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POLIDRONE – PLAN DE NEGOCIO DE UN DRON MODULAR Y MULTIPROPÓSITO FABRICADO POR MDF.

Autor:

Sanzo Sánchez, Adrián

Responsable de Intercambio en la Uva:

Vicente Maroto, Isabel

Universidad de destino:

Politecnico di Torino

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TFG REALIZADO EN PROGRAMA DE INTERCAMBIO

TÍTULO: **Polidrone – Business Plan of a multipurpose modular drone produced via FDM.**

ALUMNO: **Adrián Sanzo Sánchez.**

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TUTOR: **Dr. Salvatore Brischetto.**

Resumen (Abstract)

El TFG, realizado conjuntamente con la oficina I3P del Politécnico de Turín, constituye un Plan de Negocio para un dron creado y patentado por una serie de personas vinculadas al Politécnico de Turín con el fin de evaluar su viabilidad.

La primera fase del Proyecto fue la definición de los casos de uso o nichos de mercado para los que iba destinado el dron. Para ello se tuvo que tener una absoluta comprensión mecánica del dron, destacando nuestras ventajas competitivas. También se realizó una serie de encuestas, entrevistas y análisis de mercado.

Tomando como base los casos de uso elegidos, se realizó el Plan de Negocio completo. El cual analiza los puntos fuertes del dron, los segmentos y el tamaño de mercado, los clientes potenciales, la forma de comercialización, su distribución y venta, su promoción, fijar el precio, los proveedores, los materiales y equipos necesarios, su plan de financiación y beneficios esperados en 5 años, análisis de la competencia, etc.

Finalmente, el Plan de Negocio fue presentado como concursante en una competición regional de proyectos innovadores. La START CUP Piemonte-Valle d'Aosta.

Palabras clave (Keywords)

Dron	Drone
Impresión 3D	3D printing
Plan	Plan
Negocio	Business
MDF	FDM

POLIDRONE

A multipurpose modular drone with adjustable arms produced via the FDM additive manufacturing process.

Salvatore Brischetto *Alessandro Ciano* *Adrián Sanzo*

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1. Executive Summary

PoliDrone, the modular drone with adjustable number of arms, manufactured by 3D printing, multipurpose perfect for Rescue Assistance. It is the universal platform capable of being an all in one born in the Politecnico di Torino.

Most drones on the market offer fixed designs without any flexibility in their configurations, they are not drones to be able to change the number of arms. This creates the problem that it is necessary to purchase a new platform to accomplish several missions different from those for which the drone was initially bought. In the field of search and rescue, the helicopter is a useful solution when aerial vision is needed, but the problem lies in the fact that it is too slow, costly and dependent on flight conditions.

As a solution we offer a Remotely Piloted Aircraft System, which provides a flexible, fast and reliable response. The product marketed includes the aircraft, its carrying briefcase, the payload chosen by the customer, the software installed and all other devices necessary for the immediate use by the client.

The drone market is clearly growing because of the large number of applications for which they can be used. The global commercial drone market size was estimated to be $552 million in 2014 and is expected to grow at a Compound Annual Growth Rate of 16.9 per cent. Also, the global first responders C3i and emergency response is expected to grow at the annual rate of 14.7 per cent and reach revenue worth $131.62 billion by 2019. In this last analysis, the drones are considered as a valid and essential solution for the emergency first response in the next years.

Our main advantage over the competition is our flexibility to choose the number of arms (quadrotor, hexarotor and octorotor) and the payload, among many compatible options, depending on the flight conditions and the task to be performed, in addition to a competitive price and the ability to land in the water. All the pieces are designed for the Fused Deposition Modelling (FDM) additive manufacturing taking advantage of the mechanical properties and the low mass density that this manufacturing method creates

Our revenues will come directly from the sale of the complete drone batch and the after-sales services we will offer. The first few years we will direct our product towards the Italian rescue bodies and emergency services. From the third year, we will expand into European territory and into new market segments (structural building health and water measurement market).

Our personnel form a perfectly qualified team in this field, having educational background in the Politecnico di Torino. They all have experience, knowledge and motivations in 3D printing and in the world of drones and aerospace devices. Our CEO has a PhD in Aerospace engineering and mechanics, being author of more than 100 articles related with this subject, more than 60 of which have been published in international journals; In addition, he is co-

founder and co-chair of the research group “ASTRA: Additive manufacturing for Systems and Structures in Aerospace” at Politecnico di Torino. Our CTO has a bachelor’s degree in aerospace engineering and has worked for more than 5 years as a fire-fighter at Corpo Nazionale Vigili del Fuoco, experiencing first person rescue missions. The other team member, the COO, holds a master's degree in aerospace engineering, and has a good experience in the preliminary project of the drone having made its master thesis: “Mechanical characterization of ABS and preliminary design for a 3D printed UAV produced via FDM.

The first three years will require remarkable investments, which will mainly come from the share capital or the participation of investors. However, from that same year, the volume of sales will increase significantly, with net benefits of 500k € in the fourth year and 1.25M € in the second, reaching to sell 350 and 765 units respectively. The complete recovery of the investments will be at the fourth year, and the cash break-even will be at the 40th month.

For the realization of this project we need an economic support from investors during the first two years at least. The investor’s participation would be a first round of 150.000€ in the first year, and a second round of 150.000€ in the second year.

2. Entrepreneurial Team

The company team is constituted by three permanent components (You can see their CVs in the Annex VI. Entrepreneurial Team CVs.).

- Salvatore Brischetto:

Salvatore Brischetto received his PhD in Aerospace Engineering (Politecnico di Torino) and in Mechanics (Université Paris Ouest-Nanterre La Défense) in 2009. Dr. Brischetto worked as a Research Assistant in the Department of Mechanical and Aerospace Engineering at the Politecnico di Torino from 2006 to 2010, and has been Assistant Professor in the same department since 2010. He is the author of more than 100 articles, more than 60 of which have been published in international journals. He is co-founder and co-chair of the research group “ASTRA: Additive manufacturing for Systems and Structures in Aerospace” at the Department of Mechanical and Aerospace Engineering of Politecnico di Torino. He is an expert of additive manufacturing and UAVs.

He has been worked on the structural analysis and design of the drone (also material characterization and FEM analysis for the structural optimization).

His role in the company is CEO (Chief Executive Officer). He will be the maximum responsible for the management and administration of the company.

- Alessandro Ciano.

He has a bachelor's degree in aerospace engineering and it is an expert in 3D printing and drone components. He is fundamental for the assembling of the aircraft. Moreover, he has experience in rescue activity, having worked as firefighter.

His role in the company is CTO (Chief Technology Officer). He will be the responsible for the engineering team and to implement the technical strategy to improve the final product.

- Roberto Torre:

He has a master's degree in aerospace engineering. He is an expert in FEM and 3D printing. Also he has a good experience in the preliminary project in order to select the opportune avionic, engines, rotors and to see the preliminary flight characteristic of the drone.

His role in the company is COO (Chief Operating Officer). He will supervise how the product creation and distribution system is working.

In addition, there will be personnel in charge of the configuration and installation of the drone and the activities of Research and Development, electronic engineers mainly. The commercial activity will be made through commercial depends, which will be part of the team also.

3. Business Model.

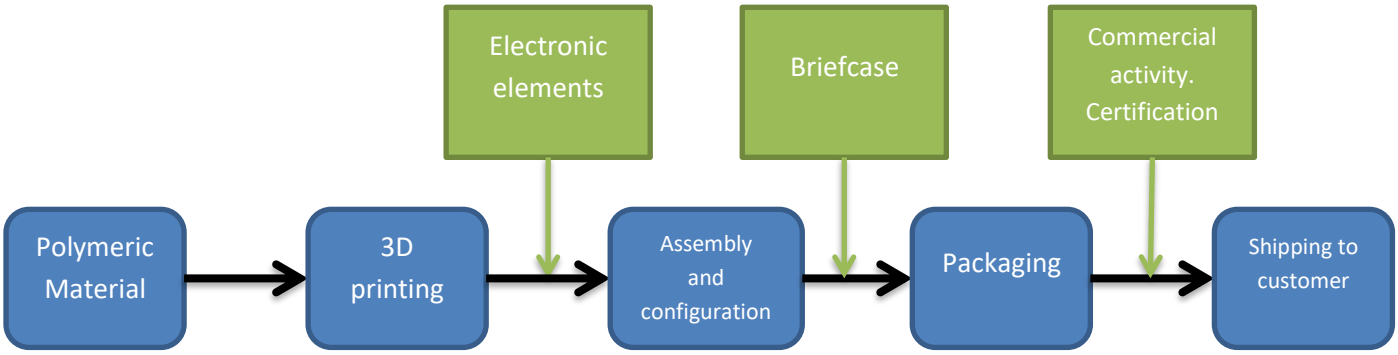


Figure 3.1. Activities of the company.

3.1. Value Proposition.

PoliDrone is a modular drone manufactured from FDM that weighs less than 2 kg. Its modularity allows it to change its configuration easily, it can vary from 3 to 8 arms, as well as its terminal arm elements (one rotor, two rotors or inflatable element). In addition, PoliDrone is waterproof and can land in water with the amphibious configuration.

It can carry 0.5 kg of interchangeable payload. This payload will be chosen from different possible options by the customer. All the drone pieces and the different types of payloads can be transported in the briefcase that we provide. In addition, the drone can broadcast live through FPV installed system (First Person View). The FPV transmitter sends the image to the receiver, the TFT LCD. The drone is controlled by remote control and has integrated a microphone and a speaker.

For all of this, PoliDrone gives us the possibility of being able to be used for many rescue tasks and in different flight conditions. The drone can also be used to monitor the structural health of buildings from the air, complementing other more traditional techniques such as laser or terrestrial photogrammetry. A further use of the drone concerns the measurement of water composition in areas of difficult access thanks to its ability to land on it.

3.2. Customer Segments.

Our customer segments are all bodies and organizations of emergency services that carry out rescue work at the international level. Initially, the team will focus mainly on Italian firefighters (Corpo Nazionale dei Vigili del Fuoco), after which it will expand the market to other types of rescue missions where drone can be very useful: nautical rescue (such as the Guardia Costiera) and alpine rescue (such as Corpo Nazionale Soccorso Alpino e Speleologico or the Meteomont Squadra di Soccorso) and other organizations such as the Crocce Rossa Italiana and the Guardia di Finanza.

For the market of structural health of buildings, customers will be companies dedicated to this task, some of which are not yet using UAV technology, such as Structural Investigations SRL or Field SRL. Indagini Strutturali SRL or Field SRL. For the market of measurement of water composition we would look for companies in charge of monitoring and controlling the environment.

3.3. Channels.

The distribution and sales channels to reach the customer are contact or direct sales, creation of a website in which we can sell our product. It is also considered to participate in fairs and events in the field of drones and rescue. All of these channels are usable as it is possible to use the contacts and the networking of the Politecnico di Torino.

3.4. Customer relationships.

The type of relationship with the clients will be direct, without any intermediaries. We will make pre-sale commercial visits and establish an after-sales service in order to solve any problems. The client will be informed permanently of any type of update that improves the performance of the drone. We consider there will be new versions of the drone every 2 years.

3.5. Key activities.

We take care of the manufacturing of plastic drone parts and their assembly. In addition, we take care of buying the electrical and avionics elements through suppliers, as well as the payload required by the customer. Also we have to buy externally the FPV system, emitter and receiver (TFT LCD screen), and finally, the remote control through suppliers. We are responsible for installing and configuring all these elements ensuring an optimal performance. We carry out the commercial activity (promotion and pre-sale service), as well as drone certification and patent management. We will also manage the after-sales service.

3.6. Key resources.

Our resources will be Human Resources, among which we need commercial dependents and people in charge of the production and R&D. We will invest 3D printers, warehouse and equipment (computers and CAM programs) for the print management, for the configuration of the drone and for the ability to broadcast live.

3.7. Partners and suppliers.

One of our main partners is the Politecnico di Torino, which will enable us to exploit its network of contacts. Other key partners are suppliers of polymeric materials, electrical components, and all the components needed to build the drone. We also need a shipping service to deliver the drone to our customers, which will be outsourced. Other important partners to consider are the suppliers of the briefcase where to carry the drone and those who produce the different payloads, depending on the activity and needs of our customer.

3.8. Revenue Streams.

Our benefits come directly from the sale of the complete drone system, its suitcase and the different options of payloads. We consider that we can sell with a repeatability of 2 drones per customer.

3.9. Structure of costs.

Our costs can be organized as variable costs, investments, fixed costs and optional costs (depending on the customer's choice). The variable costs are those that related to manufacture, pack and distribute a single drone (polymer material, electronic elements, briefcase...). Investments will be mainly legal, patents and certifications, and the creation and implementation of a laboratory. The fixed costs are independent of the number of units produced, such as the expenses of office, warehouse and Human Resources (commercials depends, personnel in charge of G&A and other engineers dedicated to the configuration and R&D). Finally, the optional costs are those destined to the purchase of the payload chosen by the customer.

4. Context and Problem.

The use of drones or Unmanned Aerial Vehicles (UAVs) in commercial and industrial applications has an enormous and unexplored potential which could completely change the society and the industry [1].

The Italian fire department, Corpo nazionale dei Vigili Del Fuoco, receives annually 5.000.000 emergency calls at its headquarters and about 700.000 in its provincial commands [2]. In 2016, around 174,000 immigrants were rescued by different bodies, all coordinated by the MCRR Rome (Maritime Rescue Coordination Centre), meanwhile they trying to reach Europe through the Mediterranean Sea [3]. The Corpo Nazionale di Soccorso Alpino e Speleologico, the Meteomont Service, the Croce Rossa Italiana or the Soccorso Alpino Guardia di Finanza are Italian organisms that also receive numerous emergency and rescue calls.

Many of these calls require the intervention of a helicopter for a search and rescue from the air, to survey forest fires… but it is an expensive and slow response that has too many drawbacks when it comes to flying in adverse weather conditions (Inability to fly at night, with fog...). In order to solve these problems, UAVs have been seen as a valid substitution option and a valid complementary option for the rest of the emergency techniques.

Generally, drones are viewed as platforms for sensors of any kind, and they have been used primarily for surveillance and inspection [4]. Today, drones are being used in many different tasks like survey crops, in search and rescue operation, to count wild life and keep track of animal population, in land surveying, to survey forest fires, and to inspect oil pipelines, power lines and other remote infrastructure [5]. Their ability to carry heavy equipment has been leveraged for spraying crops in large farm and delivering food, medical supplies and drugs to inaccessible locations [6].

In the literature and on the market, several types of multirotor are proposed which show different configurations depending on the number of arms and rotors and on the amphibious abilities. A great problem is that the most of drones have a fixed design, so there is a need to purchase a new platform to accomplish several missions different from those for which the drone was initially bought [1].

None of the market options solves the problem of providing a modular drone capable of landing in different surfaces comprising rough terrains and water [1].

5. Value Proposition.

Universal, dynamic and economic multi-rotor UAV. It is the sentence which defines our PoliDrone. It is presented as a viable solution for Rescue Assistance.

The PoliDrone could be proposed as a self-building kit composed by 8 pieces also comprising a universal central plate and a variable number of all-in-one arms. The possible configurations vary from 3 to 8 arms, with a single rotor per arm (Figure 1[1]), double rotors per arms (Figure 2), or the amphibious configuration (Figure 3) with a rotor at the top of the arm and an inflatable element at the bottom of the arm able to allow a landing on open water or the shock absorption for hard landing [1].

This universal platform allows 12 different configurations with ability to exchange the payload required for each rescue task. The drone is able to carry a payload of 0.5kg, allowing the use of normal vision, night vision or thermal cameras including several types of sensors and microphone and speaker giving the possibility to emergency services can give the proper instructions. These payloads must be mounted on the lower dome with the proper support, usually a generic 3 or 2 axis gimbal, which guarantees easy interchangeability. You can also carry light first aid kit or inflatable items in case of nautical rescue. We offer these different payload options so that the client chooses the one that needs.

All the necessary pieces to change the configuration of the drone, and the different types of payload can be transported in the same briefcase that we provide, thus the emergency services can arrive at the incident site and decide between a faster configuration with more endurance (3-4 arms), or a more stable configuration for difficult flight conditions (6-8 arms) and the correct payload.

In addition, the drone has the ability to transmit live from the camera. This function is called FPV (First Person View) and is done thanks to an emitter connected to the drone camera which transmits to a receiver, in our case a screen. The drone is controlled thanks to a remote control station and has integrated an audio system with a small microphone and speaker allowing communication between the emergency services and the person in danger.

The use of the drone provides a much faster and cheaper solution, performing a reconnaissance task similar to the helicopter and with the possibility of flying in difficult conditions (through smoke, night flight...) without risk to the pilots. In addition, the drone not only serves as a substitute for the helicopter, both can work together complementing each other. Approximately in half of this type of emergency situations, the emergency services could use a drone in order to complement the other search and rescue techniques.

Moreover, the arms are also telescopic and adjustable in order to avoid the contact between the propellers without changing the propeller dimensions in the cases of six and eight arms.

[1] For this figure and the successive ones, go to Annex I.

All these changes in the drone configuration can be made by any customer without any specific knowledge of mechanics, electronics or flight control management. The Flight Control Unit (FCU) self-recognizes the configuration and adapts the flight management system of the drone.

PoliDrone has a mixed flight time close to 20min reaching maximum speeds of 45 km/h and it weighs between 1.5kg for 4 arms configuration and about 2 kg for 8 arms configuration.

According to EENA experiences (European Emergency Number Association), RPAS (Remotely Piloted Aircraft System) can be used to find missing persons quickly and efficiently, provide an aerial perspective over burning buildings containing highly dangerous chemicals, detect fire 'hot spots' within buildings on fire and guide emergency first responders away from danger. All together, they help the emergency services to make more informed decisions that lead to better outcomes for our citizens and help keep our emergency services safer. Also, Italian Fire-Fighters Services told us how useful the drone is to get a general view of the situation more quickly. RPAS will become integrated into the overall emergency response and disaster relief efforts leading to more informed decisions and better outcomes [7].

Our drone has all the necessary for a minimum RPAS configuration for first responders:

- Reliable platform with redundant system.
- GPS and GLONNAS systems.
- Integrated camera systems, preferably modular, with live downstream capabilities in HD format. Video FPV (First Person View).
- Ability to fly in moderate winds and light rain.

It can be also effectively used in Nautical Rescues. PoliDrone allows the water landing with an increased stability on waves due to the bottom cover design and the inflatable elements at the bottom of the arms. Giving the possibility of offering a response from the air (lifejacket…) and from the water, close to the person in danger (vitamin supplement…). Our drone can also save battery by landing in the water waiting for the next order.

The eight different pieces that constitute the PoliDrone are designed for the Fused Deposition Modeling (FDM) additive manufacturing, allowing customers to have a low-cost flying vehicle that everyone can produce taking advantages from the mechanical properties and the low mass density of FDM parts. In particular, if this feature will be translated in large scale, the advantages from the economical point of view will be clearer [1].

Moreover, Fused Deposition Modeling allows choosing the kind of material of the drone, the PLA (PolyLactic Acid), and the ABS (Acrylonitrile Butadiene Styrene). PLA is easier to be printed and it is a 100% biodegradable material, giving the drone an eco-green character. In the other hand, ABS is lighter with higher performance requirements.

PoliDrone is the first in its category which introduces active measures of damage control using inflatable elements. Therefore, it is ready to fulfill the stringent requirements to fly in critical areas or over groups of persons [1].

