RRS News

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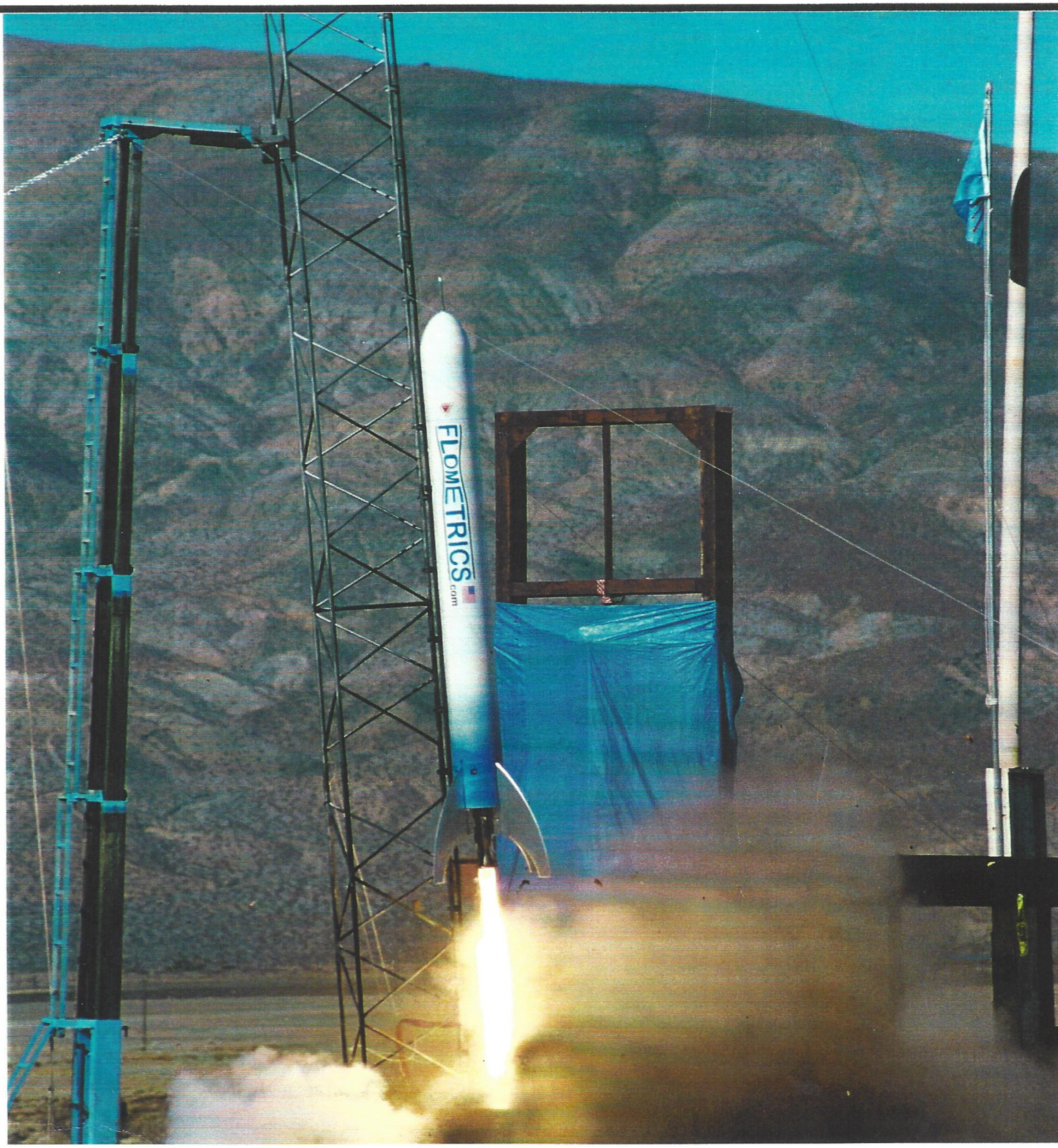

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The Reaction Research Society is the oldest continuously operating amateur rocket group in the nation. Founded in 1943 as a nonprofit civilian organization, its purpose has been to aid in the development of reaction propulsion and to promote interest and education in this science as well as its applications. The Society owns and operates the Mojave Test Area, a 40 acre site located two and a half hours north of Los Angeles. Over the years, thousands of solid, hybrid, and recently, liquid propellant rockets have been static and flight tested. Currently, there are over 250 active RRS members throughout the United States and in several foreign countries.

This newsletter is a, more-or-less, quarterly publication issued by the Society as a technical journal and is intended to be educational and to provide communication between members and other societies. It is also the historical documentation of the activities conducted by the Society, as a whole, and by its individual members. Information regarding the RRS can be obtained by writing to:

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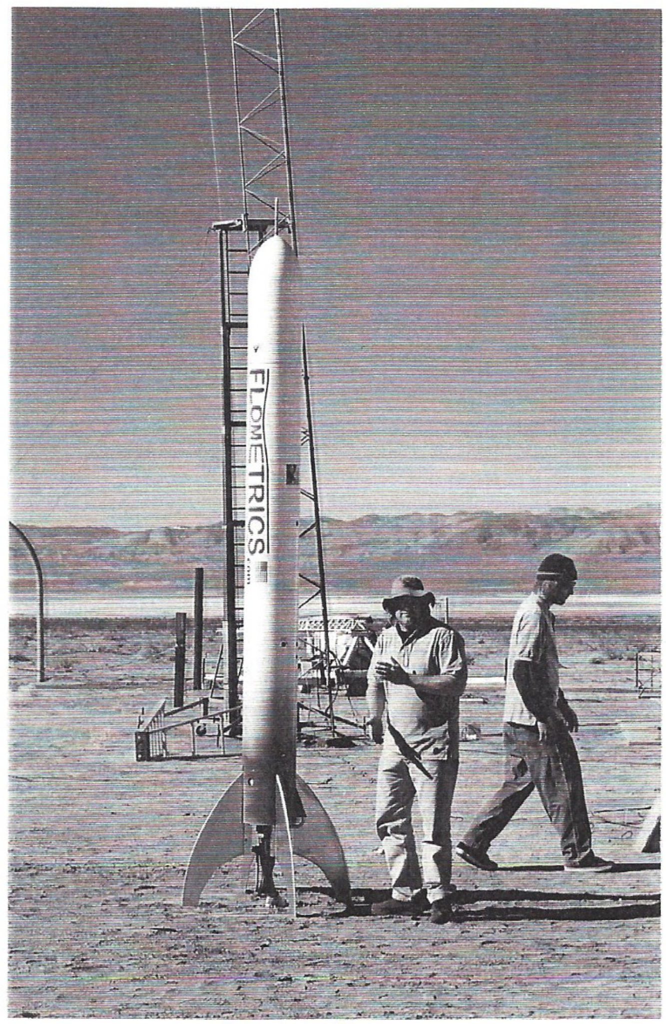


On the Cover: The Flometrics LOX/kerosene, 1000 lb. thrust rocket bolts skyward.

"Scalded Cat" Steam Rocket Project Report

by William J. Inman

Steam Rocket Theory

Water has the ability to hold and store a tremendous amount of energy in the form of heat. Unlike more conventional propellants that store their energy chemically, the steam rocket, or hot water rocket as it's also known, relies on the amount of heat stored in the water. Two other properties of water that make the steam rocket work so well are the vapor pressure developed as the water is heated beyond it's "normal" boiling point and that when released, it will expand to 1700 times the volume it occupied in the liquid state. It can be heated to 705 degrees F (3200 psi) before it reaches it's critical point. Power increases with heat, but so does pressure, so the farther up the scale it goes, the stronger the tank needs to be to withstand the pressure. Optimum performance is a balancing act between the power of higher pressure and the weight of a stronger tank. Obviously the tank should be made of the strongest, lightest weight, heat resistant material available .... Titanium would undoubtedly be the ultimate if cost were no object.

In the nozzle, the water starts flowing as it enters the convergent section. The venturi principal causes the local pressure to drop as velocity increases through the nozzle, and as pressure drops, the water starts flashing to steam. This steam, as it expands, continues to accelerate in the divergent section. The percentage of water that actually becomes steam depends on the amount of stored heat in the water. The temperature will drop all the way to the ambient boiling point at the nozzle exit, being converted to kinetic energy in the form of jet velocity. This velocity can exceed Mach 2 in a well-designed nozzle. As the water level in the tank drops, it boils, keeping the volume above it filled with steam, maintaining the equilibrium. This also consumes some of the heat in the tank, so the tank pressure will drop about 25% during the course of the discharge.

The Rocket

The "Scalded Cat" Motor

At the time I started this project, I knew much less about steam rocket theory than I do now. The motor was based on a piece of surplus 4" diameter, type-316 stainless steel, schedule 10 pipe I found. Wall thickness was 0.120" and the burst pressure as stated by the supplier was 4000 psi. I got a pair of stainless steel domed end caps and had them welded on, then a hole bored in the center of one and a 1" threaded stainless pipe fitting welded in for the nozzle attachment. Three steel fin-mounting tabs were welded to the nozzle end of the tank and a flange for mounting the payload section was welded to the other end. Compared to the 45 lb. welding oxygen cylinder I used for most of my static testing, this was a lightweight tank, but at 24 lbs. it's still pretty heavy for a flight tank. To take advantage of it's strength and to partially offset it's weight, I ran it at higher pressures than most previous steam rockets I'd read about. The flight on Dec. 2, 2000 was at 1500 psi tank pressure (610 degrees F). Theoretical specific impulse (Isp) at this heat is around 75 lb.-sec./lb.

The nozzle was machined aluminum with a 3/8" throat; a figure arrived at because I wanted the throat area to be 0.110 sq. in. There was a curved convergent section who's curve radius was 12 times the throat diameter, then the divergent section had a half angle of 10 degrees (20 degrees between walls) and an expansion ratio of 18.3 to 1. This made the exit diameter 1.6". The throat was ½" long to give the pair of o-rings on the plug a place to seat.

The fins were 0.085" thick aluminum and were bolted to the steel fin tabs at the bottom of the tank by running machine screws through the fins and screwing them into the threaded holes in the tabs. The fins extended beyond the back of the tank and also bolted to tabs on the fiberglass boattail to help secure it. The boattail also had a ring at the back end that slipped over the nozzle to help keep it straight.

The payload section mounting flange was a piece of stainless pipe 1/4" smaller in diameter than the tank and 0.030" thinner. It was 3" long with 3 semi-circular notches cut in one end leaving 3 "pedestals" that were welded to the top of the tank. This reduced the steel to steel contact and hopefully the heat transfer rate from the tank to the flange. A total of six holes, 3 sets of 2, were drilled and tapped in this flange for the mounting of the payload section adapter.

The Payload Section Adapter

This part was used to provide a slip-fit mount for the composite payload section while helping isolate it from the heat. It bolted to the mounting flange with six machine screws and extended 6.5" up beyond the end of the flange so the area in contact with the payload section would not be touching a hot steel surface on the other side. I needed something strong, heat resistant, a poor heat conductor, and made of a material I could work with. The only epoxy I could find that claimed to be good to 600 degrees was J-B Weld, so it was thinned with lacquer thinner and used as the laminating resin for a Kevlar structure. A J-B Weld and Kevlar ring was epoxied to the outside as a stop to keep the bottom edge of the payload section 1.85" above the upper edge of the steel flange. A Kevlar and J-B Weld "floor" or bulkhead was added to put another heat barrier between the tank and the payload section. Cellulose insulation was stuffed into the area between the tank and bulkhead.

The Payload Section

For this section I used an 18" length of 4" phenolic tubing from LOC/Precision with several layers of fiberglass wrapped around it. I was concerned about the heat from the tank damaging it so I added 2" of Kevlar and J-B Weld composite to the bottom where it was closest to the metal flange. The bottom 11" of the payload section was open and housed the 84" PML parachute. The Kevlar "muletape" shock line was attached to a 3/8" eyebolt in the top of the tank. Above this section was a ½" plywood bulkhead that housed a black powder charge and expansion chamber/ stainless steel gas baffle section. There were two igniters in this charge, one connected to the Adept ALTS2 altimeter and the other to the Blacksky AltAcc2 accelerometer. These were to be triggered by the "main" event switches on the two electronic devices to blow the 'chute out if the 54" pilot 'chute hadn't already deployed it. I did this for a backup system in case the payload section got soft and sticky from the heat and didn't slide off easily as planned.

There was a compartment above the bulkhead where the altimeter and accelerometer were housed. The 3 canisters for the powder charges were also in this compartment, blowing their gasses through the bulkheads into the gas baffles. The canisters were ½" brass pipe nipples with 3/8" plugs inserted in one end with pipe threads, sealed with Teflon tape. The igniter wires were inserted through holes in these plugs and sealed with 6-minute epoxy. The AltAcc was attached to the inner wall of the airframe in the usual manner and the ALTS2 was attached to a piece of aluminum box tubing that was epoxied to the removable lid of this compartment.

