Bicopter Control Scheme Simulations

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Overview

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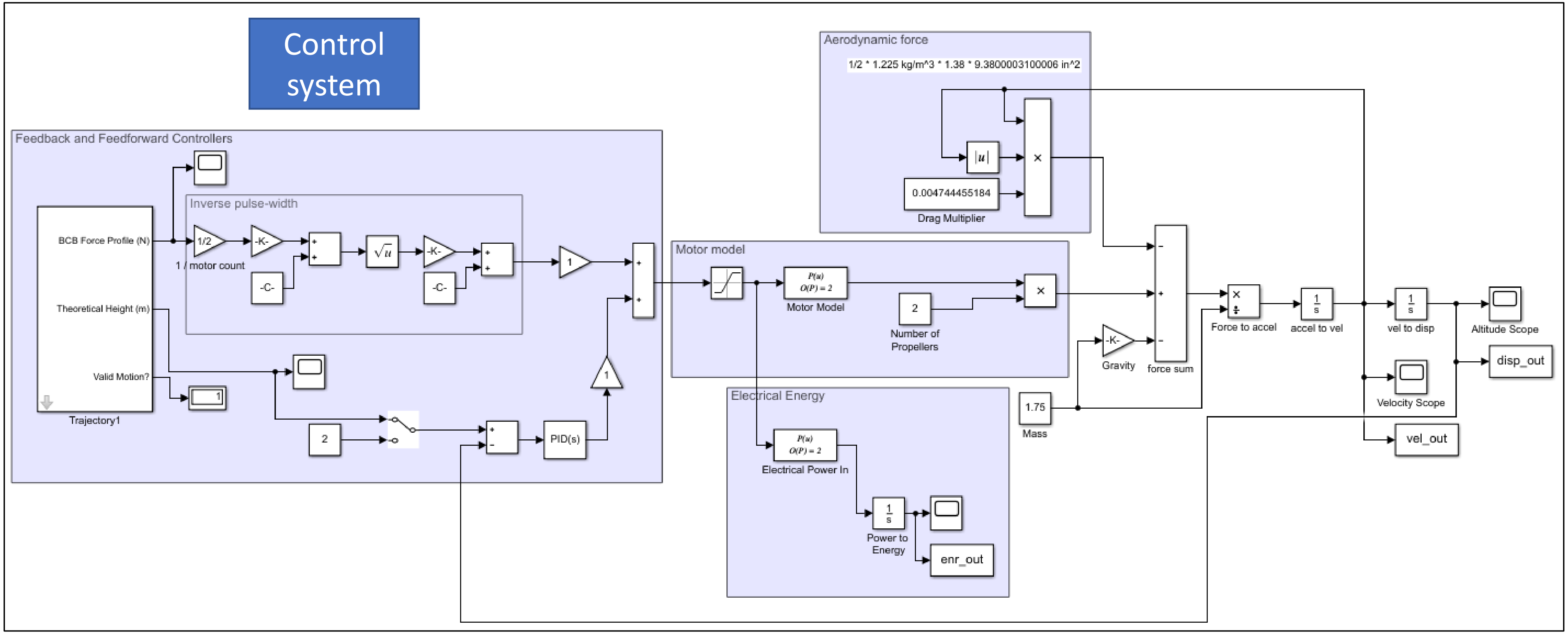
1. Background

I have been given a directive to analyze control schemes for a bicopter. This is built upon previous work that was to put together a Simulink simulation of the bicopter's dynamics and this adds a combination control system to it that can do feedforward control, feedback control, and a combination of the two.

Four difference control schemes are analyzed, a feedforward system, a step feedback system, a trajectory feedback system, and a combination feedback and feedforward system. All use the same Simulink block diagram, shown on the next slide.

