

Drone technology training to boost EU entrepreneurship and Industry 4.0



Guidelines on Industry 4.0 and Drone Entrepreneurship for VET students



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“Guidelines on Industry 4.0 and Drone Entrepreneurship for VET students”

Authors: Catalin Gheorghe Amza; Doru Cantemir; Ioana Cantemir; Anastasia Oikonomoula; Paweł Poterucha; Giulia Salucci; Paulina Spanu; Francesco Tarantino; Mike Triantafillou.

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1. Industry 4.0

1.1 Industry 4.0 concept

The term of Industry 4.0 was first used in 2011 at Hannover Messe, in Germany as a basic concept for the fourth industrial revolution. Currently, the concept of Industry 4.0 is a general title for the automation and data exchange in manufacturing sectors.

Figure 1 shows the main components of the Industry 4.0.

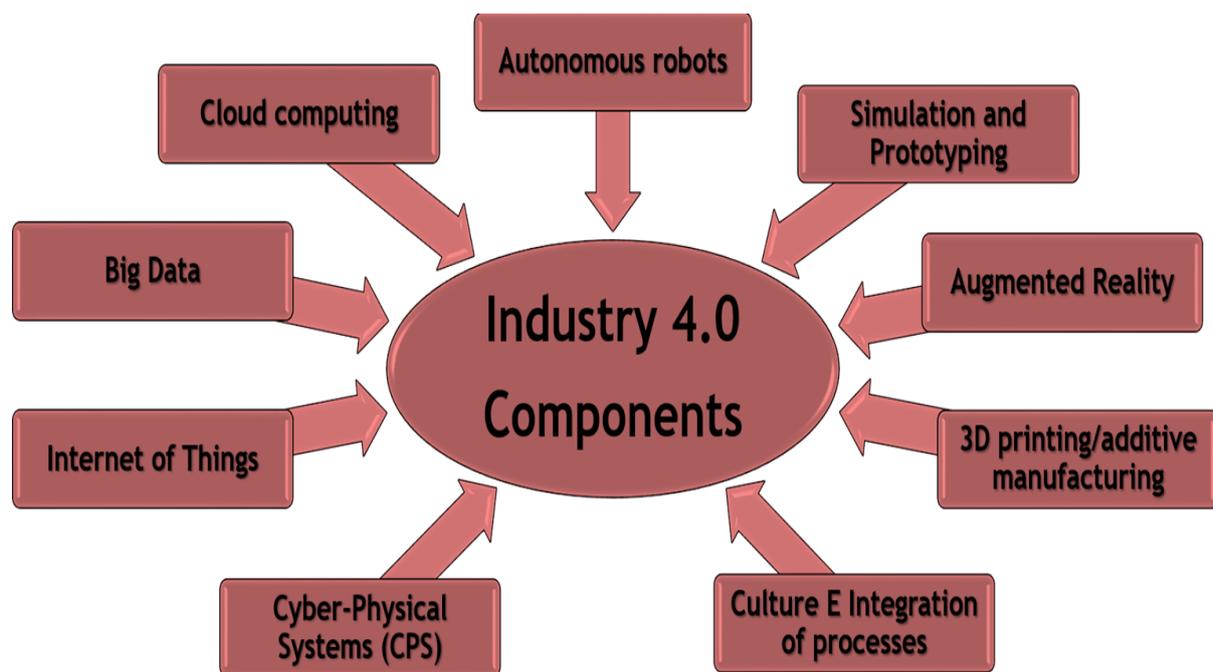


Fig. 1. The Industry 4.0 components

Considering its basic components, the Fourth Industrial Revolution includes different global concepts:

- **in Europe** the “*Industry 4.0*” concept is considered a new technology based on the Cyber-Physical System, defined as the combination of physical and cybernetic systems. The Cyber-Physical Systems are used to develop the autonomous productive processes.
- **in China** – “*Made in China 2025*” is an initiative to comprehensively upgrade the Chinese industry by 2025. The “*Made in China 2025*” principles are:
 - to make manufacturing innovation-driven;
 - to emphasize the quality over quantity and to achieve green development;
 - to optimize the structure of the Chinese industry and focus on the human capital.
- **in Japan** - The “*Innovation 25*” plan is a long-term strategy initiative of the Japanese government for the creation of innovation to promote economic growth until 2025. The long-term strategic guidelines “*Innovation 25*,” has the following basic concepts based on the characteristics of innovation:

- setting the goals high and anticipating challenges for the future;
 - timely and effective adaption to the globalization and advancement of digitalisation;
 - embracing the changes that come with diversity and reforming of a society filled with possibilities;
 - focusing on the human resources development - encouragement of people who think creatively or “out of the box”.
- **The United States** – the „*Smart Manufacturing*” concept is a term coined by several agencies such as the Department of Energy (DoE) and the National Institute of Standards and Technology (NIST). Wallace and Riddick describe *Smart manufacturing* in short as “a data intensive application of information technology at the shop floor level and above to enable intelligent, efficient, and responsive operations.” The main objectives are: plant wide optimization, sustainable production and agile supply chains.

Moreover, the Fourth Industrial Revolution describes a “*smart manufacturing*” that uses information technology to change the way products are made by focusing on cost reduction and efficiency.

1.2 History of Industry 4.0

The concept Industry 4.0 was originated in 2011 at the Hanover Fair in Germany and was accepted and implemented by most industries in other countries.

Figure 2 shows the evolution of industry over time.

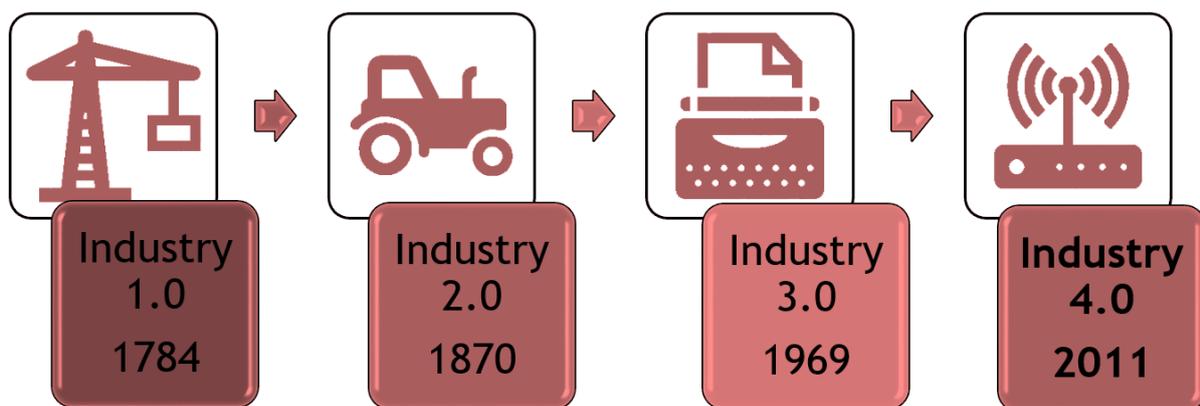


Fig. 2. The Industry evolution

The First Industrial Revolution (Industry 1.0) was based on the mechanized production thanks to the harnessing of water and steam power. Steam engines were first used in the textile industry and later spread in many other industries.

The Second Industrial Revolution (Industry 2.0) was characterized by the use of new energy source - electricity and mass production. Mass production systems were usually based on assembly lines and together with the use of interchangeable parts, led to increased productivity.

The Third Industrial Revolution (Industry 3.0) was the result of electronic technology and information used to automate manufacturing.

The Fourth Industrial Revolution (Industry 4.0) combines the virtual and physical world of production, machines, systems and sensors to communicate with each other, to share information and to control each other independently.

Nowadays, many companies are using Industry 4.0 as a buzzword for their activities. It is known that over 75% of manufacturers are already investing in digitalization and in integrating Industry 4.0 into their production.

Moreover, the 4.0 industry concept is becoming more and more profound, being transferred from its original field of application in industrial production to other fields such as Logistic 4.0 and Education 4.0.

1.3 Industry 4.0 features

Generally, Industry 4.0 is focused on creating intelligent products, processes and procedures.

The features of the Industry 4.0, that make it revolutionary in the era of information technology, are the following [1]:

- ✓ **Interoperability:** the ability of machines, devices, sensors, and people to connect and communicate with each other via the Internet of Things (IoT) or the Internet of People (IoP).
- ✓ **Information transparency:** the ability of information systems to create a virtual copy of the physical world by enriching digital plant models with sensor data.
- ✓ **Technical assistance:** first, the ability of assistance systems to support humans by aggregating and visualizing information comprehensively for making informed decisions and solving urgent problems on short notice. Second, the ability of cyber physical systems to physically support humans by conducting a range of tasks that are unpleasant, too exhausting, or unsafe for their human co-workers.
- ✓ **Decentralized decisions:** the ability of cyber physical systems to make decisions on their own and to perform their tasks as autonomously as possible.
- ✓ **Cross solution.** The operator interaction is the same regardless the kind of control system architecture, the peculiarities of different plants are normalized through the Cloud Database; the uniformity of the information is the main benefit for the user and a basis for the economy of the companies.
- ✓ **Modularity [2]:** the ability to adapt fast and smoothly to seasonal changes and market trends.

All these features make companies more flexible and responsive to business trends. They become more innovative, increase productivity and self-optimize the production.

1.4 Industry 4.0 trends

In the future, a larger number of consumers and producers will be digitally interconnected, leading to the highest level of personalization of products. The companies will be able to respond to customer issues much quicker by accessing real-time data. Devices, process control systems, manufacturing execution systems will be connected to IoT platforms.

The sensors will be integrated with the production equipment in order to monitor their functionality and to predict when maintenance should be performed. The equipment will be repaired when needed, ahead of manufacturing non-compliant products. Furthermore, the machinery status and productivity data can be recorded and transmitted in real-time to the cloud for data statistical analysis. This is particularly useful when it comes to reducing the maintenance costs.

