User Guide

WiMA-Extension, Version 0.1

February 7, 2020

Contents

1 Introduction

1.1 Purpose

The purpose of this document is to introduce the user to WiMA (**Wi**reless **M**easurement **A**pplication) integrated in QGroundControl. QGroundControl is a ground control station software intended for the remote control of UAVs (Unmaned Arial Vehicle). A Documentation of the QGroundControl program can be found under `https://docs.qgroundcontrol.com/en/`. The WiMA extends the functionality of QGroundControl to simplify mobile UAV based coverage measurements.

1.2 Scope

The current goal of the WiMA is to provide software able to generate flight plans form minimal user input. This guide contains information about how to use WiMA.

1.3 How to use this Guide

The guide is structured into short sections describing specific problems. Most likely your question can be answered by reading only a few of those section. Try to find your problem in the table of contents before reading the entire guide. Additionally it is advised to read section 3.1, section 3.2, and section 3.3.

2 System Description

2.1 Key Features

The extension can generate flight plans based on minimal user input. This is done by defining different areas on a world map. Additionally WiMA offers to partition generated flight plans, which gives more flexibility. Partitioning makes it possibly to execute a subset of a flight plan, which makes it less tedious to cover large areas. As a security feature WiMA offers a smart return to launch routine. Most return to launch implementations choose the direct path for return, which can be blocked. WiMA can automatically calculate a save return path, based on user defined save area. WiMA also offers fast adaption of flight altitude and speed.

2.2 Inventory

The source code can be cloned from the git repository `https://dummyurl.com`. The root directory of the project contains the folder "deploy" inside which a `.AppImage` of the program can be found. Under GNU/Linux QGroundControl can be launched from console or by double-clicking the `.AppImage`. It is also possible to build versions for Microsoft Windows, Android or Mac. For this purpose refer to the QGroundControl documentation under `https://docs.qgroundcontrol.com/en/`.
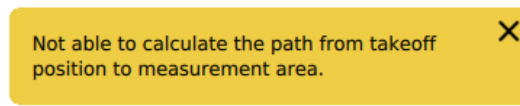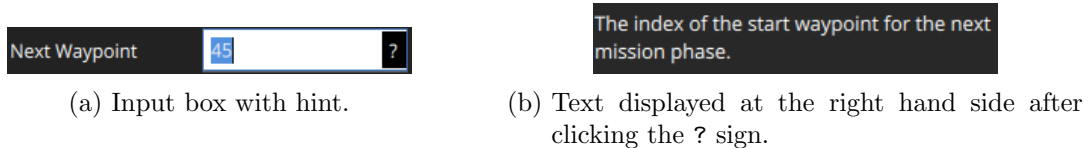
Figure 1: Warning at the top of the window.

(a) Input box with hint.

(b) Text displayed at the right hand side after clicking the ? sign.

Figure 2: Hints can be displayed by clicking the ? sign.

3 Menus and Instructions

3.1 Warnings

Warnings in QGroundControl are displayed inside yellow boxes at the top of the window (see fig. 1). They automatically disappear after some time.

3.2 Hints

QGroundControl gives many hints on how to use it. E. g. input boxes have a hint sign (?), see fig. 2

3.3 Brief Summary

Figure fig. 3b shows a detail view of the QGC main window. Relevant for this documentation are the flight view, the plan view and the WiMA view. Their function will now be briefly summarized.

The **plan view** is used to create flight plans and is part of standard QGroundControl. Flight plans can be stored as `.plan` files or directly be uploaded to a vehicle (either a real one or to a simulator). Flight plans consist of way-points. Each way-point stores, among others, a coordinate (latitude, longitude, altitude) and a command (take off, land, wait for x seconds, etc.). To define a sensible flight plan a sequence of way-points should begin with a take off command and end with a land command. Besides way-points more complex patterns can be defined, which is done by inserting a Survey, a Circular Survey, a Structure Scan or a Corridor Scan.

