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Some of these can have a significant impact on maximum altitude, while others may only add 1 or 2%. The tips are roughly organized from most effective to least effective ways of flying higher.  There are many factors that affect a rocket's performance, and not every rocket flight will be able to take advantage of all of these suggestions. Almost always there are trade-offs, so trying to maximize one parameter will have a negative impact on another. For example reinforcing a bottle will allow it to hold more pressure at the expense of more weight. |  |  |  | | --- | --- | | |  | | --- | | **Tips**   1. **Use higher pressures.** As long as the rocket's pressure chamber remains within [safe limits](http://home.people.net.au/~aircommand/procedures.htm#BurstTest), increasing the pressure can have a significant impact on altitude gain. It may be possible to reinforce the rocket to hold higher pressures without adding too much extra weight. 2. **Keep weight to a minimum.** Every rocket has an optimal weight. Small and simple single bottle rockets may sometimes be under their optimal weight, and adding a little weight to the rocket may increase altitude. Due to construction techniques, larger rockets typically come in above their optimum weight and as a result need to be built as light as possible. Use a [simulator](http://cjh.polyplex.org/rockets/simulation/) to calculate the optimum weight for a particular rocket. Also keep any payload weight to a minimum. 3. **Increase rocket volume.** Generally increasing a rocket volume will also increase altitude. The best way to increase the volume is to make the pressure chamber longer. This doesn't increase drag significantly, although there is a corresponding weight penalty. Increasing the diameter of a rocket to increase the volume will not only result in more weight, but more drag, and generally lower the maximum pressure the pressure vessel can hold. 4. **Streamline the body of the rocket to reduce drag.** Avoid any unnecessary protrusions into the air stream. Keep the body of the rocket as smooth as possible, avoiding sharp transitions. The ideal shape is an elongated teardrop. Depending on the construction materials available, a minimal diameter rocket can reduce drag significantly, at the cost of volume. A smaller diameter rocket can also hold higher maximum pressure. 5. **Use a launch tube on the launcher.** A launch tube can have a significant effect on the apogee of a rocket. The longer the launch tube the better. The diameter of the launch tube should be as big as possible and should be about the size of the nozzle to reduce the amount of water loss as the rocket accelerates up the tube. Note that a maximum sized nozzle may not be the most optimum size after the rocket leaves the launch tube. Consider using a [T-nozzle](http://www.youtube.com/watch?v=tTNR4Biqdis) for better efficiency. 6. **Use the right amount of water.** While a third the volume may be a good approximation, every particular rocket will have an optimal water fill based on its weight, drag coefficient, pressure, nozzle size etc. Use a [simulator](http://cjh.polyplex.org/rockets/simulation/) to predict the best amount of water to use for each rocket configuration. 7. **Use an optimum sized nozzle.** The nozzle diameter should be optimized based on the various rocket parameters. Use a [simulator](http://cjh.polyplex.org/rockets/simulation/) to figure out the optimal nozzle size. There may be limitations on changing the nozzle size due to the type of launcher and launch tube used. 8. **Use multiple stages.** Correctly designed multi-staged rockets can increase the altitude of the sustainer over single stage designs. Consider your highly optimized rocket sitting on top of a booster. 9. **Optimize stage release timing.** Releasing the next stage of a multi-stage rocket is critical in maximizing the altitude reached. Use of real-time in-flight measured flight parameters for initiating staging can achieve best results. The best time to release the next stage is just after booster burn out just as the booster starts slowing down. 10. **Use a boat-tail on the rocket.** A smooth transition from the rocket body diameter down to the nozzle will assist with [base drag](http://www.daviddarling.info/encyclopedia/B/base_drag.html) reduction. 11. **Allow the air to cool inside the pressure chamber.**  As air is compressed inside the rocket it is heated. As the air cools, the pressure will drop in proportion to the temperature decrease. You can trickle fill the rocket before launch to make sure the optimal pressure is achieved. 12. **Streamline the leading and trailing edges of your fins.** To reduce the profile drag of your fins they should have an aerofoil profile. See [this document](http://www.apogeerockets.com/technical_publication_16) for more details. 13. **Use 3 fins instead of 4 or more.** If the launcher allows it, and the rocket is otherwise designed to be stable, the use of less fins should result in less drag and less weight on the rocket. 14. **Use optimally shaped fins.** The fins should have an optimal shape. See [this document](http://www.apogeerockets.com/technical_publication_16) for more details. The optimal shape will vary based on the rocket design and the rockets flight profile. 15. **Use optimally sized fins.