The compartment lid was also ½" plywood with a 3/8" eyebolt attached to it's center and a gas baffle compartment on each side of the eyebolt. The under side of this lid had a ring of Permatex "blue" silicone form-a-gasket where it sealed to the mounting ring. There were also two threaded holes, one at the base of each gas baffle, for the brass charge canisters to screw into. Four # 6 stainless steel machine screws held the lid to the mounting ring, which was made of 1" plywood epoxied to the inner wall of the airframe tube. "T"–nuts imbedded in this built-up ring distributed the load from the screws. On the 3/8" eyebolt was the Kevlar "muletape" shock line to the 54" PML pilot 'chute.

The Nosecone and Parachute Arrangement
The nosecone was a 4" LOC/Precision unit with a wrap of 1.8 oz. Kevlar on the inside of the neck to help reinforce it after the bottom had been removed to gain access to the interior space. A 3 ft. length of Kevlar "muletape" was attached to the inside of the tip of the nosecone by having a loop go around an aluminum cross-rod inserted through holes on each side of the nosecone tip. This whole assembly was then encased in a solid mass of epoxy, then the cross-rod cut off flush with the outside surface of the nosecone. On the other end of this line was a loop sewn in with Kevlar thread from Edmund Scientific. The 15 ft. main shock line and parachute shroud lines were all attached at this point. The main shock line had accordion folds sewn into it with Kevlar thread. The stitches were not heavy duty so they would break when a load was applied. The first 6 folds had a single stitch holding them, the second set of 6 folds had a double stitch, the 3rd set had a triple stitch and the 4th had a quadruple stitch. The idea was that the singles would break first, letting 3" of line out at each break and adding tension. Then the doubles would start breaking, increasing tension and still letting out 3" per fold. By the time all the stitches were broken (which they were), hopefully things would be slowed down enough to keep the final shock from being too severe. (Kevlar does not stretch). The 25 ft. line from the tank to the 84" parachute was stitched up in this same manner.

The Ground Support Equipment

The Launch Tower
Somehow I got the bright idea to build a tower with six longitudinal tubes of ½" EMT. There would be one on each side of each of the 3 fins, just far enough apart to let the fin pass without binding. The reason was so I could pop rivet the 3 burner shrouds to these tubes, allowing each shroud to cover the entire tank surface between fins. "U" shaped strap steel brackets were welded to each set of tubes to hold them together and allow the fins to pass through. The 3 "U" brackets were held together by other pieces of steel strap welded to the outside corners, making a triangle shape at each of these brace points. The braces were spaced every 47" along the length of the 25 ft. tower. For the real support, three lengths of 1" EMT were welded to the outside of the points of these "triangles", also running the full length of the tower. In retrospect, diagonal cross braces should have been used and the second set of ½" tubes should have ended right above the tank where there was no longer any need for them. Anyway, it worked well enough. Three guy wires ran from the 12 ft. point to anchors in the ground and another three ran from the 24 ft. point to a second set of anchors 2 ft. past the first set. Turnbuckles on all six ends made adjustment precise and easy.

The tower could be raised and lowered by pivoting on a stand which was a ¾" galvanized pipe sitting in mounts on two 37" high welded steel "A-frames". A flat attachment point was welded to two of the 1" EMT main supports and "U-bolts" went around the ¾" pipe and through holes in the flats. To raise it, a couple of guys would get under the top end, raise it over their heads and start walking towards the base. After it was raised a certain amount, a third guy would start pulling a rope tied to the 12 ft. point. A bolt on the bottom of the lower tower extension went through the base to hold it in position while the guy wires were being adjusted, and then help lock everything together.

The lower tower extension was a 17" piece of 7" diameter well casing with slots and access holes cut in it. A bottom plate was welded on for a place to bolt to the plywood base, and three 3/8" headless bolts were welded to the upper end to bolt to the bottom of the tower. There was a fiberglassed styrofoam steam deflector in the bottom of this piece to direct the steam flow away from the electric actuators and the gas valve.

The Tower Base

This was what the tower sat on and what held all the peripheral ground support equipment. It was a 30" square piece of ¾" plywood with two galvanized "Telespar" box sections bolted along the bottom of two opposite edges. These box sections were 36" long so they protruded 3" past each end of the plywood. Each of these 4 ends had a hole drilled in it to accept a 5/8" steel hold-down stake. The two welded "A-frame" tower supports bolted to the edges of the plywood base and had cross bracing on the back side. A pipe coupler was welded to the top of each of these "A-frames" so the ¾" tower support pipe could slide through.

A bracket to hold the release actuator was attached to one side of the tower and a bracket to hold the gas valve actuator was attached near the back of the lower tower extension. Then there was a third bracket to hold the clamp that secured the gas manifold near the back edge of the base. The plywood was thoroughly primed and painted to ward off the effects of the elements and the steam blast.

The Nozzle Plug/Release

Based loosely on the release mechanism designed by Bob Truax for his steam rockets in the '50s and '60s, this multi-talented device serves several purposes. First, it plugs the nozzle throat so no water or steam will escape before it's released. Second, it provides a connection to the pressure gauge so it can be monitored during heating. Third, it has the integral clamping system that holds the rocket on the plug until released, and the means of releasing it.

The central plug is machined out of steel and has a long, narrow taper to the 3/8" tip that goes into the nozzle throat. This tip is 0.6" long and has two O-ring grooves that accept Parker fluorocarbon, or "Viton", O-rings to make the seal. The part below the taper is threaded with 7/8" bolt threads. A hole is drilled through the center to provide access to the tank pressure.

The bottom end of the plug is drilled and threaded to accept a 1/8" brass pipe fitting. This fitting is an adapter that allows a 5/16" automotive steel brake line to be used to connect the pressure gauge, which sits on the tower's ¾" support pipe on the end facing the blockhouse.

A support structure with 3 "spokes" is built around a 7/8" nut that screws onto the plug. The "spokes" are steel box tubing long enough to reach past the wall of the lower tower extension and sit in the bottom of three dedicated notches in the extension. Each of the spokes has a rectangular hole cut in it's top and bottom to allow a smaller piece of square steel bar to pass through. This bar is pinned to the spoke by a ¼" bolt running through it crossways, allowing it to pivot. When the three bars are brought together at the top, they contact the tapered outer walls of the nozzle like fingers.

Below the structure with the spokes and bars is a cam plate made from a round piece of 1/8" sheet steel welded to a bored-out 7/8" nut that slips onto the plug. Three equally-spaced half-round notches are cut into the edge of this plate. The spacing between the plate or cam and the "spokes" structure is adjusted with washers between the two. When adjusted correctly, the "cam" edges of the plate will hold the bottom edges of the three bars out at a distance that positions the other end of the bars so they hold the nozzle firmly onto the plug, with the O-rings seated in the throat, by "gripping" the tapered outer wall like fingers holding a knob. Rotating this cam by pulling on an attached lever arm with a 12-volt DC electric linear actuator allows the bottoms of the three bars, or fingers, to fall into the three notches, pivoting around the ¼" bolts and releasing the nozzle from it's grip. A 7/8" "keeper nut" with a nylon insert is screwed onto the plug below the cam to give it something to ride on and keep the spacing so it turns freely but doesn't have excess play.

The Burners and Gas Delivery System

At the bottom of the tower are three sheetmetal burner shrouds that are as long as the tank (48"). In the bottom of each of these shrouds is a 30,000 BTU propane gas log lighter for a fireplace attached by two "u-bolts". There are adapters for flexible appliance gas lines on each burner to attach to the manifold. The manifold is a ½" pipe nipple that feeds into a "cross" that has short nipples and "L"s on each side, creating three points to attach the flex-lines. A clamp with three notches fits over these three lines at the manifold, holding it to the plywood base. On the other end of the feed nipple is a brass ball valve with a union on the other end. The rubber hose from the propane bottle is connected to the manifold at this union.

Attached to the ball valve is an aluminum extension that is painted bright red so the valve position can be determined visually from the blockhouse. Also attached to the valve handle is the end of a 24-volt DC electric linear actuator attached to the control panel in the blockhouse. This actuator is used to open and close the gas supply to the main burners.

Three small handheld propane torches are positioned around the base of the tower pointed up into the shroud/burner areas. These act as pilot lights for the main burners should they need to be turned off and then back on again. They also add additional BTU's to the heating effort but don't put out enough to maintain heat (and pressure) by themselves.

The Control Devices and Panel

Pressure is monitored visually by watching a 4.5" diameter pressure gauge with binoculars from the blockhouse. Heating is controlled by a gas valve in the line to the main burners. A 24-volt DC linear actuator is attached to the handle of the gas valve and opens and closes it by pushing or pulling. It is wired to a double pole-double throw (DPDT) toggle switch on the control panel so that pushing it one direction opens the valve and pushing it the other direction closes it. It is a three position momentary switch so releasing it allows it to spring back to the center "off" position. The power comes from two 12-volt batteries wired in series in the box. The control panel is actually the lid of the battery box.

Launch is initiated with another electric actuator, this one a 12-volt DC unit, also wired through a DPDT toggle switch in the battery box. Three 12-volt batteries wired in parallel power this actuator. One lead goes through a momentary red pushbutton switch wired in series with the DPDT switch. The DPDT is a two position, one for extend, the other for retract. This allows the cam to be rotated back to the "reset" position easily, which is good because we had to move it back and forth once to release the rocket for it's maiden flight. The red "launch" pushbutton and the DPDT toggle switch controlling the direction of the release actuator are both under a spring-loaded safety flap made from an outside electrical box outlet cover.

To connect the control box to the actuators at the pad, color-coded 12-gage extension cord is used. Two 25 ft. cords were bought, one yellow, the other blue with an orange stripe. Yellow is for the 24-volt gas valve actuator while blue and orange is for the 12-volt release actuator. These 25 ft. cords were cut a few feet from the "female" end and attached to their respective switches in the box with the ends dangling outside a foot or so. The other long piece was wired to the actuators with the "male" end like a regular power cord on any appliance or power tool. Two 100 ft. cords with the same color coding bridged the distance from the blockhouse to the pad.

The Maiden Flight

Setup and Preparation

The tower base was already leveled and staked down on launch day and the tower was waiting nearby. The guy wire anchors were driven in at the pre-determined and marked spots and the peripherals were all attached to the base and tower. The igniters and deployment charges were already set up earlier in the motel room, so once it was time to start the heating, the altimeter and AltAcc were turned on. After the tower was raised vertical and secured, the burners were lit and the AltAcc armed. We did not time the heating, but it went fairly quickly once a piece of sheet metal was wrapped around the tower at the position of the heaters. It was carefully bent so the fins would pass inside it during launch. When the pressure reached 1400 psi, the main burners were shut off while people got under cover and road and air checks were conducted. The idea was to take it to 1400 psi and then launch hopefully at a point where it had dropped to 1350, the target pressure. Instead, the pressure continued to climb to 1500, where it stayed until launch.

The Flight

When the release actuator was retracted, nothing happened. This had happened before, but when checked again during my last static test, it worked fine. Here we were sitting at 1500 psi with the release cam turned and the rocket just sitting there. So I had Tim Clifford, my partner and launch officer, switch the directional control to "reset", work the actuator, then flip it back to "launch" and try it again. This time, after a couple seconds of hesitation, it took off on the most beautiful plume of steam I've ever seen. From the blockhouse it is not possible to visually follow a rocket very far into it's flight through the small windows, so we just stood there listening to the roar as the sound came from farther and farther away. Finally it stopped and for a brief moment there was no sound, until there was some cheering from the bunkers. The command was given over the P. A. system to "quiet down", and to "listen for an impact". A few seconds later there was cheering again, and this time a more irritated repeat command was given only to be answered by shouts. "What was that?" .... "A parachute?".... "Two parachutes?".... "O.K. Keep an eye on it and stay under cover until the heavy piece is down."

