
# D1.3
## DELIVERABLE

# Final Public Report

AiRT


# FINAL PUBLIC REPORT

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| **Coordinator** | Virginia Santamarina (Universitat Politècnica de València) |
| **Author** | Virginia Santamarina, María de Miguel y Blanca de Miguel (Universitat Politècnica de València) |
| **Design and layout** | Virginia Santamarina (Universitat Politècnica de València) |
| **Figures** | Virginia Santamarina (Universitat Politècnica de València) |
| **Photography** | Greta Zabulyte and Megan Hoang (Clearhead) |
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# 1 EXECUTIVE SUMMARY

This document summarises The AiRT project's results, achieved jointly by all partners in the last 24 months. Significant innovative progress has been made in this short period of time. The far-reaching effects on the drone manufacturing industry as a whole, as well as in the cultural and creative industries (CCIs), will likely only be precisely quantified in the coming years. This is primarily due to the fact that the innovative integrated indoor positioning system not only brings advantages to the CCIs, but will certainly inspire other industries in the future that will adapt this innovative product to their specific needs (Figure 1). Overall, however, we hope that the AiRT project has drawn attention to the needs of the CCIs, especially for SMEs, so that they will be able to strengthen their economic position within the EU through the solution we offer.


Fig1. Final demonstration at the ICT 2018 Exhibition in Vienna. Source: AiRT project..

# 02. SUMMARY AND OVERALL OBJECTIVES

Nowadays, Aerial filming and photography are indispensable resources for the Creative Industries (CIs) since they expand their creative possibilities. The options for filming special shots from different angles and heights arise as a competitive advantage for them. For example, film directors like tilting or panning in movies when filming actors stepping out of a car, or leaving a building. Until now, for shots like these, helicopters needed to be rented which resulted in high costs and only financially sound companies could afford them. Or, if the scene didn't require high angle shots but just a shot from a moderate height, scaffolding, jibs or lifting platforms were usually hired or bought. With the rise of the drone industry and the resulting drop of acquisition costs for those "flying robots", the Creative Industries are employing more and more drones for aerial filming. This is quite easy to understand, since

a) Costs are affordable

b) Bulky infrastructure can be removed (scaffolding, jibs, cable cam,…)

c) Drones are less invasive (they just fly out of the set and are removed)

d) Drones lower the risks for the camera operator (no need to climb up a scaffold, lifting platform,…)

However, professional drone use by CCIs is limited to outdoor applications.

Why are they not used indoors? Because existing drones lack a precise, robust and affordable indoor positioning system (IPS), as well as advanced safety features. Everyone who has flown a drone understands why positioning systems are so important for drone flights. When filming outdoors, drones use a GPS, which not only helps the operator to locate the drone and to program flight paths, but also to stabilise the drone while avoiding drifting issues. This is an important factor for camera operators, but GPS localisation does not work indoors. Firstly, the signal is too subdued, and secondly, even if it were not so, the GPS's precision is far too inaccurate with a meter range margin of error. Be that as it may, CCIs would also like to use drones indoors. Unfortunately, there is not safe and affordable technology available for the CCIs to do so. The technologies available to work in confined spaces are the following:

1) The motion capture system, that has a very reliable and precise (mm-range) IPS. However, this system is very expensive (>200,000 euros) and it needs several auxiliary devices, which as a result makes setting up time consuming.

2) The vision position system, which is affordable. However, how it functions depends on its surroundings. For instance, on transparent or reflective surfaces the device might malfunction. Moreover, localisation is just in z-axis and with a maximum altitude of 2.5m.

To overcome these issues, within the AiRT project, we have developed a drone which includes a new indoor positioning system with cm range precision and an intelligent flight control system. Additionally, the integration of active and passive safety measures guarantees safe and user-friendly experiences for the drone operator. Also, an important consideration should be made to the time needed for assembling and disassembling the filming set, which can be dramatically reduced. Data obtained from the performed demonstrations tests showed results of "ready to fly settings" of 20 minutes and just 10 minutes for disassembling. Another interesting feature of this innovative project is that self-calibration is included, which also reduces time needed for setting-up the filming set.

The professional camera control will make the AiRT drone an attractive tool (Figure 2), especially for the Creative Industries.

This product, with its innovative features, will allow most of small and medium-sized companies to provide new services which, in turn, will increase their chances to grow within the European and international market.

Fig.2. Detail of the use of AiRT software by experts. Source: AiRT project..

# 3 WORK PERFORMED AND RESULTS ACHIEVED

Four interconnected phases have been developed in our approach to transfer the AiRT system to the creative industries in an efficient way (Figure 3):

a) Identification of needs

b) Adaptation and optimisation of different technologies

c) Integration and validation of the system

d) Evaluation and demonstration of the system

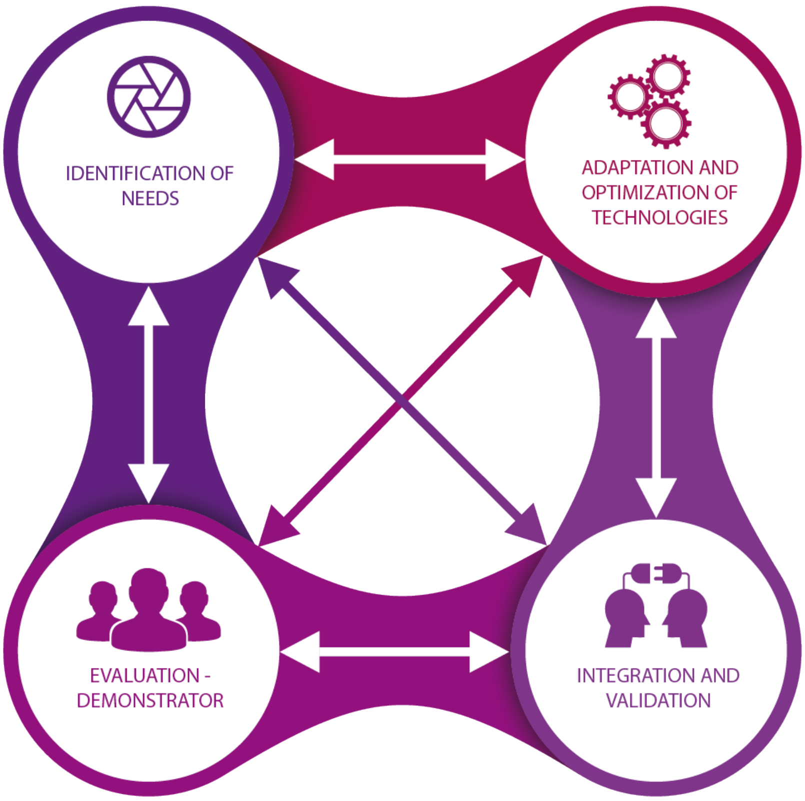



Fig. 3. Approach of AiRT in four phases. Source: Own elaboration.

At the same time, our methodology is end-user centred with the goal of using technological innovation to provide feasible solutions to the Creative Industries. To do it, this technique relies on three fundamental pillars (Figure 4):

- Empathise with creative industries to understand their problems and requirements.

- Generate collaborative activities with end-users. Feedback from all the different stakeholders will be considered for incorporation.

- Prototype development validated by end-users. The evaluation may lead to improvements before producing the final product.

After identifying these three pillars, we applied the design thinking methodology (Rowe, 1991, Both, 2009, Dorst, 2011), where the participation of the CCIs is present throughout the process (Figure 5), to AiRT's project.

This resulted in five interrelated phases in which the end user is always involved:

1. Empathise
2. Define
3. Ideate
4. Prototype
5. Test

In the first phase three focus groups (Liamputtong, 2011) were held in three different countries -Spain, the UK and Belgium- to identify customers' needs. From these meetings, we were able to obtain information from thirteen different sectors of the CCIs.

Informants (experts) were chosen strategically from 13 different sectors to guarantee that all the Creative Industry's needs are detected, including experienced drone pilots working in different CCI sectors (40% of the informants). The Photography sector was the most numerous (21% of the total), followed by Movie and Advertising (19%), being these three sectors the most directly related to the industries that are currently leading the use of drones.

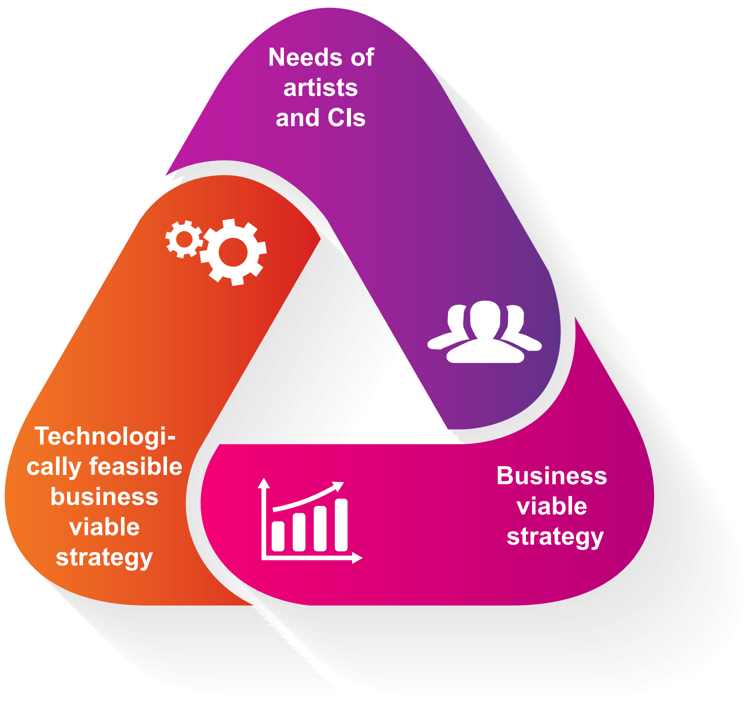



Fig. 4. The three pillars. Requirements to be satisfied in AiRT project methodology. Source: own elaboration.

