# Development Of A High-Scoring G Superroc By Use Of Optimized Engine Choice, Conventional Design, And Conventional Construction Methods.

By the Southern Neutron Team
(George Gassaway, Ed LaCroix, Terrill Willard, & Ryan Woebkenberg)

T-553

Team Division

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## Summary:

Our objective was to develop a highly competitive G Superroc model, without using composite fabrication, special construction, or special design tricks.

We realized that winning Superroc models are almost always maximum length, so a highly competitive G class model probably needed to be maximum length, at 450 CM (or 14.76 feet) tall.

We first built and flew a maximum length G Superroc, and quickly found out some of the problems associated with building and fly a nearly 15 foot tall rocket powered by a G engine. When that model failed, we had to work up two less-than ideal models to compete with at a Novembers regionalcontest, and get some more practical in-the-field experience at an actual contest.

Having obtained more experience, we set about to build a highly competitive model, of maximum length, which would require less structural strength than the other models that were being flown. We realized that the optimum engine choice seemed to be a cluster of long burn low thrust engines, either two F10's or one F10 and two E6's. Those choices also are rated at 160 N-sec, giving full total impulse for flying the event. For practical purposes, like using a 160 N-sec "G20" engine.

By using one of those two choices, the model would fly slower and have less structural flight loads than with any other viable G engine choice. That is the key to obtaining good flight performance out of paper/cardboard G Superrocs, reducing the flight loads so they do not have to be as strong as with other engines in the 80.01 to 160 N-sec class.

An all-BT-60 model of 450 CM was built and tested, successfully flying on an F10 and two E6's.

Refinements were made to that design, to reduce drag of the lower section with the engines and fins.

In addition to flight testing, some Rocksim simulations were run, based on some of the test models, to evaluate and compare other engine choices which had been considered. Those simulations show that higher thrust engines produce lower altitudes and often significantly higher flight loads than two F10's or one F10 and two E6's. Those simulations helped to confirm our conclusions.

We feel that we have a competitive design approach to use at NARAM-49.

Special note to judges:

We respectfully request that you not allow the contents of this report to be seen or described to anyone other than yourselves until after we have made our first G Superroc flight on Thursday, or the oral presentations, whichever comes first. The key elements of this report are a special choice of the best engines for G Superroc, and the right airframes to use with them. It would not be fair to us if key parts our work preparing for G Superroc were allowed to be leaked to other competitors who might have time to build or modify their models and obtain these engines in time.

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Background:

The choice of G Superroc for NARAM-49 was quite a surprising one. It had rarely been flown, and apparently not flown all-out seriously as would be seen at a few major regional meets or a NARAM. The few who held it did so mostly for "fun", with models that apparently were not much beyond minimum length of 225 CM. Apparently there were no G Superrocs close to max. length (450 CM) flown, and even then it was for G Superroc Duration. The same can be said for a few contests that have held F Superroc. In the early 1980's, George's club held F Superroc Duration several times, where the competitors used models not much beyond minimum length and usually far less than optimum design such as BT-70 and BT-80.

The highest power Superroc event flown seriously by all-out contest fliers was E power, at NARAM-34 in 1992, where the best models tended to fly on an E6 engine, and in 1977 at NARAM-19 where the best models tended to fly on AVI E11.8 engines. Those cases were notable since in 1992 the optimum single engine for an E altitude event was an E6 (decent thrust on a long burn, close to 40 N-sec), and in 1977 the best single E engine for Altitude was the AVI E11.8 (close to 40 N-sec, higher thrust and short burn than an E6, but far better than the 22 N-sec and too-low-thrust FSI E5).

Given that the winning Superrocs are almost always maximum length, it seemed to us that the likely way to win G Superroc at NARAM-49 is to fly a maximum length model as well. But 450 centimeters, 14.76 feet long, is quite a lot longer than almost any model a contest flier has ever built for.

We saw the key elements for G Superroc to be both propulsion and structural. With propulsion directly impacting the structural requirements .

We chose not to get into composite construction, because there are too many gray areas in the rules. Below is rule 21.4:

* * * *

21.4 Construction

Entries with bodies or significant structural parts made from hard or potentially unsafe material (e.g., hardwood doweling or fiberglass shafts) shall not be allowed, under the provisions of Rule 1.1.

* * * *

This has been interpreted in the past to prevent use of commercially made graphite tubing, but has also been interpreted to allow homemade fiberglass bodies that were sturdy without being “hard”. A few fiberglass bodies made with lengthwise strips of graphite being included in the fiberglass lay-up. There has to be some sort of point where such a homemade composite body would be judged to be too “hard” and declared illegal according to rule 21.4, but lacking any actual testing or measuring criteria, competitors would be risking their labor-intensive and expensively fabricated models to the whims of an RSO.

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## Objective:

The objective of this project was to develop a highly competitive G Superroc. One which would not run a risk of being DQ’ed for composite construction that might be too strong.

For the purpose of this project, we chose not to try to develop the brute-force strongest rocket. But to work out the optimal thrust profile among contest certified engines, by means of clustering and/or air-starting. And then tailoring model design to those that would hold up, without getting into composite construction.

One of the basic rocket science reasons for looking for a slower boost is the fact that aerodynamic loads increase as the square of the velocity. Let’s assume that Model A has a maximum velocity of 300 ft/sec, and model B has a maximum velocity of 400 ft/sec. Model B flies at 133.33% the velocity of Model A. But since the aerodynamic loads are square the velocity, Model B has 177.78% of the aerodynamic loads of Model A.

To flip it around, let’s say that Model B is a typical NARAM Superroc model flying on a higher thrust engine such as a G40, at 400 ft/sec. If by a better engine choice, Model A can fly at 300 ft/sec max., it has aerodynamic loads that are only 56.25% of the loads that Model B has. So, Model A does not need to be nearly as strong as Model B does, which in turn means that Model A can be built lighter and fly even higher.

So, this was the basis of investigating and settling on the use of lower thrust and longer burn engines for Superroc, to reduce the stress on boost so the model did not have to be as strongly built (and therefore heavier) as for models flying on higher thrust engine combinations.

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## Approach:

Our approach was to evaluate engine choices which could produce a hopefully winning model, and tailor the model design to work with that engine choice (to be light enough without folding).

Another part of the approach was to find out structural issues which were not typically found or noticed with small Superrocs. This included some early models which did not use optimum engines, in order to fly G Superroc at a November contest, and to see what issues cropped up with models flown by others.

There are no engines which are really well suited for G Superroc. Not when considering average thrust, and not considering that the event is for 160 N-sec, and some G engines do not even top 100 N-sec. Indeed, the G40 used to be about 120 N-sec, but a redesign in recent years has dropped it to about 100 N-sec or so.

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Potential engine choices:

1 - Single Ellis Mountain G20-3 - 124 N-sec - The lowest average thrust contest certified G engine. Unfortunately, only the 3 second delay is certified. Would have to either go with a too-short delay or add a timer.

2 - Single Aerotech G40 - 100 or 120 N-sec - The lowest average thrust contest certified G engine with a suitably long enough time delay. This engine used to be 120 N-sec, but a redesign a few years ago dropped it to about 100 N-sec. Some people have old G40's, the rest are flying newer ones at about a 20 N-sec disadvantage.