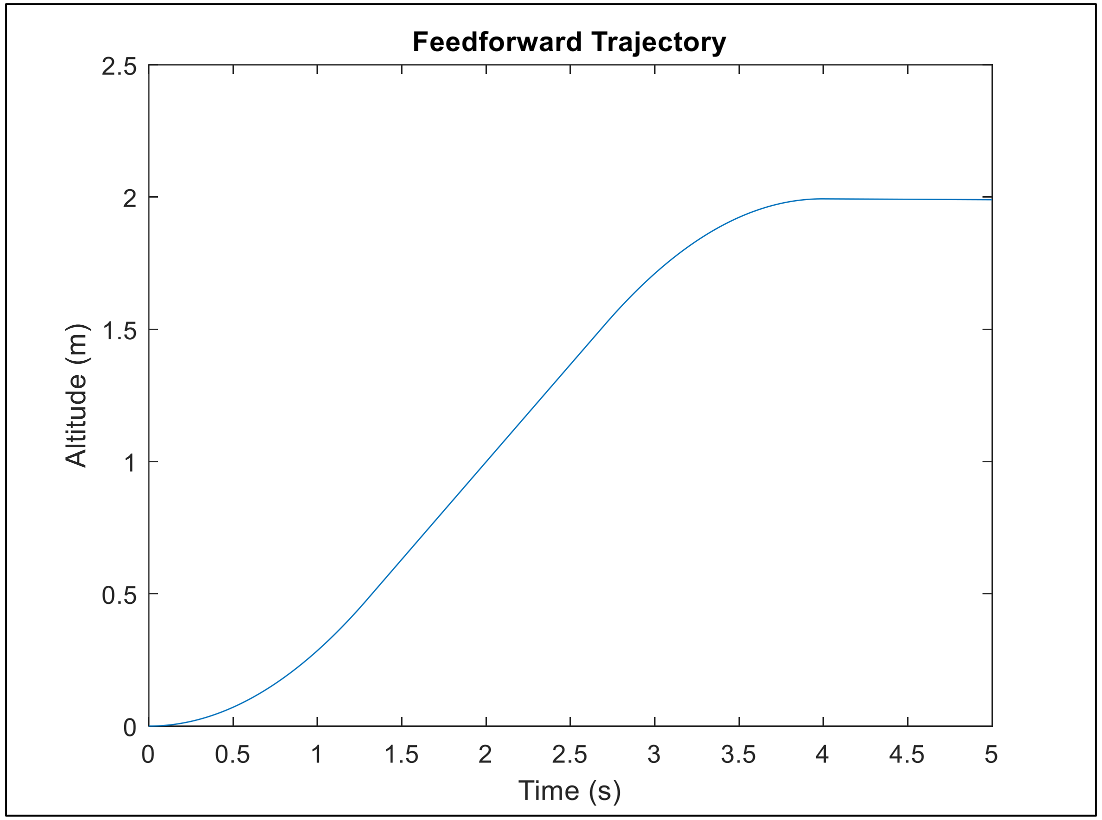
STARK INDUSTRIES

2. Block Diagram



Test Engineer: Ross Smyth

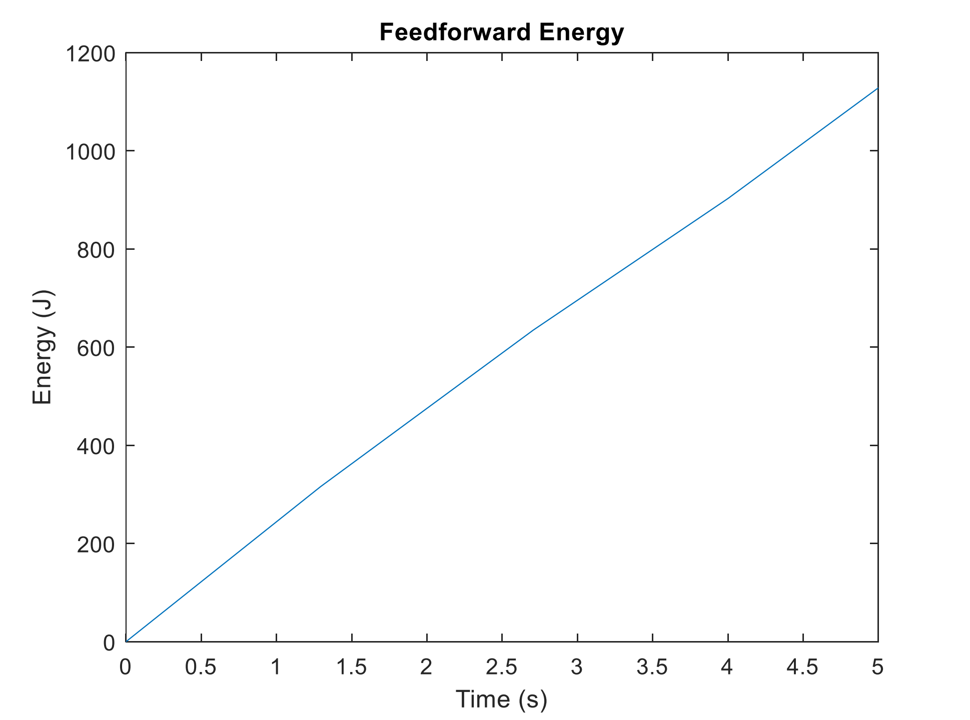
3. Feedforward



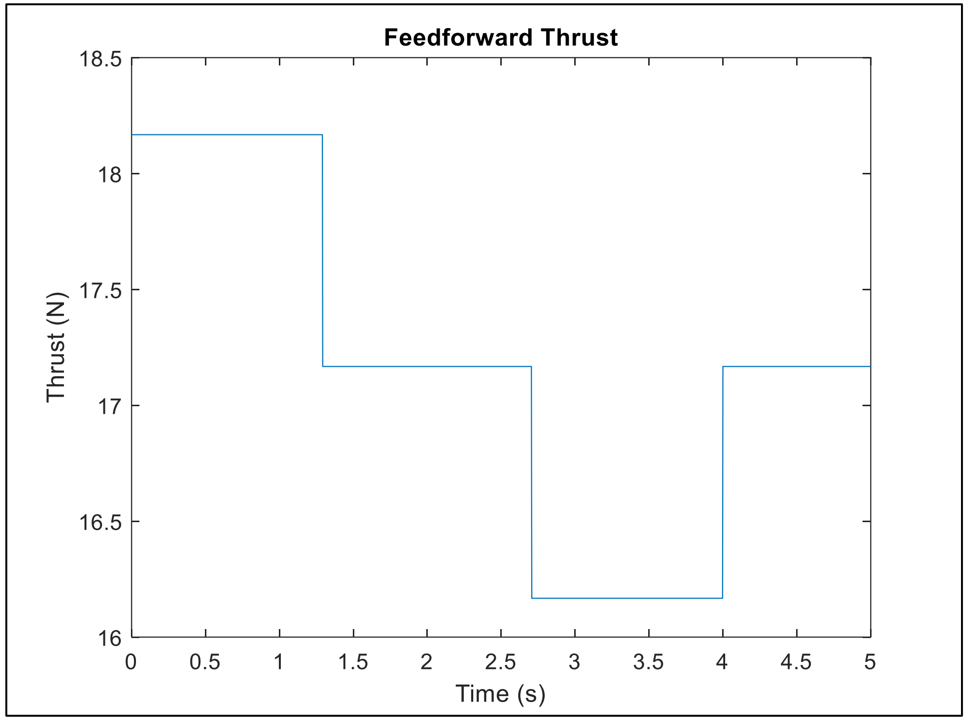
The feedforward was created with the supplied feedforward block with the parameters of 1 Newton max force pulse, 4 seconds for the desired maneuver time, a 2 meter height change, and a 1.75 kg copter.

This worked well in the simulation, with the only problem being that the final velocity settled at is slightly less than zero, and while not very visible on the plot to the left over a longer period of time is drifts from the 2 meter mark without correction.

4. Feedforward Cont.

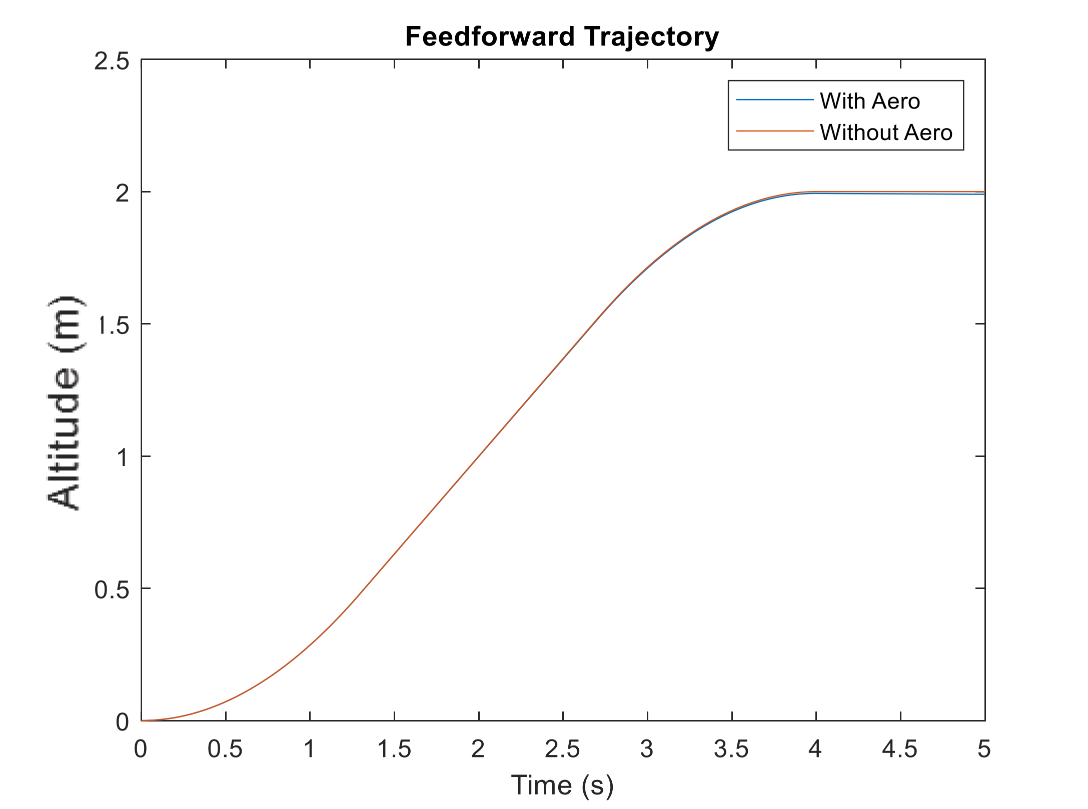


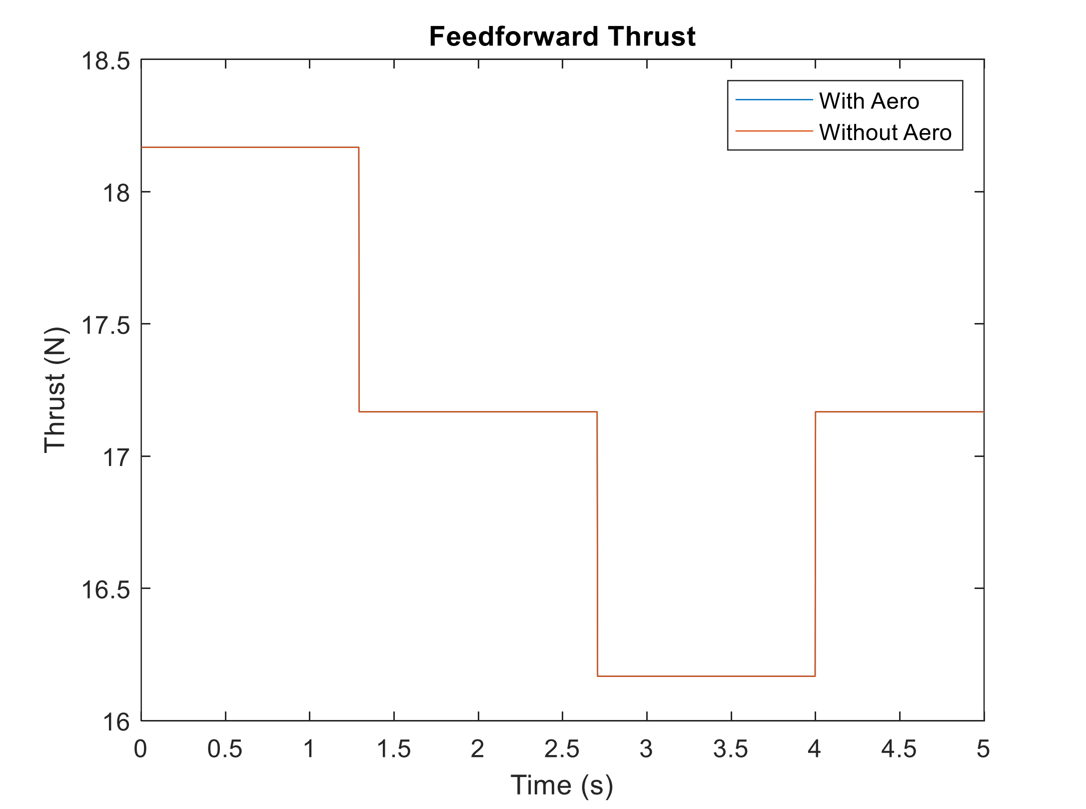
The power doesn't change too much along the determined power curve at the thrust levels used, it stays between 200 and 250 Watts, which means it looks fairly linear throughout the scenario.



