

Dexter's AeroTech 54/1280 RMS Hybrid Revival Maiden Flight

4/13/2024 – TRA LA Goldmine Plantation Launch Site

Motor Specifications:

A version of Patrick Carroll's AT 54/1280 RMS Hybrid Revival motor

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|--|---------------------------|
| Nitrous tank and pin valve | 586 grams (20.7 ounces) |
| Nitrous charge | 265 grams (9.4 ounces) |
| Forward closure w/ injector plate | 126 grams (4.4 ounces) |
| Standard AT 54/1280 motor case and rear closure | 237 grams (8.4 ounces) |
| Other reusable parts | 19 grams (0.7 ounce) |
| Phenolic nozzle | 56 grams (2.0 ounces) |
| Cardboard fuel grain (front) | 45 grams (1.6 ounce) |
| Cardboard fuel grain (rear) | 118 grams (4.1 ounces) |
| Phenolic motor liner | 71 grams (2.5 ounces) |
| Consumables (washers, pre-heater etc.) | 30 grams (1.1 ounces) |
| Total motor launch weight | 1551 grams (54.8 ounces) |
| Paper fuel grain burned weight (front) | 33 grams (1.2 ounces) |
| Paper fuel grain burned weight (rear) | 66 grams (2.3 ounces) |
| Total fuel burned | 64 grams (2.3 ounces) |
| Oxidizer burned (some leakage which was estimated) | 252 grams (8.9 ounces) |
| Phenolic nozzle burned weight 7/16" throat | 51 grams (1.8 ounces) |
| Phenolic nozzle erosion loss (0.375" to 0.438") | 5 grams (0.1 ounce) |
| Other consumables burned | 30 grams (1.1 ounces) |
| Motor post-burn weight | 1202 grams (42.4 ounces) |

Rocket Specifications:

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|--|------------------------|
| Horizon 54 airframe diameter | 102 mm (4") |
| Horizon 54 airframe length | 170 cm (66.5") |
| Horizon 54 airframe CG (flight ready) | 118 cm (46.6") |
| Horizon 54 airframe CP | 138 cm (54") |
| Horizon 54 stability margin | 1.87 |
| Horizon 54 base unloaded airframe weight | 1400 grams (49 ounces) |

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|--|--------------------------|
| Rocketman 30' Streamer | 105 grams (3.7 ounces) |
| PML 54" Parachute | 155 grams (5.5 ounces) |
| Altimeter (Missileworks RRC3) battery and all bay components | 292 grams (10.3 ounces) |
| Harness (rear) | 165 grams (5.8 ounces) |
| Harness (front) | 234 grams (8.3 ounces) |
| Forward avionics (Marco Polo tag, Eggfinder GPS TX, Raven 3) | 86 grams (3.0 ounces) |
| Miscellaneous (wadding, e-matches, powder, tape etc.) | 49 grams (1.7 ounces) |
| Assembled airframe launch weight | 2526 grams (89 ounces) |
| Total launch weight | 4077 grams (144 ounces) |
| Landing weight (estimated) | 3727 grams (131 ounces) |

Description and analysis of the flight:

Motor:

This version of Patrick Carroll's AeroTech Hybrid Revival motor used the AT 54/1280 case in conjunction with a Tuxing 380 cc tank fitted with a Dexter modified Interstate Pneumatics pin valve. The special AeroTech forward closure that makes this motor possible was fitted with a Dexter produced 3-orifice injector plate with an extended 0.234" depressor pin. The complete tank and pin valve weighs 586 grams and the complete case plus forward closure weighs 387 grams.



Oxidizer:

The 380 cc Tuxing tank was loaded with 265 grams of N₂O three days ahead of launch day. The tank was weighed several times over those three days to quantify any leakage. By launch day no detectable nitrous loss was measured with a 1 gram resolution electronic scale. In addition the tank was mated to the loaded motor case to detect leaks that might occur during a protracted hold while on the launch pad. This mating takes a bit of twisting force to overcome the approximately 800 psi of tank pressure.

For the three hour duration of the test no measurable loss of nitrous was noted. All of this resulted in a filled tank that weighed 851 grams on launch day.

