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Programme	:	**B.TECH**	Semester	:	**WIN-22-23**
Course	:	**Drone Applications, Components and Assembly**	Code	:	**CSE2040**
Faculty	:	**Dr Muthu Manikandad**	Slot	:	**L43+L44**

NAME: GEORGE MATHEW **REG_NO:** 20BRS1176

Ex. No. 6

Date: 04.04.2023

LAB-6:

Question 1. Python program for Model predictive control using CasADI library:

```
[Running] python -u "/home/kailash/Desktop/lab6_1.py"

******************************************************************************
This program contains Ipopt, a library for large-scale nonlinear optimization.
 Ipopt is released as open source code under the Eclipse Public License (EPL).
         For more information visit https://github.com/coin-or/Ipopt
******************************************************************************

This is Ipopt version 3.14.11, running with linear solver MUMPS 5.4.1.

Number of nonzeros in equality constraint Jacobian...:       42
Number of nonzeros in inequality constraint Jacobian.:       10
Number of nonzeros in Lagrangian Hessian.............:       20

Total number of variables............................:       17
                     variables with only lower bounds:        0
                variables with lower and upper bounds:        0
                     variables with only upper bounds:        0
Total number of equality constraints.................:       12
Total number of inequality constraints...............:       10
        inequality constraints with only lower bounds:        5
   inequality constraints with lower and upper bounds:        0
        inequality constraints with only upper bounds:        5

iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du alpha_pr  ls
   0  1.2000000e+00 0.00e+00 7.37e-01  -1.0 0.00e+00    -  0.00e+00 0.00e+00   0
   1  3.3091670e-01 1.11e-16 1.93e-01  -1.7 7.22e-01    -  8.37e-01 1.00e+00f  1
   2  3.2274534e-01 1.11e-16 2.00e-07  -1.7 3.68e-02    -  1.00e+00 1.00e+00f  1
   3  3.2269431e-01 1.11e-16 1.50e-09  -3.8 3.14e-03    -  1.00e+00 1.00e+00f  1
   4  3.2269430e-01 2.78e-17 1.84e-11  -5.7 4.15e-05    -  1.00e+00 1.00e+00h  1
   5  3.2269430e-01 5.55e-17 2.51e-14  -8.6 9.66e-08    -  1.00e+00 1.00e+00h  1
```

```
Number of iterations..... 5

                                   (scaled)                 (unscaled)
Objective...............:   3.2269430051813469e-01    3.2269430051813469e-01
Dual infeasibility......:   2.5059035640133008e-14    2.5059035640133008e-14
Constraint violation....:   5.5511151231257827e-17    5.5511151231257827e-17
Variable bound violation:   0.0000000000000000e+00    0.0000000000000000e+00
Complementarity.........:   2.5061070880374509e-09    2.5061070880374509e-09
Overall NLP error.......:   2.5061070880374509e-09    2.5061070880374509e-09


Number of objective function evaluations             = 6
Number of objective gradient evaluations             = 6
Number of equality constraint evaluations            = 6
Number of inequality constraint evaluations          = 6
Number of equality constraint Jacobian evaluations   = 6
Number of inequality constraint Jacobian evaluations = 6
Number of Lagrangian Hessian evaluations             = 5
Total seconds in IPOPT                               = 0.075

EXIT: Optimal Solution Found.
      solver  :   t_proc      (avg)   t_wall      (avg)    n_eval
       nlp_f  |  64.00us ( 10.67us)  63.41us ( 10.57us)         6
       nlp_g  |  77.00us ( 12.83us)  72.88us ( 12.15us)         6
  nlp_grad_f  |  79.00us ( 11.29us)  78.73us ( 11.25us)         7
  nlp_hess_l  |  60.00us ( 12.00us)  58.02us ( 11.60us)         5
   nlp_jac_g  | 271.00us ( 38.71us) 819.81us (117.12us)         7
       total  |  40.24ms ( 40.24ms)  95.43ms ( 95.43ms)         1
This is Ipopt version 3.14.11, running with linear solver MUMPS 5.4.1.

Number of nonzeros in equality constraint Jacobian...:       42
Number of nonzeros in inequality constraint Jacobian.:       10
Number of nonzeros in Lagrangian Hessian.............:       20

Total number of variables............................:       17
                     variables with only lower bounds:        0
                variables with lower and upper bounds:        0
```

```
Number of objective function evaluations             = 7
Number of objective gradient evaluations             = 7
Number of equality constraint evaluations            = 7
Number of inequality constraint evaluations          = 7
Number of equality constraint Jacobian evaluations   = 7
Number of inequality constraint Jacobian evaluations = 7
Number of Lagrangian Hessian evaluations             = 6
Total seconds in IPOPT                               = 0.003

EXIT: Optimal Solution Found.
      solver  :   t_proc      (avg)   t_wall      (avg)    n_eval
       nlp_f  |  33.00us (  4.71us)  31.91us (  4.56us)         7
       nlp_g  |  37.00us (  5.29us)  33.60us (  4.80us)         7
  nlp_grad_f  |  40.00us (  5.00us)  39.83us (  4.98us)         8
  nlp_hess_l  |  42.00us (  7.00us)  41.10us (  6.85us)         6
   nlp_jac_g  |  55.00us (  6.88us)  55.30us (  6.91us)         8
