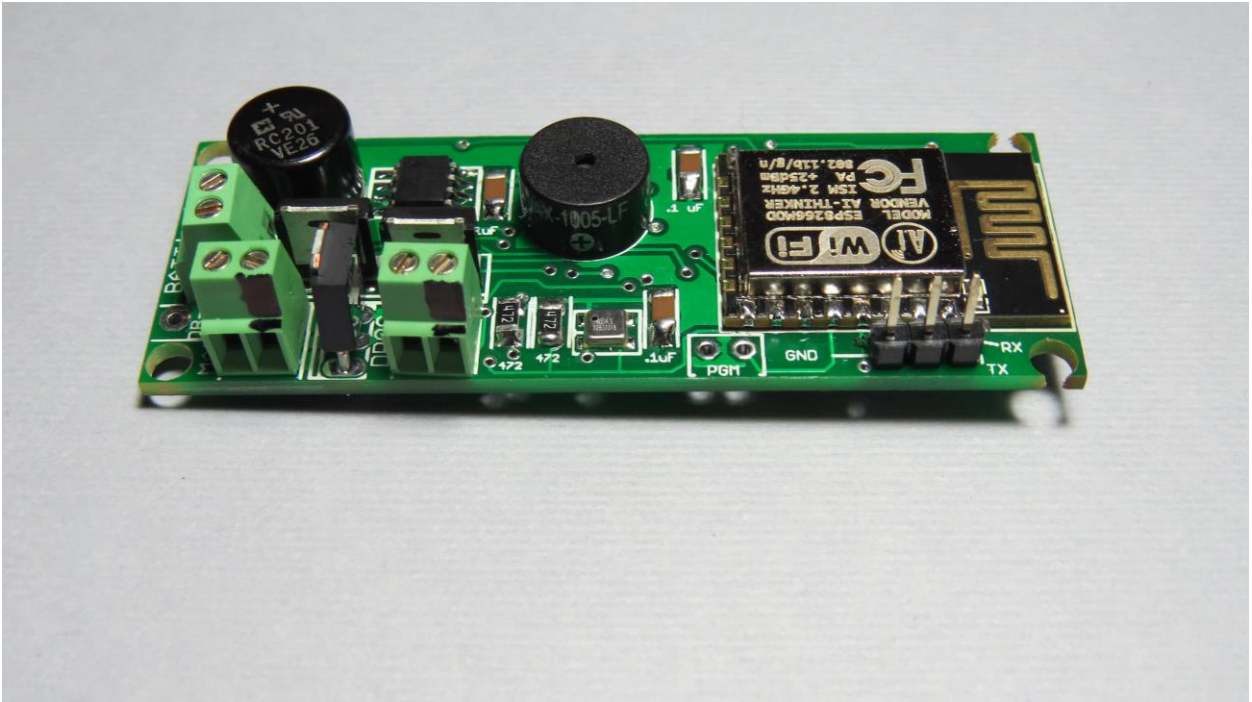


Eggtimer Quantum Airstart Manual

Board RevA12/A12f
Software Rev. 1.06N



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Disclaimers, Legal Stuff, Etc.

The Eggtimer Quantum is meant to be used for hobby and experimental rocketry purposes. Although hobby rocketry has an admirable safety record, largely due to the efforts of the good people at the National Association of Rocketry (NAR) and the Tripoli Rocketry Association (TRA), rocketry can be dangerous if proper safety precautions are not observed. This is particularly true with some of the advanced techniques like pyrotechnic parachute deployment and airstarting a motor in flight. People can and have been seriously injured by not following recognized and accepted safety practices. We cannot be responsible for your actions.

We *strongly* recommend that if you are not a member of either the NAR or the TRA, you join one of them, join a local rocketry club, and pick the brains of experienced members before you try any kind of multiple deployment or airstart flight. The safety information included in these instructions is by no means comprehensive or complete, and is no substitute for the supervision and advice of experienced rocketeers.

A Brief Word About Airstarts...

The techniques in the manual are intended for use by relatively advanced rocketry hobbyists, generally with a NAR or TRA high-power certification. A lot of the discussion assumes that you have some experience with electronic deployments, high-power rocketry building techniques, the basic physics of rocketry flight, and a good general knowledge of the safety procedures involved in flying high-power rockets. It is not a complete course in these subjects, nor can any short manual like this be.

We strongly recommend that if you do not have experience in electronic deployments that you tackle that first **BEFORE** you try airstarts. A lot of things can go wrong with airstarts, even with low-power motors. Remember that **YOU** are responsible for **YOUR** actions and the consequences thereof. We help provide you with the tools you need for your projects, but it's up to **YOU** to know how to use them correctly.

An Overview of Airstarts and the Eggtimer Quantum

One of the coolest (and most complex) things you can do in hobby rocketry is to electronically ignite a motor while you're in flight. This is called an "airstart". Airstarts are typically of two types... you can ignite extra motors while in flight, or you can have multiple stages and separate/ignite them in flight. These have different flight characteristics and requirements, but from the electronics point of view it's the same... you're triggering something at a certain time in the flight while going up. That's a much different requirement than a deployment controller, which typically will trigger something (generally, parachutes) while you're going down, generally at a relatively slow velocity.

The Eggtimer Quantum performs this function by acting as a timer, triggered by the same launch detect mechanism as the deployment functions (Launch Detect Altitude, or LDA). Since the Quantum keeps track of about 4,000 altitude readings prior to reaching LDA, it "knows" when you actually started the flight by seeing when you first started moving off the pad, so it can accurately time your flight from that point. That time is the Start of Flight, or SOF.

Each output channel on the Quantum is an independent timer, triggered by the SOF. They can be used for igniting a motor, firing a charge to separate stages, or just about anything else you can think of. Since these functions may have some serious safety ramifications (i.e. you don't want a high-power rocket motor firing when you don't want it to fire) there are several safety features and qualifications built into the Quantum's airstart software. Those are discussed below.

In addition to the timer functions, you also get the usual Quantum features... 15-flight memory, remote WiFi interface for configuring, arming/disarming, downloading, and testing, and your choice of single or dual battery operation. Since the Quantum uses a unique dual-ended deployment circuit, the airstart igniter is basically "dead" until you arm it, and you're well into the flight. It's considerably safer than arming an airstart controller with a switch of some sort, because you can do it remotely from over 100' away if you wish, without having to stick your face right next to the rocket to turn on a switch and hope the motor doesn't fire.

