high-lift devices as slats and double-slotted flaps. Therefore, the take-off and landing performance have been carefully analysed. The difficulties encountered in the realisation of this analysis, however, have been several and they were mostly centred on the lack of aerodynamics data which led to assumptions and approximations. Despite the inaccuracy of some data, however, the analysis has been carried out correctly and should not deviate much from the actual aircraft performances.
The results that came up from this analysis, in particular, clearly show how the plane, with the current performances, is still not able to perform a take-off in 100 m and either a landing in such distance. Alérion M1h, in fact, needs around 160 meters to complete the take-off, overcoming 15 m obstacle, and 115 meters to stop completely. A study of the possible solutions to reduce these distances has been, therefore, shown in the paper, bringing to light how the project needs to be revisited. According to that, two aspects of the project have been analysed: the propulsion system and aerodynamics. The paper shows then as the first has been set aside, as to get to a satisfactory result the project should be upset drastically providing the plane with an engine bigger than the EMRAX 268, and new batteries suitable with the new specifics of the propulsion system. At the date, therefore, an effort should be put, in particular, on the aerodynamics project, as the most efficient solution to perform the desired performance has been considered, in fact, the reduction of the V_{Stall}, possible acting on the factor (S$\cdot C_L$). The latter, therefore, must be increased on the ongoing project according to the increase of the surface of the flaps, thus of the wing, considered better and most feasible than a massive modification of the airfoil, close to the tests, to increase considerably the $C_L max$.

With these operational performances, plus its 600 km range, Alérion could satisfy then two markets: point-to-point market and hub-and-spoke market. In the first case, Alérion could provide a new level of mobility for the commuting service between any point of interest, for both work and leisure, even in the heart of the cities if appropriate airparks or occasional surfaces are provided. For the hub-and-spoke market, instead, Alérion could come in help bringing passengers from any rough and unprepared surfaces to the main hubs obviating the connection lack between secondary airports and main hubs and lightening the trip from a small town to an oversea destination. Two cases, in particular, have been analysed and shown in the paper: Belfort-Toulouse and Paris-London. In both the cases, Alérion has presented advantages, in terms of time and comfort, over the current means of commuting.

Perspectives The results obtained by the analysis carried out in this thesis can be used as benchmark for the further development of Alérion M1h's performances. In particular, the infeasibility of the operational performances desired, shown for the current performances of the plane at the current stage of the project, should push the company towards a crossroads: upset the project to reach the performances desired or make changes to the project within the limits allowed without distorting it and without lengthening the time. In the first case, time and resources have to be spent, in fact, on the propulsion system, which could lead to several changes on the design of the planes, and on the design of the wing. Therefore, the path that Avions Mauboussin should take, in my opinion, is the second one because, even if the results are not the desired ones, however, they can be considered satisfactory and surprising for an aircraft with a maximum power of 106 KW and MTOM of 600kg, placing it definitely ahead of its direct competitors. Furthermore, the effort to land and take-off in 100 meters is not justified and does not worth it, as, according to the regulations, the runways that can host the plane, must be long enough to satisfy the safety factors foreseen by the requirements for both the phases. According with the specifics of pilot's manuals and national safety standards like the AIC 127/2006 - 'Take-Off and Landing performance of light aeroplanes', issued by the CAA, in fact, other than the safety factors foreseen in case of a wet surface or an increase of temperature, is highly recommended to consider a supplemental safety factor of 30% [68]. Plus, even the airparks, according to the ASTM standard F2507-15, they must have a minimum length, twice the demonstrated or published minimum landing and take-off distance requirements of the aircraft to be served or 275 m at sea level, whichever is greater. [39]
Taking advantage of the results already obtained, instead, they would still allow the plane to perform all the operations desired and foreseen by the company, becoming a valuable asset to the UAM scenario and to the commuting activities.
Finally, the two studies that should follow this thesis are: the feasibility study of a steep slope approach of 20 % and the training of the future pilots of Alérion M1h. The latter, is a topic rather hostile that should be carried out carefully, as the pilots have to be trained in a scenario perfectly matching the operations that will be carried out by Alérion.

[**Certification**] The second objective of this thesis, not less important than the previous one, was to define the regulatory framework suitable for the extreme operations and innovations carried out by Alérion M1h like the hybrid propulsion. The paper, first of all, shows how the CS-23 has been favoured, over the simpler CS-LSA, as certification specification for Alérion M1h. The flexibility, the easier considerations of unusual design features and the full harmonisation with the FAA's requirements have been the the key points of this choice. It is followed by the choices made for the certification of the hybrid propulsion, considered an absolute novelty, and for the certification of urban operations, considered unusual for a fixed-wing aircraft. For the urban operations, since no special conditions for STOL aircraft have been issued and are not in planning by the authority, the category enhanced of the SC VTOL has been considered the most pertaining way to cover those operations. The paper, furthermore, highlights the main issues of this special condition, already in an advanced stage, concerning, in particular, the classification of VTOL aircraft as a new category of aircraft devoid of operating procedures and with a safety level of an airline that aroused several controversies.
To obviate to the first aspect, namely the hybrid propulsion system, instead, the SC E-19 has been considered the most pertaining to the Alérion project since the already existing certifications specifications, like the CS-E Amendment 5, did not consider electric or hybrid propulsion system. The aforementioned special condition, however, is still in development by EASA, and at the date, only a proposed document has been issued with obviously lacks such as the absence of specifications on the Battery Management System, or BMS, cornerstone of a hybrid propulsion system that foresees the use of batteries. For this, the thesis proposes examples of new standards that should be included in the SC E-19 to cover the BMS specifications
Finally, the thesis shows the implementation of the certification tool License to Fly, thought and

designed by Dassault Systémes, which will simplify the certification process of small size aircraft like Alérion, in terms of time and project management.