The **flight view** comes in necessary as soon as you want a vehicle to get in action. Once the vehicle established a connection (serial, TCP, UDP, etc.), QGroundControl starts to communicate automatically with it, in most cases. If not, check the settings menu of QGroundControl. A connected vehicle will appear as a red arrow on the map, showing the vehicles position and orientation. On the top indicator strip (fig. 4), telemetry data will be published. At the left edge a tool strip (fig. 3a) will be activated, which can be used to command the vehicle.

The **WiMA view** is used to generate flight paths from minimal user input. The user can define a Measurement Area, a Service Area (for take off, land, supply tasks, etc.) and a Corridor, which connects the other two areas. Further the WiMA plan view and flight view will be described.
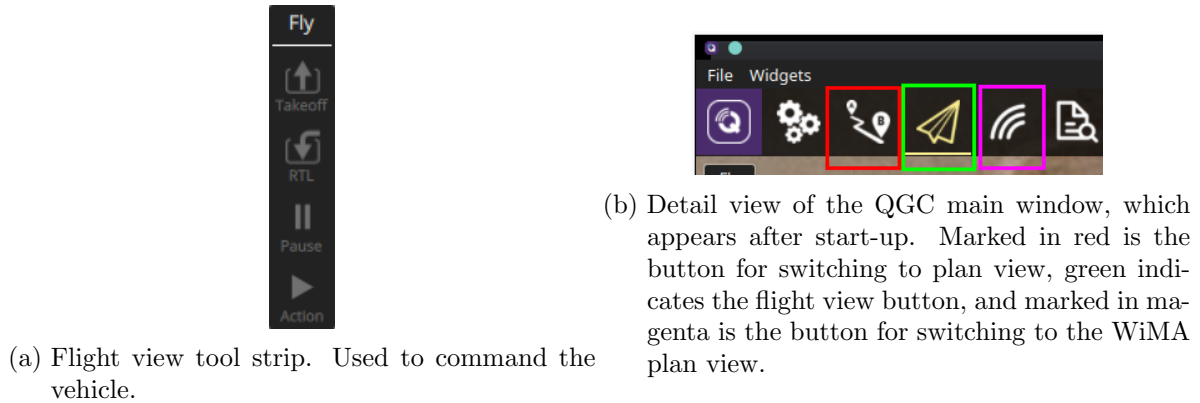
(a) Flight view tool strip. Used to command the vehicle.

(b) Detail view of the QGC main window, which appears after start-up. Marked in red is the button for switching to plan view, green indicates the flight view button, and marked in magenta is the button for switching to the WiMA plan view.

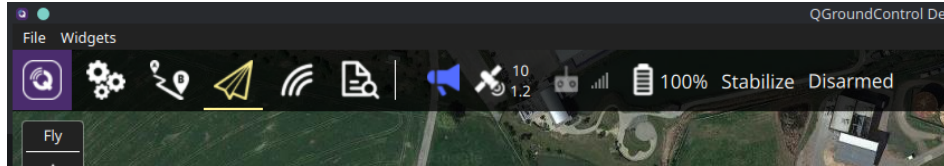Figure 3: Flight view tool strip and view switching.

Figure 4: Flight view top indicator strip. Show's data about a connected vehicle. Among others satellite count, telemetry quality, battery level etc. are displayed.

3.4 WiMA Plan View

By clicking the wave symbol (see fig. 3b, magenta square) the WiMA view appears. After entering, at the left screen edge, the WiMA tool strip will appear (depicted in fig. 5).

3.4.1 WiMA Tool Strip

The WiMA tool strip is used for load/ save operations as well as editing tasks. The file button can be used to load, save and clear missions. Measurement and service area as well as corridor can be added by clicking the corresponding buttons. The calculate button can be used to regenerate the current mission. However with the current version regeneration is done automatically. The center and zoom buttons are used to navigate the map.