       total  |   3.21ms (  3.21ms)   3.21ms (  3.21ms)         1
This is Ipopt version 3.14.11, running with linear solver MUMPS 5.4.1.

Number of nonzeros in equality constraint Jacobian...:       42
Number of nonzeros in inequality constraint Jacobian.:       10
Number of nonzeros in Lagrangian Hessian.............:       20

Total number of variables............................:       17
                     variables with only lower bounds:        0
                variables with lower and upper bounds:        0
                     variables with only upper bounds:        0
Total number of equality constraints.................:       12
Total number of inequality constraints...............:       10
        inequality constraints with only lower bounds:        5
   inequality constraints with lower and upper bounds:        0
        inequality constraints with only upper bounds:        5

iter    objective    inf_pr   inf_du lg(mu)  ||d||  lg(rg) alpha_du alpha_pr  ls
   0  1.6159725e+00 7.03e-01 5.65e-01   1.0 0.00e+00        0.00e+00 0.00e+00   0
```

```
Number of Iterations....: 6

                                   (scaled)                 (unscaled)
Objective...............:   3.2269430051813480e-01    3.2269430051813480e-01
Dual infeasibility......:   2.5059035640133008e-14    2.5059035640133008e-14
Constraint violation....:   1.1102230246251565e-16    1.1102230246251565e-16
Variable bound violation:   0.0000000000000000e+00    0.0000000000000000e+00
Complementarity.........:   2.5061004443245525e-09    2.5061004443245525e-09
Overall NLP error.......:   2.5061004443245525e-09    2.5061004443245525e-09


Number of objective function evaluations             = 7
Number of objective gradient evaluations             = 7
Number of equality constraint evaluations            = 7
Number of inequality constraint evaluations          = 7
Number of equality constraint Jacobian evaluations   = 7
Number of inequality constraint Jacobian evaluations = 7
Number of Lagrangian Hessian evaluations             = 6
Total seconds in IPOPT                               = 0.004

EXIT: Optimal Solution Found.
      solver  :   t_proc      (avg)   t_wall      (avg)    n_eval
       nlp_f  |  39.00us (  5.57us)  37.47us (  5.35us)         7
       nlp_g  |  40.00us (  5.71us)  37.91us (  5.42us)         7
  nlp_grad_f  |  63.00us (  7.88us)  60.68us (  7.59us)         8
  nlp_hess_l  |  45.00us (  7.50us)  43.74us (  7.29us)         6
   nlp_jac_g  |  63.00us (  7.88us)  62.65us (  7.83us)         8
       total  |   3.42ms (  3.42ms)   4.26ms (  4.26ms)         1
This is Ipopt version 3.14.11, running with linear solver MUMPS 5.4.1.

Number of nonzeros in equality constraint Jacobian...:       42
Number of nonzeros in inequality constraint Jacobian.:       10
Number of nonzeros in Lagrangian Hessian.............:       20

Total number of variables............................:       17
                     variables with only lower bounds:        0
```

```
   0  2.3639464e+00 2.34e+00 1.16e+00  -1.0 0.00e+00    -  0.00e+00 0.00e+00   0
   1  3.7148939e-01 3.33e-16 2.10e-01  -1.0 8.52e-01    -  8.25e-01 1.00e+00f  1
   2  3.2324261e-01 5.55e-17 2.00e-07  -1.7 2.14e-01    -  1.00e+00 1.00e+00f  1
   3  3.2269470e-01 1.11e-16 2.83e-08  -2.5 2.70e-02    -  1.00e+00 1.00e+00f  1
   4  3.2269430e-01 1.11e-16 1.50e-09  -3.8 6.59e-04    -  1.00e+00 1.00e+00f  1
   5  3.2269430e-01 1.11e-16 1.84e-11  -5.7 9.17e-06    -  1.00e+00 1.00e+00h  1
   6  3.2269430e-01 1.11e-16 2.51e-14  -8.6 9.54e-08    -  1.00e+00 1.00e+00h  1

Number of Iterations....: 6

                                   (scaled)                 (unscaled)
Objective...............:   3.2269430051813480e-01    3.2269430051813480e-01
Dual infeasibility......:   2.5059035640133008e-14    2.5059035640133008e-14
Constraint violation....:   1.1102230246251565e-16    1.1102230246251565e-16
Variable bound violation:   0.0000000000000000e+00    0.0000000000000000e+00
Complementarity.........:   2.5061004443245525e-09    2.5061004443245525e-09
Overall NLP error.......:   2.5061004443245525e-09    2.5061004443245525e-09


Number of objective function evaluations             = 7
Number of objective gradient evaluations             = 7
Number of equality constraint evaluations            = 7
Number of inequality constraint evaluations          = 7
Number of equality constraint Jacobian evaluations   = 7
Number of inequality constraint Jacobian evaluations = 7
Number of Lagrangian Hessian evaluations             = 6
Total seconds in IPOPT                               = 0.019

EXIT: Optimal Solution Found.
      solver  :   t_proc      (avg)   t_wall      (avg)    n_eval
       nlp_f  |  47.00us (  6.71us)  47.45us (  6.78us)         7
       nlp_g  |  60.00us (  8.57us)  55.93us (  7.99us)         7
  nlp_grad_f  | 159.00us ( 19.87us) 387.68us ( 48.46us)         8
  nlp_hess_l  |  80.00us ( 13.33us)  77.95us ( 12.99us)         6
   nlp_jac_g  |  89.00us ( 11.12us)  91.00us ( 11.38us)         8
       total  |   4.67ms (  4.67ms)  19.63ms ( 19.63ms)         1
```