The thrust looks as expected with a bang-coast-bang layout.

5. Feedforward Without Aerodynamics

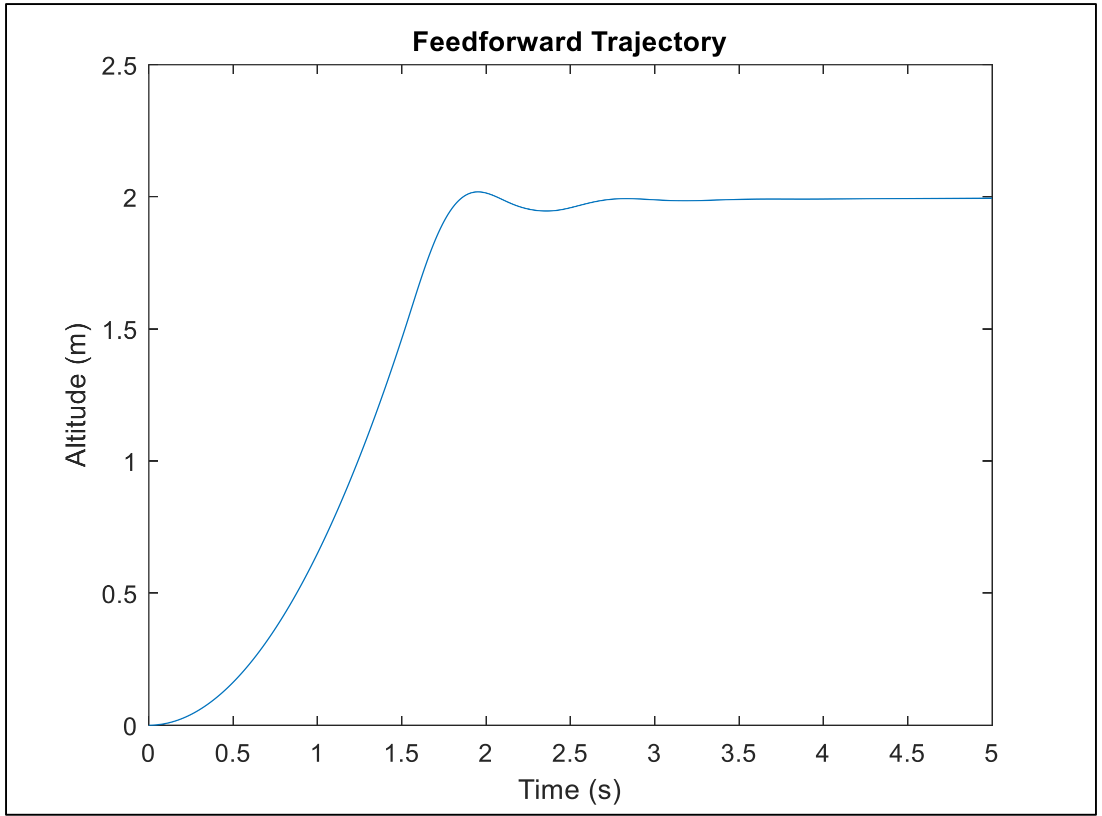




Without aerodynamics, as shown above, the slight misalignment from zero velocity is mostly fixed. But there is still a slight misalignment from zero total force on the bicopter that still effects it. But it is much better than before.

The thrust is identical between the two as the same feedforward profile is used, so it should be identical.

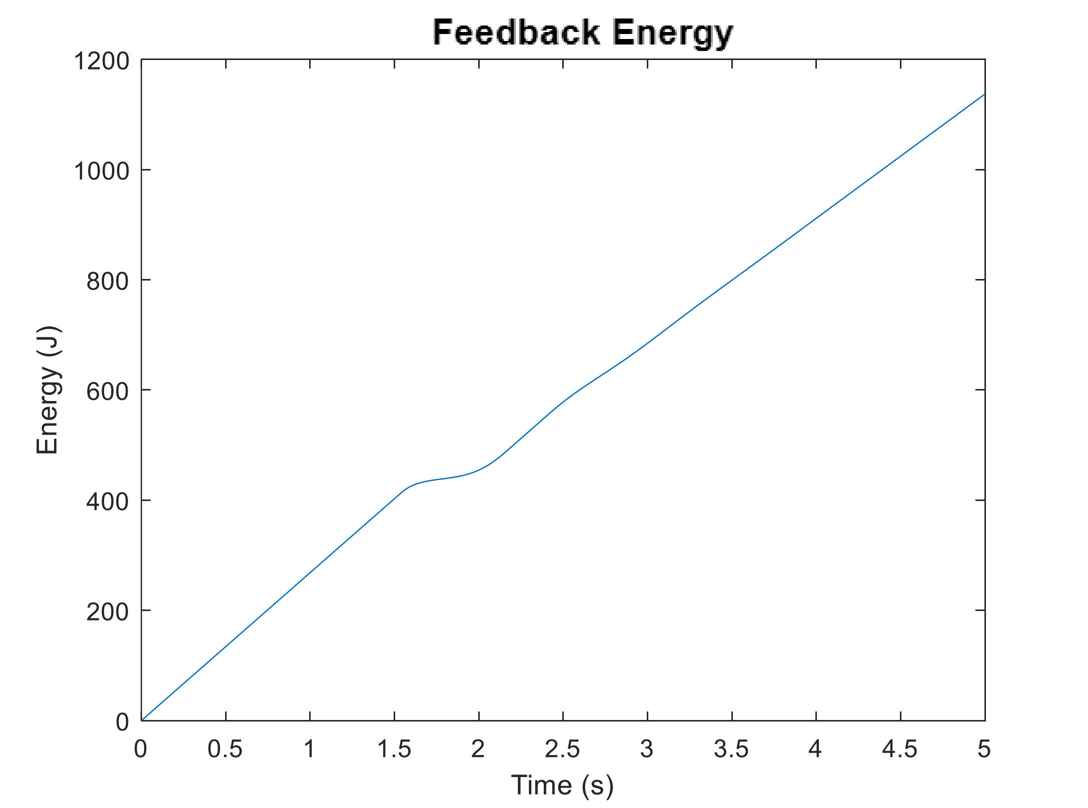
6. Feedback (Step)