Fuel:

Fuel grains were fabricated from used cardboard tubes (specifically old Cesaroni 38 mm reload shipping tubes) enhanced by kraft paper wrapping to fit the necessary diameters. The configuration of the grains followed the original AeroTech hybrid reloads as closely as possible. This includes a forward portion of the grain that is 1.85" OD by 0.875" ID by 2" long. This portion of the grain weighed 45.4 grams. The rear portion of the grain is 1.85" OD by 1.40" ID by 7.875" long and it weighed 117.5 grams. These grains were fit inside an AT phenolic liner designed for the 54/1280 case. An Aerotech phenolic nozzle designed for these motors was used and its throat had been drilled to 0.375", the standard for the AT J170H reload kits. Standard washers and O-rings were used to complete the motor assembly.

Forward closure fittings:

As mentioned above the forward closure was fitted with a 3-orifice (1/16" jet diameter) injector plate. This configuration is used for the J170 class motor specification in the original AeroTech line. An Estes 18 mm BP motor was sliced and peeled to produce the equivalent of the original 1/4" thick by 5/8" diameter "pyrovalve element". 0.01" thick teflon sheet was punched 5/8" for the burst disk, and a 1" diameter by 1" long slug of Blue Thunder propellant was drilled 3/8" to form the pre-heater grain.

All of this assembled led to a total motor weight of 1551 grams.

Airframe:

I refitted my old Binder Designs (BSD) four inch Horizon 54 into a dual deployment configuration. A Missile Works RRC3 altimeter was used for deployment control. Apogee deployment put out a Rocketman 30' streamer to keep fall speed reasonable and to provide a vision-challenged operator a way to track the descent. Main parachute deployment was set for 600' and was accomplished with a PML 54" parachute. One other little addition was a piece of 2" foam pipe insulation cut to length to fit over the forward end of the nitrous tank once the motor was installed in the rocket. This was done out of an abundance of caution to keep the deployment tether from contacting the rapidly cooling tank during ascent. Additional electronics were added in the nose cone and included a Marco Polo radio locator, An Eggfinder GPS TX unit and finally a ride-along Featherweight Raven 3 flight computer used to derive a thrust curve from acceleration data. All of this led to an airframe weight of 2,526 grams and a fully loaded launch weight of 4,077 grams or 8.8 pounds!



Flight:

This rocket was flown April 13, 2024 at the Tripoli Louisiana launch site on the Goldmine Plantation near Winnsboro LA. Winds were light out of the S or SSW and rarely went above 5 or 6 mph. Clouds were high and scattered. Temperatures reached into the low 80s. Flight conditions were considered near perfect. The nitrous had been pre-loaded at home 3 days prior to the launch. The tank was transported in a cooler bag with no special extra cooling supplied. The launch temperatures were deemed to be safe for the nitrous as long as the tank was kept away from direct sunlight. After a smooth trouble-free test assembly at home, problems arose in the field when screwing the tank to the forward closure/motor case. It had previously been determined that the pin needed to be extended to match the operation of the original AeroTech motor. This had been done so when the final 1+ turn of the tank needed to open the pin valve was reached more resistance was encountered than expected. I retried the assembly three times losing a hiss or two of nitrous each time in the process. I finally achieved a reasonable closure after very forceful turning of the tank. I was not too happy with this situation and I worried that I may have even damaged the pin arrangement. However, post flight disassembly showed this did not happen.

Loading the rocket on the rail/pad went smoothly. All electronics were powered up and functioned properly including a strap-on Estes Astrocams. Since I had some trepidation over the tank assembly the RSO made this a heads-up launch. And also, since the grass was very tall, a fire crew at the ready was determined to be prudent. However, the count went without a hitch and the launch was letter perfect! The quick ignition followed by smooth liftoff pleased everyone! The burn seemed long as the rocket ascended nice and vertical but flew directly toward the sun so photography was pathetic.

Apogee was reached at 1,902 feet and streamer deployment went without a hitch. Shortly thereafter the main parachute deployed as well without the benefit of the BP charge. All I can surmise here is the momentum from the apogee deployment was translated to the main recovery items and that was sufficient to push the nose cone off. All in all the descent was beautiful with that long flowing Rocketman streamer and the cheery multi-colored PML chute bringing everything down in front of the crowd and only a couple hundred feet away from the launch area!