Devices equipped with sensors could also be integrated into the industrial environment by using Virtual Reality and Augmented Reality technology. In this way, we can display real-time processes through computer-generated sensory inputs, such as video and sound, or simulation models. The use of augmented reality together with the availability of real-time data from the industrial environment helps the staff involved in industrial activities, while providing clearer information about the working processes. Augmented Reality and wireless systems should be used for data sharing and visualization of factory information through the cloud to help improving working and monitoring processes.

With mobile and cloud applications, the 3D printing technology will continue to grow in the future. It is estimated that the potential economic impact of additive manufacturing based on reduced cost (compared with buying items through retailers) and the value of customization could range from 100 billion to 300 billion dollars per year by 2025 [3].

Significant growth of the sales is estimated for the industrial equipment with sensors and actuators that can exchange data with other machines and computer networks in real time via the cloud. According to the studies by Price Waterhouse Coopers (PwC), about one third of companies have a high level of digitization. Industrial digitisation is expected to increase from 33% to 72% over the next five years. A significant number of companies are developing new products and services with digital features that cover the entire life cycle of the product.

2. Incorporating drones into Industry 4.0

2.1 Drones Technology as part of Industry 4.0

Industry 4.0 is mainly about new innovative business models embracing the new possibilities offered by the new technologies. As can be seen from the case studies presented in the brochure “Guidelines on the use of drones in VET” published by the eduDrone partnership, the Drones Technology clearly offers new possibilities and allows for new innovative business models. Nowadays, drones are seen as a revolutionary tool for Industry 4.0.

Moreover, drones can be part of or can benefit from the main Industry 4.0 components, as it is detailed bellow.

Cyber-physical systems (CPS)

CPS are integrations of computation and physical processes and an important component of Industry 4.0. Drones can be used both as mobile sensors, acquiring and transmitting data about processes and as actuators, performing various physical operations.

Big Data

Drones enable a huge amount of data to be gathered, via cameras or sensors. All that data needs to be stored and processed in order to benefit from it and here is where Big Data technologies step in.

Internet of Things (IoT)

The integration of drones and the IoT has huge commercial potential. Drones acting like sensor platforms integrated with ground-based sensor networks through the IoT can provide value in countless applications.

Autonomous robots

A properly equipped drone can act like a flying robot and can be integrated in assembly and manufacturing processes, to move parts across large factories or to perform various other operations.

Additive manufacturing

Additive manufacturing (or 3D printing) can be used to achieve reduced weight and high modularity of drone systems.

Also, the 3D printing technologies can be combined with drone technologies and used, for instance, to maintain and repair infrastructure. Such solutions already exist on the market. For example, the Fly Elephant 3D printing drone which has an extruder that can be used for 3D printing with plastic, concrete mix or other materials.



Fig. 3. The Fly Elephant 3D printing drone (Credit: DediBot)

Augmented Reality (AR)

AR can equip drones with an advanced range of capabilities, opening up new opportunities for business. A drone + AR system allows users to receive critical information in addition to the real-time video stream from drone's camera. This can be very useful in industrial inspections, firefighting, disaster rescue, etc.

Cloud Computing

Drones can be connected to the Internet, becoming a cloud infrastructure and being able to provide their resources and services. Also, there are cloud-based web applications that provide real-time flight monitoring and management for drones. They could, for example, detect and prevent potential collisions by automatically adjusting drone flight paths.

Cyber security

The use of drones has many cyber security implications, with drones being both possible target and potential offender.

2.2 Drones applications for Industry 4.0

The Industry 4.0 aims to incorporate more and more devices to give the maximum intelligence to the processes developed within these environments. Among these devices, drones have a distinct role to play.

A drone is, actually, a flying robot and can be integrated in a given workflow in order to help companies to do things easier, more efficiently and much safer. Drones can be incorporated in assembly and manufacturing processes, in repair and maintenance operations, delivery, surveillance, etc.

A drone can be also a flying industrial sensor or a mobile device for data gathering, this opening a broad range of possible applications for Industry 4.0.

Drones can be an essential part of industrial automation. An industrial drone is fitted with cameras and IoT sensors able to measure parameters like temperature, humidity, atmospheric pressure, motion, electric and magnetic field strength, coronal arc discharge, cell phone signals, methane

levels, etc. The acquired data can be processed on board and/or communicated to a control system or directly in cloud.

Other characteristics that enables drones to have a great impact within the Industry 4.0 are their flexibility and usefulness in different industrial sectors. They can be employed in engineering, maintenance, critical infrastructure monitoring, asset management operations, etc. with the aim to improve and optimize industrial processes as well as enhance operational efficiencies.

The main advantages of using drones in industrial application are as follows:

- Unique capability to capture aerial data
- Ability to deliver rapid and seamless data collection
- Capacity for action in hazardous areas
- Easy access to difficult areas such as electricity grids, power station chimneys, etc.
- Autonomous navigation, without need for human interaction regarding the ongoing management of their trajectories
- Simple integration with other systems, by using the Industry 4.0 principle of Modularity

Some of the drones' application for Industry 4.0 will be discussed below. Other applications are already in place and, definitely, many others are still to come.

Industrial inspections

Drones become an integral part of industrial inspections due to their ability to operate without any human intervention for prolonged periods, to gain inspection data from hard to reach or unsafe areas and to ensure consistent inspection. By using high definition cameras and IoT solutions, drones are able to quickly recognize key inspection points and to immediately gain a complete 360-degree, high-resolution overview of the inspected objective. This data can be send to an IoT platform to analyse it and identify specific areas of concern, to auto-detect potential issues and predict degradations. Using IoT, computer vision, artificial intelligence algorithms and deep learning techniques the inspection process became a smart process of the Industry 4.0 that enables quick reaction in case of issues, prioritization of detailed inspections and maintenance activities as well as Predictive Maintenance.

Infrastructure monitoring

Intelligent solutions based on high-speed data analytics combined with Industrial IoT, cybersecurity, and sensor-mounted drones are increasingly used to monitor critical infrastructure like factories, refineries, power grids, wastewater treatment, mines, well platforms and other oil and gas assets, etc.

Delivery Systems

Drones are becoming increasingly popular intelligent logistics tools in manufacturing and other industries. In 2017, Amazon filed a patent for an AI-powered drone that can “conduct a speech dialog with a nearby person in order to request information and/or answer questions.” Audi tested the use of drones for automated transport of parts in factory halls.

Agriculture

Drones are important assets for the transformation of agriculture towards Industry 4.0., especially due to their ability to collect data and measurement. As in other sectors, drones can connect with intelligent platforms and can be empowered by a broad array of new technologies enabling the production of useful tools like 3D maps for soil and field analysis or information on crop health, vegetation index, irrigation efficiency, crop development. In addition, the drones can perform operations such as planting or crop spraying.

Supply chain applications

Supply chains are transformed by the Industry 4.0 revolution and the advanced physical technologies, such as drones, are an important part of this transformation. Drones can act as plug-and-play aerial robots able to:

- autonomously navigate through warehouses and avoid obstacles
- detect, identify, and locate parcels thanks to advanced computer vision and sensors combined with artificial intelligence
- automatically upload resulting scans to the cloud and synchronize it to the inventory management system
- ensure scalable and increasing inventory accuracy, reducing operational costs, and improving employee safety.

Mapping

Mapping and aerial imaging are providing vital information for companies activating in construction, mining or energy: topography, natural resources, environmental contamination, etc. Drones supported by new technologies can produce very accurate 3D maps that are further used to analyse job sites and mines, to assess risks, to measure the volume of excavated materials, to make informed decisions.

Other applications

Drones equipped with specialised sensors can detect leaks, can be used in hot and/or hazardous areas unsafe for humans carrying traditional portable spectrometers. Also, they can monitor specific chemicals in a process to optimize yield and to reduce emissions.

Drones monitoring continuously air quality, integrated in an automated machine-to-machine workflow, can immediately alarm about leaks or too high concentration of certain substances. This could be an important application for chemical industry, oil and gas, mining, etc.

2.3 Drones Impact on Industry 4.0

Drones are very powerful and versatile industrial tools capable of completing a broad range of applications. They are increasingly used to improve and optimize industrial processes as well as to enhance operational efficiencies. Automated drones are valuable assets for several industry sectors due to their capabilities related to data gathering and analysing as well as their nearly limitless visibility.

Drones are having a great impact on the Industry 4.0 thanks to their relevance for most of the Industry 4.0 key features, as is described below.

- **Interoperability** – through the IoT devices mounted on board, drones have the ability to connect and communicate with other machines, devices and people.
- **Virtualization** – drones are able to monitor physical process through their sensors, providing data required for modelling and simulation. In addition, they can make use of 3D models, for example in planes or ships inspections.
- **Capacities in real time** – drones can respond in real time based on the information gathered, for example to avoid collisions. In addition, they enable other elements and processes of Industry 4.0 by delivering real-time data.
- **Service-orientation** – Drone-as-a-service is a reality and offer a new wealth of business opportunities. Many other services on the market are involving drones.
- **Decentralization** – Artificial Intelligence is granting the drone an ability to make decisions independent of the pilot.
- **Modularity** – drone solutions may be configured to act as a plug-and-play module that can be added to existing processes.

These advanced machines are helping entire sectors to accelerate the digital transformation of their operations and are adding value to other emerging technologies. There are many applications where drones have a distinct advantage over the traditional methods and this is a key factor for further increase of their impact on Industry 4.0. The possibilities for drones to create value in an Industry 4.0 environment are limitless.

Autonomous robots are among the nine technologies considered to form the building blocks of Industry 4.0. and drones are, in fact, autonomous flying robots. Therefore, their crucial role in Industry 4.0 is very clear.

2.4 Smarter drones

Drones need to become smarter in order to maximize their usefulness and to be broadly adopted in the factories of the future.

Autonomous drones

Autonomous drones are devices programmed to perform tasks needing no input or control from the pilot once the destination or task is set. Smart sensors are controlling and monitoring the flight while guiding is provided by computer vision systems along with object detection and collision avoidance programs. They can be even more adaptable thanks to AI or algorithms. When the start button is selected, the drone takes off and does the work according to the programmed mission. This is a very important feature, a mandatory requirement for most of the Industry 4.0 applications.