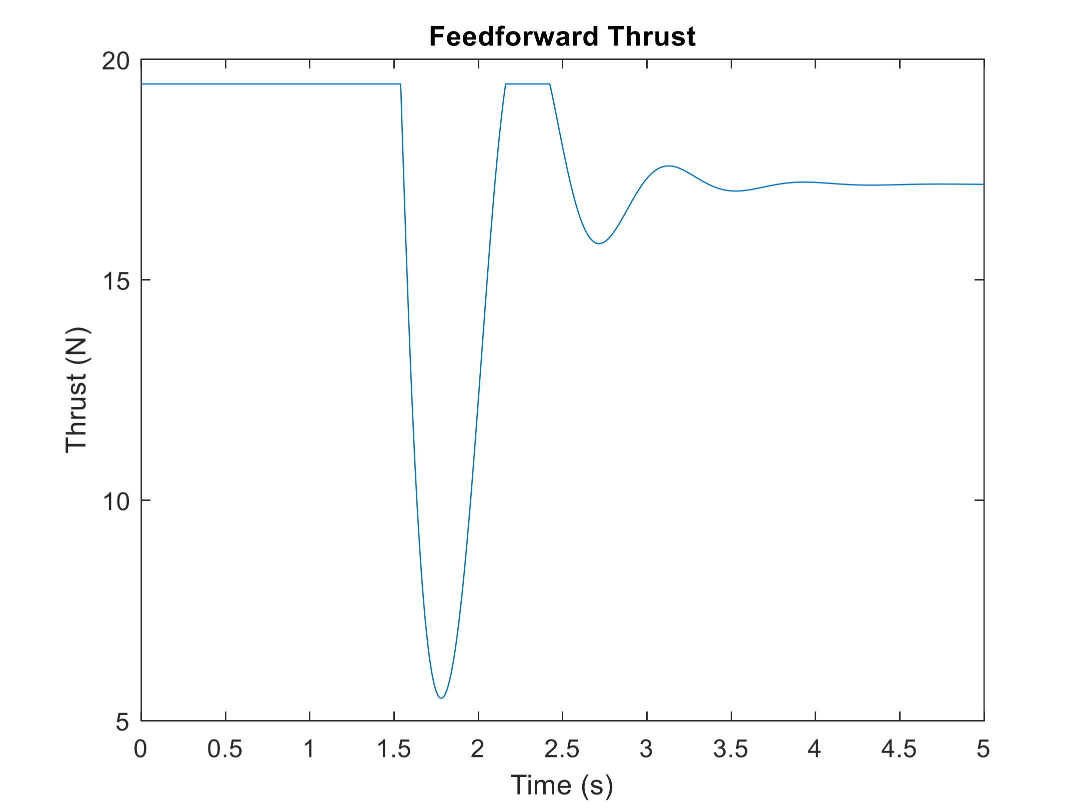


The feedback was created with the supplied feedforward block with the controller gains of 2, 0.8, and 0.4 for the P, I, and D gains respectively. It also has a derivative filter coefficient of 10. This had a step input of 2 meters at t=0 as the reference.

This rose up to the 2 meter mark within 2 seconds, and then settled to the 2 meter position by around the 3 second mark.

7. Feedback (Step) Cont.

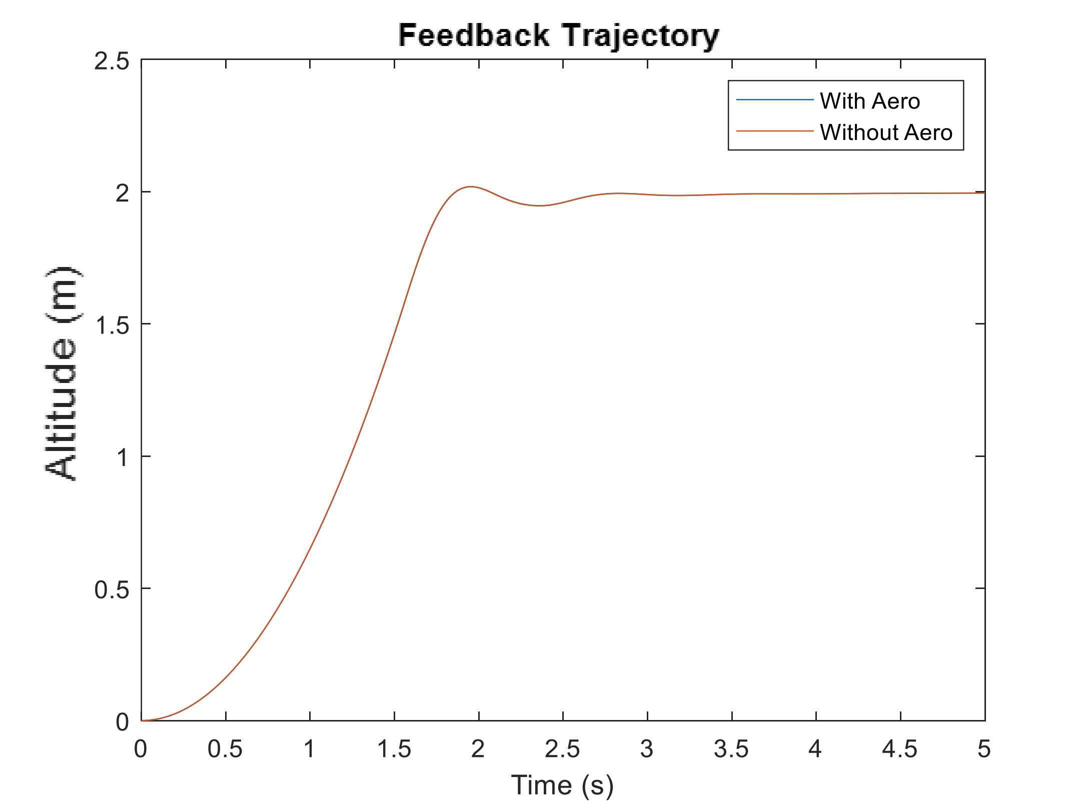


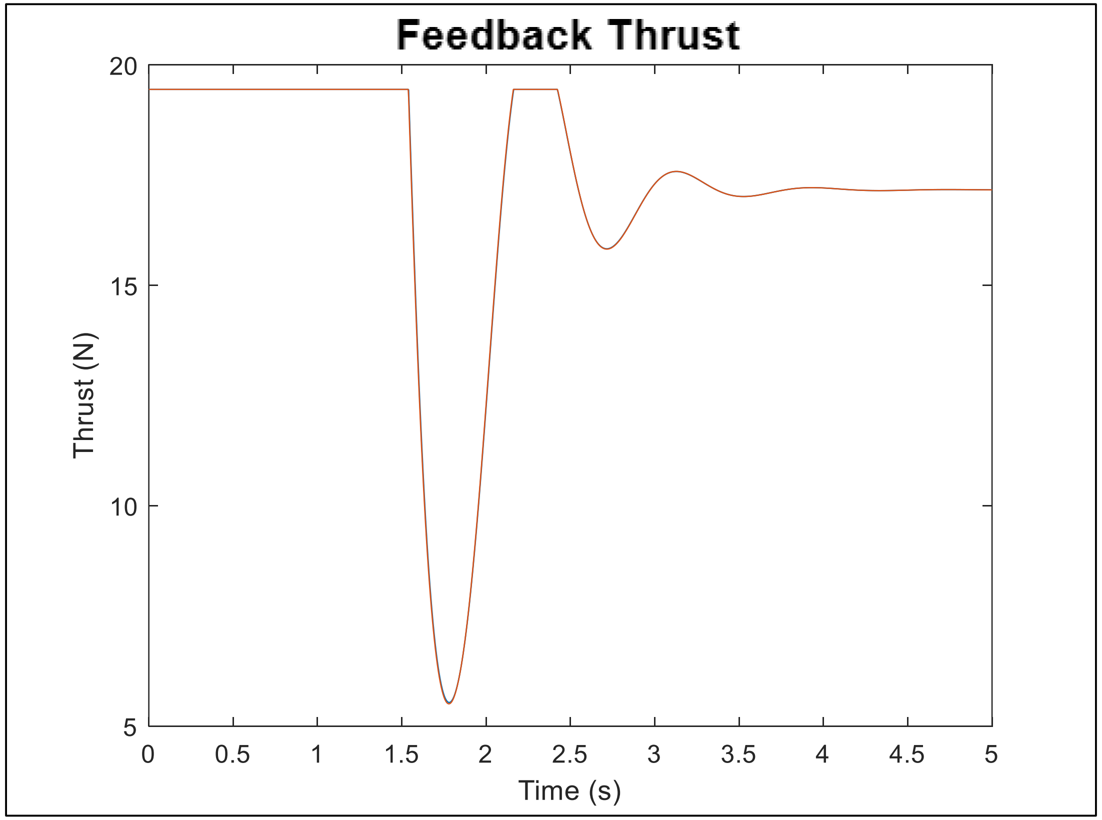


The energy, as before is for the most part linear with time. The only difference is the thrust drops at one point around 2 seconds in, and that can be seen in the energy plot as well.