** While having the correct fin profile and shape is important, it is also important to not make the fins too large. Fins that are larger than what they need to be add to the drag and weight of the rocket. Large fins may also cause the rocket to be over-stable. 16. **Ensure smooth internal water flow through the nozzle.** Increase nozzle efficiency by ensuring non-turbulent flow of water and air from the pressure chamber and through the nozzle. There should be no sharp transitions in the flow. Polish the inside of the nozzle. 17. **Fly on a windless day.** Wind will cause the rocket to weather-cock into the wind causing it to fly in an arc and achieving a lower altitude than if it went straight up. The amount of weather-cocking will depend on the rocket's stability design and the wind speed. A rocket that is [over-stable](http://www.apogeerockets.com/Education/downloads/Newsletter05.pdf) will tend to weather-cock more. 18. **Use a rounded nosecone.** Parabolic nosecones are the most efficient for water rockets as they travel well in the subsonic range. Here is a nosecone shape comparison [document](http://www.aerospaceweb.org/question/aerodynamics/q0151.shtml) detailing common nosecones used by model rockets. 19. **Use a less dense liquid.** Lower density liquid can have a positive effect on raising the apogee of the rocket. However, using a liquid other than water may mean that the rocket may not be considered a water rocket. Changing the density of water can be achieved by aerating the water such as in a foam. Use a [simulator](http://cjh.polyplex.org/rockets/simulation/) to predict the altitude of a rocket with a lower density liquid. 20. **Use a heavier gas.** Some gasses like CO2 can provide better performance due to their heavier molecular weight and hence  provide a greater reactive mass. 21. **Align the fins properly.** Misaligned fins can cause more drag and potentially excessive rotation of the rocket. The rocket looses energy due to drag and some of the energy goes into the rotation of the rocket. Fins should also be as rigid as possible to prevent fins fluttering. 22. **Make the rocket stable.** An unstable rocket will not fly straight and achieve a lower altitude. Rockets should be designed to be [stable](http://www.rockets4schools.org/education/Basic_Rocket_Stability.pdf) when they are dry. The boost phase is generally very short with larger nozzles and so the rocket spends most of its ascent dry. When using smaller nozzles, the rocket should be designed to be slightly more stable to account for the longer duration of the water being in the tail of the rocket. 23. **Remove internal obstructions.** Streamlining the internal water and air flow adds to the efficiency of the rocket. If the construction techniques allow, consider removing flow constrictions such as couplings/baffles to insure most efficient flow and prevent water being retained during the thrust phase. 24. **Fly from higher elevation launch sites.** Starting at a higher altitude means the air is less dense and therefore the rocket will experience less drag. For example on average the air in Denver, Colorado is ~15% less dense than at sea level. See here for [elevation vs air density graphs](http://www.engineeringtoolbox.com/air-altitude-density-volume-d_195.html). 25. **Launch rockets into thermals.** Flying a rocket in a thermal can add extra tail wind to the rocket reducing drag. Here is an [extensive document](http://www.aviationweather.ws/095_Thermal_Soaring.php) on thermals, how they work and how to find them. Thermals are also useful for increasing the air time of your rocket. 26. **Point the launcher as vertically as possible.** All things being equal, a rocket that flies 2 degrees away from vertical will fly about 0.5% lower, and a rocket that flies 5 degrees away from vertical will fly about 2-3% lower. 27. **Optimize direction of second stage after staging.** Ensuring the next stage of a multi-stage rocket leaves as close to vertical as possible can be tricky, but is essential in reaching maximum altitude. 28. **Launch rockets on a humid day.** Humid air is [less dense than dry air](http://www.engineeringtoolbox.com/density-air-d_680.html). Lower density air will lower the drag on the rocket. At standard temperature and pressure at sea level, 100% humid air is approximately ~1% less dense than dry air. See the [air density calculators](https://www.brisbanehotairballooning.com.au/faqs/education/116-calculate-air-density.html) for more information. 29. **Launch rockets on a hot day.** Higher air temperature means lower density. Here is a [document](http://www.engineeringtoolbox.com/density-moist-air-d_1533.html) relating air pressure, air density and temperature. See the [air density calculators](https://www.brisbanehotairballooning.com.au/faqs/education/116-calculate-air-density.html) for more information. 30. **Grease the launch tube for less friction.** If you are using a launch tube with your launcher that has a relatively tight fit on the nozzle, make sure friction is reduced by lightly lubricating the launch tube. Less friction will result in higher take-off velocity.   If your rocket is not flying straight, here are some [suggestions for flying straight](http://www.aircommandrockets.com/flying_straight.htm). | |   [Back To Top](http://www.aircommandrockets.com/flying_higher.htm#top) | |

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