The key challenges to achieving autonomy of drone operations include:

- the ability to detect and avoid traffic (cooperative and non-cooperative) and multiple types of obstacles
- appropriate datalinks for command and control (the identification, allocation and protection)
- cyber resilience (in order to mitigate against theft or deliberate use of the drone)

- human factors, to manage the transition towards effective solutions regarding contingency and failure management
- validation to the regulator
- high precision navigation.

Various companies developed collision avoidance technologies and algorithms for drones. However, much more work is required to make drones safer and more reliable.

In some applications, like maritime surveying, the drones can be pre-loaded with a 3D model of the object to be inspected. This allows the drone to autonomously work its way around the object, stopping at points of interest to obtain detailed video or image data.

Artificial Intelligence

The true potential of drones can be unleashed if key enabling technologies of Industry 4.0 like Machine Learning, Internet of Things and Big Data are used to make them true intelligent machines and to efficiently process the gathered data.

The Artificial Intelligence (AI) is increasingly used in drone projects and this is set to boom, making drones become more and more intelligent in the next years. This will definitely boost their use in many sectors and help a lot the implementation of Industry 4.0 on a large scale. Drone operators can use AI to augment their own abilities, thus increasing their competitiveness and customer satisfaction.

AI gives the drone the capability to make decisions independent of the pilot. For example, it could have the ability to identify unfavourable flight conditions and bypass them entirely. In addition, Machine Learning allow drones to take data and the result of their actions, and use that to make decisions in the future. This removes pilot from repetitive and time-consuming tasks.

AI also allows pilots to examine in real time the data gathered, when drone pilot also acts as the data interpreter. Thus, efficiency is increased and greater value is delivered to the customers.

Drone swarms are another great way to leverage AI. These can use AI to operate under loose commands from their operator. For example, for data acquisition, the area for data gathering is fixed and the swarm of drones then maps the area autonomously. Employing AI, they are able to avoid each other and the obstacles while also performing their mission in the most efficient way possible. Drone swarms are ideal for missions involving large areas and a high level of detail. Other applications can involve heavy parts moving by multiple drones, drone writing in the sky or other drone shows, etc.

AI drones used in automated infrastructure inspections not only perform safe and efficient surveillance but, thanks to their Machine Learning capabilities, they are also able to analyse the large volume of images to identify patterns and/or map the images to detect anomalies in data. Machine Learning is the key to unleash the drone inspection's true potential.

IBM's Watson internet of things technology is already used by drone operators. The visual recognition application programming interfaces analyses the drone-taken images to detect issues like equipment defects or damaged cabling.

Watson IoT interacts with information received from devices and sensors to learn or analyses it for patterns and can, for example, help making decisions on repairs timing.

A team of researchers from MIT has created an algorithm that enables a drone to monitor its own “health” while in flight and take action as necessary. The drone can monitor its fuel levels, and check for damage to its propellers, cameras and sensors. If a problem is found, the drone can take an alternative route that includes a charging station, or select another action to minimize potential damage.

Drones using AI have many applications: automated surveillance, identification of violent behaviour in crowds, objects detection, airplane inspections, traffic and roads supervision, etc.

Smart features

Some of the features that can make a drone smarter are given below. Many others could be considered.

Communication

Next-generation Smart Drones could be fitted with technology that allows them to connect to a cloud-based drone traffic management system, which would provide constant communication, navigation and surveillance, directing drones and warning them of congestion or severe weather ahead. NASA and the Federal Aviation Administration (FAA) are working on such an unmanned aircraft systems traffic management (UTM).

Smart sensors

A decisive factor for the quality and application possibilities of industrial drones is the built-in sensor technology. Sensors to detect the presence (and the course) of other aircrafts and obstacles, in real-time, are a must for integrating drones in industrial applications.

Cameras with 3D sensors technology are able to not only acquire images but, also, they send the feedback to on-board computers to be used for orientation, navigation and recognition to implement obstacle avoidance.

Thermographic cameras are using infrared radiation and are able to effectively display different temperatures of given objects with a pinpoint precision. Pairing IR, which can see through smoke, with a mobile drone that can sense and avoid obstacles on its own, is an intriguing use that could save lives in the case of a plant fire.

MIR sensor detects the specific frequencies of liquids or gases when they interact with light and was developed by the MIRPHAB European project. It could be fitted on a drone and used in wide range of applications: chemical sensing in processing applications, emissions monitoring, hazard detection, etc.

Augmented Reality (AR)

AR is a great way to complement the drones' capabilities. AR glasses featuring a transparent heads-up display designed to allow seeing drone's live video feed or flight statistics while also keeping an eye on the actual drone are quite common.



Fig. 4. AR glasses. Credit: Epson

AR drones are very useful in applications related to industrial inspections, disaster rescue, etc. For example, they can provide firefighters with crucial information regarding the building they are about to enter. In addition, during the rescue operations they can get real time data about what areas are unsafe and about to collapse, how and where to find survivors, etc.

2.5 Case study - Using drones in the Smart Factory

Smart Factory is the centrepiece of the Industry 4.0, a structure where intelligent machinery equipment is connected to the Internet of Things allowing for a level of automation and control greater than ever before.

With increased technological capabilities and connectivity, drones are one of the latest technologies to fit into the smart factory, at various stages of the process. Right now, the drones are not much used in manufacturing. According to Federal Aviation Administration, manufacturing is accounting only for 1.5% of the USA market. Uses include asset monitoring, visual inspection and inventorying by scanning RFID chips and bar codes. The main reasons for the little use of drones in manufacturing are related to the complexity of the job, safety concerns and legislation. Drones must become smarter and safer to be trusted in a major operations.

However, as their potential is enormous and the technology is advancing, we will see more and more drones integrated in manufacturing processes.

Drones can be used in various stages of the manufacturing process, from the discovery of raw material sources to materials handling, transporting products, inspections, quality monitoring, etc. Within the warehouse, drones can measure inventory, using barcodes, QR codes or radio-frequency identification technology.

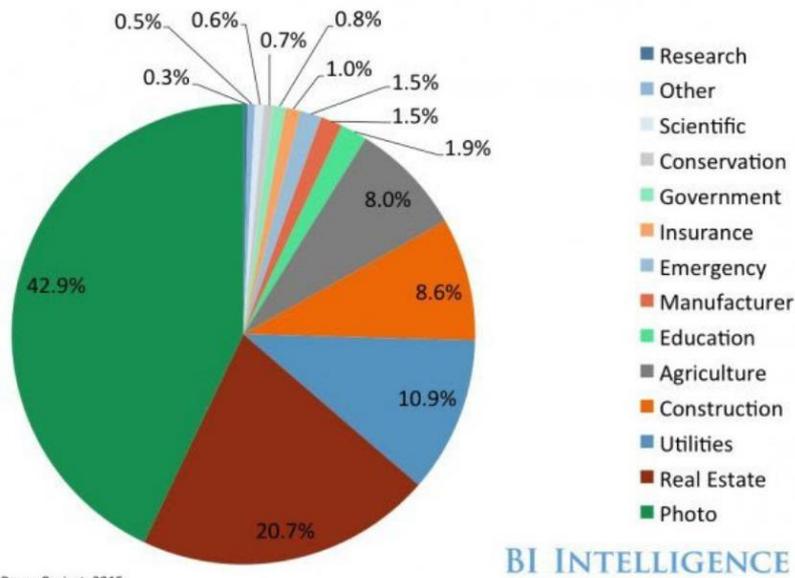


Fig. 5. Top Industries using drones. Credit: FAA

Drones can improve plant safety by performing difficult or dangerous tasks. They are small and manoeuvrable so they can access places that might be difficult for a human to get to. Once there, the drone can start to perform the desired task, for example inspecting equipment, repairing equipment or mixing chemicals where it would not be safe for humans to do so.

Drones could detect parts failure on the production line and immediately report back to the control system or plant manager, thus preventing downtime. In addition, if a member of staff urgently needs a spare part, a tool, etc. they can simply pick up a tablet and have it delivered by drones, thus avoiding wasting production time.

Case study: Audi factory, Ingolstad

German automaker Audi is one of the companies that are making good use of Industry 4.0 technologies at its factories to improve the plant and supply chain processes. Audi tested also Drone Technology in the Ingolstadt factory.

Two types of applications have been tested – automated transportation of parts in factory halls and camera-based repair and maintenance. Autonomous drones, with the ability to detect obstacles and to avoid collision, have been used.

In a traditional automobile plant, the transport infrastructure is very crowded and there is usually no more space for additional transport paths. Most of the parts needed by in series production are transported to the desired place at the specified times by conveyor vehicles moving along the floor. However, this system has its limits: the case of a subsequent order of parts, a so-called urgent call-off, can sometimes lead to long replacement times. A faster alternative in this case would be to employ drones that are carrying the goods on a direct route through the air.

The use of drones for automated component transport has been tested by logistics experts in the factories. In early September 2016, the first drone was in the air for the transport of components in an Audi plant, carrying out test flights on a production-free day.

The test route of the drone was defined mainly in a straight line through the production hall, including also one change of direction to the right and two to the left. The quadcopters, with the four rotors enclosed for safety reasons, have mastered their programmed routes with no problems.

Outdoors and under normal conditions, with a stable GPS signal, short flights like this would not pose a significant technical challenge. However, the things are different inside an automotive plant where severe safety rules apply and the departments involved (Logistics, Assembly, Occupational Safety) place different requirements on supply through the air.

The first tests and all flight manoeuvres were carried out via remote control by specially trained pilots supported by intelligent sensor technology, developed especially for the needs of the automotive industry. Of course, the drones' potential clearly lies in their automated use. The drones' flight speeds were initially limited to 2.2 meters per second, the speed of conventional floor-vehicles.



Fig. 6. Drone transporting a part. Credit: Audi

According to Audi, the results of pilot test were positive, although there are still many limits, such as battery life and the fact that drones cannot handle heavy parts like engines or other large components.