The thrust is maxed at the beginning, then drops while the integration term builds up to correct it towards 2. There is a bit of settling but it is not that major as seen on the trajectory plot seen previously.

8. Feedback (Ste) Without Aerodynamics

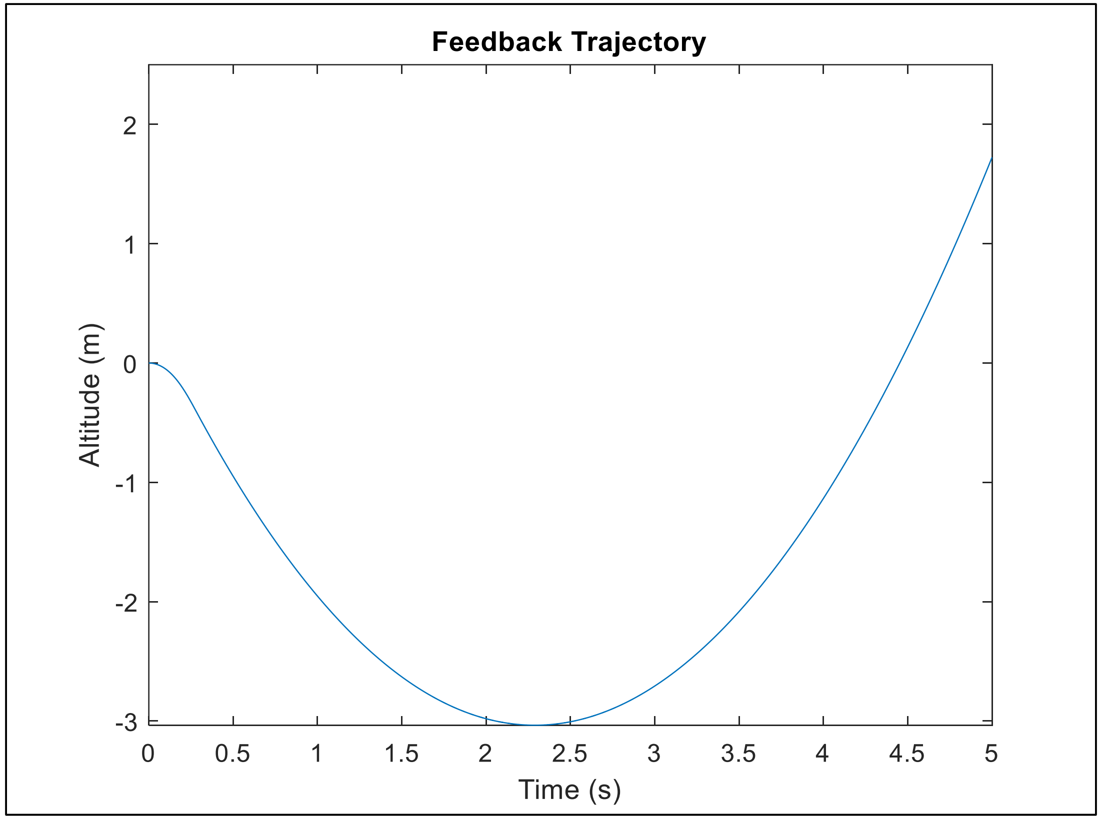




The difference between the two trajectories is negligible, while there is a slight difference throughout it is within 1 millimeter throughout the whole scenario.

The thrust is the same story, with the thrust profile being near identical with the largest difference being in the large dip, with a difference of around 3 milliNewtons which is not relevant at this scale.

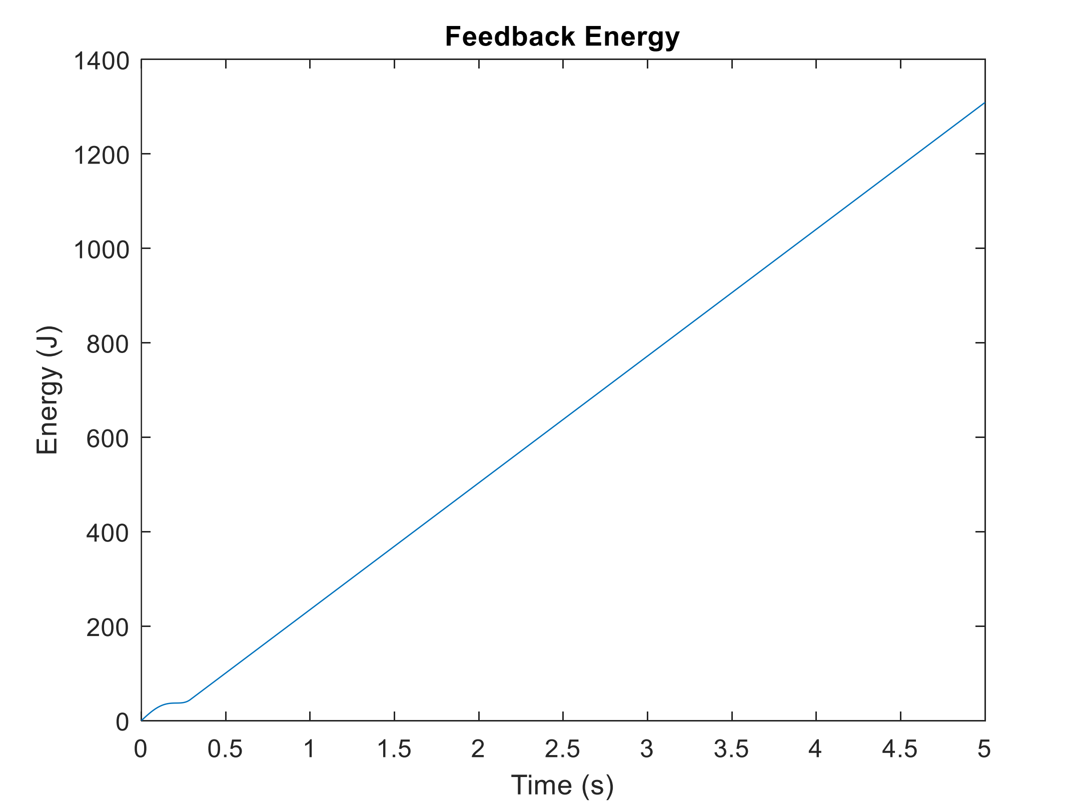
9. Feedback (Trajectory)