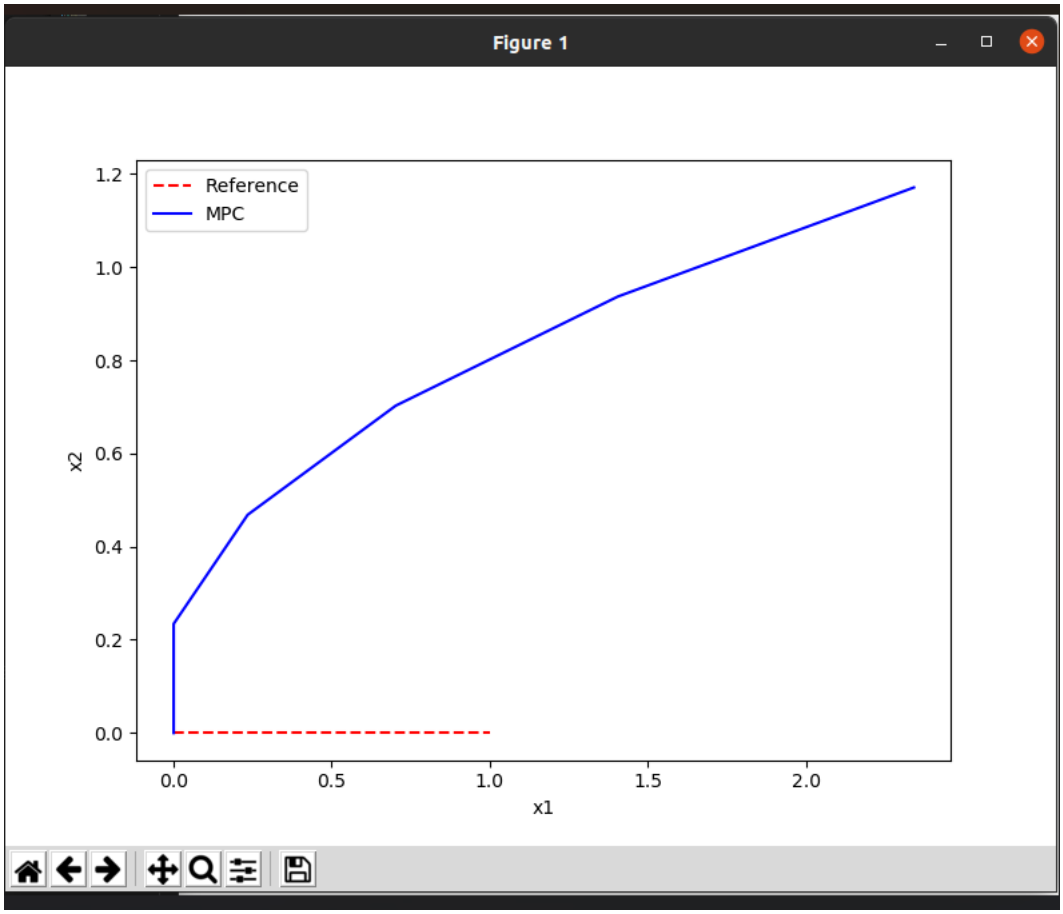
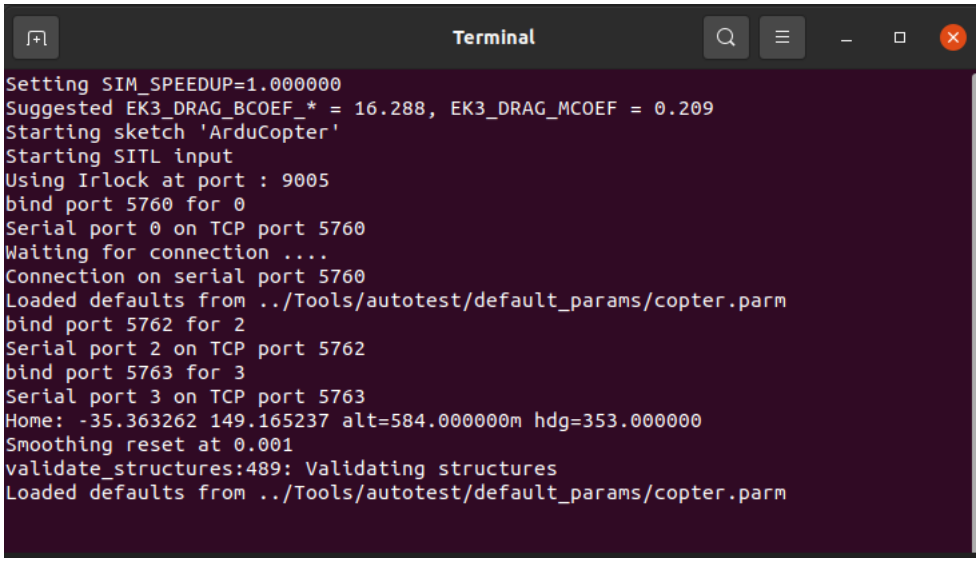
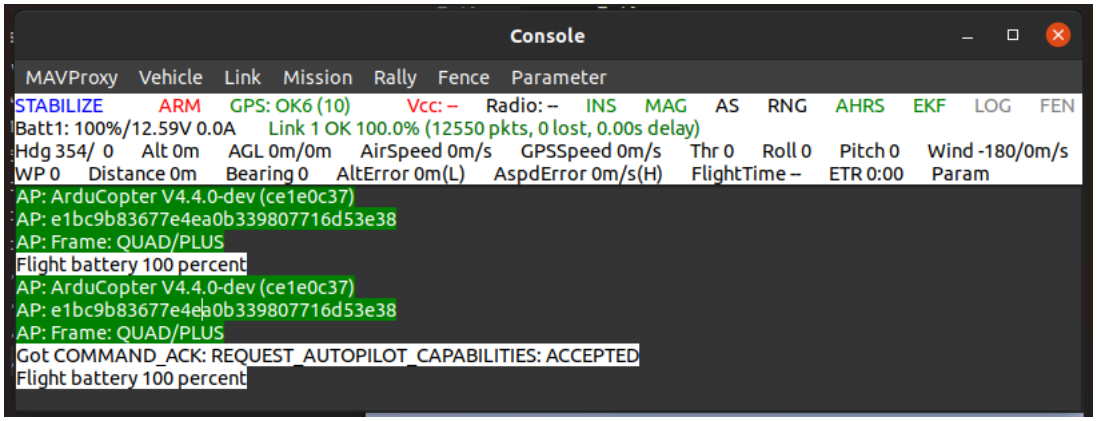


