Requirements for aerial robots participating in euRathlon 2015 competition

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1. SCOPE OF THE DOCUMENT

This document set the requirements that the aerial robotic systems must meet to participate in euRathlon 2015 competition.

2. REQUIREMENTS

2.1 Requirements for aerial robots

- Only VTOL (Vertical Take-Off and Landing) aircrafts will be allowed to participate in the competition. The area for taking-off and landing will be of 3x3m
- The aircraft maximum take-off weight (MTOW) must be smaller than 25 kg.

- The UAS system must include a flight termination system that must be capable of being remotely activated from the ground by pressing a “crash button”. When remotely activated, the flight termination system must stop the aircraft motors.
- A member of the organization, an aerial expert, will be in charge of pressing the “crash button” only in the case that safety is seriously compromised.
    - It is important to highlight that the flight termination system will only be activated in extreme circumstances in which is evident that the aircraft will put people in danger, crash against a critical building or element (e.g. a power plant) or is going so far that is evident that it won’t be possible to recover its control.
    - The member of the organization in charge of the “crash button” will be a highly experienced and qualified UAS pilot.
- The device on ground used to activate the flight termination system has to be completely independent from the rest of the system so if other parts of the system fail, the flight termination system can still work.
- Optionally, the flight termination system can also activate other complementary systems (e.g. activating a parachute) in addition to stopping the motors.

- The RC (Radio Control) radio used by safety pilots cannot operate in 2.4 GHz. <u>Aircrafts with a MTOW lower than 2 kg will be exempt from this requirement</u>.
    - Alternative bands such as 433 MHz could be used for this purpose (section 4 includes more information about devices operating in this band). Teams using safety pilot radio links operating in the 5 GHz band must notify the organizing committee.

- It is compulsory that teams use RC radiolinks based on FHSS (Frequency Hopping Spread Spectrum) which makes the signal more robust against interferences.

- euRathlon organizing committee does not impose any particular safety pilot radio system. Teams are free to choose the RC radiolink that as long as it fulfils these requirements.

- Teams can bring multiple aerial robots to the competition (e.g. a back-up vehicle, different vehicles for different tasks, etc) but only one aerial robot will be allowed to fly at a time. All the aerial robots to be used during the competition must pass the validation tests and provide the documentation described in section 3.

2.2 Requirements for pilots

- Each aerial team must have one or more safety pilots.
- The safety pilot must be exclusively devoted to manually control the aircraft using the RC radio if needed. If the aerial team chooses to perform a mission task flying manually the safety pilot will be on charge of controlling the aircraft. If the aerial team chooses to perform a mission task flying autonomously, the safety pilot will supervise the operation and will take manual control of the aerial robot if any misbehavior is observed during the flight.
- Safety pilots must be over 18 years old.
- Safety pilots will have to provide a valid second class medical certificate. You can get more information on this e.g. on http://aviation.about.com/od/Career-Training/a/Qanda-Medical-Certificate-Requirements-For-Pilots.htm.
- Safety pilots must be properly identified with a photo ID during the competition.
- Only those pilots indicated in the documentation that is submitted to the euRathlon organization will be allowed to fly.
- Not all the pilots that were included in the documentation must attend the competition (e.g. an aerial team can include in the documentation some pilots that might be attending the competition just in case that the main pilot gets ill).
- Safety pilots that intend to fly during the competition will have to perform the in-site validation flight tests indicated in section 3.

3. Procedure for aerial team validation.

In order to be accepted as a participating team in euRathlon 2015, aerial teams will have to provide evidence showing that their aerial system is safe and they have enough knowledge and skills to safely operate it. When applying for participation, aerial teams must submit a good-quality video showing their aerial system performing the following operations:

- Take-Off operation, in manual mode.
- Hovering operation, in manual mode at 40 meters from the ground.

- Fly following a rectangular trajectory as the one shown in Figure 1, both clockwise and counter-clockwise, in manual mode. These flights must be performed at an altitude of 20 meters.
- Perform vertical displacements of at least 20 meters, in manual mode.
- Landing, in manual mode.
- Execution of the flight termination functionality on the ground. The video must show how the motors are stopped when the crash button is pressed.

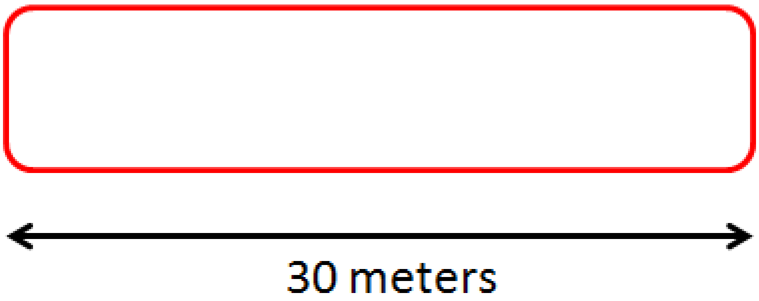


Figure 1. Flight trajectory for validation test.

