Rocket Electronics 101

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Good morning class and welcome to Rocket Electronics 101. In this class we will cover the basics of electronics use in rocketry. We will be discussing the why's, wherefore's and how-to's of using the various electronic devices we use in our rockets. As this is an intro-level class we'll try to avoid many of the intricacies involved in circuit design and keep things simple.

First, let's discuss the why's of rocket electronics. Some of you will find this a bit 'old hat' but hang in there and we'll get to the more interesting aspects in just a bit. So, why do we use electronics on a rocket? Let's list some of the reasons:

- Air-start motors either for clusters or for staging
- Parachute deployment - both single and dual deployment
- Timed functions such as controlling a camera shutter
- Tracking functions - both radio frequency, audible or physical
- Telemetry - real time and delayed
- Data acquisition from onboard instrumentation

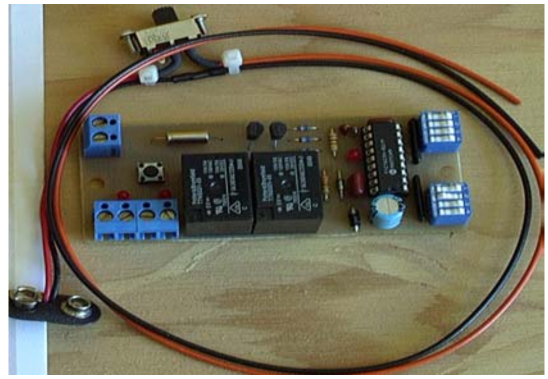
That's quite a list. We'll try to hit on each of these as we go through this class, although for obvious reasons, we will be putting more emphasis on certain select areas. So let's get started.

First, the above list, while impressive does not actually address the question of why we use electronics. It tells us how and not why. So 'why' do we use electronics? We use electronics anytime we want more control over some aspect of our flight than we can get with a conventional delay element/ejection charge or anytime we need to capture data not readily determined from the ground. The only control we have without electronics is by means of the motor's ejection charge. This is quite limiting, both from a timing aspect and from the range of functions that can be controlled. If we use a timer or an altimeter, we can more closely match the action of our rocket to an ideal behavior. We can set that ideal 11.5 second delay that we need for maximum coast time to apogee or start a timing motor to click the shutter on our camera. We can get data and information back from our flights: How high did it go? How fast? Or my personal nightmare - how hard did it hit? Or we can locate a rocket that drifts out of sight on the wind or follow a rocket as it flies at night. The downside of electronics is that while they free us up to do more things with our rockets, they also add weight, complexity and cost to our toys. On that basis, you can characterize the need to be familiar with and use electronics as such:

Model & Mid-powered	- no real need to use electronics
Certification I flyers	- may use electronics
Certification II flyers	- should learn to use electronics
Certification III flyers	- must use electronics

Now in our discussions, I've mentioned several devices of electronics that we can use. To recap, the most common types of electronics finding their way into rocketry are timers, altimeters - both recording and non-recording, flight computers, and audio/radio frequency tracking devices. We will discuss these devices in detail beginning with the simplest of them, the timer.

Timers



LOC Timer

Timers do exactly that. They time. Some timers have a single timer on the board, some have two, and a few have three, four, or more timing channels. A timer measures time from an event (usually, but not necessarily, liftoff) and then activates some function (usually, but not necessarily, an electric match or deployment charge). Did you note the "usually, but not necessarily, . . ." That's because you can use these timed events for any manner of actions - they are much more flexible than the delay/ejection charge on a typical motor. A good example of this flexibility would be to use a timing channel to repetitively trip a camera shutter or to monitor a g-switch for the start of deceleration <u>after</u> motor burnout before lighting a second stage motor. Activation is usually by G-switch or Break-Wire/Pull-Pin. Break-wire or pull-pin activation involves a wire or plug completing an electrical circuit - when this circuit is broken by the wire breaking or the plug being pulled from the socket, the timer starts counting. The timer counts until the pre-set time is reached and then switches power to an output channel. Depending on the timer, the output channel can be activated once or pulsed continuously from that point on. Most timers either use a large capacitor to store the energy they discharge through the output channel or they require a large enough battery to activate whatever is connected to the output channel. A typical mission for a timer would be to monitor the liftoff of a rocket and, once liftoff is detected, start timing a period of time equal to the burn time of the motor and the amount of coasting time desired. At the conclusion of this time interval (which must be predetermined and set **on the ground before flight**), the timer would allow current to flow into a pair of igniters inside the airstarted motors, lighting them and sending the rocket onward and upward (we hope) to the "Ooochs" and "Aaaahs" of the assembled crowd.

<u>Electric Matches as Initiator Devices</u>

Timers exist as a class of electronics that we call "active" devices. They are intended to initiate an action – but how do they do this? One very common way is the ignition of a pyrotechnic device such as an electric match (e-match) or an igniter. What is an e-match and how does it work? An e-match is a device commonly used in pyrotechnics (read: fireworks) to cause the ignition of pyrotechnic materials. It is usually composed of relatively high resistance bridgewire surrounded by a small quantity of a heat-sensitive pyrotechnic compound. Current passing through the wire heats it and causes the pyrotechnic composition to ignite producing a small burst of flame. This small flame can be used to ignite other materials (such as ejection charges) or, with augmentation (dipping in pyrotechnic compound, attaching a length of Thermalite, etc.), they can be used to ignite a composite motor. Current requirements to fire an e-match vary with type of e-match ranging from 0.4 amps to ignite an Oxral or Daveyfire N28B, to 1+ amps to ignite a Daveyfire N28F, to several amps for other types of igniters. This is important information, as the amount of current your timer can put out will severely affect your choice of igniters. Or, conversely, your choice of an e-match that your timer doesn't have enough current to fire will significantly enhance your chance of failure! If you are using the timer to control a recovery event (parachute deployment) things could get real ugly if you use the wrong match (Trust me on this – I know!!). For more information on igniters, check out Rob Briody's article "Electrical Current Requirements of Model Rocket Igniters" at www.gwiz-partners.com/igniters.pdf.

Now that we have some understanding of what a timer is and what it can do for us, let's talk about some typical uses for these units. Timers are most typically used to control the starting of onboard motors separate from the ground control equipment (launch system) or to eject a parachute at a certain time after launch is detected. Figure 1 and 2 show typical placements within the airframe of the rocket when used in this manner. Note that in Figure 1 the timer is placed back of the forward centering ring and that in figure 2 it is placed in a separate compartment forward of the motors. The forward placement makes it more difficult to control airstarts but makes it possible to do a two-stage deployment, if desired.