3.4.2 WiMA Areas

The three areas, namely the measurement area, the service area and the corridor, can be defined using the corresponding buttons (see section 3.4.6). In the default mode the areas will be displayed as a half transparent polygon surrounded by a white lines. The polygon shape can be altered by using the drag and split handles shown in fig. 8a, fig. 8b and fig. 8c. All areas will
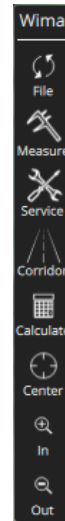

Figure 5: WiMA Toolstrip inside WiMA Main Window.

be listed at the right side within the WiMA Item Editor (see fig. 6b). The WiMA Item Editor can be used to modify area parameters. The Parameters `Altitude`, `Layers`, and `Layer Dist.` are reserved for future use and don't yet have any impact. The `Offset` parameter changes the distance between the area and its border polygon. The border polygon is a helper to provide sufficient clearance between the area and nearby obstacles, like trees or buildings. The border polygon can be deactivated by unchecking the `Border Polygon` check box. This can be use full for service area and corridor. Additionally the WiMA item editor shows some statistics about the polygon, like area and number of nodes.

The three areas have the following purpose. The WiMA measurement area defines, as the name indicates, the area of interest within which any measurements are performed. See section 3.4.2 for more information about WiMA areas. The WiMA service area is meant to be the place were takeoff and landing happens as well as battery exchange or repair work. See section 3.4.2 for more information about WiMA areas. The WiMA corridor connects the measurement area and the service areas and defines a path which the vehicles uses to travel between Service and Measurement Area.

A minimal configuration of areas consists of measurement and service area. In that case the two areas must be overlapping. The corridor can additionally be used to connect measurement and service area if overlapping of those two is not desired. A valid configuration including measurement, service area and corridor could look like in fig. 9a. The sum of all three areas is further refereed to as the joined area.
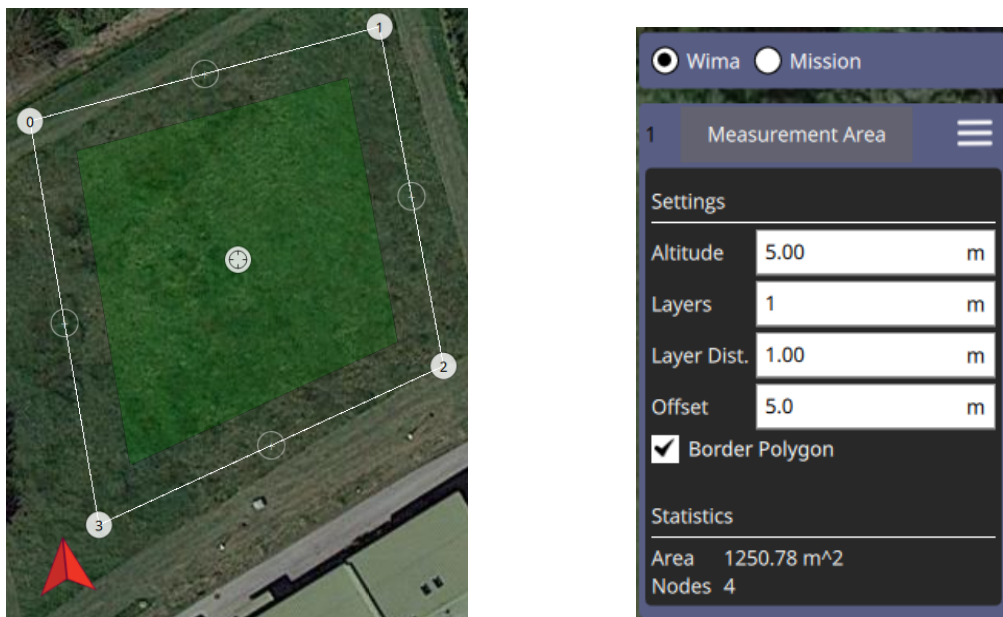
(a) WiMA area with border polygon. Shown is a measurement area (green).

(b) WiMA item editor at the right edge of the WiMA plan view.

Figure 6: WiMA Area and corresponding item editor.