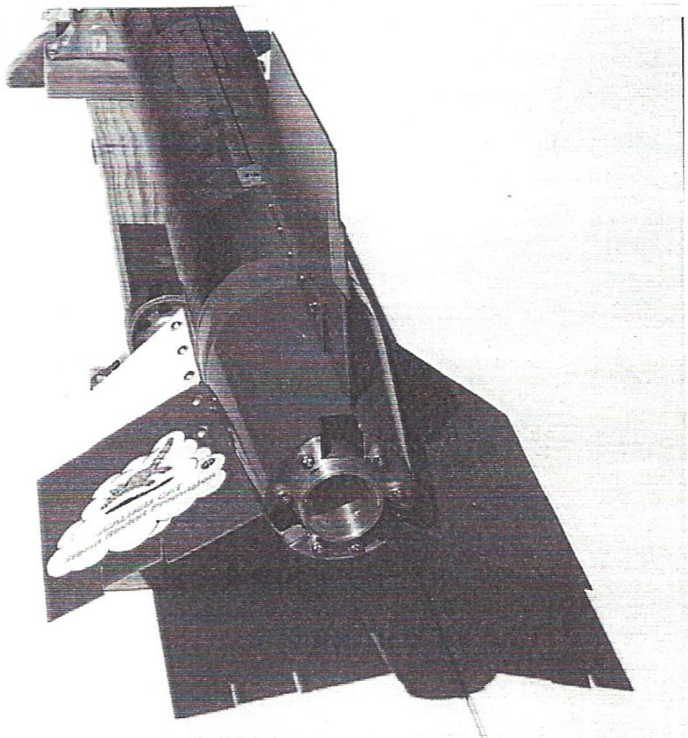
Knowing it was under canopy was the best feeling of all. I have seen so many rockets crash because of recovery system failure that it makes that part especially critical. There was also the satisfaction of knowing that along with being the first successful steam rocket launch in the 57 year history of the RRS, it was also going to be one of the very few RRS flights to make a soft landing under parachute. I was able to squeeze out through the blockhouse door enough to actually see the parachutes coming down in the SW sky, the tank falling slightly faster than the payload section.

Post Recovery Examination

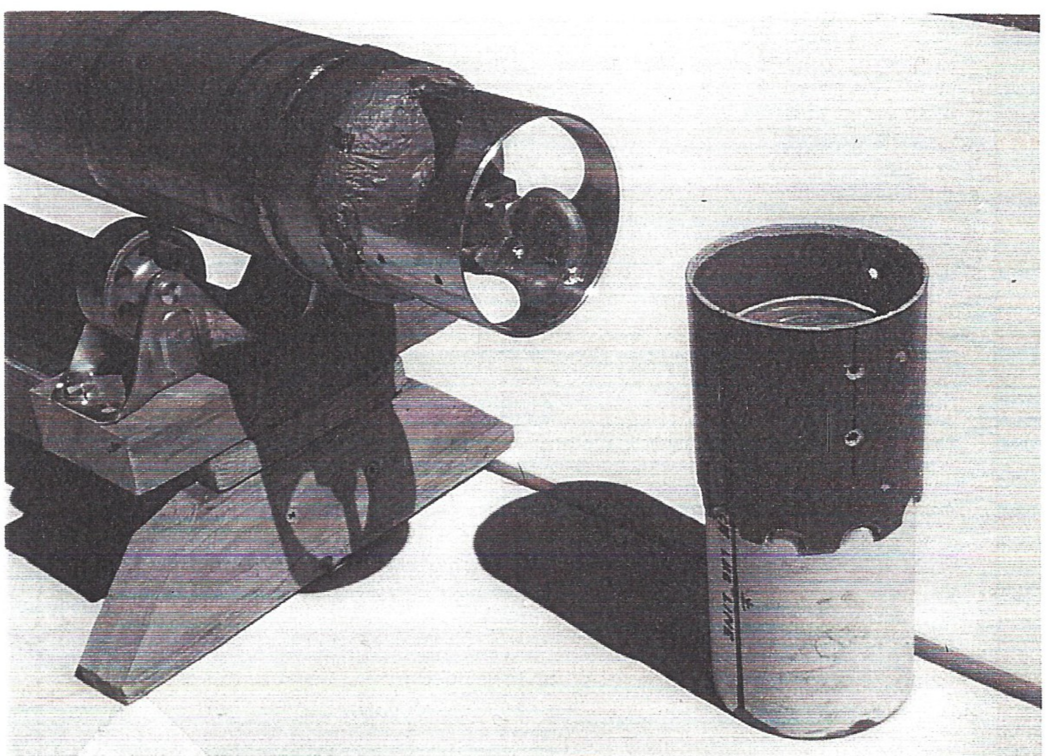
The only damage found was where the ring at the base of the boattail got broken in two spots from being driven into the ground from the weight of the tank. Otherwise, everything was all right and the altimeter was reporting 4479 ft. That evening, Bill Seiders was kind enough to download the AltAcc on his computer. It showed a maximum acceleration of 128 ft/sec./sec. (4 g's) to a velocity of 506 ft. per second (345 mph), a coast time of 15 seconds, and a peak altitude of 4400 ft.

Vehicle Specifications

Length:	7.5 ft.	Parachutes: (tank)	PML 84"
Diameter:	4.5 in.	(payload)	PML 54"
Weight (filled):	53.2 lbs.	Electronics:	Adept ALTS2
Water capacity:	8.5 liters (80% full)		Blacksky AltAcc2
Operating temp.	610 degrees F	Deployment charges:	3 (Redundant)
Tank pressure:	1500 psi	Charge igniters:	4 (Redundant)
Calc. tank yield point:	1800 psi	Bridle (shock cord):	Kevlar "muletape"
Est. peak thrust:	297 lbs	Fins:	3 (aluminum)
Thrust duration:	4.75 seconds	Nozzle throat area:	0.110 sq. in.
Estimated power:	5500 N-sec "M 1155"	Nozzle expansion ratio:	18.3
Propellant mass fraction:	35%	Divergent cone taper:	20 degrees between walls

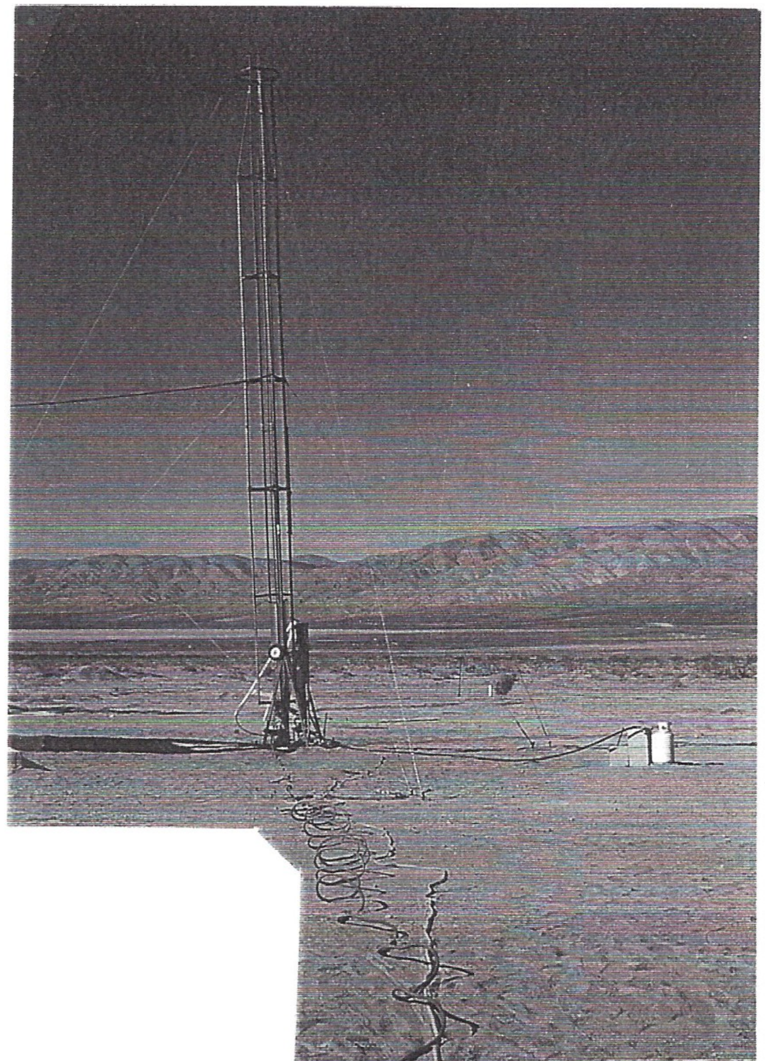


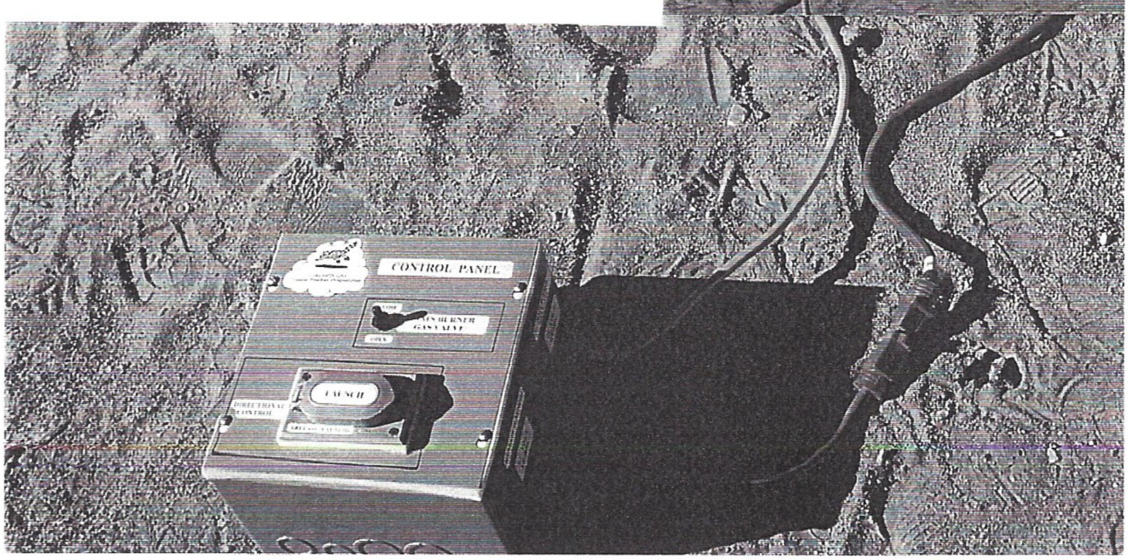
The tail end showing fin and boattail attachment. Slots around the nozzle are for the lock/ release bars.



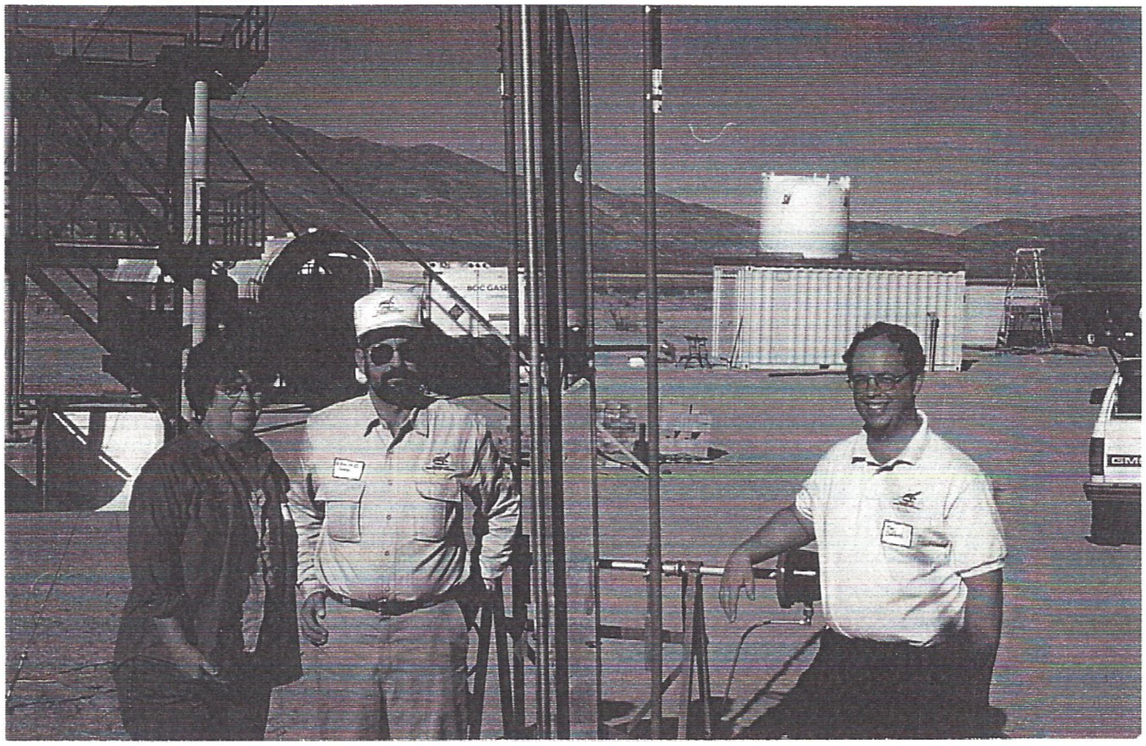
The top end of the tank and mounting flange and eyebolt. The payload section adapter is in front of the motor. Notches in the Kevlar ring are to minimize contact with the payload tube.