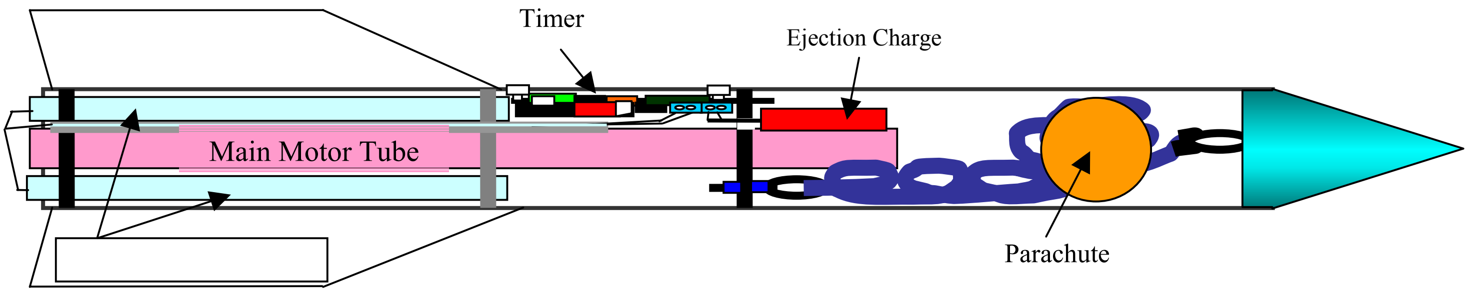


Figure 1 : Timer placement - Aft

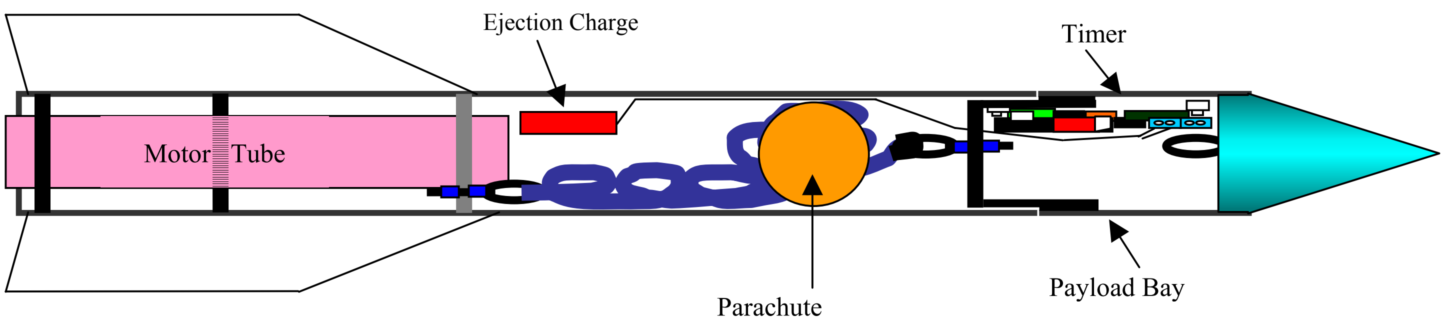


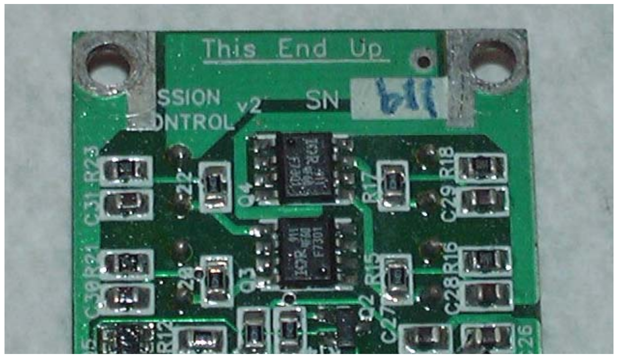
Figure 2 : Timer placement - Forward

In all cases, the timer must be located so that it is isolated from any black powder or motor residues. This is very important as such residues contain carbonaceous (fancy word that means the stuff contains carbon) matter that can settle on the circuits and contacts and cause shorts within the

Other Common Initiator Devices

If we don't have access to electric matches what else can be or has been used to initiate deployment charges? Historically, one of the first electrically driven initiators was the lowly flash-bulb. Robby's Rockets and others will sell you AG-1B flash-bulbs which, when flashed, will generate enough heat to light black powder that is in contact with the bulb. These initiators are non-pyrotechnic and appear to be reasonably reliable (however, there are some concerns on the part of some members of the rocket community about the 'appropriateness' and reliability of this technology – check it out if you're concerned). Another initiator that has made its way into the marketing stream is based on exposed light bulb filaments. Pratt Hobbies and others will sell you this type of initiator based on a low voltage 'peanut' light bulb with the glass envelope removed. Black powder is packed in contact with the filament and when the electronics apply voltage to the filament, it heats up and ignites the powder (it also burns out so you need a new igniter – good for business). Of course, if you don't want to buy them pre-made, you can easily make them yourself from low voltage Christmas tree lights. If you make them yourself I recommend rigorously testing them to validate your assembly technique. For a tested way to make them, check out the article on ejection charge holders at:

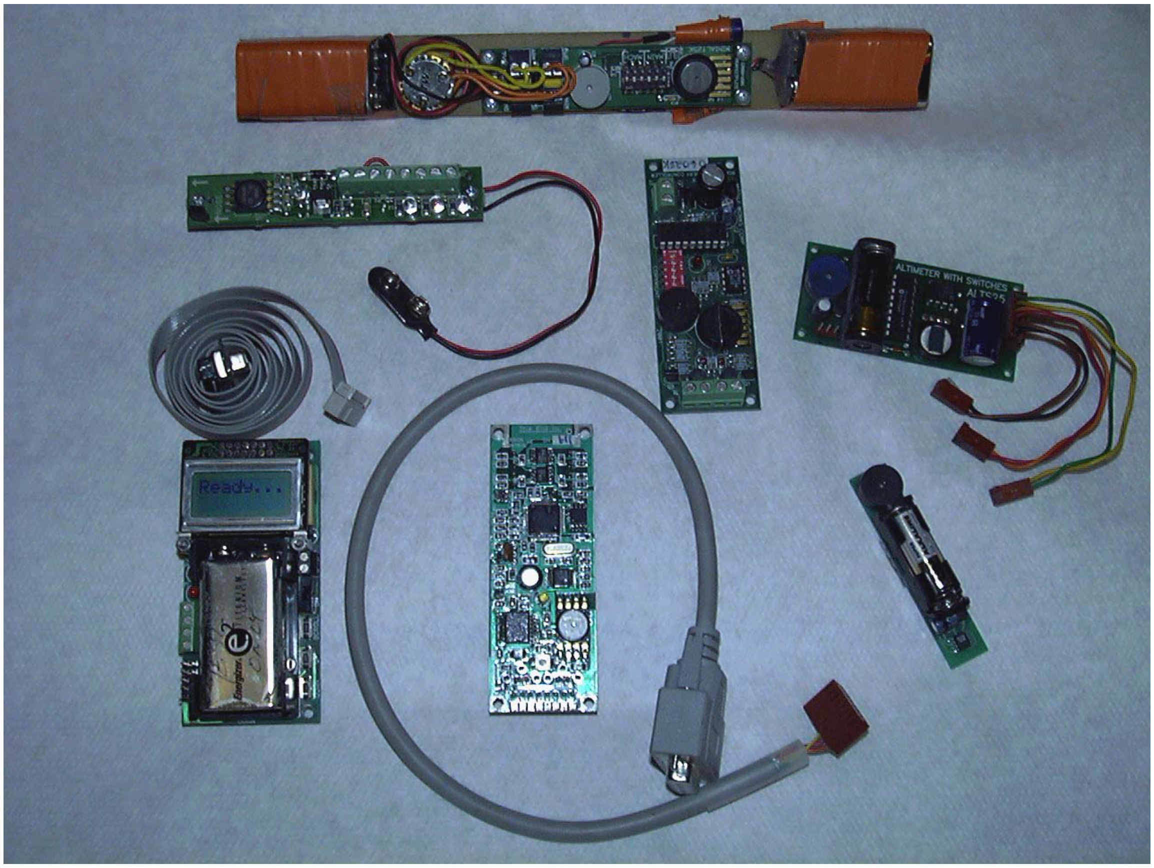
www.perfectflite.com/downloads/ejection.pdf circuitry, often causing the board to cease proper function (another words, it fails). Additionally, the residues tend to be corrosive so that even if they don't immediately short out the board they can attack the circuit traces and components causing the timer to fail down the road – usually when it is under stress (i.e. in the middle of your flight). And finally, a word on mounting – watch the orientation of any timer that uses a G-Switch to activate it. These timers must always be mounted so that the G-Switch is lined up with the direction the rocket will accelerate. Such a



unit will usually have some kind of warning printed on the circuit board saying "This End Up" or something equivalent to aid in properly orienting the board. A G-Switch will only operate properly if it can be closed by the rockets acceleration and, therefore, it must be oriented in the same plane as the rockets acceleration in order to function. Don't mount the board upside down or sideways – if you do your timer won't activate and you will have a less than optimal flight.

Remember that while airstarts and parachute deployment are the most common uses for timers, there are a range of other functions that they can be used for: Camera operation, releasing outboard boosters, igniting a tracking smoke canister, or anything else you can dream up that you want to tie to an event in time. To assist in making the selection of an appropriate timer for your particular application, a table listing all of the currently commercially available timers is included on the Rocketry Organization of California's (ROC) website (www.rocstock.org). It is my intention to keep this table as up to date as possible, so should you have information to fill in some of the blanks in the table or updates to what is listed, please contact me at wahlquist@altrionet.com and I'll do my best to keep this resource up to date. This table will also cover the various altimeters, tracking devices and miscellaneous toys available to those of us in the hobby.

Session 2 – Altimeters



(Clockwise from top) Perfectflite MiniAlt 25 (mounted for minimum I.D. installation), Missileworks RRC2X, Adept ALTS25, Adept A-1, Defy Gravity 'Control', Olsen FCP-M2, G-Wiz LC Deluxe 400

Welcome back class. In our previous sessions we discussed some of the basic uses for electronics in hobby rocketry and why we used them. Again, the primary reasons to use electronics are to provide additional control over a rocket's flight characteristics, control in flight activity, or capture and return data from the flight. In addition to the basic reasons and uses of electronics we also discussed, in some depth, the use of timers and presented a table illustrating a number of timing units currently available on the market. This session we will move forward and discuss that darling of the rocket world – Altimeters. As with the last session, we will not only deal with function and uses, but also take a look at currently available examples of this class of controllers. So, without further delay, let's get started.

Altimeters

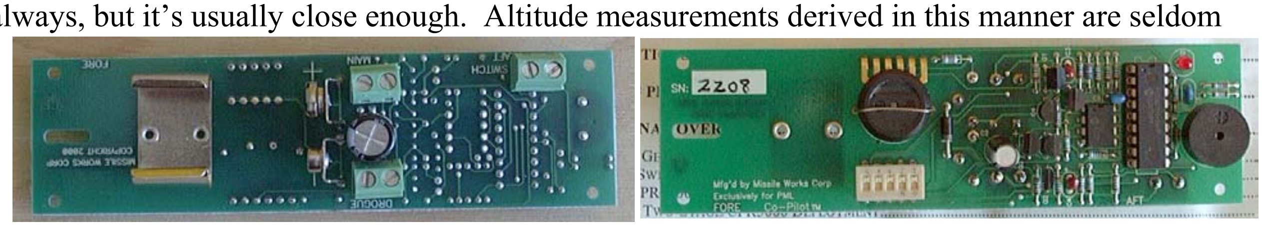
Altimeters generally come in two flavors, barometric or accelerometer based. Barometric altimeters work by measuring changes in atmospheric pressure using a barometric cell. As you go up in altitude the pressure exerted by the atmosphere drops. The amount that the atmospheric pressure drops with increased altitude is well characterized. The designers of altimeters can use this not only to measure when an altimeter starts rising and stops rising, but to also note the exact (or very close to exact) altitude (pressure) at apogee. Most barometric altimeters are activated by a quick change in pressure equivalent to anywhere from 100' - 300' of altitude change. Typical ranges for barometric altimeters are from sea level up to 15,000' - 25,000' of altitude. Some special models claim to be readable up to 50,000'. Barometric altimeters are quite versatile, but they have two drawbacks: (1) they need to be in a chamber that is sealed off from any ejection charge gases (which are corrosive and can foul the altimeter), but is vented to the outside so that changes in atmospheric pressure can be detected; and, (2) as a rocket passes through the sound barrier (Mach) a shock wave forms at the tip of the nosecone and travels down the airframe. When the shock wave passes over the vent ports for the altimeter chamber, the pressure fluctuation it causes can fool the altimeter into believing the rocket has reached apogee and is started back down to the ground. This can result in a premature parachute deployment while the rocket is traveling at a high rate of speed (as we are talking Mach+ speeds, this usually results in the destruction of the rocket). Both these problems have been addressed by the various altimeter manufacturers, either in their designs or in their instructions on how to make reliable use of the altimeter <<Please read the instructions that come with your altimeter – **Before You Use It!!!**>>. Accelerometer based altimeters use a small solid state accelerometer rated to measure anywhere from +/- 25 G's of acceleration to +/- 100 G's (a G is one gravity or 9.8 meters/second/ second of acceleration). As the acceleration sensor in the altimeter must be in the proper position to measure the acceleration, orientation of these accelerometers is critical to the proper operation of the altimeter. Because of this, all accelerometer based altimeters (and those altimeters that use a G-Switch to arm) have wording or markings on the altimeter to indicate "this end up", ensuring, if installed in that orientation, that the sensor is properly oriented with respect to the (intended) direction of flight. Determination of apogee is made by monitoring the accelerometer and integrating the signal to determine the point at which the rocket stops rising. Is this a true apogee? Not always, but it's usually close enough. Altitude measurements derived in this manner are seldom

How Does a Barometric Sensor Work?