Although we have defined the structure and commercialization of the drone according to the needs of rescue assistance, the drone is perfectly valid for many more uses cases. Thus, we establish as future use potentials:

1. «Structural Health» Monitoring: Inspection and monitoring of historical buildings and places in order to understand its cultural and economic evaluation. Ability to create representations and 3D models of these places. Necessary payloads for this type of tasks are the cameras with great resolutions and lasers.
2. Measurement of water: Our main advantage is the ability to land in the water, offering a better stability to catch the water sample. Being waterproof we don't have the risk of losing the drone if it falls into the water. Sensors and meters which indicate the composition of water are essential payloads.

Once defined the main advantages and values of the drone, we will proceed to the description of each of its components:

5.1.1. The structural components.

The 8 different structural parts are manufactured using the FDM (Fused Deposition Modeling) technique. They are printed with the help of our Sharebot Next Generation 3D printer, and the WASP Delta 2040 by FabLab Biella. The pieces are made with filaments arranged in zig-zag. A layer height of 0.3mm has been chosen as optimum compromise between the accuracy and the printing time with 3 peripheral beads and a density infill of 85% [1]. The material depends on the customer's choice, it can be ABS or PLA with its different properties.

- **ABS (Acrylonitrile butadiene styrene):** It is a low cost plastic, easy to machine and fabricate. Furthermore, due to its mechanical characteristics it is ideal for structural applications where impact resistance, strength and stiffness are required [8]. We can see its physical and mechanical properties on the Table 5.1.

Physical and mechanical properties of ABS.	
Density	1.02 – 1.2 g/cm^3
Water Absorption	0.25 – 1.00%
Melt Flow	0.100 – 35.0 g/10min
Hardness, Rockwell R	68 – 113
Tensile Strength, Ultimate	23 – 49 MPa
Tensile Strength, Yield	13 – 65 MPa
Elongation at Break	3 – 150%
Elongation at Yield	0.620 – 70.00%
Modulus of Elasticity	1.00 – 2.65 GPa
Flexural Yield Strength	28.3 – 88.3 MPa
Flexural Modulus	0.200 – 5.50 GPa
Izod Impact, Notched	0.380 – 10.3 J/cm^2
Charpy Impact, Notched	0.900 – 5.00 J/cm^2

Table 5.1. Physical and mechanical properties of ABS [8].

- **PLA (Polylactic acid):** The most important property of the PLA is to be biodegradable; in fact there are at least two species of bacteria (Amycolatopsis and Saccharotrix) that are able to degrade this material. Furthermore it can be recycled to monomer allowing manufacturing a virgin PLA with no loss of original properties. It is heavier and with lesser performance requirements than the ABS. Its physical and mechanical properties are listed in the Table 5.2.

Physical and mechanical properties of PLA.	
Density	1.00 – 2.47 g/cm^3
Water Absorption	0.13 – 2.00%
Melt Flow	1.00 – 85.0 g/10min
Hardness, Shore D	59 – 77
Tensile Strength, Ultimate	16 – 114 MPa
Tensile Strength, Yield	16 – 103 MPa
Elongation at Break	0.5 – 430%
Elongation at Yield	2.00 – 400%
Modulus of Elasticity	0.230 – 13.8 GPa
Flexural Yield Strength	6.00 – 145 MPa
Flexural Modulus	0.215 – 13.8 GPa
Izod Impact, Notched	0.128 – 8.54 J/cm^2
Charpy Impact, Notched	0.100 – 1000 J/cm^2

Table 5.2. Physical and mechanical properties of PLA [8].

5.1.1.1. The Central Plate.

The geometrically more relevant alteration that can be performed by the user is in the number of arms of the aircraft. For this reason, the central plate design is a universal plate regardless of the chosen configuration. The geometry has a circular symmetry so that it is easily possible to change the number of arms and their position. The central plate is made of an upper (Figure 4) and a bottom element (Figure 5), both equipped with a guide which allows the support of each arm to be fitted and, during assembly or disassembly, to be able to slide in order to easily change the number of arms [8].

To facilitate the assembly or disassembly procedure, the holes are numbered (Figure 6). In this way, having chosen the configuration to be assumed by the drone it would be sufficient to read in an attached table the numbers that correspond to the holes to be occupied by the clamping elements [8].

The plate has eyelets to allow the passage of electric cables. Both the top plate and the lower plate have four teeth in order to allow the assembly of the two spherical domes. Also, the central part has a panel where the battery will be placed, drilled adequately to ensure the air flow.

5.1.1.2. The arms.

Another key component of the drone is, of course, represented by the arms, whose number can be freely changed by the user choosing amoung a quadri-, exa-, octacopter configuration. Each arm is made of an upper (Figure 7) and a bottom element (Figure 8); the assembly of the two lets obtain a hollow assembly that will house all the electronics with which each arm will be provided. The terminal areas of the arms are equipped with suitable supports for the thrusters and the inflatable elements [8]

As the number of arms increases, the maximum allowable diameter for each propeller decreases, therefore the aircraft has telescopic arms, so that, even with the most critical configuration, the diameter of the propellers is optimal. This brings with it a further advantage; it allows, also, providing the aircraft of greater stability: as the arm of the force generated by each propeller increases there is a greater torque reaction during manoeuvres or in presence of destabilizing factors. This feature is also implementable even in configurations with reduced number of arms when wanting to increase the stability without affecting the hourly autonomy [8].

To ensure that each arm attack would have been firmly bounded to the central plate, thus avoiding any type of relative movement, fastening elements are present for each arm (Figure 9). The holes not used, in the configuration chosen by the user, will be properly closed by plugs to prevent the entry of water or any other external agent [8].

5.1.1.3. The Spherical domes.

Both the elements that constitute the central plate provide sufficient surface for the electronics and the payload housing. These domes provide sufficient protection to the payload (the lower dome) and to the avionics electronics (the upper one); furthermore they are also designed so as to ensure the flotation of the aircraft in case of water landing[8]. The payload can be mounted with the relevant support elements in the lower dome.

The mounting system with the central plate was designed integrating a guide inside which it is possible to make some teeth slide (Figure 10) [8].

5.1.1.4. The landing gear.

The goal of this element is obvious, it allows the landing and drone stability. The dimensions ensure a sufficient separation from the ground upon landing; also the design shape dissipates, as much as possible, the vertical kinetic energy of the aircraft. The legs have a coupling system to the central plate that was entirely similar to that of the arm supports so that it would be possible to change the position and number (Figure 11) [8].

With all the structural parts defined, you can see the exploded view of the drone in the Figure 12.

5.1.2. The avionics and electrical elements.

There are basic elements (one for all configurations) that will be housed in the central plate and protected by the upper dome such as the FCU (Flight Control Unit), the battery, the IMU (Inertial Measurement Unit) or gyroscopes, the GPS, and the FPV system (including the receptor, the TFT LCD screen). We also classified in this category the remote control.

The other elements are end pieces of each arm and depend on the number of them. These are the motors, the propellers, the ECS (Electronic Speed Controllers) and the inflatable element and its CO_2 cartridge.

5.1.2.1. The Flight Control Unit.

The Flight Control Unit, which self recognizes the configuration and adapts the flight management system, is the KK-Mini Multi Rotor Flight Control Board (Figure 13). Its specs can be seen in the Table 5.3.

KK-Mini Multi-Rotor Flight Control Board.	
Size	36x36x11.5 mm
Weight	8.6 g
Gyro/Acc	6050MPU InvenSense Inc.
Auto-Level	Yes
Input Voltage	4.8 – 6.0 V
AVR interface	Standard 6 pin

Table 5.3. FCU datasheet [8]

5.1.2.2. The battery.

The drone carries the battery ZIPPY Flightmax 8000mAh 3S1P 30C Lipo Pack (Figure 14). This battery has sufficient capacity and voltage for our drone, and its main advantage is its lightness. We can see its specifications in the Table 5.4.

ZIPPY Flightmax 8000mAh 3S1P 30C Lipo Pack	
Capacity	8000mAh
Voltage	3S1P/3Cell/11.1V
Discharge	30CConstant/40CBurst
Weight	644g
Dimensions	169x69x27mm

Table 5.4. Battery datasheet [8].

5.1.2.3. The IMU. Inertial Measurement Unit.

It is an electronic device that measures and reports the velocity, orientation and gravitational forces of an apparatus using a combination of accelerometers and gyroscopes. The data collected by the sensors of an IMU allow a computer to follow the position of the device using a method known as estimation navigation.

5.1.2.4. GPS system.

Installed in the central plate, the GPS system allows knowing the position of the aircraft via satellite. Its work is complemented by the task of the IMU.

5.1.2.5. Motors.

We have the possibility to use up to 16 engines, as we can configure the drone with 8 arms and 2 rotors in each one. The motors chosen are the RCTimer SL2212/920Kv (Figure 15). Its specs are detailed in the Table 5.5.

RCTimer SL2212/920KV	
KV	920
Configuration	12N14P
Shaft diameter	3mm
Motor dimensions	28x24mm
Weight	48g
Idle current(10)@10v(A)	0.4A
No.of Cells (LiPo)	3 – 6S
Max Continuous current (A) 180S	20A
Max Continuous Power (W) 180S	400W
Max efficiency current	(3 – 10A)>85%
Internal resistance	62mω

Table 5.5. Engine datasheet [8].

5.1.2.6. Propellers.

The number of propellers can be very large, since with each different configuration, the propellers change in size avoiding the clash between them. The 4-arm configuration uses 4 or 8 propellers (depending on whether the drone carries one or two rotors per arm) with a diameter of 13 inches and a pitch of 4.7 inches. The 6-arm configuration uses 6 or 12 propellers with a diameter of 11 inches and a pitch of 4.7 inches. And finally, the 8-arm configuration carries 8 or 16 propellers with a diameter of 8 inches and a pitch of 4.5 inches.

All propellers are Turnigy Slowfly (Figure 16) Propellers, and the total number of them is:

$$8\ propellers\ for\ the\ quadrotor + 12\ propellers\ for\ the\ hexarotor + 16\ propellers\ for\ the\ octorotor = 36\ propellers.$$

It should also be emphasized that these propellers are generic propellers and can be replaced by others with care that they do not collide with each other.

5.1.2.7. The ESC. Electronic Speed Controller.

Is an electronic circuit with the purpose to vary an electric motor's speed, its direction and possibly also to act as a dynamic brake. It is connected to each motor, therefore the

configuration of 8 arms and two propellers in each one would need 16 ZTW Spider OPTO Small 30A (Figure 17). The ESCs must be able to handle the maximum rated current required from the motors. Its characteristics are reported in the Table 5.6.

ZTW Spider OPTO Small	
Continuous current	30A
Burst current (@10s)	40A
Max Power	380W
Length	47mm
Width	20g
Height	8mm
Weight	24g

Table 5.6. ESC datasheet [8].

5.1.2.8. The inflatable element and the CO_2 cartridge.

The amphibious configuration includes an inflatable element (Figure 18) on the underside of each arm; therefore, the number of them is 8 as maximum. The work of a disposable CO_2 cartridge (Figure 19) is also needed for its inflation and proper functioning.

5.1.2.9. The FPV system (including video display).

The video transmitter, installed in the central plate and connected to the camera, takes the signal from the camera and sends it out an antenna installed in the drone. This antenna sends the signal through a previously chosen frequency to the receptor, in our case a TFT LCD video display, in order to see everything that is seen from the camera in real time.

5.1.2.10. Remote Controller.

The remote control station allows manual operation of the drone thanks to its radio frequency communication. The frequencies most used are 2.4GHz and 5.8GHz.

6. Marketing Plan.

6.1. Product.

The product we offer is a modular drone with the ability to change the number of arms and rotors with the possibility of choosing an amphibious configuration, allowing the landing in water.

In addition, the drone is able to broadcast live through its software FPV (First Person View).

The diagonal dimension of the drone is 63.2 cm without considering the propellers. For all configurations, it is capable of lifting many types of payload without exceeding 500g. This payload is easily interchangeable according to the task.

All the components of the drone and the different types of payload go inside a briefcase for the purpose of easy transportation.

The technical specifications of the drone are listed in the Table 6.1 in the case of one rotor per arm.

	4R Conf.	6R Conf.	8R Conf.
All-up weight	1434 g	1679 g	1923 g
Max Till	74º	70º	48º
Max Speed	44 km/h	43 km/h	38 km/h
Rate of climb	9.7 m/s	9.1 m/s	5.6 m/s
Mixed flight time	17.9 min	16.8 min	15.1 min
Hover flight time	32.4 min	27.5 min	19.0 min
With rotor fail	Uncontrollable	Controllable	Controllable

Table 6.1. Technical specifications of PoliDrone [8].

Figure 6.1. The PoliDrone [8].

The lot we sell together has the following components:

- The briefcase.
- The Polidrone (RPAS complete). Made of ABS or PLA.
    - Central Plate.
        - x1 upper plate.
        - x1 lower plate.
    - Arms.
        - x8 upper arm element.
        - x8 lower arm element.
        - x8 arm support.
    - Spherical domes.
        - x1 upper dome.
        - x1 lower dome.
    - x2 landing gear.
    - x1 FCU (KK-Mini Multi-Rotor Flight Control Board)
    - x1 Battery (ZIPPY Flightmax 8000mAh 3S1P 30C Lipo Pack)
    - x1 IMU.
    - x1 GPS system.
    - x8 engines (RCTimer SL2212/920 Kv)
    - Propellers Turnigy Slowfly:
        - x4 Propellers. Diameter: 13 inches // Pitch 4.7 inches.
        - x6 Propellers. Diameter: 11 inches // Pitch 4.7 inches.
        - x8 Propellers. Diameter: 8 inches // Pitch 4.5 inches.
    - x8 ESC (ZTW Spider OPTO Small 30A)
    - x15 CO_2 cartridge (Crosman 12g)
    - FPV System.
        - A transmitter.
        - A receptor (screen).
    - Microphone and speaker.
- Remote Controller.
- Payloads (Different options to choose, it depends the use case and the task, see the following section).

Although the drone has the possibility of having a double rotor in each arm, in the lot we offer half of motors, ESCs and propellers (eight). If the customer wishes, he can request the quantity needed to choose a configuration of two rotors per arm (sixteen).

6.1.1. Payloads.

We consider that the choice of payload should be made by our customers in order to have the flexibility to choose the cameras or other type of payload they really need. We order the payload to our suppliers and proceed to its installation in the drone. The client has the

possibility to choose several options of payload; He isn't obliged to choose only one. No option exceeds 0.5kg.

- **Option 1. Normal Camera View.**

  - x1 GH3-3D 3-Axis Camera Gimbal (Figure 20).
    Compatible with iLook / iLook+ / GoPro Hero 3+ 3 / Sony Cam TE066.

GH3-3D-Axis Camera Gimbal	
Working voltage	3S LiPo Battery
Working Current	50 – 600mAh
Pitch angle range	(up) -48º // +95º (down)
Roll angle range	(left) -35º // +35°(right)
Yaw angle range	(left) -45° // +45°(right)
Weight	168g
Dimension	87.3mm x 80mm x 94.4mm

Table 6.2. GH3-3D-Axis Camera Gimbal datasheet [9].

  - x1 Walkera iLook+ Camera (Figure 21).
    This unit has a built-in video transmitter and is a capable all-in-one FPV camera.

Walkera I Look+ Camera	
Video resolution	1920x1080P 60fps 4K HD
Micro SD	Max 64 Gb
Photo	13MP
Frecuency transmission	5.8GHz
Lens angle	150º (max)
Weight	125
Dimension	59mm x 41mm x 21mm

Table 6.3. Walkera I Look+ Camera datasheet [10].

- **Option 2. Thermal Camera. (Lower resolution).**

  - x1 Tarot FLIR VUE PRO 3Axis gimbal TL03FLIR (Figure 22).
    Compatible with the FLIR Vue Pro 336 and FLIR Vue Pro 640.

Tarot FLIR VUE PRO 3Axis gimbal TL03FLIR	
Working voltage	3S – 6S LiPo Battery (11V – 26V)
Working Current	30 mAh
Pitch angle range	-120º // +80º
Roll angle range	±50º
Yaw angle range	±125º
Weight	191g
Dimension	85mm x 100mm x 101mm

Table 6.4. Tarot FLIR VUE PRO 3Axis Gimbal TL03FLIR datasheet [11].

  - x1 FLIR Vue Pro 336 (Figure 23).

FLIR Vue Pro 336	
Video resolution	336x256
Lens option	9mm; 35ºx27º
Spectral Band	7.5 – 13.5 µm
Frame Rates	7.5 Hz (NTSC); 8.3 Hz (PAL)
Weight	92.1 – 113.4 g
Dimension	63mm x 44.4mm x 44.4mm

Table 6.5. FLIR Vue Pro 336 datasheet [12].

- **Option 3. Thermal Camera. (Higher resolution).**

  - x1 Tarot FLIR VUE PRO 3Axis gimbal TL03FLIR (The same one of the previous option).

  - x1 FLIR Vue Pro 640 (Figure 24).

FLIR Vue Pro 640	
Video resolution	640x512
Lens option	13mm; 45ºx37º
Spectral Band	7.5 – 13.5 µm
Frame Rates	7.5 Hz (NTSC); 8.3 Hz (PAL)
Weight	92.1 – 113.4 g
Dimension	63mm x 44.4mm x 44.4mm

Table 6.6. FLIR Vue Pro 640 datasheet [12].

- **Option 4. Nautical Rescue.**

  - RESTUBE Classic. (Figure 25).

    Inflatable water rescue element that inflates when pulling its cord.

RESTUBE Classic	
Material	Nylon / TPU
Dimensions	150mm x 60mm x 50mm
Weight	295g

Table 6.7. RESTUBE classic datasheet [13].

6.2. Price of the drone.

The standard price of the product is 3.800€. This price includes the complete RPAS system, including the briefcase, the complete aircraft, the FPV video display and the remote controller.

At this standard price is added the price according to the payload option chosen by the customer:

Option	Price of Payload.	Total RPAS price.
Option 1. Normal Camera View:	160€	3.960€
Option 2. Thermal Camera. (Lower resolution):	1.872€	5.672€
Option 3. Thermal Camera. (Higher resolution):	2.952€	6.752€
Option 4. Nautical Rescue:	67,5€	3.867,60€

Table 6.8. Price of the drone.

The payload will be purchased from the suppliers and sold, along with the drone, to the customers directly without obtaining economic benefit in this activity. We consider a 10% reduction when we buying the payload, as we will do it in large quantities.

The shipping price will be paid by the customer according to prices of a generic shipping service.

6.3. Distribution and sale.

The distribution of our product will be direct sales to the emergency and rescue bodies or by means of concessions, since many of these bodies are controlled by public administrations. In the latter case, our drone will have to be approved and financed its purchase by the relevant public administration; for example, the Corpo Nazionale dei Vigili del Fuoco depends on the Ministry of the Interior of the Italian Republic [14]; the Guardia di Finanza depends directly on Ministry of Economy and Finance [15]; and the Guardia Costiera depends on the Ministry of Infrastructure and Transport and has a functional dependency on several departments such as

the Ministry of Environment and the Protection of Land and Sea, and the Ministry of Agriculture, Food and Forestry Policies [16].

Most emergency and rescue bodies are organized into several small stations per region that perform tasks and have primary responses; in turn, these stations are coordinated by larger provincial or regional departments which provide more complex solutions and are where vehicles, helicopters and other rescue technologies are usually stored. For example: the Corpo Nazionale dei Vigili del Fuoco has approximately 800 relief centers scattered throughout the country coordinated by 100 provincial headquarter [17]. The Guardia Costiera has 128 Local Maritime Offices and 61 Beach Delegations but these stations are regulated by 51 District Maritime Offices… These last provincial, regional or district departments are the ideal places to go and realize the sale of the drone.