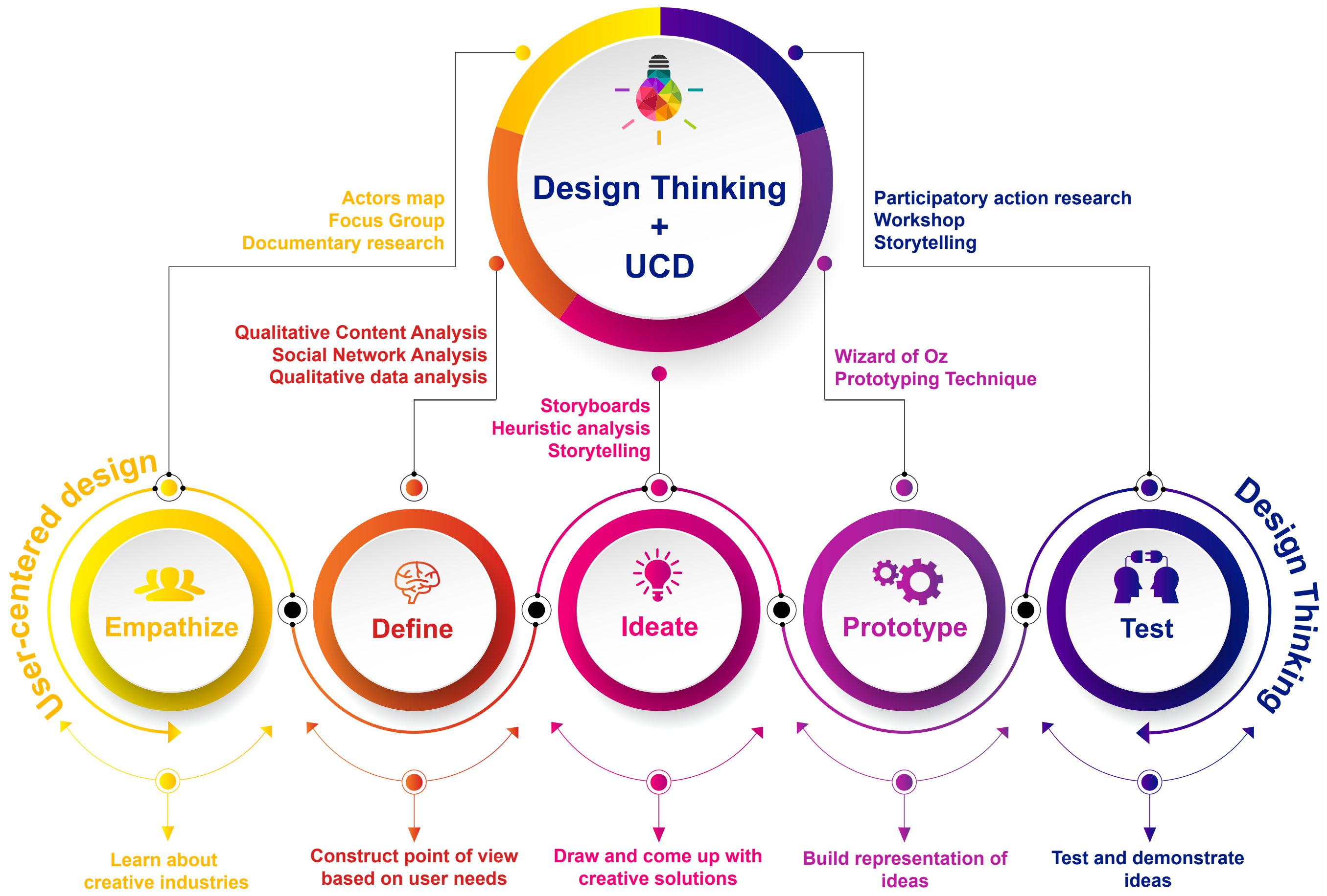
From the analysis of the information gathered in these sessions, we obtained the needs, the ethical issues and the risk analysis. Results from focus groups were obtained by using a Qualitative Content Analysis method. Qualitative data was obtained through the analysis of interviews of participants in focus groups, which were recorded and transcribed. The software QDA Miner (Provalis Research) was used to undertake the analysis and all the information in the transcriptions was codified. Codes were organized in relation to the predefined questions, trying to guide the focus group participants' answers to these questions.

Additional codes were defined to cover information that was also considered to be important and, moreover, strategies for the commercialisation phase. That is why results from focus groups have been incorporated in the basic design of the drone, the development of the European Policy book and the redefinition of the exploitation plan.

In the Third phase, from the synthesis of the information obtained in the focus groups, we wrote a script and a breakdown of that script which were used to apply the storyboard method (Van der Lelie, 2006), representing the use of the AiRT system in different creative settings, which allowed us to convey our main ideas more clearly by applying scientific knowledge to a real environment (Maguire, 2001).

On the other hand, by using the storyboard, we were able to extract the requirements to define the functionalities of the AiRT system, which will include the Ground

Fig. 5. Design thinking method applied to AiRT Project. Source: Own elaboration based on Both (2009).



Control Station (GCS) software, the intelligent flight control system and the final design of the drone.

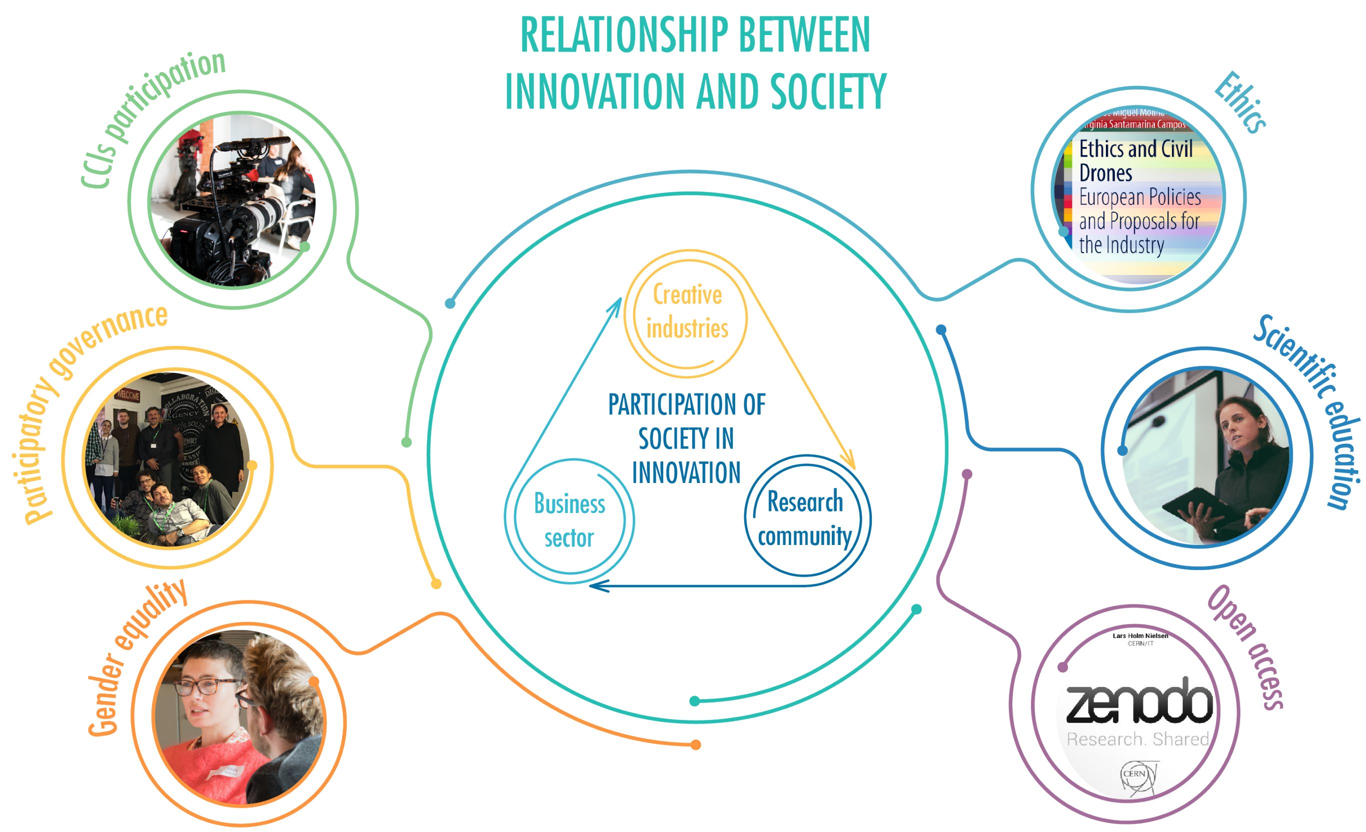
The main focus of the fourth phase was on the integration process. All of the components of the AiRT system have been tested and efforts were devoted to the system integration and technical validation.

In the last phase, we did the demonstration of the AiRT system with the collaboration of the CCIs. Through the use of PAR, Participation action research (Whyte, 1991), we carried out the demonstration in real environments chosen by the users.

Finally, after the demonstration, we presented the AiRT system at the workshop celebrated in Valencia in June 2018, and at the ICT2018 event in Vienna in December 2018, not only to the CCIs but also to other sectors of the industry. The different research methodologies, problems and solutions, future benefits and applications, main features of the innovative product were explained and also a demonstration was developed to show the objectives achieved by the AiRT team.

As a conclusion, the methodology used has allowed to carry out a responsible innovation process (Figure 6), in which the creative industries, the business sector and the research community have participated together throughout the project process. Open access to the results obtained, gender equality tried to be achieved in all the activities, scientific education through the dissemination of results, the definition of ethics in the area of drones and participatory governance have been pursued.