A modern barometric sensor is made with two chambers separated by a diaphragm. The diaphragm has an electronic strain gauge on its surface to detect any stretching due to differences in pressure on the diaphragm. There is generally a vacuum on one side of the diaphragm (reference pressure) while the other side is exposed to the atmosphere whose pressure is being measured. As we go up in altitude, the 'measured' atmospheric pressure decreases and the amount of pressure (strain) on the diaphragm changes. This change is measured by the strain gauge and a signal proportional to the current pressure is sent to the electronics for processing.

How Does an Accelerometer Work?

Today's accelerometers are typically based on a small plate on an arm supported in a cavity in an integrated circuit (IC). This arm/plate assembly moves closer to one side of the chamber and farther from the other when acceleration (G forces) occurs along the axis of the chamber. Think of it as a weight on a spring. The ends of the chamber and the sprung mass are electrically isolated from each other forming a capacitor. By applying a charge to the sprung mass and an opposite charge to each end of the chamber, the capacitor is charged. As the sprung mass is moved closer to one end of the chamber or the other by the force of acceleration, the amount of capacitance in the system changes. By monitoring the capacitance of the cell, it can be determined what the force of acceleration on the sprung mass is and, thereby, the acceleration of the rocket as well.



Front and Rear Surfaces of PML's Co-Pilot Altimeter accurate as the accelerometer integrates acceleration versus time (which yields velocity) and then integrates velocity vs. time to obtain distance traveled. The main problem with this approach is that the distance traveled is only equal to altitude if the rocket flies a perfectly vertical trajectory - no weather-cocking, no arcing over, no deviation from a vertical flight, period. If the rockets flight path is anything other than vertical the actual altitude attained will be less than the distance traveled by the rocket to reach apogee. In spite of this measurement problem with altitude, an accelerometer-based altimeter does have two significant advantages over the barometric altimeter when used in high performance rockets. These advantages are that the accelerometer requires no venting of the electronics bay in order to work and that the accelerometer is not sensitive to pressure differentials caused by supersonic flight. One significant negative for accelerometers is that a single axis accelerometer of the type most often used in rocket electronics cannot measure how high the rocket is following apogee and, therefore, is not a suitable sensor for dual deployment situations. This limitation could be gotten around by employing a full three axis accelerometer suite and a more powerful microprocessor, but that would raise costs beyond what most of us would be willing to pay.

Precision versus Accuracy

Many of the electronic packages listed in the attached tables make certain claims about their precision or their accuracy. Precision and accuracy are not the same thing and we must be careful to evaluate each unit in light of its own merits. Precision is a measure of how fine a unit can measure while accuracy is a measure of how closely it matches the actual value. A simple analogy using firearms would tell us that precision is the ability to shoot the same spot time after time while accuracy is the ability to hit the bulls-eye. What we want from our electronics is for them to be both precise and accurate. As an example, altimeters A and B claim to be able to measure altitudes to 30,000 feet and will beep out an altitude report after flight to the nearest foot. Is this justified? Let's look at the units and see. Both units use the same sensor but Altimeter A is using a 16 bit Analog-to-Digital Converter (ADC) while unit B is using an 8 bit ADC. Why do we use an ADC? The signal from the sensors is analog but the onboard controller is a digital microprocessor requiring a digital input therefore we **C**onvert the signal from **A**nalog to **D**igital. For unit B, eight bits (2^8) can only represent 256 steps so the output of the sensor is broken into 256 equal sized steps. Dividing 30,000 feet by 256 steps yields a step size of 117 feet. For unit A, the 30,000 feet is divided 65,536 steps (16 bits or 2^{16}) resulting in a measured step height of about 0.5 feet. Obviously unit A is more precise (finer **real** resolution) than unit B and is justified in reporting to the nearest foot while unit B can only measure to about the nearest 100'. Now what about how accurate they are? Let's say we launched both units together in a payload bay on our rocket to an altitude of 1,505'. After recovery unit A is beeping out that it went to 1,451' while unit B beeps out an altitude of 1,521'. In this example, even though unit A has a higher precision it's accuracy is less than that of unit B as unit B reported within 16' of the correct altitude while unit A was off by over 50'. Is this important? Depends on what you're up to!

Most altimeters are designed to indicate the peak altitude attained - that's why they are called "Altimeters" (short for **alti**tude **meter**). This need not be the only thing they can do. Most of the better altimeters will also activate an event at apogee that can be used to deploy a parachute - just like with the timers, but here you don't have to guess ... err, calculate, the desired flight time before parachute deployment. Apogee is determined by the altimeter and acted upon when detected, whenever it occurs. Many altimeters equipped with barometric cells also monitor the altitude on the way down (after a parachute has been deployed) and control deployment of a second parachute based on reaching a set altitude above the launch site. This feature, which allows the deployment of a small drogue parachute at apogee - allowing the rocket to fall rapidly back towards the ground - and then releases a larger chute in time to slow the rocket for a soft landing, is often called “two stage deployment”, “dual deployment” or “close proximity recovery”. Two-stage recovery can dramatically reduce wind drift on a windy day or for rockets that are flying to extreme altitudes.

Now based on the strengths of each type of altimeter, you would think that you could use both sensor types together and come up with an altimeter that has all of the strengths of the two techniques with none of the weaknesses. And guess what? You would be right. Such units exist and are listed in the comparison table for altimeters. Their only drawback is that they have more onboard components and as a result ‘tend’ to cost more than single sensor altimeters (the cost of an altimeter is very dependant on what a manufacturer thinks his unit is worth to those of us who are buying these toys – in their defense, it does cost money to design, troubleshoot and market a product and the manufacturers are entitled to a fair return on their investment of time and labor, Right? That’s Capitalism at work!). For a summary of some of the various units available, see the product comparison chart for Altimeters.