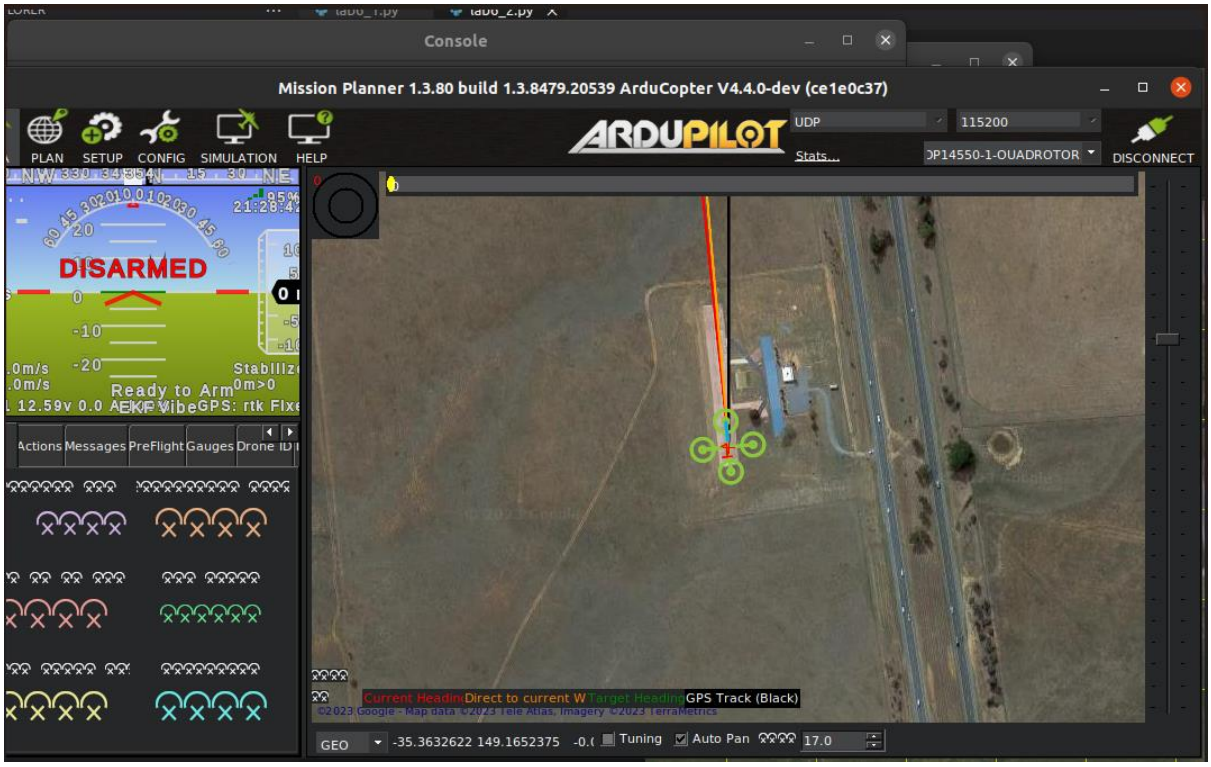
Figure 1
Reference
MPC
1.2
1.0
0.8
0.6
0.4
0.2
0.0
x2
0.0
0.5
1.0
1.5
2.0
x1