3 - An interesting option would have been the Aerotech G25. But it is no longer Contest Certified.

4 - Ellis Mountain G20 with clustered D11-P's - 160 N-sec - A full power combo, but with a lot higher average thrust than desired, sort of like a 160 N-sec G40. Also would need a timer for ejection, unless the D12's were used in place of D11's and a D12-7 ejection was routed into the main body.

5 - Ellis Mountain G20 with air-started D11-P's - 160 n-sec - Would air-start the D11's to reduce the maximum velocity as would occur with clustering. Would need a timer for air-starting and also a second timer for ejection or use a D12 with time delay and ejection charge.

6 - Aerotech G40 clustered with two D11's - 156 N-sec - Would have too much maximum velocity, with a G62 average thrust, compared with other engine options.

7 - Aerotech G40 air-starting two D11's - 156 N-sec - Air-start two D11's later so that they would not increase the max. velocity reached by the G40 burn. This would be the optimal use of a G40 based model, at the expense of using a timer for air-start and an airframe that could hold up to a G40.

8 - Twin E6 liftoff, with F10 air-start at E6 burnout - 160 N-sec total - Theorized it might not stay straight enough, might need horizon-sensing guidance. Finally ran some flight sims which showed that for a max. length superroc of this size and mass, it did fly any better than having all engines clustered at liftoff. Given the added complexity of a timer to air-start, plus increased potential for weathercocking, the air-start twin E6 to F10 option was dropped.

9 - Two clustered F10 (or twin E6 and F10) - 160 N-sec total - Flight simulations showed this combo was the highest boosting motor combination, period. Even ignoring structural failure issues, a G40 would not boost nearly as high, even with air-starting two D12's at G40 burnout.

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Based on the engine combinations considered above, the last seemed to be the best. To use either two F10’s clustered, or an F10 with two E6’s clustered.

The advantage of using lower thrust is not simply more aerodynamic efficiency. It is to reduce structural loads on the Superroc models. Models that shred on a G40, might hold up to two F10’s. A model that is built from the start to be just strong enough to fly on two F10’s, would definitely shred on a G40. So, a model built to fly on two F10’s (or an F10 and two E6’s) can be built lighter than one built to fly on a G40. Of course, a composite model could perhaps be built to hold up to a G40 that would weigh less than an all-cardboard model on two F10’s. But the premise of our design choice was not to go with composites.

Last fall, F10’s and E6’s were not contest certified. We had heard they might be submitted to regain contest certification, so that seemed like a good option to explore. If they had not been certified, another option would have been to use two E7 R/C reloads and G12 R/C reload (with onboard timer for ejection).

Such were the options we had last fall. Meantime, the first NAR contest, and as it turned out, only NAR contest to hold G Superroc Altitude this season was coming up in November. Launch Crue’s “RIDE THE ROCKET” regional meet, in southern Indiana. We wanted to have a competitive model for that contest, but realized it was premature to try to develop an optimal model in time for that contest. In theory we could have developed a model to fly on a G12 and two E6 reloads (contest certified) , to use a timer for ejection, but not only would that have been overkill for that contest, we did not want to reveal our intended key strategy for NARAM-49, by using such long burn engines.

We took two approaches for that contest, max. length and minimum length:

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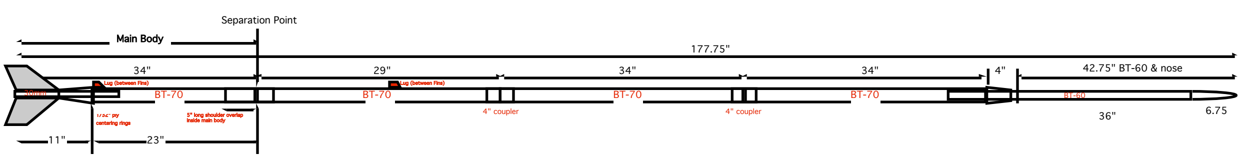
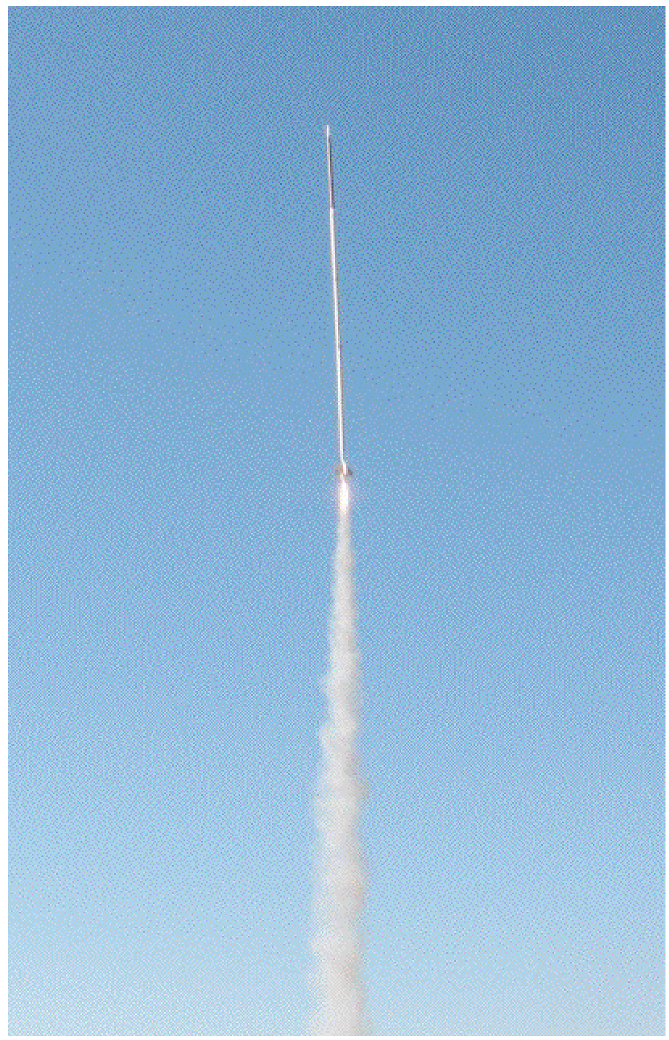
**Model #1** - George Gassaway built a model out of mostly BT-70 tubing, with a BT-60 upper section, powered by a G40 engine.




It was maximum length (450 CM) , the first known maximum length G Superroc to be attempted. It was test flown in Alabama on October 21st. The model took off well but accelerated faster than had been anticipated. It was about 100 feet up when it started to bow slightly to its left, veered a bit left, then the more it bowed, the more it veered, in an ever-tightening radius. It went past horizontal and was going downwards when it finally came apart, into two main segments. The main body fell to the ground and crashed before ejection, crashing about 700 feet away, while the upper section free-fell to the ground.



The analysis of the failure was the use of insufficient tube couplers, compounded by the use of too-weak tape around the coupler joints. The model was built to be plugged together and taken apart to facilitate transport. The couplers were 4” long couplers. So, only 2” of each end of the coupler fit into the BT-70 tube, a length to diameter aspect ratio of about 0.92. In retrospect, that was way too short. For normal BT-20 type Superrocs, couplers would usually have a length of 4” or more, with 2” or more fitting into each end of the BT-20 tube, for an aspect ratio of at least 2.82.