Note: This manual is not meant to be an exhaustive description of all of the Quantum's features and its operation, it's a supplement to the Eggtimer Quantum User's Manual, specifically addressing the airstart functions. You need to read the User's Manual before you read this one, common functions (such as connecting to the WiFi interface) and wiring/mounting not directly related to airstart use are NOT covered in this manual!

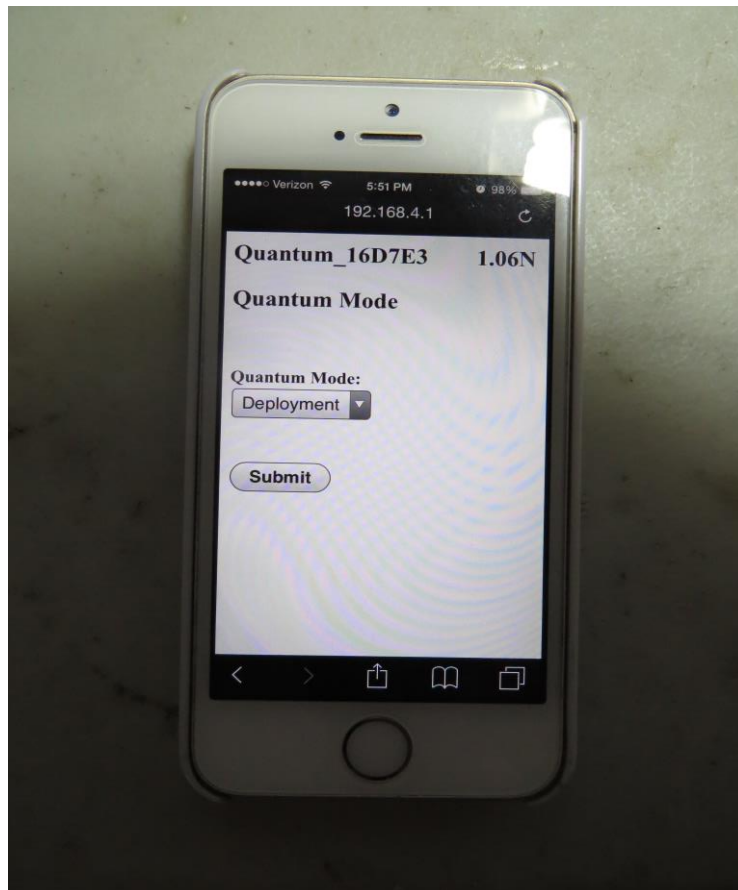
Selecting the Airstart Option

The Quantum comes pre-configured for use as a deployment controller. The airstart options are in a “hidden” menu that you cannot select from the standard WiFi screens. In order to select them, you have to put the Quantum into Airstart Mode.

To put the Quantum into Airstart Mode, connect to it via WiFi, and go to the following page:

<http://192.168.4.1/mode>

You will see this menu:

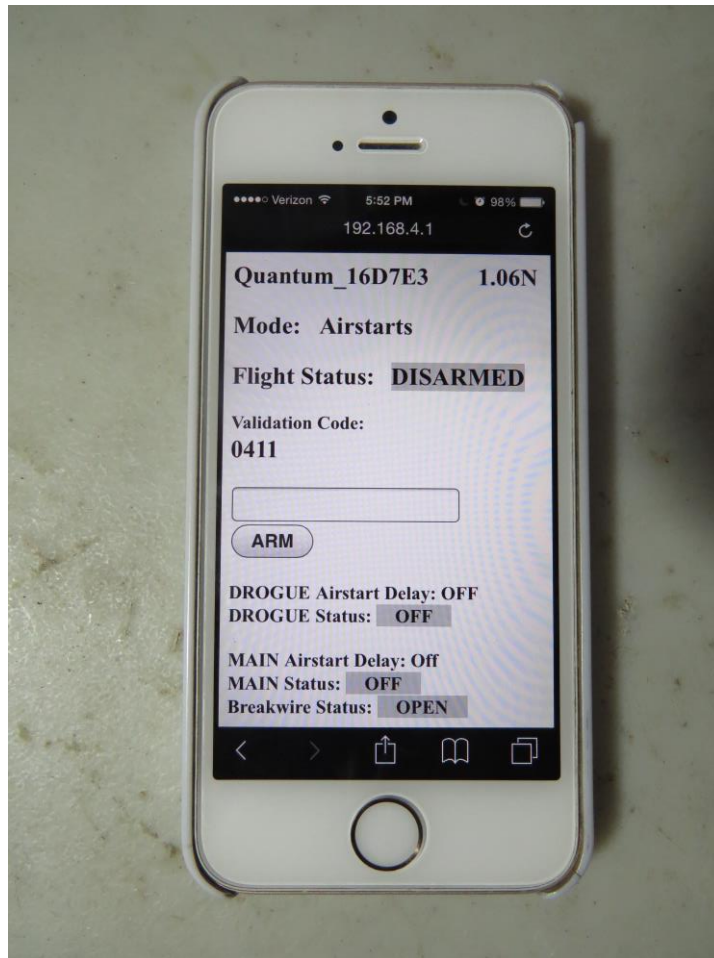


To put your Quantum into Airstart Mode, select the **Airstart** option from the dropdown menu (you may have to click Done on some platforms), then click on the Submit button. Note that when you do this, it clears any options that you have previously selected and sets them to the default for the Airstart Mode. It will then take you to the Status Page.

(To put your Quantum back into Deployment Mode (its default), go into the modes screen and select Deployment under the Mode, then click on Select. It will clear any options you have selected previously, and set them to the defaults for the Deployment Mode. It will then take you to the Status Page.)

The Status Page in Airstart Mode

The Status Page in Airstart Mode is very similar to the one that you're used to seeing in Deployment Mode. It shows your Flight Status (normally DISARMED), the validation code for arming along with a text entry box and an "ARM" (or "DISARM") button, and your battery voltage, ASL altitude, and current temperature. Down below are links to the Settings screen and a Flights link to display your saved flights.