Perspectives This thesis, as already explained, shows as result the definition of a certification basis suitable to the technologies and performance of Alérion M1h. It, therefore, will allow Avions Mauboussin to discuss the acceptance of the certification programme with EASA and be a point of reference for the certification of small size aircraft with hybrid propulsion and technologies similar to the ones of Alérion. Furthermore, the paper should create awareness of the issues and ever-presents lacks within the special conditions SC VTOL and SC E-19, pushing the authorities to revise some aspects of them. Finally, the thesis can be considered as the the most complete presentation of the advantages and functionalities of the certification tool License to Fly, allowing those who are undergoing a certification process to understand the advantages of using the aforementioned tool, taking advantage of it and thus contributing to a revolution in the certification process.

Chapter 6

Acronyms

	A
ACM	Acceptable Means of Compliance
AESA	Agencia Estatal de Seguridad Aérea
AFM	Aircraft Flight Manual
AGL	Above Ground Level
AltMoCs	Alternative Means of Compliance
ANP	Non-sloping airfield
AP	Sloping Airfield
a_R	Acceleration during the rotation
ASTM	American Society for Testing
ATC	Aircraft Type Code
ATC	Air Traffic Control
ATM	Air Traffic Management
	B
BAs	Bilateral Agreement
BMS	Battery Management System
BOE	Boletín Oficial del Estado
	C
CAMO	Continuing Airworthiness Management Organisation
CAT	Commercial Air Transport
CB	Certification Basis
CCS	Carbon Capture and Storage
CDI	Compliance Demonstration activities
C_L	Lift Coefficient
CoFA	Certificate of Airworthiness
ConOps	Concept of Operations
CPL	Commercial Pilot License
CS	Certification Specifications
	D
D	Drag
Daero	Aerodynamics Drag
D_fr	Friction Resistance
DGAC	Direction générale de l'Aviation civile
DOA	Design Organisation Approval
DR	Delegated Regulations
DSAC	Direction de la sécurité de l'aviation civile
D_tg	Total resistance on the ground
	E
EASA	European Aviation Safety Agency
EHPS	Electric and/or Hybrid Propulsion System
EIS	Entry Into Service
ELA	European Light Aircraft
ELISA	École d'Ingénieurs des Sciences Aérospatiales
ENAC	Ente Nazionale per l'Aviazione Civile
ENAC	Ecole Nationale de l' Aviation Civile
ER	Essential Requirements
ESF	Equivalent Safety Finding
eSTOL	extremely Short Take-Off and Landing
ETSO	European Technical Standard Order
EU	European Union
eVTOL	electric Vertical Take-Off and Landing
	F
F	rolling friction coefficient
FAA	Federal Aviation Administration
FATO	Final Approach and Takeoff
FIKI	Flight Into Known Icing
Fpm	Feet per minute
Ft	Feet
	G
g	Gravitational acceleration
GHG	Greenhouse Gas
GM	Guidance Material

	H
HEMS	Helicopter Emergency Medical Services
Hf	flare height
HOTAS	Hands on Throttle-And-Stick
	I
IAC	Instrument Approach Charts
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
INSA	Institut National des sciences appliquées
IPSA	Ecole d'Ingénieurs en Aéronautique et Spatial
IR	Implenting Rules
	K
KIAS	Knots Indicated Air Speed
	L
L	Lift
LCY	London City Airport
LoI	Level of Involvement
LSA	Light Sport Aircraft
CDI	Compliance Demonstration activities
	M
m	metres
MAHEPA	Modular Approach to Hybrid-Electric Propulsion Architecture
MOC	Means Of Compliance
MPH	Mile per Hour
MTOM	Maximum Take-Off Mass
	N
N	Newton
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NCO	Non-Commercial Operations
NSO	NATO Standardization Office
	O
OSAC	Organisme pour la Sécurité de l'Aviation Civile
OPS	Operations
OSD	Operational Suitability Data
	P
PAC	Police Aux Frontières
PCM	Programme Certification Manager
PIC	Pilot In Command

POA	Product Organisation Approval
PPL	Private Pilot License
PSU	Provider of Services for UAM
	Q
QFE	Atmospheric pressure at Field Elevation
QFU	Magnetic bearing of the runway in use
QNH	Regional Pressure Setting
	R
R	Radius of the flare
RTCA	Radio Technical Commission for Aeronautics
	S
SAF	Sustainable Aviation Fuel
SAE	International: Society of Automotive Engineers
SC	Special Conditions
SDSP	Supplemental Data Service Provider
STAP	Système de transmission automatique de paramètres sur un aérodrome
STOL	Short Take-Off and Landing
	T
T	Thrust
T/O	Take-Off
TAS	True Air Speed
TC	Type Certificate
t_R	rotation time
	U
UAM	Urban Air Mobility
UTBM	Université de technologie de
	Belfort Montbéliard
UTM	Unmanned Aircraft System Traffic Management
	V
VAC	Visual Approach and landing Charts
Vapp	Approach speed
Vf	flare speed
VFR	Visual Flight Rules
VHF	Very High Frequency
V/STOL	Vertical and/or Short Take-Off and Landing
VTOL	Vertical Take-Off and Landing
Vz	best rate of climb speed
	W
W	Weight
Wm	Average weight

