ZnS

ZINC/SULFUR

It Wasn't Always Just For Betas

by David Crisalli

Although there are thousands of people today who enjoy the hobbies of model and high power rocketry, there are still very few who work in a category called amateur-experimental rocketry. In this arena, the design, fabrication, and testing of the propulsion system itself is the key interest. Using both solid and liquid propellants, these rocket systems are all unique. They are usually designed completely by one individual and built in the garage. There are no kits available or even parts. As a consequence, the real educational value of working in this field is the experience gained in learning all the skills required to build propulsion systems. People who have never run a lathe, machined a part on a mill, arc welded, or calculated a throat diameter are soon training themselves in these areas. Each component must be designed and built from scratch by the experimenter. Unlike their model and high power counterparts, amateur-experimental rockets are fabricated almost entirely of metal and typically produce 1000 pounds or more of thrust for up to sixty seconds.

Because of the total energy available in these systems, flight and static testing is restricted to very remote sites equipped with blockhouses, bunkers, assembly areas, propellant handling facilities, and all appropriate safety equipment. One of the few such sites in the United States is the Mojave Test Area (MTA) owned and operated by the Reaction Research Society. Propellants are not prepackaged for these rockets, and are handled on site under the watchful eye of experienced pyrotechnic operators licensed by the state of California. It is the pyrotechnician's responsibility to insure that all propellant loading, static, and flight testing operations are conducted safely and efficiently. In over a half a century of this type of rocket testing, the Reaction Research Society has never suffered a single mishap resulting in injury to any member or observer.

In the late 1960's and early 1970's many types and sizes of amateur-experimental rockets were launched by members of the Reaction Research Society from the towers of the Mojave Test Area. As an example, from April of 1967 to August of 1968 forty six rockets were fired by the RRS during ten launches. The following year over thirty more took to the desert skies. Although these numbers are not impressive when compared to the numbers of rockets launched at many

George Bassett holds his Standard RRS Beta in front of the Mojave Test Area blockhouse just before the flight on 16 October 1993.

Zinc/sulfur rockets are only a blur on liftoff, looking and sounding like they have been shot out of a cannon. Catching a photo like this one is more of a startled reaction and luck than it is a planned event.

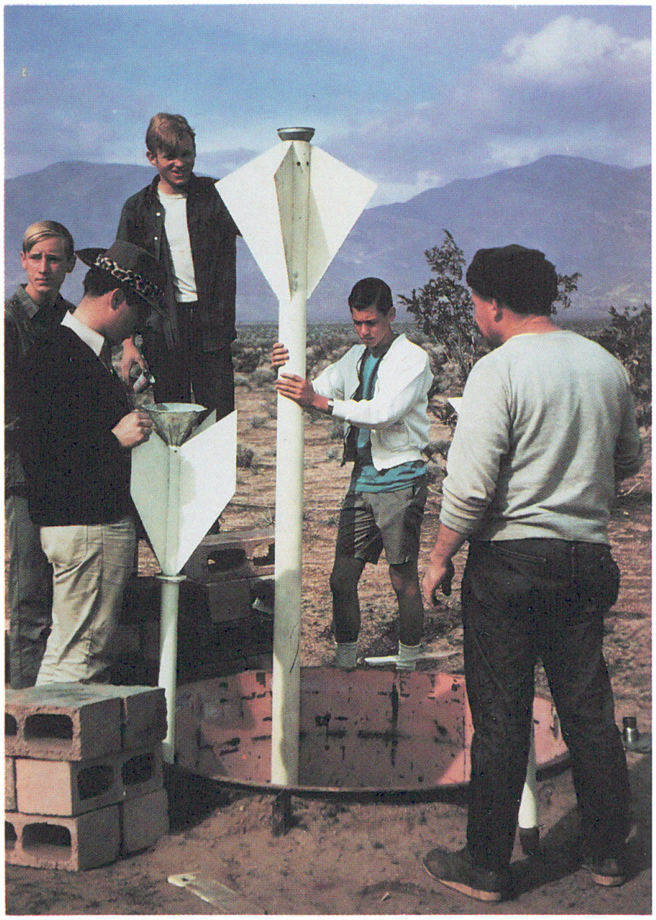
of the high power events, it must be remembered that there were only fifty or so members in the RRS at the time and all these propulsion systems were built from scratch out of steel and aluminum. This type of construction is relatively difficult and requires more specialized equipment than does fabrication with wood, phenolic and fiberglass.