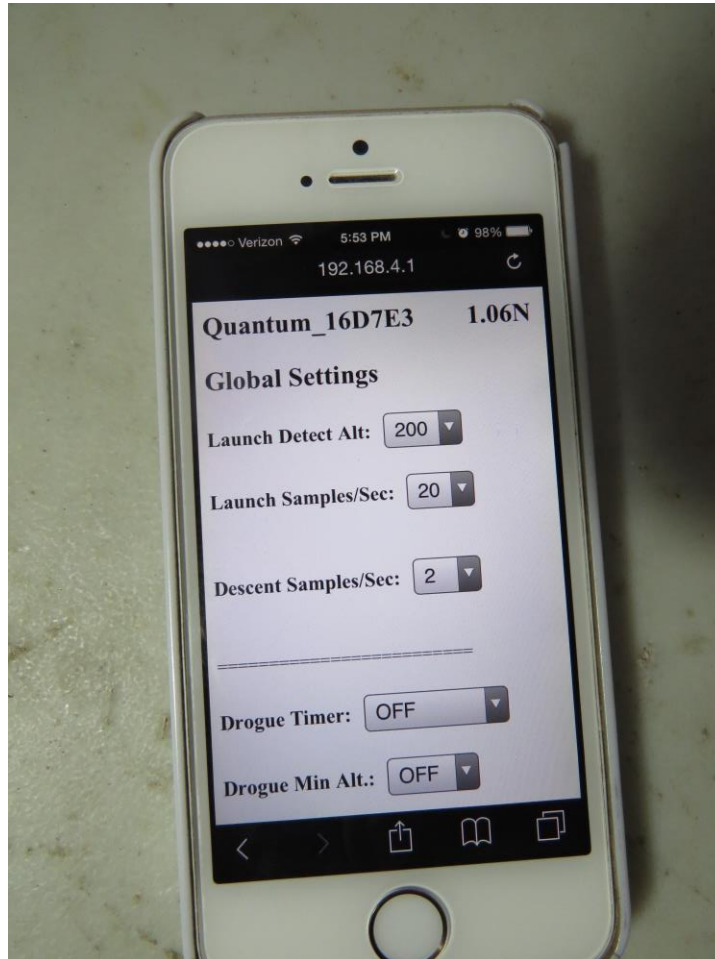


There are also a few differences. First, instead of display "DROGUE Time" and "MAIN Altitude", it displays "DROGUE Airstart Delay" and "MAIN Airstart Delay". There is no link next to these to change the values; they are all done from the Settings screen, since they are relatively complex. It also displays "Breakwire Status" (either OPEN or CLOSED), which is the current status of the breakwire input (more on that later).

Screens that are common to both modes are the Flights screen, and the Test screen. Operation is exactly the same as in Deployment Mode, except that in some cases you may see references to Airstart functions instead of Deployment functions (i.e., the Flight Summary will show "Drogue Airstart Altitude" instead of "Drogue Altitude").

The Airstart Flight Settings Page

The Global Settings page is used to change settings in Airstart Mode. You get into this page by clicking on the “Settings” link on the Status Page:



Some of the features are common between the Airstart and Deployment modes... since they're explained in the Eggtimer Quantum User's Guide we won't go into their function here, except to list which ones are common:

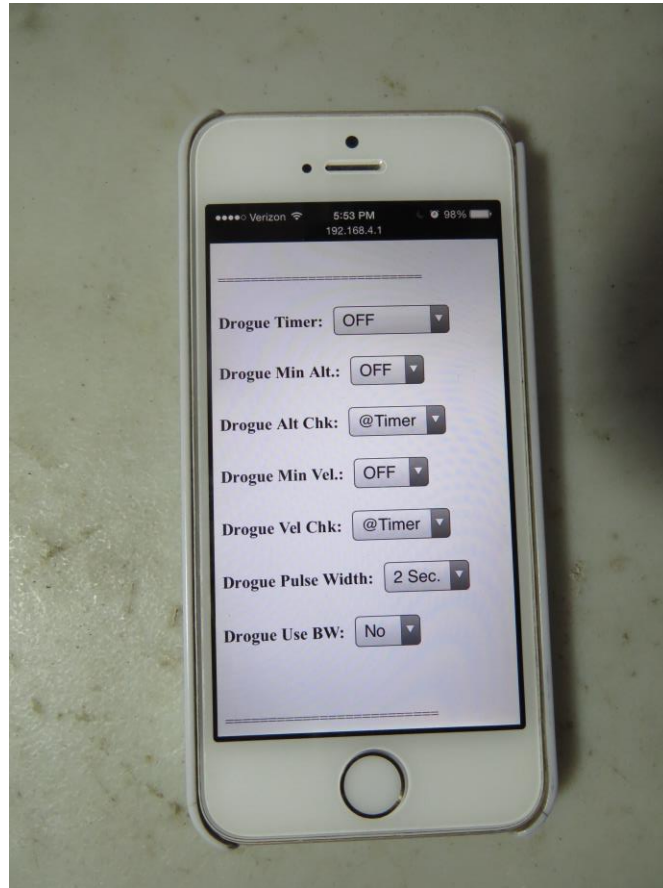
Launch Detect Altitude (LDA) - Range: 100'-500' by 50' (default 200')

**Launch Samples per Second - Range: 10,15, 20, 25, 30, 33 samples/sec.
(default 20 samples/sec.)**

**Descent Samples per Second - Range: 1, 2, 4, 5, 8, 10 samples/sec.
(default 2 samples/sec.)**

Airstart Mode Channel Options

Channel options in the Airstart Mode are generally the same for the Drogue and the Main channels, with a few notable exceptions. The channels are completely independent of each other, and the timer function starts for both of them when the Quantum detects the Start of Flight.



Drogue Channel Options

Drogue Timer: OFF (default), Nose-Over, 0.3-3.0 by .1 secs, 3.2-9.8 by .2 secs

This is the time that the DROGUE channel will fire based on the Start of Flight. Theoretically this should be pretty close to the actual time that your rocket starts moving, although it may lag by .1 or .2 secs. You can also turn the channel off (“OFF”), or have it fire at nose-over (“Nose-Over”) just like a drogue chute or a single chute at apogee. More on these functions under the “Typical Settings for Airstarted Flights” section.