Fig. 6. Responsible research and innovation applied to AiRT Project. Source: Own elaboration.



# 4 PROGRESS BEYOND THE STATE OF THE ART

Four major technical innovations have to be highlighted in the AiRT Project (Figure 7):

**1) The RPAS itself, since it**

a) Is especially designed for professional indoor use by CCIs with passive and active safety measures.

b) Integrates a user-friendly fully automated flight control system.

c) Integrates an IPS based on Ultra-wideband technology (UWB) and an on board RGB-D camera which allows 3D reconstruction of the space prior to the flights for filming.

d) Integrates a new flight mode system. We have designed in total 9 flight modes providing users with different degrees of freedom, from totally manual flight to totally autonomous flight, and a number of intermediate flight modes with configurable restrictions.

e) Internal protocol’s communication among components were developed considering secure emissions as the main variables (instead of interoperability or speed, that are the current mainly used protocols).

**2) The IPS**

The positioning system is based on novel UWB wireless radio technology, especially suitable for indoor spaces. The improved hardware solution, adapted to RPAS, incorporates multiple antennas for improved reliability and an alternative source for the orientation, as the magnetometer is typically unreliable indoors. Moreover, an auto-calibration system is introduced. The AiRT project team has been able to implement an algorithm which calculates the auto calibration error of the IPS and detects which anchor(s) are responsible for the encountered error. This helps the user detect error sources and rearrange the anchor setup and thus improves overall accuracy/precision. Moreover, the reduction time for the deployment time of the whole positioning system must also be highlighted.

**3) The 3D mapping software for indoor environments**

The software allows 3D reconstruction of the indoor space (3D model), achieved in real-time from data that it is collected from the RPAS prior to the filming process. The transmission and visualization of the image is in real time. Therefore, the user can move around the captured environment to study in detail the different areas of the scene while it is being scanned.

**4) Multiplexers approach to integrate a number of sensors and systems for managing a complex data flow and providing an adequate decision-making process on operation.**

Two multiplexers devices have been developed and integrated as a key tool to manage RPAS flight and functionalities. The CONTROL Multiplexer receives data from all the sensors (positioning, obstacles…) and communicates with the flying control systems prioritizing orders to comply with the planned paths safely. Meanwhile, the GIMBAL Multiplexer deals with camera and gimbal to provide the designed angles and movements of the camera for filming as the drone is flying the planned path.

Apart from technological innovations, the AiRT system also addresses socially relevant topics, such as helping to suppress risky auxiliary means and thus improving the safety of the workers. Users will not need auxiliary devices which present unnecessary risks to their safety or the safety of the workers on set.

To conclude, AiRT contributes, not only to the economic growth of CCIs, but also to other sectors and thus to European economic prosperity. Therefore, industries will be able to offer new services to their clients, helping them expand within the European market and as a result, employment within CCIs and other sectors will be secured and new jobs created.


Fig. 7. Main technical innovations of the AiRT project. Source: Own elaboration.

# 5 PROGRESS AND ACHIEVEMENTS

To achieve the above-mentioned objective AiRT project relied on the following 7 specific objectives:

**SO1.** Analysis of CCIs needs, ethical/ security issues and risk analysis.

**SO2.** Adaptation of Pozyx's indoor positioning system (IPS) for RPAS.

**SO3.** Graphical user interface of indoor navigation.

**SO4.** Adaptation of RPAS according SO1 (CIs' needs)

**SO5.** Integration and validation.

**SO6.** Demonstration.

**SO7.** Elaboration of a proposal for a European legislation for indoor RPAS safety and security (policy handbook, partially result of SO1)

This subdivision led to the AiRT workplan, which consisted of 7 work packages (WP). In the following sections we describe in more detail the progress and achievements we have made during the project – in relation to each work package (Figure 8).

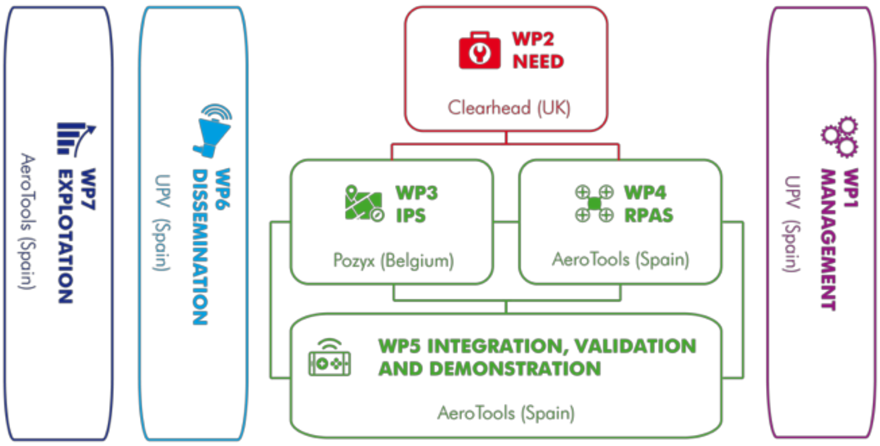



Fig. 8. Work plan of the AiRT project. Source: Own elaboration.

# ☐ Work Package 1

## Project management and coordination

This work package develops activities which have ensured the smooth workflow of all the WPs and their compliance with the overall work plan.

As communication channel between partners the consortium agreed to use the web-based project management tool Basecamp . All relevant documents (deliverables, drafts, minutes, photos, etc.) have been uploaded and made available to each member of the consortium. Moreover, on 31 March 2018 a Quality Plan (QP) was elaborated which played a big part in the success of this project. The measures decided upon helped to:

**a)** Improve internal communication,

**b)** Improve efficiency of the project execution and to

**c)** Reduce response time in case of important issues.

In this work package, the biggest achievement we have had is to accomplish lean management (Figure 9) by establishing open communication even if the consortium is multi-disciplined. We have achieved it thanks to two points.

**The first**, the use of the platform basecamp and,

**The second**, the implementation of collaborative and interdisciplinary work sessions, with partial and weekly deadlines for the final product.

Fig. 9. Lean management of the airt project. Source: Own elaboration.

# Work package 2

## Analysis of CCIs needs, ethical / security issues and risk analysis

In workpackage two, through three focus groups from Spain, the UK and Belgium, we were able to obtain information from thirteen different sectors of the creative industries of which forty per cent were drone pilots (Figures 10-13. As a result, we obtained the needs analysis, the ethical issues and the risk analysis (Figure 14). Furthermore, on one hand, the design of the drone, the GUI interface and the development of advanced functionalities were based on the results. On the other, it was useful for the development of the European policy book and to enrich  the Exploitation plan (Figure 15).

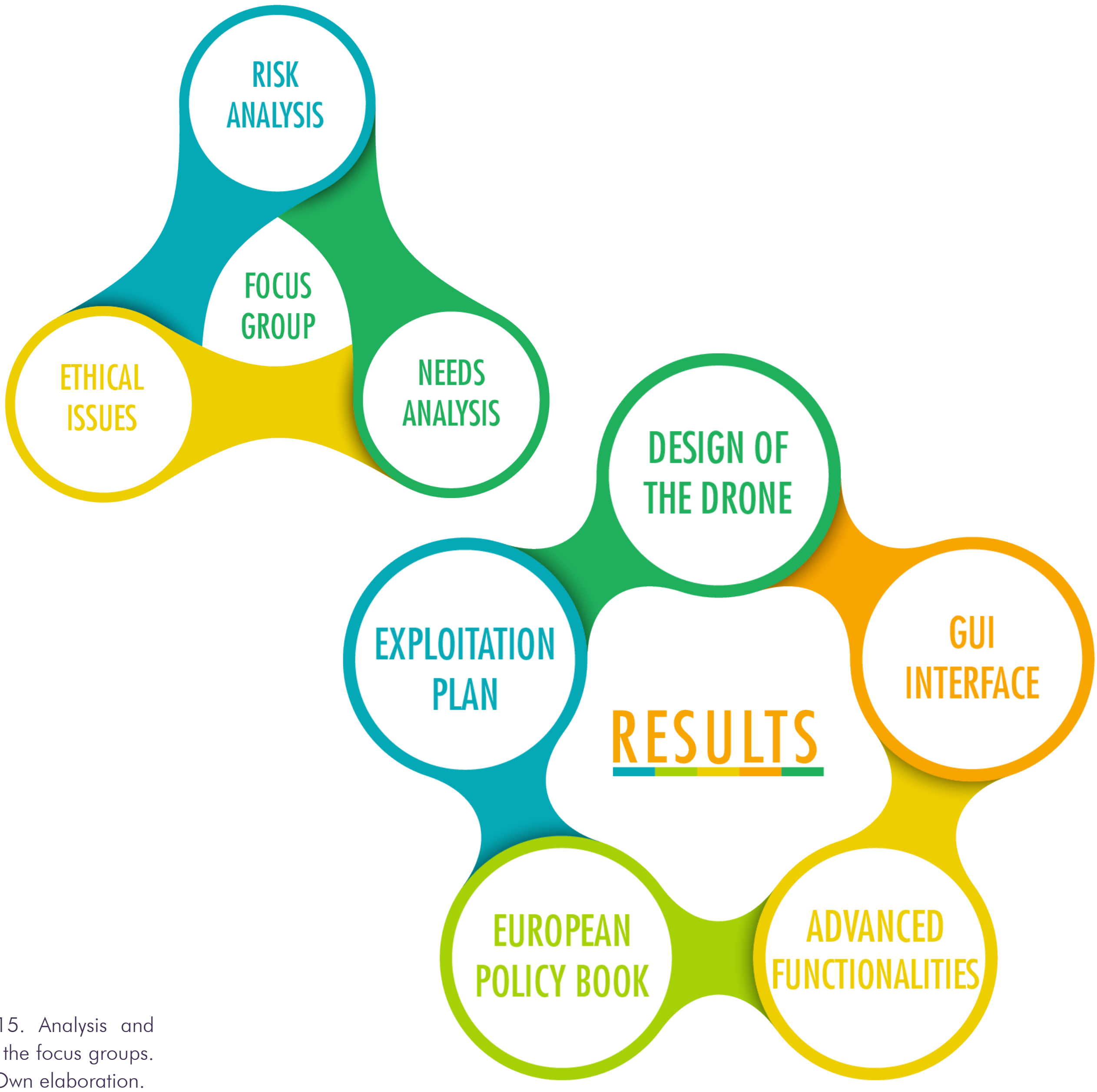



Fig. 14-15. Analysis and results of the focus groups. Source: Own elaboration.