Audi is not pursuing further the plan to use drones in production because the current legal framework in Germany does not allow to use drones in closed surroundings, such as a production hall. If the regulations were changed, Audi could think about reviving the project.

Additional scenarios for drones implementation in Audi factories include supplying the production lines with urgently needed spare parts, general servicing and maintenance work or monitoring tasks with the aid of their cameras, a follow-me function for trucks on the plant site and the high-speed transport of urgently needed instruments such as a defibrillator for use in first aid.

3. Industry 4.0 and Drone Entrepreneurship

3.1 What is an entrepreneur?

In order to be able to define what an entrepreneur is, one must first think, what we define as entrepreneurship. In existing literature, there are many different definitions available on what we define as entrepreneurship. For the purposes of this brochure we are going to use the definition coming from the Harvard Business School and the Professor Howard Stevenson, which is the following:

“Entrepreneurship is the pursuit of opportunity beyond resources controlled”¹

The key components of the definition is the words “pursuit”, “opportunity” and the phrase “beyond resources controlled”

“Pursuit” implies a singular, relentless focus. Entrepreneurs need to stay alerted, as they are often given limited opportunities in success. They need to show tangible progress to attract resources, and the mere passage of time consumes limited cash balances. Henceforth, entrepreneurs have the characteristic of urgency that is not usually seen in established companies, where resources and opportunities are more promptly available.

“Opportunity” implies an offering that is considered as innovation in one or more of four ways.

The opportunity may include:

- 1) The development of a real innovative product;
- 2) The formulation of a new type of business model;
- 3) The creation of an improved or more price competitive version of an extant product;
- 4) The change of sales target group (e.g. targeting an existing product to new sets of customers)

The above list of opportunity types is not exhaustive, as there are more set of opportunities available, depending on the nature of each venture or organization. In addition, the opportunities can be combined e.g. a new venture might employ a new business model for an innovative product.

“Beyond resources controlled” implies resource constraints.

At a new venture’s outset, its founders control only their own human, social, and financial capital. Many entrepreneurs in their start, try to keep costs to a bare minimum while they invest only their own time and where necessary, their personal funds. In some cases, this is enough to bring a new venture to the point where it becomes self-sustaining from internally generated cash flow.

On the other hand, in the cases of high-potential ventures, founders must mobilize more resources than they control personally: the venture eventually will require further production facilities, distribution channels, working capital, and so on.

From the above we understand that it is very difficult to give a specific definition to an entrepreneur, providing that individual entrepreneurs don’t fit to standard models. Entrepreneurs are known for thinking outside of the box and going against the grain in their efforts to create valuable goods and

¹ (Eisenmann, 2013)

services for society. Their economic role involves making smart decisions about what people might want in the future. Such a task requires certain personality and character traits, which can be found common to different entrepreneurs such as:

- Passion for your business concept
- Innovation driven
- Persistence and vision to make their dream into reality
- Strong character (integrity, honesty, respect toward others, personal responsibility, good judgment)
- Courage and willingness to take risks

Indeed, combinations of characteristics are required for a successful entrepreneur: courage is required whenever one is going against the majority or a long-held tradition. Integrity is required when producing quality goods consumers will enjoy, and being honest about what the produced product can do. Personal responsibility is required to build and maintain your venture and products, for which you are accountable only to yourself and your customers.

3.2 Drone Entrepreneurs

Drone Entrepreneurs face the same issues that any tech-based business may face such as:

- Creating a tech- product or service to solve a current challenge
- Improve the production of a product or service in terms of production development or cost effectiveness or improve a behaviour of some kind.

Of course there are some other elements that are common in every new venture, that an entrepreneur needs to be careful of, such as customer service, reliability, legitimacy and of course brand identity but what a drone entrepreneur needs to change mostly, are the traditional ways people do things in different sectors, and introduce drones into this. For example, in delivery services how can people be convinced about the benefits of using a drone instead of a delivery truck/person? A drone entrepreneur needs to market their product/service effectively and persuade the market and consumers about the benefits of the use of drone technology in different sectors (drones can be faster/cheaper etc.). In today's business world, as a drone entrepreneur you need to prove that you're able to do it better than anyone else, and show that you can make use of the latest technologies to save time, money, and reduce risk and drones have become a tool to help you do just that.²

Successful drone entrepreneurs such as Jordi Muñoz and Chris Anderson, the co-founder and founder of 3D Robotics³, one of the largest and vast developing Drone businesses in California, USA, express the opinion that the future of the drone entrepreneurship doesn't rely much in the further development of drone technology itself, but more on how it can be used. According to Muñoz, we

² eBook: How to Win More Business with Drones, 3D Robotics, 2017

³ <https://3dr.com/company/history/>

need two types of entrepreneurs now: people who can make the technology do new things and perfect those things (this will mostly be with new software built on our existing platforms); and people who can apply the technology in new and meaningful ways. The next drone revolution, will be about the people who figure out what to do with drones: how to make them do new things, and how to use them to do new things.⁴

3.3 Types of drone's business opportunities

The future is bright for drones in business. With retail giant Amazon using drone tech to deliver goods, and Facebook's ambitious plans to deliver wireless internet connectivity to remote areas, the opportunities for businesses to develop around this technology is enormous. Below you can find some interesting drone's business opportunities in various sectors.

Agriculture

Drones are already appearing on farms, but haven't yet reached a critical mass. The role of drones in agriculture can be helpful in both large and small farming areas, with operations such as water management and disease management. Drone enterprises will soon be able to offer services such as improvement of planting and crop rotation strategies with the use of drones and provide a higher degree of all-around knowledge of how crops are progressing day-to-day in different parts of a given field. This boost in crop intelligence should make farms more efficient and help smaller operations compete with the more well equipped big agricultural operations⁵.

Photography and filmmaking

Prior to the development of drones, taking photographs or video from the air required the costly rental of fixed-wing or helicopter aircraft. Now with the low-cost drones equipped with high-resolution cameras, taking aerial images becomes an easy and affordable solution for photographers. Images and video taken from the air offer a perspective that cannot be matched from the ground, and drones can safely operate at much lower altitudes and in more confined spaces than aircraft. Photographers and filmmakers now routinely use drones to take high-quality images and video from the air such as landscapes. The business opportunities in this sector can range from wedding video coverage businesses till launching a filmmaking studio that specializes in the field of aerial footage. Such a company can work with both direct consumers as well as a wide range of business to business customers. Aerial footage is an impressive way to promote a business and it can greatly benefit different types of businesses, from accommodation spots to real estate agencies and entertainment spots such as theme parks.

⁴ <https://www.virgin.com/virgin-unite/business-innovation/how-become-drone-entrepreneur>

⁵ <https://www.profitableventure.com/drone-business-ideas/>

Drone Sales, Repair, Training and Customization

Drone repair is another excellent business idea. It is true that drones are fragile devices that can be easily damaged, especially if misused. Even though the cost of buying a drone is considerably lower than it used to be, still drones are in many cases too expensive to be just “thrown away”. In case you are interested in becoming technical expert with drones and are mechanically inclined with knowledge of electronics, drone sales/repair/customization is a great business idea for you. Having in mind the future drone-use expansion in other sectors of our everyday lives and the fact that drones require knowledge and skills to be safely operated, the market demand for experienced drone instructors will increase⁶.

Detective work and security:

Security is another sector that is considered as a great drone-business opportunity. Drones can be operated day and night and even capturing live footage of inspections. Here are some examples of drone uses and business opportunities in the security sector:

- use of drones for investigative and detective work: with drones you can get limitless information without being in the field. The drone will travel the distance and uncover or get information from restricted areas.
- use of drones for protecting industrial estates, business centres, schools and playgrounds and possibly entire communities
- use of drones detecting other threats to property such as intrusion, fire and water leaks. Live video feeds from drones can be sent to the home/business owner's mobile device, to a central monitoring facility, or directly to emergency responders.

Building Inspections - Roofs, Chimneys, Siding, etc.

Building inspections by a person costs a lot and of course it can be a dangerous process as it involves (especially in multi-store buildings) people in high altitude carrying equipment while making the inspection in parallel. With drone technology, however, building inspections can be done in a safer and cheaper way. A drone can perform a close-up survey of the exterior of a building and deliver high-resolution video of the roof, gutters, chimneys, enabling the building owner to detect trouble spots in advance.

Delivery

Drone-based delivery services is also another business opportunity. While still restricted to a pretty low maximum load-bearing weight (25 kg including the drone itself), delivery-by-drone is considered

⁶ <https://www.thebalancesmb.com/best-drone-business-ideas-4125154>

another much-needed application especially for remote areas where travelling by road can be difficult and hard to reach⁷.

Opportunities in other sectors

-Studying tropical cyclones: with the current climate change, tropical cyclones and storms are becoming more and more frequent. The application of drones will enable studying tropical cyclones (atmospheric pressure along they eye wall of the cyclone etc.) with safety⁸

-Medical use of drones: e.g. smart portable drones will be used by doctors during a colonoscopy procedure

-Documentary journalism: drones can replace cameramen for documentary journalism especially in dangerous areas such as war zones

-Volcanology experimentation: the application of the drone is to visualize the current location of the lava lake that is unreachable by human presence due to extreme heat⁹.

-Town planning: use of drones for real estate purposes, mapping and designing of real estate, housing and industrial complexes.

3.3.1 Inclusive drone business for people with fewer opportunities (disabled people)

Drone Technology can play an important role, due to the fact that it can be used for the social inclusion of people with disabilities. There are different types of disabilities, such as people with mobility problems, persons suffering from hearing disorders, speech disability or persons with invisible disabilities, that could participate in a training procedure. The skills that will be acquired through training, will let them carry out with success, different tasks in the security business sector.

The invasion of drones in the educational procedure will help them not only to get interested in the technology sector but also to regain their strength to acquire professional skills and their personal development and satisfaction. When this translates into a profession with objectives and benefits, this satisfaction can only increase.

Indeed, the fact that drones can navigate to a location faster than a person and reduce the risk, constitutes a great opportunity for disabled people to find a job in security sector and a strong motivation for companies to hire people with disabilities, tackling the discrimination in work place.