Drogue Min Alt: OFF (default), 300’-3000’ by 100’, 3200’-9800’ by 200’

Drogue Alt Chk: @Timer (default), Anytime

This is the MINIMUM altitude that your rocket must attain in order to fire the Drogue channel. This is a safety mechanism to prevent your airstart from happening unless the rocket is

reasonably high up in the air, and if you model your flight properly will also be pretty good insurance that your rocket is pointing “up” too.

This value can be checked ONCE at the same time that the channel would be due to fire (“@Timer”), or it can be checked continuously up to that point and if that altitude is reached at any time it will set a flag that allows it to fire (“Anytime”). This is typically used with very high speed airstarts... see the discussion in the sections below.

Note than the channel will NOT fire until (and unless) your rocket reaches the LDA altitude, regardless of what this value is set to.

If you do not want to use this check, set it to OFF. That is the default.

Drogue Min Vel.: OFF (default), 100-1000 fps by 100 fps, 1200-2000 fps by 200 fps
Drogue Vel. Chk: @Timer (default), Anytime

This is the MINIMUM velocity that your rocket must attain (or must have attained) in order to fire the Drogue channel. This is a safety mechanism to prevent your airstart from happening unless the rocket is moving relatively fast and pointing “up” because this is derived from the barometric altitudes.

This value can be checked ONCE at the same time that the channel would be due to fire (“@Timer”), or it can be checked continuously up to that point and if that altitude is reached at any time it will set a flag that allows it to fire (“Anytime”). This is typically used with very high speed airstarts... see the discussion in the sections below.

Note than the channel will NOT fire until (and unless) your rocket reaches the LDA altitude, regardless of what this value is set to.

If you do not want to use this check, set it to OFF. That is the default.

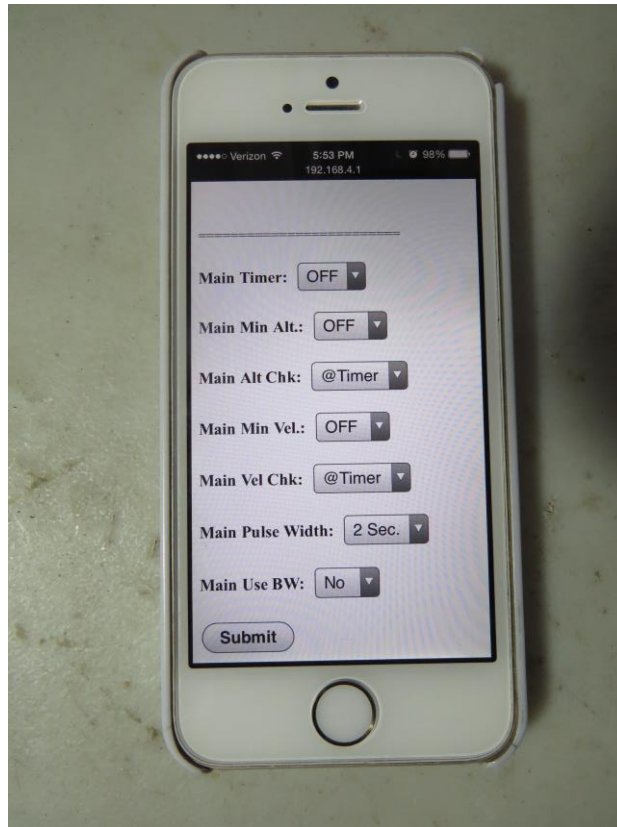
Drogue Pulse Width: 1-9 sec (default 2 sec)

Similar to the Deployment Mode, this is the amount of time that the igniter will be fired, from 1-9 seconds. Unlike the Deployment Mode, however, you cannot select “Continuous”. The airstart channels turn off when this timer expires, OR when low-velocity detect has been triggered. That happens when the rocket has reached < 100 ft/sec for at least one second. The purpose of this is to prevent any airstart events from happening while the rocket is moving slowly and potentially not pointed “up”.

Drogue Use BW: NO (default), Yes

The airstart events can be qualified with a “breakwire”, which is a physical connection that must be broken for the airstart to occur. The Breakwire is only checked once, when the timer expires; if check fails, the airstart event is disabled. Note that there is only one physical Breakwire connection; it is shared between the Drogue and the Main channels. Please see the Appendix for a discussion of how to use the Breakwire.

Main Channel Options



Main Timer: OFF (default), 0.3-3.0 by .1 secs, 3.2-9.8 by .2 secs

This is the time that the MAIN channel will fire based on the Start of Flight. Theoretically this should be pretty close to the actual time that your rocket starts moving, although it may lag by .1 or .2 secs. You can also turn the channel off (“OFF”). More on these functions under the “Typical Settings for Airstarted Flights” section.

Main Min Alt: OFF (default), 300'-3000' by 100', 3200'-9800' by 200'

MainAlt Chk: @Timer (default), Anytime

This is the MINIMUM altitude that your rocket must attain in order to fire the Main channel. This is a safety mechanism to prevent your airstart from happening unless the rocket is reasonably high up in the air, and if you model your flight properly will also be pretty good insurance that your rocket is pointing “up” too.

This value can be checked ONCE at the same time that the channel would be due to fire (“@Timer”), or it can be checked continuously up to that point and if that altitude is reached at

any time it will set a flag that allows it to fire (“Anytime”). This is typically used with very high speed airstarts... see the discussion in the sections below.

Note than the channel will NOT fire until (and unless) your rocket reaches the LDA altitude, regardless of what this value is set to.

If you do not want to use this check, set it to OFF. That is the default.

Main Min Vel.: OFF (default), 100-1000 fps by 100 fps, 1200-2000 fps by 200 fps
Main Vel. Chk: @Timer (default), Anytime

This is the MINIMUM velocity that your rocket must attain (or must have attained) in order to fire the Main channel. This is a safety mechanism to prevent your airstart from happening unless the rocket is moving relatively fast and pointing “up” because this is derived from the barometric altitudes.

This value can be checked ONCE at the same time that the channel would be due to fire (“@Timer”), or it can be checked continuously up to that point and if that altitude is reached at any time it will set a flag that allows it to fire (“Anytime”). This is typically used with very high speed airstarts... see the discussion in the sections below.

