Montgomery County Community College

APM Mission Planner 1.2.1 –R2 Final

Research Document – G03

EGR299 Students and Engineering Faculty

2012

Table of Contents

Introduction

The ArduPilot Mega (APM) utilizes a sophisticated mission planning language. It allows users to create missions using a point-and-click ground control and waypoint planning editor.

This document consists of 4 chapters:

- The basics of the APM Mission Planner
- Designing and implementing a mission
- Text-based waypoint editing
- The full list of commands, command codes, and command parameters

The MC3 students and faculty recognize and show appreciation to Michael Oborne from Australia for developing a state of the art open source ground control program.

Warning

Please note that the autopilot and the software to control it are open source. The code that runs it is community-created and tested. It has been loaded and successfully run on many different platforms by many different people. This does not mean that the autopilot and its software are fool-proof. Read all literature pertaining to the quad and its software before flying. While flying always use caution and follow all safety procedures. Also note that this document is written for the ArduCopter 2.7 firmware and the APM Mission Planner 1.2.1. Older versions of the firmware and of the Mission Planner are not supported. Newer versions may correct some bugs and add/or new ones, update the ArduCopter and/or the APM Mission Planner at your own risk.

Credits

The EGR299 class students

Aaron Wilz
Daniel Rowe
Jason Cassel
Jacob Simon
Kevin Healy
Michael Marino
Michelle Gavan
Scot Kantner
William Fellmeth

The engineering faculty

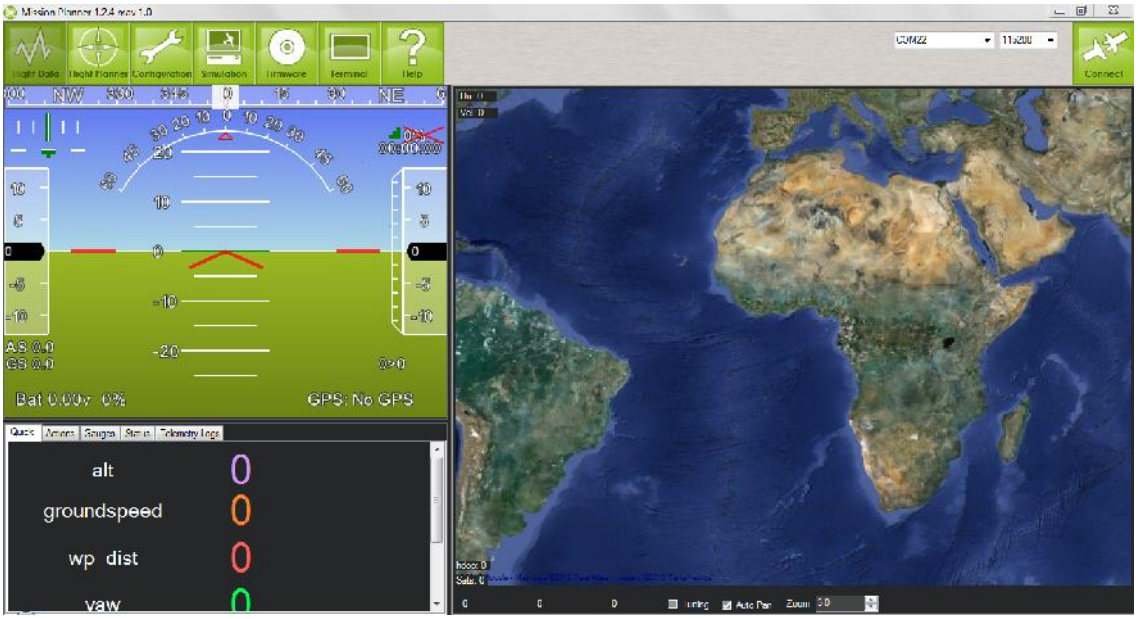
Andrew Ippolito
Bill Brownlowe
Jean-Jacques Reymond