The view of the tower from the block-house the day after the launch is shown at right. The propane bottle can be seen behind the cinder blocks to the right of the tower. The dark line running from the tower to the left is a nylon rope used in raising and lowering the tower.

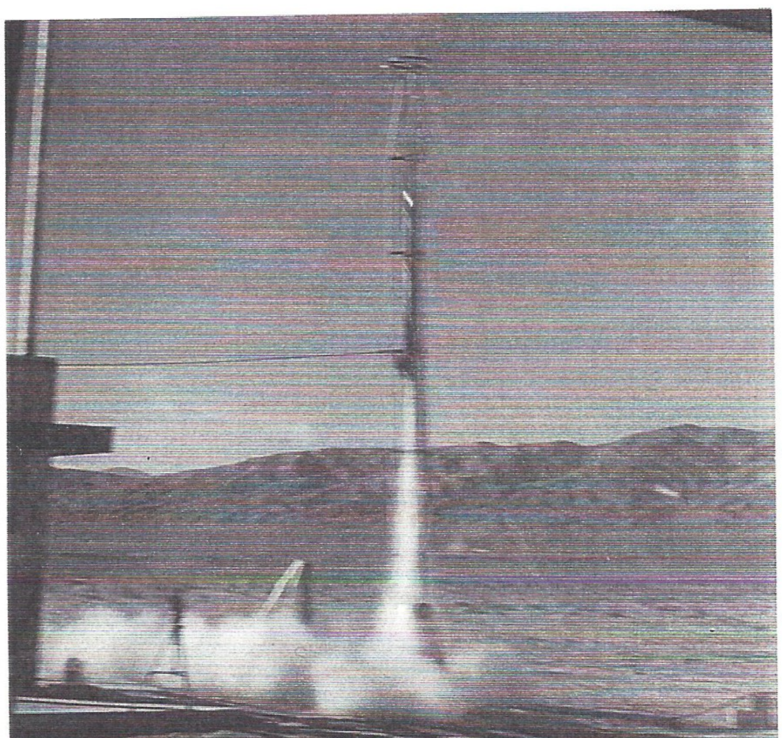




The battery box and control panel are shown above. The black toggle switch opens and closes the gas valve to the burner. The directional switch and "launch" button under are under the spring loaded safety flap. The connection to the pad is with a regular 12-gauge extension cord.

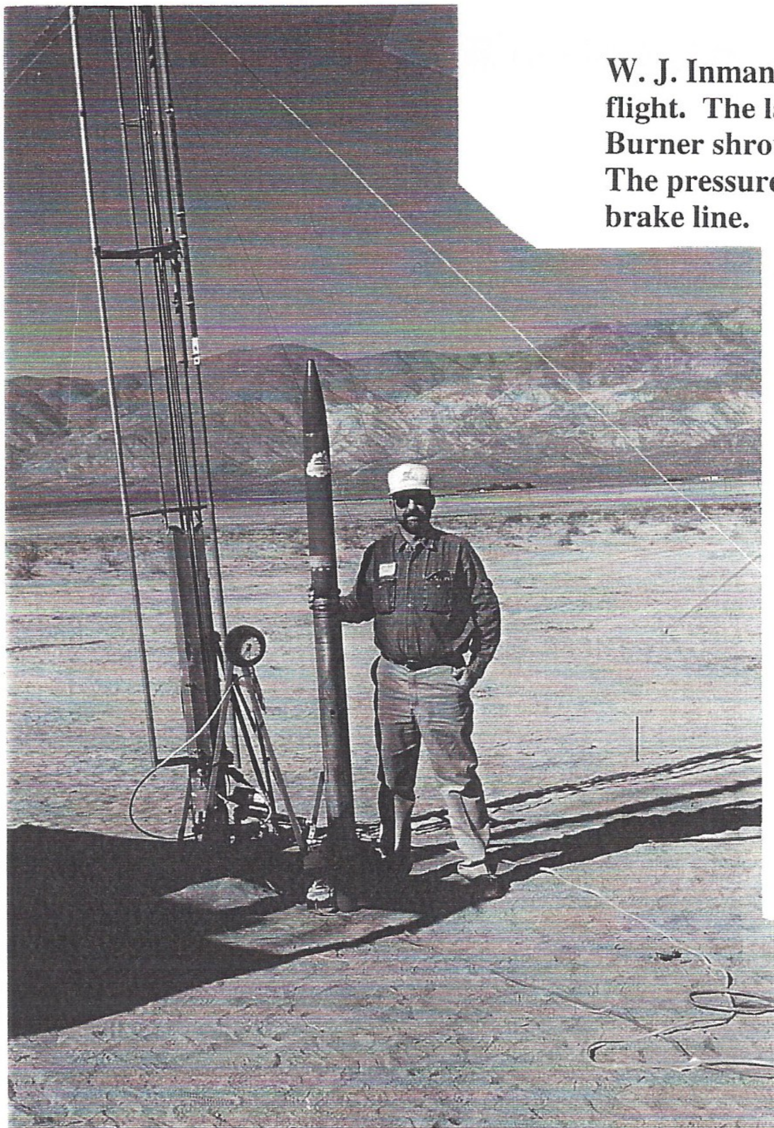


"Team Steam" shortly before the launch. From left: Jeanne Hoover, Bill Inman and Tim Clifford.

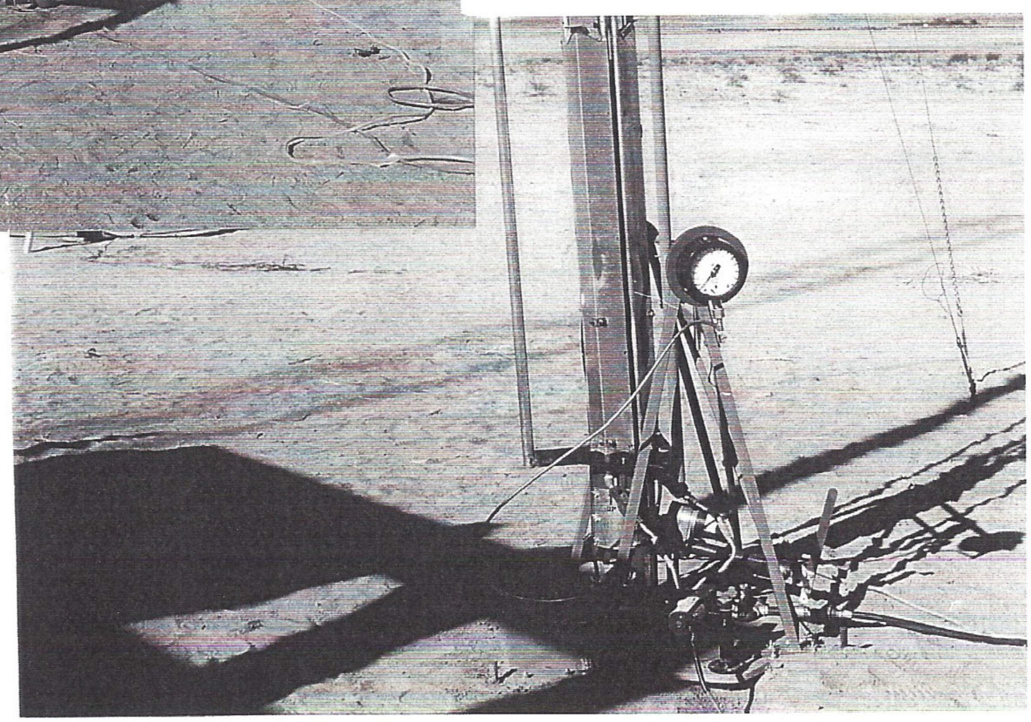


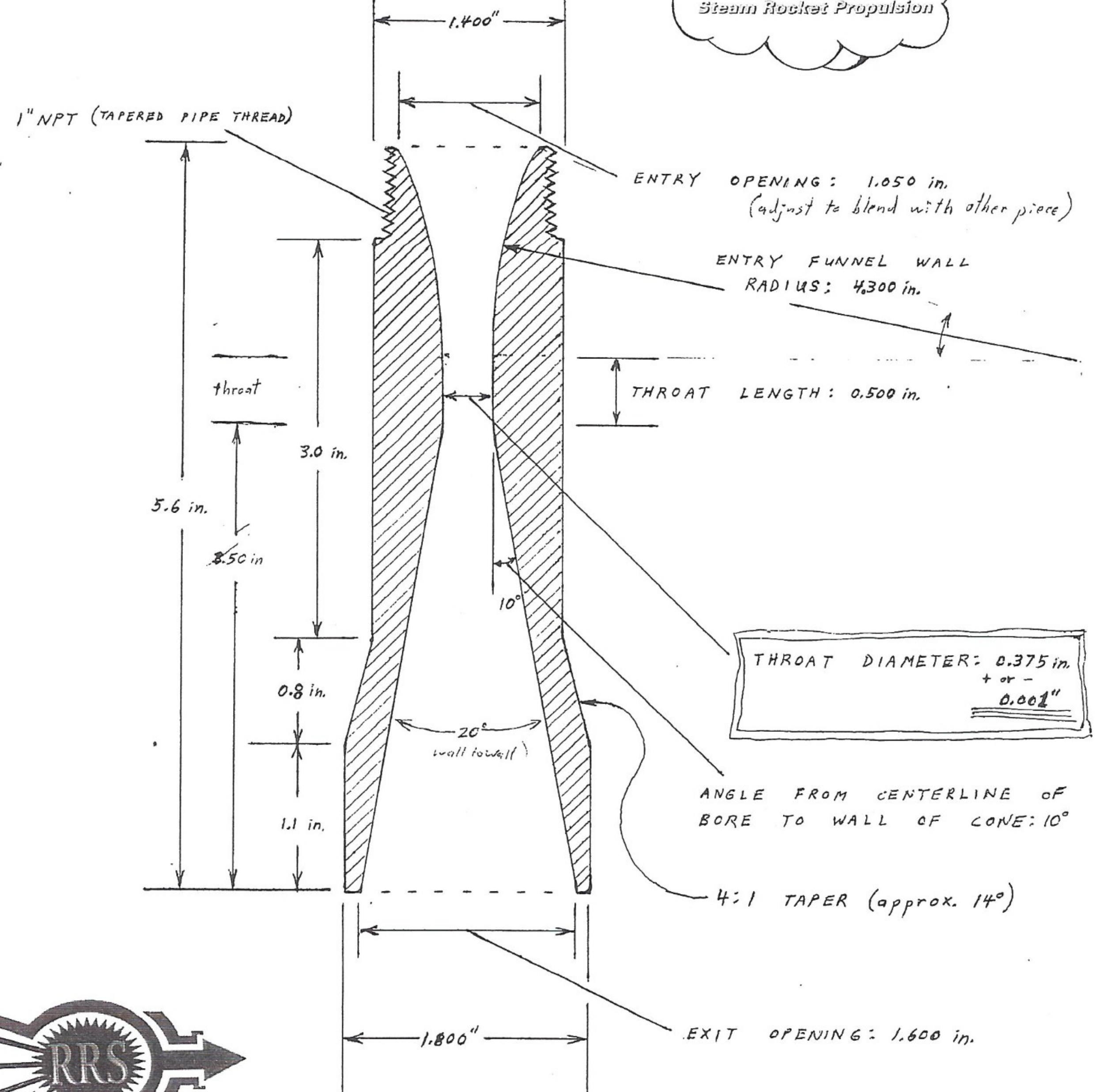
Launch of the Scalded Cat at approximately 2:30 pm, December 2, 2000. Acceleration was 4 g's at lift-off and the vehicle reached an altitude of 4479 feet. The motive power came from 2.25 gallons of water heated to 610 degrees F.

W. J. Inman with Scalded Cat after its maiden flight. The launch tower is made of EMT conduit. Burner shrouds are visible on the bottom section. The pressure gauge is connected with automotive brake line.