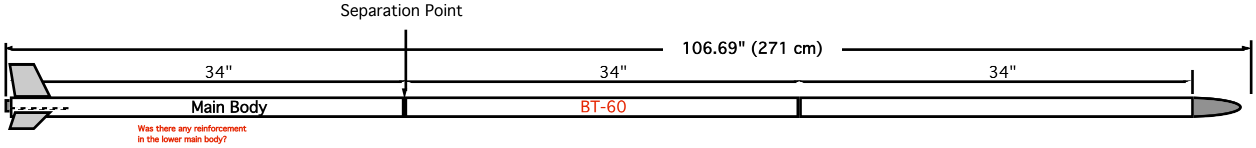
The model had been seen to be bowing when it was near-horizontal on the launch rail, it apparently was bending at the coupler joints and not the BT-70 tubing itself. When the model came apart, it pried itself apart at the middle joint of the four BT-70 sections, stretching and ripping the vinyl tape used for keeping the joints form falling apart during parachute deceleration.

So, two key mistakes learned form that were to use much longer tube couplers, for as little “wiggle” as possible, and to use high-tensile strength tape such as package tape across joints instead of tape that can stretch.

Two practical-use things were confirmed with that flight. To launch off of a very long launch rail, not a rod. A rail is much sturdier to launch from than a rod.  For rail lugs, Plastruct “H” beam material 3/8” wide was used. The H Rail fits loose on the rail for a very low friction slide compared to some rail buttons. The H lug can possibly wiggle out from the rail slot due to the thin thickness of the middle part of the “H”. That was fixed by gluing 1/16” balsa strips to each side of the middle part to make it about 3/16” thick, still plenty loose sliding in the 1/4” slot.

The crash of that model eliminated it from use at the November regional meet.

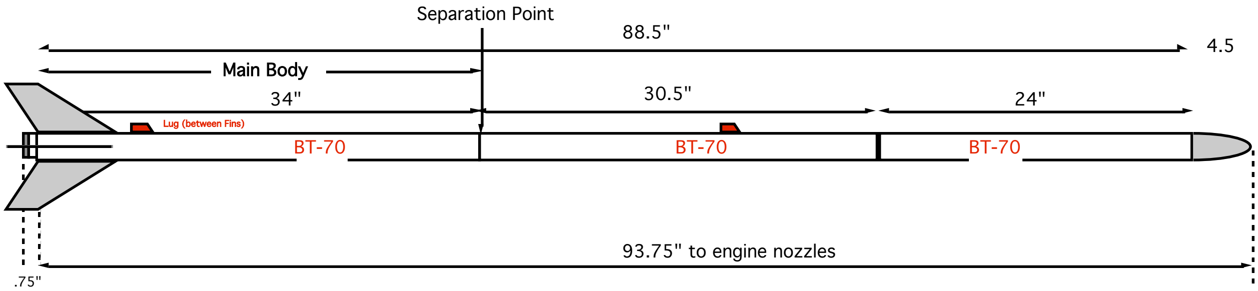
**Model #2** - Ryan Woebkenberg made an all BT-60 model, with some full-length BT-60 coupler tubing inside of it, to make it sturdy enough to hold up to a G40.




It was based on a similar model that has been successfully test-flown by Launch Crue member Jim Stum. The length was 271 CM, 46 CM over minimum.

At the contest, the first flight of the all-BT-60 model was tracked to 557 meters, but the closure was 15% so it did not close. The second flight (officially, reflight of the first), tipped off and flew to 376 meters, closed. Unfortunately a shock cord failure caused the flight to be DQ'ed.

**Model #3** - A Back-up model had been built by George, using some parts from the crashed BT-70 model, and some new parts.




It was all-BT-70, close to minimum length, at 238 CM. Instead of a G40, the engine choice was a cluster of three E9's. This model was intended as a back-up model to Ryan's, and was flown for the second official contest flight. It flew successfully, tracked to 419 meters. That gave it a score of 99,722 points, which won the contest for Team Division and set the record for G Superroc Alt for Teams (no record existed before that).

There were other models of note at the Launch Crue November Regional contest, for various reasons. Jim Stum's BT-60 model, with internal full length couplers, flew on a G40 to 442 meters, at 308 CM, for a score of 136,136 points. David Woebkenberg's Team used a stretched 2.26" diameter LOC kit with three E9's, 289 meters on a 231 CM long model, for a score of 66,759 points.

Chad Ring had a reinforced model that was half BT-55, and half BT-50 (with 34" long tube couplers inside of most of it to reinforce it). For the first flight, he used a G40 engine. About 2/3 the way into the boost, the model folded. He repaired it, and then flew it on a G20-3. The delay should have been too short at 3 seconds, but the Ellis motors have a variance in performance, and it seems Chad got something more than a 3 second delay. His 343 CM long model held up, and flew to 683 meters, for a score of 243,148 points.

There were two other people who fielded models at the contest. Both failed structurally on boost. One was a cluster of two F50 engines.

The contest results showed pretty much what we expected. Models using high thrust engines like G40's needed to be very strong and not much over minimum length. Our own two models at the contest (Reinforced BT-60 n G40, and BT-70 on three E9's) were not intended to be optimized, but to be used as sensible entries given the level of the competition. The best performing model of the contest was Chad Ring's when he used a G20-3 engine, one that had the lowest thrust level of any contest certified engine. On the G20, it survived what it had failed to survive on a G40 motor.

It was notable that Launch Crue had prepared for the contest by having two 16-foot rails made up for flying G Superrocs. They were made of two 8 foot rails, plus a joiner. We had already decided to use longer than 8 feet, but went with 12 feet to use at NARAM.

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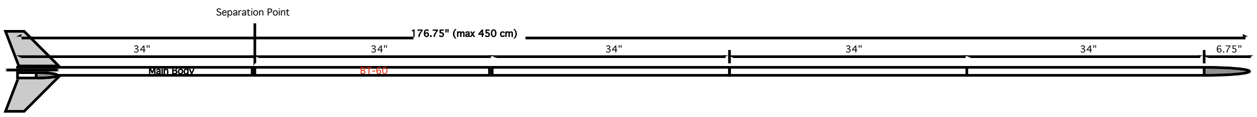
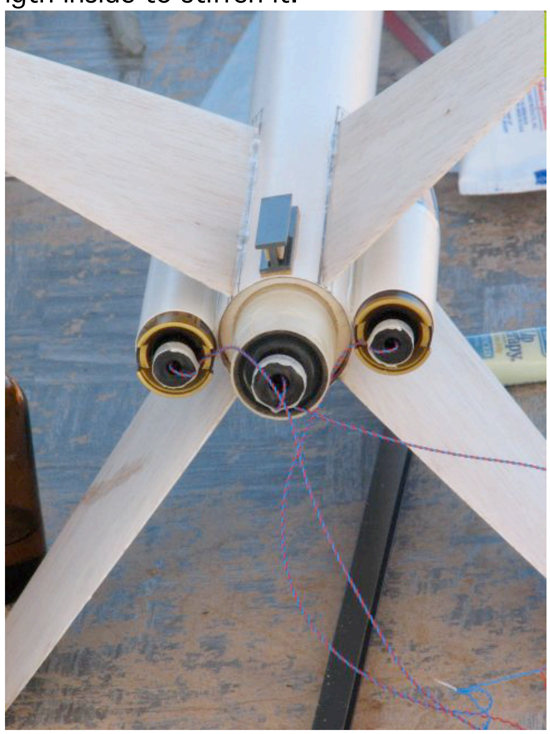
Model #4 - By early March of 2007, we were ready to try out our first optimized model, to fly on two E6 reloads and one F10 engine. We had heard that Apogee had resubmitted the F10 and E6 expendable engines to NAR S&T to get re-certified for contest cert. Indeed the engines had been tested months before, and passed. But there was a discussion among the NAR Contest board as to whether those engines should be considered to be "available" enough to be contest certified, given that the engines are produced in small batches and are often out of stock for long periods of time. We were feeling by that time it was probably likely that the engines would get contest certified, but if not we still needed to make a flight soon so if it worked well we could evaluate going to "Plan B" to use a G12 and two E7 reloads.