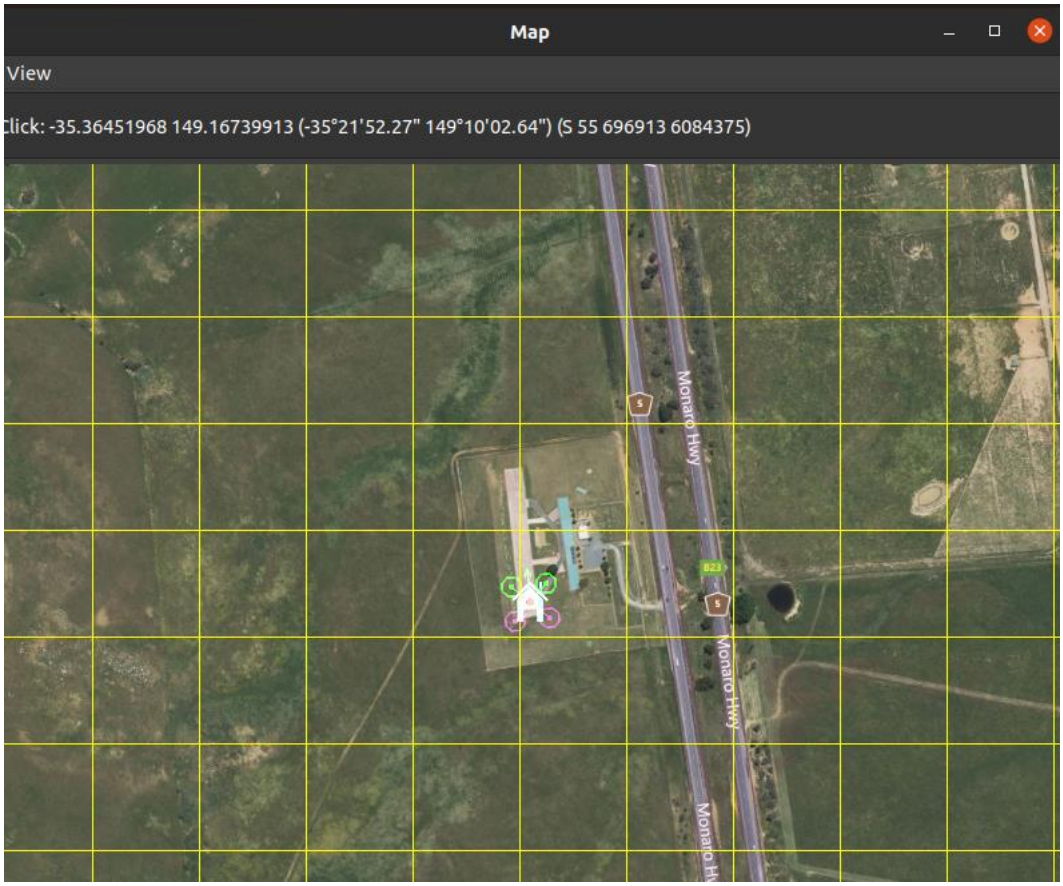
Question 2: A program to set the altitude to 20 meters for all waypoints. And also set the vehicle mode to RTL instead of LAND