During this time, the majority of the rockets launched were vehicles called "BETAS." These were zinc/sulfur rockets built primarily of steel and having a motor section two inches in diameter and four feet long. They could hold about ten pounds of propellant and could reach altitudes of 10,000 to 15,000 feet. Inexpensive and relatively easy to build, as metal rockets go, they were often equipped with various types of expanded diameter payload sections forward of the motor. Developing 1000 pounds of thrust, they left their launch racks at more than fifty g's on a billowing pillar of fire and smoke.

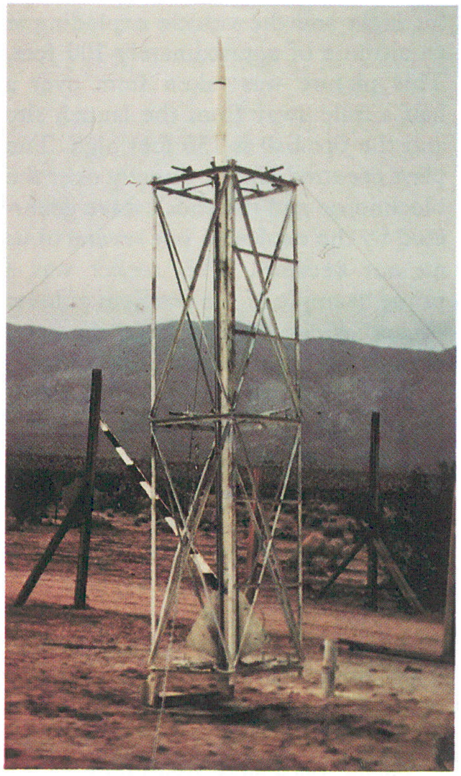
However, while many of the rockets launched during these years were Betas or some derivative thereof, several were multiple stages or much larger vehicles. One rocket built by a group of high school students in South Bend, Indiana and fired in cooperation with the RRS, was fifteen feet tall, six inches in diameter, and required 368 pounds of zinc/sulfur to load.

There was much to be learned from these larger rockets, but many with motors over 3.5 inches in diameter exploded at various points in the burn. The method of loose packing the propellant, used successfully in the smaller diameter motors, did not work well in the larger diameters. The loose packing allowed the propellant to fall or shift during the rocket's considerable acceleration greatly increasing the combustion area and over pressurizing the motor. The photo below shows a large rocket built by Jerry Thomas in 1969 being readied for propellant loading along with a smaller vehicle. Jerry's rocket was four inches in diameter and fifteen feet long. The motor section was the full vehicle diameter of four inches, ten feet long, and it took 130 pounds of propellant to load. The two photos on the following page show the rocket in the launch tower ready for flight and the vehicle exploding at an altitude of approximately 100 feet. This picture was taken from over a half a mile away from the launch site and the fire ball is 150 feet high. The blast occurred almost directly over the blockhouse and the shock wave generated by the explosion put several of us on our keesters. This rocket was a prime example of the problem of loose packed propellant in large diameter motors. So while there was, at times, a desire to build larger rockets, limitations on the type of propellant available and the method of loading restricted motor diameters to an upper limit of approximately three inches. Engines above this limit could not be counted upon to function reliably.

In late 1969 I began in earnest to design a large liquid propellant rocket. The preliminary layout showed a structure some eight inches in diameter and almost twenty feet long. Such a vehicle was a large step up for a high school student whose largest previous



Jerry Thomas's huge rocket being loaded with 130 pounds of propellant under the watchful eye of the pyrotechnic operator, Richard Butterfield. The smaller ER-15 is also being fueled here.



rocket had been a zinc/sulfur vehicle with a 2.5 inch diameter motor six feet long. It was desirable, therefore, to build some intermediate vehicle to gain experience with larger rockets capable of reaching higher altitudes and to test several of the flight and ground support systems that might eventually be used in the liquid project. Some type of zinc/sulfur rocket was the immediate choice since the fabrication would be relatively straightforward and since the propellants were available. The challenge then became to design a rocket of meaningful size that could be built with available equipment and that would not use a motor diameter larger than three inches.