George was visiting in Phoenix for a few days, having come in part for a Regional meet that was held earlier. Ed LaCroix and George discussed the design, then built a model to test before George left for home.




The airframe choice was full length BT-60. Five 34” sections of 34” tubing. With tube couplers 8.5” long, 4.25” inside of each tube end, for a length to diameter ratio of 2.67 to 1. The joints were taped over with high-tensile strength package tape.

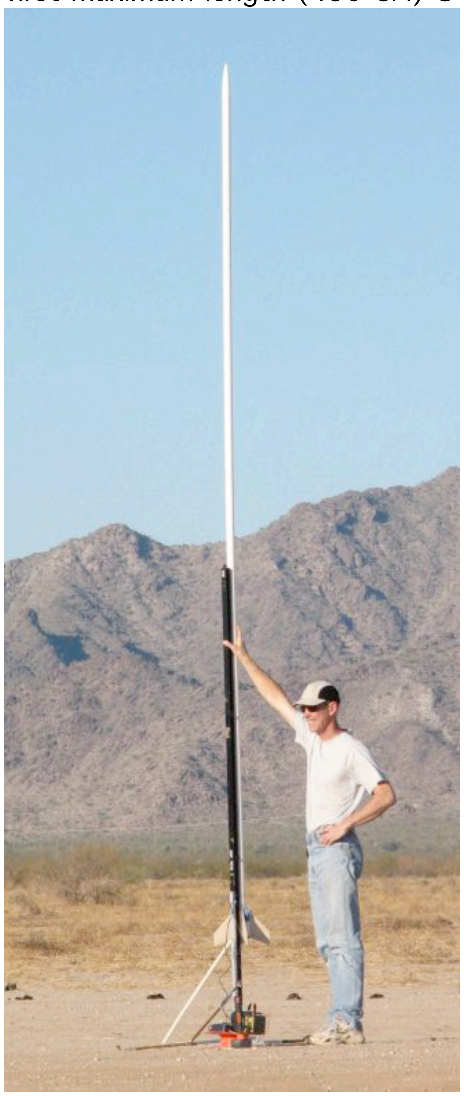
Previous experience with all-BT-60 models 8 to 9 feet long, flying on a cluster of three D12’s, we felt that an all-BT-60 model nearly 15 feet tall probably would be strong enough at the speeds produced by a cluster or two E6’s and one F10. If it failed on boost, we’d look at adding more tube coupler length inside to stiffen it.

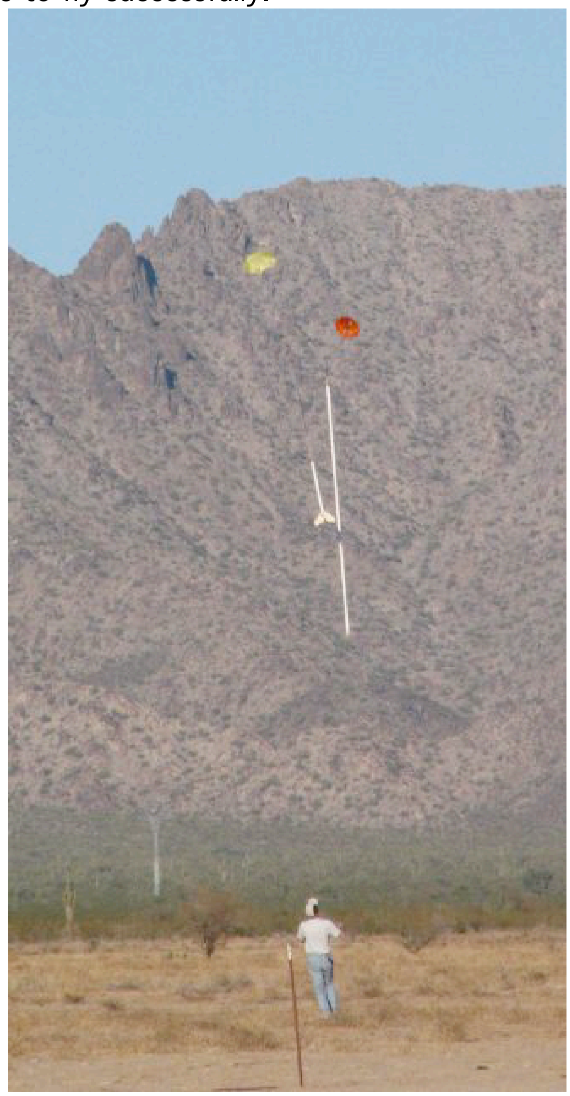


The upper sections were prepared by Ed LaCroix, who has many years of experience at doing well in Superroc altitude events. He checked the fit of the couplers to make sure that the upper sections were properly aligned axially.

The lowermost coupler, which slides-fit into the main body to separate at ejection, had the exposed outer layer very carefully peeled down to reduce the diameter a bit, then the diameter was built back up with carefully placed pieces of tape. The purpose of this was to achieve a nice smooth slide-fit so that the upper section did not wiggle at the joint due to unwanted looseness, but also would be able to slide out freely enough at ejection. The “fuzzy” outer surface of cardboard tube couplers such as sold by BMS and Totally Tubular, tend to have a good fit for coupling alignment but often have far too much friction to be safe for use as a coupler for ejection. The above process was used for our other models made later.

The model was tested near Phoenix, Arizona, at the same site as used for NARAM-48. It was tested in isolation, as we did not want to do it at a launch where others could find out about the design and most importantly the engine choice. The model was launched in wind of about 3 mph. Three Firestar ignitors  ignited all three engines instantly, and the model took off rapidly. The model held up to the boost,  and weathercocked only slightly, less weathercocking than might have been expected for a model using such long burn engines. The  model reached apogee, and went into a tail-slide that turned into a “backslider” type of glide for a few seconds, then the F10-8 ejected. The dual chutes deployed, and the model landed safely. To our knowledge, this was the first maximum length (450 CM) G Superroc to fly successfully.





A very small altimeter was mounted into the nose cone of one of the E6 side pods. The altimeter indicated 607 meters, for a theoretical score of 273,150 points.