We considered that the sale of the drone would be done with a repeatability of two units per customer, per station. The customer will be constantly informed of new updates that improve drone performance. In addition, our product won't be obsolete since every 2 years there will be a new version of PoliDrone. Also, the customer will enjoy an after-sales service in which we will respond and solve possible problems.

Our product is sold in individual batches. These lots include a briefcase, inside which are all the structural parts and electrical and avionic elements of the drone. The main electrical elements (FCU, GPS, IMU, the battery...) will already be mounted on the central plate. The other parts that depend on the task to be carried out (the arms, the motors, the propellers...) will be disassembled and prepared for an easy connection by the customer. The lot will be packaged and sent to the customer by a generic shipping service.

Also, our drone is destined for the Structural Health Building market and the water measurement market. For the first market, we will make the direct sale of the drone to companies specialized in the monitoring of buildings, search for defects in structures, 3D models of historical elements... For the water measurement market, we will do the same, but heading towards companies in charge of preserving the environment, NGOs...

6.4. Promotion.

We will carry out a pre-sale commercial activity in order to promote our product to potential customers. Our commercial dependents will contact directly the potential customers (departments and emergency bodies and companies related with the structural health of buildings and with the preservation of environment), giving them information of PoliDrone by phone, email... In cases where the client requests it, visits will be made for a practical demonstration of the drone.

For a better promotion, the contacts, networking and support of Politecnico di Torino will be considered.

A website will be created, which will include all the information, specifications and key points of our product. Through the website, the customer can contact us for any questions and will have at his disposal a sales service, from which his can buy the product directly. The website will include a demonstrative and advertising video of the drone for the purpose of the client has complete information.

In addition, our company will participate in drone and rescue tasks fairs and events in order to make known the drone technology and our product in the field of emergency services. Also, in later years, we will participate in fairs in the field of structural health of buildings and the environment.

7. Operative and Organizational Plan.

We can make a list with the most important tasks and activities, using different resources (human and material):

- Firstly, we will buy the necessary plastic material (1,75mm filament PLA and ABS) through suppliers.

- We take care of the manufacturing of plastic drone parts. The production operators will be in charge of the manipulation of the designs in the programs CAM and of the subsequent impression in 3D. For this we have the necessary equipment, computers, CAM programs specialized in 3D printing like the Slic3r, a 3D printer (Sharebot NG). With the growth of production, will be invested in the purchase of new 3D printers.

- We will check the plastic parts so that they are all in optimal conditions for subsequent assembly.

- We take care of buying the electrical and avionics elements through suppliers, as well as the payload required by the customer. The purchase of the payload will be made to a specialized company, we only offer the different options of payload, and we buy and install it in the drone according to the customer's choice.

- We assemble, configure and program all the structural, electrical and avionics elements in the drone ensuring a good performance maintaining the PoliDrone modularity. Including the FPV system and its correct configuration to watch live on the TFT LCD screen.

- We will buy a briefcase through a supplier, in which we will insert the batch of the complete drone (including the selected payloads).

- We will send the complete package to the customer thanks to a generic shipping service (For example, Poste Italiane).

- We will carry out the commercial activity, mainly developed by our commercial dependents. This involves promotion, being able to use the contacts and the networking of the Politecnico for example, and contact via email or telephone with the different customers. In addition to the participation of fairs and events of drones and emergency services and the possible visits to clients to make a practical demonstration.

- We will be responsible for the project certification of the drone by the ENAC (Ente Nazionale per l'aviazione civile), so that it can be used without any limitation and can be marketed by us.

- In addition, we will consider the patent management, first in Italy, and the following years in different European countries.

- We will subcontract a freelance professional in order to design our website and take care of your daily maintenance. In this website, will include the information of the drone and the possibility of buying it by the customers.

- We will also manage the after-sales service, solving any later problems and keeping the client informed of updates that improve the performance of the drone.

- We will be in continuous Research and Development activity, with the commercialization of a new version of drone every 2 years.

We can synthesize the activity of the company in the following tables, all these numbers have been estimated considering the market and industry analysis.

M&S	Year 1	Year 2	Year 3	Year 4	Year 5
Sales volumes	57k €	190k €	437k €	1330k €	2907k €
Total sold units	15	50	115	350	765
New costumers sold units	15	50	100	300	650
New customers	7,5	25	50	125	250
Customers	7,5	33	83	208	458
Negotiations	9	30	60	150	300
Demo products	12	40	80	200	400
Commercial activities	30	100	200	500	1000
Sold units to old clients (new version)	0	0	15	50	115
Sold units for other uses cases	0	0	0	50	150
HR M&S	1	1	2	2	3
Fairs and events	2	4	8	12	16

Table 7.1. Marketing and sales activity.

The first two years we go to the national market of emergency services, from the third year we will expand to the European market. In addition, the fourth year we started to make sales to the markets of the other uses cases. Because of, the contracting of commercial dependents increases as the years pass.

We have also considered that the customers, to whom we sell the drone, will buy the new version every two years.

We estimate that about 30% of commercial activities reach negotiations and 25% of commercial activities end up for sale to the customer with a repeatability of two units each.

G&A	Year 1	Year 2	Year 3	Year 4	Year 5
HR G&A	0	0	1	1	2

Table 7.2. General and Administrative activity.

From the third year we will need staff in charge of general and administrative activity.

R&D	Year 1	Year 2	Year 3	Year 4	Year 5
Versions	Version 1	Version 1	Version 2	Version 2	Version 3
Defined concepts		Version 2		Version 3	
Prototypes made		Version 2		Version 3	
HR R&D	1	1	3	3	3

Table 7.3. Research and Development activity.

As we said before, we will be in continuous search for new versions in order to get a new product every two years. This involves hiring Research and Development staff over the years. Generally, mechanical, aerospace and electronic engineers.

8. Financial Plan.

The plan considers the following phases:

- The sales will start from the 9th month of the first year. It will start in Italy and from the third year in whole Europe.
- The rescue assistance will be our first costumer target, from the fourth year we will also start selling to structural health monitoring companies and water measurement companies.

The next table resume the sales volume for the different product lines. The measurement unit are the number of sold pieces and the quantities have been estimated considering the market analysis.

Polidrone Sales volumes	Year 1	Year 2	Year 3	Year 4	Year 5
Rescue assistance	15	50	115	300	615
Other uses	0	0	0	50	150
Total	15	50	115	350	765

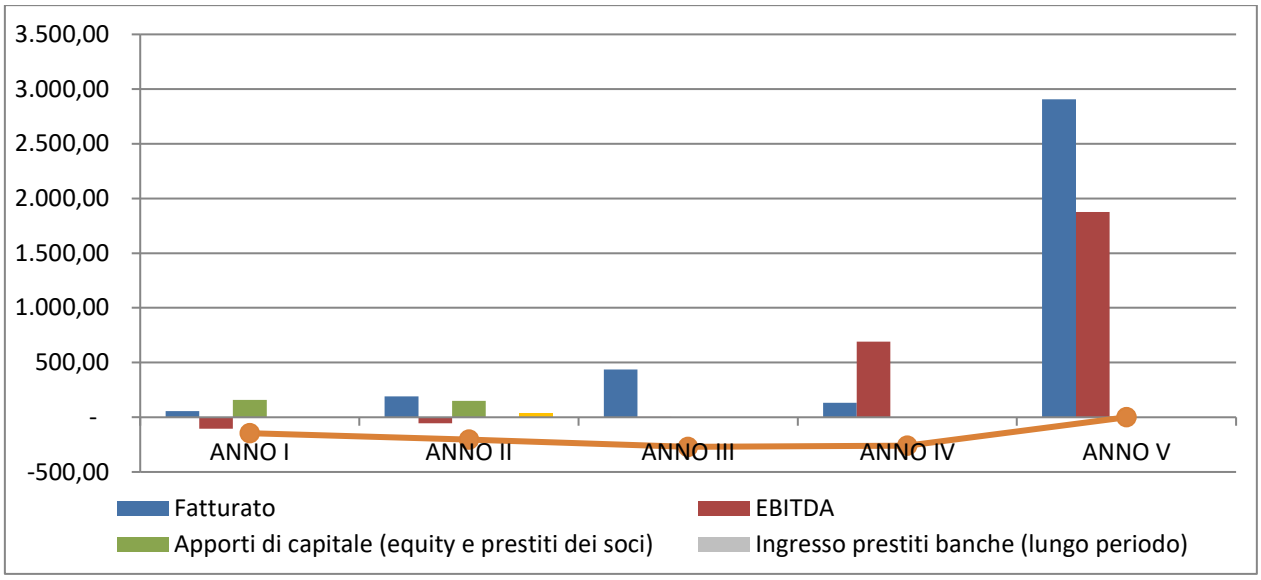
Table 8.1. PoliDrone sales volumes.

The following economics results have been hypothesized (in thousands of euros):

	Year 1	Year 2	Year 3	Year 4	Year 5
Factured	57,00	190,00	437,00	1.330,00	2.907,00
EBITDA	-105,16	-53,92	3,90	692,11	1.876,91
EBIT	-107,61	-60,47	-10,10	671,51	1.854,71
Gross profit	-107,61	-61,64	-10,21	671,51	1.854,71
Net profit	-79,24	-49,04	-18,59	448,49	1.257,04
Equity capital (equity and shareholder loans)	160,00	150,00	-	-	-
Bank Loans Entry (Long Term)	-	-	-	-	-
Bank Loans Entry (Short Term)	-	32,00	-	-	-
Maximum intra-annual operating requirement	-145,39	-203,36	-270,12	-259,73	-

Table 8.2. Economic result of the company.

The complete recovery of the investments will be at the fourth year, and the cash break-even will be at the 40th month.



Graph 8.1. Economic evolution of the company.

The graphic above shows the revenue and EBITDA rising, the financial requirement and the capital inflows. The maximum financial requirement is about 270.120€ in the third year. It has been hypothesized that can be covered using the following financial instruments:

- 10.000€ of social capital from the founders.
- Investor's participation as follows: first round of 150.000€ in the first year, and a second round of 150.000€ in the second year.
- A short-term bank loans (12 months) for 32.000€ the second year.

The key assumptions are the followings:

- Sales target as previously stated,
- It was considered a total variable cost of 520€ for the drone and 160€ for the camera (standard composition)
- Fixed costs as the next table (in thousands of euros): the more relevant fixed costs are for the commercial activity and R&D.

	Fixed costs (excluding amortization)				
	Year 1	Year 2	Year 3	Year 4	Year 5
Transfers	5,0	20,0	30,0	50,0	70,0
CEO	35,0	40,0	45,0	50,0	60,0

CTO	35,0	40,0	45,0	50,0	60,0
COO	35,0	40,0	45,0	50,0	60,0
HR R&D	12,0	30,0	90,0	90,0	90,0
HR M&S	30,0	30,0	60,0	60,0	90,0
HR G&A	-	-	20,0	20,0	40,0
Office	-	10,0	20,0	30,0	40,0

Table 8.3. Fixed costs of the company.

- Investments as following (in thousands of euros): there are not need too great investments to start the business. The more relevant investment is the intellectual property and R&D.

	Investments					Useful life
	Year 1	Year 2	Year 3	Year 4	Year 5	
Certification	10,0	-	-	-	-	5
IP	-	10,0	50,0	-	-	5
3D printer	-	-	1,5	1,5	1,5	5
Constitution and acts	8,0	-	-	-	-	5
R&D	10,0	10,0	10,0	10,0	10,0	0
Website	1,5	1,5	1,5	1,5	1,5	5
Other machinery	5,0	5,0	5,0	5,0	5,0	5

Table 8.4. Investments of the company.

The principal assumptions are:

- IVA corresponding to the 22%
- Interest fee of 4%

The forecast balance sheet is therefore as follows (figures in thousands of Euro):

ACTIVE					
	Year 1	Year 2	Year 3	Year 4	Year 5
Net fixed assets	**32,1**	**52,0**	**106,0**	**103,4**	**99,2**
Net fixed intangible assets	27,6	44,0	94,2	89,0	83,6
Net fixed tangible assets	4,5	8,0	11,9	14,4	15,7
Financial fixed assets	-	-	-	-	-
Availability Illiquide	**0,0**	**0,1**	**0,2**	**0,3**	**0,4**
Warehouse finished products	0,0	0,1	0,2	0,3	0,4
Warehouse raw material	-	-	-	-	-
Deferred Liquidity	**47,0**	**65,9**	**93,8**	**135,2**	**295,5**
Commercial credits	17,4	19,3	44,4	135,2	295,5
IRES Credits	29,6	46,5	49,4	-	-
IVA Credits	-	-	-	-	-
Immediate liquidity	**23,5**	**137,5**	**47,2**	**691,0**	**2.116,3**
Cash	23,5	137,5	47,2	691,0	2.116,3
Prepayments and accrued income	-	0,0	0,0	0,0	0,0
Total ACTIVE	**102,6**	**255,5**	**247,2**	**930,0**	**2.511,5**

Table 8.5. Actives of the company.

PASIVE					
	Year 1	Year 2	Year 3	Year 4	Year 5
Net Assets	**80,8**	**181,7**	**163,1**	**611,6**	**1.868,7**
Social capital and restricted reserves	160,0	310,0	310,0	310,0	310,0
Other reserves and retained earnings	-	-79,2	-128,3	-146,9	301,6
Current management profit	-79,2	-49,0	-18,6	448,5	1.257,0
Funds	**7,9**	**17,7**	**34,1**	**51,4**	**73,0**
TFR Fund	7,9	17,7	34,1	51,4	73,0
Long debts	**-**	**-**	**-**	**-**	**-**
Partners debts	-	-	-	-	-
Debts to banks for a long time	-	-	-	-	-
Short debts	**13,9**	**56,1**	**50,0**	**267,0**	**569,9**
Short bank debts	-	32,0	0,0	0,0	0,0
commercial debts	11,1	15,4	29,3	57,8	107,8
Erary debt	2,8	8,6	20,7	209,2	462,0
Accruals and deferred income	-	-	-	-	-
Total PASIVE	**102,6**	**255,5**	**247,2**	**930,0**	**2.511,5**

Table 8.6. Pasives of the company

In addition, you can see the variable costs of a drone manufactured in the Annex II. Variable Costs.

9. Market Analysis

Firstly, to know which use case to give the drone and in which market to focus our activity, we made up to 4 different questionnaires. These questionnaires were distributed over the Internet and were filled out and answered by more than 100 people, helping to choose the market of Rescue Assistance as first objective, following of the market of the structural health of buildings and the market of the measurement of the water. You can see these questionnaires in the Annex III. Questionnaries.

9.1. Types of drones.

We will define the types of drones that exist in the market. We can differentiate 4 types of drones with common characteristics and purposes for each group:

9.1.1. Toys.

Small and very light (<500g) drones, made mainly of plastic, with small ranges of use (approximately 50m) and low speeds. They serve as a hobby and fun for the user. The design is focused on easy handling in order to do certain turns and manoeuvres.

The camera they carry, if it has, is usually of poor quality. They don't require any application on the mobile phone, are controlled by Remote Controller. Their flight times are short (Don't usually exceed 10 minutes) and their batteries are of low capacity.

The altitude that they can reach, the resistance to the wind or the amount of weight that they can raise in their take-off are unnecessary aspects for this type of drones.

For all this, their price is between 40€-120€.

Figure 9.1. Parrot MAMBO.

Figure 9.2. Syma x5c-1.

9.1.2. Consumer drones.

Consumer drones for a civilian use that doesn't need great sophistication. Most of them are destined to taking photos and recording videos by the user, so a good camera is indispensable. They are not very heavy (0.6kg-2kg), nor very big (they don't usually surpass 50cm in diagonal) to be able to handle them with easily.

For greater convenience and better distribution among buyers, most companies have their own app for the mobile phone (android/iOS), through which the drone can be handled, take

photos from it, see what the camera is recording and plan its flights. Some of them also have the option of handling from a Remote Controller.

Their flight times usually go from 12 minutes, to 25 minutes more or less. The altitude or range they can reach isn't definitive for the acquisition of this type of drones.

Generally, they aren't equipped to lift more weight than their own. Their prices range from 400€-1.200€.

Figure 9.3. DJI Phantom 4.

Figure 9.4. Parrot Bebop 2.

Figure 9.5. Xiaomi MI Drone

9.1.3. Commercial drones.

They differ with consumer drones, in that their ranges, ability to carry heavier payloads and quality of material are better.

They are bigger (1m-2m diagonal) and heavier (2kg-5kg). They are destined to tasks that require greater precision, stability and travel. They can fulfill many functions (recording, monitoring, mapping, inspection...), facing difficult weather situations. Their batteries are larger than those of the consumer drones, but their flight time doesn't increase too much (15min-30min), due to their greater weight.

They also usually have an app for android/iOS for their control and vision from the drone, In addition to the possibility of adding a Remote Controller.

Some of them have the possibility to exchange their payload (camera, sensors...) depending on the task to be performed. Their price is between 2.000€-10.000€.

Figure 9.6. DJI Inspire 2.

Figure 9.7. Yuneec H920 Plus.

9.1.4. Professional drones.

Big and heavy drones, most of them with a single propeller and fixed wing that can travel great distances. Their flight times are the largest (2h- +24h), and their main tasks are military (defense, reconnaissance, transportation...). All of them are compatible with many different and highly sophisticated payloads (radars, sensors, infrared and night cameras…)

Their power supply can be from big lithium batteries, through fuel engines, to ground power. Their handling must be very precise and the amount of data that collect their payloads are very large, therefore, They are usually controlled by Ground Control Station using GPS.

Their cost is very high, being able to reach the 250.000€ per unit, so the main customers are the governments of countries that want to incorporate these drones into their military defenses.

Figure 9.8. AeroVironment RQ-11b Raven.

Figure 9.9. Aeryon Labs Sky Ranger.

PoliDrone can be somewhere in between the concept of Consumer drone and Commercial drone. Due to the measurements and weight of our drone, it could be classified in the list of consumer drones. But its modularity, its ability to carry payload and the type of activities to be performed give it a more commercial character.

For these reasons, a global and regional market analysis of consumer drones and commercial drones has been done separately, collecting current data and predictions about the next few years in order to see its evolution. All these information has been checked and evaluated strictly.

9.2. Global drone market.

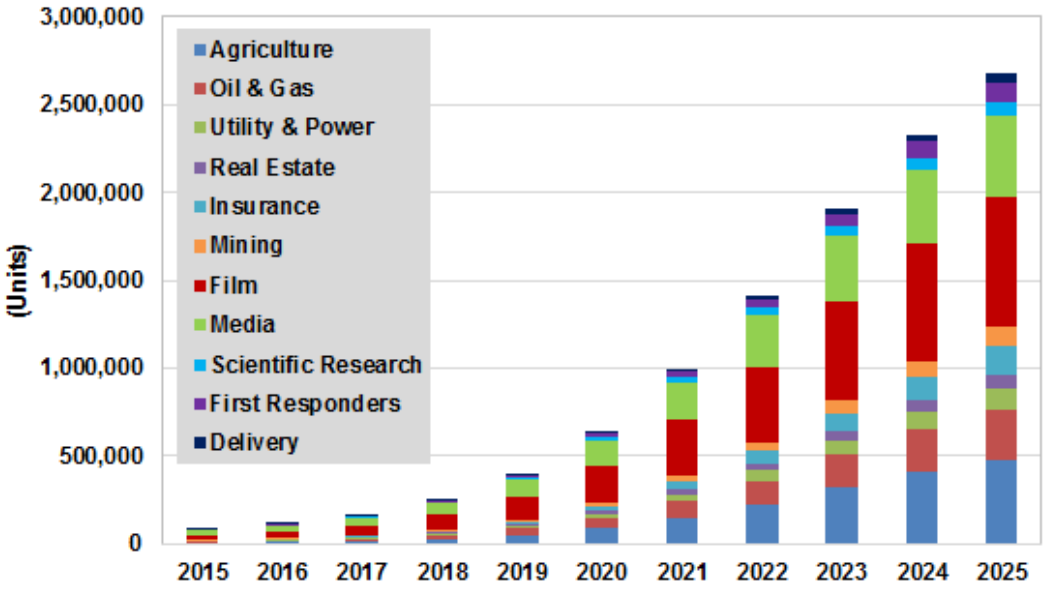
9.2.1. Global commercial drone market.