Fig. 10. Participants Focus Group in Luton. Source: AiRT project..

Fig. 11. Participants Focus Group in Valencia Source: AiRT project..

Fig. 12. Participants Focus Group in Ghent. Source: AiRT project..

# ☐ Work package 3

## Analysis of CCIs needs, ethical / security issues and risk analysis

This WP is mainly dedicated to adapt the indoor positioning system (IPS) from Pozyx to the drone. The work done can be divided into three parts:

a) IPS,

b) Communication IPS and drone and

c) 3D mapping.

### The Indoor Positioning System

The Pozyx positioning system was adapted for use on drones. In an indoor environment, the drone cannot rely on the position from GPS, nor the heading provided by a digital compass due to the abundance of metal. Both this information is required for autonomous flights. The adapted IPS addresses both issues, with the focus on providing accurate and reliable data.

The adapted drone positioning system consists of a central processing unit connected to four ultra-wideband (UWB) units to be mounted on the corners of the drone. The four UWB units consist of a small wireless transceiver and an antenna.

To make optimal use of the novel hardware, a specialized positioning algorithm was developed.

For the validation of the algorithm, a comparison with GPS was made in an outdoor environment on a scale of 20m x 20m.

Finally, an improved system for automatic calibration of the IPS was developed to automatically determine the positions of the IPS infrastructure (Figure 16).

### The IPS <-> Drone

For the development of WP3, main task assigned to AeroTools has been to provide technical support to Pozyx in several aspects, such as:

- Communication between IPS and RPAS, defining the communication protocol with the FCS.

- Providing support and performing functioning tests of the IPS in RPAS environment (how electromagnetic noise generated by motors can affect the system, turbulences, etc.).

- Mechanical requirements of the tags to a better adaptation to the RPAS.

- Increasing stability and robustness of position signal provided by IPS.

- To define orientation (yaw) requirements for a proper operation of the RPAS, as well as performing evaluation tests and optimization.

- Integrating communication protocol between IPS and RPAS.

- Performing tests to identify bugs, running problems, improvement of precision, stability and operational approach of the IPS.

The support has been provided in the form of both technical knowledge and material resources and spaces dedicated to perform required tests.

## On-board Control System and Mapping

During the development of the project, the main results achieved by the Universitat Politècnica de València development team have been:

1. The hardware design of an On-board Control System (OCS) suitable to be installed on a RPAS.

2. The design of the high-level software architecture of the OCS/GCS

3. The design of an offline update procedure of the OCS

4. The design and implementation of a multiplatform software for a Ground Control System (GCS) to allow the users to command the RPAS remotely via the OCS and receive and display telemetry information from the drone in the GCS.

5. The design of the communication protocol to transfer the commands from the GCS to the OCS.

6. The design and implementation of a mapping system

7. The implementation, troubleshooting and refining of the communication protocol (designed and defined by Aerotools) to transfer the commands from the OCS to the FCS and to receive the information generated by the FCS.

8. The implementation, troubleshooting and refining of the communication protocol (designed and defined by Aerotools) to transfer the commands from the OCS to the Gimbal controller.

9. The implementation of the communication protocols (defined by the recording camera manufacturer) to transfer the commands from the OCS to the Camera controller.

10. The implementation, troubleshooting and refining of the communication protocol (defined by Pozyx) to transfer the IPS information from IPS to the OCS, and to calibrate the IPS from the GCS.

11. Secure the transmissions between the OCS and the GCS.

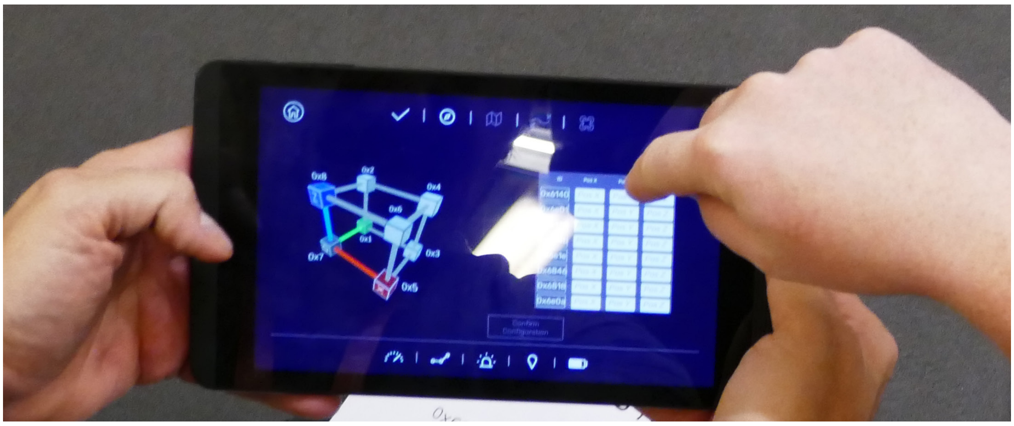


Fig. 16. Detail of the automatic calibration of the IPS in AiRT Software. Source: AiRT project.

# ☐ Work package 4

## RPAS Design and optimization

The main goal of the WP4 was the definition and manufacturing of a flexible flying platform that meets the needs of the Creative Industries (end-users), set by the focus groups. The final design considered parameters like weight, easy to deploy, flexible platform capable of allocating a complex electronic architecture and outstanding performer drone. Based on information from the focus group activities, the following 5 identified central topics were taken into account in the design specifications: (easy and safe) navigation, (high quality) filming, safety, usability and price.

Given the complexity of the task, set two separates lines of development for the prototypes:

- Line 1 for DEMO DRONE (Demonstrator), the prototype to be used in the final demonstrations integrating all the systems as well as any improvement made during the process from Month 2 to Month 17 of the project, a long period with many changes occurring when using emerging technologies in order to have an updated Drone.

- Line 2 for DUMMY DRONES (Testing), smaller prototypes that have allowed to work specifically in each single system or technical component in development, as for instance, the IPS, the Control Multiplexor, the OCS, the Distance Sensors or the Gimbal Multiplexor. They have also allowed to progressivelly increase loads and number of sensors working together in a coordinated way. With these downscaled drones, every change of configuration, test, movement or action have been very easy, agile and optimal for the project.

The dummy drone helped to perform many quick tests that were particularly advantageous in the integration process. The knowledge gained from this drone was then applied to the demo drone.

The two separated lines of development contributed decisively to reach a high percentage of the goals of the Project. Line 1 allowed to optimize the DEMO DRONE in areas such as:

- Housing for electronics.

- Reduction in weight of all the components.

- Size and shape of ducts to reduce their impact in motors thrust.

- Repositioning and optimization of the configuration of electronics boards inside the central housing of the structure.

At the same time, Line 2 gave the possibility to test every new system in an isolated situation, in order to check correct functioning or propose modifications in case the system did not work correctly, as well as proposing optimization when possible.

### Optimization of prototypes

The process of manufacturing has been linked all the way to a previous analysis of options in every component, as well as optimization routines, due to the challenging combination of features and performance that had been defined.

In the last six months of the project, intense optimization work has been developed to improve performance of the DEMO DRONE. The integration of such range of different systems and electronic boards, each of them designed and developed separately has a significant impact on weight and interferences which is mandatory to reduce at a minimum. Figure 17 shows the current aspect of the DEMO DRONE. The prototype is based on a coaxial chassis with ducts on an outer shell or fairing to provide safety and support to additional systems such as distance sensors, or R-Cam. The whole package has been optimized (from motors & propellers to reduced wiring or lighter materials in specific pieces) in a second iteration. The striking holes in the fairing have been designed and tested to provide better aerodynamic performance as well as reducing weight.

Regarding the RPAS design, some achievements can be highlighted:

- Repositioning and optimization of the configuration of electronics boards inside de central housing of the structure.

- Modularity: The arrangement of housing for electronics, wiring, battery, and remaining components has been designed and optimized in such a way that changes of any part or the addition of new systems are easily implemented.