THIS PAGE BLANK

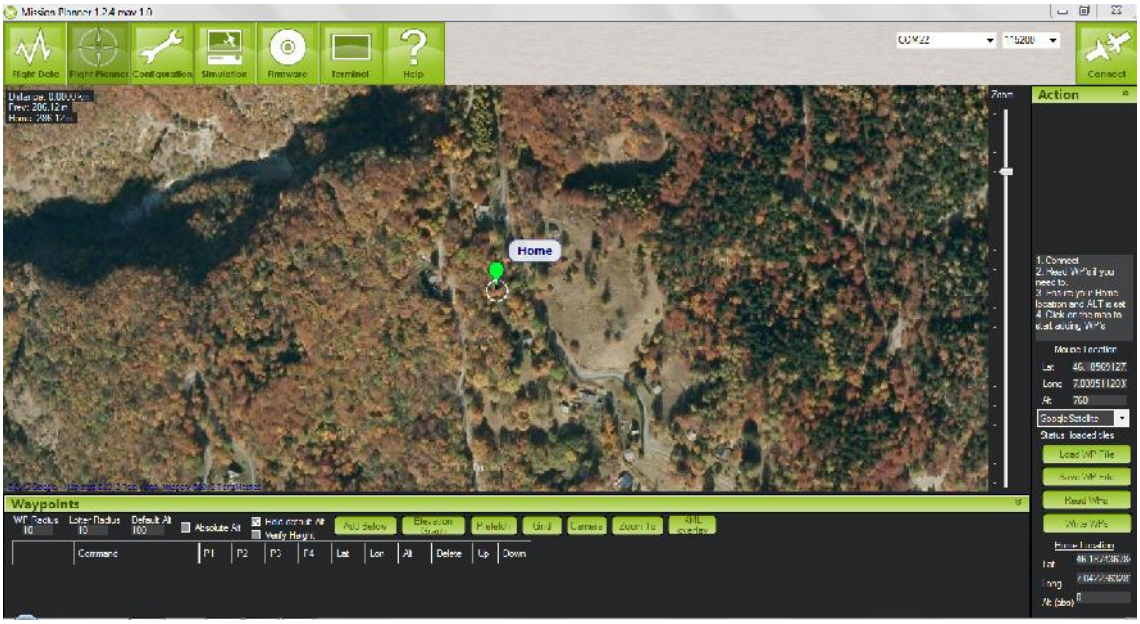
Chapter 1 – The basics of the APM Mission Planner

Using the Mission Planner as a Waypoint Editor

Open the Mission Planner.



Click on the “Flight Planner” tab on the top of the screen. This will open a screen that looks like the screenshot below:



Now you can enter waypoints and other commands. See the Commands section in Chapter 4 for the full list. You can add commands to the command list in four ways:

- ***Left clicking*** on the map will create a waypoint using the GPS coordinates of the mouse
- ***Right clicking*** on the map will bring up a list of commands
- ***Clicking on the "Add Below"*** button found underneath the map
- ***Loading a waypoint file*** using the "Load WP File" button to the right of the map

If waypoints do not appear on the map click the "Add Below" button to create a new waypoint. This should make the waypoints appear on the map. Make sure to delete the newly created waypoint if you are not using it.

In the dropdown menus on each row, select the command you want. The column headings will change to show you what data that command requires. All columns without headings should have a value of 0. Note that altitude is relative to your launch altitude, so if you set 100, for example, it will fly 100m above your present position.

Default Alt is the default altitude when entering new waypoints. As of ArduCopter version 2.7 and Mission Planner version 1.2.1 this button does not set a default altitude. You must set an altitude for all commands that ask for one. Despite this, we suggest that the **"Hold default Alt"** checkbox remain checked as it helps with mission performance.

Having the **"Verify Height"** checkbox checked makes the Mission Planner use Google Earth topology data to adjust your desired altitude at each waypoint to reflect the height of the ground beneath. So if your waypoint is on a hill and if this option is selected, the Mission Planner will increase your ALT setting by the height of the hill. Keep this box checked, but do not trust that this feature will keep the quad from crashing into a mountain. Always manually put the altitude of the waypoints well above the height of any terrain features it could encounter.

The **"Absolute Altitude"** checkbox in the Mission Planner is ignored. ArduCopter uses only relative altitudes.

Once at the takeoff location, connect to the quad and ensure that the GPS on the quad is locked in for, at least, a minute[1]. The delay is for the GPS to acquire the maximum number of satellites. Click on the underlined Home Location in the bottom right corner of the Flight Planner tab to set the home location of the quad. Do this before every mission as the TAKEOFF command uses the home location as its location for takeoff. With this complete, select "Write" and the mission will be sent to the APM and saved in EEPROM. You can confirm that the mission was written by selecting "Read".