Recording Altimeters - Flight Computers

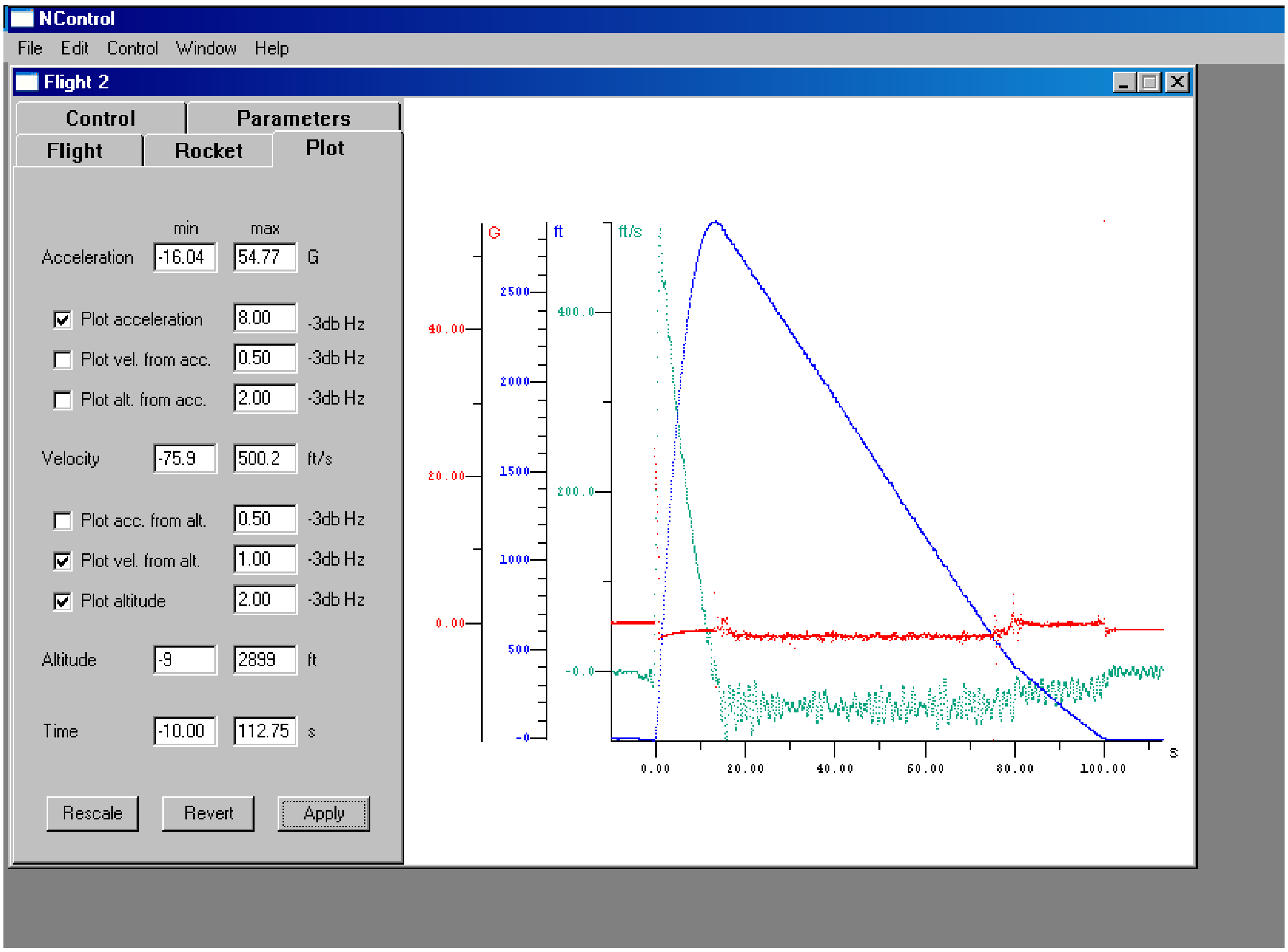
This is a rapidly growing segment of rocket electronics. Originally pioneered by Adept and Emmanuel Avionics, the recording altimeter/flight computer is coming into its own as other companies enter the market with competing visions of what the rocket community wants in on-board intelligence. A recording altimeter will record the data from the accelerometer, barometric cell, or both for a period of time after launch. Data collection interval (number of samples per second) and length of time data is recorded is usually fixed by the manufacturer. Collected data is usually fed to a computer after the flight for analysis and archiving of the flight data. While some units can store more than one flights worth of data, most units will only hold the data for the last flight, with the next launch overwriting the data from the last stored launch. Data is usually stored in non-volatile random access memory (NVRAM or Flash RAM) so that it is available even if the battery power to the unit fails (or, God forbid, the rocket crashes - in this case, as long as the memory chip is not damaged, the data can still be recovered). Some of the newer units, such as the RDAS, FC-877, or Control, can either be programmed to collect additional data or be programmed to handle additional tasks beyond dual parachute deployment and firing airstarted motors. For example, one gentleman I know has designed a fast response temperature monitoring device and is using his RDAS to collect data on temperature versus altitude. Another flier I know is using his Control altimeter to fire a Tether (a pyrotechnic release device from Defy Gravity www.defygravitynow.com) releasing half the shroud lines on a big 14' parachute when the Control detects landing. This collapses his chute and prevents his rocket from being dragged all over the playa. I use my Control to monitor the rate of fall after firing my Mains (Main parachute) ejection charge - if the rate is too high, I fire a backup charge in hopes of getting the ‘potentially’ hung up main chute out of the body. Essentially, an emergency back-up ejection charge that fires <u>only</u> <u>**if**</u> it is <u>needed</u>.

<u>Altimter Mounting Location Restrictions</u>

1) Locate vent ports 4+ calibers back from point at which the rocket body diameter becomes constant
2) Locate so as to keep wiring runs short and simple.
3) Insure adequately sized vents are used – one ¼” diameter vent per 100 cubic inches of altimeter bay volume is adequate. If using multiple vents, use a minimum of three vents spaced equidistant around the rocket body
4) Insure that vent ports are drilled cleanly and have no ragged edges to cause turbulence
5) Insure that altimeter chamber is sealed from motor gasses and ejection charge gasses.

Added versatility is generally high on the list of things required by people stepping up to a recording altimeter, but, again, the one thing that sets a recording altimeter apart from its non-recording cousins is the ability to collect and store data from its flight sensor(s) during flight. After the flight, the collected flight data can be downloaded to a computer or PDA for storage and

Figure 1: 'Stress Relief' on an I435



analysis. An example of the output from one of these units is shown in Figure 1. This chart documents a successful flight of my rocket "Stress Relief" on an AeroTech I435 Blue Thunder motor.