Teams will also have to submit the following documentation:

1. Description of the aerial system.
2. Safety aeronautical analysis.
3. Operation and maintenance manuals.

Templates with guideline information on how to write those documents are available at euRathlon website. The submitted documentation and videos will be analyzed by euRathlon organization. Based on this analysis the organization will decide which teams are accepted for participation.

During the competition, flights will be subject to approval from the aerial expert designated by euRathlon organization at any time. Aerial experts will be properly identified so teams can recognize him/her. Any aircraft will be allowed to take-off and fly without the explicit authorization from the aerial expert designated by euRathlon organization. Obviously, teams cannot flight if an aerial expert is not physically present. Team pilots will always have to follow the indications of euRathlon aerial experts at any time before, during and after the flight.

Before the actual competition, validation test flights will be carried out on-site to test that the aircraft can be flown safely by the team pilot. The operations that will have to be performed will be basically the same as required for the video. However, euRathlon aerial experts will be able to request any additional operation. euRathlon aerial experts will decide if a team has proven they can operate the aerial vehicle safely and hence they are allowed to perform the aerial missions.

4. Safety pilot radio link.

As the name suggests, Remotely Piloted Aircraft Systems (RPAS) must be remotely controlled by a pilot on the ground. When operating in manual mode, the pilot is in charge of directly controlling the aircraft. When operating in autonomous mode, the aircraft is controlled by the autopilot and the pilot on the ground is in charge of taking manual control of the aircraft when any issue is experienced during flight of the aircraft. Hence, this pilot is normally referred as the safety pilot. A specific radio link must be used exclusively as the safety pilot radio link.

It is critical that the security pilot can take control of the aircraft when needed. Therefore, this radio link must assure connectivity between the security pilot and the aircraft. Most of the commercial radio links used by security pilots operate in the 2.4 GHz ISM band. It is widely known that the 2.4 GHz ISM band is very populated as it's used by a lot of radio systems including WiFi devices, Bluetooth, etc. For this reason, security radio links use Frequency Hopping Spread Spectrum (FHSS) techniques in order to increase the robustness against interferences. However, some interference issues affecting 2.4 GHz security radio links have been reported and experienced in the past. Although these issues are not common, their effects can be catastrophic and hence it is preferred to avoid any risks. In a multi-domain robotic competition as euRathlon, it is expected that many 2.4 GHz radio devices are used by the different robots for different communication tasks (and control, telemetry or payload sensor management). For these reasons, it is mandatory that safety pilot radio links operate in a different frequency band of the spectrum.

euRathlon organizing committee does not impose any particular safety pilot radio system. Teams are free to choose the system that better fit their requirements as long as it doesn´t operate in the 2.4 GHz band. Nevertheless, after analyzing the different commercial solutions available in the market, euRathlon organizing committee proposes using LRS (Long Range System) devices as they can be easily integrated with existing systems with a minimum effort.

4.1 LRS radiolinks.

Long Range Systems (LRS) operate in the 433 MHz band. In addition to an extended range, using lower frequencies also increases the penetration of the radiofrequency signals into buildings which is important for indoor scenarios as those found in euRathlon 2015 competition.

Figure 2. LRS module installed on a transmitter.

RC radio transmitters are the most expensive component of the safety pilot's radio link. Additionally, safety pilots are often reluctant to changing the radio transmitter that they normally use. Fortunately, LRS transmitters are sold as modules that can be connected to RC transmitters via what is called the trainer port as shown in Figure 2. The output of the trainer port is a PPM (Pulse Position Modulation) signal that contains the values of the different channels as commanded by the transmitter controls. When operating with an LRS module it is important to disable the 2.4 GHz radio of the RC transmitter to avoid extra radiation in that band.

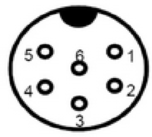
Figure 3. Elements of a LRS system.

In order to use LRS, adequate LRS receivers and antennas must be installed on-board the RPA. Figure 3 shows the elements that form the LRS system including the transmitter, receiver, transmitting and receiving antennas, and cables.