Jerry's rocket (left) in the launch rack ready for flight. At liftoff, the rocket weighed over 200 pounds and was designed to produce 3,000 pounds of thrust. The launch and detonation of this large zinc/sulfur rocket (below). Those in the blockhouse could attest to the power of this explosion.

The ER-16 (Experimental Rocket-16) was designed and constructed from March through June of 1970. It was decided that a two stage vehicle with clustered motors was the best approach to use in accomplishing the goals of building a large, high altitude vehicle with small diameter motors. The rocket was designed specifically to test clustered engines (a potential booster arrangement for liquid rockets), multiple stage coupling and separation, large diameter (eight inch) structural fabrication, ground support equipment, an automated launch system, tracking equipment, a telemetry transmitter, graphite lined nozzles, and an umbilical disconnect system. Many of these features were envisioned for use in the liquid rocket or on a booster for such a vehicle.

The rocket, shown in Figure 1, was over eighteen feet tall. The first stage was eight inches in diameter and included a cluster of four engines. The motors were 2.5 inches in diameter and six feet long designed to produce 2000 pounds of thrust each. The combined first stage thrust was, therefore, 8000 pounds. The four engines were assembled into an aluminum structure and covered with an aluminum skin. The first stage fins were also aluminum and were riveted to the structure/skin assembly. Four small parachute pods were attached to the end of each fin to house the first stage parachutes. The upper stage had a four inch diameter payload/parachute section and a three inch diameter motor producing 2500 pounds of thrust. This motor was also six feet long. Fins for the upper stage were constructed of steel welded directly to the motor tube. They were moved up from the end of the motor several inches to allow the recessed nozzle section of the upper stage to slide into the staging adaptor. The fins were cut to match the adaptor upper angle thereby providing strength and rigidity to the interstage joint. This arrangement proved to have more than adequate strength, but also allowed the two stages to separate easily and cleanly.