The global commercial drone market size was estimated to be USD 552 million in 2014 and is expected to grow at a CAGR of 16.9% according *Grand View Research* [18].

Increased applications in agriculture and law enforcement sectors are expected to favorably impact the market. UAVs find applications in various industrial verticals which include military, homeland security, agriculture, infrastructure, scientific research and R&D, environmental studies, delivery, disaster management activities… For the commercial or professional drones the demand is higher for military applications, although commercial applications are gradually catching up [18].

Actually, aviation regulatory bodies such as the Federal Aviation Administration (FAA) from the U.S. and the European Aviation Safety Agency (EASA) have banned certain uses of drones, like transport and logistics, keeping in view the limitations in managing air traffic on such a huge scale and the safety of the citizens. In the coming years, a necessary update of the airspace rules for drones is expected, leaving more freedom and diversity of uses [18].

According to a new report from *Tractica*, this interest in utilizing drones for commercial applications will drive commercial-grade UAV shipments from 80,000 in 2015 to more than 2.6 million units annually by 2025 [19]. As you can see in the Graph 9.1, differentiating by application.

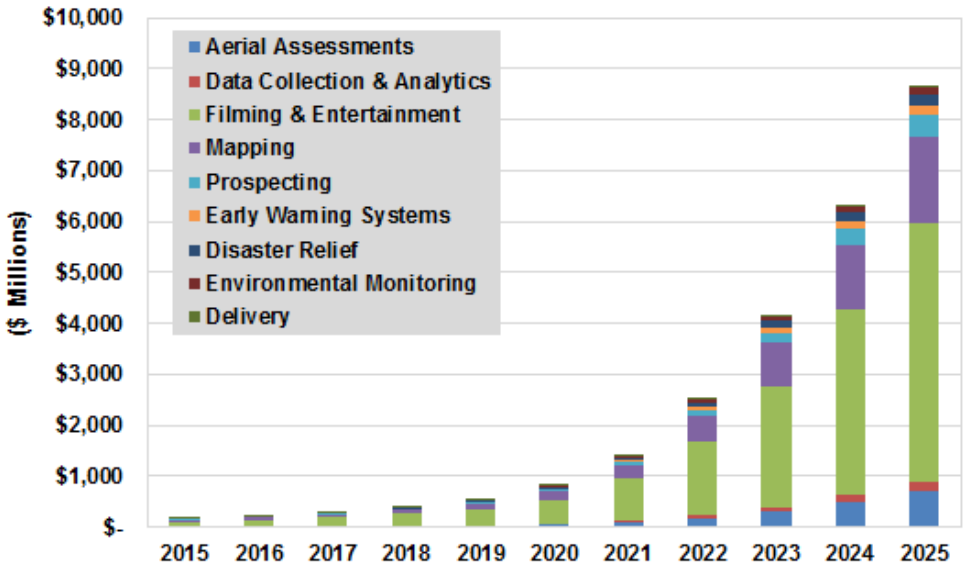


Graph 9.1 Global commercial UAVs shipments (2015-2025) [20].

Continuing with the same studio of *Tractica, c*ommercial applications for drones fall into two major categories: aerial imagery and data analysis. Imaging applications involve the utilization of a drone-mounted camera for a multitude of purposes, ranging from the ability to capture aerial footage to the creation of digital elevation maps by means of geo-referencing capabilities.

For data analysis applications, one key value of flying a commercial drone happens post-flight. Data collection and image processing capabilities and techniques deliver the ability to produce fine-grained data.

Tractica forecasts that annual revenue from commercial drone hardware sales will reach nearly $4 billion within the same timeframe. However, the more significant revenue opportunity will be in commercial drone-enabled services, which *Tractica* forecasts will grow to $8.7 billion annually by 2025 (Graph 9.2). Most drone-enabled services will rely on onboard imaging capabilities; the largest applications will include filming and entertainment, mapping, prospecting, and aerial assessments [20].



Graph 9.2. Global commercial drone-enabled services revenue (2015-2025) [20].

In the near term, the four main industries that will lead this market are film, agriculture, media, and oil and gas. The aerial imagery and data analytics functions mentioned previously are the primary drivers for their use in these industries. The capacity to collect, analyze, and deliver information in near real time will continue to be a reason for industries to adopt this technology in their supply chains [20].

According a study of *PwC (PriceWaterhouseCoopers*), we have decided to show the potential of addressable markets. To measure such markets the cost of labor and services that have a high potential for replacement in the very near future by drone powered solutions has been indicated. The analysis was performed separately for each industry and based on data from 2015. The total addressable value of drone powered solutions in all applicable industries is

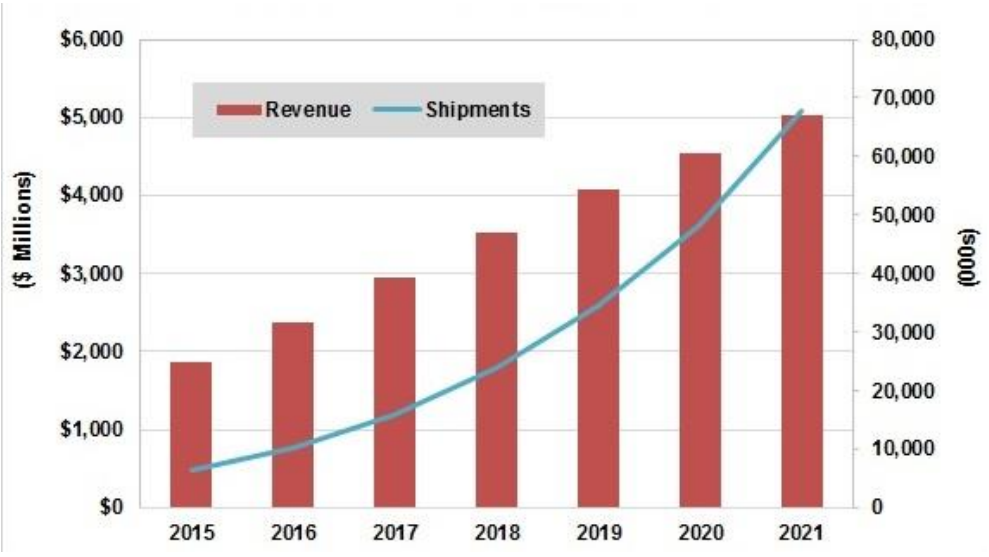
estimated by *PwC* at over $127 billion (Table 9.1). The industry with the best prospects for drone applications is infrastructure, with total addressable value of just over $45 billion [21].

Value of drone powered solutions addressable industries – global view ($ billion)	
Infrastructure	45.2
Transport	13.0
Insurance	6.8
Media & entertainment	8.8
Telecommunication	6.3
Agriculture	32.4
Security	10.5
Mining	4.3
Total	127.3

Table 9.1. Value of drone powered solutions addressable industries – global view ($ billion) [21].

9.2.2. Global consumer drone market.

The market growth opportunity for vision processing in consumer drones, both to expand the total number of drone owners and to encourage existing owners to upgrade their hardware, is notable. Worldwide sales of consumer drones reached $1.9 billion in 2015, according to market analysis firm *Tractica*, and the market will continue to grow rapidly over the next few years, reaching a value of $5 billion by 2021. *Tractica* also forecasts that worldwide consumer drone unit shipments will increase from 6.4 million units in 2015 to 67.7 million units annually by 2021 (Graph 9.3) [20].



Graph 9.3. Revenue and shipments of global consumer drones market (2015-2021) [20].

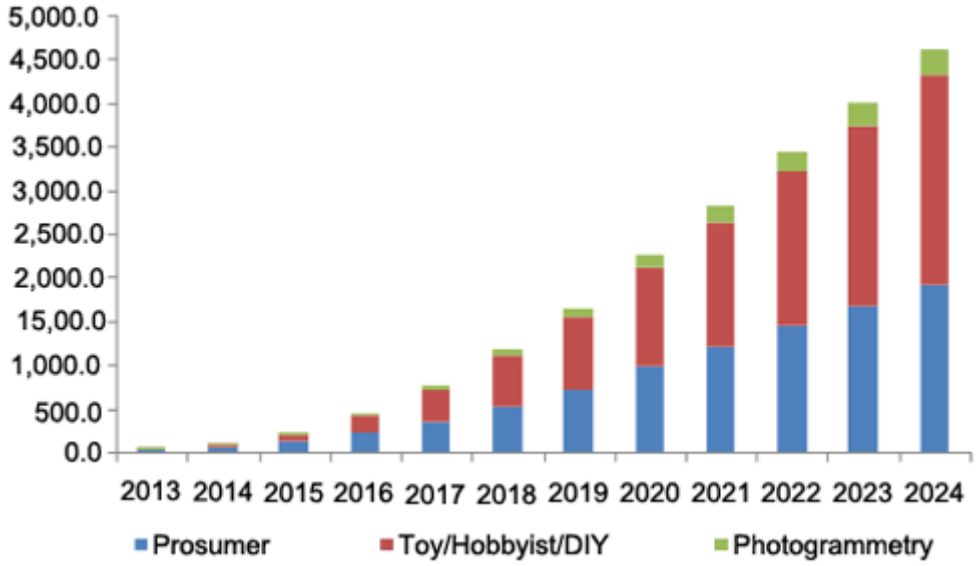
Global population is increasingly accepting the imminent trend of the drone as a far and wide accepted hobby. Casual enthusiasts and early adopters comprise a significant portion of the industry. Novel technology in electronics has also attracted gaming segment enthusiasts to accept drones as their new found source of entertainment with along with organizing various competitions [22]

The industry incorporates significant opportunities for growth over the forecast period. Manufacturers are focusing on the development of innovative technologies, in order to broaden its application base. One such innovation is the transformation of consumer UAVs into flying smartphone-like platforms. These developments in the market are expected to retain consumers' interest longer, expand product lifespan, and increase product value [22].

Multi-rotor drones dominated the market share in 2015 and are expected to retain their dominance over the forecast period. Their growth can be attributed to increased use of multi-rotor drones in aerial photography and FPV racing application.

Nano drones are expected to witness considerable growth over the next few years owing to their cost-effective operation. Their relative operational cost effectiveness is presumed to increase the usage of such drones for various purposes. Nano drones are expected to grow at a CAGR of close to 34% over the forecast period [22].

Prosumer application segment is envisioned to remain the dominating segment over the next eight years and accounted for close to 60% of the overall market share in 2015. Toy/hobbyist applications segment is expected to witness considerable growth, growing at a CAGR of close to 35% from 2016 to 2024. The demand for drones in photogrammetry application segment was estimated to be close to 20 thousand units in 2014, which is expected to grow considerably over the next eight years [22]. All these information are included in the Graph 9.4, for the North American market.



Graph 9.4. US consumer drones market revenue (2013-2024) [22].

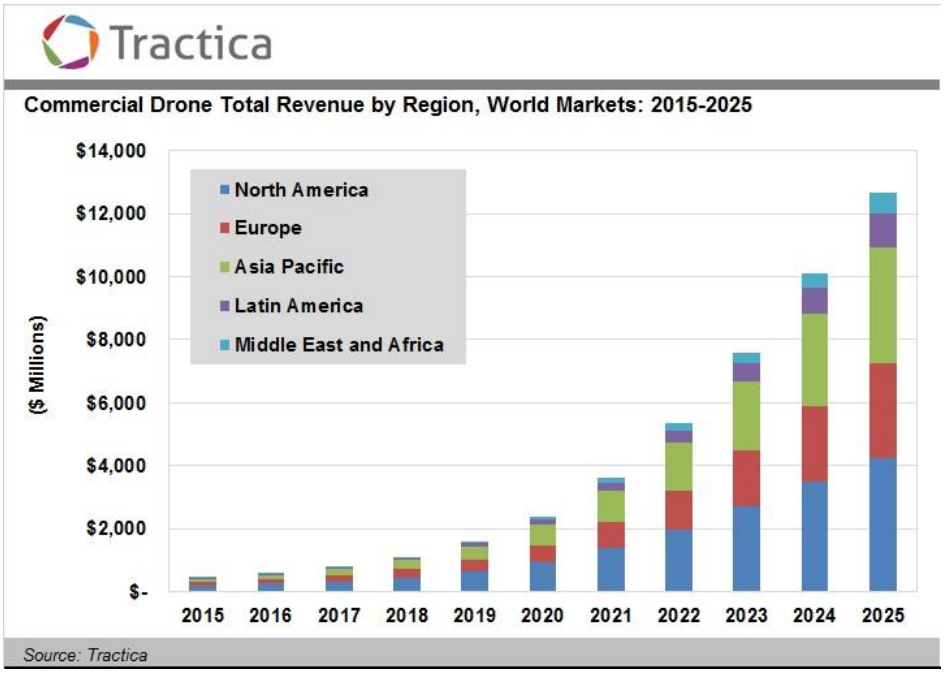
9.3. Regional drone market

9.3.1. Regional commercial drones market.

North America dominates the global industry owing to high production and increasing applications in the commercial sectors. However, the Europe commercial drone market is expected to grow considerably in the next seven years owing to the relaxations in regulations and increasing applications in law enforcement and agricultural applications [18].

Favorable government initiatives and building retrofits are expected to be the key growth factors for the European market. Moreover, the demand for UAVs is expected to gain traction in Asia-Pacific. Australia, along with Asian countries such as Japan, has focused on the use of UAVs for agricultural purposes [18].

Summing up $4 billion of sales of the hardware of commercial drones, and the $8.7 billion of sales of commercial drone enabled-services, we have the total revenue by region (Graph 9.5).



Graph 9.5. Revenue of global commercial drone enabled-services [19].

9.3.2. Regional consumer drone market.

North America market was valued at close to USD 140 million in 2015 and is expected to grow considerably over the forecast period. Upcoming favorable initiatives by the Federal Aviation Authority (FAA) and an increased governmental spending on such advanced drones are expected to drive the industry growth in the region [22].

Europe accounted for over 30% of the overall industry share in 2015 and is envisioned to emerge as a predominant region over the forecast period. This growth can be attributed to the

proposal of new regulations to provide a safe and fertile environment for such promising industry and grow by integrating drones into European civil airspace [22].

Asia Pacific consumer drone market is estimated to witness significant growth over the forecast period and is projected to grow at a CAGR of over 35% over the forecast period. This can be attributed to heavy investment initiatives in China drone companies by investors in the U.S. Moreover, the region has made plans to build a UAV production base in China, to tap into the emerging industry [22].

9.4. Use cases market.

Once the market study of the drones at the global level has been done, we will study the market of the use case for which the drone is destined, the Rescue Assistance. We will also do a market study of the future potential uses, the Structural Health Monitoring; and the Water Measurement.

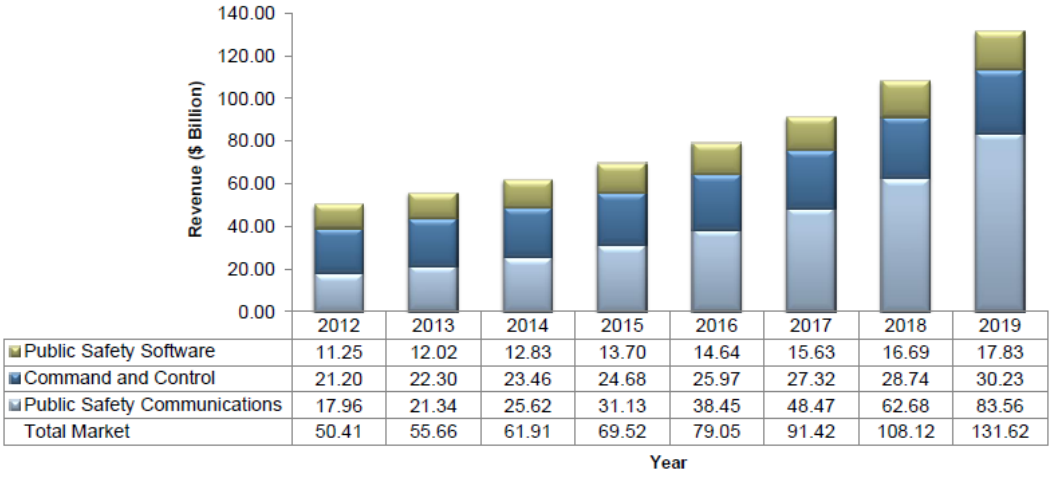
9.4.1. Rescue Assistance.

The global first responders C3i and emergency response market (including public safety communications, command and control solutions, and public safety software solutions)is expected to grow at the rate of 14.7 per cent, and reach revenue worth $131.62 billion by 2019 (Graph 9.6) [23].

Public safety communications market (Land Mobile Radio/Professional Mobile Radio, Software Defined Radio and Public Safety LTE); will have the fastest growth rate of 23.2% [23].

Followed by public safety software solutions (Intelligent Transportation Systems, Unmanned Aerial Systems, Mobile Computers, Smartphones…) with a growth rate of 6.8% [23].

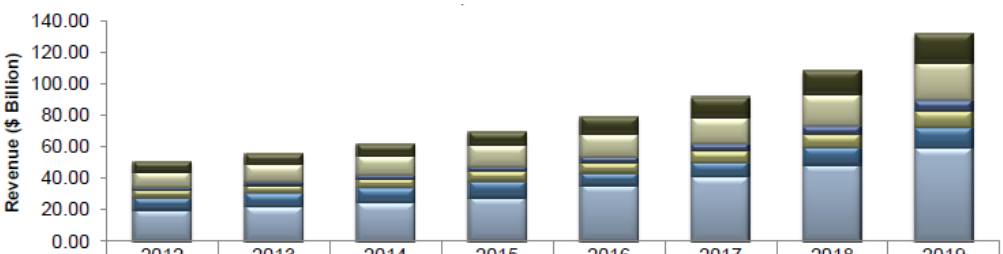
And finally, the command and control segment (Command Centers, Mobile Incident Command Systems…) with a 5.2% [23].



	2012	2013	2014	2015	2016	2017	2018	2019
Public Safety Software	11.25	12.02	12.83	13.70	14.64	15.63	16.69	17.83
Command and Control	21.20	22.30	23.46	24.68	25.97	27.32	28.74	30.23
Public Safety Communications	17.96	21.34	25.62	31.13	38.45	48.47	62.68	83.56
Total Market	50.41	55.66	61.91	69.52	79.05	91.42	108.12	131.62

Graph 9.6. Revenue of global emergency response [23].

In the Graph 9.7 you can see the market of total first responder and emergency response by region.



	2012	2013	2014	2015	2016	2017	2018	2019
South America	6.05	6.68	7.43	8.34	11.07	12.80	15.14	18.43
Asia-Pacific	10.08	11.13	12.38	13.90	14.23	16.46	19.46	23.69
Africa	2.02	2.23	2.48	2.78	3.95	4.57	5.41	6.58
Middle East	4.54	5.01	5.57	6.26	6.32	7.31	8.65	10.53
Europe	7.56	8.35	9.29	10.43	7.91	9.14	10.81	13.16
North America	20.16	22.26	24.76	27.81	35.57	41.14	48.65	59.23
Total	50.41	55.66	61.91	69.52	79.05	91.42	108.12	131.62

Graph 9.7. Revenue of global emergency response by region [23].

Once the global market for emergency services has been presented, we will focus on the domestic market and specifically in search and rescue activities.