We had expected a somewhat higher altitude than that. We are unsure if the altimeter data was accurate, due in part to the location in a side pod nose cone like that, and due in part to the altimeter being intended for use in model airplanes,  taking one data sample per second. As well, the model  was built to be a bit less than optimum, with rough fins, engine pods in-between fins, and some excess internal mass by use of relatively heavy HPR type chutes.

With this successful flight, our team efforts went to other pressing matters for  awhile.

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On April 16th, NAR S&T announcement R108 was posted, the F10 and E6 were given Contest Certification.

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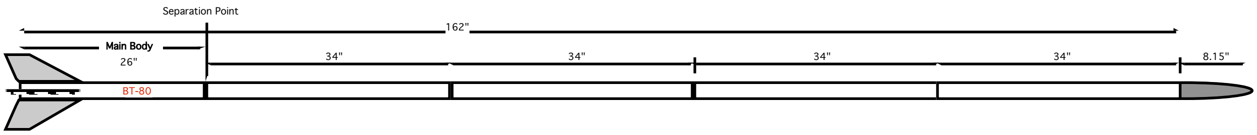
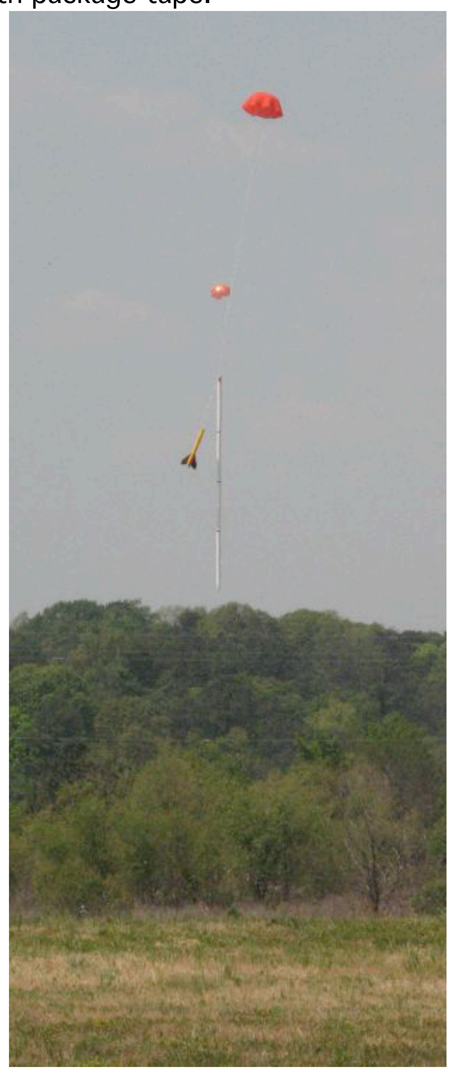
**Model #5** - An opportunity to test out a low performance near-maximum length model arose in April, as a “demonstration” model George Gassaway assembled to fly during the annual Birmingham Blast Off launch.




The lower main body was from an old F Superroc Duration model, from around 1982. It was given four BT-80 tube sections (when flown as an F Superroc Duration model, it was only around 8 feet or 250 CM tall). The couplers were 8.5” long, 4.25” inside each tube, for an aspect ratio of 1.66 to 1. The couplers were originally a little bit loose, so tape was added to make them friction fit tightly. The joints were taped with package tape.



The main body of that model used to fly on four D12’s. For this flight, it was flown on four E9’s. The propellant mass technically made it an HPR model, in order t o have been legal G Superroc it would have needed to fly on two E9’s and two D12’s. It ignited all four E9’s, and boosted very nicely. It had no altimeter onboard, estimates and flight sims indicate it would have flown about 1000 feet. Most significantly it had held together while using a 114 N-sec "G36" engine. That indicated that had it flown on a G40 engine, it probably would have held up. However, a person probably would have been better off using a near-minimum length reinforced BT-60 model than a max-length BT-80 model.

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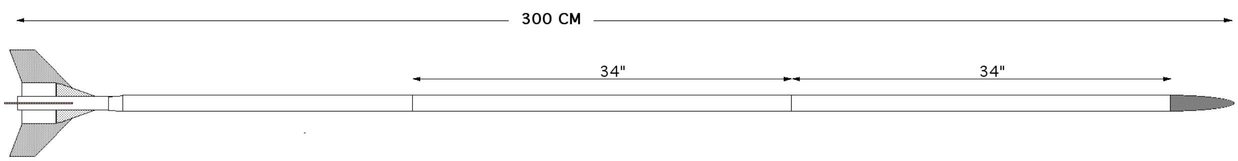
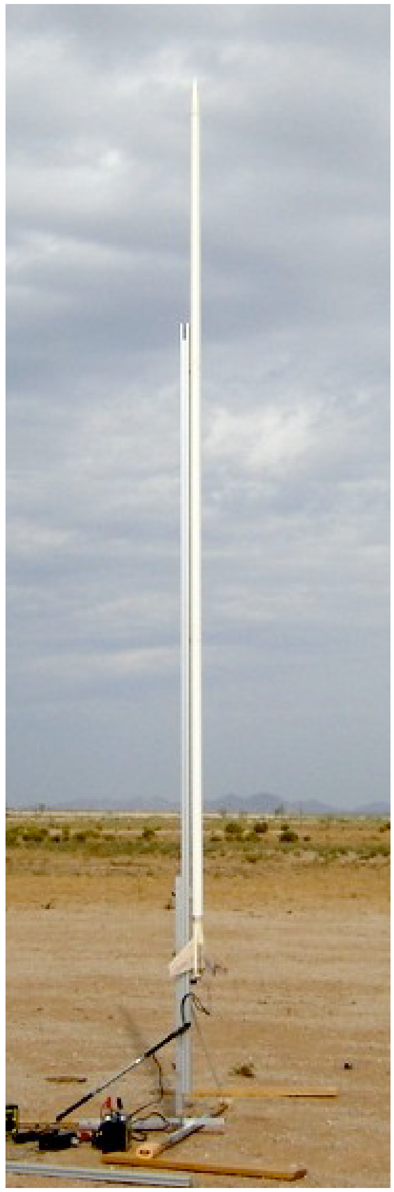
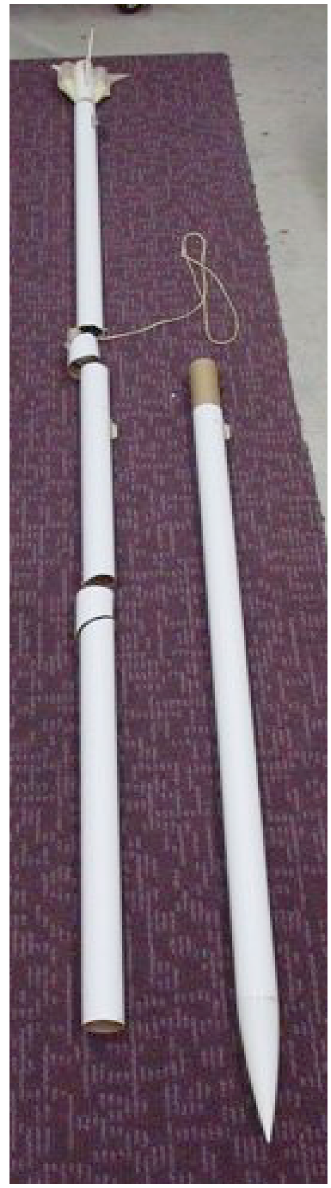
**Model #6** - "Windy Weather" BT-55 Superroc, flown July 21, 2007. Built by Ed LaCroix.