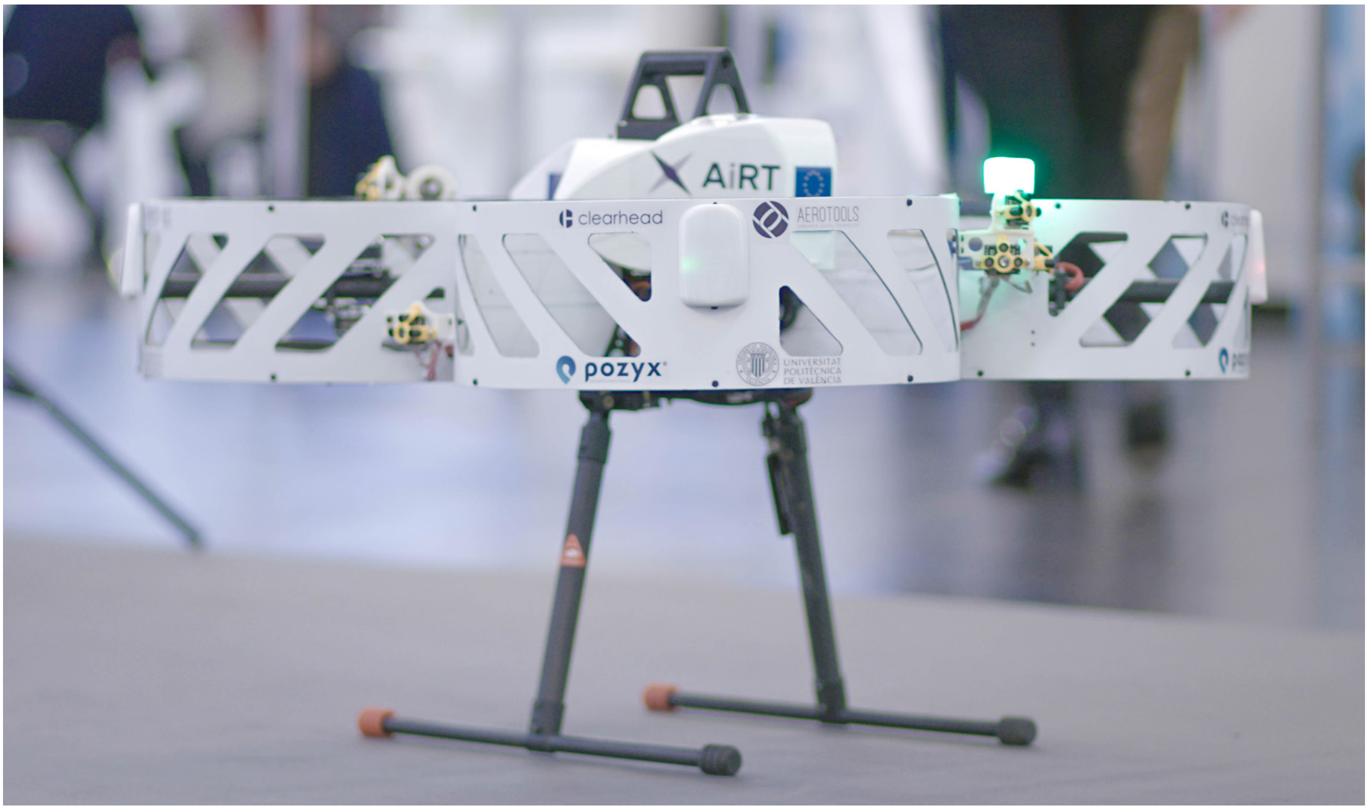
- Size and shape of ducts to reduce their impact in motors thrust: extensive tests in motor test bench were performed to optimize configuration.

- Reduction in weight of all the components: outer shell or ducts made of composite materials; lightening in the carbon plates, etc.

- Camera and gimbal. The camera is mounted on a Gimbal with full 360° movement around vertical axis, having also 2 working positions, at the bottom and at the top of the central structure a feature that is rare to find in most of the drone´s gimbals.

Considering the RPAS design, the AIRT drone is a solid and reliable flying platform, very stable and gentle when moving, as it has demonstrated during the test flights.

Fig. 17. Picture of the final prototype configuration. Source: AiRT project.



# Work package 5

## Integration, validation and demonstration

This WP5 can be divided into 3 main tasks:

a) The GUI (graphical user interface),

b) The integration process and its flight operation tests and,

c) The demonstration

### The GUI

Figure 18 shows the five non-linear phases that have been applied to develop the AiRT software: empathise, define, ideate, prototype and test.

**1st phase. Empathise**: This phase started with the Focus Groups activities in the three participating countries (Spain, UK and Belgium). There, the topic of "software" was included in the discussions.

**2nd phase. Define**: The evaluation of the 1st phase was carried out, using the Qualitative Content Analysis, Social Network Analysis (SNA). This process is known as the define phase.

**3rd phase. Ideate**: In the third phase, based on the synthesis of the information obtained in the Focus groups, written scripts were prepared and then transferred to Storyboards representing the possible functionalities of the GCS software in different creative scenarios. This helped to communicate the main ideas and needs more clearly. This step included also the analysis of available software on the market. In this phase the requirements of the software were defined more precisely, based on simulated real case scenarios (the storyboards).

**4th phase. Prototype**: Once the heuristic evaluation of the flight plan software available in the market was completed, and the design elements extracted from the Storyboards were defined (user interface of the client application), an iterative design process was initiated

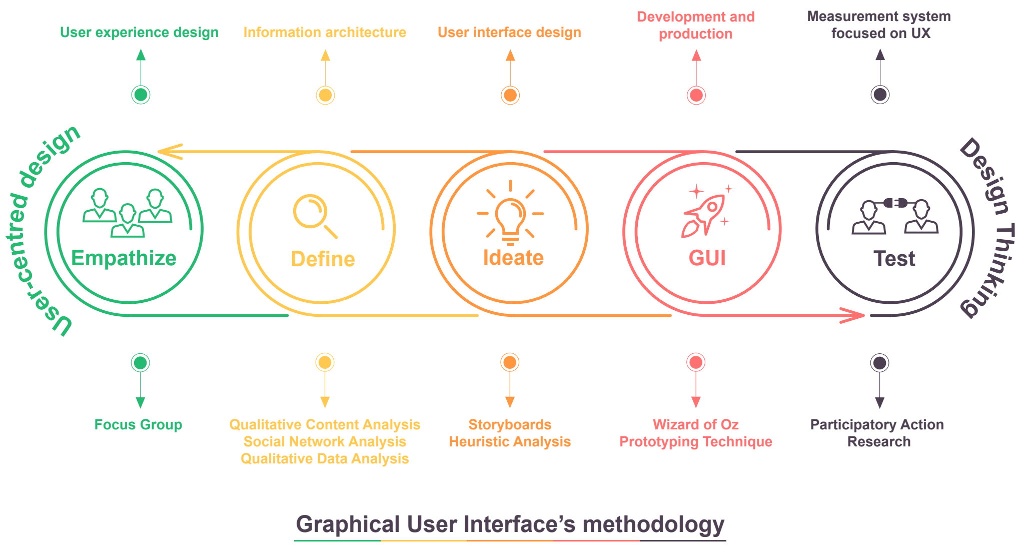



Fig. 18. Methodologies used in the design of the GCS software and GUI. Source: Own elaboration, adapted from (Both 2010).

using the Wizard of Oz Prototyping Technique (Both, 2010). To do this, the models for the GUI were designed, first using paper prototypes as visual language and then the online tool NinjaMok© (Figures 13, 14a and 15b). All these results have been integrated in the final user interface.

**5th phase. Tests**: In this last phase, end users made use of the prototypes, based on the selection of relevant scenarios for the creative industries, in the three participating countries. The objective of this stage was to identify failures or to provide new improvements, through the Participation Action Research tool (PAR). The evaluation of this step helped to identify potential usability issues, and to check compliance with previously established usable design principles.

The results of the UCD are presented in the following sections.

## Design and implementation of a multiplatform Ground Control System (GCS)

The objective of this task, led by UPV, was to develop an application for allowing users to command remotely the RPAS via the OCS and to receive and display telemetry information from the drone.

We designed a new workflow for helping users of the creative industry to design their desired shots within a friendly, easy to use and complete interface. The application has been developed using a framework that allows us to build it for different platforms, mainly Android and Windows.

The AiRT Software GUI is feature complete. It contains all the planned functionality and some new functionality that has arisen during the development. The interactive and autonomous control of both the recording camera and the RPAS itself has been integrated. The GUI allows the end-users to control all parameters of the AiRT system in a simple and intuitive way. The application is divided into four sections, for allowing the user to perform all the tasks available in AiRT:

**1. Configuration**: used for setting the main parameters of the system and for calibrating the IPS. The main responsibility of this section is to provide users with a simple means of interacting with Pozyx's system for setting up the IPS. In order to perform positioning, the IPS needs to define the position of the anchors in the space. The GUI supports both: manual calibration and auto calibration.

**2. Mapping**: consists of capturing the environment with a depth camera for providing users with a simple model that will offer a visual reference for designing the flight plans. The goal of the project was to obtain a low-power, real-time capture system for acquiring a simplified model of the location where the final shooting will take place. Our system is capable of acquiring point clouds during the flight, and of forwarding the information to the GCS GUI. The user can see in real time the scene as it is being captured. It is also able to direct the acquisition, by pausing/resuming the capture at any moment, and by discarding point clouds that are not properly captured.

**3. Planning**. In this section, the user designs the different flight plans that will be flown during the recording session. This stage is the only of the four that does not require a direct connection with the drone. The user can create the flight plan without being physically close to the drone and into the recording environment. The GUI supports three types of maps: point clouds captured during the mapping session, a 3D model stored in a file and a 3D volume whose size is defined by the user. The latter option allows her to quickly design simple flight plans without requiring a 3D model of the space. Flight plans are designed using a simple graphical interface that allows the user to define trajectories by placing waypoints. A waypoint is a point in the scene that the drone will traverse during the automatic flight. The GUI also provides a means for setting the orientation of the gimbal (and, therefore, the framing of the recording camera) and for setting the recording camera parameters (attributes like white balance, brightness, etc.) and actions (such as taking a picture or starting and stopping video recording).