Note than the channel will NOT fire until (and unless) your rocket reaches the LDA altitude, regardless of what this value is set to.

If you do not want to use this check, set it to OFF. That is the default.

Main Pulse Width: 1-9 sec (default 2 sec)

Similar to the Deployment Mode, this is the amount of time that the igniter will be fired, from 1-9 seconds. Unlike the Deployment Mode, however, you cannot select “Continuous”. The airstart channels turn off when this timer expires, OR when low-velocity detect has been triggered. That happens when the rocket has reached < 100 ft/sec for at least one second. The purpose of this is to prevent any airstart events from happening while the rocket is moving slowly and potentially not pointed “up”.

Main Use BW: NO (default), Yes

The airstart events can be qualified with a “breakwire”, which is a physical connection that must be broken for the airstart to occur. The Breakwire is only checked once, when the timer expires; if check fails, the airstart event is disabled. Note that there is only one physical Breakwire connection; it is shared between the Drogue and the Main channels. Please see the Appendix for a discussion of how to use the Breakwire.

Setting Up Two-Stage Airstarts with Your Quantum

Before you do anything, you **MUST** use some kind of simulation program to map out the flight, so that you have a very good idea of what altitude and velocity your rocket will be attaining at three critical points: burnout, separation, and sustainer motor ignition. Knowing when these should occur is the key to a successful two-stage flight.

Burnout

This is when your motor's thrust stops. Every motor has published thrust curves that give you that exact information, you can get them either from the manufacturer's web site, a third-party web site like thrustcurve.org, or from the data sheet that's typically include with the motor. Note that these figures are averages based on tests of a number of samples; they are "typical" values, not absolute. Because of that, we strongly recommend that you add 20% to the typical figure, so you have a "worst case" value to work with.

Separation

This is when you want the booster stage to separate from the "stack". Typically, you will want to do this before you fire the sustainer's motor, because the smoke and fire from the sustainer's motor can do significant damage to the coupler. However, if this is an acceptable risk (maybe you have some kind of liner in the coupler, or it's replaceable) then you may actually want the motor blast to separate the stack.

There are three ways of doing a separation: drag separation, separation charge (or a variant of it), and motor separation. With drag separation, the coupler is fit relatively loosely into the sustainer, with the idea being that when the booster motor burns out the resultant negative acceleration and the higher drag on the booster will be enough to pull the booster apart. This works best for boosters with large fins, for example we've done it with a Rocketry Warehouse Double Shot which uses a 4" booster with a 54mm motor, and a 54mm sustainer with a 38mm motor. The booster is larger than the sustainer and has large fins, so it drag separates well.

We've already mentioned motor separation, so we won't elaborate on that further except to say that it works well but tends to cook the inside of your interstage coupler pretty badly, depending on the motor that you're using in your sustainer. If you decide to do that, you might want to think about putting some kind of replaceable lining inside the coupler, and possibly fill it with some "dog barf" wadding too.

Finally, there's the separation charge method. With a separation charge, you use a pyrotechnic charge to forcefully separate the stages. Typically, this is done shortly after motor burnout, but before your sustainer ignition. The trick is that you don't want the separation charge to pop the stages apart while the booster is still firing, so you need to give it a little extra time from your booster's burnout time. You also have to wait a little bit to fire the sustainer motor if it's an AP motor, because the pressure generated by the separation charge can snuff out the sustainer's igniter; the pressure has to subside first before you ignite the sustainer. You must also be careful to make sure that the separation doesn't happen while the booster motor is still burning; if it does, it can knock the sustainer (and possibly the booster) off-axis.

Sustainer Motor Ignition

This is the paydirt, when you light your sustainer motor. As has been mentioned previously, the ideal situation would be that it happens after the booster motor burns out, you separate the stages, and you wait a short time for the separation pressure to subside.

The reality is that this can be a tricky value to come up with. Black powder (Estes) motors igniter almost instantly, but high-power AP motors take awhile to light and come up to pressure. The amount of time that this takes is highly dependent on the propellant formula and the igniter; “white” or “blue” propellants tend to light relatively fast (maybe about one second), and “red” or “green” propellants tend to take a few seconds to light. Since it’s difficult to predict the actual time that the motor will light, it can be a little difficult to precisely model the flight. Fortunately, a delay of a second or two usually doesn’t matter, and in fact will translate to additional altitude since the rocket will be moving at a lower velocity when the sustainer motor ignites, with a resultant reduction in drag. In fact, the maximum altitude for a given set of motors can usually be obtained by delaying the sustainer motor ignition for several seconds and allowing the rocket to coast. There are some issues with doing that... more on that later.

Locating Your Electronics

Before you start building your two-stage rocket (or in some cases, before you start planning it) you need to figure out where the separation and airstart electronics are going to go. There are several ways of doing it:

- Sustainer ignition in the interstage, motor-ignition separation, motor deploy for the booster chute
- Sustainer ignition and electronic booster chute deployment in the interstage, motor-ignition separation
- Separation and booster chute deployment in the interstage, sustainer ignition in the sustainer’s AV bay
- Booster chute deployment in the interstage, sustainer ignition and separation in the sustainer’s AV bay

You would also add whatever electronics are doing deployments for your sustainer, of course, and if it’s a big project you probably want to have redundancy on all of the deployments. This can get complicated. In general, you can usually do motor deployment for the booster, since they typically slow down relatively quickly once they separate. It never hurts to have BOTH motor deploy and electronic deployment for the booster.

Doing sustainer motor ignition in the interstage makes the build easy, because you don’t have to run any wires through the sustainer and you don’t have to figure out how to make the wire disconnect when the sustainer’s drogue fires. You just mount your Quantum in the interstage (with a suitable bulkhead, of course!), and you can use the drogue channel for the booster’s chute deployment at nose-over if you wish. The problem is that you pretty much HAVE to do separation by motor ignition... if it drag separates or you fire a separation charge you’ll pull your igniter out of the motor before it lights. You’ll want a relatively snug fit between the interstage coupler and the sustainer, you might even want to use shear pins (although we haven’t tried it...). If you do this, use a relatively gentle motor (10:1 thrust:weight ratio or so)... in general, we don’t recommend using high-thrust motors like a CTI VMax in two-stage rockets anyway.