Building and testing of follow-up models got delayed into July. We had some concerns in case it was very windy the day of the NARAM event, that a maximum length BT-60 model might have a problem. So, we decided to hedge our bets with a 2/3 length (300 CM) model using BT-55 tubing. It would score fewer static points, but would go significantly higher than the 450 CM BT-60 model, so it would get in a pretty good score for a very windy day.


The design was for one F10 and two E6's, somewhat similar to the March model #4, but shorter and with drag reduced. The drag reduction included fairing in the 24mm engine pod noses ("Soyuz booster" style), and changing the fin orientation 45 degrees so two fins would be glued to the pods and two fins at 90 degrees to the pods. Another change was to boat-tail the model by going down from BT-55 to a 30mm tube for the last 10 inches of the tail section.

The model was tested on a calm day. It took off much faster that the max. length BT-60 model #4 did in March. It was going straight up, very fast. At about 5 seconds into the boost, the model bent in half and broke apart. There was no warning, no veering. The conclusion was that the model reached a velocity that the airframe could not take, and with the airframe forces concentrated in the middle, that made the middle fold first, then everything came apart after that. Had it been say, a fin shredding first, it would not have been likely that the airframe would have bent almost exactly in the middle.

Later Rocksim analysis indicated that this model probably flew 100 ft/sec faster than the max. length BT-60 Model #4 in March. Sims indicated model #6 flying at 399 ft/sec compared to 299 ft/sec for Model #4. That means that Model #6 flew 33.4% faster than Model #4, and had 78% more aerodynamic loads on it than Model #4.

The model had a small altimeter onboard, but it produced no data.

We are unsure if we will have a BT-55 windy weather model at NARAM or not. If we do, it will have a full length coupler tube in the middle to reinforce it. The extra mass will also reduce the maximum velocity somewhat. There will not be time to have the boat-tail and faired noses, a replacement model will be almost exactly like the BT-60 March model #4’s main body, with fins between fins, except on a BT-55 body. If we do not replace this model, we may account for wind with other BT-60 models by angling the launcher the appropriate number of degrees downwind, or if windy enough reduce the length of the BT-60 models.

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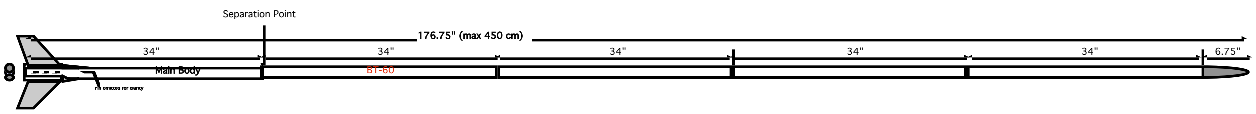
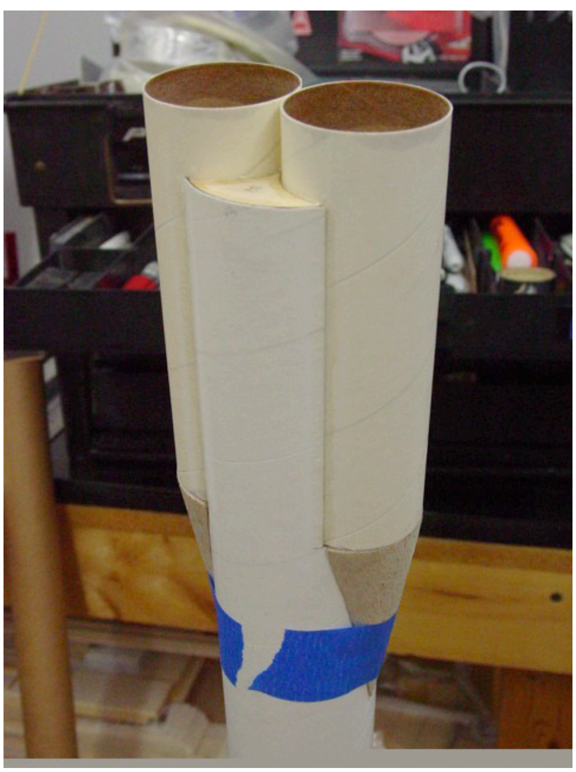
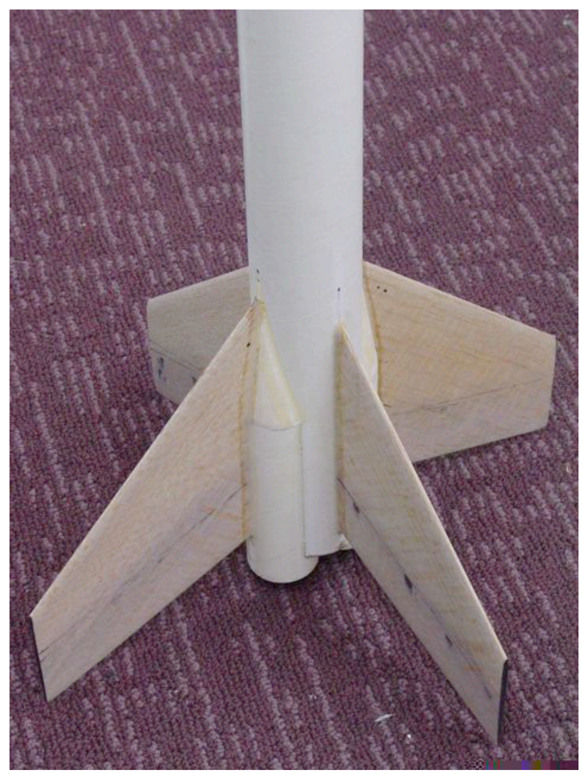
**Model #7** - Twin F10 model, all BT-60, max. length - Built by Ed LaCroix