Chapter 7

Appendix

7.1 Appendix 1

7.1.1 REGULATIONS Structure 28 October 2019

EASA
European Union Aviation Safety Agency

Latest information is available via https://www.easa.europa.eu/regulations
Including Acceptable Means of Compliance, Guidance Material (AMC/GM) and Certification Specifications (CS)
View our FAQ's via https://www.easa.europa.eu/the-agency/faqs

	IR: Implementing regulation DR: Delegated regulation	Annexes	
Basic Regulation	IR: (EU) 2018/1139		
Initial Airworthiness	IR: (EU) No 748/2012	Annex I: Part-21	
Additional airworthiness specifications for operations	IR: (EU) 2015/640	Annex I: Part-26	
Continuing airworthiness	IR: (EU) No 1321/2014	Annex I: Part-M Annex II: Part-145 Annex III: Part-66 Annex IV: Part-147 Annex Va: Part-T	
Aircrew	IR: (EU) No 1178/2011	Annex I: Part-FCL Annex II: Conversion of non-EU licences Annex III: Licences of non-EU states Annex IV: Part-MED	Annex V: Part-CC Annex VI: Part-ARA Annex VII: Part-ORA Annex VIII: Part-DTO
Air operations	IR: (EU) No 965/2012	Annex I: Definitions Annex II: Part-ARO Annex III: Part-ORO Annex IV: Part-CAT	Annex V: Part-SPA Annex VI: Part-NCC Annex VII: Part-NCO Annex VIII: Part-SPO
Balloons - Air Operations	IR: (EU) 2018/395	Annex I: Part-DEF Annex II: Part-BOP	
Third country operators	IR: (EU) No 452/2014	Annex I: Part-TCO Annex II: Part-ART	
ATM/ANS	IR: (EU) 2017/373	Annex I: Definitions Annex II: Part-ATM/ANS.AR Annex III: Part-ATM/ANS.OR Annex IV: Part-ATS Annex V: Part-MET Annex VI: Part-AIS Annex VII: Part-DAT	Annex VIII: Part-CNS Annex IX: Part-ATFM Annex X: Part-ASM Annex XI: Part- ASD Annex XII: Part-NM Annex XIII: Part-PERS

ATCO	IR: (EU) 2015/340	Annex I: Part ATCO Annex II: Part ATCO.AR Annex III: Part ATCO.OR Annex IV: Part ATCO.MED
Airspace usage requirements (ACAS II)	IR: (EU) No 1332/2011	Annex: ACAS
Airspace usage requirements (PBN)	IR: (EU) 2018/1048	Annex: Subpart PBN
SERA	IR: (EU) No 923/2012	Annex: Standardised European rules of the air
Aerodromes	IR: (EU) No 139/2014	Annex I: Definitions Annex II: Part-ADR.AR Annex III: Part-ADR.OR Annex IV: Part-ADR.OPS
SKPI - Safety Key Performance Indicators	IR: (EU) 2019/317	
Sailplanes – Air Operations	IR: (EU) 2018/1976	Annex I: Part-DEF Annex II: Part-SAO
Unmanned Aircraft Systems (UAS) (Rules and procedures for the operation of unmanned aircraft)	IR: (EU) 2019/947	Annex: UAS ops in the 'Open' and 'Specific' categories
Unmanned Aircraft Systems (UAS) (Rules for design and manufacture of Unmanned aircraft systems and rules for third-country operators of unmanned aircraft systems)	DR: (EU) 2019/945	Annex: Annex

An agency of the European Union

Figure 7.1: EASA regulations structure

7.2 Appendix 2

7.2.1 Example of TC - EASA Type Certificate EASA.A.573 (Pipistrel Velis Electro)

EASA
European Union Aviation Safety Agency

TYPE CERTIFICATE

EASA.A.573

This certificate is issued by the European Union Aviation Safety Agency (EASA) in accordance with Regulation (EU) 2018/1139, in particular Article 77 (1) (e) thereof and Commission Regulation (EU) No. 748/2012 to

PIPISTREL VERTICAL SOLUTIONS d.o.o.

VIPAVSKA CESTA 2
5270 AJDOVSCINA
SLOVENIA

EASA.21J.524

and certifies that the product type design listed below complies with the applicable Type Certification Basis and, if applicable, environmental protection requirements when operated within the conditions and limitations specified on the associated Type Certificate Data Sheet Number: **EASA.A.573**

Type Design: **Virus SW 121**

Model	**Initial Certification Date***
Virus SW 121	18 April 2016
Virus SW 128 (Velis Electro)	10 June 2020

*Note: With regard to a product for which a type certificate was issued before 28 September 2003 by an EASA Member State, the Initial Certification Date refers to the date of issuance of the initial type certificate of this product by the competent authority of that State.