From a safety point of view, this isn't a bad choice, because the sustainer not lighting if there's a problem is always an acceptable safety option... everything just comes down on chutes and you try it again with another booster motor. There's no igniter left in the sustainer motor, so it's basically inert. Just make sure that you have some way of getting both pieces down safely.

We've found that it's more flexible (although more complicated) to do the separation in the booster using a separation charge in the interstage coupler, and to place the airstart electronics in the sustainer. This makes it somewhat easier to do parachute redundancy for the booster, you can use a single Quantum in the booster for the separation charge and chute at nose-over, and use the booster's motor ejection as the backup for the chute. If the booster drag separates (intentionally or otherwise), your sustainer is still going to light because the igniter isn't tied to the interstage. You can use higher thrust motors with this configuration, maybe 15:1 or so, and your rocket is most likely going to go straight where it's pointed. Just don't use really high thrust motors like a VMax... we'll tell you why later.

The complication with doing this is that you need to either have the electronics somehow located near the motor so that you can run the wire to the igniter (easy for a large build, harder for a minimum-diameter build), or run a tunnel inside the body tube from the AV bay to the motor's nozzle end and have some kind of break-away electrical disconnect so that when the drogue fires the wire comes apart without fouling the drogue shock cord and parachute lines. Small Molex connectors can be used for this... just don't expect them to last for more than one or two flights before you have to redo them, because the pins tend to get pulled out and the little tabs that hold them into the connector tend to break. You also have to be careful that they don't get separated during the boost, but you don't want to tape them together either or they won't come apart when they should. Taping each end to the inside of your body tube (or the AV bay bulkplate) usually fixes that.

If you also do the separation in the sustainer's AV bay, you'll generally need to run TWO pairs of wires down the body tube, and have TWO break points when the drogue side of the AV bay separates. Obviously, this adds more complication. If you can do the separation in the interstage, it makes things quite a bit easier on the build.

If you put the sustainer ignition in the sustainer AV bay, you'll need to have whatever normal deployment electronics you build would use. The Quantum has two channels, so chances are pretty good that you'll need two of them in your AV bay, but that also gives you the opportunity to have some deployment redundancy. In general, we recommend that you have redundancy in at least your drogue. If your main chute gets jammed or you have a bad ematch or for some other reason it doesn't come out, if you land under drogue the landing will be a bit hard but it generally doesn't cause serious damage. If your drogue doesn't come out... you're coming in ballistic. Even if your main chute fires on cue, you're going to be going so fast that it will tear up the chute and maybe take 100 ft/sec off your velocity because there's not enough time for the rocket to slow down before it hits the ground because you're moving at ft/sec or so. Trust us... we know. Better our rockets than yours...

A Word About Motor Selection

As we have mentioned several times, you MUST run a simulation on your airstarted flights. That's the only way to really get an idea of what the delay times need to be, and how high it's going to go, and what the velocity at sustainer ignition is going to be. This is particularly important for long-burn

motors in the sustainer. We've used them, and they're very cool, but you have to make sure that the rocket is pointed "up" before you light them.

In general, we recommend that your booster motor should have at least a 10:1 thrust:weight ratio at launch. Assuming that your rocket is stable (and a typical long and skinny two-stage rocket tends to be a bit overstable), it's going to go straight up, and it will be pointing up when the sustainer fires. Long-burn motors in the booster won't get the air flowing over the fins and any disturbance (wind, slightly misaligned fins) can make your rocket point off-axis and possibly lead to you chasing your sustainer for a very long distance. We're talking miles for a J or bigger motor in the sustainer. If you want to use a long-burn motor in the sustainer, go on the large side for the booster... we've used a K805 to J94 in the Double Shot, for example.

As we have mentioned before, we do not recommend the use of high-thrust motors like CTI's VMax for two stage rockets, particularly for the booster. The reason is that there is a possibility that the "mach dip" created by the boost will cause the timer to start very late, since for safety it's dependent on hitting the LDA altitude first. Since those motors typically fire for less than 0.5 seconds, you may hit mach before you hit the LDA altitude, and there may be a perceived altitude drop that may cause your timer to not start for at least a second after that. If the perceived altitude comes back to the LDA after a delay, the timer may start after one or both of the channel times have elapsed, and you may end up firing both the separation and the igniter simultaneously which will most likely snuff out the sustainer motor. Also, there is a much higher chance of fins shredding off, and the sustainer's igniter being pushed away from the top of the grain by the G forces. All good reasons to avoid these motors for the booster. If you want to try one in the sustainer... well, it would be interesting.

If your booster motor is going to get you reasonably close to Mach 1 before separation, we recommend that you increase the sampling rate from the default to 25 or 33 samples/sec. This will improve the accuracy of the timer's SOF detection mechanism. Also, if your simulation shows that the velocity at the LDA altitude (normally 200') is above 700 ft/sec, we recommend that you lower the LDA so that it occurs at a lower velocity. This is unlikely to happen with motors in the recommended thrust:weight ratio range of 10:1 or so, but it's something you need to be aware of.

Using the Quantum for Airstarting Clusters

Another cool thing you can do is to have a cluster of motors in your rocket, but instead of lighting them all on the pad you light some of them in the air. Some rockets lend themselves to doing this... anything with sidepods, for example (think Titan IIIC or Falcon Heavy). You can use this to get some neat effects, like having a “sparky” main engine with “smokey” airstarted motors. You can also use it to get the rocket going with a higher thrust main motor then airstart some long-burn motors in the air.

You’ll notice that we say “motors” and not “motor”. That’s because when you airstart a cluster, you’ll always need more than one motor, symmetrically arranged around the center. Otherwise, when you light them the rocket will go very nicely off-axis for a long, long ways, possibly heading into the ground. That’s also the primary risk factor with an airstarted cluster... that one or more of the motors doesn’t light. For safety sake, you need to use motors that light easily, and/or a really good igniter. CTI motors with the black powder pellet in the top grain are a good choice, as are white/blue/smoky motors. Most long-burn motors work fine, too.

The setup for the Quantum is the same as you would use for lighting the sustainer of a two-stage rocket, except you don’t have a separation charge. That leaves the second channel free for something else, possibly redundant igniters or a charge that releases the pods after burnout (you’d use motor deploy for their chutes). As with a two-stage build, you need to simulate everything thoroughly to make sure that you have the correct timing (and altitude/velocity if you’re using the qualifications).