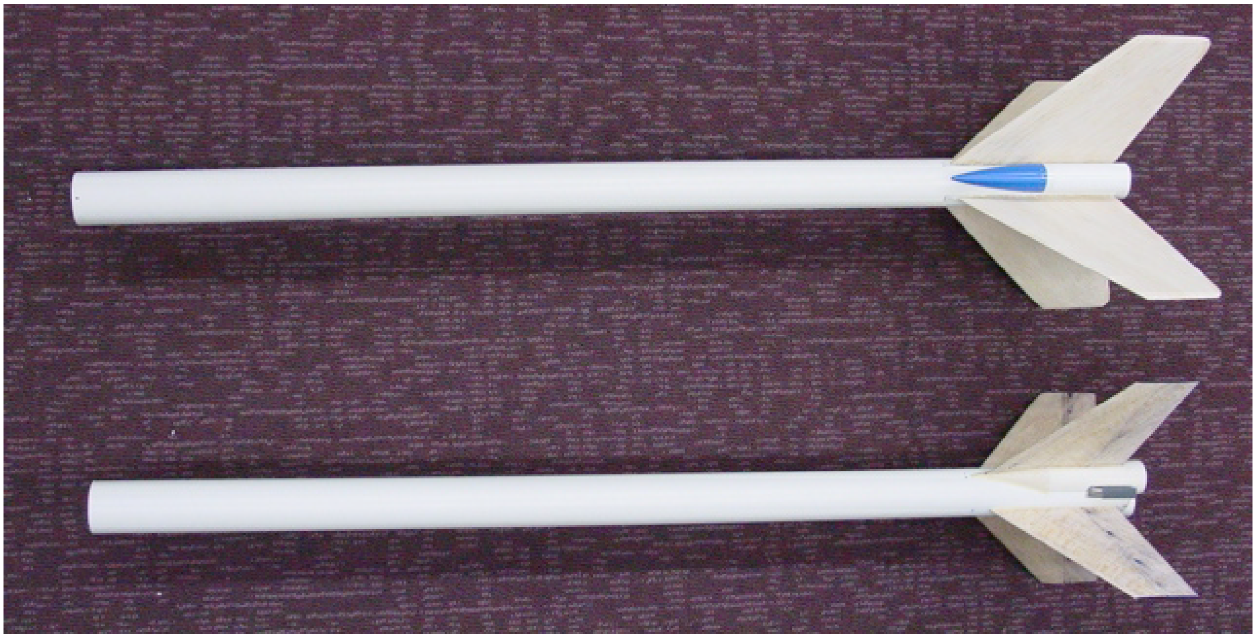



This model was built with the idea that two clustered F10’s would have the lowest amount of drag, being faired into the BT-60, compared to having 24mm side pods. It was planned to be test flown, but it was not completed in time to be tested. Since it shares the same structure as the March F10 and two E6 model (also all-BT-60), we have confidence that it is structurally as strong as the March model #4.





Our planned contest models for NARAM are the twin 10 all BT-60 model (#7) and the F10 and two E6 all BT-60 model (#4). Possibly with a 2/3 length BT-55 windy weather model like #6.



In the above photo, the lowermost main doby of Model #4 is at the top (blue noses on 24mm sidepods), and model #7 is at the bottom. The upper sections will be identical, four 34" long BT-60 with 8.5" joiners.

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Other Observations and research:

At various launches during the 2006-2007 season, some people have test flown G Superroc models. A lot of the models crashed. Some whose models crashed did not understand why flying a skinny model on something like a say a G80 would be a bad idea. Even those using G40's did not have a good feel for the power of the G40 in long model, or a weak model. At a record trials in Phoenix, two people had much the same model, minimum length BT-55, on G40 power. Both models did much the same, bowed on boost and half-looped into the ground.

We took a survey in Contestroc to ask about what people had seen or planned to do for G Superroc for NARAM. We did not get much in the way of flight test reports. We did hear of a couple of people talking about the Ellis G20, at least one or them planning to air-start two D11's or D12's.

There had also been mention previously on contestroc of a "lance" type of Superroc. Made from two back to back long skinny tapered cones of foam, with a thin graphite skin. The person who built it reported that he had flown it twice, confirming it was strong enough for G power, by flying it twice on H power. That is opposite of our theory for this event, even ignoring the composite construction and whether it might be too stiff - Any model that is strong enough to fly on an H engine almost surely would be unnecessarily strong and heavy for flying on a sensible G engine. It could have been interesting to perhaps refine what he did in overkill strength with his model, to tailor it to be just a bit stronger than necessary to fly on two F10's or an F10 and E6.

We are left wondering if perhaps nobody else has thought of using F10's and/or E6's for G Superroc. Has it not occurred to others, or do they have similar plans but are keeping their plans under wraps for the same reasons we are? Outside of our team, the only person we do know who plans to do a model with two F10's or one F10 and two E6 power is Chad Ring, whom we share contest information with. However, Matt Steele of the Pod Bay doors team happened to be out test flying the same day as Ed LaCroix and Terrill Willard tested out Model #5 (with F10 and two E6's), so Matt Steele knows of that possible engine strategy.

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Flight Data:

The following is a mixture of information and data from some of the flights, as well as some Rocksim simulations:

Model #1 - October 2007 - BT-70 model on G40. Failed during boost due to too much bending due to coupler tubes being too short and tape being too stretchy. First known max-length (450 CM) G Superroc to be attempted. First known max-length (450 CM) G Superroc to crash.

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Model #2 - November 2007 - Reinforced BT-60 model on G40. 271 CM long.
Flight 1 Track 15% error, Alt of 557 meters, would have been around 150,000 points
Flight 2 track 376 meters, DQ'ed, would have been 101,896 points.

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Model #3 - November 2007 - BT-70 model on three E9's. 238 CM long. Successful, tracked to 419 meters, score of 99,722 points. Won Contest in Team Div, Set current Team Div record.

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Model #4 - March 2007 - BT-60 max length - F10 and two E6's, 486 grams without engines. Successful, first known max length G Superroc to work.
Onboard Altimeter reported 607 meters, for a score of 273,150 points.

Rocksim of Model #4 at 486 grams: 2410 feet, 299 ft-sec, 13.30 sec to apogee
735 meters * 450 CM = 330,750 points

Rocksim of Model #4 at 622 grams (add two full length couplers for windy weather reinforcement): 2080 feet, 262 ft-sec, 13.12 sec to apogee
2080 meters * 450 CM = 285,300 points

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Model #5 - April 2007. BT-80 model on four E9's. 432 CM.  283 grams W/O engines. Successful, but propellant mass was over the Model Rocket limit.

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Model #6 - July 2007 - BT-55 windy weather model - F10 and two E6's.
300 CM length, 283 grams without engines. - Shredded about 5 seconds into boost. Altitude unknown (altimeter failure)

Rocksim of Model #6 at flown at 283 grams W/O engines:
3365 feet, max velocity 399 ft/sec, 14.11 sec to apogee.
1025 meters * 300 CM = 307,800 points.

Rocksim of Model #6 with full length tube coupler added for 341 grams:
3245 feet, 388 ft-sec, 14.32 sec to apogee
989 meters * 300 CM = 296,700 points

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Model #7 - BT-60 max length (450 CM) - Two F10. 431 grams W/O engines. Not flown.

Rocksim of Model #7 at 431 grams W/O engines:
2534 feet, 317 ft/sec, 13.06 sec apogee
772 meters * 450 CM = 347,400 points

In case there is enough wind to consider shortening the model:

Rocksim at 567 grams (two full length tube couplers added):
2240 feet, 284 ft/sec, 13.09 sec to apogee
683 meters * 450 CM = 307,500 points

Model #6 shortened by one segment to 368 CM, with one full length coupler added (approximately 432 grams):
2696 feet, 334 ft/sec, 13.47 sec to apogee
822 meters * 368 CM = 302,496 points

Model #6 shortened by two segments with two full length couplers added:
2894 feet, 355 ft/sec, 13.95 sec to apogee
882 meters * 281.81 CM = 248,556 points

## Engine Choice Simulations:

For the purpose of documenting relative altitude and velocity performance of some previously discussed engine combinations, some sims were run with model #4. As a reminder, basic model #4 information is:

Model #4 mass without engines of 486 grams, 29mm main engine mount and two 24mm side pods. Model completely built of BT-60 diameter tubing plus nose cone for max length of 450 CM:

G40 only (Rocksim shows the current G40 at 99 n-sec)
1540 feet, at 383 ft/sec

G40 and two D11's clustered (134 N-sec):
1892 feet, at 468 ft/sec.