For the European Union Aviation Safety Agency

Cologne, Germany, 10 June 2020

Dominique ROLAND
Head of Department
General Aviation

An Agency of the European Union

Task Number: 10006366
PIPISTREL VERTICAL SOLUTIONS d.o.o. - 309146

TE.CERT.00090-006 Page 1 of 1

Figure 7.2: EASA.A.573 (Pipistrel Velis Electro)

7.3 Appendix 3

7.3.1 Environmental conditions and test specifications for the batteries according with the DO-160G

Table 7.1: Environmental conditions and test specifications for batteries according with the DO 160-G

Section	**Chapter**	**Category 1 Title**	**Category Level 1**	**Modifications for AMO***
Temperature and Altitude	4	Equipment	B4	**Altitude**: [AMO]; **Op.Low T**: [AMO]; **Op.High T**: [AMO]; **Short-Term Op. High T.**:[AMO]; **G.Sur.Low**:[AMO]; **G.Sur.High**:[AMO]
Temperature Variation	5	Temperature Change Rate	B	2 cycles
Humidity	6	Humidity	B	**Survival T**:[AMO]
Operational Shocks and Crash Safety	7	Operational Shocks and Crash Safety	E	**Category F**: Fixed orientation
Operational Shocks and Crash Safety	7	Test Procedure (2)	Fixed-Wing Non-Transport	
Vibration	8	Aircraft Category	Fixed Wing	
Vibration	8	Test Category	S	
Vibration	8	Aircraft Zone	Aircraft zone 1	Curves [AMO]
Vibration	8	Aircraft Zone	Aircraft zone 2	Curves [AMO]
Vibration	8	Aircraft Zone	Aircraft zone 3	Curves [AMO]
Vibration	8	Aircraft Zone	Aircraft zone 4	Curves [AMO]
Vibration	8	Aircraft Zone	Aircraft zone 5	Curves [AMO]
Vibration	8	Aircraft Zone	Aircraft zone 6	
Vibration	8	Aircraft Zone	Aircraft zone 7	
Explosive Atmosphere	9	Equipment	E	
Explosion Proofness	9	Explosion Zone	Aircraft Zone II	
Explosion Proofness	Appendix	Explosion Zone	Aircraft Zone II	
Explosion Proofness	9	Explosion Zone	Aircraft Zone III	
Explosion Proofness	Appendix	Explosion Zone	Aircraft Zone III	
Waterproofness	10	Equipment	Y	
Fluids Susceptibility	11	Equipment	F	
Fluids Susceptibility	11	Contaminant	1	
Fluids Susceptibility	11	Contaminant	2	
Fluids Susceptibility	11	Contaminant	3	
Fluids Susceptibility	11	Contaminant	4	
Fluids Susceptibility	11	Contaminant	5	
Fluids Susceptibility	11	Contaminant	6	
Fluids Susceptibility	11	Contaminant	7	
Fluids Susceptibility	11	Contaminant	8	
Fluids Susceptibility	11	Contaminant	9	
Fluids Susceptibility	11	Contaminant	10	
Sand and Dust	12	Equipment	S	
Fungus Resistance	13	Equipment	F	
Salt Spray	14	Equipment	S	
Magnetic Effect	15	Equipment	C	Except for landing and taxi lights, Nav-lights, strobes

Section	**Chapter**	**Category 1 Title**	**Category Level 1**	**Modifications for AMO***
Power Input	16	Equipment	B	
Power Input	16	Equipment	D	Only for the propulsion: **-Voltage**: [AMO]; **- D*R**: [AMO]; **- Surge Voltage**: [AMO]; **- Abnormal Surge Volt.**: [AMO];
Power Input	16	Equipment Cat. for additional tests	R	Only for electronic power
Power Input	16	Equipment Cat. for additional tests	I	
Voltage Spike	17	Equipment	A	
Audio Frequency Conducted Susceptibility - Power Inputs	18	Equipment	B	
Induced Signal Susceptibility	19	Equipment	CC	
Induced Signal Susceptibility	19	Equipment	ZC	
Radio Frequency Susceptibility	20	Equipment	R	High Criticality Equipment
Radio Frequency Susceptibility	20	Equipment	W	Low Criticality Equipment
Emission of Radio Frequency Energy	21	Equipment	Q	
Lightning Induced Transient Susceptibility	22	Waveform Set Designators (First and Third Characters)	B3	
Lightning Induced Transient Susceptibility	22	Waveform Set Designators (First and Third Characters)	K3	
Lightning Induced Transient Susceptibility Susceptibility	22	Waveform Set Designators (First and Third Characters)	M3	
Lightning Direct Effect	23	Test Category	Not applicable	
Icing	24	Test Category	A	Pitot probe only
Electrostatic Discharge	25 25	Equipment Equipment	A A	
Fire, Flammability	26	Equipment	B Fire Resistant	Turbine compartment
Fire, Flammability	26	Equipment	C Flammability	Except for small parts

