# Requirement Specification
# Tricopter with stabilized camera

Version 1.1

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### Status

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| | |
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## Document History

| Version | Date | Changes made | Sign | Reviewer |
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| 0.1 | 110914 | First draft. | KJB | Karl-Johan Barsk |
| 0.2 | 110920 | Second draft. | KJB | Karl-Johan Barsk |
| 0.3 | 110921 | Third draft. | KJB | Karl-Johan Barsk |
| 1.0 | 110922 | Added some lines and did some continuity changes. | KJB | Karl-Johan Barsk |
| 1.1 | 110928 | Corrected typos and the numbering of the requirements. | KJB | Karl-Johan Barsk |

# Contents


**1 Introduction** **1**
- 1.1 What is the aim of the project . . . 1
- 1.2 Who is involved . . . 1
- 1.3 Goals . . . 1
- 1.4 Definitions . . . 2

**2 Overview of the system** **2**
- 2.1 Product components . . . 3
- 2.2 Dependency of other systems . . . 3
- 2.3 Included subsystems . . . 3
- 2.4 General requirements on the complete system . . . 4

**3 Flight unit** **4**
- 3.1 Description of the Flight unit . . . 4
- 3.2 Design requirements . . . 4
- 3.3 Functional requirements on Flight unit . . . 4

**4 Surveillance unit** **5**
- 4.1 Description of the Surveillance unit . . . 5
- 4.2 Interfaces . . . 5
- 4.3 Design requirements . . . 5
- 4.4 Functional requirements on Surveillance unit . . . 5

**5 Sensor unit** **6**
- 5.1 Description of the Sensor unit . . . 6
- 5.2 Design requirements . . . 6
- 5.3 Functional requirements on Sensor unit . . . 7

**6 Communication unit** **7**
- 6.1 Description of the Communication unit . . . 7
- 6.2 Interfaces . . . 7
- 6.3 Design requirements . . . 7
- 6.4 Functional requirements of Communication unit . . . 7

**7 Ground station** **7**
- 7.1 Description of the Ground station . . . 8
- 7.2 Interfaces . . . 8
- 7.3 Design requirements . . . 8
- 7.4 Functional requirements on Ground station . . . 8

**8 Economy** **9**

**9 Deliverables and sub-deliverables** **9**

**10 Documentation** **9**

# 1 Introduction

Practical surveillance solutions for remote areas will be increasingly common in the near future. Unmanned aerial vehicles (UAVs) are superior to many other currently existing solutions when it comes to mobility and could provide assistance to for example the police force, security companies, emergency services and more.

## 1.1 What is the aim of the project

During the project the group will construct a surveillance system made up of an UAV with a mounted camera. The user will be able to specify a flying route along with one target of interest for surveillance and the UAV will then perform the surveillance mission. This will be referred to as the autonomous flight mode. Waypoints and the target will be chosen as coordinates in a fixed coordinate system. During the flight a video stream from the camera will be broadcasted to a ground station.

Additionally to the autonomous flight mode there will be a manual flight mode. The manual mode is for manual control of the tricopter with two optional safety features to prevent accidents. This will allow for unexperienced pilots to try out the equipment without risking damage to it. These are:

1. A virtual box with pre-specified boundaries. If this feature is enabled and the user breaches the boundaries, an auto-pilot will take control of the tricopter and fly it back to the center of the virtual box.
2. Easy-control, which when enabled translates the user control signals to direction commands in a fixed coordinate system instead of directly forwarding the signals to the rotors.

## 1.2 Who is involved

The customer is David Törnqvist, employee of the department of electrical engineering at Linköping University (ISY). Orderer is Fredrik Lindsten also an employee of ISY. Manon Kok (ISY) will be assisting the group consisting of:

- Project Manager: Josefin Kemppainen
- Documents: Karl-Johan Barsk
- Firmware: Joakim Hallqvist
- Hardware: Patrik Johansson
- Software: Rasmus Jönsson
- Test: Johan Larsson
- Information: Mattis Lorentzon
- Design: Björn Rödseth

## 1.3 Goals

All the listed requirements in this document should be fulfilled according to ascending priority. All priority 1 requirements are necessary for the project to be considered complete. Priority 2 and above are optional and will be dealt with if time permits.