Post flight:

Data downloaded from the altimeters yielded two nice flight profiles. Up first is the plot from the primary flight controller which is the Missile Works RRC3 altimeter. Results derived from this plot include:

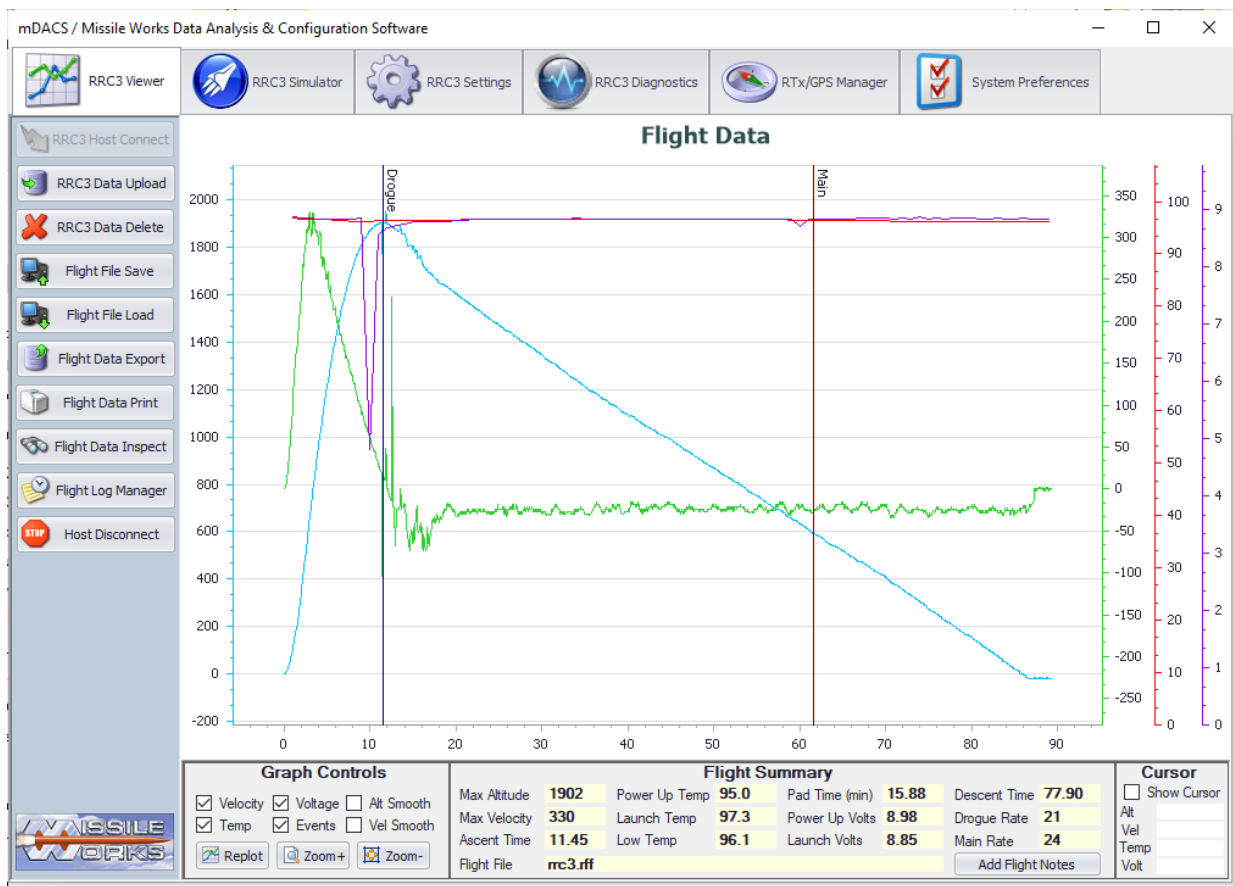
Peak Altitude = 1,902'

