INGENIA SE | YEAR 2022-2023

OpsCon V1.0

Hell-ix Group

11th November 2022

INDUSTRIALES
ETSII | UPM

Contents

1. Stakeholders

Stakeholders can be defined as all those people or organizations affected by the actions of a company or, in this case, a team. It is especially important to consider which stakeholders will be involved throughout the entire process during the making of the OpsCon and to properly recognize their needs.

The main reason about this is the influence that they will have over the system. This influence can be positive or negative, at different stages of time, so identifying them beforehand will help us to be prepared to avoid possible issues.

The following list shows some of the most important stakeholders in this project. It is important to clarify the non-definitive character of this list, being very likely that it will evolve, and new stakeholders will be incorporated throughout the project.

1.1 Suppliers

They are in charge of delivering the drone to the team, as well as the different accessories that will be installed. They mainly influence the construction and testing stages due to possible delays in delivery.

1.2 Government (European, Spanish and Madrid)

They limit the conditions of the project by imposing laws. As it was studied during the law investigation, there are two main laws that affect this project: the *Commission Implementing Regulation (EU) 2020/746* and the *Commission Delegated Regulation (EU) 2019/945*. They influence the initial stages of the project, in aspects such as the location of the competition or the weight of the drone.

1.3 Competition management team

In this case, for practical purposes, the other team has been considered as this stakeholder, as it will limit some aspects related to the competition tests and the drone specifications. They influence primary stages, setting conditions of the competition.

1.4 Rival team

It is the only competitor. They force the project team to anticipate the specifications of the rival drone in order to try to beat them in the competition. They influence the entire course of the project.

1.5 Escuela Técnica Superior de Ingenieros Industriales

They are in charge of supplying the team with facilities to test and carry out the competition, as well as financing it. They influence during the entire course of the project.

1.6 Teaching team

They instruct and advise the different teams on macro level knowledge, such as the functioning of an organization or system, and on micro level, programming oriented to autonomous drones. They are influential throughout the course of the project.

1.7 CVAR team

A reliable and experienced source of advice on the subject of autonomous drones. It influences punctually, depending on the needs of the team, but throughout the course of the project.

2. Autonomous Racing Drone

In this project we intend to work with an autonomous drone. Therefore, it is not intended to design a drone with great technical qualities, but a drone that performs a series of basic tasks and is capable of achieving a simple mission, autonomously. Taking into account the above, the use of three possible drones for the competition has been discussed.

These drones are Crazyflie, Ryze Tello and a custom drone made by the team from scratch.

2.1 Crazyflie

Crazyflie is a 27 grams drone that offers a wide range of possibilities to make it autonomous. Several sensors are already included in Crazyflie, like a three-axis accelerometer or a pressure sensor. It is 9 cm long, its battery is supposed to last up to 7 minutes, and its charging time is about 40 minutes. It can reach a fly speed of up to 5 m/s. This is the chosen drone for the competition. In the next section further information can be found.

2.2 Ryze Tello

Ryze Tello is a heavier drone (it weighs about 80 grams) than Crazy Flie, but its size is about the same. It has a 720p video camera onboard with an electronic stabilization system to record stable videos. It also has a LED, Wi-Fi connection, and it can reach 10 m/s while flying human-controlled. Yet, making it fly autonomously may reduce its speed due to its limited data processing capabilities. The drone can fly up to 13 minutes.

2.3 Custom Drone

Despite building a drone from scratch is an exciting project, it is not a possibility for this project because of various reasons. First, a drone made in this way is usually large in size, because it is necessary to install the different pieces, wires and sensors. As its size increases, its weight increases, and if it exceeds the weight limited by law, 250 grams in this case, one of the team members must obtain a license to pilot the drone.

The last parameter that is important to talk about is the cost of this type of drones. Obtaining the license mentioned above costs more than €400, and buying all the parts separately is also quite expensive, reaching prices of up to €800-€2000.

2.4 Comparative

The following table collects the principal characteristics of each drone.

Table 2.1: Drone Comparative

Drone	Weight	Speed	Battery	Price	Special Features
Crazyflie	27g	5 m/s	7 min	600 €	Wide range of possibilities.
Ryze Tello	80g	10 m/s	13 min	109 €	Cheap. No hardware modification.
Custom Drone	$\geq 250g$	-	-	≥ 800	Drone driving license essential.

After taking a quick look at each drone and discussing the pros and cons of each one, the Crazyflie drone is selected due to its modifications capabilities, despite its price. The Ryze Tello is a good option too but its limitations were the reason for its rejection. The custom drone was discarded because of its weight, as it is mentioned above.

2.5 Specifications of the Crazyflie drone

This is the drone which has been chosen for the competition. This drone meets the characteristics required for this project. First of all, it is not a very complex drone to use nor excessively expensive.

Crazyflie can be improved with additional decks. This capacity gives the Crazyflie extra abilities in positioning, visualization and sensing. There is a broad range of decks available to customize the drone. Furthermore, the platform allows to create and add custom decks. This enables the user to utilize customized sensors and other devices on the platform. Communication buses and GPIO pins are exposed by the expansion bus to be used by decks as required.

2.5.1 Hardware

In terms of hardware components, the Crazyflie is composed of many LED'S and components. These have all their specific skills and functionalities. The microprocessors are the most important components of the Crazyflie : the STM32F4 controls the main Crazyflie firmware with all the low-level and high-level controls, and the NRF51822 manages the power control and all the radio communication.

In order to control the Crazyflie flight, a mobile device or a computer are needed. A mobile device is the best option to get quickly into the air. In the other hand, piloting skills are required. A computer offers more options and greater control but it requires two things : A standard gamepad for maneuvering, and a Crazyradio PA for communication. In this project, a computer will be the chosen tool.