The requirements will be listed according to the example table below. The first column shows the requirement identification number (which is unique), the second is for revision history, the third describes the requirement and the fourth states the priority.

| Req.nr.x | Original<br>Changed | Description of req.nr.x | priority |
|---|---|---|---|

### 1.4 Definitions

| | |
|---|---|
| UAV | Unmanned Aerial Vehicle |
| RF | Radio Frequency |
| ISY | Department of electrical engineering at Linköping University |
| DPx | Decision Point x |
| Arduino | An open source electronics prototyping platform |
| ArduCopter | Auto-pilot system running on an Arduino platform |
| IMU | Inertial Measurement Unit |
| IMU-shield | Sensor module with accelerometers, gyroscopes, magnetometers and a barometer |
| GPS | Global Positioning System |
| XBee | Wireless RF system |
| Gimbal | A pivoted support that allows the rotation of an object about a single axis |
| APM Mission Planner | Software for mission planning and display of flight data |
| ArduPilot Mega | ArduPilot Mega hardware board |

## 2 Overview of the system

For this project a UAV platform with three vertical rotors will be used. An ArduPilot chipset is placed on the UAV running a preprogrammed software called ArduCopter. ArduCopter is an open source product with extensive documentation and a lot of room for customization. A gimbal with two degrees of freedom will be used as a mount for the on-board camera.

The system is split up into five subsystems, see section 2.3. The subsystems are the Flight unit (see section 3), Surveillance unit (see section 4), Sensor unit (see section 5), Communication unit (see section 6) and Ground station (see section 7). A block diagram of the subsystems can been seen in figure 1.

For more information about the ArduPilot, see [1].

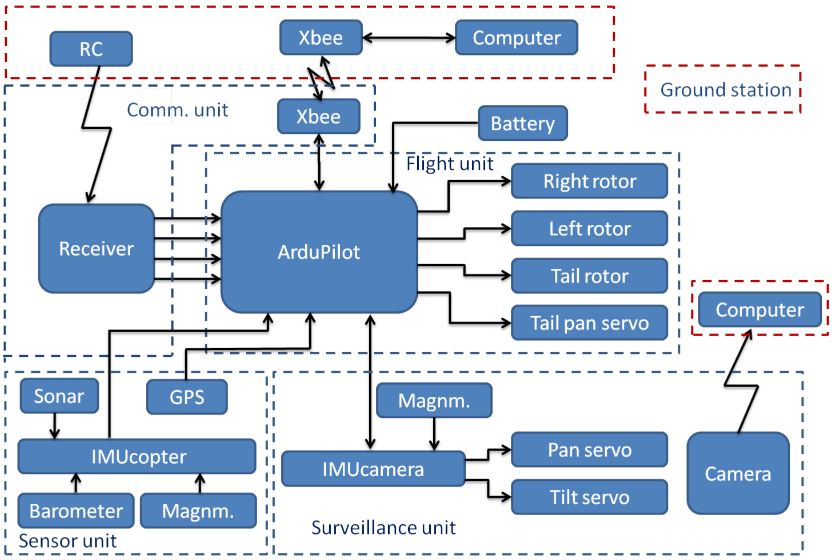


Figure 1: Block diagram of the system. For a more detailed description, see Outline Plan [3].

## 2.1 Product components

The tricopter is equipped with the autopilot ArduCopter which is based on the open source control system ArduPilot. The camera is mounted on a gimbal with two degrees of freedom (pan and tilt). The gimbal is also equipped with a separate IMU which is used to stabilize it. On the tricopter itself is another IMU mounted and also a GPS, magnetometer and a barometer. A sonar sensor is attached to the tricopter to be able to perform autonomous landing.

The camera sends an analogue video stream to the ground station and the whole system communicates with the ground station via XBee, see section 6.1.

## 2.2 Dependency of other systems

For the product to be flown in autonomous mode, the path must be specified via a computer running APM Mission Planner before takeoff.

## 2.3 Included subsystems

The system is divided into the following subsystems:

- Flight unit
- Sensor unit
- Surveillance unit
- Communication unit
- Ground station

Every subsystem has its own section in this document where it will be described in more detail along with its associated requirements.

### 2.4 General requirements on the complete system

| | | | |
|---|---|---|---|
| **1** | Original | An autonomous flying tricopter with a stabilised camera pointing at a specified stationary target's coordinates on the ground. Stabilized meaning that the target coordinates will not deviate from the image's center more than 25 percent of the captured image's width and height. | 1 |
| **2** | Original | Wireless video communication between the camera and a ground station. | 1 |
| **3** | Original | There will be a manual mode with manual control of the tricopter. | 1 |
| **4** | Original | There will be a virtual box feature in manual mode where an autopilot will return the tricopter back to a 1x1x1 m proximity of the center of the box if the box boundaries are breached. The control will then be given back to the pilot. | 1 |
| **5** | Original | There will be an easy-control feature in manual mode where the control signals will be interpreted as flight directions in a static coordinate system. | 1 |

## 3 Flight unit

This section describes the flight unit and lists the requirements placed on the flight unit.