3.4.3 Saving and Loading WiMA Missions

Pressing the `File` button (see fig. 9b) of WiMA tool strip (see section 3.4.1) opens a menu offering saving and loading operations. At one hand all WiMA areas and mission items can be

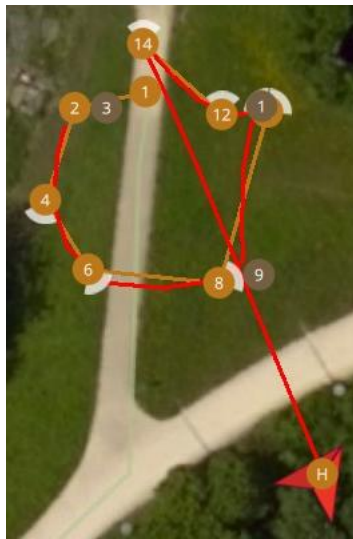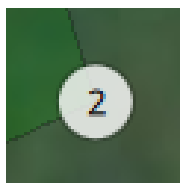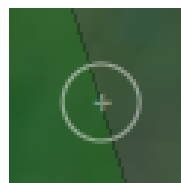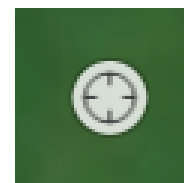Figure 7: Flight path of a real vehicle (red line).

(a) Adjust the vertex by dragging it's handle.
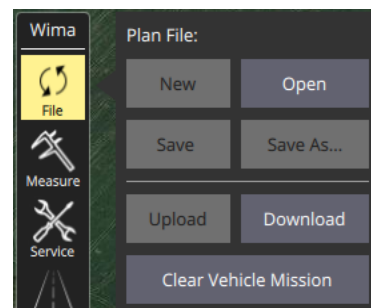

(b) Add vertices by hitting the plus sign.

(c) Move the entire area by dragging its drag handle.

Figure 8: Move and drag handles.

(a) A valid configuration of measurement, service area and corridor.

(b) WiMA tool strip save/load dialogue.

Figure 9: WiMA areas and WiMA save/load dialogue.

saved using the `.wima` file extension, at the other hand the mission items only can be stored using the `.plan` file extension. The `Open` button can be used to load previously stored files.

3.4.4 Clearing WiMA Missions

Press the `File` button (see fig. 9b) of WiMA tool strip (see section 3.4.1) to open the dialogue window. Pressing the `New` button deletes all contents within the WiMA Main Window.

3.4.5 Uploading, Downloading and Clearing vehicle Missions

Press `File` button (see fig. 9b) of WiMA tool strip (see section 3.4.1) to open the dialog window. With the `Upload`, `Download` and `Clear Vehicle Mission` button, the mission items (if present) can be uploaded, downloaded or deleted from the vehicle.

3.4.6 Inserting WiMA Areas

The `Measure`, `Service` and `Corridor` buttons of the WiMA tool strip (see section 3.4.1) are used to insert a measurement, service and corridor area, respectively. Only one of each can be inserted. To generate a flight plan, at least a measurement and a service area must be defined. In that case both must be overlapping.

3.4.7 Generating a WiMA flight plan

The current version of WiMA automatically updates the flight plan, after terminated user interaction. However using the `Calculate` button (see fig. 9b) of the WiMA tool strip (see section 3.4.1), manual regeneration can be triggered. The flight plan will be generated such that all way-points are within or at least at the edge of the joined[1] area. However it should be taken in account, that the vehicle could still leave the save area, even under fully functional operation. Depending on the software implementation of the vehicles flight stack (firmware), the flight controller could perform a path change. Additionally drifts caused by wind gusts could occur. An example can be seen in fig. 7. The vehicles flight controller has no information about any WiMA Areas, they exist exclusively within the QGroundControl application.

3.4.8 Navigating the Map

The three buttons `Center`, `In` and `Out` (see fig. 9b) of the WiMA tool strip (see section 3.4.1) can be used to center the view to a object of interest, and for zooming. The Map can be navigated by dragging the mouse pointer or touch screen.