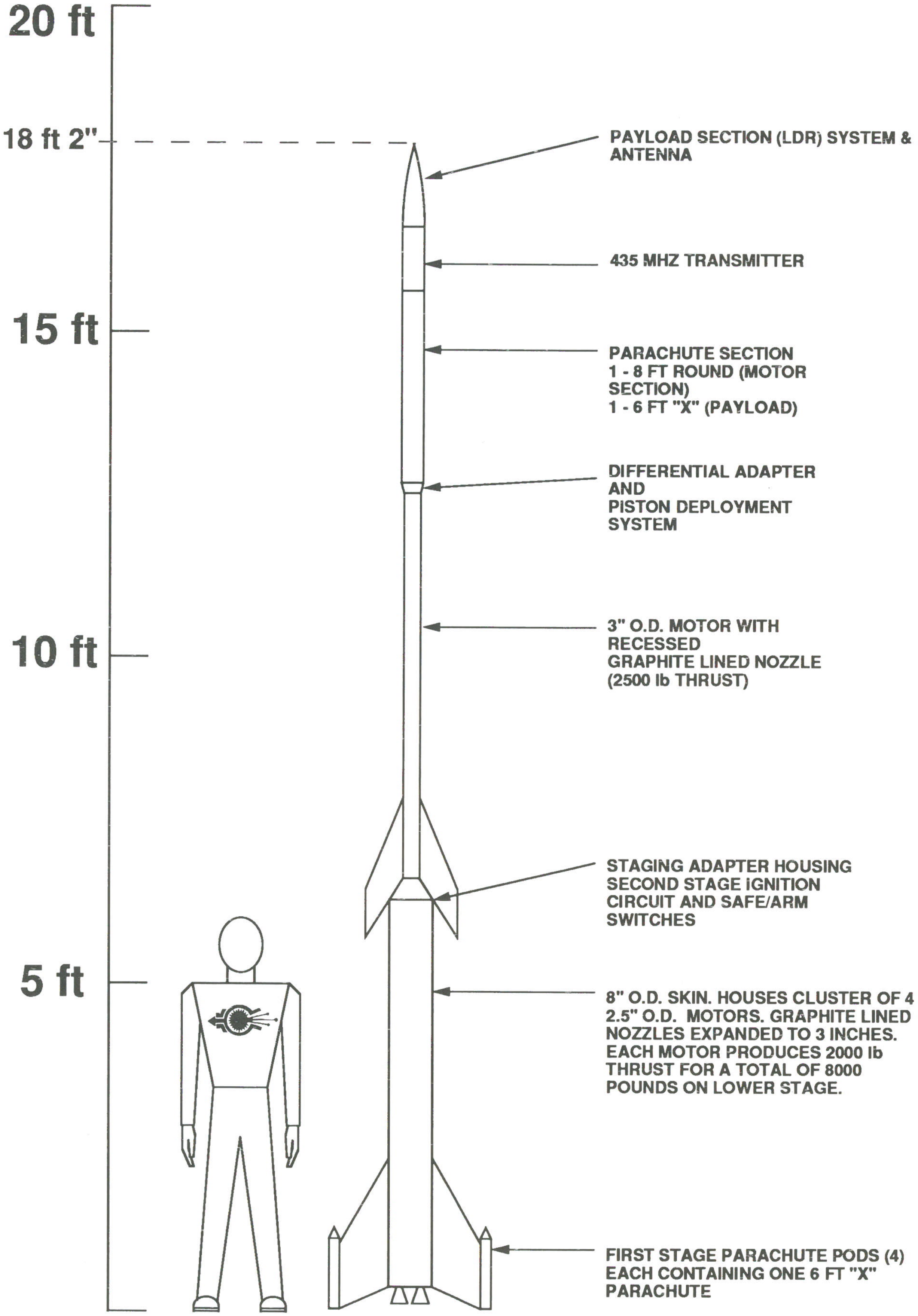


FIGURE 1

THE ER-16 TEST VEHICLE LAUNCHED AT THE MTA ON 27 JUNE, 1970.

It was desirable to recover as much of the rocket as possible so that flight components might be reused and, if possible, the vehicle refurbished and flown again. It was decided that the LDR (Light Dependant Resistor) parachute ejection system developed previously (on vehicles ER-8 through ER-15) and a piston deployment mechanism would be used on this rocket. It had proven to be reliable in the past and it was worthwhile to see how well it would perform at the much higher altitudes expected on this flight. The system was comprised of a light dependant resister mounted in the nose tip and coupled to a miniature relay. When the rocket reached peak and turned over, the drop in light intensity increased the resistance of the LDR and actuated the relay. The relay fired the pyrotechnic charge that separated the nose and deployed the parachute. The system was modified slightly to allow for the recovery of both stages by parachute. The upper stage carried its two parachutes in a tube forward of the motor but below the payload area. One parachute would bring down the motor section and the other the payload. As mentioned previously, the first stage carried four parachutes in fin pods. Both upper stage parachutes were reduced in size from the ideal to allow a greater decent rate and to minimize drift from high altitude.

The LDR system was armed before launch with a small manual switch in the nose section. However, to insure that the system would remain safe until after launch, a mercury switch was included in the firing circuit to the pyrotechnic charge in the piston deployment mechanism. This would only allow the system to be fully armed after burnout of the upper stage motor. Another mercury switch was also used to fire the second stage. Safe and arm for the second stage ignition circuit was accomplished through a firing interrupt that was built into the umbilical disconnect system. The upper stage would only be armed seconds before flight when the umbilical fell away. Therefore, at burnout of the first stage several things were to occur. The LDR system would arm (then be briefly disarmed by the acceleration of the second stage and rearmed at second stage burnout), the second stage would ignite and separate, and the first stage parachutes would deploy. Ejection of these parachutes from their pods was accomplished by the use of a small pyrotechnic charge actuated by a mercury switch system in each pod.