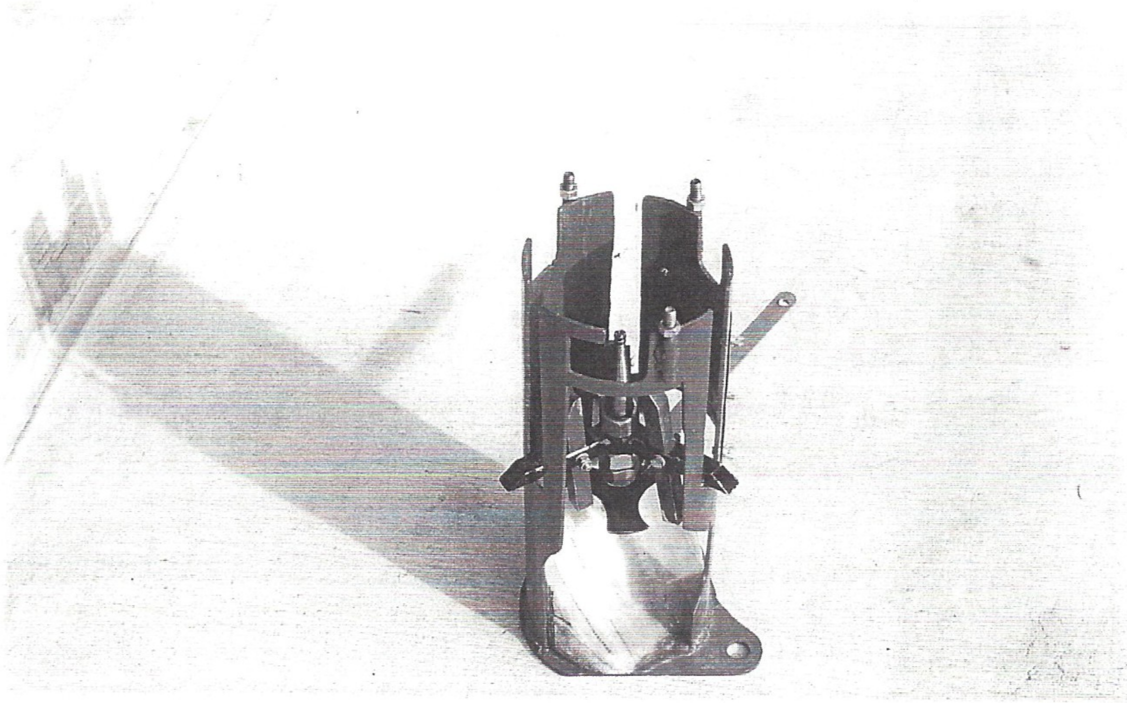


A close-up of the tower base is shown below. Black propane gas line comes in from the right. The release actuator is in the foreground. Behind it is the gas valve actuator and valve indicator flag. Two flex lines and gas/air mixers on the burners are visible.

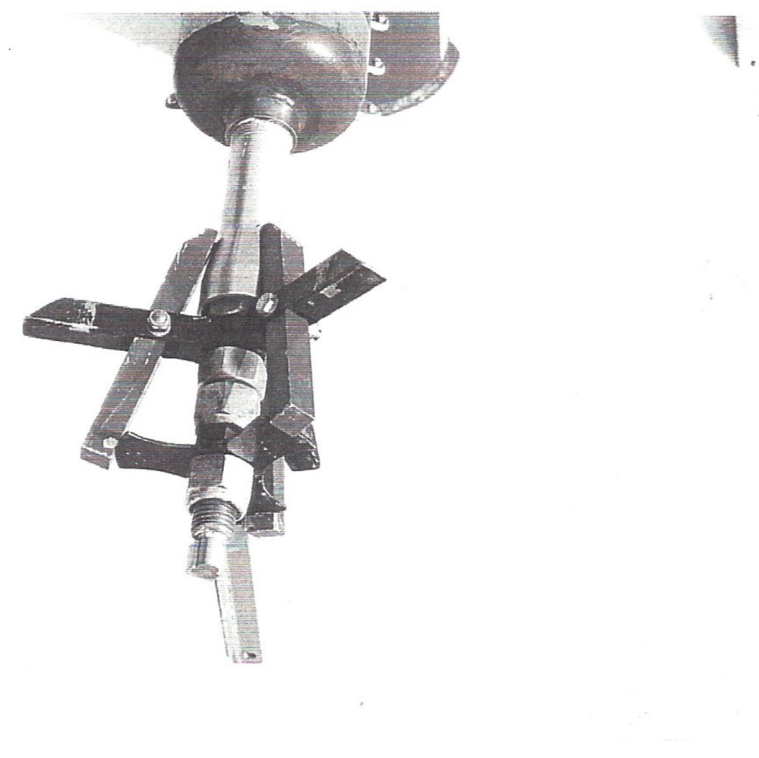




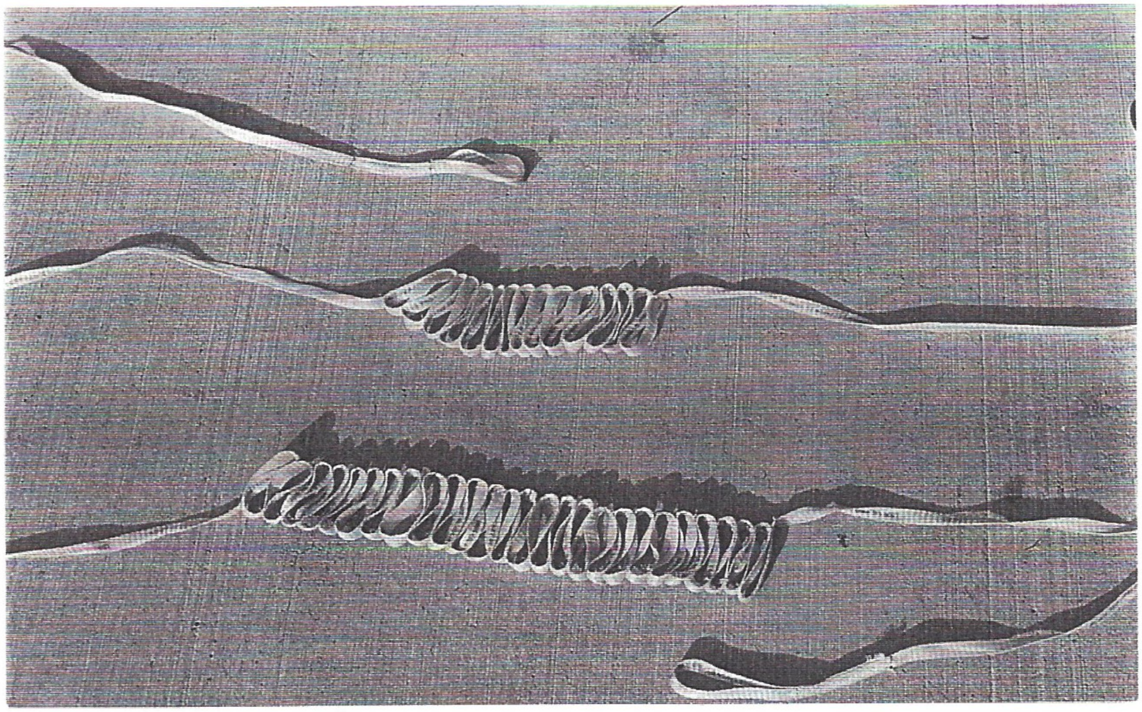
A cutaway section of the Scalded Cat steam rocket flight nozzle. The nozzle was machined out of aluminum and screws into a 1-inch fitting on the bottom of the tank. The 1/2-inch throat length allows double o-rings to seat. The tapered section of the outer wall near the exit end is where the lock/release fingers rest.



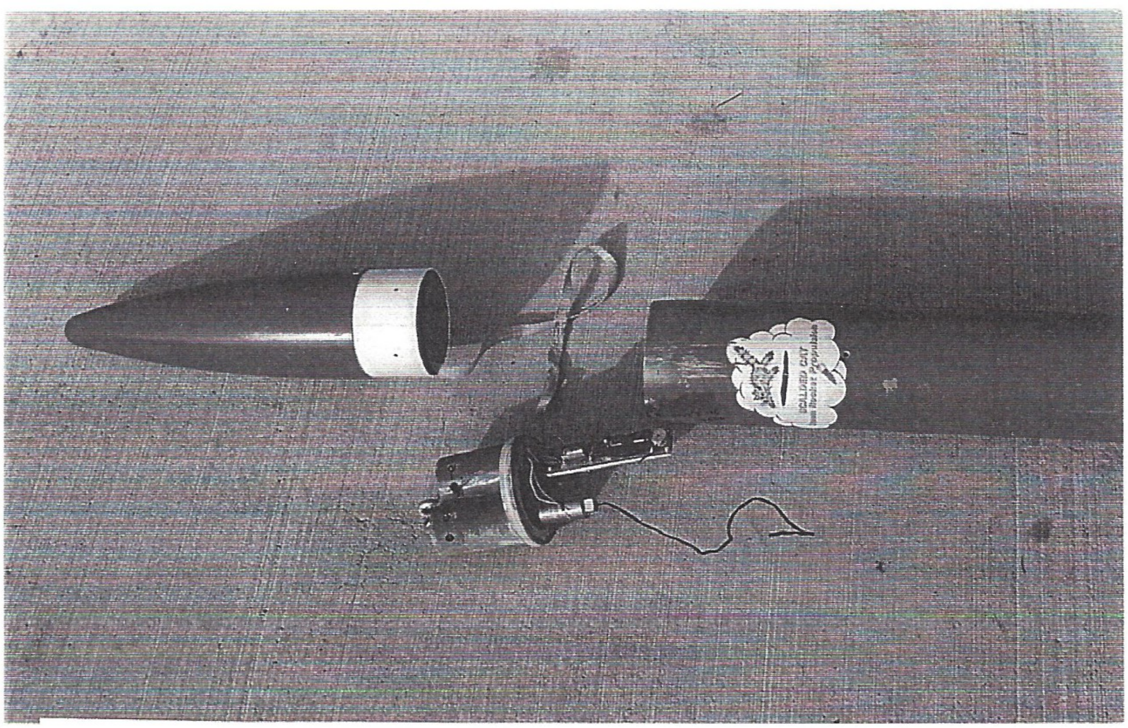
The detached lower tower extension with the plug/release mechanism sitting in its notches. The release lever arm is sticking out in back. The fiberglassed styrofoam steam deflector is epoxied into the bottom. The hole in the flat bottom plate on the right is to bolt it to the plywood base.



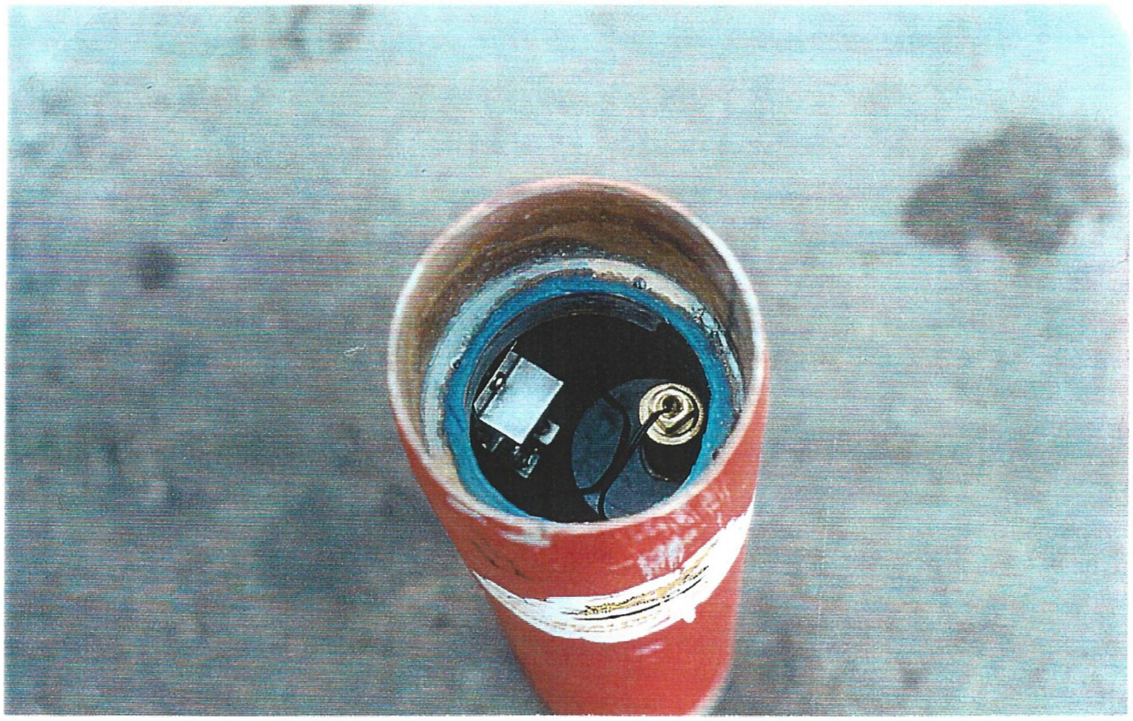
The plug/release mechanism locked onto the nozzle (boattail removed). The brass fitting connects to a steel brake line to the pressure gauge. Rotating the release cam (holding the red bars out) allows the bars to pivot off the nozzle.