3.4.9 How to display the generated flight plan

The flight plan can be displayed by checking the `Mission` radio button above the WiMA item editor (see. fig. 10a), as depicted in fig fig. 10a. An example of a generated flight path can be seen in fig. 10b. Within the green measurement area the program has generated a circular survey (see section 3.4.10). The survey has an entry and an exit point. The program has routed paths from the take off point to the surveys entry point and from the surveys exit point to the landing point. The paths have been chosen to be within the joined area and to be as short as possible.

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[1]The joined area is the sum of measurement, service area and corridor (see section 3.4.2).

(a) Checking the Mission radio button, on the right hand side, displays the mission items.

(b) The flight path generated from the areas depicted in fig. 9a.

Figure 10: Mission radio button and an example flight plan.

3.4.10 Circular Survey

The Circular Survey (green area in fig. 10b, containing circular tracks) is a flight pattern provided by WiMA. It is similar to the Survey pattern of the standard QGround-Control application. The Circular Survey was adapted for mobile coverage measurements. It consists of circle segments refereed to as transects. Ideally, the transects are connected with each other such that the path between entry and exit point is as short as possible. Currently this goal is approximated by a heuristics. The solution might not always be the global optimum. The `Reference` point (Circle with R symbol and Reference tag, see fig. 10b) defines the center of the circle segments. It is supposed to be placed on the base stations position.

Circular survey parameters can be edited with the circular survey editor (see fig. 11). The `Altitude` input box adjusts the altitude of the survey's way-points. The distance between adjacent circle segments can be modified by changing the `Delta R` value. The circle segments are approximated by polygonal structures, consisting of way-points. Two arbitrary adjacent way-points of a circle segment have a maximum angle between them. This angle can be adjusted by editing the `Delta Alpha` input box.
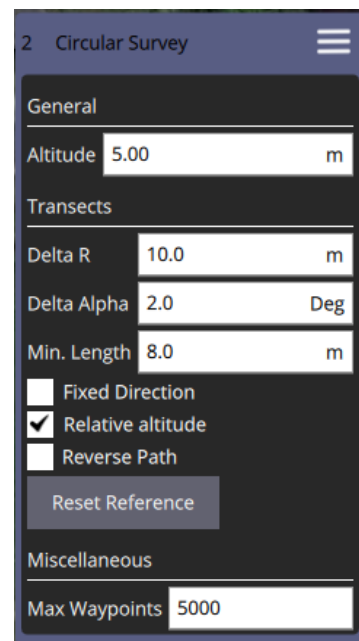

Figure 11: The circular survey item editor at the right hand side.

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The `Delta Alpha` value can assume everything between 0.3° and 90°. The higher the value the rougher the circle appears. The survey will contain the less way-points the higher the `Delta R` and the `Delta Alpha` values are. The number of way-points impacts the recreation and upload time. In general the following holds. The less way-points the better. Use only as many way-point as you really need.

Short transects are often undesired, to remove them, the minimal transect length can be specified by the `Min. Length` value.

If it is desired that the UAV flies with the same direction each transect the `Fixed Direction` check box can be activated. The `Relative Altitude` check box enables relative height. With the `Reverse Path` check box path reversal can be obtained. The `Reset Reference` button the reference handle can be set to the survey area center. This can be helpful if the reference handle is hidden.

To reduce calculation effort, the maximum number of way-points can be set using the `Max Waypoints` input box. Transects are hidden and calculations aborted, if the number of way-points exceeds `Max Waypoints`.

3.4.11 How to synchronize Data with Flight View

To synchronize the generated flight plan with the WiMA flight view (see section 3.5) press the `Sync WiMA` button in the upper right corner (see fig. 12a). The button will be visible only if a valid flight plan was generated and flash if data is not synchronized with the WiMA flight view.

3.4.12 Editing Flight Plans

The generated flight plan can be edited in the same way as it would be done inside the standard plan view using the mission tool strip (see fig. 12b). After editing, the flight plan can be saved (see section 3.4.3) or synchronized with WiMA flight view (see section 3.4.11).