When reading the mission from the quad, you will be asked if you want to reset the home location. Click yes, but do not use this saved Home Location as the true location of the quad. Always click on home location to obtain the true location of the quad.

[1] In the Mission Planner's Flight Data tab it will say "3D Fix".

You can also enter commands by right clicking on the satellite map. This brings up a list of commands: Delete Waypoint, Loiter, Jump, Create Wp Circle, Measure Distance, Rotate Map, Draw Polygon, Geo-Fence, and Clear Mission. **Delete Waypoint** will delete the waypoint your courser is currently over. **Loiter** and **Jump** follow the same parameters as the commands of the same name. **Create WP Circle** will create a circle of waypoints around the current cursor position with the ability to enter the radius of the circle and the number of waypoints comprising it. **Measure Distance** will measure the distance between two cursor locations; you must select Measure Distance at both locations to get a reading. **Rotate Map** will rotate the satellite map to a given degree. **Draw Polygon** and **Geo-Fence** have not been tested; use at your own risk. **Clear Mission** will clear all commands.

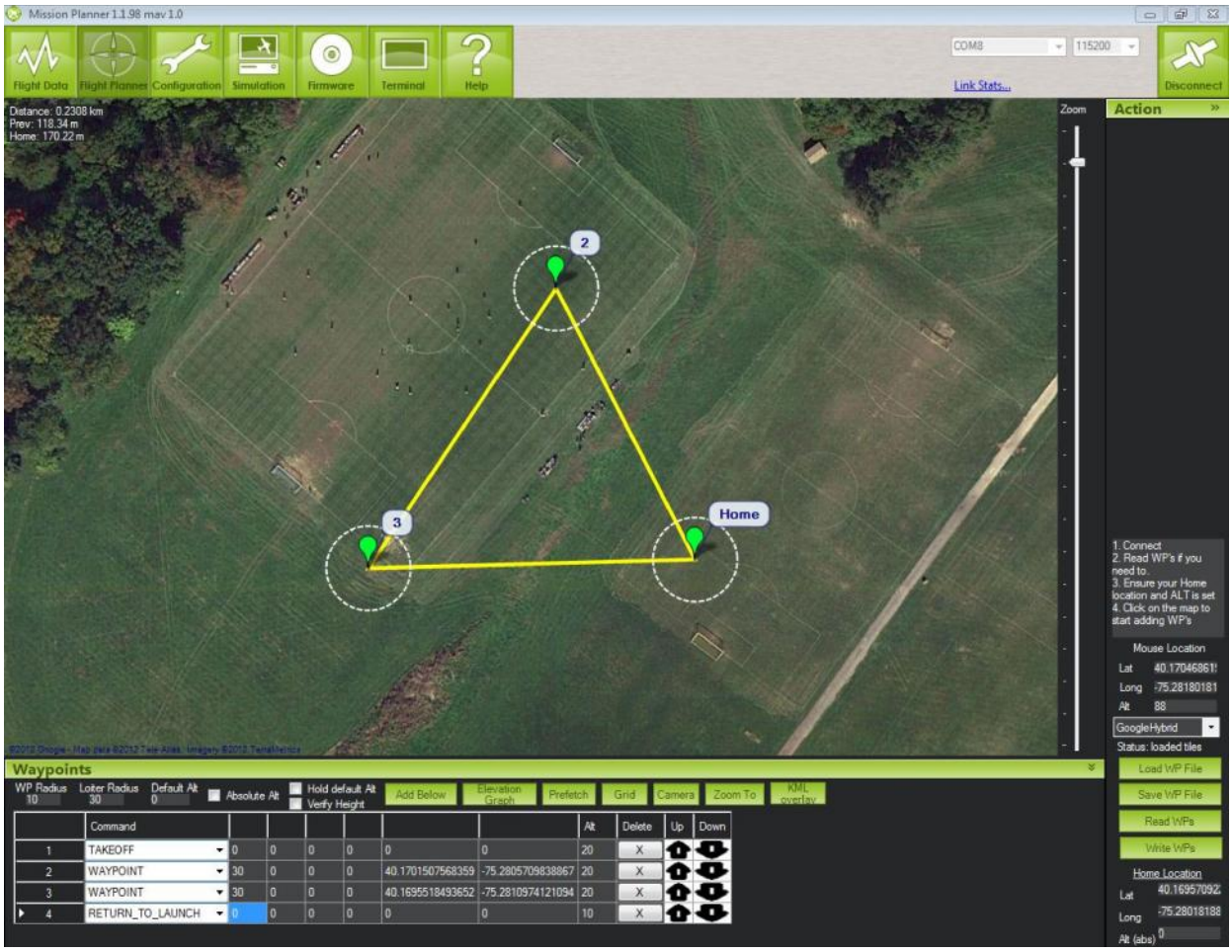
You can save multiple mission files to your local hard drive by selecting “Save WP File” or read in files by selecting “Load WP File”.