Most of Italian Search and Rescue (SAR) operations and other emergency activities are carried out by the national Corps of Firefighters (Corpo Nazionale dei Vigili del Fuoco), the Guardia Costiera, the Corpo Nazionale Soccorso Alpino e Speleologico, the Meteomont Rescue Team, the Italian Red Cross and the Guardia di Finanze. These organizations are coordinated by Control Rooms and Secondary Coordination Centres, which are connected together, creating the National System for Search and Rescue (SAR) [24].

All these organisms are potential clients. Below we are going to show the number of interventions, calls-out, offices, members of the bodies... in order to understand and have an idea of the size of the market.

9.4.1.1. Corpo Nazionale dei Vigili del Fuoco.

Rescue calls arriving each year at the headquarters of the Corpo Nazionale dei Vigili del Fuoco are estimated at least 5.000.000, compared to approximately 700.000 for the Provincial Commands [17]. The body is composed of 8 central offices, 18 regional offices and 100 provincial headquarters (main relief centers) with approximately 800 relief centers scattered throughout the country. It operates all over Italy, except Valle d'Aosta region, Bolzano and Trento provinces, with around 35.000 professional and volunteer units [17].

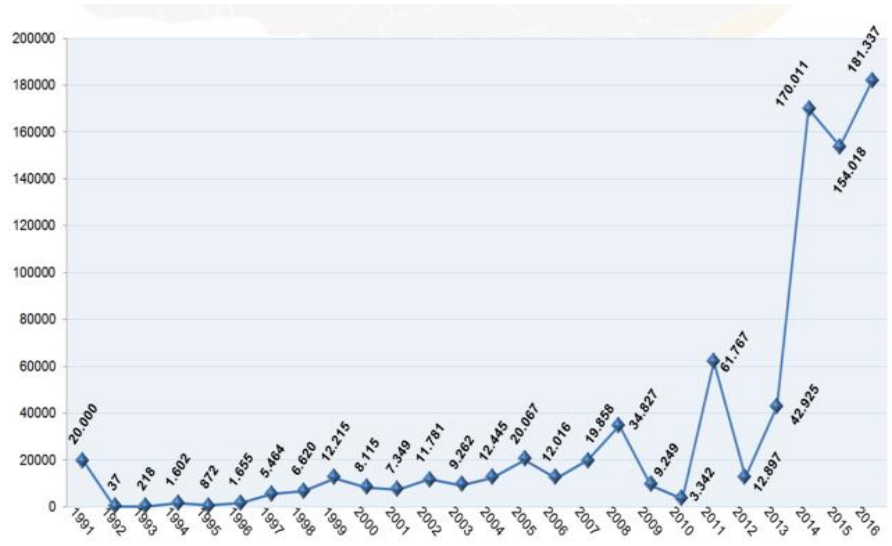
Apart from this, a search of primary information was carried out, an interview was conducted with Alessandro Ciano (he had previously worked with firefighters). From this interview (See full interview in Annex IV. Interview to Alessandro Ciano.), different conclusions were drawn:

- Half of the emergency and rescue situations require the work of a drone, since in these cases, all available resources are needed.

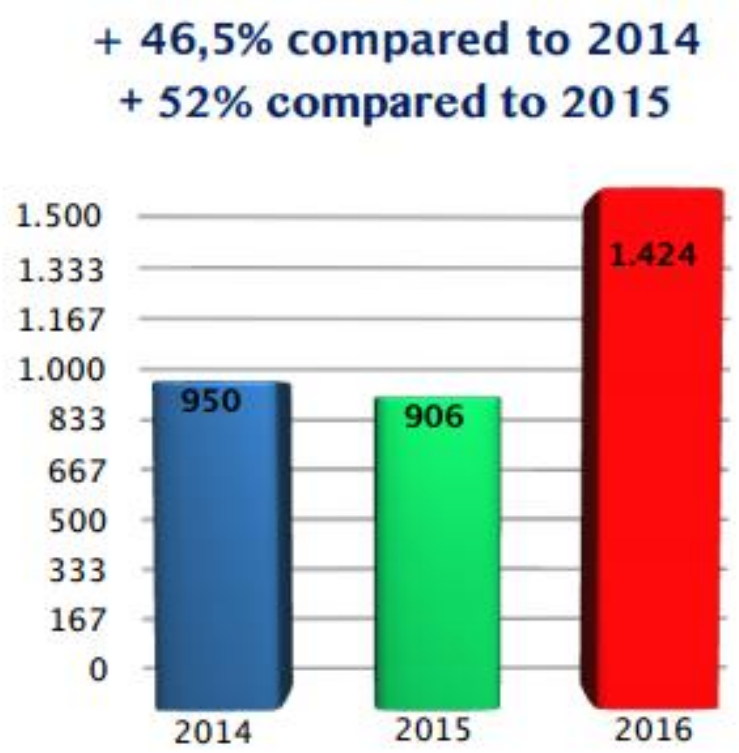
- Torino's Fire Department has a drone. This is probably done in the Politecnico, with a standard configuration and design and with a basic camera.
- The sale relationship is almost direct between the manufacturer and the fire department.
- The drone can cover a large area giving an aerial view and can help with the use of thermal cameras.
- The main activity of the drone is to have a clear prior situation of the place where the firemen are going to approach.
- In the case of fires. The drone provides a panoramic view. A helicopter can do the same task, but it can be dangerous (through smoke, ashes, at night can't fly by law).
- In the case of nautical rescue the drone can see through the thermal cameras for people search and if it falls in the water, it won't disable.
- For missing person, the drone is very interesting due to its thermal vision.
- The modularity is very important, since no situation is the same.
- The payloads most useful are a thermal camera, normal vision camera, night vision camera, speaker, microphone, sensors of measure of the temperature, water…

9.4.1.2. Guardia Costiera.

The current staff of Guardia Costiera consists of 11.000 men and women, distributed in a capillary structure consisting of 15 Maritime Offices, 55 Port Harbourmaster, 51 District Maritime Offices, 128 Local Maritime Offices and 61 Beach Delegations. The MRCC Rome (Maritime Rescue Coordination Center Rome) is the organism responsible for coordinating all rescue operations in Italian waters, especially the rescue of immigrants trying to reach Europe from Africa across the Mediterranean Sea. This organism organizes the nautical rescue activities of Guardia Costiera, Guardia di Finanza, Italian Navy, Non-Government Organizations… In recent years, the number of migrants rescued from the sea (Graph 9.8) and the number of rescue operations coordinated by the MRCC Rome (Graph 9.9) has grown significantly [3].



Graph 9.8. Migrants rescued from the sea in Italy [3].



Graph 9.9. Rescue operations coordinated by the MRCC Rome [3].

9.4.1.3. Corpo Nazionale Soccorso Alpino e Speleologico.

The CNSAS (Corpo Nazionale Soccorso Alpino e Speleologico) operates in all accidents which may occur while hiking or mountaineering, caving, cave diving, avalanches, flooding, earthquakes… and also for a medical emergencies in any location difficult to reach with a standard medical team. The more than 7.000 members of the CNSAS are all expert climbers or cavers of proven experience and capabilities, with a basic knowledge of medical rescue [25].

The CNSAS is articulated across the territory through 21 Services each set up for each autonomous region or province of the Italian State. There are 31 alpine delegations and 16 speleological delegations, which in turn enclose the operating cores, called Stations, whose task is to bring relief. Alpine stations are 242, while speleological stations are 27 [26]. The number of interventions of this body is in the Table 9.2.

2016	Interventi complessivi (7.070 nazionali + 1.133 Valle D'Aosta)	8.203
2015	Interventi complessivi (7.005 nazionali + 1.027 Valle D'Aosta)	8.032

Table 9.2. Number of interventions of CNSAS [27].

9.4.1.4. Meteomont Rescue Team.

Meteomont is a service for the prevention and prediction of avalanche danger, carried out all over the country by the command troops of the Alps and the Police Command [28]. In addition to carrying out climate measurements in high mountains and snow analysis, it also carries out search and rescue work in alpine areas. Meteomont has its headquarter in Bolzano, and has 6 Sector Centers (Torino, Aosta, Bolzano, Brunico, Belluno and Udine) [29].

9.4.1.5. Italian Red Cross.

The Italian Red Cross is a humanitarian organism which helps in first Aid, health Education, international humanitarian law, activities for young people, civil protection and defense… It also conducts numerous emergency services. It is composed of 150.000 volunteers and 29.000 military personnel [30] and has 21 Regional Headquarters [31]. At the moment it has centers in which the use of drone is being valued, as the SAPR training unit of Bologna, which uses a drones fleet in specialized civil and critical operations. This center is dedicated to training the pilots of several types of drones (such as IA-3 Colibrì, a product of IDS) [32].

9.4.1.6. Guardia di Finanza.

The S.A.G.F. (Soccorso Alpino Guardia di Finanza) is an organism in charge of emergency services and rescue tasks in mountainous areas. It is composed of 275 military and has 25 stations distribuited mainly of the area of the Alps (Figure 9.10) [33].

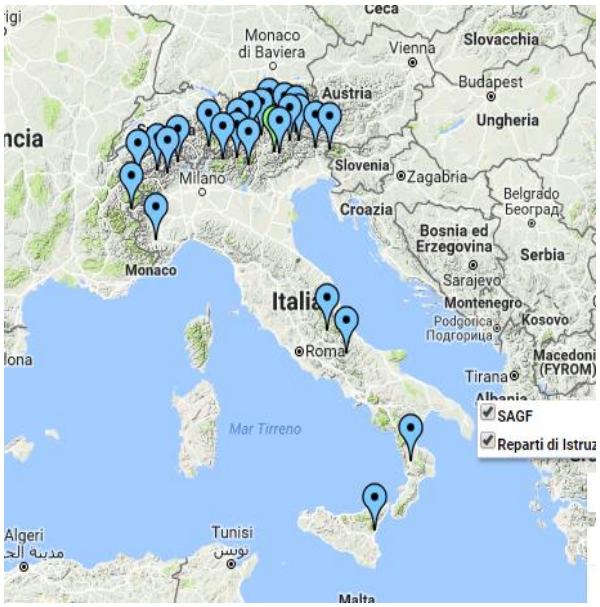


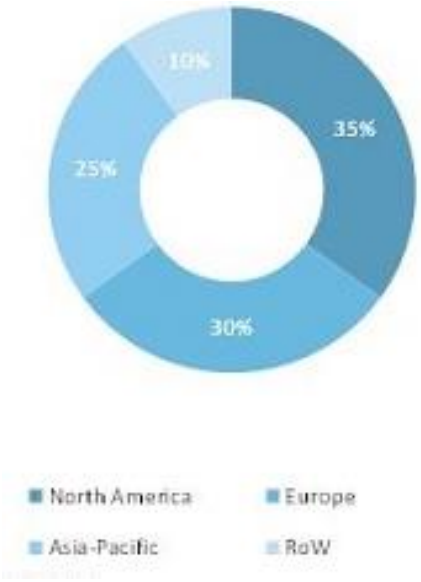
Figure 9.10. S.A.G.F. stations [33].

All these entities have 234 offices or regional headquarters that we will direct our commercial activity.

Apart from the analysis of the national territory, a primary analysis has been done which includes the number of stations and most important brigades of 26 European countries (Germany, Belgium, France, Denmark, Portugal, Spain, UK, Sweden and Switzerland among the distinguished). In total, the sum of potential customers in these countries is 955 (Regional offices, district departments, private fire brigades…). We estimate that this number can be increase the double if we consider the rest of European countries and if it wasn't for the lack of information or incomplete data that we have found at the time of analysis.

9.4.2. Structural Health Monitoring market.

The structural health monitoring market is estimated to grow from USD 701.4 Million in 2015 to USD 3407.7 Million by 2022, at a CAGR of 24.99% between 2016 and 2022. This market growth could be attributed to the rapidly aging infrastructure in the world, the growing use of composites, and the need for monitoring of structures in hazardous and inaccessible areas [34].



Graph 9.10. Global Structural Health Monitoring market by region [34].

Wide availability of low-cost sensors, growing infrastructural development across the globe, and increasing government initiatives towards public safety and structural health monitoring system standardization are factors expected to drive growth of the global structural health monitoring market over the forecast period [35].

However, complexity in implementing structural health monitoring solutions for massive structures coupled with a lack of trained professionals could hamper overall market growth to a certain extent during the forecast period [35].

9.4.3. Water measurement market.

The market of global environmental monitoring is expected to reach USD 19.56 Billion by 2021, growing at a CAGR of 7.7% during the forecast period. Factors such as increasing number of government initiatives to control environmental pollution levels, increasing government funding for pollution control and monitoring, ongoing installations of environment monitoring stations, and growing initiatives for the development of environment-friendly industries are propelling the growth of the environmental monitoring market [36].

Specifically, the water quality monitoring market is expected to be worth USD 4.69 billion by 2025, growing at a CAGR of 4.54% between 2016 and 2025. The growth of this market is driven by stringent government policies, initiatives toward lowering the water pollution level, and growing industrial applications pushing the market for improved water testing and analysis products [37].

The market in APAC (Asia-Pacific) is expected to grow at the highest CAGR. The growth of the water quality monitoring market in APAC can be attributed to factors such as increasing demand for drinking water from residential sectors; implementation of stringent rules and regulations related to water and wastewater in countries such as China and India; and increasing industrial growth in countries such as India, China, South Korea, Malaysia, and Thailand [37].

9.5. Italian Legal Framework.

There is a regulation for the use of drones. In Italy, the legal framework is regulated by the ENAC (Ente nazionale per l'aviazione civile). This regulation is coordinated and approved in the European framework by the EASA (European Aviation Safety Agency). The drones, being a relatively new technology, don't have a completely concrete and defined regulation. In the coming years, a continuous evolution of the laws is expected, with better concretion and allowing greater freedom and applications of use. Next, we are going to summarize the most important laws of the Italian legal framework that affect our drone [38]:

- The RPAS (Remotely Piloted Aircraft System) shall be identified by a plate installed on the RPA showing the identification of the system and of the operator. An identical plate shall be installed also on the remote ground pilot station.

- Any RPAS shall be equipped with an Electronic Identification Device that allows the transmission of RPA real time data, its owner/operator and basic flight parameters, as well as the recording of these data. Electronic Identification Device performances and characteristics are defined by ENAC.

- "Non-critical" specialized operations are VLOS (Visual Line of Sight) operations which do not overfly, even in case of malfunctions and/or failures:

- Congested area, gathering of persons, urban areas.
- Critical infrastructures.

- RPAS specialised operations with RPA with operating take-off mass of less than or equal to 2 kg are to be considered non critical in any operative scenario, providing that the RPA design criteria and manufacturing techniques result in harmless features, that shall be verified in advance by ENAC or by an organization recognized by ENAC.
- In order to pilot RPAS with RPA having operating take-off mass less than 25 kg , in VLOS operations it is necessary to hold the RPAS pilot certificate, issued by a recognized RPAS training Centre according to the following art. 23. The certificate is issued, based on different RPA class and category and defines operative limitations to exercise relevant privileges.
- VLOS operations are permitted in daylight, up to maximum height of 150 m AGL, within maximum horizontal distance of 500 m, and shall be carried out safely, without causing damages to third parties.

However, for search and rescue tasks and other emergency situations, the limits of the last point (500m horizontally and 150m AGL) disappear having authorization from the ENAC.

Considering this legal framework, we need the certification of project by the ENAC. ENAC defines this certification as:

- The Project Certification allows the serial drone constructors to issue certificates of conformity for the purpose of complying with the rules of the Regulation of Remote Piloting.
- Based on the research carried out by the ENAC, the mass-produced product can be used for critical special operations in scenarios that do not involve the over flight of persons in the area of operations unless these people are indispensable for the operations and trained to this purpose.
- The operator, who wants to use the drone for its operations, will not be forced to demonstrate the suitability of the configuration of the medium used, only have to demonstrate compliance with the operational aspects showing the request for authorization. [39]

10. Industry Analysis

The study of the main competitors in the design and manufacture of drones and UAVs has been made, formed by the following parts.

Firstly, a classification of the most popular and requested companies in this sector by customers, as a way of giving an overall view of which can be the most important companies.

Then, there are the charts corresponding to the market share of consumer drones, commercial drones and the market share of drones sold in USA. Market share is the proportion of market which consumes the products or services of a particular company.

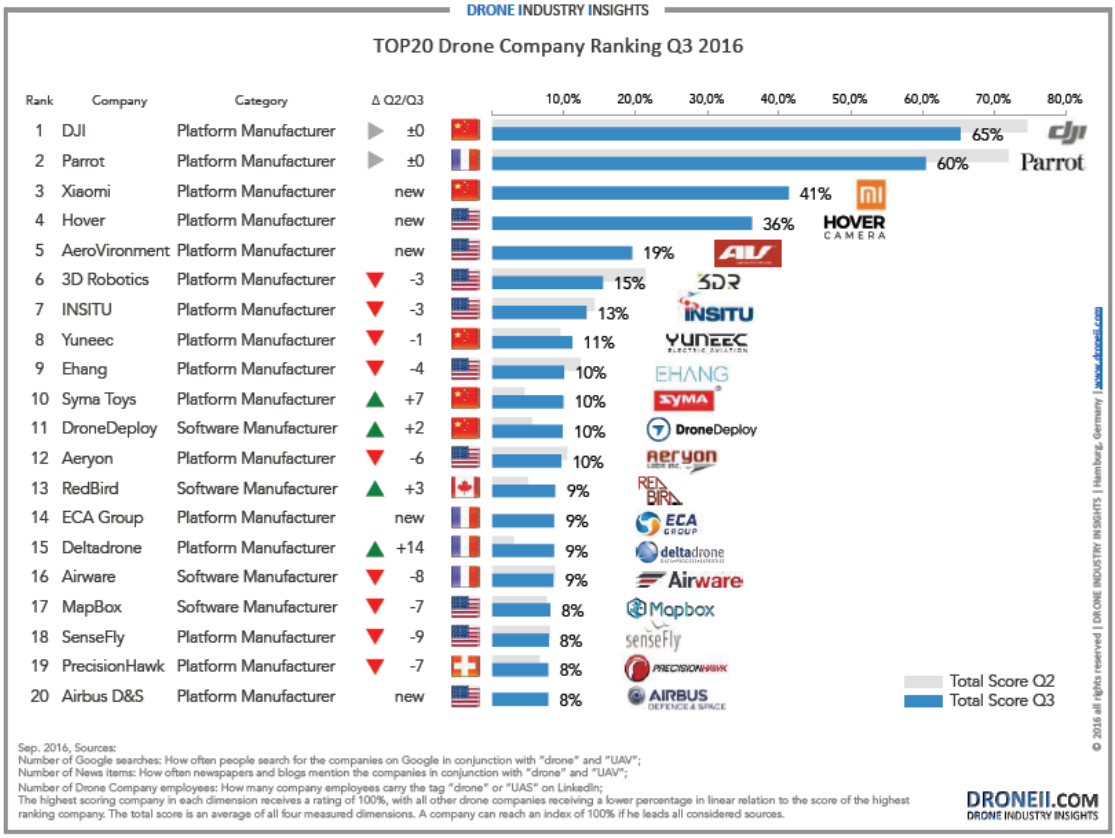
Continuing with a list of competing companies that manufacture consumer and commercial UAVs with possible similar applications to ours. In this list appear the characteristics of the company, main products they sell, traffic of its web pages [40], number of employees, revenues, remarkable news…

10.1. Most popular competitors.

To get an overview of the most famous companies in the design and manufacture of drones worldwide, they have been classified in the Graph 10.1, in accordance with the following criteria:

- Number of Google searches: How often people search for the companies on Google in conjunction with the words “drone” or “UAV”.
- Number of news items: How often newspapers and blogs mention the companies in conjunction with the words “drone” or “UAV”.
- Number of Drone Company employees: How many company employees carry the tag “drone or “UAV” on LinkedIn.
- The highest scoring company in each dimension receives a rating of 100%, with all other drone companies receiving a lower percentage in linear relation to the score of the highest ranking company.
- The total score is an average of all three measured dimensions [41]

In the graph on the next page, there are two different types of manufacturer: the Platforms manufacturer, responsible for the design and manufacture of the drone, the physical aircraft; There are also companies of the type Software manufacturer, more in charge of the development of programs and applications for the handling of drones. The study of competitors will focus on the Platform manufacturer, because our product is a physical aircraft.