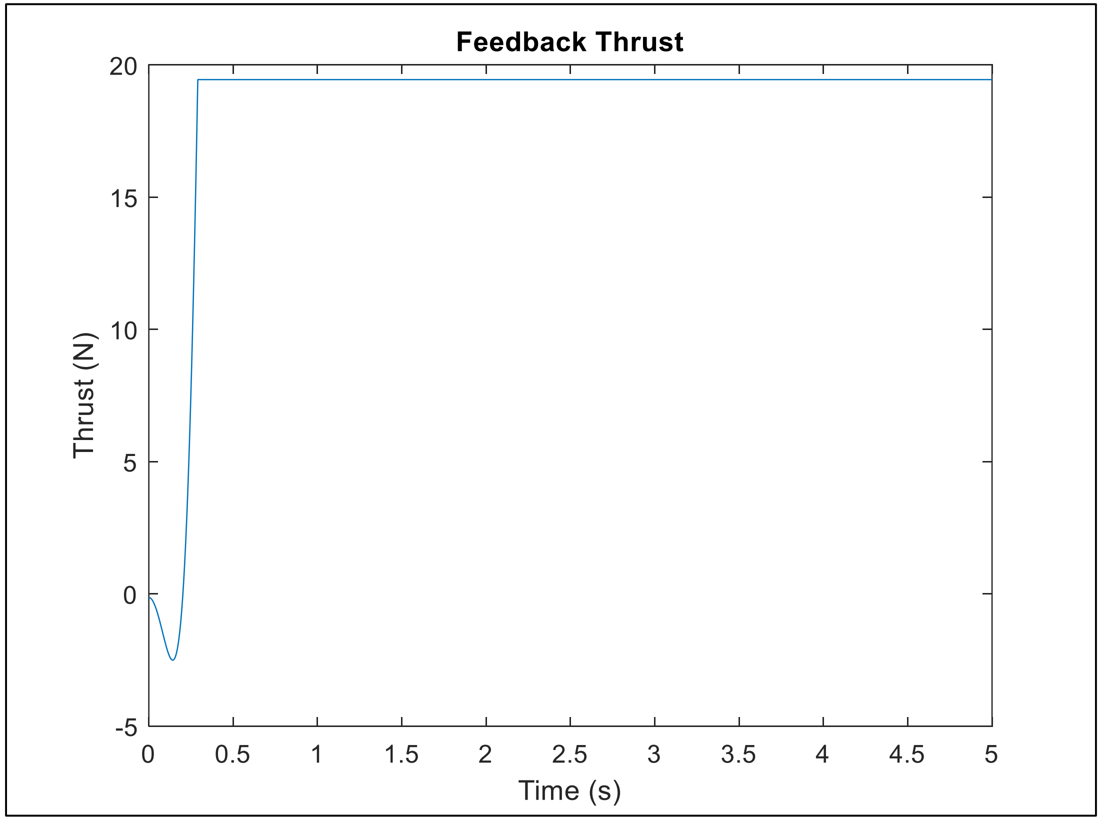


This feedback configuration had gains of 3, 5, 0.2, and 10 for the P, I, D, and filter inputs. For the refence the theoretical feedforward altitude was used.

This did not work very well, even after tuning for a while. It never had a steady state of 2 meters within the time frame, it either overshot by a lot or became unstable.

10. Feedback (Trajectory) Cont.

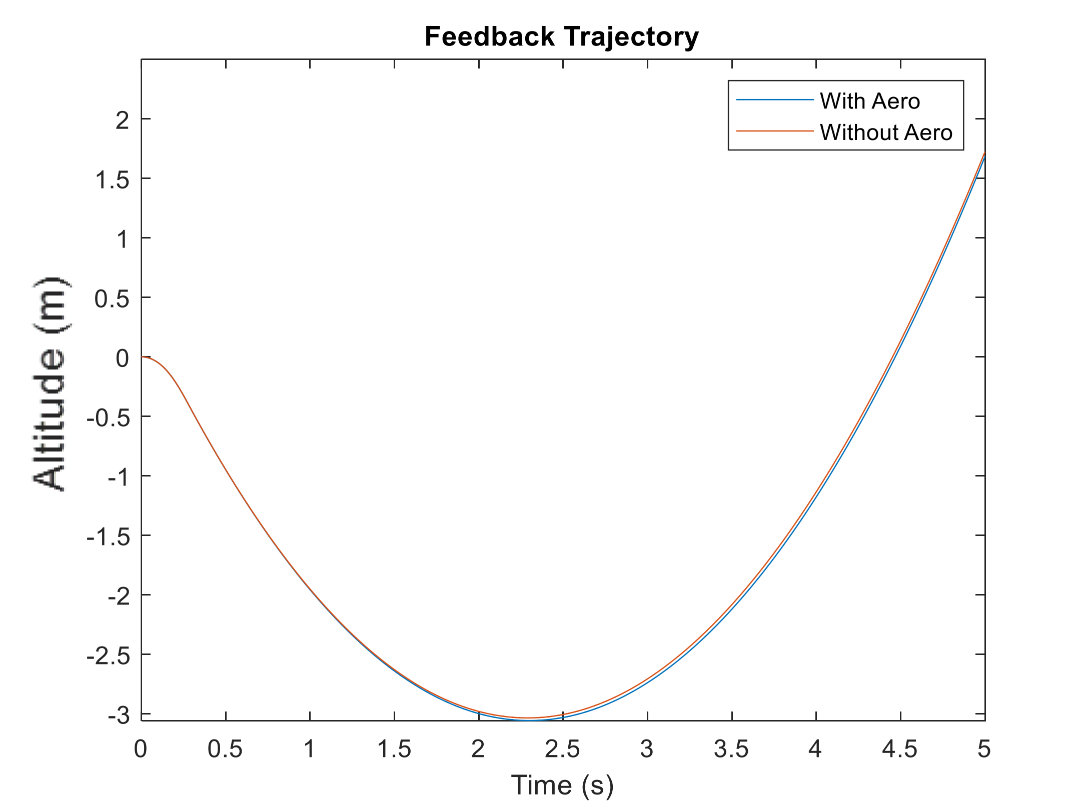


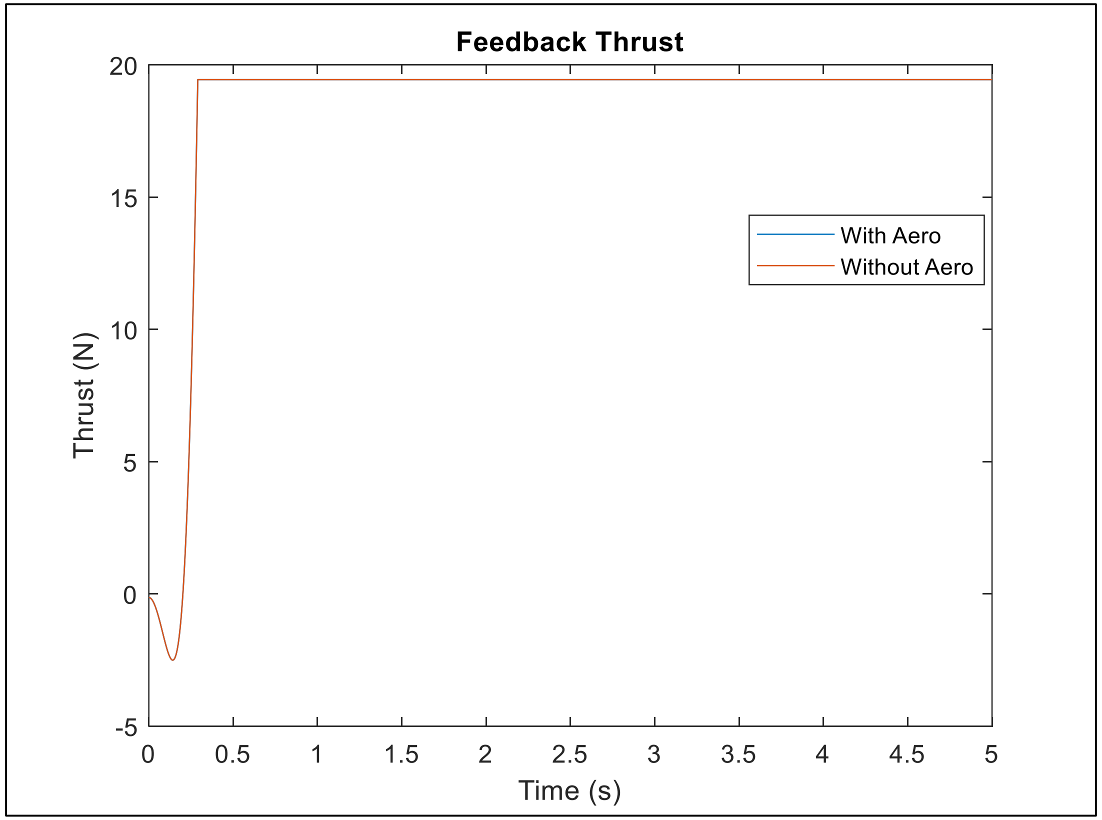


The energy is linear like all the others as the thrust range isn't very large.

The thrust is zero at the beginning as the feedforward height is equal to the starting height, leading to the bicopter to drop, leading to large error. Then the controller is able to compensate, but by then it is too late.

