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1. There is a landing key: ‘d’ or ‘D’. If you want to land the lander in any scenario. You **FIRST** need to turn on the autopilot if it is off (the default is on), **then press** the **landing key** to land the lander.
2. There is an orbit_injection key: ‘g’ or ‘G’. This **only** works well in **scenario 9.** Similarly, in scenario 9, you **First need** to turn **on** the **autopilot** if it is off (the default is on), **then press** the **orbit_injection key** to inject the lander into an orbit at 100km. NOTE THAT, PLEASE PRESS orbit_injection key as soon as possible after the simulation starts in scenario 9 otherwise the lander might crash. You should speed up the simulation speed as it is slow. Then if you want to deorbit and land the lander, press landing key (‘d’ or ‘D’).
3. All scenarios run with unlimited fuel. Only scenario 1&5 can work with limited fuel when Kh is changed into 0.017 and `FUEL_RATE_AT_MAX_THRUST` is changed to 0.5. Kh = 0.001 works for all scenarios with unlimited fuel.

Innovative features of my solution to EXTENSION 4&5

I. ---<<Orbit injection>>---

I spent lots of time on this topic. Finally, I used the control theory to 'land' the lander to an orbit with a certain altitude. The idea for this algorithm is very straightforward: If we ignore the rotation of the lander around the Mars during orbit injection, then orbit injection is simply an 'inverse' landing process --- instead of landing to the ground, the lander will 'land' to a specific altitude. Now, if we take rotation around Mars into consideration, we need to consider centrifugal force when we calculate the delta term in the control theory equations. I tackled this by making a force analysis to the lander and calculate the net force component in position.norm() direction. That equals the magnitude of delta term. Also, the lander needs to be tilted during the orbit injection.

In order to do this, I created two functions --- the first one is to control the tilted angle and the other is used to control the throttle needed at one specific altitude during the orbit injection.

```
attitude_stabilization_gravity_turn(det_phi_radian)
```

```
throttle_control_autopilot(det_phi_radian)
```

II. ---<<Deorbiting and landing process>>---

My solution of deorbiting is a bit clumsy and not very efficient: I first decelerate the lander by pointing its bottom to the velocity direction. Then when the velocity is almost zero, the lander starts the descent --- like a vertical descent. For the landing algorithm, I simply use the control theory mentioned in the handout.

Extensions

I went to extension5 and spent lots of time on extension5.

Any unusual compilation instructions --- No