2.5.2 Control

There are a different options of how to run the computer. The first one, a virtual machine. The second one, Operating Systems as Windows/Mac/Linux. For the virtual machine, there is a virtual machine (VM) created to get the drone into the air as quickly as possible. This VM has pre-installed all the needed software for flight and development.

This way is the chosen one by the team to control the drone using a computer. All the required steps to be successful in the installation of the VM are detailed in the official Crazyflie's website.

2.5.3 Drone Vision

To identify an obstacle and execute the corresponding movement, is necessary to use image processing software and a camera installed on the drone. OpenCV is the huge open-source library for the computer vision, machine learning, and image processing. It has C++, C, Python and Java interfaces and supports Windows, Linux, Mac OS, iOS and Android.

This tool can be used to process the images taken by the drone. Depending on the camera selected, it will be able to separate colors, identify shapes and calculate areas of the photo. With this information the drone´s computer is able to know which obstacle is in front of it, how far away is it and how to avoid it.

3. The Competition

The objective of the competition is to overcome a circuit in the shortest possible time. The first to complete the circuit will be the winner of the race. The circuit consists of a series of obstacles that the drone must avoid or dodge in a certain way depending on its shape or color.

In terms of technical characteristics, to achieve the objective it is necessary to accurately capture data from the environment and then control it using specialized software. Thus, it is necessary that a support pilot checks the operation of the drone to avoid accidents or unforeseen events. He has to be able to check through a computer the status of the drone and the process at all times, verifying that everything follows the established plan.

3.1 The Races

The race will take place at the sports center of the university and will consist in two parts. In the first one, the circuit will be known previously; trajectories can be programmed to reduce time. This circuit must be designed to prove that the drones are capable of performing the basic tasks of an autonomous drone: flying in the three spatial directions, rotating on its axes, detecting and avoiding objects or obstacles (fixed or moving), following programmed trajectories, landing...

In the second one, obstacles position will be aleatory, so the drone must be prepared to complete any possible configuration.

Other challenges that are proposed to the future are a straight-line speed race, aiming a target with a laser or a follow-line race, where the drones have to overcome a painted circuit on the ground as quickly as possible.

3.2 Obstacles

The drone will encounter various obstacles during the races. These obstacles can have different shapes and colours, which will influence the behaviour of the drone to overcome them. Some of the obstacles are listed below:

- **Hoops:** The drone should be able to go through them.
- **Poles:** They have different colours. Depending on them, the drone should take decisions such as going to its left or its right.
- **Doors:** The functioning of this obstacle is the same than the hoops but with a different shape.
- **Split Rectangle:** It has the same utility than doors and hoops.

3.3 Scoring System

In order to proclaim the winner of the competition, a scoring system is being developed that will reward or penalize the team based on the behavior of the drone. In this way, some parameters such as overcoming obstacles or getting a good lap time will score points but hitting obstacles will subtract them.

This scoring system is up to changes and will be fully determined in the testing phase.

4. Stages of development

As it has been mentioned above, the drone must do tasks such as taking off, landing, recognise different elements and dodge obstacles, all of them autonomously. To achieve that, these tasks are divided in three development states: initial state, intermediate state, and final state.

4.1 Initial Stage: Basic Operations

The initial stage is the first development stage of the drone and the most basic. It must be able to take off and land autonomously.To achieve that, the drone should be programmed correctly with languages like C++ or Python.

While flying, the drone must recognise different elements such as obstacles or doors, with an onboard camera that scan the surroundings of the drone, as it has been explained in previous chapters. This element recognition will be used in the following intermediate state, for the purpose of moving in directions other than the vertical one.

4.2 Intermediate Stage: Obstacle Detection

In the initial stage we achieved a drone which can take off, know where obstacles are, and finally land. In this intermediate stage, the drone must move itself forward and backward, and change its direction.

Moreover, it must use the element recognition's information to avoid obstacles while flying. To manage the drone going forward and backward autonomously, it should be programmed taking into consideration the power of the motors, the weight of the drone and the battery capacity. Furthermore, the camera's information is going to be used to draw the path the drone will follow.

Another critical issue to take into account is the loop running time, which will influence the speed of the drone: if the drone processing capacity is too low, it will fly very slowly because the path is going to be drawn very slowly. Yet, if the drone processes quickly enough, the drone's flying speed is going to be restricted by its motors' power, not its processing speed.

4.3 Final Stage: Speed

In this stage there are two goals: follow some objectives and increase speed.

Regarding the speed increment, it would depend on the motors' power and the controller speed, as explained before. The other goal is following objectives, and the camera information is going to be needed to do that.

The drone must recognise the objective, and it should try to follow it by pointing at it with an onboard laser. The objective may be moving on a screen or flying, being the former more likely to be used.

5. Bibliography

1. Price, G. [2020]. *Urban Air Mobility Operational Concept (OpsCon).* Recovered from: https://ntrs.nasa.gov
2. Banco Santander [2022]. *¿Qué son los stakeholders y por qué son tan importantes para una empresa?*. Recovered from: https://www.becas-santander.com/es/blog/stakeholders.html
3. Schwartz, B. [2021]. *The Operations Concept: Developing and Using an OpsCon*. Recovered from: https://www.engineeringforhumans.com/systems-engineering/the-operations-concept-developing-and-using-an-opscon/
4. BitCraze AB. *Crazyflie platform overview* Recovered from: bitcraze.io
5. BitCraze AB. *Getting started with the Crazyflie 2.X* Recovered from: bitcraze.io