Disabled workers fit in well in the world of drone operation, as long as they have the training to fly them and abide by the right regulations. Drone operator can be a highly rewarding profession for the disabled people especially those with movement impairments. With the right training and

⁷ <https://www.businessnewsdaily.com/9276-commercial-drones-business-uses.html>

⁸ <http://grinddrone.com/applications/40-drone-applications-list>

⁹ <http://grinddrone.com/drone-features/advantages-and-disadvantages-drone>

technology, they can control a highly-technical machine that they may have assumed was impossible to master in the past. In the workplace, they would also get to make decisions and discoveries that may have a massive impact on the development of a project for increasing the disabled people social inclusion through training and employment e.g. as HandiDrone.

HandiDrone¹⁰ is an innovative project that has as an aim to assist in the fight against the discrimination of disabled people by equipping those with disabilities with valuable job skills in emerging fields. LADAPT, a French association for social and professional inclusion of people with disabilities, in coordination with digital agency Kindai developed the HandiDrone program. The initiative gives those with mobility issues access to drones and teaches them how to be drone pilots.

This initiative has the following results:

- fosters the social inclusion of disabled people by introducing them to emerging and innovative employment sector
- raises their employability skills in a creative sector
- gives physically disabled program participants the chance to "experience the tranquillity and control of being outside their own bodies through FPV flying."

3.4 Obstacles and challenges for the drone entrepreneur

The obstacles and challenges for a drone entrepreneur fall mostly into 3 categories a) insurance b) safety c) privacy. Drone technology is a quickly developing technology and is still undergoing many changes, especially regarding the regulatory framework, either in an EU or in a national level. The challenges are that you need to take all the necessary measures and follow the regulation framework of each country you plan to operate. If you have already started to operate a drone venture you need to keep up with the regulations regarding the above themes and of course adjust your actions accordingly.

A. Insurance

The use of drones in connection with a business activity is allowed in many European countries, but under very strict conditions. In most countries a professional drone user needs different authorizations/licenses from their National Aviation Authority before they can start any operation. Here is a summary of insurance rules in EU:

In Europe, professional drone operators flying over the territory of an EU Member State must comply with Regulation (EC) 785/2004 on insurance requirements for Air Carriers and Aircraft Operators. Article 4 indeed stipulates that "Aircraft operators [...] shall be insured in accordance with this Regulation as regards their aviation-specific liability in respect of [...] third parties." The Regulation has as a main aim to ensure that there is a minimum level of insurance requirements that will secure adequate compensation for victims in case of an accident. In spite of the appealing opportunities and characteristics of the drone technology, all professional users should always have in mind that drones belong to the aircraft category

¹⁰ <https://www.trendhunter.com/trends/discrimination-of-disabled>

and can create serious damages especially if they are misused. As a professional operator you are responsible to have applicable insurance and liability requirements and make sure you are adequately insured for flying your drone¹¹.

B. Safety

In Europe, the majority of the National Aviation Authorities (NAA) have established aviation safety rules regulating the use of drones in the airspace. These rules aim to regulate drone operations and secure that their use will not become dangerous towards people and properties or for other airspace users (airplanes, gliders, helicopters, etc.)¹²

It is essential that a drone entrepreneur knows the local flight rules before operating in a country and follow some basic safety rules.

These rules differ from country to country but typically include:

- **Flying restrictions.** National Aviation Authorities have established a regulatory framework based upon the operational complexity of your flight and the weight of your drone. In most countries there is a maximum flying altitude that drones are allowed to reach and it requires special permission to operate over populated areas or Beyond Visual Line of Sight (BVLOS) of the operator.
- **Pilot training obligations** to ensure that potential operators have all necessary skills and a basic understanding of aviation safety rules. In many countries, prospective operator will be required to pass a written exam and a flight test. In case you are not the user, but the owner of a drone business it is advisable first to have a basic understanding of pilot obligations and of course hire a certified drone pilot for your operations.
- **The obligation for your drone to have an airworthiness certificate** attesting that it is safe to fly.
- **The obligation to register your drone** with the competent authority.

C. Privacy

In Europe, every citizen has a fundamental right to privacy and to the protection of his/her personal data¹³. This right is regulated by the General Data Protection Regulation which sets out the various requirements for the collection, processing and storage of personal data. As a professional drone operator, you must always respect these rights and strictly comply with

¹¹ <http://dronerules.eu/en/professional/obligations/summary-of-insurance-rules-in-eu>

¹² <http://dronerules.eu/en/professional/obligations/summary-of-safety-rules-in-eu>

¹³ <http://dronerules.eu/en/professional/obligations/summary-of-privacy-rules-in-eu>

the applicable privacy and data protection legislations. Failure to comply with these rules may result in significant financial and/or legal consequences.

You can find more about the drone regulations in each country, in the European Legislation Map

<http://dronerules.eu/en/professional/regulations>

3.5 Additive manufacturing opportunities in drone manufacturing

The latest innovation in manufacturing, additive manufacturing (also known as 3D printing) is fabrication of parts – adding material layer by layer. Additive manufacturing technologies reshape the way parts are designed and constructed, supporting rapid development of new or replacement parts, which can greatly benefit sectors such as the aviation and the Unmanned Aviation Vehicles (Drones) as well as the marine and offshore industries.

Indeed, according to a recent study of the Research and Markets, the firm projects that the yearly value of AM manufactured parts in the drone industry to reach \$1.9 billion, driving over \$400 million in yearly sales of AM equipment, software, materials and services¹⁴.

So, which exactly are the additive manufacturing opportunities in the drone sector? Additive manufacturing contribution in the drone manufacturing can play a major role and can offer the following:

- **Customized Drones:** 3D Printing allows us to manufacture personalized products according to a person's needs and requirements. This gives the opportunity for the creation of customized drones with any specific part of a store-bought drone possible to be tailored according to someone's needs¹⁵
- **It's cheaper to create them:** If you're not an experienced drone pilot, crashing and breaking parts of your aerial vehicle can cost you a lot. Instead of having to buy new parts for your drone, you can 3D print your own spare parts as needed¹⁶.
- **Improved Performance:** one of the most important elements regarding the performance of a drone is its weight. The weight of a drone affects its flight time, with the heavier drones to fly less time than the lighter ones. A light drone remains more stable in case of crashes and abrupt/hard landing and they tend to have improved battery life. With the 3D printing you can choose the material in order to reduce the weight of your drone and make it more agile in the flight
- **Save you time and effort:** Instead of searching and ordering the specific part of a drone and waiting for it to be delivered in cases of online shopping or visiting the hobby/model store of

¹⁴ <https://www.researchandmarkets.com/research/bwxwqf/additive>

¹⁵ <https://www.entrepreneur.com/article/292815>

¹⁶ <https://all3dp.com/3d-print-drone-parts/>

your area you can just 3D print spare parts of your drone. This will save you a lot of time and effort.

Drone Parts that can be 3D Printed

Apart from the electronic elements of the drone everything else can be 3D printed, below you can find some examples of the parts you can 3D print¹⁷.

- Propellers
- Frame Landing gear
- Landing gear
- Camera mounts
- Antenna holder
- Protective equipment (i.e. prop guards)
- Remote casing
- Battery pack casing

There above list is not complete, as you can 3D print numerous functional as well as non-functional accessories for your drone such as propeller guards, cases for transportation and mounts for various cameras used on FPV drones.

As we can see the business opportunities are increasing for the drone entrepreneurs and the drone manufacturing as the additive manufacturing technology advances.

¹⁷ <https://all3dp.com/3d-print-drone-parts/>

4. Teaching Industry 4.0 and Drone Technology (DT) to VET students

4.1 Global drone technology market in education sector

Global Drone Technology Market in Education Sector is a growing market with a CAGR of 14.61% in Information & Communication Technology, Information Technology sector during the period 2017-2021. The Drone Technology Market in Education Sector has covered rapid development in the current and past years and is probably going to proceed with a continuing development in the upcoming years¹⁸.

There are many factors that may drive us to use drones in the education sector:

- Development of high-level digital skills;
- Incorporation of thermal imaging in drones;
- Cost-effective technology;
- Continuous development in drone technology;
- Didactic innovation;
- Make learning fun.

Below you can find the examples of the companies and institutions along with the main characteristics to present global drone technology market.

BonaDrone

BonaDrone is a Spanish company that provides teachers with tools that can help attract students towards IT and STEM technologies and disciplines.

Their tools involve 3D designing through CAD software, 3D printing and the operation of drones, as well as manuals and documentation for the teachers. BonaDrone provides drones along with a manual for its assembly and also a manual directed at all the STEM disciplines.

Teachers can therefore easily integrate the drone technology in their curricula.

BonaDrone provides:

- Three different kits;
- Two types of drones;
- Syllabus on drones;
- Manuals;
- Courses for teachers.

OnPoynt

OnPoynt is an American company specialized in the creation of drones for educational purposes. Their products are durable so that many generations of students can work on them without them breaking and they also come with manuals and booklet with resources related to STEM disciplines

¹⁸(Prnewswire.com, 2018)

that can be used in the classroom.

Their kits include from 1 to 4 drones, the equipment to assemble them, the manuals and more. For safety, it is suggested that only kids 18 y.o. or older program the drones, but they can be assembled and used by kids, that are at least 14 years old.

FabLab

FabLab is a company that provides training, machines, equipment and support for projects related to technology and 3D printing. They collaborate also with schools in the territory of the Bologna Municipality, both encouraging field trips to their workshop and activating projects with the schools to improve their curricula.

FabLab is currently working with secondary schools and institutes from Bologna.

They provide:

- courses to implement already existing curricula;
- Training courses for teachers and educators;
- Digital and technical assistance;
- Field trips to make your projects come true.

Istitutosuperiore Primo Levi

An Italian school for students wishing to become surveyors has successfully introduce drones in one of its curricula dedicated to designing related to buildings, the environment and the territory.

This will give the students competitive skills in the labour market and the collaboration with a local flying school will allow them to get their license.

The school has one drone the students can practice with. The environment is completely safe for its use and the students are followed during their practice by certified instructors from the local flying school.