Graph 10.1. TOP20 Drone Company Ranking Q3 2016 by popularity [41].

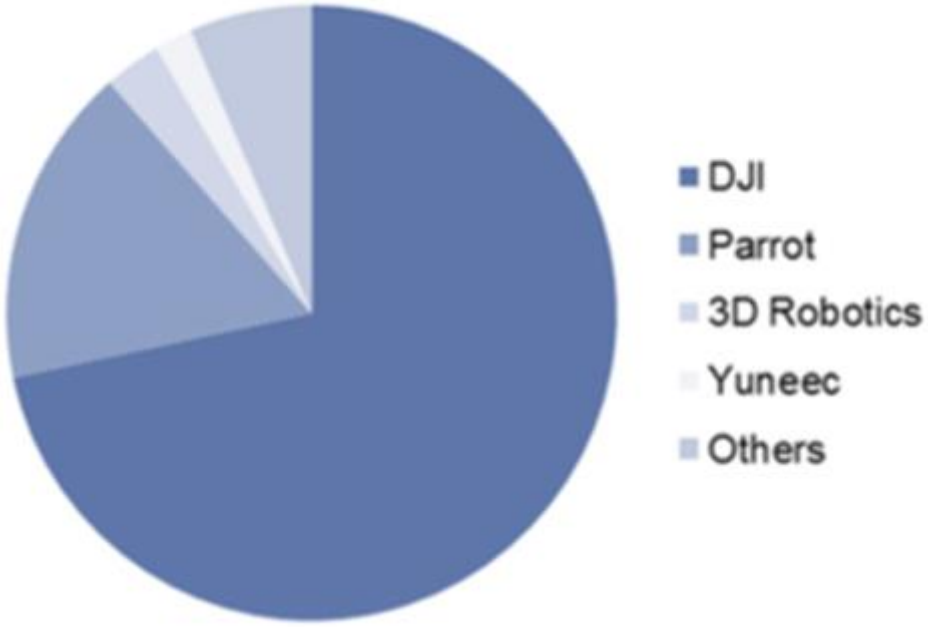
It can be seen that DJI and Parrot companies have a leading role with 65% and 60% respectively. Followed by emerging companies in this field like Xiaomi, with 41%; Hover Camera, with 36%; and AeroVironment, with 19%.

Behind them, and with similar percentages, there are 3DRobotics, Insitu, Yuneec, Ehang…

10.2. Market share.

In addition to ranking by popularity, a study has been carried out on the market share of each of the competitors. For a better understanding, we will distinguish between consumer drones, and commercial drones. The difference between consumer and commercial drone hardware components is primarily in the level of sophistication of the components (e.g., commercial drones may require higher resolution cameras or heavy lift abilities) [42].

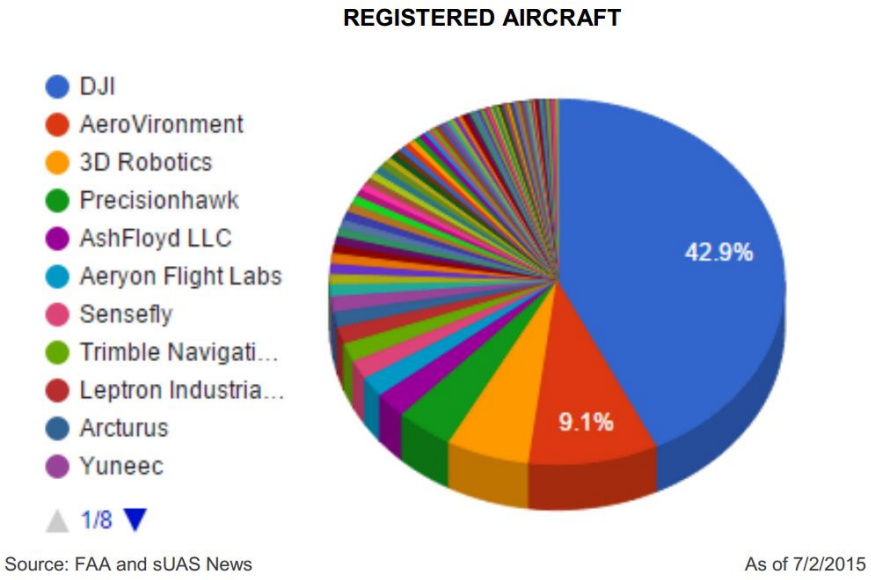
The Graph 10.2 is what the consumer market looks like in 2014:



Graph 10.2. Consumer market share in 2014 [42].

DJI dominates the consumer market reaching almost 75% market share, followed by Parrot, and to a lesser extent by 3D Robotics and Yuneec. The other companies are grouped into a small portion, similar to the sum between 3DRobotics and Yuneec.

In the section of commercial drones, the market has the appearance of the Graph 10.3:

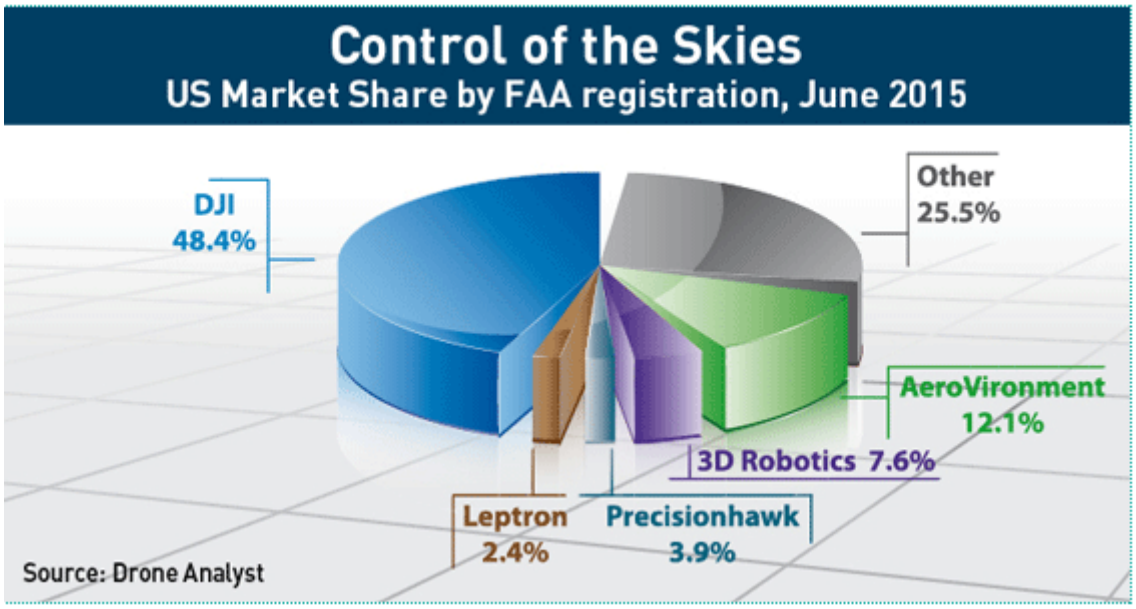


Graph 10.3. Commercial drone market share [42].

DJI continues to lead with a clear dominance with almost the 43%. In this market appear specialized brands in the manufacture of commercial drones such as AeroVironment or PrecisionHawk. With the exception of the 4 or 5 leading companies in this market, the rest are distributed in very small percentages and similar between them. It's suggested that if you take into account the dark market and consider commercial drones globally, DJI has closer to 70% share [42].

It has differentiated between two types of markets, consumer drones market and commercial drones market, however, with the increasing sophistication of consumer drones, Soon we will converge on the same market, in which companies will manufacture commercial and consumer drones without apparent differences, both of them will be used in almost the activities equally.

Apart from the vision of the world market, is added the vision of the market in USA in the Graph 10.4.



Graph 10.4. US drone market share in 2015 [42].

DJI dominance with the over the American companies AeroVironment, 3DRobotics and PrecisionHawk already seen previously. The remaining companies barely share the 25.5% of the market.

The conclusion of the three graphs is that the great dominator in the world in the marketing of drones is the Chinese company DJI well above the other competitors. It is followed by companies like Parrot, AeroVironment, 3DRobotics, PrecisionHawk, Yuneec with remarkable percentages; the other companies are grouped in percentages between 25%-15% being very similar between them.

10.3. List of competitors.

DJI.

Company founded in Shenzhen, China, in 2006. It is the most important company and with the greatest revenue in the market of drones and UAVs. It has drones at the consumer level, the most popular are the Phantom 4, the Phantom 3 and the Mavic PRO; and at the commercial level, like the Inspire 2 and the Inspire 1.

It receives approximately 10 million visits per month, the 1.48% from Italia. It is the most visited web page number 3,823 in the world.

It currently has more than 6,000 employees, of which 1,500 people working on research and development, having offices in United States, Germany, the Netherlands, Japan, Beijing and Hong Kong [43].

In 2013 the revenue was $131 million, and the company said to have a growth of 300 to 500 per cent a year by then [44]. From 2015 to 2016, the company's revenue grew 60%, reaching $1.5 Billion [45]

Part of the success is due to the large number of partnerships they have, for example Sony Camera, Certain products are sold at Apple Stores... This facilitates its distribution and flexibility. Another advantage is that DJI has its own manufacturing facilities in China, they haven't to travel to build their products.

En USA, DJI owns the 36% of the market in drones between $500-$1000. The 66% between the UAVs of $1.000-$2.000. And the 67% in drones over $2000. The only market that doesn't lead is the market of drones of less than $500 [46].

3D Robotics.

Founded in 2009, Berkeley, California, USA. Company whose main drone is SOLO, similar to DJI Phantom or Parrot Bebop 2. The company, besides the aircraft, offers specialized software for different tasks like surveying and mapping, earthworks, civil engineering... They have forged partnerships with companies like Autodesk or esri to allow commercial users to do mapping and analysis.

It has approximately 120 employees [47]. Its website, *www.3dr.com*, is visited 301.983 times per month, of which the 1.8% is from Italy.

At present, the company is in losses, despite having revenue of $93 million [47]. In the year 2016 it accumulated more than 60,000 unsold drones, since the DJI Phantom or the Parrot Bebop 2 are much more competitive in price [48].

Yuneec.

Yuneec appeared in 1999, Hong Kong, China, although currently its headquarters is in Ontario, California, USA. Has quite a variety of drones with prices ranging from $450 to $4000. Its most famous drones are the Typhoon H and the Typhoon 4K. It also has simpler ones like the Breeze and others for a more professional use like the H920 Plus.

It has more than 1800 employees distributed in its offices in Hong Kong, Shanghai, Los Angeles and Hamburg. Its website *www.yuneec.com* is visited 264.428 times per month, being Italy The 5th country that most visits it with a 2.91%.

It works in collaboration with Intel, which invested $60 million in 2015. This collaboration did the company rapidly rise in popularity. It is expected to be the great competition for DJI in the coming years [49]. It has revenue of $30 million [50].

Ehang.

Established in April 2014 in Guangzhou, China. This young company manufactures its own UAVs, such as Ghostdrone 2.0 and Ehang Falcon, and enjoys great popularity because it is selling the Ehang 184, the first AAVs (Autonomous Aerial Vehicle), vehicle that will allow the transport of people automatically by the air. It is thought that in July of this year, circulate as a taxi in Dubai [51].

Its website, *www.ehang.com,* has 103.331 monthly visits, with a 1.95% from Italy.

According its LinkedIn profile, the company has approximately 200 employees. The benefits of the company are not yet clear due to its young age, but had $42 million in funding in 2015 [52].

Delta Drone.

Company founded in 2011 in Dardilly, France. In charge of the design and manufacture of the aircraft, ground control station and own software. It has two drones, one fixed wing, Delta Y; and another with 4 propellers, the Delta X.

Its number of employees is between 11-50 according to its LinkedIn profile. In 2015 it had revenues of €1.2 million and losses of €5.6 million. In 2016, revenues of €1.4 million compared to losses of €8.1 million. Despite having lost money these past two years, the company expects to have revenues of €7 million in 2017 [53].

Apart from all these drone manufacturers, there are well-known companies that are closely related to the UAV market. This is the case of SkyWard, Company that is in charge of the simplification of the software of some drones. The great company FLIR, specialist in thermal and infrared sensors, is currently betting on thermal cameras using DJI drones. Airware, Company that after the purchase of Redbird, a software drone company, offers solutions for agriculture, industry, mapping… o AGI, focused on the manufacture of software, 3D models, spatial analysis, mapping…

10.4. Competition in rescue assistance.

A Table 10.1 has been prepared with the technical specifications of the 4 drones that we consider to be competence in the field of Rescue Assistance. In addition, the specifications of our drone are also collected. It is known that the DJI Phantom 4 and INSPIRE 2 have already worked in emergency services (Figure 26) [7]. The IA-3 Colibrì (Figure 27) is a drone of the Italian company IDS (Ingegneria Dei Sistemi), which is beginning to be tested by the emergency services of the Italian Red Cross [32]. The other candidate to be our competition is the commercial drone H920 Plus of the company Yuneec (Figure 28).

You can see a table with the specifications of more drones in the Annex V. Specs of other drones.

Company	Name of drone.	Type of drone and number of propellers	Weight (g)	Dimensions (mm)	Max. Speed (m/s) [1].			Max service ceiling above the sea (m)	Max wind resistance (m/s)	Max flight time (min)	Camera or payload.	Frecuency of Remote controller and range	Battery	Maximum payload weight (kg)	Price ($ or €)
					A	H	D								
DJI	Phantom 4	Consumer 4	1380	350 (diagonal)	6	20	4	6000	10	28	Integrated 12M 4K HD Video 60Mbps FOV 94º	Remote Controller or mobile controller 2.4 GHz/ 5.8 GHz. 7 km	5350 mAh 15.2V Lipo 4S	-	1.050 €
DJI	Inspire 2	Commer. 4	2870	559 (diameter)	5	18	4	2500	10	15	16M 4K HD Video 60 Mbps FOV 94º Many types of DJI camera, normal and thermal vision.	Remote Controller or mobile controller 2.4 GHz/ 5.8 GHz 7 km	4500-5700 mAh 22.2V Lipo 6S	0.53 Only the DJI camera	3.400€ (camera Normal vision) 9.000€ - 10.500€ (camera thermal vision)
Yuneec	H920 Plus	Commer. 6	4990	920+440 (diagonal +propeller)	-	11	-	4000	-	24	Only normal camera video 16M 4K HD Video	Ground station 2.4GHz/ 5.8 GHz. 2 km	4000 mAh LiPo 6S	1.5	3.000€
IDS	IA-3 Colibrì	Commer/ Proffesion. 4	2200	810 diameter 280 height	6	17	-	2000	9.2	40	Compatible with many payloads IR Thermal camera EO Zoom camera Digital Camera 16MP (Dual payload bay)	Tactical ground control unit 1 km	10000 mAh LiPoly 6S	1	43.000€
PoliDrone	PoliDrone	Consumer/ Commer. 4-6-8	1500 - 2000	632 (diagonal)	10	12	-	-	-	25-20	Compatible with all types of payload.	Remote Controller 2.4GHz/5.8GHz	8000 mAh 11.1V LiPo 3S	0.5	3.800€ 3.960€ Normal View Camera

Table 10.1. Specs of competition drones [54] [55] [56] [57].

Apart from its specifications, we have elaborated the next table comparing the main advantages and disadvantages of each drone:

Name	Advantages	Disadvantages
Phantom 4	• High speed. • Remarkable flight autonomy. • Small dimensions. • Very competitive price	• DJI Camera integrated only with normal vision. • It can't carry more payloads. • It can't land in water. • Not modular.
Inspire 2	• High speed. • It can carry many types of camera.	• Can only carry DJI cameras (no flexibility). • Should not carry more weight than the gimbal and camera. • It can´t land in water. • Low flight autonomy. • Not modular.
H920 Plus	• Remarkable flight autonomy. • Can carry up to 1.5 kg. • Excellent video recording.	• Offers an only option: normal vision camera. • It can't land in water. • Not modular.
IA-3 Colibrì	• Capacity to carry 1 kg of payload. • Dual payload bay. • Can carry all kind of payload. • Waterproof, it can land in water. • Very high flight autonomy.	• Not modular. • Very high price.
PoliDrone	• Modular. • Can carry 0.5kg of payload. • Can carry different types of payload. • Waterproof, it can land in water. • Competitive price.	

Table 10.2. Advantages and disadvantages of competition drones.

In conclusion, PoliDrone is an economical solution with total flexibility in its configuration since it is modular. It has capacity to carry up to 0.5kg of different types of payload and can land in water. All this differentiates our product from the rest of the market drones.

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ANNEXES

Annex I. Figures.

Figure 1.

Figure 2.

Figure 3

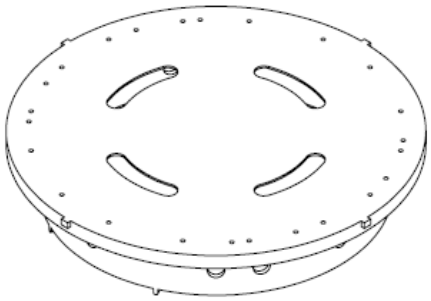

Figure 4

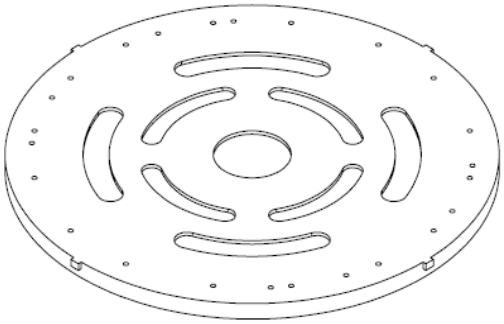

Figure 5

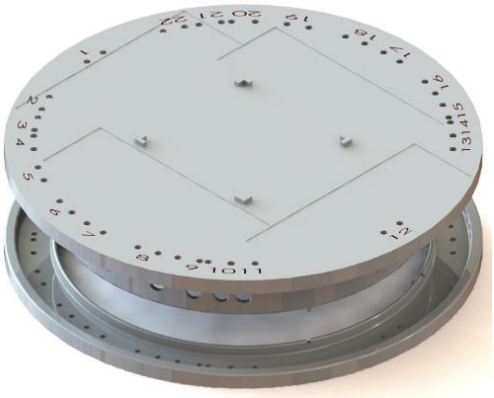

Figure 6

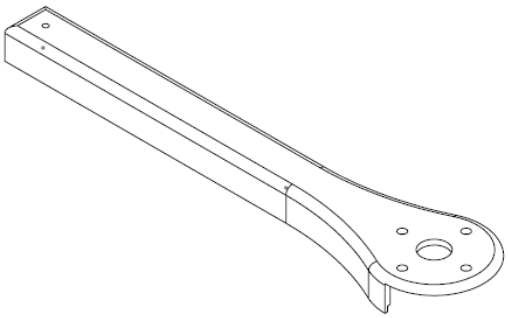

Figure 7

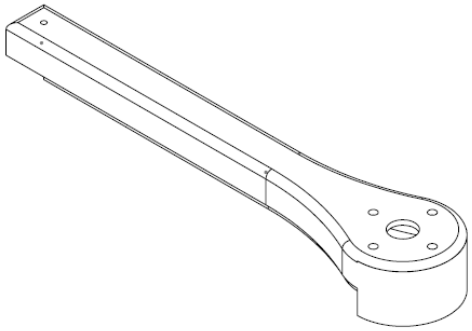

Figure 8

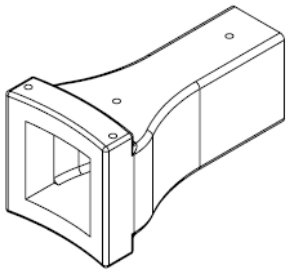

Figure 9

Figure 10

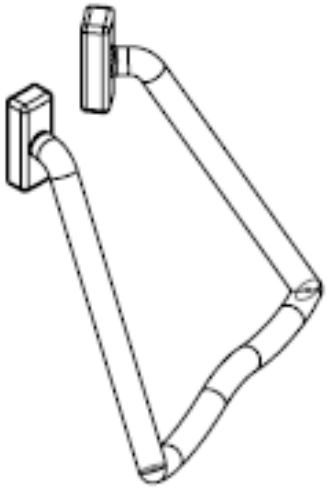

Figure 11

Figure 12

Figure 13

Figure 14

Figure 15

Figure 16

Figure 17

Figure 18

Figure 19

Gopro Camera not included

Figure 20

Figure 21

Figure 22

Figure 23

Figure 24

Figure 25

Figure 26

Figure 27

Figure 28

Annex II. Variable Costs.