Using the Altitude and Velocity Qualifications

One thing that the Quantum can do that most airstart timers can not is to qualify an ignition using altitude or velocity. This allows you to pretty much insure that your rocket is pointing “up”, because those qualifications can only happen if your rocket doesn’t have a significant horizontal component. This is useful for motors with a lower thrust:weight ratio, or if you’re using a long burn sustainer motor and you absolutely want to make sure that it only lights near vertically.

There are basically two reasons why you want to make sure your sustainer fires while pointing near vertical. The first one is that if your sustainer fires off—axis, it’s going to go a long ways away from you. This means that you’re going to have to drive or walk for awhile, or even worse, you might lose your tracking signal and have a very long hunt. Not good. The second, and more important reason, is that you don’t want the sustainer firing if it’s not pointing “up”. If you have a shred and your sustainer is pointing down when it fires, that’s a huge safety issue.

So, to prevent that from happening you want to make sure that it’s firing while pointing “up”. The most basic way of doing this is to make sure that your rocket has sufficient stability, and is built sufficiently for the motor that you’re using. That’s another reason why we don’t recommend using very high-thrust motors for two-stage builds... they tend to make parts fly off the rocket. If your motor has a 10:1 thrust:weight ratio and at least 2C stability at launch, then your rocket is going to go straight up and you’ll be fine. If your motor has a little less punch (i.e. it’s a long-burn) or the rocket’s stability margin is a bit less, then you might want to think about implementing a velocity or altitude qualification.

To use these qualifications, you need to take your simulation, using the burnout, separation, and motor ignition figures that you found earlier. Don’t forget to figure in the amount of time that the motor takes to light into your motor ignition figure... it’s usually at least one second, but it can be longer for some motors. If you aren’t sure, ask around... chances are pretty good that the members in your TRA or NAR club will have lots of advice on this. Also, be sure to add in values for the rod/rail angle, and your expected wind, and don’t be afraid to get a few different values of each in case the conditions change during launch day. The Quantum makes it easy to change these values right before you fly, so there’s no reason not to get it right.

One you have those numbers, take a look at the predicted altitude and velocity that your rocket will be moving when the IGNITER fires, NOT when your motor will actually light. THAT is what the qualification will be based on. What you are going to do is to take the altitude/velocity value at the ignition time, and figure out how much you are willing to deviate from those before you decide not to light the motor. In general, you don’t want to igniter the sustainer if it’s more than 20 degrees from vertical. That’s why we recommend using a booster motor thrust:weight ratio of at least 10:1... it generally keeps your rocket pointing wherever the rod or rail is pointed. Assuming that’s the case, the difference would be 20 degrees minus whatever angle your rail is pointed at. For a close approximation, figure 1 percent for every degree, so for a 5 degree rod/rail angle that’s a 15 percent variation.

So, you simply reduce your projected sustainer ignition altitude or velocity by 15 percent, and use that as the value for your qualification. Note that these are going to be processed in the Quantum using the filtered value, which lags behind the “real” value by about ¼ second, so you’ll want to take that into account too.

For example, let's say that you have the rail set to 5 degrees, and with your expected wind the altitude at ignition is 1200' at 4.0 seconds. You've chosen a fast-lighting motor, so the ignition will happen at maybe 3.0 seconds, and the simulation says that it will happen at 800' going at about 400 ft/sec. Take another ¼ second off the time, so you're looking at 2.75 secs, the rocket was at 700' going just above 400 ft/sec (it's not doing to slow down much in ¼ second...). Take 85% of the 700' that you expect the ignition to be triggered at, so that's 595 feet. We'll use 600' as the qualification. Similarly, if you want to use velocity rather than altitude, take 85% of the 400 ft/sec, that's 340 ft/sec, so we'll use 350 ft/sec as the value. You will want to set the qualification so that it is effective "@Timer", i.e. it does the check when the timer expires.

Remember how we told you earlier not to use high-thrust motors for two-stage builds? This is another reason why. When you get near Mach 1, the pressure buildup drops the perceived altitude (and also the perceived velocity) so the Quantum "thinks" that it's going lower and slower than it actually is. You're more likely to have a failure to trigger due to a failed qualification with high-thrust motors, one more reason to avoid them.

Now, if your motor isn't quite so high-thrust but burns long enough that your rocket may hit mach on the booster before the motor burns out, you probably don't need to use the qualifications. It's pretty hard to get too far off-axis when you're going that fast, and if you go unstable you'll never get that fast. However, it is still possible to use the qualifications as long as the timer starts at LDA (and almost all motors will). To do that, you'll use the "Anytime" qualification option, and use the velocity qualification, setting it to a lower value than you might expect to see at your expected ignition altitude, typically something around 700 ft/sec. What this means is that if the rocket achieves this velocity ANYTIME between the start of the flight and the ignition, it will assume that you're going fast enough to be vertical. That's a pretty good assumption if you KNOW that your booster motor is going to get you near Mach 1.

Another good reason to use the altitude/velocity qualification is if you're going for the absolute maximum altitude you can get out of a given set of motors. Contrary to intuition, that's not achieved by firing the sustainer right after the booster; it's achieved by waiting until the rocket has slowed for some time. We've done some simulations and seen some maximum altitudes with the sustainer firing when the velocity was under 200 ft/sec... that's a lot of slowing from the 800 ft/sec that the booster got it up to. Obviously, if you wait a long time to light your sustainer the chance of it going off-axis due to wind effects goes up, so an altitude or velocity qualification is a really good idea.

This brings up the issue of whether it is better to separate early or coast with the booster still on if you're going to coast for awhile after burnout. In general, if your booster is the same diameter as your sustainer, you should hang onto it because the extra mass will reduce the deceleration after burnout without causing a significantly higher drag penalty. If your booster is larger (i.e. RW/Madcow Double Shot, 4" booster and 54mm sustainer), the sooner you ditch it the better, because that booster will be a big drag on the sustainer. Again, doing a good simulation with Open Rocket or Rocsim is your best bet, but you'll probably find these guidelines to be pretty accurate.