Futaba

Pin	Designation
SHIELD	GROUND
1	$V_{ENCODER}$
2	PPM_{OUT}
3	PPM_{IN}
4	V_{ENC2}
5	$V_{BATTERY}$
6	UNKNOWN

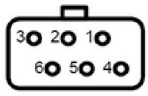
Connector:



Futaba

Pin	Designation
1	NC
2	GROUND
3	PPM_{OUT}
4	$V_{BATTERY}$
5	$V_{ENCODER}$
6	PPM_{IN}

Connector:



Hitec

Pin	Designation
1	$V_{SWITCHED}$
3	PPM_{OUT}
2	PPM_{IN}
4	$V_{SWITCHED}$
5	$RF_{DISABLE}$
6	GROUND
SHIELD	GROUND

Connector:

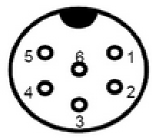


Figure 4. Futaba and Hitec trainer-port connectors.

When choosing a LSR device it is important to check the compatibility with commercial RC transmitters (basically this is a matter of electrical and physical characteristics of the connector). Figure 4 shows some examples of trainer ports. The cables that are used for connecting the RC transmitter to another device via the trainer port are commonly called buddy box cables.

4.2 LRS products.

There are a wide variety of commercial of the shelf LRS products that are available in the market. Some of these commercial systems are presented below.

4.2.1 ImmersionRC.

ImmersionRC (http://www.immersionrc.com/) EzUHF transmitter costs 209 $. It uses a 4-pin round connector (as an S-Video connector). This device can be connected to the trainer port of the following RC radios:

- Futaba radios with square connector (see Figure 5).
- Futaba radios with round connector (see Figure 6).
- Radios with jack connectors (Spektrum, JR, Turnigy, Hitec, Graupner radios).
- Radios with Multiplex DIN connectors.

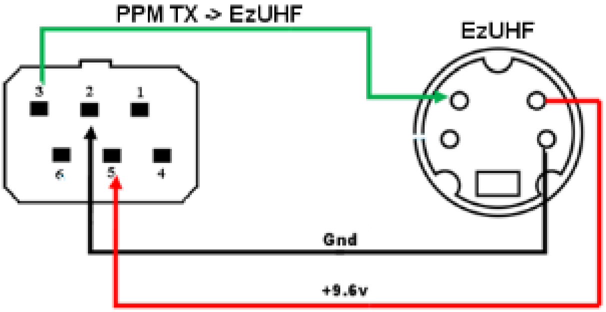


Figure 5. Connection between Futaba with square connector and EzUHF.

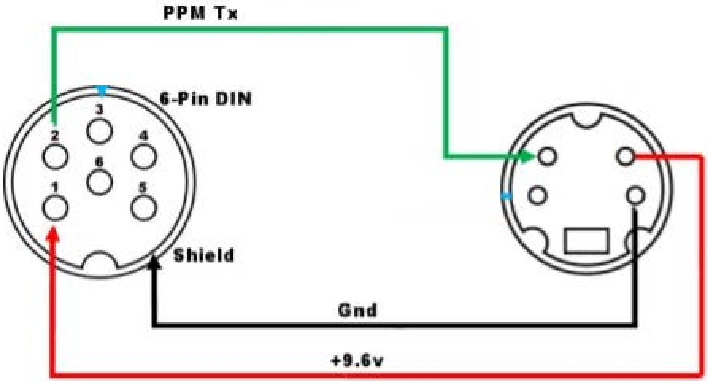


Figure 6. Connection between multiplex DIN connector and EzUHF.

Figure 7. Buddy cable for EzUHF and Spektrum, JR, turnigy, Graupner, Fly Sky and Hitec radios.

With regards to the receiver devices, there are two suitable options:

- 8 channels with antenna diversity: 124 $.
- 8 channels without antenna diversity: 109 $.

EzUHF receivers can be connected to PixHawk, APM2 and Paparazzi autopilots which are the most common open source autopilots. A complete kit including the transmitter, receiver, cables (for a specific RC radio) and antennas can be bought for 269 €.

4.3 Dragon Link.

Dragon Link transmitters cost 168 $ (http://www.dragonlinkrc.com/v2/). It uses a flat cable with 3 pins. This device can be purchased with cables for connection with the following radios (via the trainer port):

- Futaba radios with square connector.
- Radios with jack connectors (Spektrum, JR, Turnigy, Hitec, Graupner radios).

Very little evidence of people using this system with open source autopilots has been found. However, at first glance they appeared to be able to connect to these autopilots.

A complete kit including the transmitter, receiver, cables (for a specific RC radio) and antennas can be bought for 268 $. However, it seems that there are availability issues (it seems that they are frequently out of stock).

4.3.1 Orange OpenLSR.

Orange system is based on the open source LRS system called OpenLRS (http://openlrsng.org/). This system is compatible with JR and Turnigy radio device. It can be used with Ardupilot. However, it is worth to mention that the setup and use of OpenLRS requires computer programming skills and basic Arduino experience. It is not a "plug and play" system. The complete kit can cost around 80-100 $.