### 3.1 Description of the Flight unit

The flight unit consists of the hardware and software required for flight ability. The included hardware is an ArduPilot mega card, three motors and one servo. The motors drive the rotors and the servo is used to tilt the back rotor, causing the tricopter to turn around its vertical axis (pan).

### 3.2 Design requirements

Listed below are the requirements set for what the Flight unit subsystem should contain.

| | | | |
|---|---|---|---|
| **6** | Original | The Flight unit will contain a control system based on ArduCopter. | 1 |
| **7** | Original | The Flight unit will contain an ArduPilot Mega board. | 1 |
| **8** | Original | There will be three rotors to lift the UAV and one servo for tilting one of the rotors. | 1 |

### 3.3 Functional requirements on Flight unit

Listed in the table below are the functional requirements on the Flight unit.

| | | | |
|---|---|---|---|
| **9** | Original | Manual mode were the tricopter follows radio control signals. | 1 |
| **10** | Original | The size of the box for the virtual box feature will be no more than 5 x 5 x 5 m and not located more than 10 m above the ground. | 1 |
| **11** | Original | The size of the box for the virtual box feature will be arbitrary. | 2 |
| **12** | Original | Autonomous landing outdoors on level ground with no precipitation and wind speeds below 1 m/s. | 1 |
| **13** | Original | Autonomous flight following a pre-specified path free from obstacles within 10 meters of the flight path. | 1 |
| **14** | Original | Performing loops in Autonomous mode. | 2 |
| **15** | Original | Autonomous take off outdoors on level ground with no precipitation and wind speeds below 1 m/s. | 2 |
| **16** | Original | Possibility to switch between different modes online. | 2 |

# 4 Surveillance unit

In this section a description of the surveillance unit is given with its listed requirements.

## 4.1 Description of the Surveillance unit

The surveillance unit consists of a camera mounted on a gimbal consisting of two separate servos for pan and tilt control of the camera. Also included is a separate IMU-shield (hereon referred to as IMUcamera) mounted on the camera required for determining the camera's orientation to be able to lock on to a target. The IMU-shield consists of accelerometers, gyros, magnetometers, a barometric pressure senor and a voltage sensor for battery status.

## 4.2 Interfaces

Included is a wireless analog video link to a ground station. This will be used for capturing images of a pre-specified target. The Surveillance unit will also communicate with the Flight unit through an $I^2C$-bus.

## 4.3 Design requirements

Listed below are the hardware requirements for the surveillance unit.

| | | | |
|---|---|---|---|
| **17** | Original | Two gimbals combined for two degrees of freedom in camera motion (pan and tilt). | 1 |
| **18** | Original | There will be a camera mounted on the gimbal. | 1 |
| **19** | Original | There will be a wireless video transmitter connected to the camera. | 1 |

## 4.4 Functional requirements on Surveillance unit

The requirements set for the surveillance unit's functionality are listed below.

| | | | |
|---|---|---|---|
| **20** | Original | Stabilize camera by compensating for wind speeds below 1 m/s with same stabilization accuracy as stated in requirement 1. | 1 |
| **21** | Original | Wireless transmission of video signal from camera. | 1 |
| **22** | Original | Send status flag when the stationary target's coordinates are in sight and within a 40 m radius of the tricopter. | 2 |
| **23** | Original | The camera will be able to capture the target's coordinates providing that it's within a 30 degree visibility cone pointing from the heading of the tricopter following its path. See figure 2 | 1 |