The competences they acquire through this curriculum will give them access later to professions in fields such as the protection of the environment and the cultural heritage or the study of the territory.

4.1.1 Drones for social inclusion

In the education system it is often hard to find or organize activities that can include people with disabilities. Formal education, for example, is not always inclusive for people with learning disabilities, such as students with dyslexia. Extra-curricular activities, on the other hand, often include physical activities and thus could exclude people with physical impairments or disabilities. Drones can be a useful tool for social inclusion. Learning how to fly a drone could be helpful with finding employment in the different fields: agriculture, security, industry and becoming a drone pilot.

People with dyslexia often have difficulties learning through formal education systems and therefore need innovative solutions. Designing drone parts on CAD tools can be a viable solution for people with dyslexia¹⁹.

¹⁹ Beall, 2016.

Feeling like they can contribute and bring value to a project like the creation of a drone can boost the self-esteem of people with dyslexia.

Drones can be a great innovation of the education system in all countries.

They can provide students with the skills and competences the market demands and they will also make STEM disciplines and curricula more attractive. It may have a positive influence at the number of students dropping out of school.

4.2 Increasing demand for drones in education sector

The increasing demand for drones in retail sector is well known in recent years and the drone retail sector will bloom even further in the next years. However, it is not only in the retail sector that there is an increasing demand for drones. Education sector currently focuses a lot on the Science, Technology, Engineering, and Mathematics (STEM) skills, preparing young students for the global jobs market demands. Use of drones in the education sector is closely connected with the development of STEM skills, as it combines the use of multiple technologies in one (electronics, photography, robotics, autonomous systems, coding etc.). Moreover, it is an excellent way to engage and attract the interest of young people and inspire kids at an early age [18].

With the latest advancements in the drone technology sector, drones have become increasingly affordable in both the private and public sectors, which led to their increased use by businesses and enterprises as well as individuals. Education sector has identified this opportunity and the fact that drones and their use are shaping the nature of services from various business and current students need to understand and familiarize themselves with this technology.

It constitutes a great opportunity for the education sector across the EU, as each educational institute that offers drone flying as part of their curriculum is equipping their students with skills that are valuable for entering the job market. A business or sector that already uses drone technology for its services, will employ new graduates who are already familiar with the technology. The above have led to an increasing demand for drones in the educational sector.

Moreover, the use of drones can also help students in achieving better results and improve their school performance. A study conducted in a Greek school examined the learning outcomes when using unmanned flying vehicles (drones) for teaching fifth-grade primary school students' units from Language and Mathematics. The results verified that, for Mathematics, the students of the experimental group achieved better results, compared to the controlled group and the sustainability of their knowledge was also greater. In addition, there was a formation of positive attitudes and perceptions of students toward drones [20].

Finally, drones are already being used in the following educational subjects and studies [19]:

- Geography – using cameras to undertake ground analysis, analysis of riverbeds or areas that is hard/dangerous for humans to approach
- Geology – using drones with cameras in remote places to observe rock formations, volcanos etc.
- Agricultural Studies – precision farming techniques, crop spraying techniques, herd management and observation

- Engineering – using drones in teaching prospective engineers will lead to the improvement of heavy engineering projects, production lines as well as the actual design and build of drones

In conclusion, with young students who are increasingly embracing the technology in education, the demand for use of drones in the schools will only rise and eventually will become an established trend.

4.3 Design of drone parts

Drones can have many different uses and their design needs to be tailored to the actual use. Students can learn how to determine the best type of drone materials or accessories for different uses and then create them. Drones have components that relate to three different sectors:

- Electronics
 - Flight controller
 - Sensors
 - Electronic Speed Controllers
 - Collision Avoidance Sensors
 - Receivers
 - Antenna
- Technology
 - Accessories
 - Materials
 - 3D printing
- IT
 - Programming

We can thus create different drone curricula and integrate them in many different schools. All drone parts and components are vital to a smooth and safe flight. Knowing the parts of a drone will give extra confidence while flying. Students will also know which components to inspect on a regular basis and the drone parts which are easy to replace or upgrade.

4.4 Selecting materials for additive manufacturing of drone parts

Drones can be composed of different materials. They all have their own characteristics, resilience and price-range and all of this will affect the choice of any drone maker. The main materials are wood, foam, plastic, aluminium, carbon fibre.

Wood

Some kinds of wood are particularly strong and tough, but they need to be treated to become waterproof. It can be a good choice for its low price.

Foam

Foam can be a great choice for the wings of the drone, but the rest of the body must be composed of other materials. Foam can also be used to protect some parts of the drone.

Plastic

There are many different types of plastic that can be employed in the manufacturing of drones. Their cost and strength come in a wide range and they should be chosen project by project.

Aluminium

Aluminium is inexpensive, light and easy to cut, shape and work with. It is easy to use and very versatile, and can also be strengthened using the right finishing techniques.

G10/FR4

It is a kind of fiberglass, but its nature requires expertise and specialized equipment to cut it to the desirable shape and form.

PBC

Printed Circuit Boards are used sometimes for the top and bottom plates of the frame, as they can reduce parts.

Carbon fiber composites

Carbon fibre materials can be very hard to cut and shape, but they are one of the lightest and most resistant materials, which make them perfect for drones.

Other

3D printing material - there are different kinds of spools of filaments that can be bought and prices can vary a lot. For one spool of filament the price to be expected is \$30.

4.5 3D printing of drone parts

3D printing is another option for construction drones in a very cost-effective technology, but of course the purchase of a 3D printer is an investment for schools.

Bonadrone is the designer and manufacturer of drones and on point innovators in the world of drones for education that provides two different types of DIY 3D printed drones:

- the Mosquito 150,
- the Mosquito 450.

The Mosquito 150 is smaller and ideal for teams of 2 students.

The Mosquito 450 is bigger and ideal for outdoors and groups of 4 students. These drones and the kits they come in are the perfect teaching and learning tools for students. Students can learn how to design the 3D model of the drone on CAD software and then move on to the actual printing of their model. The Mosquito 450 model created by BonaDrone is a great option for schools. You can choose whether you want to receive it:

- 1) Ready to fly
- 2) Ready to assemble
- 3) Ready to print

According to the specific needs and possibilities of your school.

4.6 Testing the mechanical properties of drone parts

The purpose of the mechanical testing of drone parts is to verify that the aircraft components meet the strength and weight requirements for flight.

If a commercial kit was purchased, the durability and rigidity of the drone is, normally, guaranteed by the manufacturer. However, when students designed and/or produced (by 3D printing or other methods) some of the drone parts, these ones need to be tested to evaluate their durability and to check if they can withstand vibration.

Normally, mechanical properties testing can be done in special laboratories but such facilities are not accessible for most of the VET schools. One solution is to manually test the produced parts.

Drone frames have significant impact on flight performance like aerodynamics, weight distribution, rigidity, etc. So, a frame must be strong enough for drone's safety but as light as possible to offer autonomy and good flight characteristics. Also, the frame should be rigid in order to reduce vibrations that negatively affect the other components and the quality of video data acquired.

The rigidity of the frame can be evaluated manually. If the frame is too flexible, an improved design or better materials should be used. In the same way, the frame's strength can be assessed.

5. Business ideas and opportunities related to drones and Industry 4.0

5.1 Industry 4.0 – business opportunities and challenges.

“Our intuition about the future is linear. But the reality of information technology is exponential, and that makes a profound difference. If I take 30 steps linearly, I get to 30. If I take 30 steps exponentially, I get to a billion.” – Ray Kurzweil

Most of new technologies underlying the concept of Industry 4.0 are not as new as most of us would expect. Take 3D printing, with basic equipment and materials developed in the 1980s, and printing from resin, metal, glass or bio printing available now, not to mention the wider accessibility, lower costs and higher speed of modern printers. According to PwC 71.1% of manufacturers are now using 3D Printing for prototyping and final product, and 52% of manufacturers expect 3D Printing will be used for high-volume production in the next 3-5 years.²⁰ Things look similar, when we consider drone technology, UAV innovations started in the early 1900s and originally focused on providing practice targets for training military personnel. In 2010 America’s Federal Aviation Authority (FAA) estimated that by 2020, there would be around 15,000 such drones in the country. Now, more than that are sold every month. Some analysts expect the number of drones made and sold around the world this year will exceed 1m.²¹ Have you seen Sensorama? Compare it with modern VR headsets and you will realise that the growth has become exponential.²²

It appears, that the advancement and availability of various disruptive technologies are all coming of age at once. Because some of the technologies have been around for a while in their own right – but it’s the convergence of all of the technologies that is driving the true revolutionary nature of the change in the way business will function. It also creates almost unlimited business opportunities in terms of innovative developments, projects and implementation. The more advance these technologies become, the more potential business applications they may have.

Again, let’s have a look at the Drone technology. First, as is often the case with new technology, it was supposed to serve military purpose, now it is even hard to follow new applications for this technology, as it is growing so fast. UAVs appear in areas as diverse as agriculture (farmers use drones to monitor crop growth, insect infestations and areas in need of watering); land-surveying; film-making; security; or delivering things (Swiss Post has a trial drone-borne parcel service for packages weighing up to 1kg, and many others, including Amazon, UPS and Google, are looking at similar ideas).

²⁰ <https://www.forbes.com/sites/louiscolombus/2016/04/24/7-ways-3d-printing-is-making-manufacturing-more-competitive/#76d881837dfd>

²¹ <https://www.economist.com/science-and-technology/2015/09/26/welcome-to-the-drone-age>

²² <https://www.youtube.com/watch?v=rxY9XSRCeMU>

The number of possible applications for this technology, as well as for other innovations related to Industry 4.0, may only increase, and this will be due to the reciprocal amplification.

By this term I mean that an innovation or advancement in VR may trigger another in DT or 3D printing. These technologies are often interrelated and connected. Connectivity is in fact a very crucial word, common to all new technological advancements. It's all about connectivity. IoT, that form the foundations of the Industry 4.0, is *"the network of physical devices, vehicles, home appliances, and other items embedded with electronics, software, sensors, actuators, and connectivity which enables these things to connect and exchange data, creating opportunities for more direct integration of the physical world into computer-based systems, resulting in efficiency improvements, economic benefits, and reduced human exertions."* – Wikipedia.