## 3.5 WiMA Flight View and WiMA Menu

The WiMA flight view extends the QGroundControl flight view by the WiMA menu, which offers some useful tools like flight plan partitioning, smart return to launch, fast speed changing etc. By default the WiMA menu is visible inside the flight view (see fig. 12c). The menu can be hidden using the `disable WiMA` slider at it's top. A slider showing the text `enable WiMA` will remain a few seconds at the lower left corner of the flight view befor vanishing. Hovering the mouse at the lower left corner will make the slider visible again.

3.5.1 How to synchronize a Flight Plan with the WiMA Menu

See section 3.4 and especially section 3.4.11.

3.5.2 What's the Mission Section and how to use it

The mission section (see fig. 16a) is mostly used to partition the flight plan generated with WiMA plan view (see section 3.4). Additional speed and altitude can be adjusted from here. This gives the possibility to work through large flight plans (containing thousands of way-points) in a step wise manner.
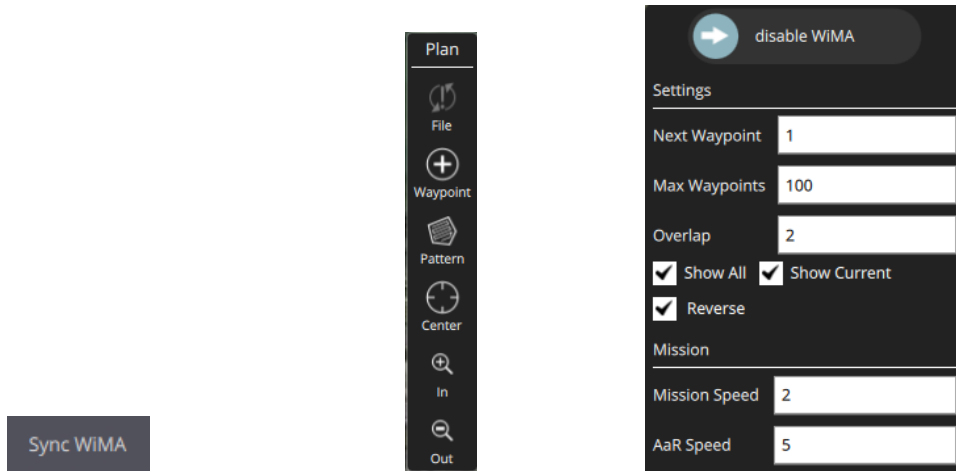
(a) Synchronize button located in the upper right corner of the WiMA plan view.

(b) Mission tool strip located at the upper left corner of the WiMA plan view.

(c) Top part of the WiMA menu located at the lower left corner of the flight view.

Figure 12: Different elements.

3.5.3 How to show the Mission Items

The mission items can be made visible/invisible by checking/unchecking the `Show Mission` check box (see fig. 16a). An example can be seen in fig. 13a and fig. 13b. The mission items consist of all items generated inside WiMA plan view without the AaR path (see section 3.5.5).

3.5.4 How to show the current Phase

The current mission items can be made visible/invisible by checking/unchecking the `Show Phase` check box (see fig. 16a). An example can be seen in fig. 13a and fig. 13c.

(a) Mission items (gray) and current phase (green) overlayed.

(b) Mission items only (`Show Phase` unchecked).

(c) Current phase only (`Show Mission` unchecked).

Figure 13: Mission Items displayed on the flight map.

3.5.5 What's the AaR Path

The abbreviation AaR means arrival and return and refers to the way-points which are not part of the actual measuring process. Those way-points are used to guide the UAV from service area to measurement area, hence the name.

3.5.6 Whats a Mission Phase

A mission phase refers to a partition of the mission items (see fig. 13b). An example of a partion can be seen in fig. 13a and fig. 13c (green way-points).