The ER-15 (Experimental Rocket 15). The 2.5 inch diameter motor held 25 pounds of propellant and produced 1500 pounds of thrust.

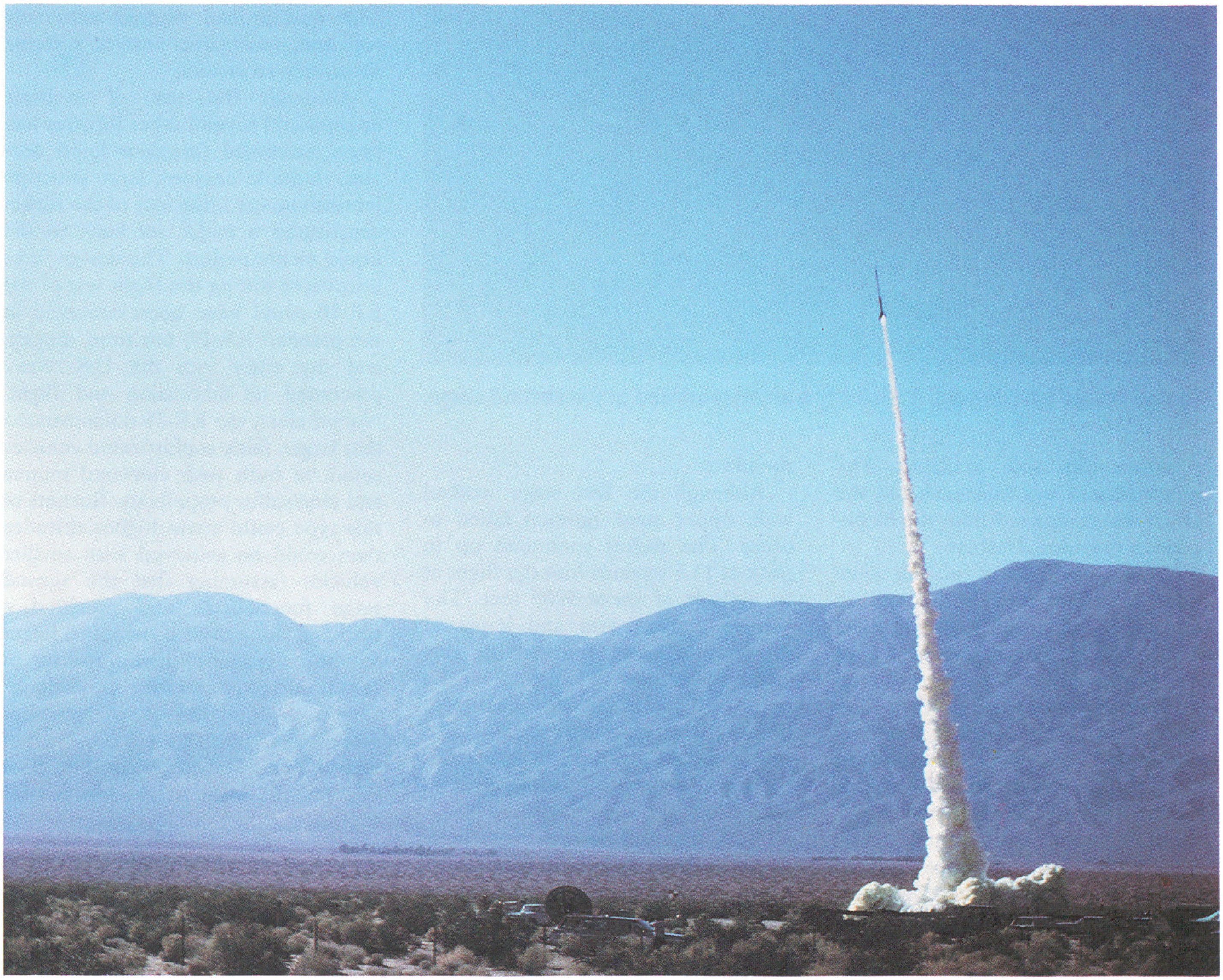
The author (top) and high school classmate, Ron Arnold, pose for a "Kodak Moment" during final vehicle checks before fueling.