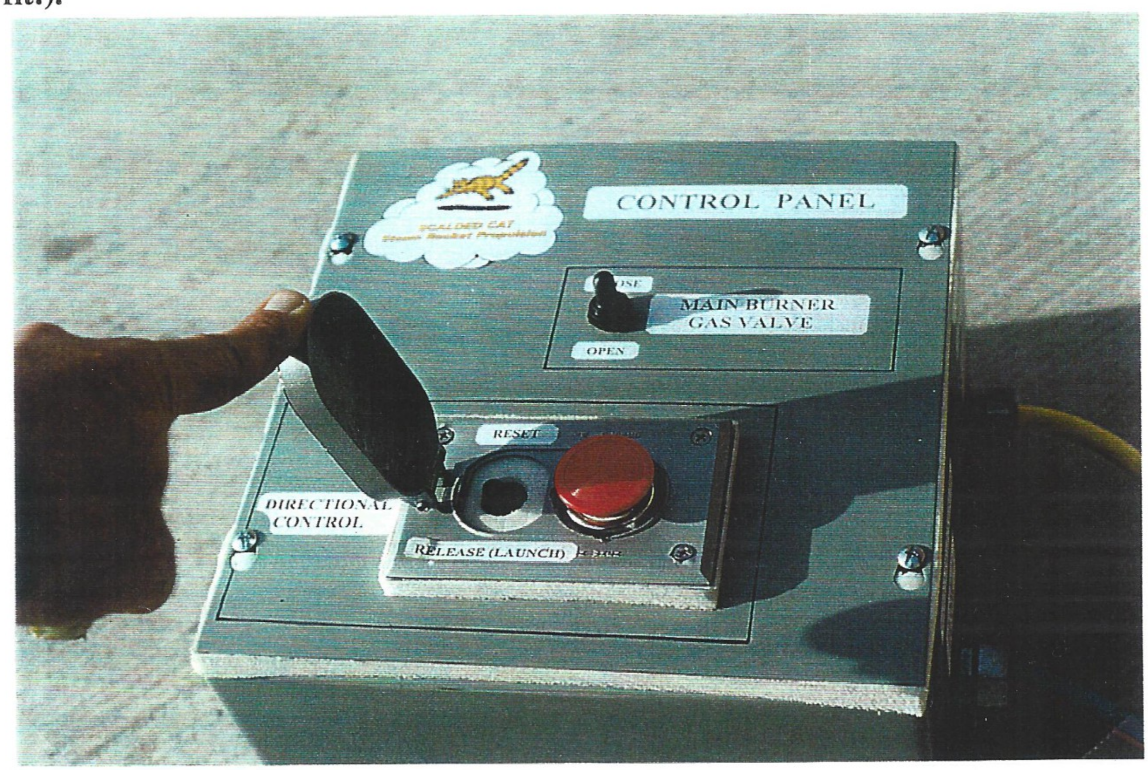
Accordion folds were sewn into "muletape" Kevlar bridle line. Breaking the stitches allows the line to lengthen while adding increased tension and slowing the rate of separation, reducing shock when the line pulls tight.



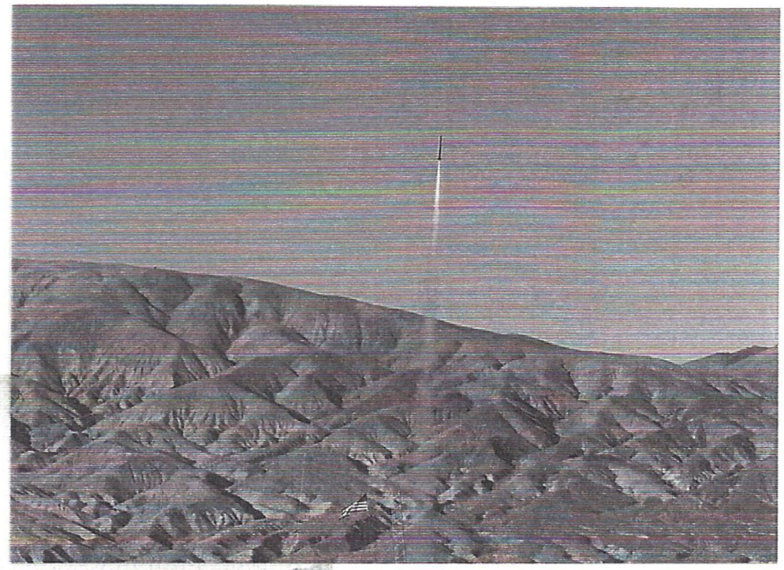
The "recovery module" was built onto a 1/2-inch plywood disc that aslo served as the electronics compartment lid. The 2 gas baffles on the left of the disc with an eye-bolt between them are reinforced with Kevlar. The two brass charge canisters (the far one is behind the altimeter) can be seen with the igniter wires in their end plugs. The Adept altimeter is bolted to a piece of aluminum box tubing.

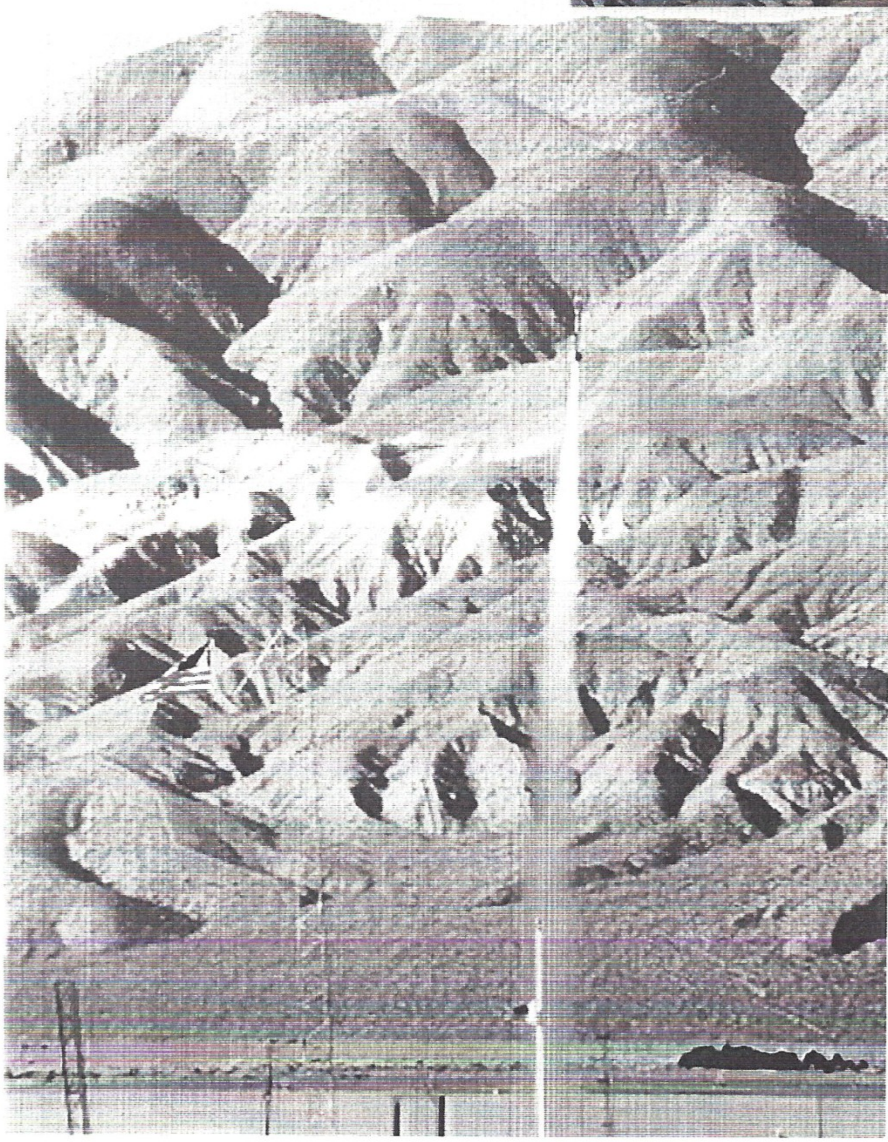


Looking down into the electronics bay. The plywood ring with ends of two "T-nuts are visible with silicone "form-a-gasket" on the inner edge. AltAcc is mounted to the airframe (left) wile a brass charge canister is inserted into the gas baffle for the backup charge (right). When the lid is installed, the altimeter and the other two canisters fit in between this other equipment (a close fit!).



The directional control switch and "launch button are located under the safety flap on the control panel. Both the 24-volt system cord to the gas valve actuator and the 12-volt system cord to the launch actuator extend from the right side of the box.





December 2, 2000. The Scalded Cat steam rocket is on its maiden flight from the MTA. Altitude achieved: 4479 feet.

The First RRS Launch of the New Millennium

By David Crisalli

20 January 2001 RRS Launch

Several members started to arrive at the Mojave Test Area about mid-morning on Friday, 19 January, to set up for the launch. Eric Claypool was there with his liquid rocket static test rig and began set up on VTS-1. John Garvey and his crew arrived in the early evening to set up for the Kimbo V launch attempt. Steve Harrington and the Flometrics group had arrived a little earlier and were already at work assembling their rocket.

The Kimbo V was a 600 pound thrust LOX/alcohol vehicle, pressure fed with a blowdown system. (To reduce takeoff weight there was no pressurant tank . The propellant tanks were only partially filled and were then pressurized to start conditions.) The vehicle used the same ablative/graphite engine and pintle injector as all the previous static tests and flights (This is a story in itself!)

The Flometrics vehicle flew on LOX/kerosene with a surplus Atlas vernier engine. Regeneratively cooled, the engine produces 1000 pounds of thrust. This was the second trip to the MTA for this rocket - it had come out in December and suffered a "RUD" (Rapid Unscheduled Disassembly) on the third launch attempt. Fuel contamination in the LOX inlet had led to a dramatic engine explosion and fire that destroyed the rocket. However, like the mythological Phoenix arising from the ashes of the fire that consumed it, the crew (and their families) rebuilt the whole rocket over the holidays and were ready to try again. (Another story in itself!)

It was very cold that night—in the mid teens. It was hard to assemble small parts with numb fingers. The set up was going slowly. But with the morning sun came a little warmth...........and a whole load of observers ready to see a flight. By 11 AM, Jeff Jakob had the first of two small experimental hybrids in the launcher and fueled. These vehicles had been modified to produce higher thrust to weight at lift off. The first flew, but not as well as Jeff had wanted. Undaunted, and in the true spirit of an experimentalist, he launched the second rocket about a half an hour later with similar results. The good news was that he recovered the rockets almost completely intact and they will undoubtedly fly again.

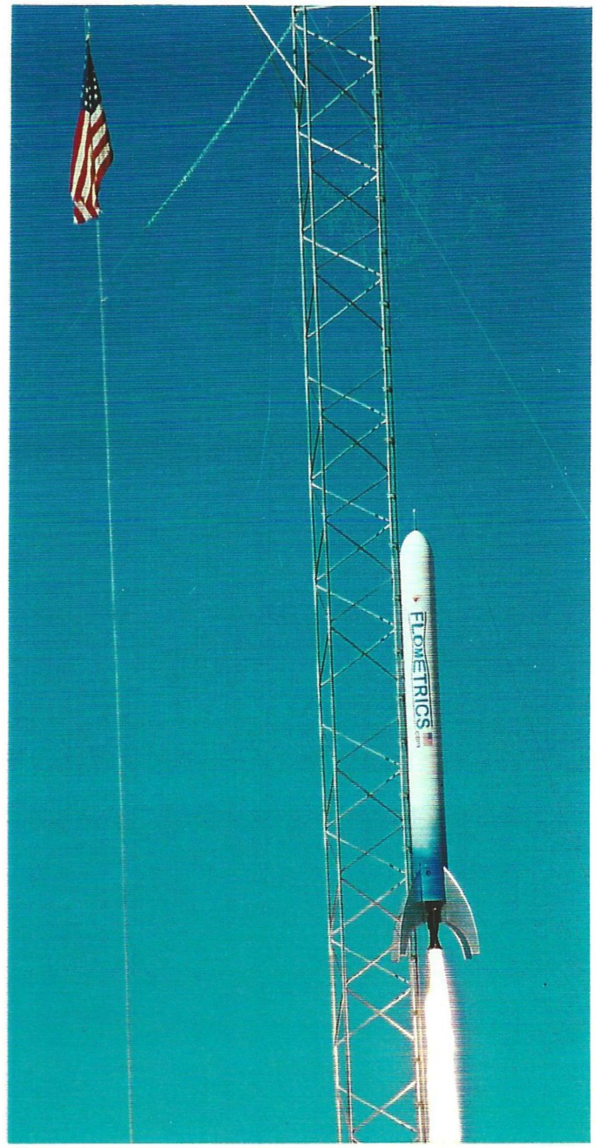
After lunch, the Flometrics crowd got their vehicle on the 60 foot launcher and started final preps. At about 1 PM, the count down commenced and the rocket began an absolutely perfect lift off. Accelerating on a blinding tail of incandescent LOX/kerosene, the vehicle flew straight and steady to peak. Although the parachutes did not deploy, the excitement over the success of the flight was not diminished by the crash. The crew had put themselves (and their families) through the wringer of a launch attempt twice in just over 6 weeks, and a little crash at the end of a long awaited and perfect flight was not going to temper the back slapping, hand shaking, and war whooping. Congratulations were expressed all around.