Polymeric Material (ABS) 20 €/kg				
Density: 1,05g/cm3				
85% density infill				
Name	Weight/ud (g)	Price per unit	Pieces	Total price
Upper arm element	11,55	0,23 €	8	1,85 €
Bottom arm element	14,65	0,29 €	8	2,34 €
Arm support	17,04	0,34 €	8	2,73 €
Landing gear	35,85	0,72 €	2	1,43 €
Upper dome	52,18	1,04 €	1	1,04 €
Lower dome	62,6	1,25 €	1	1,25 €
Upper plate	55,96	1,12 €	1	1,12 €
Bottom plate	77,91	1,56 €	1	1,56 €
TOTAL DRONE	666,27			13,33 €

Polymeric Material (PLA) 25 €/kg				
Density: 1,27g/cm3				
85% density infill				
Name	Weight/ud (g)	Price per unit	Pieces	Total price
Upper arm element	13,97	0,35 €	8	2,79 €
Bottom arm element	17,71	0,44 €	8	3,54 €
Arm support	20,61	0,52 €	8	4,12 €
Landing gear	43,36	1,08 €	2	2,17 €
Upper dome	63,12	1,58 €	1	1,58 €
Lower dome	75,72	1,89 €	1	1,89 €
Upper plate	67,68	1,69 €	1	1,69 €
Bottom plate	94,23	2,36 €	1	2,36 €
TOTAL DRONE	805,79			20,14 €

Components (Outsourcing)				
Name	**Model**	**Price per unit**	**Pieces**	**Total price**
Engines	RCTimer SL2212/920KV	12 €	8	96 €
Propellers	Turnigy Slowfly Propeller 13x4.7inch	2,10 €	4	8,40 €
	Turnigy Slowfly Propeller 11x4.7inch	1,57 €	6	9,39 €
	Turnigy Slowfly Propeller 8x4.5inch	1,05 €	8	8,38 €
Electronic Speed Control (ESC)	ZTW Spider OPTO Small 30A	15 €	8	120,00 €
Battery	Zippy Flightmax 8000mAh 3S1P 30C	42 €	1	42 €
Flight Control Unit	KK-Mini Multi Rotor Flight Control Board	15 €	1	15 €
CO2 Cartridges	Crosman 12 Gram CO2 Cartridges	0,69 €	15	10,40
Microphone		5 €	1	5,00 €
Speaker		5 €	1	5,00 €
Screen FPV		70 €	1	70,00 €
Remote Controller		50 €	1	50,00 €
GPS		12 €	1	12,00
IMU		17,30 €	1	17,30 €
Briefcase		35 €	1	35,00 €

If the Model cell is empty, it is considered a generic unit.

In total:

Drone ABS Lot cost	517,20 €	Without shipping costs
Drone PLA Lot cost	524,01 €	Without shipping costs

Annex III. Questionnaries.

- ## Questionnaire for the use case: Manual to print it with your own 3D printer.

Google Form version:
https://docs.google.com/forms/d/e/1FAIpQLSd_vJ8jh4No7DpJueQXZwgCD68_Dr7lv0oWlKU37wpDAE_kCA/viewform?usp=sf_link

As part of the assessment of the possible impact of a new technology that we are developing within the Politecnico di Torino's laboratories, we are conducting a direct research through a questionnaire addressed to the public potentially interested in our product. The objective of this questionnaire is therefore to collect some basic information to form an objective and complete picture of the potential outlet market.

The technology developed is a multipurpose modular drone with adjustable arms produced by 3D printing. It has only 8 different pieces which can be combined in various positions to complete a one of the 12 possible configurations depending on the task to be performed.

You can change easily the number of arms (3, 4, 6 and 8), and the number of propellers (1 or 2 each arm). Also, you can configure the drone giving the ability to land and take-off from the water, replacing the propeller at the bottom of the arm by the inflatable element.

Respondent data

Name: ……

Age: ……

Occupation: ……

1. Have you felt interested in printing your own devices through a 3D printer?
   - Yes / No

2. Have you ever printed a device in a 3D printer?
   - Yes / No

3. Do you know the uses and advantages currently offered by a drone?
   - Yes / No.

4. If you had a drone. For which proposes you would use it?
   - ☐ Hobby.
   - ☐ Professional.
   - ☐ Hobby and professional.

5. Specifying, what kind of role would the drone play?
   - ☐ Drone racing.
   - ☐ Free flight.
   - ☐ Video/Cinema.
   - ☐ Photography.
   - ☐ Journalism.
   - ☐ Agriculture.
   - ☐ Vigilance/Security.
   - ☐ Reconnaissance/inspection/mapping.
   - ☐ Energy/infrastructure.
   - ☐ Rescue/Accidents.
   - ☐ Others (specify).....

6. Would you be interested in purchasing a drone made by 3D printing?
   - Yes / No

7. If you have the possibility of print it by yourself (being provided with the necessary .stl files, all electronics and an assembly manual), would it be interesting for you?
   - Yes/No

   7.1. If yes, would you like to have a fixed design providing by us, or have some freedom in the design of the drone?
      - Fixed design / Freedom in the design.

8. Of the following features of a drone, please rate it according to the value added for you: (1: not important, 2: low importance, 3: medium importance, 4: quite importance, 5: very important)

	1	**2**	**3**	**4**	**5**
Modular, being able to change the number of arms and propellers easily according the task to perform.					
Made in polymeric materials (3D printing, possibility of manufacturing by the customer)					
Resistant and waterproof					
Possibility to landing and take-off from water					
Ability to carry payload					
Easy handling					
Flight time (High autonomy time)					
High maximum speed					

Stability					
Weight (lightness)					
Size (A high value means bigger / A small value means smaller)					
Compatible with other devices (cameras…)					
Price					

- ## Questionnaire for the use case: Rescue Assistance.

Google Form version:

https://docs.google.com/forms/d/e/1FAIpQLSdHdJFiswtzHsbkxgVP9GvsOdRlUgi-RZla8DXU_h1Uqq_AgQ/viewform?usp=sf_link

As part of the assessment of the possible impact of a new technical solution, that we are developing within the Politecnico di Torino's laboratories, we are conducting a direct research through a questionnaire addressed to the operators of the different potential drone applications sector. The objective of this questionnaire is therefore to collect some basic information to form an objective and complete picture of the potential outlet market.

Respondent data

Name: .....

Where do you work and what role do you play?
.....

1. Have you worked with drones in the rescue service field? Yes/No

    1.1. If not: have you heard about drones used to assist a recue? Yes/No

        1.1.1. If your answer was yes in one of the last questions: which role does the drone play? Open answer

2. If we offer you a drone with the following features:
    - Modular, being able to change the number of propellers easily depending on the task and the weather conditions, so you can choose the best configuration for each mission
    - Made of polymeric materials
    - Resistant and waterproof
    - Able to land on the water

    Would you be interested? Yes/No

    2.1. If not: why? What features do you think the drone must have to satisfy your needs? Open answer

    2.2. If yes:
        2.2.1. How often would you use it? How long each time? Open answer

The technology developed is a multipurpose modular drone with adjustable arms produced by 3D printing. It has only 8 different pieces which can be combined in various positions to complete a one of the 12 possible configurations depending on the task to be performed.

You can change easily the number of arms (3, 4, 6 and 8), and the number of propellers (1 or 2 each arm). Also, you can configure the drone giving the ability to land and take-off from the water, replacing the propeller at the bottom of the arm by the inflatable element. It is able to offer all the advantages already stated.

3. In the case that this product is available in the market, we think his value could be equal to the sum of at least two different models, considering that, in fact, you can use several configurations (for example one for a long mission with low payload and one for a short mission with an heavy payload). Do you think this assumption could be accepted from the users? Yes/No
   3.1. If not: why?
   - ☐ I'd never need two drones or more than one configuration
   - ☐ I'd never pay the price of two drones for just one
   - ☐ I would like to, but it could be too expensive considering my resources
   - ☐ Other reason ……..

- ## Questionnaire for the use case: "Structural Health" Monitoring.

Google Form version:

https://docs.google.com/forms/d/e/1FAIpQLSdaUd4G4q1i6oUuZ5uI9akjTTK2qbSZS6LFd4evEv7uMXR-sA/viewform?usp=sf_link

As part of the assessment of the possible impact of a new technical solution, that we are developing within the Politecnico di Torino's laboratories, we are conducting a direct research through a questionnaire addressed to the operators of the different potential drone applications sector. The objective of this questionnaire is therefore to collect some basic information to form an objective and complete picture of the potential outlet market.

Respondent data

Name: .....

Where do you work and what role do you play?
.....

1. Have you worked with drones in the rescue service field? Yes/No

    1.1. If not: have you heard about drones used to assist a recue? Yes/No

        1.1.1. If your answer was yes in one of the last questions: which role does the drone play? Open answer

2. If we offer you a drone with the following features:
    - Modular, being able to change the number of propellers easily
    - Made of polymeric materials, no metal parts that could make interference with some sensors
    - Resistant and waterproof

    Would you be interested? Yes/No

    2.1. If not: why? What features do you think the drone must have to satisfy your needs? Open answer

    2.2. If yes:
        2.2.1. How often would you use it? How long each time? Open answer

The technology developed is a multipurpose modular drone with adjustable arms produced by 3D printing. It has only 8 different pieces which can be combined in various positions to complete a one of the 12 possible configurations depending on the task to be performed.
You can change easily the number of arms (3, 4, 6 and 8), and the number of propellers (1 or 2 each arm). Also, you can configure the drone giving the ability to land and take-off from the water, replacing the propeller at the bottom of the arm by the inflatable element. It is able to offer all the advantages already stated.

3. In the case that this product is available in the market, we think his value could be equal to the sum of at least two different models, considering that, in fact, you can use several configurations (for example one for a long mission with low payload and one for a short mission with an heavy payload). Do you think this assumption could be accepted from the users? Yes/No

   3.1. If not: why?

   - ☐ I'd never need two drones or more than one configuration
   - ☐ I'd never pay the price of two drones for just one
   - ☐ I would like to, but it is too expensive considering my resources
   - ☐ Other reason ……..

- ## Questionnaire for the use case: Non-Urban Monitoring.

Google Form version:

https://docs.google.com/forms/d/e/1FAIpQLSd3j6QuXYKpoKB6w980AYvOYF44guBgkTip3eJi2ef7xOBYqw/viewform?usp=sf_link

As part of the assessment of the possible impact of a new technical solution, that we are developing within the Politecnico di Torino's laboratories, we are conducting a direct research through a questionnaire addressed to the operators of the different potential drone applications sector. The objective of this questionnaire is therefore to collect some basic information to form an objective and complete picture of the potential outlet market.

Respondent data

Name: .....

Where do you work and what role do you play?
.....

1. Have you worked with drones in the rescue service field? Yes/No

   1.1. If not: have you heard about drones used to assist a recue? Yes/No

      1.1.1. If your answer was yes in one of the last questions: which role does the drone play? Open answer

2. If we offer you a drone with the following features:
   - Modular, being able to change the number of propellers easily depending on the task and the weather conditions.
   - Resistant and waterproof
   - Able to land on the water
   - Self-charge system, giving the possibility of a non-interrupted monitoring system

   Would you be interested? Yes/No

   2.1. If not: why? What features do you think the drone must have to satisfy your needs? Open answer

   2.2. If yes:
      2.2.1. How often would you use it? How long each time? Open answer

The technology developed is a multipurpose modular drone with adjustable arms produced by 3D printing. It has only 8 different pieces which can be combined in various positions to complete a one of the 12 possible configurations depending on the task to be performed.
You can change easily the number of arms (3, 4, 6 and 8), and the number of propellers (1 or 2 each arm). Also, you can configure the drone giving the ability to land and take-off from the water, replacing the propeller at the bottom of the arm by the inflatable element. It is able to offer all the advantages already stated.

4. In the case that this product is available in the market, we think his value could be equal to the sum of at least two different models, considering that, in fact, you can use several configurations (for example one for a long mission with low payload and one for a short mission with an heavy payload). Do you think this assumption could be accepted from the users? Yes/No

   4.1. If not: why?

   - ☐ I'd never need two drones or more than one configuration
   - ☐ I'd never pay the price of two drones for just one
   - ☐ I would like to, but it is too expensive considering my resources
   - ☐ Other reason ……..

Annex IV. Interview to Alessandro Ciano.

The interview was conducted via Skype. Its duration was about 30 minutes and although it was not recorded, here is a compilation of the answers:

Question – "Do you know if drones are being used in rescue work?"

Answer – "Yeah, i know it. I know Torino's Fire Department has one. This is probably done in the Politecnico, with a standard configuration and design and with a basic camera".

"Torino's Fire Department took a drone to last year's earthquake in Italy, but I'm not sure it has applications on the mountain. The drone is in the test phase".

Q – "What type of organization is doing these activities? (Government or non-profit associations, ONG)".

A – "The Government, the Firefighters bodies. The sale relationship was almost direct between the manufacturer and the fire department".

Q – "Considering the rescue activities that you have participated, in which percentage of them do you think the drone is useful?"

A – "More than half, since in a rescue work you need everything you can have, the drone can cover a large area giving an aerial view and can help with the use of thermal cameras".

Q – "In which type of rescue activities does the drone is useful?"

A – "The drones can see the site to act before the firefighters arrive in order to have the situation clearer. In the avalanches the thermal camera may not work, because if the person is buried underneath it will not be perceived its presence (snow acts as insulation)".

"The main activity of the drone is to have a clear prior situation of the place where the firemen are going to approach".

"I'm not sure the drone is able to see all the people to rescue. Thermal cameras don't see behind glasses of buildings, behind walls, rocks (earthquakes)... But it is a great help for other rescue techniques".

"In the case of fires. The drone provides a panoramic view. A helicopter can do the same task, but it can be dangerous (through smoke, ashes, at night can't fly by law). The drone can measure the composition of the smoke. On the subject of volcanoes it can measure ash, smoke (the helicopter is likely to be unable to fly)".

“About Nautical Rescue. The drone can see through the thermal cameras for people search. The PoliDrone is useful since if it falls in the water, it won’t disable. To measure the composition of water is quite useful due its ability to land on it…”

“For traffic accidents: The drone is faster than the helicopter, the helicopter can take 1h until it is ready”.

“About missing person, it is very interesting, since the thermal vision is very powerful for these cases”.

“The only mission, in whom the helicopter is indispensable, is to catch a person. The other tasks can be done by the drone, being cheaper and faster”.

Q – “What features are important in the drone for rescue assistance?”

A - “Useful in all situations, no situation is the same. The drone is Multi-faceted. I think that modularity is very important”.

“The ability to carry payload is a must”.

Q - “What type of payloads is useful?”

A - “A thermal camera, night camera, microphone, speaker, sensor of measure of the temperature, the water and air composition…”

Q – “What would be useful to carry to the people that need to be rescued?”

A - “First aid kit, lifejacket, vitamin supplement”

Q - Is it enough approximately 20 minutes in order to assist the rescue activities?

A – “Yes, it is enough since you can have more drones, you can have more batteries and in 20 minutes you can make many kilometers. It isn’t a limitation. With two drones flying every 10 minutes you can have unlimited flight, since one can be in the air and the other one on land, loading or changing the battery”.

Annex V. Specs of other drones.