THIS PAGE BLANK

Chapter 2 – Designing and implementing a mission

In the screenshot below, the yellow lines between the waypoints are the path that the quad will try to follow. The dotted lines around the waypoints are the radii of the waypoints. The size of the radius is determined by the waypoint radius [**WP Radius**]. It is possible to set the waypoint radius to as little as 1m, but it is not suggested because of the difficulty in maintaining such a tight hover in wind. We have our waypoint radius set to 10m. This means that the time delay at waypoint 2 will start when the quad's GPS tells it that it is 10m away from waypoint 2. The **Loiter Radius** is the radius of the circle the quad will trace out when loitering with the LOITER_TURNS command, this circle is not shown in the Mission Planner. We have ours set to 30m, but we do not use the LOITER_TURNS feature.

Note: Do not use the command LOITER_TURNS. Every test run with LOITER_TURNS ended in an out of control quad.



The screenshot above also shows the command list for the test mission that we ran. The quad was told to takeoff to 20m, fly to the GPS coordinates of waypoint 2 at 20m, wait at waypoint 2 for 30 seconds at 20m, fly to waypoint 3 at 20m, wait at waypoint 3 for 30 seconds at 20m, return to launch (home)

location at 10m, and land. This mission was designed to simulate environmental stations at waypoints 2 and 3 that required 30 seconds to download their information.

As of ArduCopter version 2.7 you need to put the LAND command after the RETURN_TO_LAUNCH command for the quad to land. If you do not, the quad will change into LOITER mode once it has returned to home. The screenshot above does not show the LAND command. If you ran the mission above without the LAND command, the quad would change into LOITER mode when it returned to home.

We dropped the altitude parameter of the RETURN_TO_LAUNCH command because we were operating in an open field. If there had been any obstacles between waypoint 3 and the home location, we would have kept the altitude at 20m higher than any obstacle.

All commands are interpreted by the Mission Planner as waypoints. Therefore, when running the mission, the Mission Planner will say "Heading to Waypoint 4." This means that the RETURN_TO_LAUNCH command is being executed; not that the quad is going to an unmarked waypoint.

As you can see in the satellite image in the screenshot above, our waypoints are far from the trees. This is because the quad can be easily blown off course by the wind. It will eventually auto-correct its course, but it is safest to place the waypoints as far from obstacles as possible. This is also why setting the altitude above the trees, even when running missions in an open field, is strongly suggested.

With the mission area defined and the mission planned and written to the quad, it is time to save the satellite images of the mission area. To do this find the mission area in the Flight Planner tab on the tablet, zoom in to the desired resolution and click green the Prefetch button located between the satellite image and the command list. The Mission Planner will save the pictured satellite images to the Acer tablet's solid state disk. You may have to do this multiple times based on the size of mission and the resolution desired. When in the field, the Mission Planner will automatically pull up the saved images.

It is possible to plan a complete mission in the field if the Acer tablet can connect to the internet, as it needs the resource to pull up satellite images to effectively plan the mission. If you already have the satellite images saved or know the location of your waypoints, an internet connection is not required.

With the mission planned, images saved, and pre-flight checks complete, it is time to head to the field. When in the field the first thing to do is a quick manual test flight to make sure everything is working correctly.

Turn on the Spektrum radio, plug in the quad, connect to the mission planner, and do a quick test flight. If anything is wrong, DO NOT run the mission! With everything working properly, place the quad at its takeoff location and wait for it to acquire GPS. The quad has a GPS lock when, with the Flight Data tab selected, the Mission Planner says GPS:3D Lock, it should take a minute for the GPS to get a lock.