11. Feedback (Trajectory)Without Aerodynamics

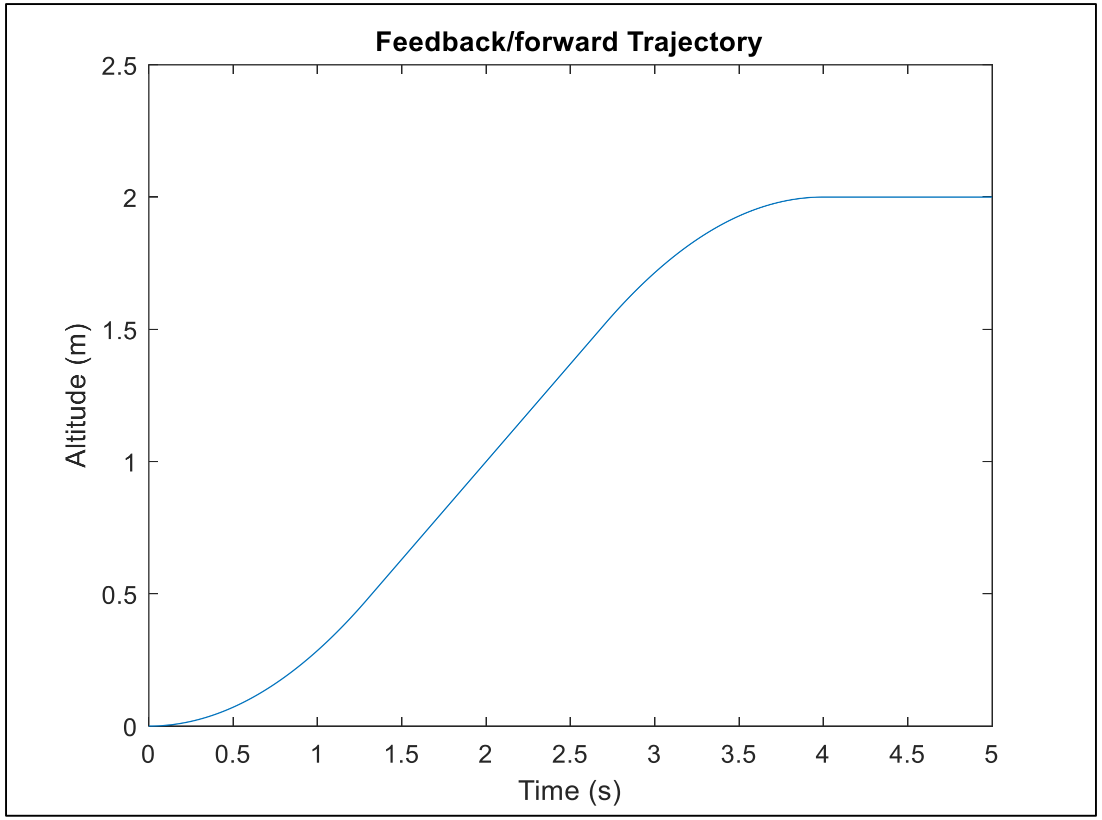




The difference between the two trajectories is negligible, while there is a slight difference throughout it is within 3 millimeter throughout the whole scenario.

The thrust is the same story, with the thrust profile being near identical with the largest difference being in the large dip, with a difference of around 4 milliNewtons which is not relevant at this scale.

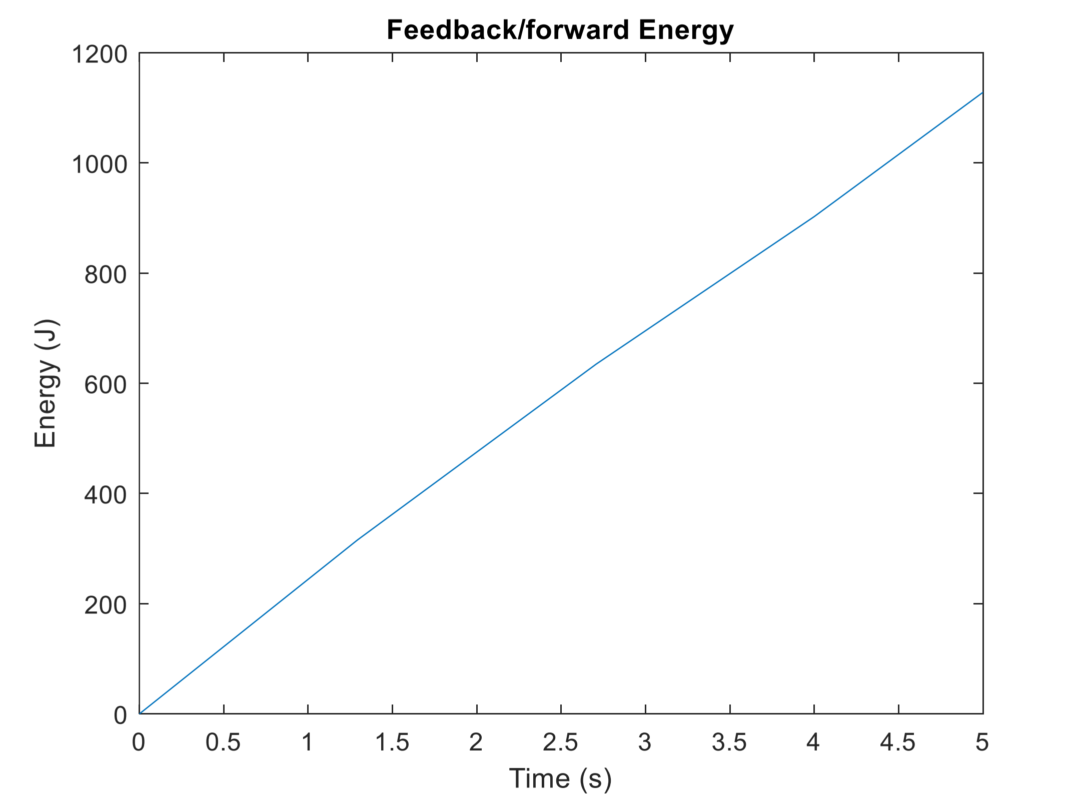
12. Feedback (Trajectory)

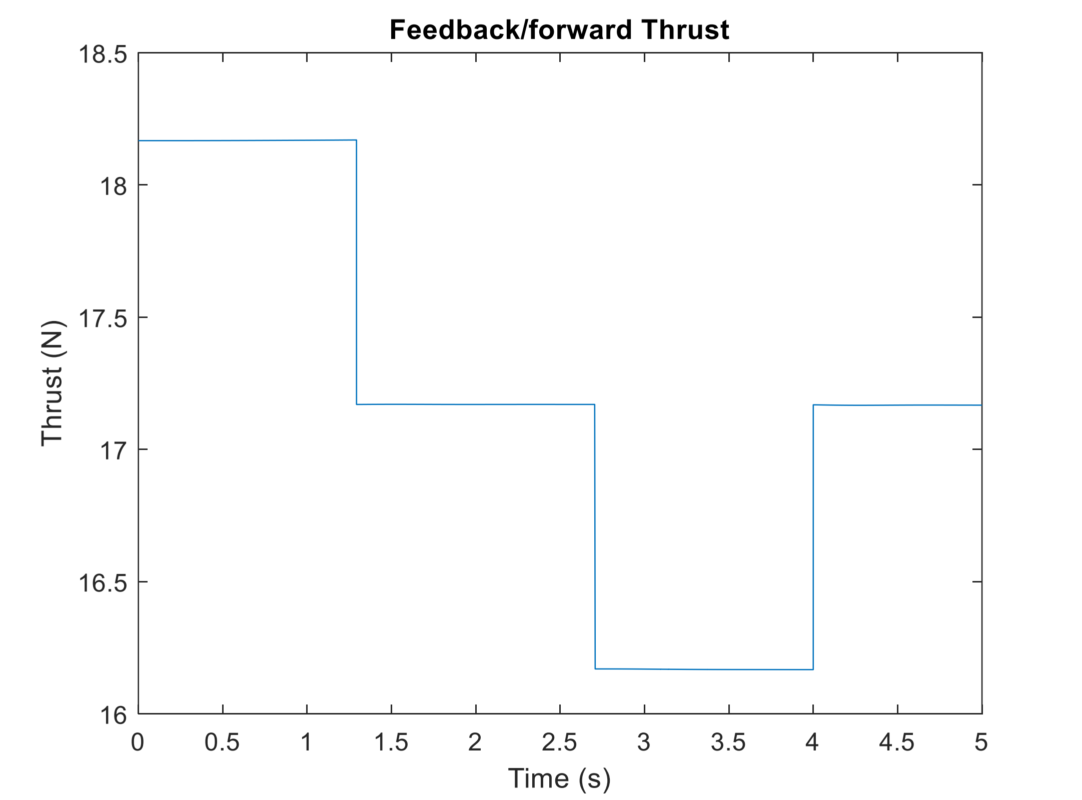


This feedback configuration had gains of 2, 0.8, 0.4, and 10 for the P, I, D, and filter inputs. For the refence the theoretical feedforward altitude was used. The feedforward was also used to provide input and the two were added together.