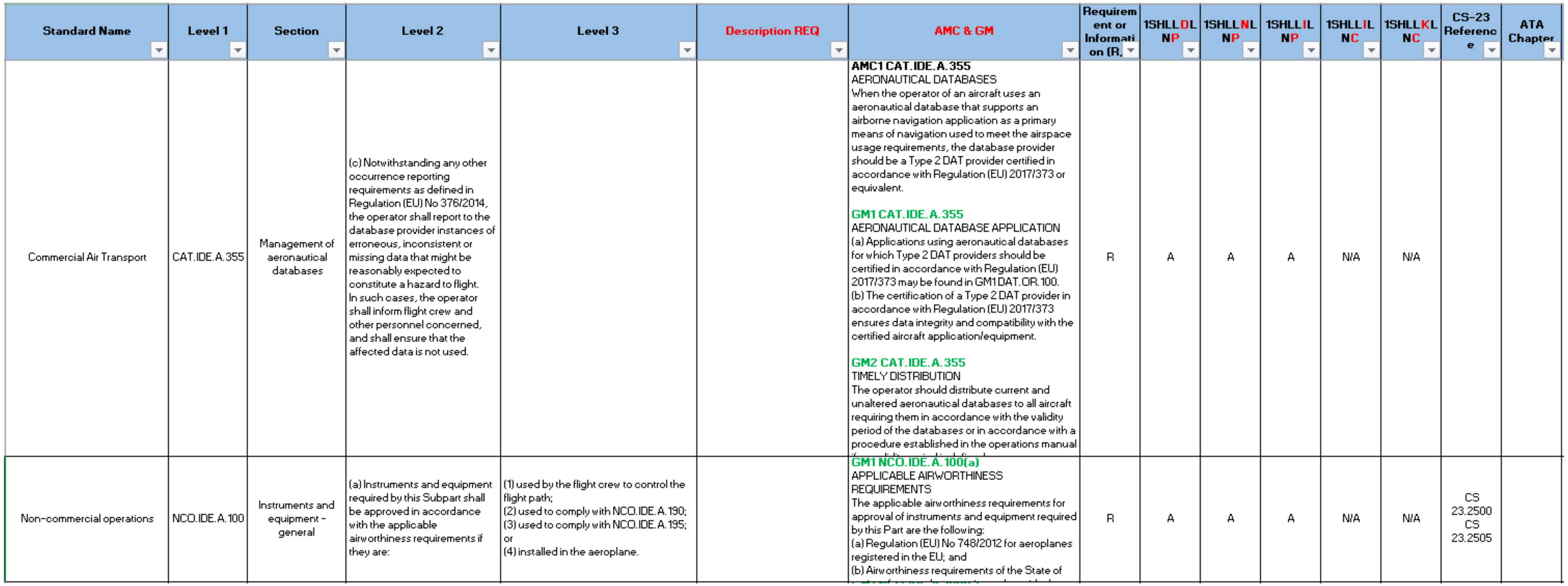
NOTE:
* *Some data have been hidden and replaced by [AMO] as confidential data according with the policy of the company Avions Mauboussin.*

7.4 Appendix 4

7.4.1 Certification Basis implementation in Excel

CS	Subpart	Title	Requirement	MOC	Compliance Document	Requirement o Inform…	1SHLLD LNI	1SHLLNL NP	1SHLLIL NP	1SHLLIL NC	1SHLLKL NC	ATA Chap
CS 23.2000	A - General	Applicability and definitions	(a) This Certification Specification prescribes airworthiness standards for the issuance of type certificates, and changes to those certificates, for aeroplanes in the normal category.	MOC 0	Type Design documents	I	A	A	A	A	A	ATA 04
CS 23.2110	B - Flight	Stall speed	The applicant must determine the aeroplane stall speed or the minimum steady flight speed for each flight configuration used in normal operations, including take-off, climb, cruise, descent, approach, and landing. The stall speed or minimum steady flight speed determination must account for the most adverse conditions for each flight configuration.	MOC 2	Substantiation reports	R	A	A	A	A	A	ATA 02
CS 23.2115	B - Flight	Take-off performance	(a) The applicant must determine aeroplane take-off performance accounting for: (1) stall speed safety margins; (2) minimum control speeds; and (3) climb gradients.	MOC 2	Substantiation reports	R	A	A	A	A	A	ATA 02
CS 23.2115	B - Flight	Take-off performance	(b) For single-engine aeroplanes and Levels 1, 2, and 3 low-speed multi-engine aeroplanes, take-off performance includes the determination of ground roll and initial climb distance to 15 m (50 ft) above the take-off surface.	MOC 2	Substantiation reports	R	A	A	A	A	A	ATA 02
CS 23.2115	B - Flight	Take-off performance	(c) For high-speed multi-engine aeroplanes of Levels 1, 2, and 3, and for all Level-4 multi engine aeroplanes, take-off performance includes a determination of the following distances after a sudden critical loss of thrust: (1) an aborted take-off at critical speed; (2) ground roll and initial climb to 11 m (35 ft) above the take-off surface; and (3) net take-off flight path.			R	N/A	N/A	N/A	N/A	N/A	ATA 02
CS 23.2120	B - Flight	Climb requirements	The design must comply with the following minimum climb performance out of ground effect: (a) with all engines operating and in the initial climb configuration(s): (1) for Level-1 and -2 low-speed aeroplanes, a climb gradient of 8.3 % for landplanes and 6.7 % for seaplanes and amphibians; and (2) for Level-1 and -2 high-speed aeroplanes and all Level-3 and -4 aeroplanes, a climb gradient at take-off of 4 %.	MOC 6	Flight Tests reports	R	A	A	A	A	A	ATA 02
CS 23.2120	B - Flight	Climb requirements	(b) after a critical loss of thrust on multi-engine aeroplanes: (1) for Level-1 and -2 low-speed aeroplanes that do not meet single-engine crashworthiness requirements, a climb gradient of 1.5 % at a pressure altitude of 1 524 m (5 000 ft) in the cruise configuration; (2) for Level-1 and -2 high-speed aeroplanes, and Level-3 low-speed aeroplanes, a 1 % climb gradient at 122 m (400 ft) above the take-off surface with the landing gear retracted and flaps in the take-off configuration; and (3) for Level-3 high-speed aeroplanes and all Level-4 aeroplanes, a 2 % climb gradient at 122 m (400 ft) above the take-off surface with the landing gear retracted and flaps in the approach configuration;			R	N/A	N/A	N/A	N/A	N/A	ATA 02