3.5.7 How to partition a flight plan

The flight plan generated with the WiMA plan view can be partitioned using the `Next Waypoint`, `Max Waypoints`, and the `Overlap` input boxes and the `Reset Phase`, `Reverse`, and `Forward` button (see fig. 16a). The entry of the `Next Waypoint` corresponds starting point of the next phase. The numbering is related to the mission items. Using the `Go Forward` or `Go Reverse` buttons increases or decreases the `Next Waypoint` value respectively (see section 3.5.9 for details). Manually editing the `Next Waypoint` value sets the first point of the current phase to the way-point of the mission item with the entered number. The number of maximum way-points per phase (AaR path excluded) can be set with the `Max Waypoints` input box.

3.5.8 What's the Overlap

The `Overlap` it a the number of way-points two consecutive phases have in common. E.g. if the `Overlap` $= 2$ and the last two way-points of phase n are 10 and 11, phase $n + 1$ will start with way-points 10 and 11 (AaR path not included).

3.5.9 What are the Go Reverse and Go Forward buttons for

The `Go Forward` or `Go Reverse` buttons are used to proceed to the next phase. The following notation will be used: the index of the first waypoint of Phase n is denoted by i_n^s and the index of the last way-point by i_n^e. The positive scalars Δ and N denote the `Overlap` (see section 3.5.8) and the maximum number of way points per phase (`Max Waypoints`, see fig. 16a). The `Go Forward` button sets start index of the next of Phase $(n + 1)$ to $i_{n+1}^s = i_n^e - \Delta + 1$ and the end index of Phase $n + 1$ to $i_{n+1}^e = i_{n+1}^s + N - 1$. A very similar result is delivered by the `Go Reverse` button. It sets the start index of the next of Phase $(n + 1)$ to $i_{n+1}^s = i_n^s + \Delta - 1$ and the end index of Phase $n + 1$ to $i_{n+1}^e = i_{n+1}^s - N + 1$. The indices are truncated, if they exceed the boundaries 1 and N.

3.5.10 What is the Reset Phase button for

The reset button sets the start way-point to the first or last mission

3.5.11 How to change Mission Flight Speed

The mission flight speed can be changed by altering the value of the `Mission Speed` input box (see fig. 16a). This affects measurement points only. The AaR path way-point speed can be altered as well (see the following section).

(a) After a smart RTL was triggered the user is asked to confirm the action by moving the slider to the right hand side.

(b) The user is asked to confirm the calculated return path.

Figure 14: Confirmation process of a smart RTL.

3.5.12 How to change AaR Speed

The AaR (see section 3.5.5) flight speed can be changed by altering the value of the `AaR Speed` input box (see fig. 16a). This affects AaR path way-points only. The measurement way-point speed can be altered as well (see the previous section).

3.5.13 How to change Altitude

The Altitude can be changed by altering the value of the `Altitude` input box (see fig. 16a). This value affects AaR path and measurement points.

3.6 Can I invert/reverse a Phase

A phase can be inverted by checking the `Invert Phase` check box (see. fig. 16a).

3.6.1 What's the Vehicle Section and how to use it

The vehicle section (see fig. 16b) is used to upload and clear the vehicle mission. Additionally this section contains the interface to trigger a smart return to launch.

3.6.2 How to upload and clear mission

Missions can be uploaded and clear using the `Upload` and `Remove` buttons (see. fig. 16b). During upload a green progress button will be displayed. After success the text `Done` will be displayed. An error message will be displayed otherwise. Successfull uploaded mission items will be colored orange.

### 3.6.3 What's Smart Return to Launch

Most return to launch (RTL) implementations choose the direct way from the vehicles current to it's takeoff position as a return path. WiMA's smart RTL algorithms chooses a return path based on the save area defined by the user (see section 3.4.2). A smart RTL can be triggered by pressing the `Smart RTL` button. As a security measure pressing this button the user will asked to confirm the action (see fig. 14a). After confirmation the vehicle will be paused at it's current position and a return path will be displayed. Again the user is asked for confirmation (see fig. 14b). On success the return path will be uploaded and executed. If configured (see section 3.6.4) a smart RTL will be triggered on low battery voltage. The confirmation procedure is the same as described above.