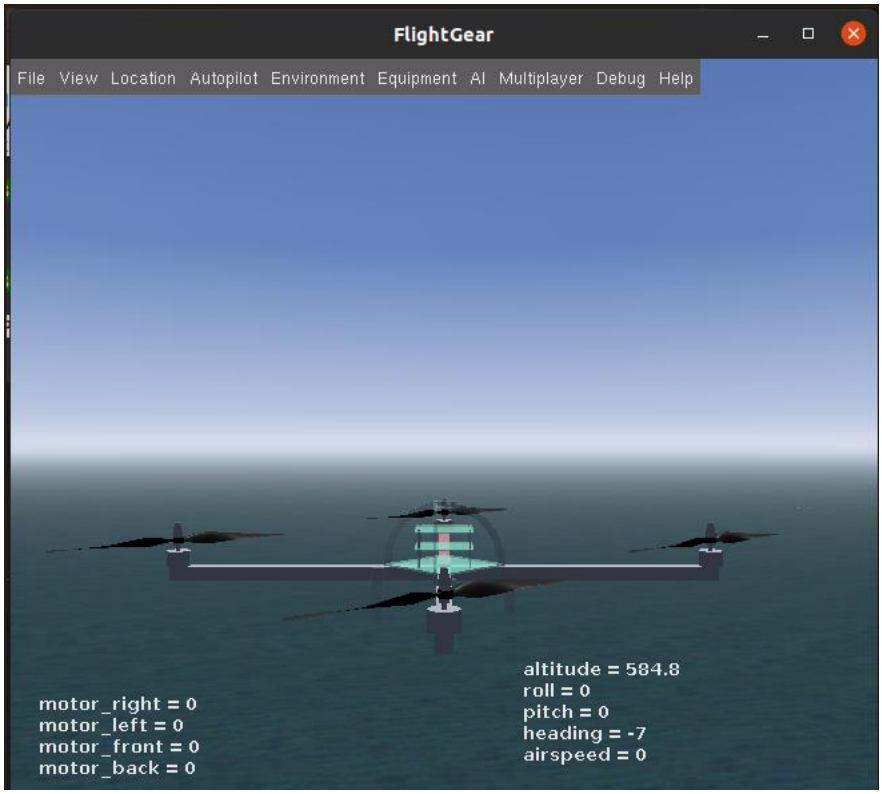



```
[Running] python -u "/home/kailash/Desktop/lab6_2.py"
Traceback (most recent call last):
  File "/home/kailash/Desktop/lab6_2.py", line 7, in <module>
    vehicle = connect(connection_string, wait_ready=True)
  File "/home/kailash/.local/lib/python3.8/site-packages/dronekit/__init__.py", line 3170, in connect
    vehicle.wait_ready(still_waiting_interval=still_waiting_interval,
  File "/home/kailash/.local/lib/python3.8/site-packages/dronekit/__init__.py", line 2374, in wait_ready
    raise TimeoutError('wait_ready experienced a timeout after %s seconds.' %
dronekit.TimeoutError: wait_ready experienced a timeout after 30 seconds.
```