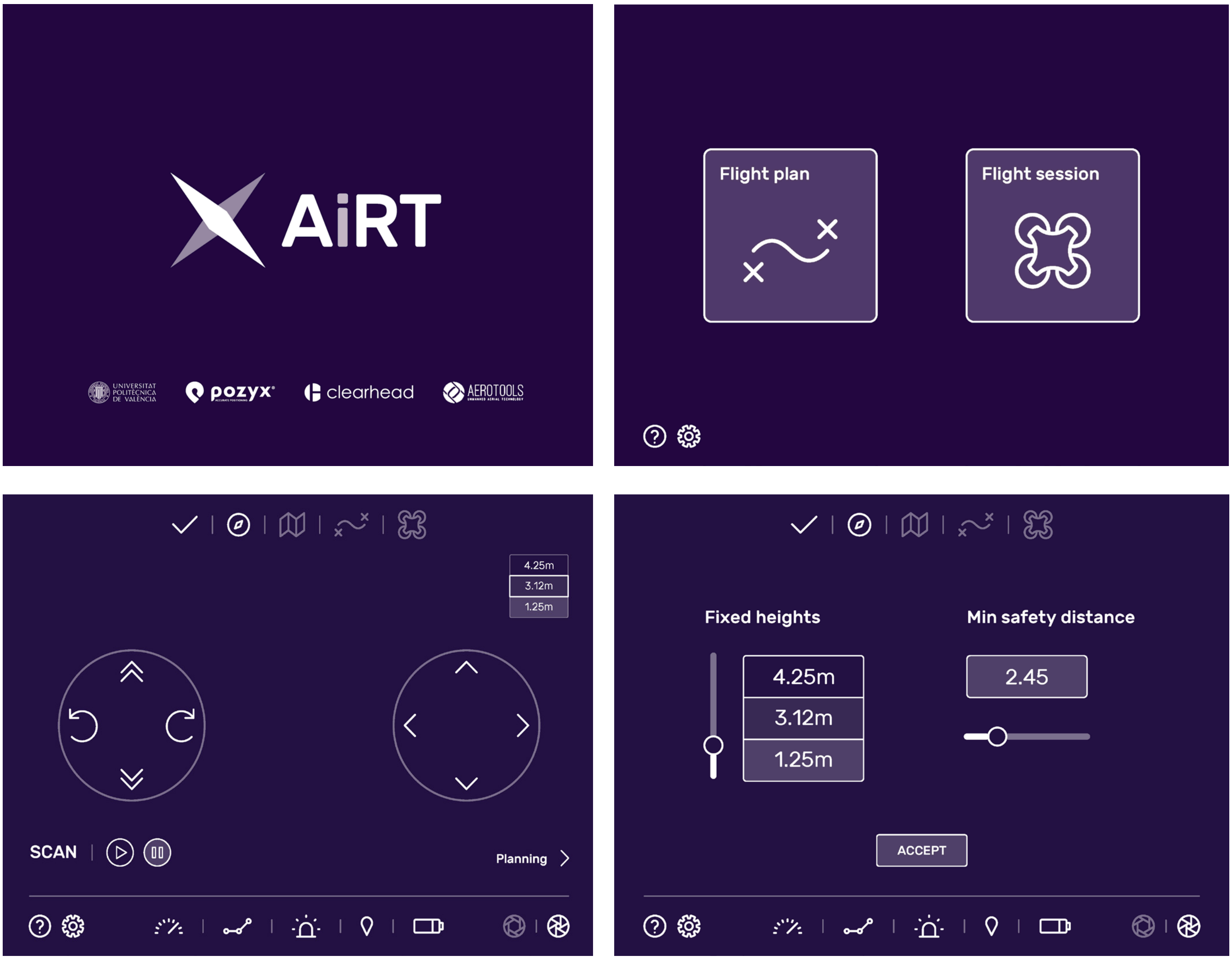
**4. Recording**. This section of the GUI is in charge of interacting with the drone to perform the final flight for recording. Images captured by the recording camera will be displayed on a dedicated tablet outside of the GCS. This section of the application takes care of the three flight plans that have to be executed in sync: one for the drone trajectory, another one for camera framing and the last one for the operation of the camera. The flight plan, designed in the previous section, is sent as a list of waypoints to the Flight Control System of the drone, who is responsible of controlling the avionics. The gimbal and camera plans are executed by the OCS.

The following sections show some screenshots of each of the four sections (Figures 19-22). The detailed instructions for using the application are available in the User Manual.(zenodo.org/communities/airt_project).

## Integration process of the different components and flight tests

Fig. 19-22. Detail of some AiRT Software windows- Source: AiRT project.

Although many of the Advanced Functionalities were already working correctly, such as the distance sensors or the safety elements, or the camera & gimbal control, the integration stage



affects the whole drone and systems. Therefore, the process and workload in integration and optimization had to be carried out very carefully.

In the last stage of the project, the IPS was tightly integrated with the onboard autopilot in order to achieve autonomous flight. More specifically, the internal EKF tracking and PID controllers of the autopilot were fine-tuned to utilize the new range of sensor data coming from the IPS.

Here are the prototype related achievements:

- Integration of COTS elements in an aerial platform meeting challenging requirements.

- Modularity of platform and systems to enable working simultaneously in different elements (flying control electronic, weight optimization, positioning, camera operation, gimbal,…) as well as the integration of all the systems.

- Handling procedures and systems to provide easy operation.

- Integration of safety measures while keeping performance as high as possible

- Meeting a number of CCI´s needs, such as:

- Camera operating in 360º turn.

- 4k camera with interchangeable lenses (optional and upgrading)

- Remote Control of the camera

- Integration of sensors

- Safety

- Moderate price

During the development of the drone several innovations must be highlighted, such as:

- A protocol oriented to a safety automatic flight that allows system to change between manual and automatic flight.

- A modular design and integration of a variety of systems and sensors.

- A Control Multiplexor as a central system that coordinates the OCS with the rest of the electronic areas, like the FCS, sensors, cameras, IPS…

- A camera and gimbal with outstanding performance:

- Free 360º turn

- Interchangeable lenses

- Remote control of both, camera parameters and function, and gimbal.

## Demonstration

In this task, end-users tested the prototype, based on the selection of a relevant scenario for the creative industries, the Science Museum designed by the Spanish architect Santiago Calatrava, which is located in the City of Arts and Sciences (CAC).

The objective of this stage was to identify failures and to provide new improvements through the PAR tool (Whyte, 1991) (Figura 23). The PAR was divided into two phases. In the first phase, two user tests were developed, one for the user guide (Figure 24) and another for the prototype. Also, the heuristic evaluation of the AiRT system was carried out with the aim of identifying potential usability problems, checking for compliance with previously established good design principles (Von Hippel and Tyre, 1995; Kemmis et al., 2013). The PAR methodology allowed us to evaluate the software (Figure 25) and the system (Figure 26).

Results for the software indicated that some elements needed to be improved, for example, the support offered in the help link and the information given about the remaining time until a task is completed.

The aim of this tool was to integrate three basic aspects in the dynamics: participation (democratic participation of the CCIs), action (engagement with experience), and research (soundness in thought and the growth of knowledge).

After the usability test, twelve basic tasks were carried out for the control and management of the AiRT system in the process of filming in an interior space. In these tasks, experts and developers worked collaboratively. This second stage was very enriching, as the developers were able to identify improvements and even to discover some new development opportunities. Once this stage was finished, a second test was carried out in which the experts provided many situations in which the drone could work indoors. However, they specified some improvements related to helping the user to understand more quickly how to use the system. After considering all our analyses, we can conclude that some of the improvements said by the experts were considered when the business model was defined.

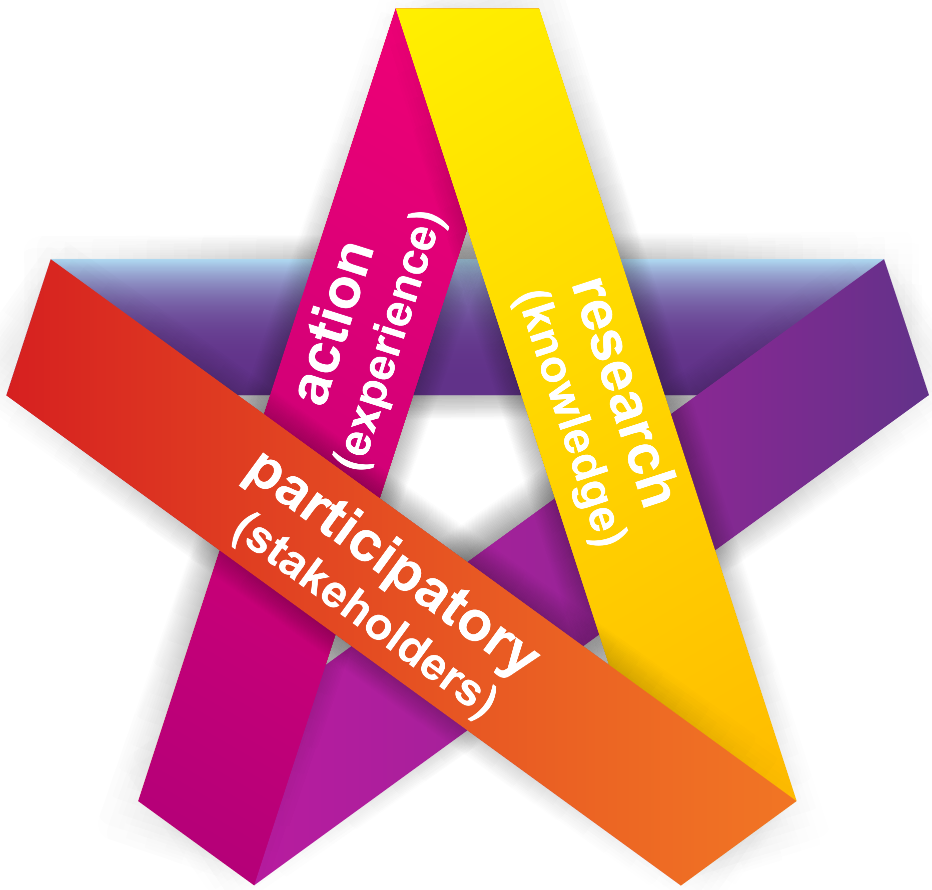



Figure 23. Participation, Action, and Research interoperation generates PAR methodology. Source: own elaboration.

Fig. 24. Detail of the lollipop icons (obverse). Source: AiRT project.


Fig. 25. Detail of the use of AiRT software by experts. Source: AiRT project.

Fig. 26. Detail of the second phase of the dynamics, in which different activities involved in the handling of the demo drone were carried out. Source: AiRT project.