Figure 7.3: CS-23 Amendment 5



Standard Name	Level 1	Section	Level 2	Level 3	Description REQ	AMC & GM	Requirement or Information (R,	1SHLLDL NP	1SHLLNL NP	1SHLLIL NP	1SHLLIL NC	1SHLLKL NC	CS-23 Reference	ATA Chapter
Commercial Air Transport	CAT.IDE.A.355	Management of aeronautical databases	(c) Notwithstanding any other occurrence reporting requirements as defined in Regulation (EU) No 376/2014, the operator shall report to the database provider instances of erroneous, inconsistent or missing data that might be reasonably expected to constitute a hazard to flight. In such cases, the operator shall inform flight crew and other personnel concerned, and shall ensure that the affected data is not used.			**AMC1 CAT.IDE.A.355** AERONAUTICAL DATABASES When the operator of an aircraft uses an aeronautical database that supports an airborne navigation application as a primary means of navigation used to meet the airspace usage requirements, the database provider should be a Type 2 DAT provider certified in accordance with Regulation (EU) 2017/373 or equivalent. **GM1 CAT.IDE.A.355** AERONAUTICAL DATABASE APPLICATION (a) Applications using aeronautical databases for which Type 2 DAT providers should be certified in accordance with Regulation (EU) 2017/373 may be found in GM1 DAT.OR.100. (b) The certification of a Type 2 DAT provider in accordance with Regulation (EU) 2017/373 ensures data integrity and compatibility with the certified aircraft application/equipment. **GM2 CAT.IDE.A.355** TIMELY DISTRIBUTION The operator should distribute current and unaltered aeronautical databases to all aircraft requiring them in accordance with the validity period of the databases or in accordance with a procedure established in the operations manual	R	A	A	A	N/A	N/A		
Non-commercial operations	NCO.IDE.A.100	Instruments and equipment - general	(a) Instruments and equipment required by this Subpart shall be approved in accordance with the applicable airworthiness requirements if they are:	(1) used by the flight crew to control the flight path; (2) used to comply with NCO.IDE.A.190; (3) used to comply with NCO.IDE.A.195; or (4) installed in the aeroplane.		**GM1 NCO.IDE.A.100(a)** APPLICABLE AIRWORTHINESS REQUIREMENTS The applicable airworthiness requirements for approval of instruments and equipment required by this Part are the following: (a) Regulation (EU) No 748/2012 for aeroplanes registered in the EU; and (b) Airworthiness requirements of the State of	R	A	A	A	N/A	N/A	CS 23.2500 CS 23.2505	

Figure 7.4: Commercial Air Transport (CAT) and non-commercial operations (NCO)