(a) Click the gear logo followed by the QGC logo to enter QGC settings.
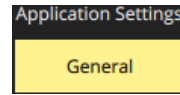
(b) Choose the general settings.
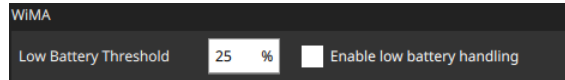
(c) The battery threshold (in percentage) below which smart RTL will be initiated can be set by altering the value of the `Low Battery Threshold` input box. The low battery handling can be enabled/disabled by checking/unchecking the `Enable low battery handling` check box.

Figure 15: How to configure WiMA smart RTL.

3.6.4 How to configure Smart Return to Launch on low Battery.

The smart RTL on low battery can be configured under general settings (see. fig. 15).

3.6.5 What's the Statistics Section and how to use it

The statistics section is the last section of the WiMA menu (see fig. 16c). It shows the length of the current mission (phase) and the estimated flight time, based on the mission speed.
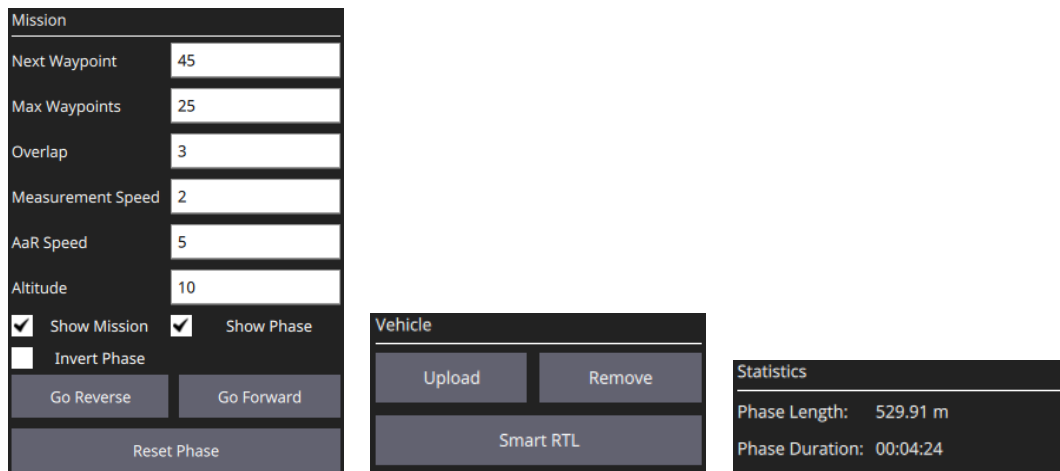
(a) The mission section of the WiMA menu.

(b) The vehicle section of the WiMA menu.

(c) The statistics section of the WiMA menu.

Figure 16: The different sections of the WiMA menu.

3.6.6 I can't find the WiMA Menu

See the introduction of section 3.5.

4 Useful third party Software

4.1 ArduPilot Simulator

For tasks like debugging, program verification or flight plan testing a UAV simulator can be very useful. It can save time, money.

For this task the ArduPilot simulator can be used. It simulates a vehicle running the ArduPilot flight stack (firmware) on your local machine. Data is being published by the simulator via UDP and should ideally connect to QGroundControl without any further tweaks.

The simulator is part of the ArduPilot project, which can be downloaded from Github: `https://github.com/ArduPilot/ardupilot`. It is recommended to fork the repository. After cloning the repository, the sub-modules must be initialized and updated. Execute the following code to do this.

```
git clone https://github.com/ArduPilot/ardupilot
cd ardupilot
git submodule init
git submodule update
```

The simulator is launched by a Python script, thus Python must be installed on your machine. The simulator can be launched from your ArduPilot root directory with the following command.

```
./Tools/autotest/sim_vehicle.py -v ArduCopter
```

Thereby the `-v` option specifies the vehicle type. The `-l` and `-L` option can be used to define a custom start location. The `-S` option increases the simulation speed. See the `sim_vehicle.py --help` option for further information. After launching, the vehicle should appear inside QGroundControl.