When the quad has GPS lock for at least a minute, go into the Flight Planner tab and hit Home Location in the lower right, then write the mission to the quad again. Now, disarm the quad in manual mode, switch to auto mode, and quickly push the throttle all the way up. The quad should take off and run the pre-programmed mission. Keep the throttle at full for the entirety of the mission. When the quad is landing and is shoulder height from the ground, begin to slowly pull back on the throttle. When the

quad touches down, drop the throttle all the way to off and switch to manual. The mission is now complete.

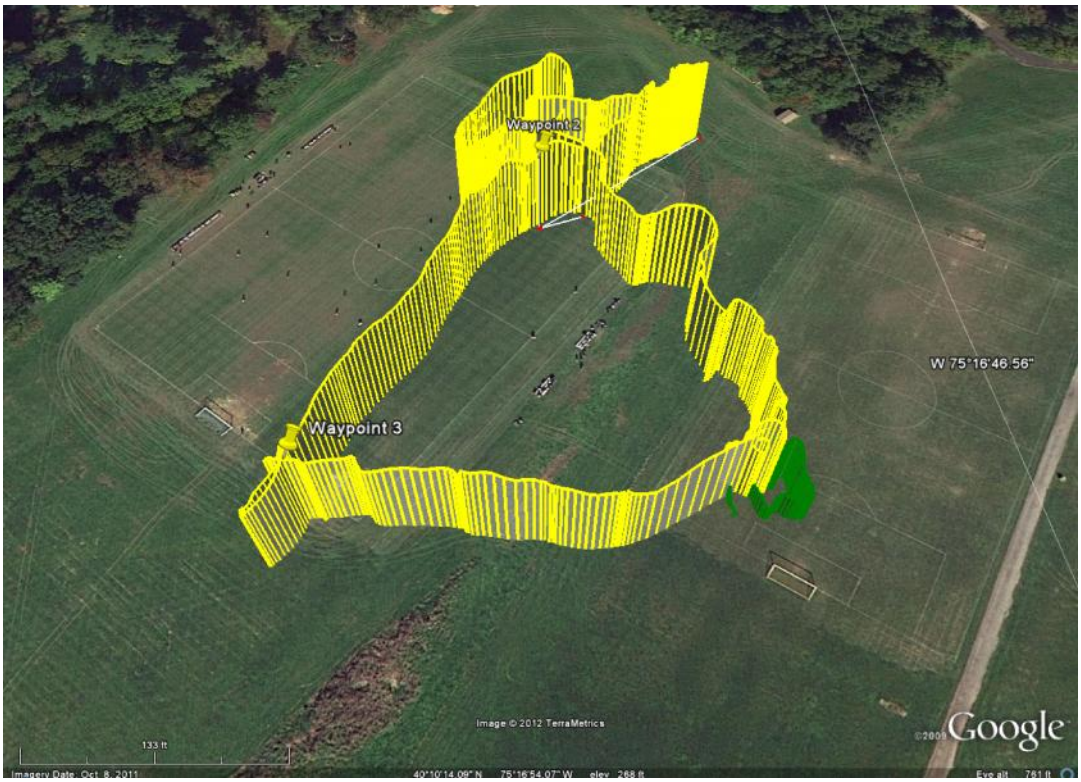
In Case of Emergency

In case of emergency, take control of the quad by switching it into manual mode from the remote control. If you cannot take control of the quad using the remote control, get closer to it. There is a chance that the radio signal is being interfered with.

If the quad is out of control, we suggest that you land it immediately in an open spot. Do not try to fly the quad back to you.

An implemented mission

The screenshot below is a Google Earth representation of the above mission's test flight. The yellow is the auto mission and the green is the landing. From waypoint 2 there are two white lines. The shorter line is the radius of the waypoint (10m). When the quad hits this radius it begins to delay for 30 seconds at 10m from the waypoint. It is then blown by wind, which reached +15km/h, to 48m away from the waypoint (38m away from the waypoint radius). From there it travels to waypoint 3 and delays for 30 seconds in a tighter pattern than for waypoint 2 (wind had lessened).The quad than returns to its home location and lands approximately 9m from its takeoff position.



These variations in flight pattern are normal. The quad is very susceptible to wind and as such should be flown clear of obstacles (cliffs, radio towers, buildings, etc.) even when there is not much wind.