# ☐ Work package 6

## Dissemination of project results

A Project communication and dissemination plan was designed in order to provide practical advice for all participating parties on how to communicate, disseminate and engage with stakeholders committed with the community. Three main topics were elaborated: Website (http://airt.eu), social media and internal/ external communication. Moreover, different types of communication material and its purpose/ target audience were produced. Simultaneously, a report on monitoring and evaluation of communication and dissemination activities was elaborated, clarifying the programme objectives and analysing whether the intended results were achieved or not. To do so, AiRT followed for both dissemination and communication strategies the 'recall' approach which relies on a 6-step model (Figure 27).

The goal of the dissemination activities was to draw people's attention to the AiRT project and Horizon 2020 funding. This was achieved on one hand by a PCPD especially tailored for the different stakeholders, dissemination material and templates, and a communication material report. At the same time, the results were presented to the various stakeholders throughout the project. The overall results of the dissemination are very positive. We have reached and even surpassed our goals.

**(1) Scientific publications**. 20 publications. Our goal was to obtain 10 papers and, in this sense, we have duplicated the objective. At present, 12 of them are published and the rest are in press. All of them are/will be gold or green open access. Moreover, we have grouped all our results in two books edited by Springer in open access. In the first one, and according to Springer metrics (December 2018), we have got 14,000 downloads. In the second book we obtained 9,100 downloads.

**(2) Social networks**. The communication channels of the social networks established in the Communication Plan were Facebook, Twitter, Instagram and Linkedin. These channels were expanded and customized to obtain a greater impact and reach other types of audiences, in this way, for the general public communication was worked through Facebook, Twitter, Instagram and Youtube, for the professional public we focus on Linkedin and Vimeo, and for researchers and academics Researchgate and Zenodo. The result obtained after two years of work, has been of great impact, exceeding in most of the channels the objectives set out in the communication plan. Among the objectives exceeded we can highlight:

- Facebook 1,175 Likes

- Twitter 113,800 Impressions

- Instagram 3,995 Likes

**(3) Press**. Our initial plan was to publish around 10 news articles about the AiRT project. Finally, we published 36, which is three times the number expected. We have also participated in other events such as fairs (Belgium, Germany and Spain), exhibitions such as NEM (Madrid) and ICT 2018 (Vienna), and other workshops by invitation, that have been disseminated through their own channels.

**(4) Website**. We have used our website to disseminate as much information of the project as possible, such as the newsletters or the workshop, among others. In these twenty-four months, we have got around 13,800 visits. The UPV has also disseminated some of our activities, specifically the workshop, through its databases.

**(5) Videos**. We have produced eight videos. Three of them were about the focus groups. Other two were videos showed the project, being one focused on the consortium and the other three on demos, workshop and Vienna exhibition.


Fig. 27. 'Recall' procedure, applied for both communication and dissemination monitoring and evaluation. Source: Own elaboration based on Kusek and Rist, (2004).

# ☐ Work package 7

## Exploitation strategy

This WP had two main goals:

1. To give a tool to the CCI SMEs which might help them to grow within the European and international market.

2. To make research data generated by selected Horizon 2020 projects accessible with as few restrictions as possible, while at the same time protecting sensitive data from inappropriate access.

Here, too, the design thinking method was applied (Figure 28). As a consequence, AiRT developed a Business Strategy Plan (BSP), including IPR strategy and agreement and Data Management Plan (DMP). The BSP was based on the Canvas Business Model (Figure 29) approach by Osterwalder and Pigneur (2010), analysing:

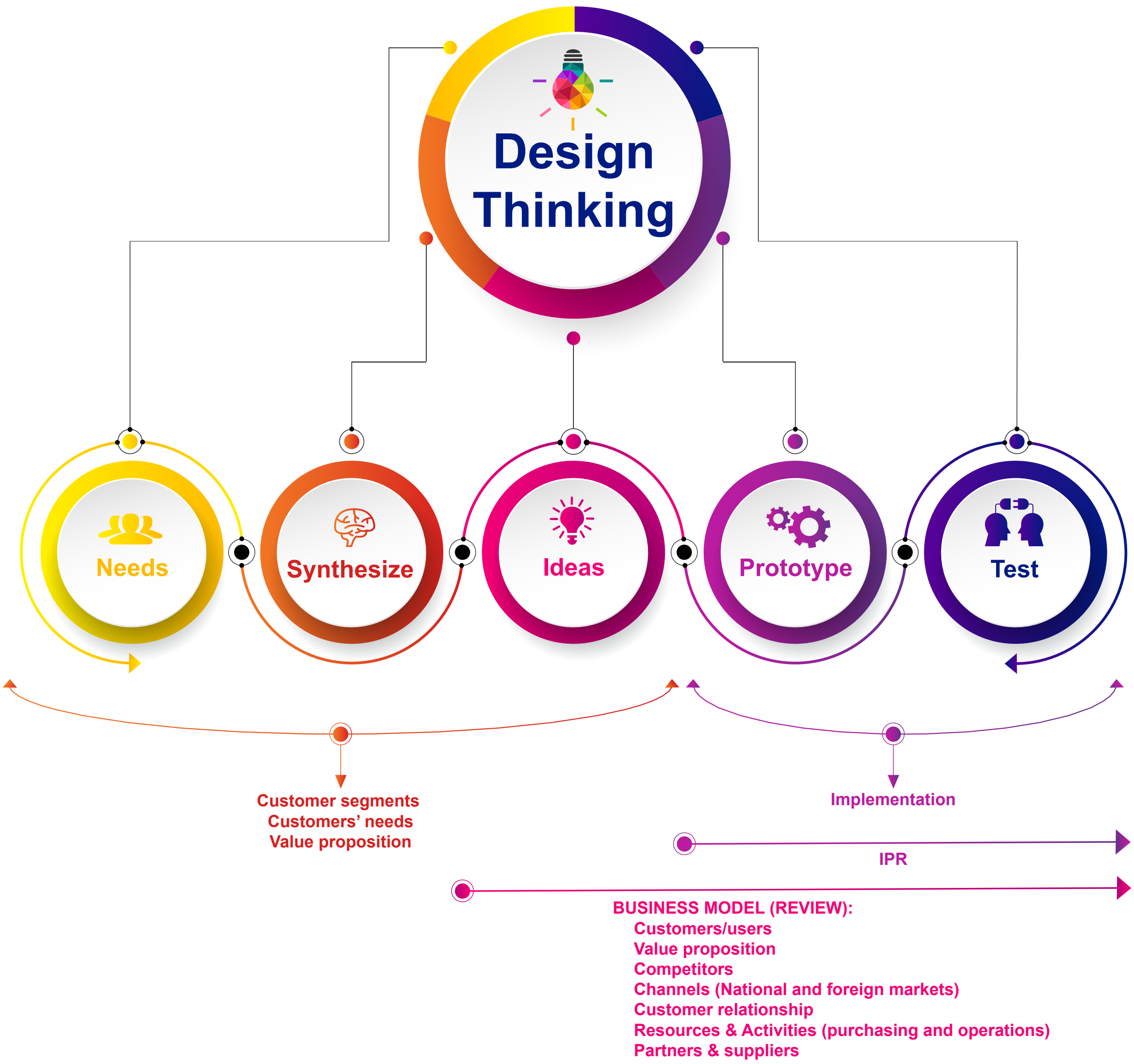



Fig. 28. Review process for the business model based on the Design Thinking methodology. Source: Own elaboration.

a) Customer segments

b) Value proposition

c) Channels

d) Customers relationship

e) Key resources and activities

f) Key partners and suppliers

g) Sources of incomes

i) Costs

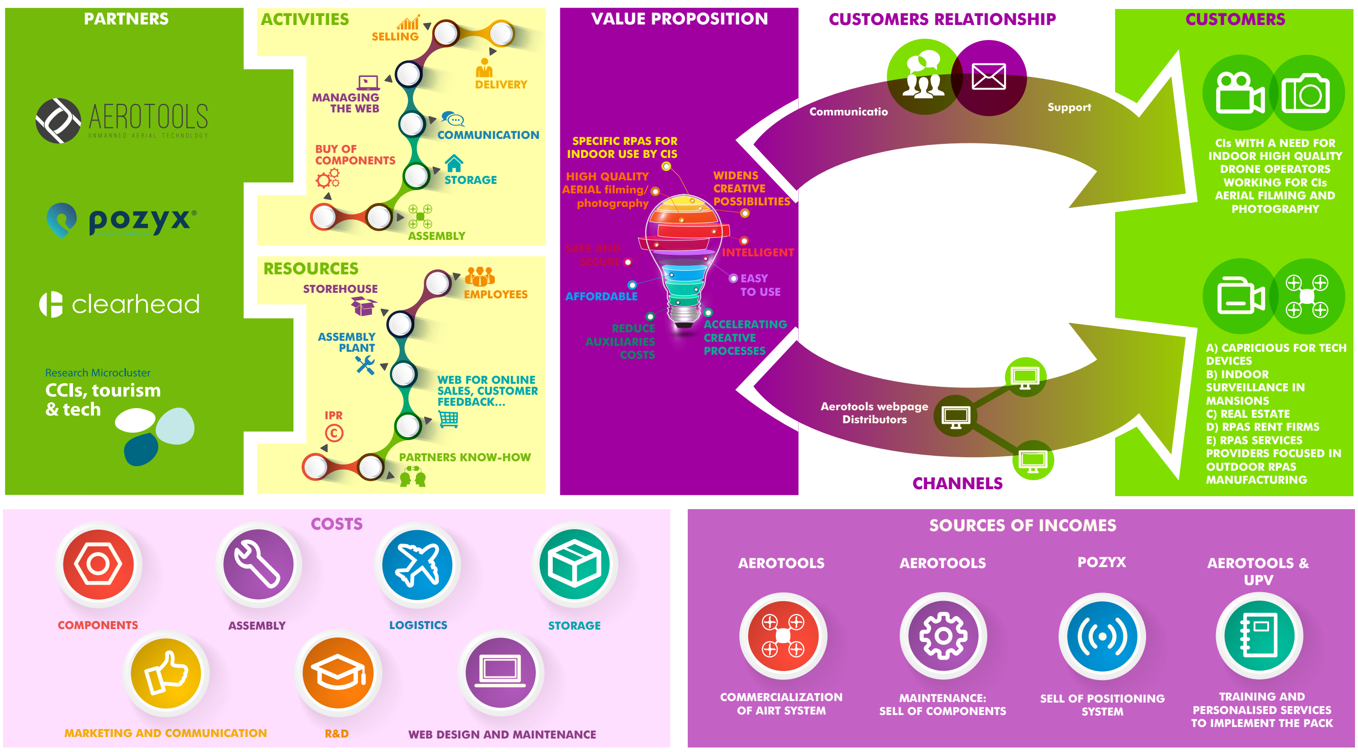
On the other hand, the Data Management Plan (DMP) has been elaborated according to the Open Research Data Pilot (ORPD) recommendations:

- https://www.openaire.eu/opendatapilot

- http://ec.europa.eu/research/participants/data/ref/h2020/grants_manual/hi/oa_pilot/h2020-hi-oa-data-mgt_en.pdf

The AiRT ORPD explains what are the data that will be disseminated as open access, how these data will be made FAIR and how the project will cover costs related to it. Moreover, it shows how the selected repositories by the consortium assure data security and how ethical aspects related to the use of information are treated.

Fig. 29. Canvas Business Model of the AiRT project. Source: Own elaboration.



# 6 CONCLUSIONS

The first conclusion we can draw is that the application of the Design thinking method for the AiRT project can be considered as a successful approach. This methodology has allowed us to carry out an innovation process in which the creative industries, the business sector, the research community, the education sector and government institutions have participated jointly throughout the project.

We have sought open access to the results obtained, gender equality in all the activities carried out, scientific education through the dissemination of results and the involvement of primary and secondary school students, the definition of ethics in the area of drones and participatory governance (Figure 88).


Fig. 30. Actors participating in the process of research and responsible innovation. Source: Own elaboration.

The AiRT project has made possible to create a drone with the cultural and creative industry and for the benefit of it, facing the enormous challenges of this sector, and generating responsible practices in innovation. The participation of end users has allowed innovation policies to be more acceptable and responsible, improving competitiveness and creativity within the framework of the project. Ethics has been considered in every step as a drive instead of as a restriction for innovation.

The AiRT project has placed special emphasis on openness, transparency, diversity, inclusion and adaptation to changes in European creative industries. It has helped us to redefine our role in the small business sector, and boost the interactions between science and the creative industry. All actors were involved in the innovation process with the aim of obtaining results more appropriate to the needs of this sector (Figure 89).

Overall, it can be stated that the AiRT project was a success. The goals were largely achieved and innovative technologies integrated. In some areas, expectations were even exceeded. For example, in the field of dissemination, it is worth mentioning the impact of scientific publications. In the case of the book "Ethics and Civil Drones, European Policies and Proposals for the Industry", it is among the top downloaded in Law (Figure 90) in the Springer publishing house, with 15.000 downloads. On the other hand, the book "Drones and the Creative Industry. Innovative Strategies for European SMEs" also published by Springer, reached around 10,000 downloads six months after its publication. This publisher is in the fourth position in the Scholarly Publisher Indicators Ranking (RSPI).

We have also checked that our paper "Ethics for civil indoor drones: A qualitative analysis", published in the International Journal of Micro Air Vehicles (in August 2018, as an open access format), is the third most read of the journal. This journal is indexed in the Journal Citation Report.

In the first step of the project, the identification of the needs of the CCIs (focus groups activities) were held successfully and made up the basis for next steps of the project (RPAS design, GUI, future market uptake etc.). In order to enable indoor operation, a novel indoor positioning


Fig. 31. Target audience of the Airt project. Source: Own elaboration.

system was designed and tailored to integrate tightly with the RPAS. More specifically, a multi-antenna system resulted in improved accuracy, reliability and orientation estimation. In the last stage of the project, the integration with the autopilot was completed, enabling the autonomous flight. The innovative integration of a new flight mode system, consisting of different flight modes with different degrees of freedom (from totally manual flight to totally autonomous flight, and a number of intermediate flight modes with configurable restrictions) must be highlighted. Also, the multiplexor approach to improve the safety of the drone during the flight is worth mentioning. Finally, we want to point out that our system was tested first in a relevant space (Science Museum at the City of Arts and Sciences, Valencia). To do so, we applied the PAR method, based on the critical analysis of the AiRT RPAS & software, with the active participation of some CCIs stakeholders. This method combines two processes, to know and to act, involving the CCIs in both of them. The extracted information from the analysis of this activity was used for cycles of product improvements/ optimizations.

It is important to note that the three main developments of the project (drone, IPS and software) can be acquired separately or together, facilitating the diversity of applications. The IPS can be purchased together with the drone, or independently and adapt it to other equipment.

On the other hand, the on-board control of unmanned aerial systems for indoor flight, and the user interface for the design of flight plans (with unmanned aerial vehicles for indoor flight), are free software (FOSS) and open source (FLOSS) licensed, in a way that users can research, modify and improve their design through the availability of their source code. For this reason, both products are available on GitHub, with the aim of expanding the possibilities of adaptability to other equipment or needs, enhancing collaborative work and making accessible to small European companies a tool without cost. In conclusion, the potential market of the software was demonstrated by its impact in Instagram. The number of “likes” that the post received in 24 hours was close to 19,000 (Figure 91).

Another important fact to be highlighted is that the AiRT Project has resulted in growth and


Figure 32. Detail of the information sent by the Springer publishing house.

development for the small companies involved in it. For example, the number of employees in these companies has grown between 44% and 275% in two years. On the other hand, all the companies involved in the project have started new lines of research and innovation linked to the results of the AiRT, with the prospect of presenting new proposals in the EU Research and Innovation programme of Horizon 2020.

Finally, the AiRT team is aware of the essential role of scientific education in responsible research and innovation. On December 2018, they developed and implementated the permanent workshop “Drones” in the Science Museum of the City of Art and Sciences from Valencia (Figure 92). This activity was developed with the support of the Science Museum, the Valencian Innovation Agency and The Generalitat Valenciana, the main governmental institution in the Valencian Region The focus of this workshop was primary and secondary school children. In this way, through the collaborative construction of drones and piloting them in an indoor circuit, students learn in a playful and co-creative way the challenges that the world of indoor drone presents, and also the ethical and legal implications that they will entail. Involving students in the innovation process and providing them with fundamental competences, educators can implement scientific education.

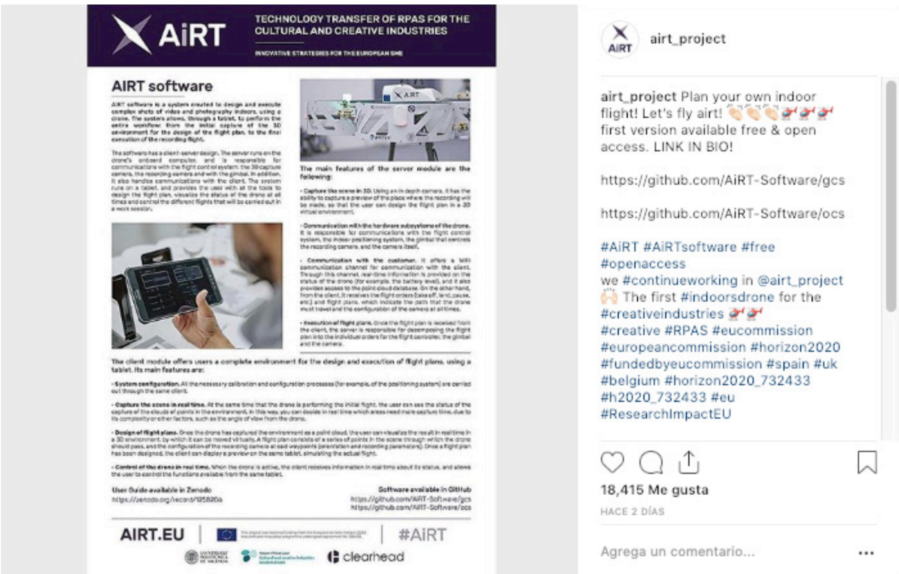



Figure 33. Instagram impact of the software.

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LA CIUTAT | PLANEA TU VISITA | AGENDA | NOTICIAS

Inicio > Prensa > Noticias > El nuevo taller 'Drones' ampliará la oferta de 'Ciencia a...

**EL NUEVO TALLER 'DRONES' AMPLIARÁ LA OFERTA DE 'CIENCIA A ESCENA' DEL MUSEU DE LES CIÈNCIES**

23-ene-2019

Se ha realizado en colaboración con la Universitat Politècnica de València (UPV) y la Agencia Valenciana de Innovación (AVI)

Un grupo de estudiantes de 5º y 6º de primaria del C.P. Magisterio Español ha participado hoy en una prueba del nuevo taller 'Drones' en el Museu de les Ciències y que en breve ampliará la oferta de 'Ciencia a Escena' para público escolar. La profesora de la UPV Virginia Santamarina ha impartido el taller que permite acercarse de forma práctica al mundo de los drones.

Gracias a la colaboración con Agencia Valenciana de la Innovación (AVI), la Universitat Politècnica de València y el Museu de les Ciències han diseñado este taller didáctico. Los participantes conocen primero en el aula la historia y características de los drones. También deben montar un robot volador y aprender las pautas básicas del manejo de vuelo que luego ponen en práctica en un circuito acondicionado, ubicado en la Calle Mayor del Museu.

Figure 34. News in newspapers for the first session of the permanent workshop “Drones” (The Science Museum, Valencia).

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