Now that we've covered the basic equipment (and the not so basic as well), the question of how to use these items comes up. Mounting and use of altimeters are subject to a few more constraints than timers. Again, we want to keep our wiring runs, where needed, short. But now we are faced with the possibility of wiring running in two directions and also some positional restrictions imposed by the use of barometric cells as sensors. Figure 2 shows one way to do this for a rocket doing 2-stage deployment (Drogue and Main). We also need to protect our electronics by making certain they are located in an area that ejection gases or rocket motor gases can't get to (a sealed chamber of some sort). The primary restriction is positional. In order to have a smooth flow of air over the vent ports (remember - barometric cell based altimeters have to be able to measure the air pressure outside of the rocket and that means pressure equalization vents) into the chamber you have mounted the altimeter in, the vents should be at least four calibers (1 caliber = 1 body diameter) back from the point at which the body diameter becomes constant (this is usually four diameters back from the shoulder of the nosecone) with no protrusions, fins or other items that could cause turbulent airflow ahead of the vents. For example, a rocket that is 54mm (~2.125") in diameter should have the vent port(s) located at least 8.5" back from the shoulder of the nosecone. As to vent port sizing, the common body of knowledge says that for every 100 cubic inches of altimeter bay volume you should have a vent port equivalent in size to a ¼" hole. Vent sizing much below this causes delays in pressure equilibration and could result in late deployments and inaccurate altitude reporting. Is a single vent port best? Not necessarily. A single port can be affected by wind blowing across it (much like a flute). A better way to go is to use 3 or 4 vent ports (never use only two vent ports) symmetrically (evenly) spaced around the altimeter bay. Vent ports should be cleanly drilled with sharp, clean edges both inside and out so no additional turbulence is introduced.

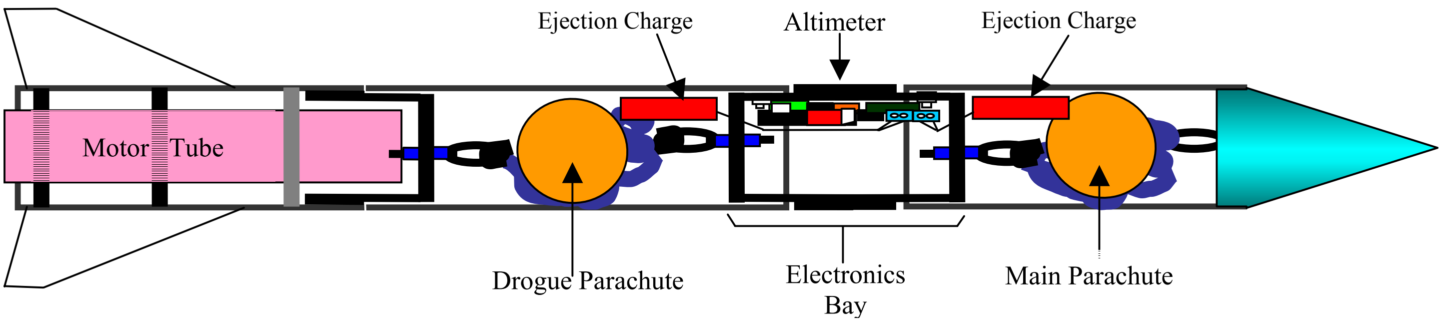


Figure 2: Typical Layout for a Two-Stage Deployment Configuration

And finally, for those of you getting involved in larger, heavier, complex rocket projects, I have only three things to say: Redundancy, **Redundancy**, **<u>REDUNDANCY</u>**!!! What I mean by this is that **every** critical event should be controlled by two (or more) **independent** controllers, each one able to make the event happen alone should the other controller flake out for some reason. I would also encourage you to consider mixed arming modes for your controllers (i.e. one to arm barometrically and the other to arm by an acceleration switch or acceleration detection). I have seen this type of mixed arming mode save projects that might otherwise have been a total loss. A recent example coming from the local ROC launches I attend, was the launch of 'The Big One" (courtesy of Carl Delzell), a 100# upscale of the rocket seen in Disney's 'Toy Story'. It was launched on a Hypertek M-1000 with a G-Wiz LC Deluxe 800 and an Olsen M2 set for altitude change launch detect (ACLD = ON). The acceleration off the rail was quite low and fluctuated[1] to such an extent that the progressive launch detect algorithm in the G-Wiz never decided that launch had occurred[2]. Fortunately, the Olsen noted the altitude change, armed, and recovered the rocket safely. Had the Olsen FCP-M2 not been set to arm on altitude change, the flight would have been lost. Olsen added the 'ACLD' arming option because of difficulties early on with launch detection when using HyperTek hybrids (the other two hybrid systems, R.A.T.T. and AeroTech, use a small preheater grain to eliminate the 'pogo'ing chamber pressure/thrust difficulties inherent in the HyperTek system design). This was only the second time I have seen a G-Wiz fail to arm, and the previous failure also

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[1] Chamber pressure and, therefore, thrust in a Hypertek hybrid motor constantly fluctuates during the motor burn – that's why they make that distinctive 'farting' sound as they fly. This can cause problems with electronics that use acceleration to indicate launching has occurred.

[2] Due to fluctuating thrust levels of the hybrid motor, thrust did not remain above the required trigger level for long enough to count as a launch so it reset and started counting on the next pulse peak which didn't stay above the required level long enough, etc.

involved a very low thrust to weight ratio (on post mortem review, that flight should have been refused by the RSO as the thrust to weight ratio was under 2.5:1 – gotta watch those low thrust flights when using an acceleration sensitive arming system).

Session 3 – Tracking Devices

Welcome back class. In our previous sessions we discussed some of the basic uses for electronics in hobby rocketry and why we used them. Again, the primary reason to use electronics is to provide additional control over a rocket's flight characteristics or some in flight activity we wish to occur. In addition to the basic reasons and uses of electronics, we also discussed the use of timers and presented a table illustrating a number of timing units currently available on the market in Part 1, and in Part 2, the use of altimeters, again with a table on units currently available in the marketplace. This session we will move forward and discuss the available options for tracking and the less easily defined category of 'Other Electronics'. As with the last session, we will not only deal with function and uses, but also take a look at currently available electronic units. So, without further delay, let's get started.

Rocket Hunter Transmitter

Tracking Devices

There are two basic kinds of tracking aids available to the rocket enthusiast, Audio and Radio Frequency (RF) beacons. The audio beepers are generally mounted inside the rocket body and activate upon deployment of the parachute. Most of these units will beep intermittently at a loud volume designed to be heard up to several hundred feet from the rocket. As long as you don't land in a lake, stream, river, or pond, these units can help guide you to that rocket that is out of sight, but not out of your mind. The output volume (measured in decibels – dB) of the units, and correspondingly, the distance over which they can be effectively heard, vary with price, although the price in general is relatively low for this type of tracking unit ($22.00 and up).