Chapter 3 – Text-based waypoint editing

The Mission Planner stores saved missions as text files. The screenshot below shows the text file for the above mission. Note that for your mission you must put a LAND command after the RETURN_TO_LAUNCH command.

```
QGC WPL 110
0       1       0       16      0       0       0       0       40.169571       -75.280182      0       1
1       0       3       22      0       0       0       0       0       0       20      1
2       0       3       16      30      0       0       0       40.170151       -75.280571      20      1
3       0       3       16      30      0       0       0       40.169552       -75.281097      20      1
4       0       3       20      0       0       0       0       0       0       10      1
```

To make the text file easier to read we have put it into a table and added descriptions of all the columns:

QGC WPL 110	(Title)										
Command Number	1=Home Location 0=Command	3=Command 0=Home Location	Command Code	P1	P2	P3	P4	Latitude	Longitude	Altitude	1=Active Command
0	1	0	16	0	0	0	0	40.16957	-75.28018	0	1
1	0	3	22	0	0	0	0	0	0	20	1
2	0	3	16	30	0	0	0	40.17015	-75.28057	20	1
3	0	3	16	30	0	0	0	40.16955	-75.2811	20	1
4	0	3	20	0	0	0	0	0	0	10	1

If you choose to write a mission in a text file, separate your columns with the <Tab> key. To load your text file to the quad you have to load it into the Mission Planner and hit the “Write” button in the right side bar.

If you decide to write a mission in a text file double check it in the Mission Planner for errors before flying. The Home Location is always Command Number 0.

THIS PAGE BLANK

Chapter 4 – The full list of commands, command codes, and command parameters

As per APM Mission Planner 1.2.1 and ArduCopter 2.7.

Commands

Note 1: All N/A parameters should be set to 0.

Note 2: CC = Command Code number

WAYPOINT

P1	*P2*	*P3*	*P4*	*Lat*	*Lon*	*Alt*
Delay (s)	Hit Radius **NOT TESTED**	N/A	Yaw Angle **NOT TESTED**	Latitude	Longitude	Altitude in meters

- Mavlink command is NAV_WAYPOINT.
- Delay option is triggered after the craft reaches the waypoint radius. The Next command is loaded after the delay.
- Delay time is in seconds, the default is 0.
- CC: 16.

[Waypoint Option Bitmask - not yet available in the Mission Planner 1.2.1]

bit 0	Altitude is stored	0: Absolute	1: Relative
bit 1	Change Alt between WP	0: Gradually	1: ASAP
bit 2			
bit 3	Requires to hit WP.alt to continue	0: No	1: Yes
bit 4	Relative to Home	0: No	1: Yes
bit 5			
bit 6			
bit 7	Move to next Command	0: YES	1: Loiter until commanded

LOITER_UNLIM

P1	*P2*	*P3*	*P4*	*Lat*	*Lon*	*Alt*
N/A	N/A	N/A	N/A	Latitude	Longitude	Altitude in meters

- Will cause the craft to begin to loiter at the current location when the command is invoked if Lat and Lon are not specified. **Has not been tested with values for Lat and Lon.**
- Alt has always been kept at the same as waypoint loitering at. **Has not been tested with a higher or lower altitude than the preceding waypoint(s).**
- CC: 17.

LOITER_TIME

P1	*P2*	*P3*	*P4*	*Lat*	*Long*	*Alt*
Time in seconds	N/A	Radius NOT T**ESTED**	Yaw per **NOT TESTED**	N/A	N/A	N/A

- Will cause the craft to begin to loiter at the current location for the time specified when the command is invoked.
- All tests have shown this to be equivalent to setting a delay on a waypoint.
- CC: 19.

LOITER_TURNS

P1	*P2*	*P3*	*P4*	*Lat*	*Lon*	*Alt*
Number of turns (N x 360°)	N/A	N/A	N/A	N/A	N/A	N/A

- Will cause the craft to begin to orbit the current location when the command is invoked if Lat and Lon are set to 0. **Has not been tested with values for Lat and Lon.**
- Alt has always been kept at the same as waypoint loitering at**. Has not been tested with higher of lower altitude.**
- Every test of LOITER_TURNS has resulted in an out of control quad. We strongly suggest that you do not use this command.
- CC: 18.