However, time, tide and formation wait for no man - there were other vehicles to fly and test. In a mad dash to clear the area around VTS-1 (Vertical Test Stand -1), several members helped take down and stow the 60 foot launcher so that Eric Claypool could static test his 650 pound thrust LOX/alcohol engine for a fourth time. The area was cleared in about an hour. Eric had already set up for his test on Friday and was ready to tank propellants. By about 3 PM, Eric ran a picture perfect test. The engine produced 690 pounds of thrust for 10 seconds.

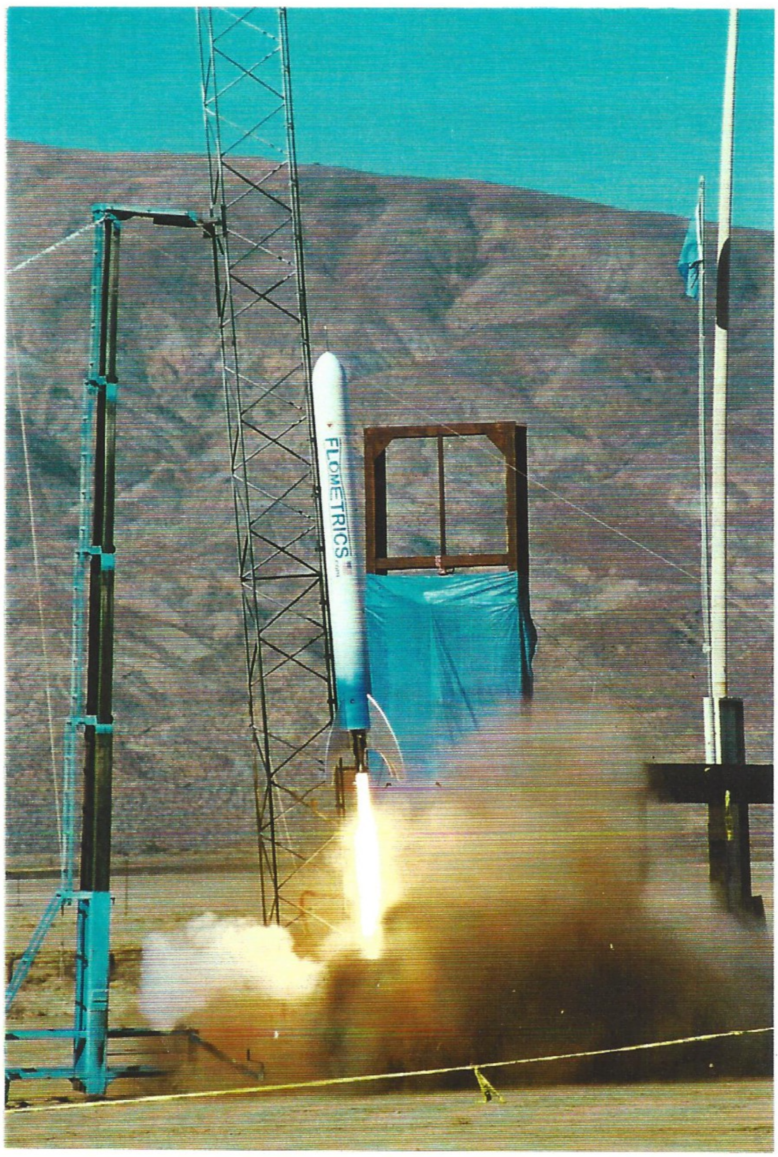
All the while these activities were going on, the Kimbo group was working to get their vehicle ready and loaded onto Kevin Baxter's really impressive, hydraulically lifted launcher. By 3:45 PM they were ready to fly. After several minor, but maddening, technical delays (and one delay due to air traffic in the lake bed area), the flight went off. I leaned back to peek out of the block house doorway just in time to see the rocket screaming straight up into a clear blue sky. It was a beautiful flight, and at about 25 seconds the rocket had reached peak and came over the top. It was then that we all saw something very rare indeed. Right on cue, the nose separated and three beautiful, full parachutes blossomed forth. It took several minutes for the rocket parts to reach the ground. Seeing the complete recovery of an amateur experimental rocket is rare, but I believe this is the only successful recovery of a liquid bipropellant rocket I have ever heard of. The rocket came back in such good shape, I believe it could have been refueled and flown again.

All in all, it was a busy, hectic, and extremely successful launch/test day.

The Flometrics guys lug the vehicle out to the Wherley/Crisalli 60 foot launcher. Here we go again!

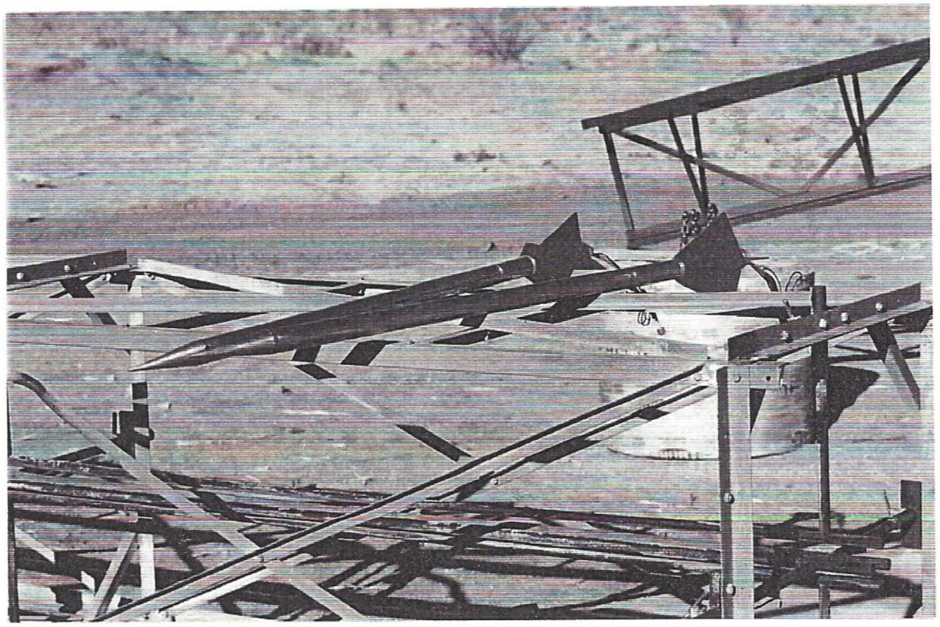


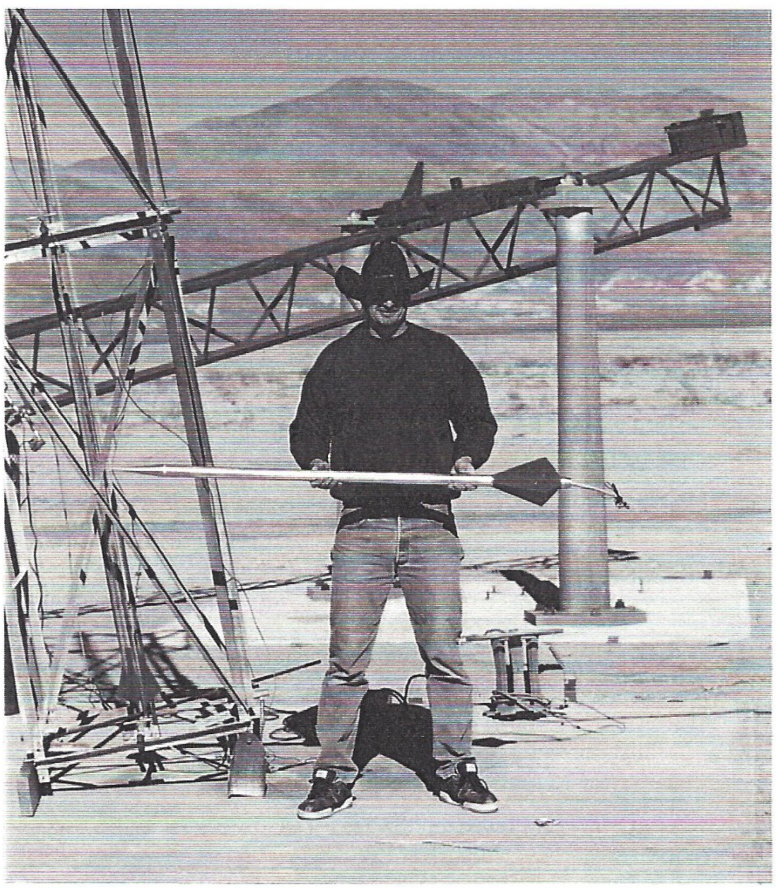
What a beautiful day… and what a beautiful flight.



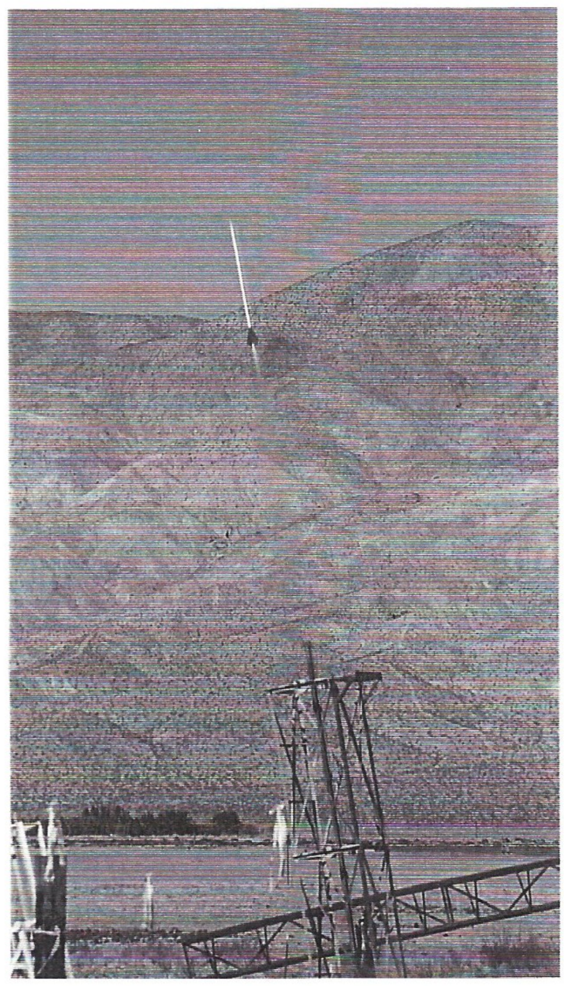
A perfect ignition and start of a fantastic flight.

Two of Jeff Jakob's nitrous oxide/HTPB hybrids awaiting launch.