Console
Mission Planner 1.3.80 build 1.3.8479.20539 ArduCopter V4.4.0-dev (ce1e0c37)
PLAN
SETUP
CONFIG
SIMULATION
HELP
ARDUPILOT
UDP
115200
Stats...
DISCONNECT
DISARMED
Ready to Arm
Actions
Messages
PreFlight
Gauges
Drone
GPS Track (Black)
GEO
Tuning
Auto Pan


Map
View
Monaro Hwy


FlightGear
File View Location Autopilot Environment Equipment AI Multiplayer Debug Help
motor_right = 0
motor_left = 0
motor_front = 0
motor_back = 0
altitude = 584.8
roll = 0
pitch = 0
heading = -7
airspeed = 0

Question 3: Program using varying altitudes for each waypoint

```
[Running] python -u "/home/kailash/Desktop/lab6_3.py"
Traceback (most recent call last):
  File "/home/kailash/Desktop/lab6_3.py", line 6, in <module>
    vehicle = connect(connection_string, wait_ready=True)
  File "/home/kailash/.local/lib/python3.8/site-packages/dronekit/__init__.py", line 3170, in connect
    vehicle.wait_ready(still_waiting_interval=still_waiting_interval,
  File "/home/kailash/.local/lib/python3.8/site-packages/dronekit/__init__.py", line 2374, in wait_ready
    raise TimeoutError('wait_ready experienced a timeout after %s seconds.' %
dronekit.TimeoutError: wait_ready experienced a timeout after 30 seconds.
```