RETURN_TO_LAUNCH

P1	P2	P3	P4	Lat	Lon	Alt
N/A	N/A	N/A	N/A	N/A	N/A	Altitude in meters

- This command is the suggested second to last command for all missions because it couples the landing and takeoff commands which allows for the landing position to be dynamically set to the landing position.
- If you are not landing at your takeoff location see LAND below.
- Will cause the craft to return to the home position set when the craft was armed or when the home location was set in the Mission Planner (requires GPS Lock).
- If landing at the home location put the LAND command after this one. If you do not the quad will loiter at the home location
- CC: 20.

LAND

P1	*P2*	*P3*	*P4*	*Lat*	*Lon*	*Alt*
N/A	N/A	N/A	N/A	N/A	N/A	N/A

- Will cause the craft to land at the current location when the command is invoked.
- If landing without using the RETURN_TO_LAUNCH command put a waypoint at your landing location with a 5 second delay and then put the LAND command.
- When the command is invoked the Mission Planner will say “Heading to waypoint <extremely large number>” this is normal.
- Allow an 11 meter landing radius for quad to descend from altitude.
- The motors will not stop in Auto mode, you must drop the throttle stick and change to manual to cut the engines.
- CC: 21.

TAKEOFF

P1	*P2*	*P3*	*P4*	*Lat*	*Lon*	*Alt*
N/A	N/A	N/A	N/A	N/A	N/A	Altitude in meters

- Will cause the craft to take off and hold position until the altitude is reached.
- Make sure throttle is all the way up.
- Home Location must be set before takeoff.
- Allow an 11 meter takeoff radius for quad to reach specified altitude.
- If takeoff radius cannot be achieved you can takeoff manually than switch into auto in flight. If you do this, proceed as usual in planning the mission but do not load the TAKEOFF command into the quad. Also, beware of the LAND command if taking off in this way. Once the quad has returned to the Home Location there is a large chance you will have to take control of the quad to land it as well. We DO NOT suggest you manually takeoff and land, instead look for a better Home Location.
- CC: 22.

ROI

P1	*P2*	*P3*	*P4*	*Lat*	*Lon*	*Alt*
N/A	N/A	N/A	N/A	N/A	N/A	N/A

- **This feature is untested. Use at your own risk.**
- CC: 80.

PATHPLANNING

P1	*P2*	*P3*	*P4*	*Lat*	*Lon*	*Alt*
N/A	N/A	N/A	N/A	N/A	N/A	N/A

- **This feature is untested. Use at your own risk.**
- CC: 81.

CONDITION_DELAY

P1	*P2*	*P3*	*P4*	*Lat*	*Lon*	*Alt*
Time in seconds	N/A	N/A	N/A	N/A	N/A	N/A

- **This feature is untested. Use at your own risk.**
- Will delay the execution of the next conditional command.
- CC: 112.

CONDITION_DISTANCE

P1	*P2*	*P3*	*P4*	*Lat*	*Lon*	*Alt*
Distance in meters	N/A	N/A	N/A	N/A	N/A	N/A

- **This feature is untested. Use at your own risk.**
- CC: 114.

CONDITION_CHANGE_ALT

P1	*P2*	*P3*	*P4*	*Lat*	*Lon*	*Alt*
Rate in cm/s	N/A	N/A	N/A	N/A	N/A	Altitude in meters

- **This feature is untested. Use at your own risk.**
- Will override the next waypoint altitude
- Useful when used after a delay or distance conditional command
- CC: 113.

CONDITION_YAW

P1	*P2*	*P3*	*P4*	*Lat*	*Lon*	*Alt*
Degrees of turn	Seconds of turn	Direction (1=CW)	Rel/abs	N/A	N/A	N/A

- **This feature is untested. Use at your own risk.**
- Fine grain controls of the Yaw.
- CC: 115.

DO_SET_MODE

P1	*P2*	*P3*	*P4*	*Lat*	*Lon*	*Alt*
N/A	N/A	N/A	N/A	N/A	N/A	N/A

- **This feature is untested. Use at your own risk.**
- Not Implemented.
- CC: 176.

DO_JUMP

P1	*P2*	*P3*	*P4*	*Lat*	*Lon*	*Alt*
WP#	Repeat	N/A	N/A	N/A	N/A	N/A

- WP# is the number that you wish to jump to. If DO_JUMP is command 3 and you wish to skip command 4 set WP# to 5.
- Repeat is the number of times DO_JUMP will execute. 1 Repeat means that DO_JUMP will execute twice. **This has not been tested.**
- When you are using the Jump command, remember that waypoint logic can be a bit confusing. A waypoint command means “start heading to this WP”, not “wait until you get to this WP.” So, for example, if you put a “Jump to WP1” command in-between WP4 and WP5, the quad will never get to WP5. That's because once it starts heading in the direction of WP5, it then executes the next command, which is the jump, and that takes priority. So in that instance, if you want the quad to hit WP5, you'd create a WP6 and issue the Jump command after that.
- CC: 177.