G40 and two D11's air-started 3 second after liftoff (134 N-sec):
2038 feet, at 341 ft/sec

Ellis Mountain G20-3 (124 N-sec)
1759 feet, at 303 ft/sec. Apogee at 10.99 seconds (approximately 5.5 seconds after burnout)

Ellis G20 with Estes D11's clustered (159 n-sec):
2238 feet, 354 ft/sec

Ellis G20 with two D11's air-started at 5 seconds after liftoff: (159 N-sec)
2204 feet, 295 ft/sec.

One F10 and two E6's (160 N-sec):
2410 feet, 299 ft/sec

Of the above motor simulations, there are only three that are around 300 ft-sec velocity, for similar aerodynamic flight loads.

Those are the single Ellis G20, at 1759 feet, air-started G20 and two D11's, at 2204 feet (plus the issue of air-starting), and the single F10 and two E6 cluster, at 2410 feet.

Any other motor combinations would have produced significantly higher velocities and higher aerodynamic loads. This means that a model like #4 would be more likely (or very likely) to structurally fail, or else extra reinforcement would have been necessary, reducing the performance significantly.

Of the above flight sims, the top two altitudes are the single F10 and two E6 at 2410 feet and 299 ft/sec, and clustered G20 and two D11's at 2238 feet and 354 ft/sec velocity. The G20 and two D11 cluster would fly lower, and at a velocity of 354 ft/sec, the G20/D11 cluster would cause 1.40 times more stress on the airframe than the F10 and two E6's.

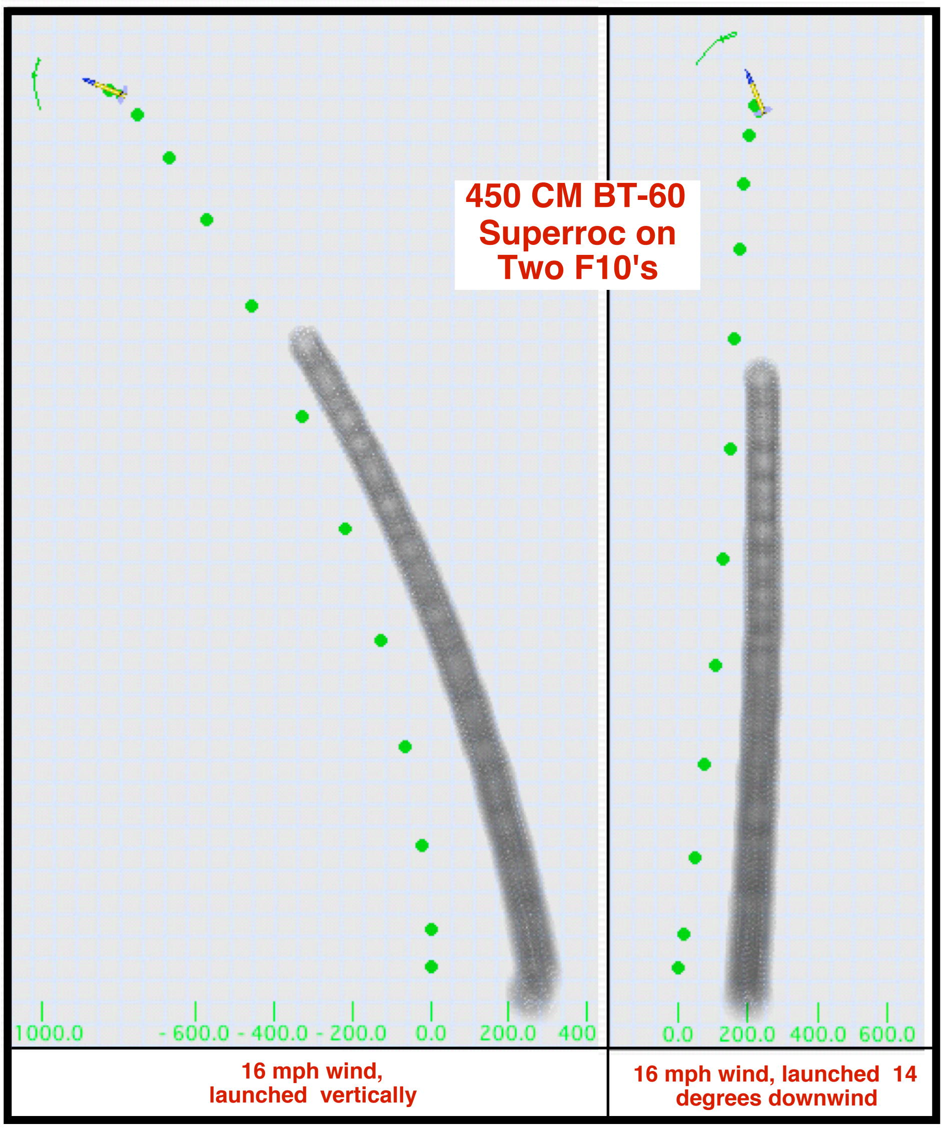
## WIND:

In case of significant wind, some simultaneous were run for the BT-60 models at max length, at different wind velocities. The launch angle was changed to be downwind to find out how many degrees to tilt from vertical that could result in a net vertical flight.

For Model #4 (F10 and two E6) and Model #7 (two F10's), both max length BT-60 models, a relationship was found. From 4 mph and above, to take the wind velocity value, subtract 2, and use that as the compensation launch angle downwind, such as:

| | |
|---|---|
| 2 mph = 1 degree | 4 mph = 2 degrees |
| 6 mph = 4 degrees | 8 mph = 6 degrees |
| 10 mph = 8 degrees | 12 mph = 10 degrees |
| 14 mph = 12 degrees | 16 mph = 14 degrees |

The following chart shows the result from flying in 16 mph winds with a vertical launch, and with a launch angle of 14 degrees downwind.



## Conclusions:

The best engine choice for this event seems to be a cluster of either two F10's or an F10 and two E6's. Higher-thrust engines do not tend to perform as well, and the models have to be built more strongly, therefore heavier and flying lower.

Maximum length seems to be the winning strategy for this event as much as it does for the lower engine classes of Superroc. The difference here is that there was no existing design base for people to have a good idea as to what type of model construction could be used to make a maximum length model that would hold up on boost and yet not be overly heavy so that it did not get a good altitude.

We feel that the model designs we have as a result of this project, whether powered by two F10's or one F10 and two E6's, are highly competitive.

## Secondary conclusion:

A Rail launcher is the most practical way to fly these models. A rod is inadequate. Rails of 12 to 16 feet long are better than 6 or 8 foot rails. With longer rails, a third lug can be mounted near the top end of the model, holding the nose from bending out in wind pre-flight. In theory the best way of all to fly Superrocs would be to fly out of a tower as is often done for lower power Superrocs, but it is not very practical to work up a 12 to 16 foot long tower as it is to add an extension to the kind of rails often used for HPR flying.

## Cost:

Approximately $300 was spent on this project. The largest share of the costs were for the airframe parts. The second largest were for the engines.