The number of IoT devices increased 31% year-over-year to 8.4 billion in 2017 and it is estimated that there will be 30 billion devices by 2020.[11] BCG (Boston Consulting Group) predicts that by 2020, €250B (\$267B) will be spent on IoT technologies, products, and services.

The spectacular growth, however, is not free from any obstacles and adoption barriers. In case of IoT these may be privacy and security concerns (Amazon Echo example²³ or Tesla autopilot²⁴). Considering UAVs, there also are implications for safety (cases of drones crashing with planes); for privacy, from both the state and nosy neighbours; and for sheer nuisance—as drones can be noisy.

First industrial revolution was triggered in the 1700s by the commercial steam engine. The harnessing of electricity and mass production sparked the second, around the start of the 20th century. The computer set the third in motion after World War II. It might seem too soon to proclaim that the fourth industrial revolution has started, but when we realise the potential of its various components and their potential influence on our everyday lives, it's hard to disagree with Henning Kagermann, the head of the German National Academy of Science and Engineering (Acatech), who first used the term Industry 4.0 in this context. Even though, the Industry 4.0 movement started in Germany, it is now gaining momentum all over the world, particularly in the United States, Japan, China, the Nordic countries, and the United Kingdom. Such influential global industrial giants as Siemens and GE have fully embraced the approach; both companies' CEOs and senior executives have declared that it is now a core part of their identity.²⁵

In 2016, PwC surveyed more than 2,000 companies from 26 countries in the industrial production sectors, including aerospace and defence; automotive; chemicals; electronics; engineering and construction; paper, and packaging; metals; transportation and logistics. In this global Industry 4.0 survey, one-third of the respondents said their company had already achieved advanced levels of integration and digitization, and 72 percent expected to reach that point by 2020. In this chapter we

²³ <http://www.politifact.com/truth-o-meter/statements/2018/may/31/ro-khanna/your-amazon-alexaspying-you/>

²⁴ <https://www.wired.com/story/tesla-autopilot-self-driving-crash-california/>

²⁵ <https://www.strategy-business.com/article/Siemens-CEO-Joe-Kaesar-on-the-Next-Industrial-Revolution?gko=efd41>

are going to present you some ideas for utilization of business potential related to Industry 4.0 and Drone Technology, along with few examples of digital market leaders.

5.2 DT and Industry 4.0 related business – success stories

Technological leaps represented by three industrial revolutions, mentioned above, have always been a huge business opportunity for those who were able to quickly understand their potential. As much as the first two revolutions, in terms of business profits, benefited mostly the biggest players on the market, fourth industrial revolution may have a wider impact. The technologies constituting Industry 4.0 can be growing exponentially in terms of their complexity and potential, and at the same time their accessibility is expanding. Examples: 3D printer – at the beginning very few companies could afford to purchase the printers as they were very expensive. A single printer could cost around \$300,000, now with the prices starting from less than \$100, almost everyone can become a maker. Along with growing need for digital content, many companies have been building and selling 3D models. Now, due to open online repositories people from around the world are able to put their 3D models online for sale.²⁶ Only on Thingiverse, the platform community has uploaded over 1,112,570 3D models.²⁷ This process looks similar in case of drones, they are rapidly increasing their consumer availability, as they get smarter (packed with sensors, that make them easier to operate) and cheaper (DJI Spark for around \$400 on Amazon²⁸). Yahoo's tech expert David Pogue estimates that a drone with similar features to the Spark would have cost around \$1,200 a year ago.²⁹

With prices becoming affordable for most consumers, it is now possible for an average student to start a business adventure based on drone technology. Apart from some basic manual and digital skills that are needed, you should have a sufficient insight into your local market in order to realise its needs and problems, and create a solution. Below, we present some possible business applications of drone technology.

- Insurance company business: Insurance companies are employing drones to inspect and quantify things like hail damage claims to roofs rather than put adjustors at risk of falling as well.
- Real estate videos: Real estate agents are very quickly realizing that very low altitude aerial video footage captured by drones sell large pieces of property and homes with unique features more quickly.
- Pipeline Monitoring and Security: UAVs equipped with cameras and video transmitters are now replacing much of the routine inspection that was very expensive and often dangerous to the pilots and inspectors.
- Making and Selling of Maps: drone operators can now provide great, detailed aerial views with costs incomparable to helicopters or airplanes.

²⁶ <https://jonpolygon.com/history-of-3d-model-marketplaces/>

²⁷ <https://www.thingiverse.com/about/>

²⁸ <https://www.amazon.com/DJI-Spark-Portable-Drone-Alpine/dp/B07173X82D>

²⁹ <http://time.com/money/4800984/drone-prices-decrease-spark-dji/>

- Film makers: launch a film making studio and cooperate with a vast range of B2B customers (tourists landmarks, theme parks, RE agencies, filmmakers)
- Drone pilot courses: more and more people are interested in learning how to fly a drone. Sell them skills and knowledge they need.

These are just a few examples of how the drone technology can serve other people and bring profits to bold entrepreneurs. Below you will learn of some real-life implementations of business ideas connected with the use of UAVs.

5.2.1 Success stories

Success story 1 – drones underwater

Drones can do more than just fly. Surprised? A company called Open ROV recently developed the Trident, a remote-controlled, easy-to-use underwater drone with a built-in HD camera that's capable of venturing down more than 300 feet. Pilots tether the Trident to a floating buoy, which connects via WiFi to a laptop or tablet that controls the machine and relays live-streaming video. The drone can be programmed to either run on auto-pilot, mapping a selected area and following pre-set routes, or in manual mode.

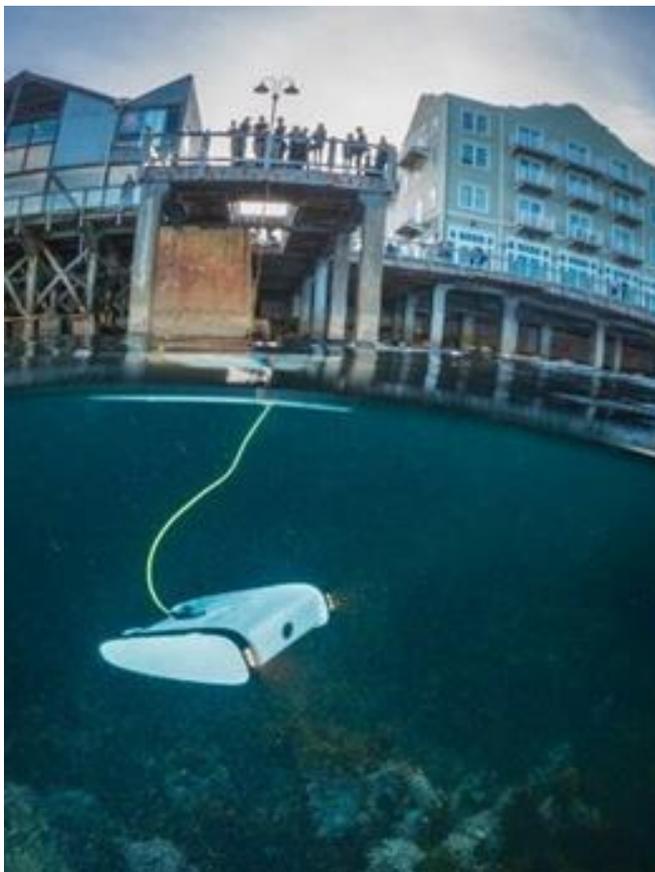


Fig. 7. Trident drone. Source: <https://www.openrov.com>

The company is offering products and services based on marine imaging and intelligence solutions, that can be used in areas like:

- Tourism & Recreation
- Shipping & Inspection
- Aquaculture
- Marine construction
- Environmental monitoring
- Search & Rescue

Founded in 2012, OpenROV develops open source underwater drones that can map out large bodies of water for exploration, education and environmental scientists. OpenROV has secured \$1.3 million in one round of investment from two investors: SK Ventures and True Ventures. OpenROV offers a build your own kit, pre-drive checklists and a global open source community.

OpenROV started out as a project among friends to get to the bottom of an underwater cave rumoured to contain buried treasure. Since then OpenROV has grown into a company and community of people who are working together to create powerful new tools for underwater exploration.³⁰

Learn more on <https://www.openrov.com/>

Success story 2 – drones protecting natural environment

SenseFly is the creator of the well-known eBee drone – an ultra-lightweight fixed wing. eBee is strictly commercial: its high price makes it an enterprise solution. But the eBee's truly unique weight and size mean that its safety case is almost self-evident. No rotors, no sharp edges, and no heavy objects make the eBee an excellent choice for many applications as well as a regulatory favourite. Due to its efficiency (The eBee can cover up to 12 km² (4.6 mi²) in a single automated mapping flight) and ease of use (no pilot skills required, you simply throw it into the air, it flies, captures images and lands itself), eBee can be a great solution for mapping harsh environments and covering large areas.



Fig. 8. eBee drone. Source: <https://www.sensefly.com/>

³⁰ <https://www.openrov.com/about/>

Professionals such as environmental engineers and scientific researchers are increasingly turning to drones in place of either slower terrestrial surveying equipment, lower-resolution satellite imagery and expensive, or sometimes unavailable, manned aircraft services.³¹

It can be used in:

- Change monitoring. Digital data allows an operator to document a site or a natural object's evolution over time;
- River and flood assessment. Mapping and modelling of river basins is essential in flood defence programs;
- Forestry. Enables health analysis, biomass estimation, inventory management or impact assessments;
- Animal management and conservation. Drones can be used to facilitate population counts.

More information on <https://www.sensefly.com/>

Success story 3 – drone analytics

Redbird is based in Paris, France and is a pioneer in the acquisition and analysis of aerial data collected by UAVs. They offer advanced cloud-based platform. This platform saves costs, ensures safety, and optimizes resources on construction sites, quarries or mines. Their team consists of over 40 professionals from various background and fields of expertise, and their technical team is composed of experts in cloud computing, GIS, remote sensing, photogrammetry, signal processing, and software development. Redbird has recently been acquired by Airware, and they've also partnered with Caterpillar, the leading construction equipment manufacturer in the world.