Radio Frequency tracking units such as those from Adept, Walston, or Rockethunter have a vastly larger trackable range. I know of a gentleman who followed his Rockethunter equipped rocket to a recovery point over five miles downrange. The transmitters from these companies are very compact, lightweight, and relatively cheap (especially when weighed against the possible loss of a rocket with electronics and re-loadable motor casing(s) onboard). In addition to the transmitter you'll need a receiver and an antenna. Antennas aren't to bad in the expense department, however the expense of the receiver a bigger problem. Where transmitters typically cost from $50 to $90 the receivers cost ~$250 and up – sometimes way up – depending on the number of channels, sensitivity and other features. This can be a major 'ouch'. I know of circumstances where vendors in an area, in order to promote sales of transmitters, will loan out the receiver set to rocketeers who purchased the transmitter from them. In other situations, a group of rocketeers may get together and buy a group receiver which is then made available to group members when they need it. There are probably other ways of spreading the cost of a receiver, but these are two I know of that seem to work in our local area. One last thing to watch for is that some of these units require that you have an FCC issued ham radio license – simple to get (if you go "No-Code"), but still one more hoop to jump through.

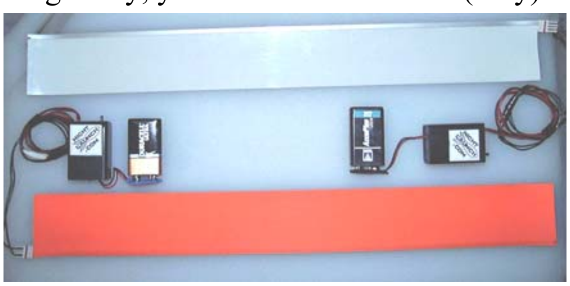
If you're not up for the cost of an expensive receiver or you don't want to get a ham radio license, you might look into an FM based system that requires no licensing and uses a simple FM radio receiver for tracking purposes. Estes used to make and sell such a unit as the TransRoc – a very limited range almost insured that you would visually locate your rocket before you heard the transmitter signal. Still it was fun to play with. Valhalla Rockets is currently marketing an FM based tracking unit with a bit more range. However, be careful with FM based tracking units from vendors you don't have experience with; (1) they don't have the range of the more expensive ham units and (2) there have been cases of FM-based units being sold that don't function as advertised (most recently through RocketryOnline's auction site). I would recommend checking out the vendor carefully before jumping here – if they don't have a permanent presence (web site, physical address, storefront) it might be best to avoid them. In fact, that pretty much applies to all of our electronic goodies.

And finally, a relatively unique (at this point) device makes it to us by way of AED. The unit is a GPS tracking board for the RDAS altimeter. It is designed to be used with the RDAS and its transmitter expansion board in order to send the current GPS coordinates of the rocket back to the ground station in real time. It functions well enough that you can acquire the exact GPS coordinates of your rocket when it lands and just drive right up to it using your handheld GPS unit to guide you in. I've even heard of two occasions where rockets were recovered due to their onboard electronics after they were 'rocketnapped' by locals who picked them up and didn't want to turn them over to the rightful owner when they came calling. In one case the owner agreed to pay a 'reward' for the return of his rocket (extortion). In the other, the local involved denied having the rocket at all (theft comes to mind here) and only the owners remote activation of the smoke tracking canister and the subsequent release of large volumes of orange dyed smoke (that came pouring out of the local's residence) caused the local not only to admit that he had it, but demand that they remove it from his house NOW! ROFL.

There is actually a third category of tracking devices available but they are of limited use as they are designed to function at night. If you are trying to fly at night from a waivered launch (i.e. high powered rockets) your group may have restrictions placed on your operations by the FAA. They want to ensure that anything you fly will be visible to any air traffic that wanders into your air space and will probably require that you equip any night launched rockets with strobing lights to ensure this visibility. On the other hand, your RSO wants to ensure that anything launched can be visually tracked in order to assure flight safety. This can be assured through the use of appropriate visual tracking aides. These generally take the form of high-output LED flashers, electro-luminescent

Personal Safety Strobe Mounted in a Strobe Bay

panels, or strobes of various forms. Companies such as Wolfstar and Night Launch provide items of this sort, although much of what is used in the typical night flying rocket is bought from a local electronics store and built directly into a particular rocket (check out the article on night flying in HPR Volume 33, Issue 2, July 2002 or for a really extreme sample of this, see the article on the **B**abylonian **I**nterstellar **T**ransport **C**arrier with **H**yperdrive in HPR Volume 33, Issue 5-6, October/November 2002). Radio Shack used to carry the perfect strobe for mid and high powered rockets. Called the Personal Safety Strobe, it used a single 'C' battery and was housed in a round plastic case that was a perfect fit for a 38mm body tube. You could remove the nosecone and attach the strobe to your shock cord using it as the nosecone or you could mount it in a payload bay with some clear tubing around it, or even mount it into a nosecone (most unpainted nosecones will flash nicely with a strobe inside). Great toys! If you find one – pick it up. Another really nice product on the market is the electro-luminescent panels from Night Launch. These come in a range of colors and can be painted over or trimmed to form designs and graphics on your rocket (if you trim them be sure to follow the directions regarding not cutting the contact strip that runs along one edge). The new inverters for these can even be set to flash the strips for a truly cool strobe effect. Night Launch is selling them at a very attractive price over what my local general aviation supply sells the same product for (you would be surprised how much it skyrockets the price when it has to be FAA certified for flight usage – let's hope that the FAA never looks to "certify" our toys). And, with a little ingenuity, you can take one of the (very) inexpensive LED flasher units sold to bicyclists and



Blue and Orange Night Launch Electroluminescent Strips

attach it to your rocket. I've seen these taped on the outside of rockets and I've seen them dissected so only the active components are used - getting rid of the bulky case and its weight - and mounting the LEDs and circuitry inside the rocket body with only the LEDs showing through to the outside. If done properly, night launching can be seriously cool!