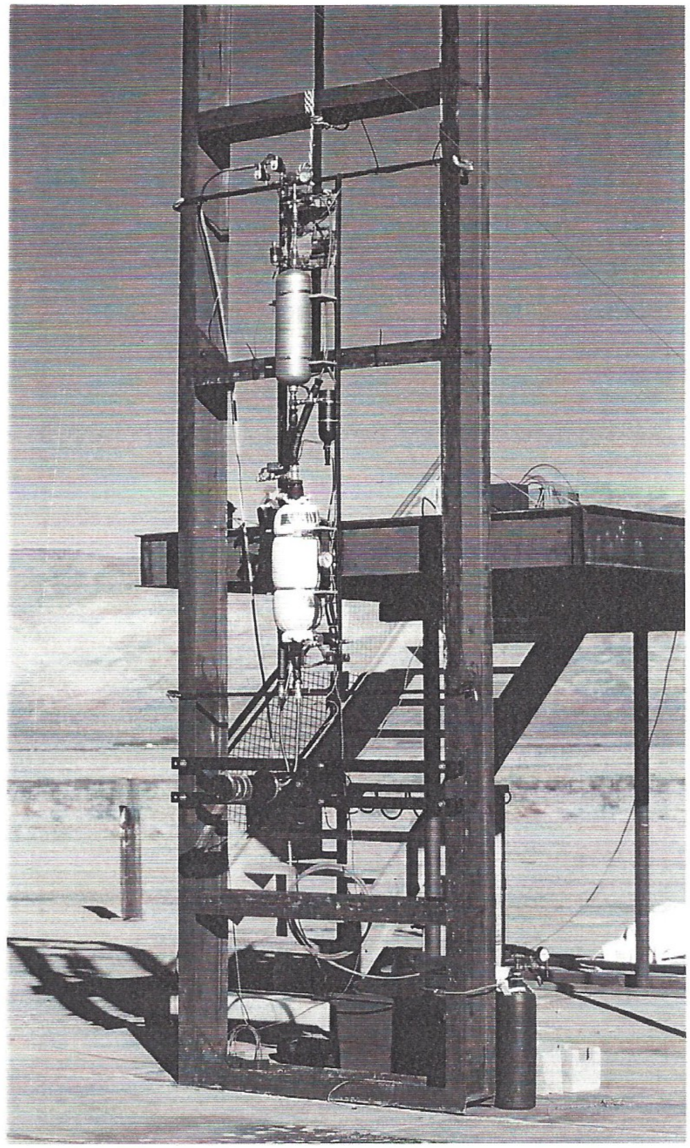


Jeff Jakob with one of his slick little hybrid rockets.



These 1.5 inch diameter hybrids take off like a shot. They're not quite as fast as a Beta, but darn close!

Eric Claypool's static test set-up of his 600 lb thrust LOX/ethanol engine system. Several previous successful tests have not stopped Eric from trying again!



John Garvey's crew load the Kimbo 5 on Kevin Baxter's launcher

Report on the Kimbo V Launch

by John Garvey

Summary of the Kimbo V flight on Saturday, 20 January 2001.

First, it was an unqualified success. The engine burned very well in ullage blow-down mode, boosting the vehicle to a peak altitude of 9,570 feet above ground level. Right at about that point, at 25 seconds into the flight, the altimeter/timer unit commanded the deployment of the nosecone and drogue parachute. 15 seconds later, the timer commanded the deployment of the main parachute, at which point all three of the vehicle components - nosecone, main parachute container and the booster - floated to the ground under their individual parachutes. We immediately recovered the latter two elements which were/are in mint condition and could fly them again with little, if any, refurbishment required. The search was still underway for the nosecone at the end of the day.

Other technical points:
-The vehicle took off at 3:32:17 in the afternoon under perfect weather conditions - no clouds, no wind, temperature in the mid-fifties.

- The rail elevation was set between 88 and 88.5 degrees (as opposed to 85 degrees on Kimbo IV) and this contributed to a "straight-up" trajectory

- By placing a break wire at the end of the launch rail, we were able to measure the vehicle's initial acceleration, which appears to have been 67 ft/sec^2.

- The upgraded electrical ground support equipment worked great. Through use of a wireless LAN, it eliminated 99% of the cables between the block-house and the pad, giving us a lot more flexibility and reducing the set-up/tear-down tasks.

- We successfully implemented our first on-board flight telemetry system. It was a basic frequency-shift-keying system that simply indicated when the nosecone and the parachute deployed, but that in itself was very helpful because initially it was difficult to visually verify these events. Furthermore, it sets the foundation for more comprehensive telemetry in the future (next time we are going to try to get end-of-burn data and maybe some analog measurements as well).

We did encounter the usual set of pre-launch technical challenges. These were associated with integrating a new recovery system, getting familiar with the Transolve timer/altimeter unit, inaccurate calibration coefficients on the tank transducers and getting the igniter started. A fighter fly-by over the dry lake bed when we had the vehicle fully fueled and pressurized was another challenge. Fortunately, the system proved to be robust and everything ultimately worked as planned.

As always, the Kimbo V launch was a team effort with a lot of key contributions. Some of the most visible ones included:
- Chris Thompson's airframe and propulsion system that reflected a weight reduction of about 40% over the Kimbo IV and will serve as our reference design for future vehicles.

- John Engberg was truly the man on the spot on Saturday. His recovery system was the primary technology enhancement on this flight and a lot of us were holding our collective breadth until the main parachute opened up. There was a lot of pressure on John in the last week and he, along with his son Christopher, came through 100%. His system should be studied by RRS members who are interested in getting insights on how to recover large vehicles in the future.

- Mike Novratil, who did his usual role of getting things going at our new shop and in building up the airframe and handling launch day vehicle prep. Furthermore, his five-year old son Austin also contributed by among other things helping to fabricate the access port doors.

- Mark Holthaus and Dave Crisalli. Besides implementing the recovery electronics and ignition system, Mark competed with Dave (who served as the pyro-op for this flight) during the final countdown on who could run to and from the pad fastest to take care of the latest problem that cropped up.

- Kevin Baxter, whose transportable launch rail once again guided one of our vehicles into the air

- Tom Mueller. Because of his previous inputs, the propulsion system is working great and requires relatively little attention. Tom also handled the FAA waiver paperwork and phone calls, which can be a major bureaucratic challenge.

- There were a lot of other folks who helped out and their efforts are appreciated, even if at times it might not have been obvious (spending a night in the sub-freezing weather, working round-the-clock, eating only Powerbars and dealing with last-minute technical glitches can make one less than hospitable at times). Steve Harrington's provision of LOX really helped out with respect to logistics (as did Kevin's supply of GHe), Tim Price's handling the telemetry data capture, "Big RV" Dave's installation of the launch rail break wire, Dave Burnett's support on the initial GSE checkout, Eric Claypool's generator, etc. were all important. Needless to say, things could not happen without the RRS's making the MTA available.

In addition to the Kimbo V launch, there were several other experiments on Saturday. Steve Harrington's team had a sweet launch of their 1000 lbf Flowmetrics vehicle and Eric Claypool's 650 lbf motor proved to be extremely stable during its latest static fire test (need to get that thing in the air Eric). Jeff Jacobs helped get the day started with two of his hybrid rockets. Between this day and the big launches in December, its truly remarkable how much advanced rocketry is going on at the MTA these days.

We are now in the data collection mode. That means photos (both digital and film), video, etc. If you are aware of any such items, please let me know. I'll also forward them to everyone who is interested. Furthermore, now that the Kimbo V crunch is over, we'll put some resources into updating the *www.kimbo-rockets.org* website.

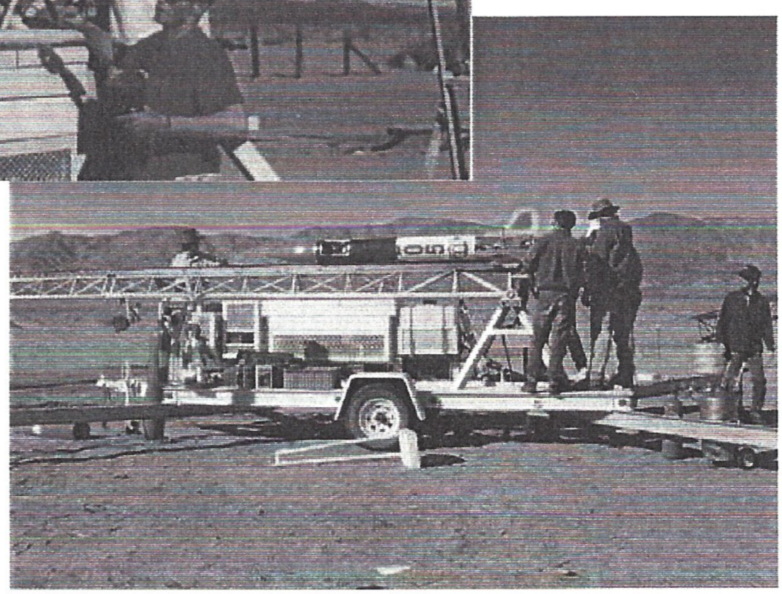
As for the future, at this point it appears that we will turn the Kimbo V into a display model. It's just too clean a vehicle and is very useful as a design reference. So, we've already challenged the CSULB students to accomplish two flights in one day with the K-V derivative vehicle that we are helping them to build. That will happen later this spring. In addition, the BFR-1 LOX tank is sitting in the shop and we are going to check with Tom Mueller on when we can expect the three fuel tanks. With luck, we'll get the 12,000 lbf engine into a static fire by this summer. In parallel, there's a lot of stuff we can try in the areas of composite materials (Jim Leslie should expect some phone calls in the very near future) and on-board avionics. It promises to be a fun year.

One final note - one great aspect of all this is the large number of young folks who either are observing or even actively participating. Even though we might joke that Austin Novratil, Ryan Thompson and Christopher Engberg help keep costs down and are good excuses in case something goes wrong, they are making valuable contributions and hopefully are learning a lot in the process. There will be a lot more similar opportunities in the future.

Left—Kim and the Kimbo V crew work on the final integration of the flight hardware.

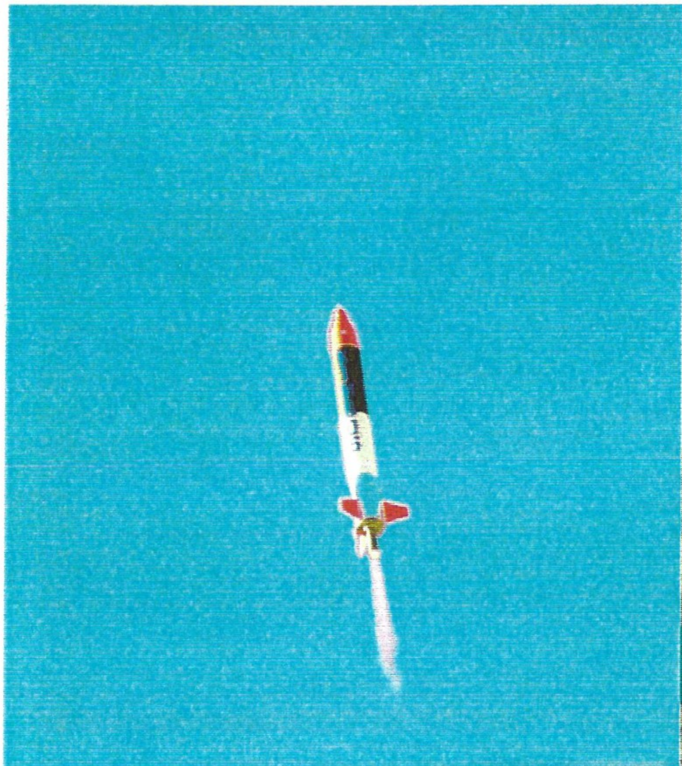
Below Left—CSULB students Seth, Jeff and Tim (to the left of the picture, holding the other end of the tape ruler) measure the distance to a break wire at the top of the launch rail. This parameter was used to calculate the initial acceleration of the Kimbo V as it flew up the launch rail.

Below—The Kimbo V Rocket is being loaded onto the portable launch rail. The rocket will be elevated to its launch angle and the GSE equipment connected.



Right—John Garvey and Mark Holthaus at the pad during preparations for loading the ethanol fuel into the vehicle.

Left—Key members of the Kimbo V launch team: (from left to right): Chris Thompson, Mike Novratil, John Garvey, John Engberg, and Mark Holthaus.



Left—Tony Richards once again captured a remarkable image of a Kimbo vehicle in free flight. The Mach diamonds are visible in the exhaust plume, indicating a clean burn.

Right—Dave Griffith's photo of the Kimbo V captures the vehicle's exhaust plume against the El Paso mountains to the north of the MTA.

Right—A greatly magnified image of Chris Thompson's photo of the core stage floating back to earth. Hopefully this will be become a common site in the future.

Far Right—Marking a major first for the Kimbo team, the recovery system operated perfectly on this flight. The main stage is seen here returning to earth under the main parachute. John Engberg put a lot of effort into developing the K-Vrecovery system, applying lessons-learned from the Kimbo III and Kimbo IV flights. Real-time, inflight telemetry from the vehicle (another first for the team) indicates that the timer unit commanded the ejection of the nosecone and deployment of the drogue parachute at T+25 seconds. The deployment of the main parachute followed at T+40 seconds and the three pieces of the vehicle (nosecone, drogue parachute/main parachute container and the core stage) each floated downrange towards the Koehn dry lake bed, taking several minutes to finally reach the ground.

Ground teams found the drogue parachute/main parachute container and the core stage within ten minutes, in perfect condition. Jim and Lin Burke located the nosecone the next day, making it a 100% successful recovery.