The acquisition allows Airware to concentrate on the insurance vertical where it helps State Farm and other customers with inspecting roofs, residential claims management, and commercial underwriting. Redbird will try to expand its lead as a provider for providing mines, quarries, and construction sites with drone-captured aerial data an analytics about their production quantities and pace, their efficiency, and their safety compliance.³²

Success story 4 – drone mapping

Drone mapping and modelling software provider Pix4D is a major player in drone software solutions. Pix4D offers precise, georeferenced 2D and 3D maps and models. They have come up with creative uses for their output, including elaborate real estate and construction models. Pix4D has covered the entire commercial workflow, with tools from data capture hardware (through their partnership with Parrot) to analysis and delivery to the client.

³¹ <https://www.sensefly.com/industry/environmental-protection/>

³² <https://techcrunch.com/2016/09/22/airware-buys-redbird-to-build-a-full-stack-commercial-drone-services-empire/?guccounter=1>

Pix4D is also very active in working with organizations to bring drone technology to underserved communities or for disaster relief. The company has done work all over the world to assist after hurricanes, earthquakes, and other disasters. Learn more on <https://pix4d.com/>

Success story 5 – drone inspection

Swiss company Flyability offers Elios, a collision-tolerant drone. Instead of relying entirely on imperfect sense and avoid technology, they take an innovative approach: the drone is inside of a freely rotating cage. The cage means that the inspection drone can be used in a new way – in new spaces, like plants, mines, container ships, chemical storage tanks or even nuclear power plants.



Fig. 9. Elios drone. Source: <https://www.flyability.com/>

The company was founded by cousins Dr. Adrien Briod and Patrick Thévoz, who were inspired by the Fukushima disaster. The realization that there were no robots available to help deal with the problem drove them to create a solution. Since launching the Elios in 2016 the company has not only provided a valuable industrial tool but has donated the product to “Robotics Without Borders” for use in disaster response. Learn more on <https://www.flyability.com/>

Success story 6 – drone for extreme sports

Back in 2014, a little-known company called Airdog launched something that would transform the drone landscape forever: a quadcopter that automatically followed (and filmed) its subject, thereby eliminating the need for manual piloting. Sure, this is a standard feature on just about every card-carrying drone that’s released these days, but Airdog was arguably one of the first to take the idea and run with it. The only problem, however, was that as soon as Airdog’s Kickstarter campaign gained a good deal of attention, big companies like DJI and Yuneec adapted the idea for their own products.³³

With the ADII, you can customize the drone’s flight path, altitude, and shooting style before you even start filming. This feature allows you to set up the perfect shot and ensure that your drone will not hit any obstacles, without having to manually pilot the drone. More on <https://www.airdog.com/>

³³ <https://www.digitaltrends.com/cool-tech/best-new-crowdfunding-projects-awesome-tech-you-cant-buy-yet-amabrush-adii/>



Fig. 10. ADII drone. Source: <https://www.flyability.com/>

For the 12 month period ending in April 2016, drone sales grew 224 percent from the previous year period to nearly \$200 million, according to a report from retail research firm the NPD group. Drones are rapidly becoming an indispensable tool in a variety of industries. Some ideas for starting a small business related to DT may include services like: photography; security surveillance; search and rescue; building inspections; agricultural surveys; mapping; sales, repair and training.³⁴

5.3 Anticipated future trends in Drone Technology and Industry 4.0

The term Industry 4.0 refers to the combination of several major innovations in digital technology, all coming to maturity right now, all ready to transform most business sectors. These technologies include advanced robotics and artificial intelligence; sophisticated sensors; cloud computing; blockchain; Internet of Things; 3D printing; AR/VR and drone technology.

Here are some experts' predictions concerning the development of these technologies:

Cloud computing. Important innovations are making cloud computing more valuable for companies as they seek to transform their operations and business models. These advances are helping accelerate deployments of artificial intelligence and Internet of Things solutions, while enabling deep, analytics-driven insights.

Blockchain. Organisations across a wide range of sectors are already experimenting with blockchain technology to establish trust networks, improve transparency, and reduce friction and costs. Despite fierce debate, interest in cryptocurrencies powered by blockchain remains strong. Industrial applications will expand, encompassing the obvious financial uses as well as innovative solutions for energy, trade, marketing, healthcare, security and more.

Artificial Intelligence. Stanford University's Scientists believe that by 2030, cities will use Artificial Intelligence (AI) to ensure the safety of the population. According to the forecast, the AI will help to prevent crimes and even act as an assistant in court proceedings. According to Gartner, global

³⁴ <https://www.thebalancesmb.com/best-drone-business-ideas-4125154>

business value derived from artificial intelligence (AI) is projected to total \$1.2 trillion in 2018, an increase of 70 percent from 2017. AI-derived business value is forecast to reach \$3.9 trillion in 2022.³⁵

Big Data. The analysis of large amounts of data is already widely used by various companies. With the growing amount of information and the AI evolution, big data will develop and will be adapted to be applicable to even more spheres of life. Big Data will be one of the online marketing tools. This technology will allow quick processing of huge amounts of data about purchasing behaviour.

Immersive experiences. Augmented reality (AR), virtual reality (VR) and mixed reality are changing the way people perceive and interact with the digital world. Combined with conversational platforms, a fundamental shift in the user experience to an invisible and immersive experience will emerge. International Data Corp estimates that total spending on AR/VR products and services will rise from \$9.1 billion in 2017 to nearly \$160 billion in 2021, representing annual growth rate of 113.2%.

3D printing. 90% of companies using 3D Printing consider it a competitive advantage in their strategy. 72% predict their spending on additive manufacturing will increase in 2018.³⁶ Some of the anticipated trends in 3DP include³⁷:

- Better software, more integration. As manufacturing processes adapt to additive approaches, we may also see a growing role for generative design and related software in facilitating the transition.
- Organic, wearable materials. Quickly expanding range of new printing materials creates new possibilities. A remarkable new 3D printing technique, developed by MIT researchers has enabled to create temporary 'living tattoos.' The method uses ink made from genetically programmed living cells, which can light up in response to different stimuli.
- Increased speed and productivity. engineers at MIT have developed a new desktop 3D printer that outputs ten times faster than existing commercial printers. Polymer material is fed through the print nozzle by a screw mechanism, while being rapidly by a laser, allowing it to flow faster. Objects that would previously have taken hours to print can now be printed in minutes.³⁸ Also metal printing is becoming a lot more accessible, with new printer by Desktop Metal, that can reportedly print a hundred times faster and ten times cheaper than its current competitors.³⁹
- Mass Customization. In 2017, "offering customized products" was one of the top priorities listed by companies surveyed in Sculpteo's annual State of 3D Printing study.

³⁵ <https://www.gartner.com/newsroom/id/3872933>

³⁶ <https://www.forbes.com/sites/louiscolombus/2017/05/23/the-state-of-3d-printing-2017/#5c30ea7c57eb>

³⁷ <https://www.cadcrowd.com/blog/3d-printing-trends-to-watch-in-2018/>

³⁸ <http://news.mit.edu/2017/new-3-d-printer-10-times-faster-commercial-counterparts-1129>

³⁹ <https://newatlas.com/desktop-metal-3d-printing/50654/>

Drone technology. Most people still think of a drone, as a sophisticated military technology or a hobbyist's tool for capturing images, taking videos of family or sporting events. However, businesses across industries realize that drones have multiple commercial applications, some of which go beyond basic surveillance, photography, or videos, and they are already using them to transform daily work in some industries. Apart from reaching wider scope of applications, and making its way to new business sectors, the following is expected by many experts:

- Artificial intelligence. Next generation of drones will inevitably be powered by AI. AI allows machines such as drones to make decisions and operate themselves on the behalf of their human controllers.
- Drone swarms. A swarm, where a number of drones move and act as one unit, is already a powerful weapon tested by military, but can also have commercial applications. Swarms could check pipelines, chimneys, power lines and industrial plants cheaply and easily. They can be used on big farms, where they spot plant disease and help manage water use, or spray pesticides and herbicides only in the exact spot needed, all working cooperatively to cover the area and fill in gaps. Swarms could also be more effective in difficult rescue missions. RoboBee project is developing tiny drones smaller than a paper clip and weighing a tenth of a gram. Thousands of RoboBees could be used for weather monitoring, surveillance – or even crop pollination as the number of honey bees declines.⁴⁰
- Nano drones. The recent trend in the evolution of drones is their miniaturization. Nano drones are the smallest and they usually have the same dimensions as insects. They are usually more durable and cheaper than other conventional quadcopters and drones due to their technical simplicity.
- Delivery drones. It is highly probable, assuming that necessary regulations will be introduced, that drones will be used as a means of package transport. At this moment, Amazon is testing their Amazon Prime Air service. This means that when you order a package, it will be delivered to you in less than 30 minutes, instead of a few days.
- Public transport. However futuristic it may sound, drones are becoming vehicles for transporting people. There are companies, that have already developed effective solutions. Chinese UAV company Ehang showcased its rapid transport solution — the Ehang 184, which can carry one person weighing up to 100kg and cover 30 — 50kms from a single charge.

At this moment, UAVs and other technologies related to Industry 4.0 are growing at such a fast pace, that their potential applications are becoming hard to follow, and we cannot be sure what other ground breaking innovations or discoveries will bring to the subject. However, we can be sure of one thing, that these technologies do create massive business opportunities, you just need to get prepared for them.

⁴⁰ <http://www.bbc.com/future/story/20170425-were-entering-the-next-era-of-drones>

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Project partners

Ludor Engineering
(Project Coordinator)

Iasi, Romania



CAMIS Centre

Bucharest, Romania



Danmar Computers

Rzeszów, Poland



Istituto per la Formazione,
l'Occupazione e la
Mobilità

Bologna, Italy



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