Peak Velocity = 330 ft/sec

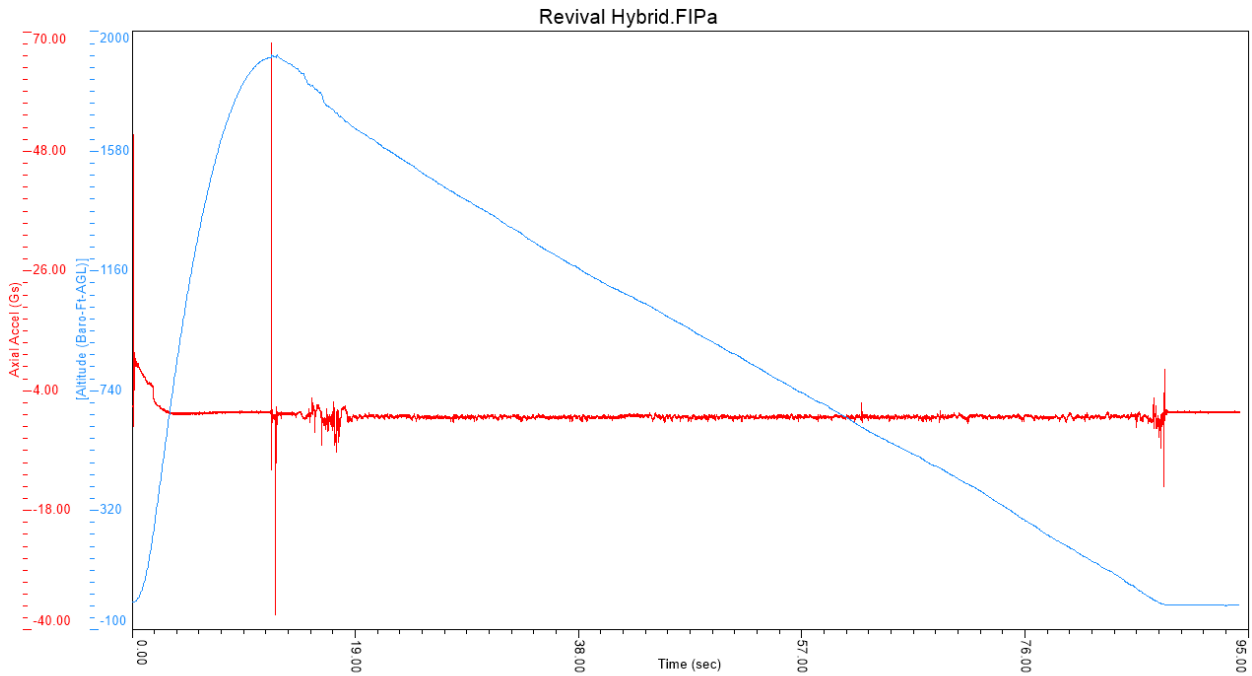
Time to Peak = 11.45 seconds

Descent Rate = Drogue, 21 fps, Main 24 fps (due to near simultaneous deployment)

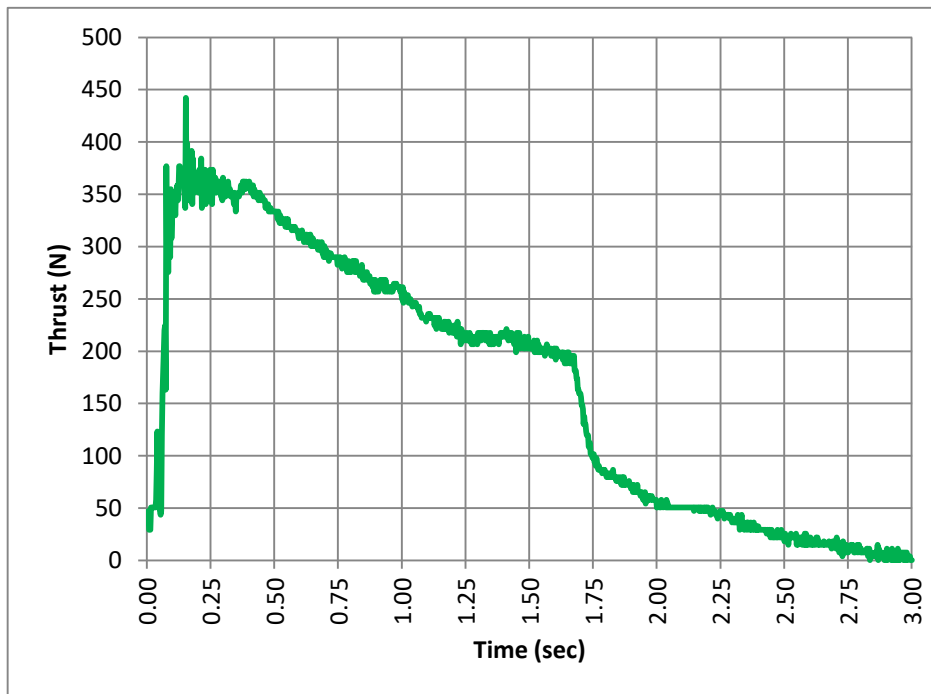
Total Flight = about 88 seconds



Next is the plot from the Featherweight Raven 3 altimeter. It was selected to be a ride-along device because of the high-resolution accelerometer (400 points per second) it has on board. This produced a nice plot of acceleration G forces (red line in the plot).