7.5 Appendix 5

7.5.1 Certification schedule Alérion M1h

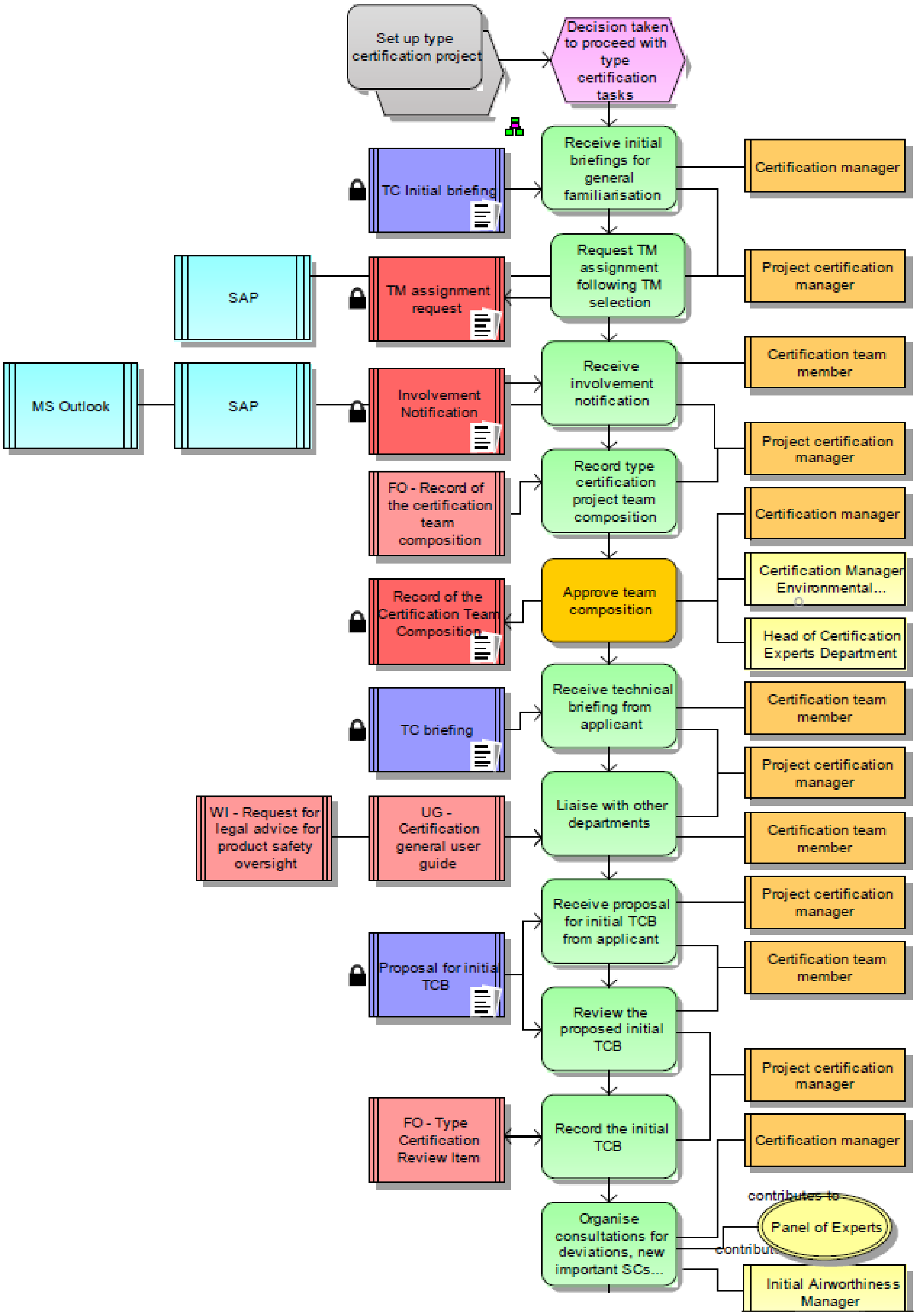


Figure 7.5: Phase 1: Technical familiarisation and establishment of TCB) - Type certification, PR.TC.00001-002, EASA

Bibliography

[1] K. R. Smith Jr., F. W. Belina, SMALL V/STOL Aircraft Analysis, Volume I, The Aerospace Corporation El Segundo, California, May 1974;

[2] Franklin D. Harris,Introduction to Autogyros, Helicopters, and Other V/STOL Aircraft Volume III, Ames Research Center Moffett Field, California, November 2015;

[3] North Atlantic Threaty Organization, AAP-06 - NATO Glossary of Terms and Definitions, NATO, 2019;

[4] EASA, Special Condition for small-category VTOL aircraft, Issue 1, Doc. No: SC-VTOL-01, 2 July 2019;

[5] Bacchini, A.; Cestino, E., Electric VTOL Configurations Comparison, In: AEROSPACE, pages 1-19, ISSN: 2226-4310, 28 February 2019;

[6] Liliul GmbH, 36 engines? What was wrong with two or four? - https://lilium.com/newsroom-detail/youve-never-seen-anything-like-this-an-introduction-to-the-lilium-jet, 15 May 2019;

[7] Electric VTOL News, Wisk (Kitty Hawk) Cora, https://evtol.news/aircraft/kitty-hawk-cora/;

[8] Electric VTOL News, VoloCity 4^{th} generation , https://evtol.news/aircraft/volocopter-volocity/;

[9] Electric VTOL News, AQUINEA-VOLTA ,https://evtol.news/aircraft/aquinea-volta/;

[10] John Kern, Aircraft Navigation and Landing Technology: Status of Implementation,U.S Government Printing Office, 1984;

[11] International Civil Aviation Organization, STOLport manual, second edition, 1991;

[12] London City Airport Noise Action Plan 2018-2023;

[13] BAE Systems,De Havilland Canada DHC-7 Dash 7, https://www.baesystems.com/en/heritage/de-havilland-canada-dhc-7-dash-7;

[14] Boldmethod, How The 4 Types Of Aircraft Flaps Work, https://www.boldmethod.com/learn-to-fly/aircraft-systems/how-the-four-types-of-aircraft-flaps-work/;

[15] Zenithair, Introducing the Zenith STOL CH701, http://www.zenithair.net/introduction-701/;

[16] Zenithair, The STOL CH701 Design, http://www.zenithair.net/design-701/;

[17] Zenithair, The STOL CH701 Performance, http://www.zenithair.net/specs-701/

[18] Avions Mauboussin website, https://www.avionsmauboussin.fr/en/mauboussin-2/;

[19] End of study report - Study of the EASA initial certification process changes for small aeroplanes through the certification exercice of Alérion m1h, Hadrienne Guerin, Avions Mauboussin, September 2018;

[20] Mauboussin croit en l'hydrogène, February 25, 2020, info-pilote;

[21] Avions Mauboussin Designs a New Hydrogen Propulsion System for Aircraft, February 21, 2020, FuelCellsWorks;

[22] The ultimate hybrid-electric solution,TG-R55, www.turbotech-aero.com;

[23] Hydrogen: A future fuel for aviation?, Roland Berger, https://www.rolandberger.com/en/Publications/Hydrogen-A-future-fuel-of-aviation.html;