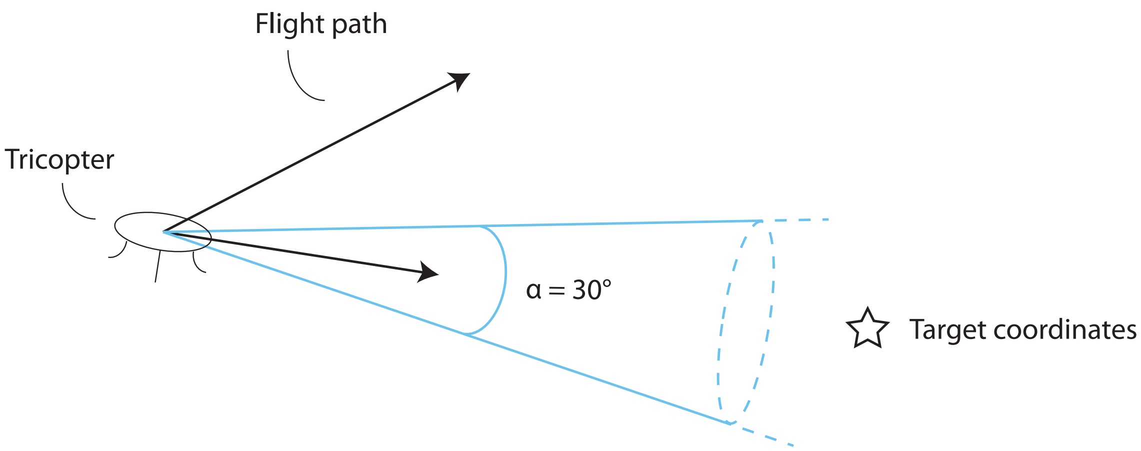


Figure 2: Visibility cone for surveillance camera aligned with the vector going along the tricopter frame through its nose.

# 5 Sensor unit

The Sensor unit's functionality consists of collecting sensor data used to estimate and determine velocity, position and heading. The Sensor unit will provide the sensor data to the Flight unit where the data will be merged by means of sensor fusion.

## 5.1 Description of the Sensor unit

The sensor unit consists of an IMU-Shield (hereon referred to as IMUcopter) and additional sensors. The IMU-shield consists of accelerometers, gyros, magnetometers, a GPS, a barometric pressure sensor, a sonar sensor and a voltage sensor for battery status.

## 5.2 Design requirements

Listed below are the hardware requirements for the sensor unit.

| | | | |
|---|---|---|---|
| **24** | Original | IMU-Shield with GPS for estimation of position, velocities and orientation. | 1 |
| **25** | Original | Barometer for estimating height above sea level. | 1 |
| **26** | Original | Sonar sensor for estimating height above ground level during autonomous landing. | 1 |

### 5.3 Functional requirements on Sensor unit

Here the functional requirements on the sensor unit are listed.

| | | | |
|---|---|---|---|
| **27** | Original | The sensor unit will estimate the tricopter's position (within 5 m), velocity (within 1 m/s) and orientation angles (within 20 degrees). | 1 |

## 6 Communication unit

This section concerns the communication unit and its requirements.

### 6.1 Description of the Communication unit

The communication unit consists of an XBee module and a radio receiver located on the tricopter for manual control. The information sent via the XBee module from the tricopter consists of flight data which covers orientation, heading, position and velocities of the tricopter and orientation and heading of the surveillance unit.

### 6.2 Interfaces

For transferring data between the Ground station and the Communication unit, XBee modules are used. Radio communication is used for manual control with a handheld transmitter.

### 6.3 Design requirements

Below is a list of the hardware requirements for the communication unit.

| | | | |
|---|---|---|---|
| **28** | Original | The communication unit will have an XBee module. | 1 |
| **29** | Original | The communication unit will have a receiver for radio control. | 1 |

### 6.4 Functional requirements of Communication unit

The requirements for the communication unit's functionality are listed below.

| | | | |
|---|---|---|---|
| **30** | Original | Receive control signals from a radio controller when in manual mode. | 1 |
| **31** | Original | Transmit a status flag, indicating that the target coordinates is in sight and within a 40 m radius, to the ground station using the wireless XBee-module. | 2 |
| **32** | Original | Transmit flight data, including heading, velocity and position, from IMU-shield to the ground station using the XBee-module. | 1 |
| **33** | Original | Receive parameters that specify the target's coordinates and way-point coordinates from the ground station using the wireless XBee-module. | 1 |

## 7 Ground station

The ground station is the main system interface for the user and consists of two computers and a radio controller. One computer is used for mission planning and to display flight information, the other computer receives the video signal from the on-board camera and the radio controller is used for maneuvering the tricopter in manual mode.

## 7.1 Description of the Ground station

One of the computers is solely responsible for receiving the analogue video signal from the on-board camera and rendering it to a separate display or video glasses.

The second computer will run the mission planning software (APM Mission Planner) which will be used prior to flight to define the next surveillance mission. The computer will communicate with the UAV by the XBee module.

The radio controller will be able to control the UAV manually when in manual mode.