From the acceleration data for the first 3 seconds of flight, combined with the mass of the rocket and motor, we can derive a thrust curve and that derivation is shown below:



This plot represents a classic hybrid burn profile including: 1) a sharp rise to peak thrust, 2) a small spike within the peak but not as pronounced as in some hybrids, and 3) in this case a particularly broad-crested peak lasting from about 0.1 second through 0.4 second averaging 357 newtons across that time, followed by 4) a long downsloping power 'plateau' lasting to about 1.7 seconds during which time the motor maintained a thrust to weight ratio of over 5:1 for a rocket with a launch weight of almost 9 pounds, next 5) a rapid oxidizer depletion segment with the main powered part of the burn ending around 2 seconds and finally, 6) a long low thrust tail lasting until burnout at 3 seconds (whew, that was a long sentence)!

Summarizing key points of this thrust curve:

Peak thrust approximately 438 N (a spike)

Sustained peak thrust of approximately 387 newtons lasting 0.3 second

Time to peak thrust approximately 0.18 second

End of useful power plateau 1.7 seconds

End of burn approximately 3.0 seconds

Average thrust 167 newtons

Total impulse 502 newton-seconds

This flight used an estimated 250 grams (after some leakage from the original 265) of nitrous compared to the 299 grams recommended for the original motor 440 cc flight tank. Using a 3 jet injector configuration the original paper grain reload was characterized as J 170 N average thrust and 690 Ns total impulse. So the reduced amount of oxidizer for this flight lowered the average thrust to 167 N and a total impulse to 502 Ns.

A preliminary shakedown flight for the airframe components was made on an AeroTech I161W with a total impulse of 320 Ns. Given that that flight yielded a peak altitude of 1,136' compared to the 1,902' peak altitude of the hybrid we can see the results all appear to be consistent.

Motor disassembly:

The paper grain performed as expected yielding a smooth burn with excess fuel remaining and no burn-throughs noted. The forward grain burned from 45 grams down to 33 grams and the rear grain burned from 118 grams down to 66 grams for a total fuel burned of 64 grams.

Looking momentarily at the 250 grams of N₂O actually burned we get a rough O/F ratio of about 4:1 The O-rings (silicone in this case) were in outstanding shape with no deformation or charring noted.

The main forward grain insulator washer was charred away in its central portion. The forward grain insulator washer for the pre-heater grain was, however, completely burned away. In light of this it may be wise to double-up these insulating washers. Both the pre-heater liner and the main grain liner (phenolic) survived with little or no damage.



The nozzle I used had been part of an AeroTech RMS Hybrid original reload kit and showed signs of damage received somewhere along the way (in red circles in the photos below). It was decided that the damage would not compromise the O-rings and thus not be fatal to the flight, so the nozzle was used as is. The original kit it came from was designated for a J170H 3-jet flight and thus the throat measured 0.375" in diameter. The nozzle performed just fine during the flight and shows even burn all-round with the throat eroded to 0.438 so over the entire burn the throat had enlarged by 0.063" (photos below).



All components in the forward closure performed nominally with no odd behavior noted. The burst disk and pyro element were completely ashed and only a skeleton of the O-ring remained. The steel washers appeared undamaged. As previously noted the pre-heater washer was burned away completely but the liner cylinder was in reasonably good condition.



The injector plate was undamaged and showed no signs of suffering any blowback or backfire leaking into the threaded well where the pin valve seats. With regard to the difficult assembly issue discussed earlier, no damage was seen on the depressor pin indicating some kind of misalignment had occurred. Nor did any damage appear on the pin valve pin. This problem does need to be resolved however.



Flight and motor burn summary:

This configuration of the RMS Hybrid Revival motor with a 380 cc flight tank can be expected to deliver a solid " I " class burn yielding an average thrust of 167 N and a Total Impulse of around 500 Ns. This motor had no trouble lifting a 4 Kg (8.8 lb) rocket to almost 2,000'. A very respectable maiden flight overall!