Company	Name of drone.	Type of drone and number of propellers	Weight (g)	Dimensions (mm)	Max. Speed (m/s) [1].			Max service ceiling above the sea (m)	Max wind resistance (m/s)	Max flight time (min)	Camera or payload.	Frecuency of Remote controller and range	Mobile app	Battery	Max take-off (kg)	Price ($ or €)
					A	H	D									
DJI	Phantom 3	Consumer 4	1216	350 (diagonal)	5	16	3	6000	10	25	12M 2.7K HD Video 40Mbps FOV 94º	5.8 GHz / 925 MHz. 7 km	iOS / Android	4480 mAh 15.2V Lipo 4S	-	500$
DJI	Mavic PRO	Consumer 4	743	335 (diagonal)	5	18	3	5000	10	27	12.4M 4K HD Video 60 Mbps FOV 79º	2.4 GHz. 7 km	iOS / Android	3830 mAh 11.4V Lipo 3S	-	1000$
DJI	Inspire 1	Commer. 4	3060	581 (diameter)	5	22	4	2500	10	18	12.4M 4K HD Video 60 Mbps FOV 94º	2.4 GHz/ 5.8 MHz 7 km	iOS / Android	4500-5700 mAh 22.2V Lipo 6S	3.5	2000$
Parrot	BEBOP 2	Consumer 4	500	380x330x90	6	17	6	150	17	25	14M Video Full HD 1080p 30fps	2.4GHz / 5GHz. 300m	iOS / Android	2700 mAh 11.1V LiPo	-	550€
Parrot	AR.Drone 2.0 Elite Ed.	Consumer 4	420	520x520x130	-	5	-	37	4	12	Video HD 720p 30fps FOV 92º	Wifi. 50m	iOS/ Android	1000 mAh 11.1V LiPo	-	300€
Parrot	Mambo	Toy. 4	63	180x180	-	8	-	-	-	8-9	VGA 300.000 pixels	Wifi / Flypad. 20m/60m	iOS/ Android	550 mAh LiPo	-	120€
Parrot	Hydrofoil ORAK	Toy. 4	247	320x340x140	-	5	-	-	-	9	VGA 300.000 pixels	Wifi. 20m	iOS/ Android	550 mAh LiPo	-	80€
Xiaomi	MI Drone 1080p	Consumer 4	1376	434 (diagonal)	6	18	2	120	-	27	16M 1080p Video FOV 104º	2.4 GHz. 1 km	iOS/ Android	5100 mAh 15.2V	-	450$
Xiaomi	MI Drone 4K	Consumer 4	1390	434 (diagonal)	6	18	2	120	-	27	16M 4K HD Video FOV 94º	2.4 GHz. 2 km	iOS/ Android	5100 mAh 15.2V	-	510$
Hover Camera	Hover Camera Passport	Consumer 4	242	182x132x33	-	8	-	2000	-	10	13M 4208x3120 4K 1080p HD Video FOV 78º	Wifi . 2.4 GHz. 5GHz. 20m	iOS/ Android	1360 mAh 7.6V LiPo 2S	-	600$
AeroVironment	RQ-11B Raven	Professional. 1. Plane	1900	Wingspan: 1900. Length: 900	-	23	-	4600	-	60-90	Gimbaled payload with high resolution EO & IR camera.	Ground station by GPS. 10 km	No	Rechargeable lithium ion batteries	-	25.000$

Company	Name of drone.	Type of drone and number of propellers	Weight (g)	Dimensions (mm)	Max. Speed (m/s)			Max service ceiling above the sea (m)	Max wind resistance (m/s)	Max flight time (min)	Camera or payload.	Frecuency of Remote controller and range	Mobille app	Battery	Max take-off (kg)	Price ($ or €)
					A	H	D									
AeroVironment	Wasp AE	Proffessional. 1. Plane	1300	Wingspan: 1020 Length: 760	-	10	-	300	-	50	Gimbaled payload with high resolution EO & IR camera	Ground station by GPS. 5 km	No	Rechargeable lithium ion batteries	-	49.000$
AeroVironment	RQ-20B Puma AB	Proffesional. 1. Plane	6300	Wingspan: 2800 Length: 1400	-	23	-	4600	-	180	Gimbaled payload with high resolution EO & IR camera.	Ground station by GPS. 20 km	No	Rechargeable lithium ion batteries	-	250.000$
3D Robotics	SOLO	Consumer 4(10 inch)	1520	460x460x250	10	25	10	600	-	20-22	Compatible with GoPro Hero 3, 3+ and 4.	Wifi. 2.4 GHz. 8 km.	iOS/ Android	5200 mAh 14.8V LiPo.	-	400$ (without camera)
Precision Hawk	Lancaster 5	Proffesional. 1. Plane	2400	Wingspan 1500	-	22	-	2500	-	45	Depending the activity (monitoring, scanning, sensors…)	Mac, Windows and Microsoft Surface. 2 km.	No.	7000 mAh	3.5	16.000$
Yuneec	Breeze	Consumer 4	358	196x196x65	1	5	-	80	-	12	13M 4K HD Video FOV 117º	App by wifi or RC by bluetooth.	iOS/ Android	1150 mAh 11.1V LiPo 3S	-	450$
Yuneec	TyphoonH	Consumer 6	1950	520x457x310	5	19	3	122	-	25	12.4M 4K HD 720p Video. FOV 98º	RC with Wifi 5.8GHz.	iOS/ Android	5400 mAh 14.8V LiPo 4S	-	1.900$
Yuneec	Typhoon 4K	Consumer 4	1700	420x420x210	3	8	-	122	-	25	12M 4K HD 1080p Video. FOV 115º	RC 2.4GHz-5.8GHz	iOS/ Android	5400 mAh 11.1V LiPo 3S	-	800$
Ehang	Ghostdrone 2.0	Consumer 4(8.5 inch)	1150	350x350x195	3	19	2	-	-	25	16M 4K HD Video FOV 120º	App by Wifi & bluethooth. 1 km.	iOS/ Android	4500 mAh 14.8V LiPo 4S	-	400$

Company	Name of drone.	Type of drone and number of propellers	Weight (g)	Dimensions (mm)	Max. Speed (m/s) [1]			Max service ceiling above the sea (m)	Max wind resistance (m/s)	Max flight time (min)	Camera or payload.	Frecuency of Remote controller and range	Mobille app	Battery	Max take-off (kg)	Price ($ or €)
					A	H	D									
Ehang	Falcon	Commer. 8.	9600	780x670x506	-	18	-	1000	-	18	Compatible with external Camera and custom modules.	App/PC or RC. 2.4 GHz / 5.8 GHz. 2km.	iOS/ Android	44.4V LiPo 12S	23	-
Syma Toys	X5C-1	Toy. 4.	103	310x310x80	-	-	-	-	-	7	2M Video 720p	RC 2.4 GHz. 50 m.	No	500 mAh 3.7V Li.poly	-	50$
Syma Toys	X11 mini-quadcopter	Toy. 4	35.4	152x152x37	-	-	-	-	-	6-8	Uncapacitable	RC 2.4 GHz. 50 m.	No	200 mAh 3.7V Li-poly	-	40$
Syma Toys	X5SW Plus Quadcopter	Toy. 4	120	500x500x190	-	-	-	-	-	9	2M Video 720p	RC 2.4 GHz 50 m	No	2000 mAh 7.4V	-	60$
Aeryon Labs	Scout	Proffesional. 4	1400	800x800x300	2	14	-	5000	-	25	Compatible with a lot of payloads.	Tablet own or Joystick. 3 km	No	Intelligent LiPo battery.	1.7	60.000$
Aeryon Labs	SkyRanger	Proffesional. 4	2400	1010x1020 x240	2	14	-	4500	25	50	15M Video 1080p and compatible with a lot of payloads.	Tablet own or Joystick. 2.4 GHz. 3-5 km	No	Intelligent LiPo battery.	-	120.000$
ECA Group	IT180	Commer. 2	16000	1800 (diameter)	-	19	-	3000	16.7	Depend engine	Compatible with a lot of payloads.	Ground Control Station. 3 km	No	Depending the model.	-	-
Delta drone	Delta X	Commer. 4	5800	1500 (diameter)	-	18	-	-	13.9	15-20	Camera, sensors, and radars depending the activity.	Ground Control Station.	No	-	7.3	20.000$
Delta Drone	Delta Y	Commer. 1. Plane	2000	1520 (Wingspan)	-	14	-	150 AGL	6-10	45	Camera, sensors, and radars depending the activity.	Ground Control Station.	No	-	-	-
Hubsan	X4 Air Pro	Toy. 4	410	220x220x80	-	-	-	-	-	20	HD 1920x1080p FOV 120º	Wifi. RC 2.4 GHz. 300m	iOS/ Android	2700 mAh 7.4V LiPo	-	200$

Annex VI. Entrepreneurial Team CVs.

SALVATORE BRISCHETTO CV and experiences.

After earning his degree in Aerospace Engineering at the Politecnico di Torino in 2005, Salvatore Brischetto received his PhD in Aerospace Engineering (Politecnico di Torino) and in Mechanics (Université Paris Ouest-Nanterre La Défense) in 2009 with a thesis titled "Classical and mixed multilayered plate/shell models for multifield problem analysis". He won the excellence prize for PhD students at the Politecnico di Torino in 2008 and the prize for young researchers at the Politecnico di Torino in 2011. Dr. Brischetto worked as a Research Assistant in the Department of Mechanical and Aerospace Engineering at the Politecnico di Torino from 2006 to 2010, and has been Assistant Professor in the same department since 2010. His main research topics are: smart structures, composite materials, multifield problems, functionally graded materials, thermal and hygroscopic stress analysis, carbon nanotubes, inflatable structures, plate and shell finite elements, 3D and 2D exact solutions for plate and shell structures, additive manufacturing and UAVs. He is the author of more than 100 articles on these topics, more than 60 of which have been published in international journals. From the website http://scholar.google.it (accessed at 22/12/2016) the bibliometric parameters of Dr. Brischetto are 102 papers with 2093 citations, the h-index is 24. He is also co-author of the book "Plates and Shells for Smart Structures: Classical and Advanced Theories for Modeling and Analysis. Carrera E, Brischetto S, Nali P. John Wiley & Sons Ltd (2011)". He serves as a reviewer for more than 60 international journals, such as Composite Structures, Journal of Mechanics of Materials and Structures, Journal of Applied Mechanics, Journal of Composite Materials, European Journal of Mechanics - A/Solids, Mechanics Research Communications, International Journal of Mechanical Sciences, etc. He has been Guest Editor for Mechanics of Advanced Materials and Structures for the Special Issues entitled "Modeling and analysis of functionally graded beams, plates and shells, Parts I and II" and he has also organized the special session "Thermo-Mechanical Analysis of Composite and Advanced Structures (Chairs: S. Brischetto & G. Giunta)" for the International Conference on Mechanics of Nano, Micro and Macro Composite Structures (Torino (Italy), 18-20 giugno 2012). Dr. Brischetto has been a committee member for the 2014 and 2015 editions of the price "Premio Nazionale di Divulgazione Scientifica" and a scientific committee member of the 2016 edition of the price "Premio Nazionale di Editoria Universitaria" organized by AIL (Associazione Italiana del Libro). For the same association, he is a scientific committee member of the journal "Scienze e Ricerche". He is also a scientific committee member of several international journals and a book series for the "Società Editrice Esculapio". He has been reviewer for the scientific projects in the calls PRIN 2012 and SIR 2014. He has been Teaching Assistant at the Politecnico di Torino for courses on computational aeroelasticity, structures for aerospace vehicles, nonlinear analysis of aerospace structures, principles of structural mechanics, aeronautic constructions and aeronautic structures. During the period October 2011-February 2012 Dr. Brischetto has been one of the coordinators of the Italian students group in the project "Design of a docking mechanism for satellites" in collaboration between Thales Alenia Space, Politecnico di Torino and Supméca (France). Dr. Brischetto was in the AMALIA Team Italia for the Google Lunar X

Prize, where he worked on the design and structural analysis of Lander and Rover configurations for Lunar missions. In the three-year period 2009-2011 he has been Carrera-Polito group's deputy in the regional project STEPS (Sistemi e Tecnologie per l'EsPlorazione Spaziale) where he has worked on multipurpose airlock deployment mechanisms, failure analysis of composite structures and use of Functionally Graded Materials for Thermal Protection Systems. In the two-year period 2006-2007 Dr. Brischetto has been Carrera- Polito group's deputy in the European project CASSEM (Composites and Adaptive Structures: Simulation, Experimentation and Modeling) where he has worked about the multifield analysis of multilayered smart structures. He is co-founder and co-chair of the research group “ASTRA: Additive manufacturing for Systems and sTRuctures in Aerospace” at the Department of Mechanical and Aerospace Engineering of Politecnico di Torino. Brischetto is also founder and chair of the project “PoliDrone, A multipurpose modular drone produced via 3D printing”. Dr. Brischetto has been Tutor for several degree theses at Politecnico di Torino and one Ph.D. thesis. In accademic years 2013/2014, 2014/2015 and 2016/17, he has been adjunct professor for the course “Aeronautic law and human factors and safety ” at Politecnico di Torino.

CURRICULUM VITAE

ROBERTO TORRE

INFORMAZIONI PERSONALI

NOME	ROBERTO
COGNOME	TORRE
LUOGO DI NASCITA	TERLIZZI (BA)
DATA DI NASCITA	25/05/1991
NAZIONALITA'	ITALIANA
RESIDENZA	BARLETTA (BT)
DOMICILIO	TORINO (TO)
TELEFONO	3701004098
E-MAIL	roberto.torre@studenti.polito.it

ISTRUZIONE E FORMAZIONE

- Periodo Ottobre '14 – Luglio '16: conseguimento del titolo di Dottore Magistrale in Ingegneria Aerospaziale (Laurea II livello) presso il Politecnico di Torino nel Luglio 2016, con tesi dal titolo "Mechanical characterization of ABS and preliminary design for a 3D printed UAV produced via FDM (relatore: Salvatore Brischetto)" con votazione di 102/110.
- Periodo Ottobre '10 – Luglio '14: conseguimento del titolo di Dottore in Ingegneria Aerospaziale (Laurea I livello) presso il Politecnico di Torino nel Luglio 2014, con tesi dal titolo "Modelli 3D esatti e 2D FE per vibrazioni libere di piastre e gusci (relatore: Salvatore Brischetto)"

con votazione di 97/110.

- Periodo Settembre ’05 – Luglio ’10: conseguimento del diploma di scuola media superiore di secondo grado presso il Liceo Scientifico C. Cafiero di Barletta nel Luglio 2010 con votazione di 100/100.

ATTIVITA’ LAVORATIVA

- Periodo Ottobre ‘16 – Maggio ’17: tirocinio extracurriculare presso LMA srl – Aerospace Technology finalizzato alla formazione professionale della figura di Ingegnere Tecnico Commerciale: studio della documentazione tecnica a corredo di componenti strutturali di precisione di applicazione aerospaziale nell’ottica della valutazione di tempi e strategie di produzione; scelta e gestione dei fornitori esterni; analisi delle specifiche tecniche relative ai trattamenti superficiali e controlli non distruttivi impattati.

ATTIVITA’ PROGETTUALE

- Nell’ambito del corso di “*Proyecto de Aviones*” presso l’UNC di Cordoba, Argentina, discussione del progetto preliminare di un velivolo di Aviazione Generale da addestramento a singolo motore; definizione delle caratteristiche dimensionanti, stima preliminare dei pesi, scelta delle caratteristiche aerodinamiche, definizione del diagramma V-N, analisi strutturale di ala e supporti motore.;
- Nell’ambito del corso di “*Construccion de Aviones*” presso l’UNC di Cordoba, Argentina, discussione di un lavoro sui processi produttivi impiegati nella produzione dell’impennaggio verticale dell’Airbus A380, con focus sul Vaacum Assisted Process (VAP) impiegato per impregnare un rinforzo in Non-Crimped Fibers;
- Durante il lavoro di tesi specialistica, collaborazione alla fase progettuale e di produzione di un drone multifunzione e modulabile, prodotto con tecnologia di stampa 3D. Nello specifico, realizzazione della caratterizzazione meccanica dell’ABS mediante la produzione di

appositi provini tramite stampa 3D – FDM e successivo studio mediante prove di trazione e compressione nei laboratori del DIMEAS; design preliminare del velivolo finito, re-design degli elementi strutturali in ottica di weight saving e di integrazione col processo produttivo;

- Partecipazione al team che ha curato l'esposizione del primo prototipo del drone presso il Salone del Libro 2016 di Torino, all'interno dello stand allestito dal Politecnico di Torino. Nello specifico, realizzazione, post-processing e final assembly del velivolo e dei suoi componenti da esporre, insieme al materiale divulgativo;
- Nel Luglio 2016 partecipazione al team impegnato nella prima prova di volo del prototipo del drone nella facility del Politecnico di Torino;
- Nell'Ottobre 2016 partecipazione al team che ha curato l'esposizione del primo prototipo del drone presso il TechShare Day – Valle d'Aosta, all'interno dello stand allestito dal Politecnico di Torino alla Pepiniere di Pont-Saint-Martin

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ATTIVITA' DI FORMAZIONE E RICERCA PRESSO ISTITUTI PUBBLICI ESTERI

- Nell'ambito del programma di mobilità aa 2014/2015, partecipazione al progetto extraUE del Politecnico di Torino con permanenza, dal Luglio 2015 al Dicembre 2015, presso l'Universidad Nacional de Cordoba, Argentina. In questo contesto, frequenza dei corsi Proyecto de Aviones, Construccion de Aviones, Mantenimiento de Aeronaves ed Ensayos no Destructivos con valutazione media 9.25/10;
- Nell'ambito del corso di Ensayos no Destructivos presso l'UNC di Cordoba, svolgimento di prove sperimentali presso INTI, Instituto Nacional de Tecnologia Industrial, sede Cordoba, Argentina, relativamente a Ultrasonic testing, Radiographic testing, Dye penetrant inspection, Magnetic particle inspection, Eddy-current testing.

PREMI E RICONOSCIMENTI

- In possesso dei risultati del GRE® General Test sostenuto in data……. e allegato alla presente;
- Nell'ambito del bando per le collaborazioni part-time del Politecnico di Torino, vincitore del concorso finalizzato al supporto nella preparazione del materiale didattico per il corso di Strutture Aeronautiche (a.a. 2015/16; titolare: Prof. Marco Di Sciuva);
- Alcuni dei risultati della tesi di I livello hanno portato alla pubblicazione di un articolo su rivista scientifica internazionale [1];
- Alcuni dei risultati della tesi di II livello hanno portato alla pubblicazione di due articoli su differenti riviste scientifiche internazionali [2], [3];
- L'attività di ricerca svolta nell'ultimo anno ha anche portato alla stesura e presentazione di 3 atti di congresso [4], [5], [6];
- Il lavoro [4], presentato da S. Brischetto alla *3rd International Conference on Mechanical Properties of Materials-ICMPM 2016* (Venezia, 14-17 Dicembre 2016), è stato giudicato il migliore degli 11 presentati all'interno della "Session 2: Material structure and mechanical properties" come attestato dal certificato di eccellenza consegnato (in allegato);
- Nel Luglio 2016, convocato al sostenimento del colloquio per l'ammissione ai corsi di Dottorato di Ricerca (XXXII Ciclo – Politecnico di Torino) con un punteggio di 40/60, nonostante la mancanza di Titolo di II Livello, Test GRE, un articolo su rivista [3], tre atti di conferenza [4], [5] e [6] e tirocinio formativo, tutti titoli assunti nell'arco degli ultimi 12 mesi.

LISTA DELLE PUBBLICAZIONI

- **Articoli pubblicati su rivista**

[1] S. Brischetto and R. Torre, Exact 3D solutions and finite element 2D models or free vibration analysis of plates and cylinders, *Curved and Layered Structures*, Vol. 1 Iss. 1, 59-93, 2014.

[2] C. G. Ferro, S. Brischetto, R. Torre and P. Maggiore, Characterisation of ABS specimens produced via the 3D printing technology for drone structural components, *Curved and Layered Structures*, Vol. 3 Iss. 1, 172-188, 2016.

[3] S. Brischetto, C. G. Ferro, P. Maggiore and R. Torre, Compression tests of ABS specimens for UAV components produced via the FDM technique, *Technologies*, Vol. 5 Iss. 2, 1-25, 2017.

- **Conferenze**

[4] S. Brischetto, C. G. Ferro, R. Torre and P. Maggiore, Tensile and compression characterization of 3D printed ABS specimens for UAV applications, *3rd International Conference on Mechanical Properties of Materials (ICMPM 2016)*, Venezia, 14-17 Dicembre 2016.

[5] S. Brischetto, C. G. Ferro, P. Maggiore and R. Torre, Characterization and analysis of homogeneous and sandwich PLA/ABS specimens produced via the FDM printing process for UAV structural elements, *3rd International Conference on Mechanics of Composites (MECHCOMP3)*, Bologna, 4-7 Luglio 2017.

[6] C. G. Ferro, S. Brischetto, P. Maggiore and R. Torre, Multi-material sandwich panel produced with Desktop 3D printer, *3rd International Conference on Mechanics of Composites (MECHCOMP3)*, Bologna, 4-7 Luglio 2017.

Interessi scientifici e di ricerca

- Modelli strutturali shell 3D esatti
- Modelli strutturali 2D FEM
- Strutture composite e sandwich
- Analisi modale
- Stampa 3D
- Ottimizzazione strutturale
- Prove sperimentali di laboratorio
- Analisi strutturale velivoli
- Avanprogetto velivoli
- Prove non distruttive

- Manutenzione velivoli

COMPETENZE LINGUISTICHE

- Madrelingua italiana.
- Conoscenza della lingua inglese con buona capacità di lettura, scrittura ed espressione orale. Conseguimento del certificato IELTS (INTERNATIONAL ENGLISH LANGUAGE TESTING SYSTEM) nel Dicembre 2010 con punteggio 6.0.
- Conoscenza della lingua spagnola con buona capacità di lettura, scrittura ed espressione orale. Livello CEFR B2 al test informatizzato del Centro Linguistico di Ateneo – Politecnico di Torino.

ATTIVITA' VARIE

- Dal 2009 gestione della Stazione Meteorologica di Barletta centro e contestuale messa online del portale web www.meteobarletta.org. I dati raccolti sono certificati ed inviati a Meteonetwork Onlus, partner del Centro Epson Meteo, ed al network CWOP, partner del National Weather Service statunitense.

Torino, 24 Maggio 2017

Autorizzo il trattamento dei dati personali ai sensi del D.lgs 196/03