[24] Voluntary airport low emission program technical report, Federal Aviation Administration, 2 December 2010;

[25] Urban air mobility - The rise of a new mode of transportation, Roland Berger , November 2018;

[26] Pioneering the urban air taxi revolution V1.0, Volocopter;

[27] Aerial logistics network for same-day e-commerc - The first electric Short Take Off and Landing (eSTOL) aircraft for middle-mile logistics, Aiflow.aero;

[28] Concept of Operations v1.0, Urban Air Mobility, U.S Department of Transportation Federal Aviation Administration (FAA) NextGen Office, 26 June 2020;

[29] Easy Access Rules for Standardised European Rules of the Air (SERA), EASA, December 2018;

[30] Autorisations de survols basses hauteurs exploitations specialisees, Direction General de l'Aviation Civile, 27 March 2019;

[31] Arrêté du 10 octobre 1957 relatif au survol des agglomérations et des rassemblements de personnes ou d'animaux, Consolidated version as of January 21, 2009, Official Journal of the French Republic.

[32] Decree 1 February 2006, Norme di attuazione della legge 2 aprile 1968, n. 518, concernente la liberalizzazione dell'uso delle aree di atterraggio, 1 February 2006, Ente Nazionale dell'Aviazione Civile;

[33] Boletin Oficial del Estado Num.204, Agencia Estatal Boletin Oficial del Estado, 25 August 2011;

[34] Boletin Oficial del Estado Num.285, Agencia Estatal Boletin Oficial del Estado, 28 November 2015;

[35] AD 3 LFPI - Heliport of Issy-les -Moulineaux, Service de l'Information Aéronautique, 16 July 2020 France;

[36] Slides of the aerotechnics course of the I.T.I.S. "G. Fauser" of Novara, http://dida.fauser.edu/aero/quinta/decollo/decollo.htm;

[37] Hybrid-electric short-haul air transportation scenarios, Lorenzo Trainelli, Slides of the webinar Mahepa-EASA, 3 July 2020;

[38]

[39] ASTM F2507-15 Recretional Airpark Design, ASTM International;

[40] The optimum airport runway orientation for different regions in Egypt, El-Sayed Mohamed Abdalla, Mahmoud Enieb Osman and Ramy Nasr Abd El-monem Mohamed, 19 November 2013;

[41] Arrêté du 30 juillet 2009, Annex I, Conditions de mise en service et de suivi d'un système de transmimssion automatique de paramètres sur un aérodrome, Légifrance;

[42] FAA Form 7480-1, Notice for Construction, Alteration and Deactivation of Airports, FAA;

[43] Demande de création d'aérodrome privé ou d'utilisation d' une aérosurface, République Français - Ministère de l'écologie, du développement durable et de l'énergie;

[44] Certification requirements for London City Airport, Isle of Man Aircraft Registry;

[45] Convention on International Civil Aviation, Doc 7300/9, ICAO, 2006;

[46] Annex 8 - Airworthiness of Aircraft, 2018, ICAO;

[47] Federal Aviation Administration (FAA), Skybrary.aero;

[48] EASA website,FAQ n.19107, www.easa.europa.eu;

[49] Delegated regulation, EU Monitor, 5 September 2020, www.eumonitor.eu;

[50] European Aviation Safety Agency (EASA), faa.gov;

[51] Design Organisations Approvals, Domains, EASA;

[52] Production Organisations Approvals, Domains, EASA;

[53] Easy Access Rules for Continuing Airworthiness (Regulation (EU) No 1321/2014), EASA, June 2020;

[54] Regulation (EU) No 2020/270 of the European Parliament and of the council, 25 February 2020;

[55] Regulation (EU) No 2018/1139 of the European Parliament and of the council, 4 July 2018;

[56] Easy Access Rules for Normal-Category Aeroplanes CS-23 (CS Amendment 5, AMC/GM Issue 2), EASA, November 2019;

[57] Easy Access Rules for Airworthiness and Environmental Certification (Regulation (EU) No 748/2012, EASA, June 2020;

[58] Aircraft Certification, Jean-François Petite, ENAC, March 2020;

[59] Military Aviation Authority Master Glossary, MAA02 Issue 9, Defence Safety Authority of the United Kingdom;

[60] EASA SC-VTOL-01 Comment Response Document, EASA;

[61] EASA Takes the First Shot at eVTOL Regulations. Did They Miss the Mark?, Mike Hirschberg, VFS Executive Director, published on The vertical flight commentary on October 2019;

[62] Proposed Means of Compliance with the Special Condition VTOL, Issue 1, 25 May 2020, EASA;

[63] ASTM standard F3093-20, 'Standard Specification for Aeroelasticity Requirements', ASTM International;

[64] SC-ELA.2015-01, Special Condition Lithium battery installations, EASA, 12 October 2018;

[65] SC-E-19, Proposed Special Condition Electric / Hybrid Propulsion System, EASA, 27 January 2020;

[66] ASTM standard F3061-20, 'Standard Specification for Systems and Equipment in Small Aircraft', ASTM International;

[67] SAE ARP4754 Revision A, Guidelines for Development of Civil Aircraft and Systems, December 2010;

[68] AIC 127/2006 (Pink 110) - 'Take-Off and Landing performance of light aeroplanes', SafetySense Laflet 7c, CAA UK, January 2013;