An Example: Two Stage K650 to J400

This is the setup from an actual flight, of the aforementioned Double Shot on a 54mm CTI K650 Smokey Sam to a 38mm CTI J400 Smokey Sam. We like using the CTI motors for sustainers because they light very reliably; they have a BP pellet pressed into the upper propellant grain which makes them very easy to light. The Smokey Sam motors leave a really nice dark trail, which makes it easy to follow both the booster and the sustainer, especially since the RSO had us launch this from the 500' "away pad".

This rocket actually had three Quantums in it. There is one in the booster that handles separation and the booster parachute (at nose-over), with the backup parachute deployment being done with the motor's ejection charge. There are two Quantums in the sustainer: one in airstart mode handling the sustainer ignition and the drogue at nose-over; and the second one in deployment mode handling the main deployment at 800' and the backup drogue (at nose-over + 1.5 seconds). There is also an EggTIMER TRS in the nose that handles the backup main at 500', and allows us to track and recover this thing.

The booster's airstart setup looks like this:

LDA Alt: 200
Launch Samp/sec: 20
Nose-Over Samp/sec: 2
Drogue Airstart Delay: Nose-Over
Drogue Min Alt: OFF
Drogue Min Vel: NO
Drogue On-Time: 2
Drogue Use Breakwire: OFF
Main Airstart Delay: 3.2
Main Min Alt: OFF
Main Min Vel: OFF
Main On-Time: 2
Main Use Breakwire: NO

Since the drogue channel is being used for the parachute, we've set it to fire at nose-over rather than being timed. The motor's ejection charge was used as the backup, it was left undrilled (14 secs). The main channel is doing the separation. The K650's rated burnout is at 2.7 seconds, so we set the separation charge to fire 20% later than that, or at 3.2 seconds.

The sustainer's airstart Quantum was set up like this:

LDA Alt: 200
Launch Samp/sec: 20
Nose-Over Samp/sec: 2
Drogue Airstart Delay: Nose-Over
Drogue Min Alt: OFF
Drogue Min Vel: NO
Drogue On-Time: 2
Drogue Use Breakwire: OFF
Main Airstart Delay: 3.8
Main Min Alt: OFF

Main Min Vel: OFF
Main On-Time: 4
Main Use Breakwire: NO

The drogue channel was set to nose-over, since the deployment Quantum is being used as the backup. We couldn't use motor eject for the backup drogue, because the coast time was too long... it simulated at 20 seconds, and the maximum ejection delay for the J400 was only 16 seconds. You will probably find that when you do your simulations on any high power two stage rocket that you're not going to be able to use the motor eject as a backup... just about every one that we've simulated has proven this out. The main channel handles the sustainer ignition, it was set to 3.8 seconds, which gives the pressure 0.6 seconds to subside before the motor is ignited (remember, the separation was at 3.2 seconds). We set the on-time to 4 seconds, "just in case", although CTI motors light pretty quickly and reliably due to the BP pellet in the top grain.

The sustainer's deployment Quantum was set to fire the drogue at nose-over + 1.5 secs, and the Main at 800'. Standard stuff, so we won't bother with the setup here.

In flight, the rocket came nice and straight off the rail, and the booster drag-separated immediately after burnout (the separation charge proved unnecessary, but we aren't about to take it out "just in case"...). The J400 lit fine, and the rocket disappeared out of sight while the booster came down very gently on a 58" parachute that fired at nose-over. We tracked the sustainer with the TRS it had in the nose (also doing the backup main chute deployment), it landed about 3000' away after hitting about 11,500'. It had simmed to about 11,700', so we were pretty happy with the way that it call came out.

When the breakwire is being used, the Quantum will not arm if it sees that it's OPEN, and the channel won't fire if it sees that it's still CLOSED. The classic breakwire is attached to the pad somehow, and is used with the sustainer motor to prevent it from firing until the rocket has left the pad, but there are lots of other things you could do.

Some ideas for the breakwire:

- A wire loop in the sustainer with a disconnect in the interstage to confirm separation
- A microswitch against the rod/rail that's closed while it's on the pad to prevent arming off the pad
- For an interstage-mounted igniter, you could use one between the interstage and the booster, to make sure that the interstage hasn't drag-separated from the booster and caused a premature booster parachute deployment

Eggtimer Quantum Airstart Quick Reference

General Rules for Successful Airstarts

- SIMULATE EVERYTHING FIRST!!!
- Your booster motor's thrust:weight ratio should ideally be 10:1 or above.
- Your separation time should be at least 120% of the motor's burn time.
- You should fire the sustainer's igniter at least ½ second after separation, longer is OK.
- Don't use high-thrust motors like VMax's in the booster.
- If you expect your booster to get you near mach, increase the sample rate and reduce the LDA altitude to ensure that the timer is triggered.
- Use an altitude or velocity qualification if your booster motor's thrust:weight is < 10:1 or your stability is < 2C, or if you're waiting an extended amount of time before firing the sustainer motor.

Quantum Airstart Functions

Drogue/Main Timer:

Values: OFF (default), Nose-Over (Drogue only), 0.3-3.0 by .1 secs, 3.2-9.8 by .2 secs
Controls when after launch the timer will fire the channel

Drogue/Main Min Alt:

Values: OFF (default), 300'-3000' by 100', 3200'-9800' by 200'
Controls the MINIMUM ALTITUDE that must have been reached for the channel to fire

Drogue/Main Alt Chk:

Values: @Timer (default), Anytime
Controls when the ALTITUDE CHECK is performed:

- @ Timer: When the timer expires
- Anytime: Anytime up to when the timer expires

Drogue/Main Min Vel.:

Values: OFF (default), 100-1000 fps by 100 fps, 1200-2000 fps by 200 fps
Controls the MINIMUM VELOCITY that must have been reached for the channel to fire

Drogue/Main Vel. Chk:

Values: @Timer (default), Anytime
Controls when the VELOCITY CHECK is performed:

- @ Timer: When the timer expires
- Anytime: Anytime up to when the timer expires

Drogue/Main Pulse Width:

Values: 1-9 sec (default 2 sec)
Controls the amount of time that the channel fires

Drogue/Main Use BW:

Values: NO (default), Yes
Controls whether or not the hardware breakwire is tested at firing time