This configuration worked very well, it did not overshoot, it reached the target smoothly, and there is not any measurable error.

13. Feedback (Trajectory) Cont.

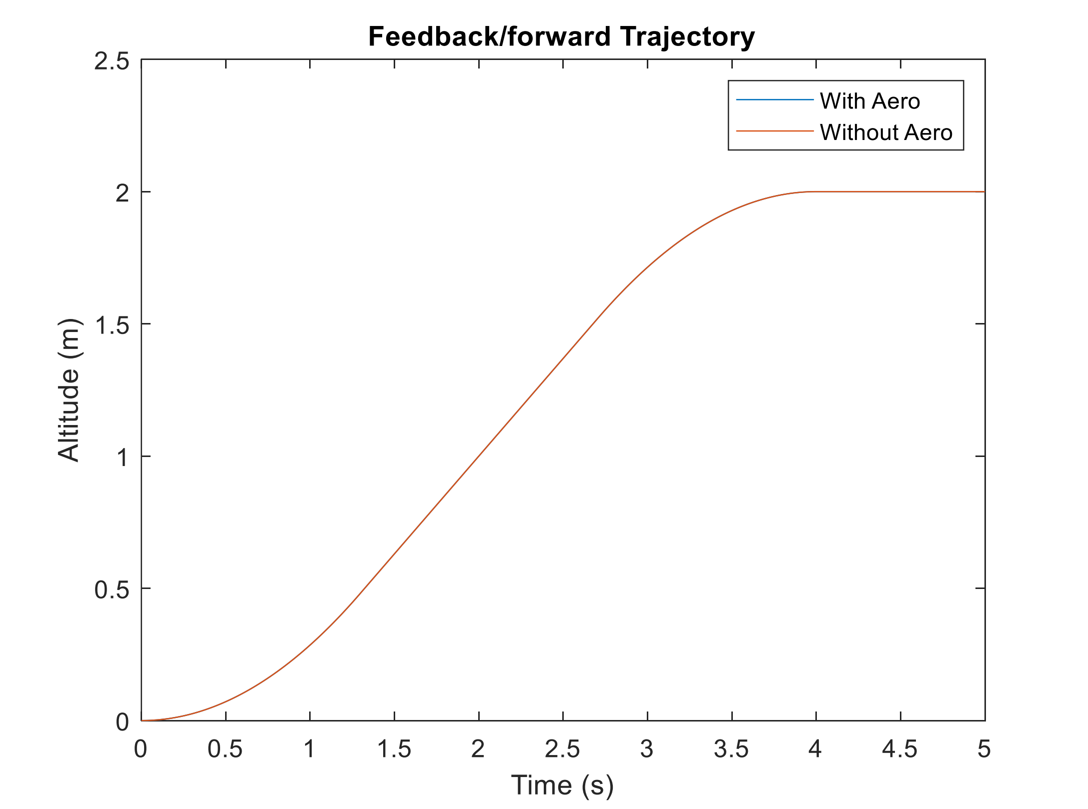


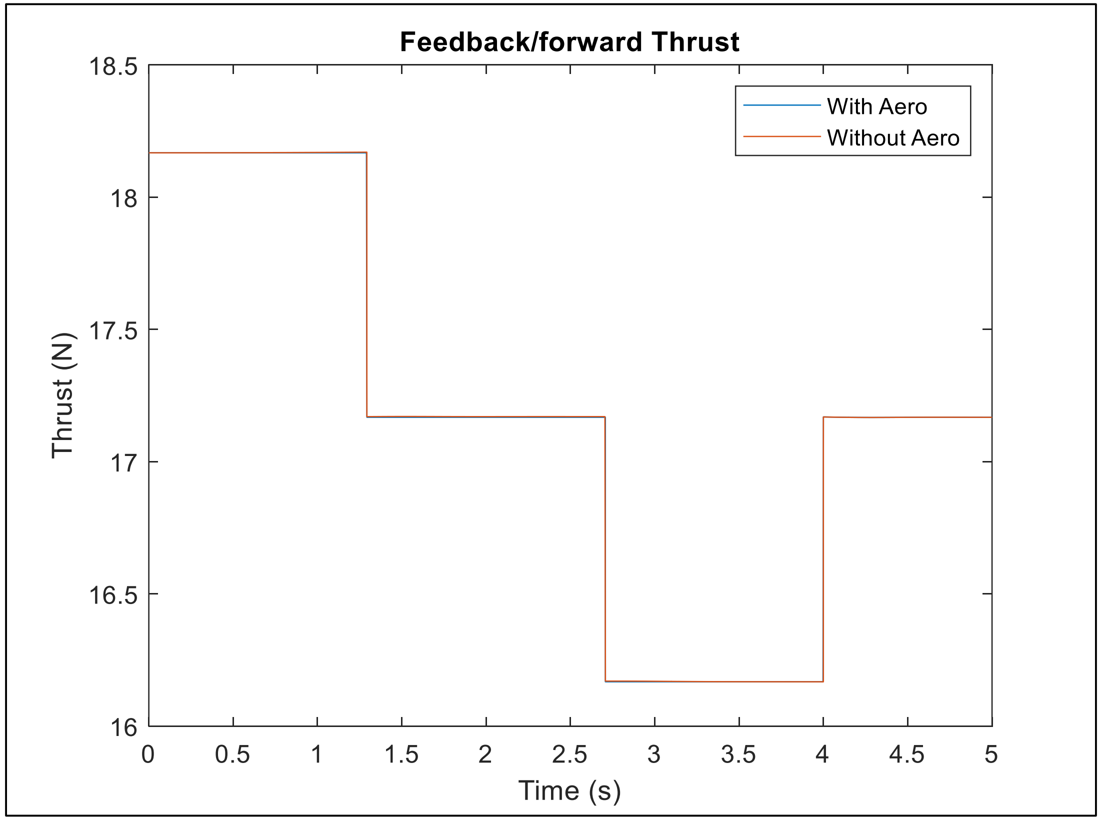


The energy is linear like all the others as the thrust range isn't very large. The energy consumed is also similar to all the others.

The thrust is perceptually identical to the feedforward, but there is a slight difference to correct errors, primarily from the aerodynamics, that the feedforward doesn't predict.

14. Feedback (Trajectory)Without Aerodynamics





The difference between the two trajectories is negligible, while there is a slight difference throughout it is within 4 millimeter throughout the whole scenario.

The thrust is the same story, with the thrust profile being near identical with the largest difference being in the large dip, with the largest difference being around 10 milliNewtons at some points, which is still small.

15. Conclusion

- Of the four control configurations analyzed, the combination of feedback and feedforward worked the best.
- Feedback had some slight overshoot and oscillation that is not wanted.
- Feedforward didn’t quite hit the zero velocity mark at the end of the scenario. It strays away from velocity mark and 2 meter mark due to the force and velocity not being zero.
- Combined there is no overshoot or oscillations, while it also stays at the 2 meter mark within observable measurement of Simulink.

This is primarily because of the integration term of the PID controller, but another advantage of this is if a step disturbance (wind, frisbee, payload drops) occurs on the bicopter, the other parts (proportional and deritive) can help correct the bicopter.

Therefore, the combination feedback and feedforward control is recommended to be implemented.