DO_CHANGE_SPEED

P1	*P2*	*P3*	*P4*	*Lat*	*Lon*	*Alt*
Speed in m/s	N/A	N/A	N/A	N/A	N/A	N/A

- Changes the speed the quad moves between waypoints.
- Speed change will stick until reset.
- CC: 178.

DO_SET_HOME

P1	*P2*	*P3*	*P4*	*Lat*	*Lon*	*Alt*
Current (1) / Spec (0)	N/A	N/A	N/A	N/A	N/A	N/A

- **This feature is untested. Use at your own risk.**
- CC: 181.

DO_SET_PARAMETER

P1	*P2*	*P3*	*P4*	*Lat*	*Lon*	*Alt*
#	Value	N/A	N/A	N/A	N/A	N/A

- **This feature is untested. Use at your own risk.**
- CC: 182.

DO_SET_RELAY

P1	*P2*	*P3*	*P4*	*Lat*	*Lon*	*Alt*
1=on, 0=off, -1=toggle	Delay in seconds	N/A	N/A	N/A	N/A	N/A

- **This feature is untested. Use at your own risk.**
- Toggling the Relay will turn an off relay on and vice versa.
- CC: 183.

DO_REPEAT_RELAY

P1	*P2*	*P3*	*P4*	*Lat*	*Lon*	*Alt*
N/A	# of repetitions	Delay in seconds	N/A	N/A	N/A	N/A

- **This feature is untested. Use at your own risk.**
- Toggling the Relay will turn an off relay on and vice versa.
- CC: 184.

DO_SET_SERVO

P1	*P2*	*P3*	*P4*	*Lat*	*Lon*	*Alt*
Servo channels (1-8)	PWM (1000-2000)	N/A	N/A	N/A	N/A	N/A

- **This feature is untested. Use at your own risk.**
- There are no servos on the shipped quads.
- CC: 179.

DO_REPEAT_SERVO

P1	*P2*	*P3*	*P4*	*Lat*	*Lon*	*Alt*
Servo channels (5-8)	PWM (1000-2000)	# of repetitions	Delay (seconds)	N/A	N/A	N/A

- **This feature is untested. Use at your own risk.**
- There are no servos on the shipped quads.
- CC: 180.

DO_DIGICAM_CONFIGURE

P1	*P2*	*P3*	*P4*	*Lat*	*Lon*	*Alt*
N/A	N/A	N/A	N/A	N/A	N/A	N/A

- **This feature is untested. Use at your own risk.**
- There are no cameras on the shipped quads.
- CC: 202.

DO_DIGICAM_CONTROL

P1	*P2*	*P3*	*P4*	*Lat*	*Lon*	*Alt*
N/A	N/A	N/A	N/A	N/A	N/A	N/A

- **This feature is untested. Use at your own risk.**
- There are no cameras on the shipped quads.
- CC: 203.

DO_MOUNT_CONFIGURE

P1	*P2*	*P3*	*P4*	*Lat*	*Lon*	*Alt*
N/A	N/A	N/A	N/A	N/A	N/A	N/A

- **This feature is untested. Use at your own risk.**
- There are no mounts on the shipped quads.
- CC: 204.

DO_MOUNT_CONTROL

P1	*P2*	*P3*	*P4*	*Lat*	*Lon*	*Alt*
N/A	N/A	N/A	N/A	N/A	N/A	N/A

- **This feature is untested. Use at your own risk.**
- CC: 205.

GeoFence

GeoFence is part of the Arducopter 2.7 code that will keep the quad "fenced in". The idea is to create a GPS fence, actually a cube, that once breached by the quad will make the quad fly back to a predetermined point[2].

This feature of code only recently became available and, as such, we haven't had time to adequately test it. We do not suggest trying to use this feature without further testing.

[2] More information here:
http://www.diydrones.com/profiles/blog/show?id=705844%3ABlogPost%3A846713&commentId=705844%3AComment%3A847260


Montgomery County
Community College