## 7.2 Interfaces

Most of the communication between the user and the UAV will go through the APM Mission Planner software that is available as open source. Modifications to this program will be made if necessary. The application offers a mostly graphical interface.

## 7.3 Design requirements

| | | | |
|---|---|---|---|
| **34** | Original | Route specification software. | 1 |
| **35** | Original | The ground station unit will have a laptop running the user interface. | 1 |
| **36** | Original | The ground station unit will have a computer receiving the video signal. This video can be displayed on a pair of video glasses or transferred to a laptop. | 1 |
| **37** | Original | The ground station unit will have a radio controller for manual control. | 1 |
| **38** | Original | The ground station unit will have an XBee module. | 1 |
| **39** | Original | Graphical user interface in route specification software. | 2 |

## 7.4 Functional requirements on Ground station

| | | | |
|---|---|---|---|
| **40** | Original | There will be a possibility to specify waypoint coordinates before an autonomous flight. | 1 |
| **41** | Original | There will be a possibility to specify one target's coordinates before an autonomous flight. | 1 |
| **42** | Original | Transmit parameters that specify one target's coordinates and waypoint coordinates to tricopter via a wireless XBee module. | 1 |
| **43** | Original | Receive wireless video signal from camera. | 1 |
| **44** | Original | Receive status flags, indicating that the target's coordinates are in sight and within a 40 m radius, from tricopter via a wireless XBee module. | 2 |
| **45** | Original | Receive flight data, including heading, velocity and position, from tricopter via a XBee module and log it. | 1 |
| **46** | Original | Display flight data, including heading, velocity and position, in a user interface. | 2 |
| **47** | Original | Record video signal and save to harddrive. | 2 |

# 8 Economy

The resources for this project are listed here.

| | | | |
|---|---|---|---|
| **48** | Original | ISY will provide 30 hours mentor time. | 1 |
| **49** | Original | ISY will provide 2 laptops. | 1 |
| **50** | Original | ISY will provide part of a room. | 1 |
| **51** | Original | ISY will provide all required equipment and software. | 1 |
| **52** | Original | Every member in the project group will work 240 hours on the project. | 1 |

# 9 Deliverables and sub-deliverables

The following should be delivered at their respective decision points (DP).

| | | | |
|---|---|---|---|
| **53** | Original | A presentation where at least all requirements with priority 1 in this document are demonstrated. | 1 |
| **54** | Original | To be delivered at DP2: Requirement Specification, Project plan, Time Plan, Outline plan. | 1 |
| **55** | Original | To be delivered at DP3: Design Specification, Test Plan. | 1 |
| **56** | Original | To be delivered at DP5: Test protocol, user manual and all functionality. | 1 |
| **57** | Original | To be delivered at DP6: Technical Documentation, project evaluations, presentation poster, project website with a short video illustrating the resulting product. The video will be posted on YouTube.com. | 1 |
| **58** | Original | Weekly status reports along with individual time and activity information. | 1 |

# 10 Documentation

The following documentation is required in the project. The documents will be written according to the LIPS model [2]. All the documents will be written in english and in LaTeX and delivered in PDF.

| **Document** | **Purpose** |
| --- | --- |
| Requirement Specification | Specifies the requirements of the project (see requirement nr. 49). |
| Outline Plan | A rough construction plan of how the project will be realized (see requirement nr. 49). |
| Project plan | A description of how the project will be accomplished (see requirement nr. 49). |
| Time Plan | The Project plan divided into activities and specified on a time line (see requirement nr. 49). |
| Design Specification | A detailed construction plan (see requirement nr. 50). |
| Test Plan | Describes how and when the requirements will be validated (see requirement nr. 50). |
| Test protocol | Protocol of all tests (see requirement nr. 51). |
| Technical Documentation | A detailed description of every aspect of the project (see requirement nr. 52). |
| User manual | Describes how to use the product (see requirement nr. 51). |
| Poster | A brief description of the product (see requirement nr. 52). |
| Homepage | A public documentation of the product (see requirement nr. 52). |
| Video | Demonstrates some of the functionality of the product (see requirement nr. 52). |
| Project evaluation | A description of the execution and the results (See requirement nr. 52) |

# References

[1] v/a, *arducopter – Arduino-based autopilot for mulitrotor craft, from quadcopters to traditional helis*. http://code.google.com/p/arducopter/, 2011-09-02.

[2] Tomas Svensson and Christian Krysander, *Projektmodellen LIPS, version 1.3*, January 2007.

[3] Karl-Johan Barsk, *Outline Plan, version 1.0*, September 2011.