Radio Frequency Event Controllers

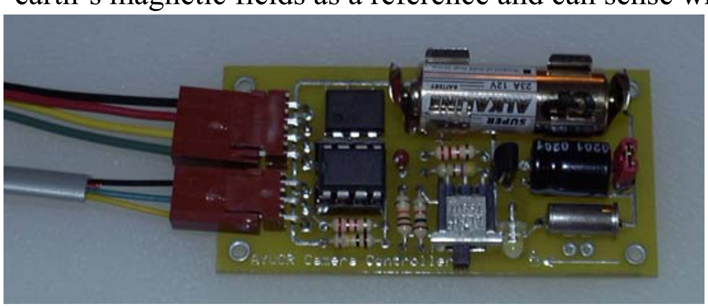
Radio based event controllers that allow a person on the ground to control events in the air or on the ground are not unknown to those of us who have tried RC airplanes and RC cars. It is not surprising that this concept can be adapted to rockets. The first commercial unit of this type was actually derived from a model airplane controller of its day. With continuing improvements it remained in production until just a few years ago as the Pratt Hobbies ECS-2B (production has been discontinued, but support for units in the field is still available). Several other vendors have offered radio actuated event controllers and a number of construction articles for such units have been published (see article on 'Radio Flyer', HPR Volume 15, Number1, April 2000). In addition to event controllers, the field of radio-based telemetry and tracking devices is also growing. AED provides an optional board for their RDAS altimeter that will transmit information (telemetry) to a ground based receiver and while they don't include transmitters, both the Olsen FCP-2 and the WH Flight Systems FC-877 will output data to their RS-232 ports during flight that could be sent to a separate onboard transmitter. While not providing controlling options, the systems from Newton's 3rd Rocketry and Wireless Video Cameras are designed to handle real time video links so you can see what your rocket sees, while it's seeing it (do record it for later viewing though). This is an option to putting a video 'recorder' in your rocket.

With all the advantages to these units you may wonder what the downside is? The biggest problem is that anything designed to function more than a few thousand feet line-of-sight is probably going to have a transmitter that falls under Federal Communications Commission (FCC) guidelines requiring the operator to be licensed in order to use them. Typically a 'Ham radio – no code' (i.e. you didn't show proficiency with Morse Code) license will do. While licensing is easy to do there is some minimal cost and time lost to doing it. On the other hand, you should learn enough from the class to make it all worthwhile. The other significant problems are those of range and interference. Range is generally less of a problem than you might think. Let's say the transmitter you are using to control chute deployment is good for 10,000' line-of-sight, but your rocket went up 15,000'. You can't reach it with the radio signal to activate the chutes at apogee because it's out of range. Don't worry, it will come back into range and then you can pop the chute (hopefully with no damage). Then you can go back to the drawing board and either find a unit with better range or just plan to use a smaller motor.

There is one last warning I would like to leave you with in regards to RF activated event controllers, and that is to watch for systems that are immune to RF interference and inadvertent activation by stray radio signals. This can be a problem for systems adapted from RC controllers. A friend of mine had a beautiful rocket built from a Little Tykes toybox – the one shaped like a basketball - and he used RC controls to launch and recover it. He lost it one day when some kids were playing with RC cars near where he launched it and their signals interfered with his. Even worse, later that launch the same interference caused a premature ignition of a rocket that was being loaded into his remotely controlled launch tower (this man has way too much time on his hands) seriously damaging the rocket and causing a brown shorts moment for those doing the loading. Now, all the electronics he uses are digitally encoded so that nothing will happen without the proper digital code being received. Much safer.

Miscellaneous Electronic Devices That Don't Fit Anywhere Else

There are a number of devices for sale that don't really fit in anywhere else in the previous categories. We have wireless video systems, camera controllers, accessory boards for some of the altimeters (mostly auxiliary firing/igniter boards) and a Flux Capacitor (no, you don't put this one in your DeLoreon – it goes in a rocket). The Flux Capacitor is a unique apogee detector that uses the earth's magnetic fields as a reference and can sense when the rocket tips over at apogee and activate an ejection charge. This cool idea was published as a construction article several years ago (Sport Rocketry, Volume 42, Number 5, September/October 1999) but is now commercially manufactured by Transolve (the Transolve version adds several features to the basic unit described in the construction article).



AYUCR II Electronic Camera Controller

Transolve also makes a camera timer that looks interesting but, for a few bucks more (and some time with a soldering iron) you can get Robert

Nees's AYUCR II controller which is a really nicely set-up camera controller. Construction is easy (I've built two of them – don't ask – I've just built two of them) and they function reliably and are very versatile in their programming and their user program-ability. If you're thinking of doing a camera rocket, take a look at the AYUCR II controller. There are also a couple of camera capable timers from Barber Park and Pico Electronics that also might be worth a look for this purpose.

Should you need a "safe" first movement switch for your rocket project, take a look at Adepts ASA3. The ASA3 requires detected acceleration to persist for 0.5 seconds before latching the circuit output on. A little more expensive than a straight G-switch but much safer as it's not subject to false activation from handling.

Another couple of neat electronics packages come to us by way of AED for the RDAS. These are a two-axis accelerometer and a GPS tracking device. The two-axis accelerometer board, in combination with the single axis accelerometer on the RDAS itself, allows the collection of three axes of acceleration data for the flight. The RDAS is not able to process the data collected from the expansion board so it cannot use the accelerometers to determine a spatial position but you can download the data later and fiddle to your hearts content. The GPS board is a useful addition to the RDAS, especially when used with the transmitter option. The positional data for the flight is collected in a memory cache located on the GPS board itself (no RDAS main-board memory is required) and can be transmitted in real time to your ground station. This allows for an immediate flight profile plot and an absolute indication of the landing site. With one of these set-ups you'll have to work real hard to loose your toys. RDAS's two-axis accelerometer board also includes a thermocouple to monitor temperature, however there is a better board for this purpose from Glitch Laboratories Ltd. The Glitch Laboratories board is designed as a fast response thermocouple sensor for low mass thermocouples. It stores the data collected in the RDAS main memory for later download and evaluation.

Is there more you can do? Most assuredly – just use your imagination and go looking for the components to fit. I've seen rockets with servo-controlled fins linked to a solar sensor so it would fly towards the sun (or maintain an initially set attitude versus the suns location) at launch. Some time back there was work done on gimbaling the motor in a rocket based on a small homemade gyroscope. A friend of mine wants to use a small onboard computer to throttle three AeroTech Hybrid motors to provide attitude control during flight. And of course, there are always the folks who fly rocket-gliders. Electronics can free you up to do the things you want to do the way you want to do them.

Again, to assist in making the selection of appropriate tracking devices or other electronics for your particular application, a table listing all of the currently commercially available items in these categories that I am aware of is included on the Rocketry Organization of California's (ROC) website (www.rocstock.org). It is my intention to keep this table as up to date as possible, so should you have information to fill in some of the blanks in the table or updates to what is listed, please contact me at wahlquist@altrionet.com and I'll do my best to keep this resource up to date.