Tracking equipment collected or built in support of this launch included a six foot diameter dish antenna mounted on a base which allowed it to be moved manually in azimuth and elevation. It was equipped with antenna elements designed to receive the signal from the 435 mhz transmitter in the payload section of the rocket. The dish antenna weighed over 200 pounds and was counterbalanced to make it easier for the operator to point it with a set of handles and shoulder braces. This feature worked like a World War II 20mm anti-aircraft gun mount. The operator was provided with an optical sight through a hole in the dish and a set of headphones. Tracking could be accomplished visually or by means of the strength of the audio signal if visual contact were lost. Considerable effort was expended by other RRS members helping me with the ground support equipment for this project, to build the antenna system, receiver and optical sighting system. Transport and set up of this equipment was also a laborious task.

The automated launch system was really not required for this launch, but was built with the liquid rocket in mind. It was thought that such a system would be necessary to launch the much more complicated liquid vehicle. Therefore, it would be prudent to build and test it in a simplified form for this flight. Later modifications would allow the same equipment to control liquid rocket static or flight testing. The unit was built into a standard six foot tall nineteen inch computer rack and included two home made digital clocks and a programmable firing sequencer. The clocks were designed around multiple pole telephone stepping relays pulsed once a second by a transistorized timer circuit (purloined from a Highway Department caution sign flasher). The unit was programmable by means of a patch panel and was limited to a one second discrimination time (clock pulse minimum time). The launch system also contained manual override systems for umbilical disconnect, upper stage arming, firing voltage, and an intercom system. A firing and control cable 300 feet long was assembled out of all the wire that could be rounded up. This was required since the launch control system was to be located in the observation bunker and not the blockhouse only fifty feet from the launch tower.

The ER-16 was launched on 27

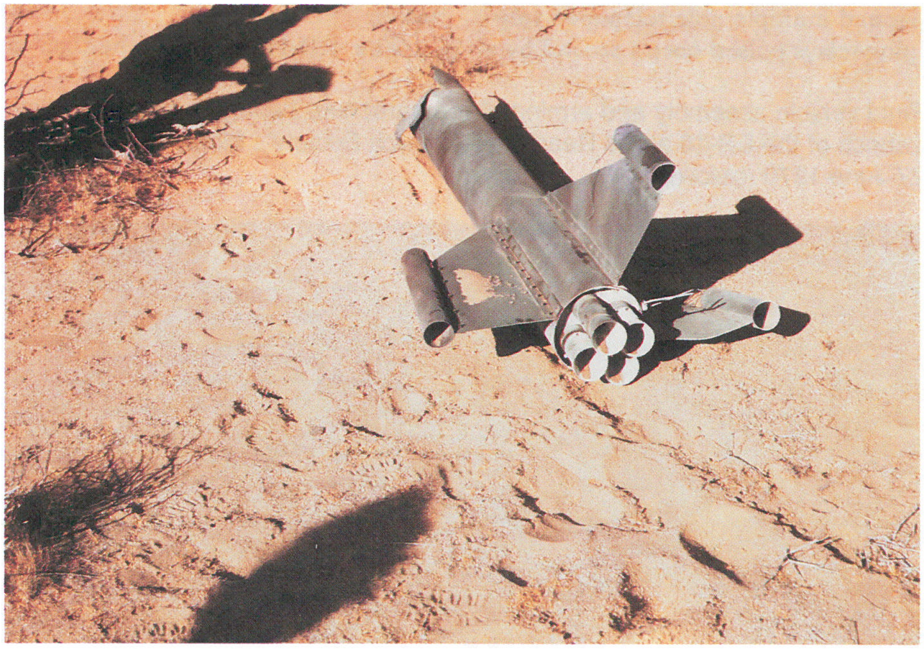
Final vehicle assembly and arming of the parachute deployment system (left). Launch of the ER-16 at the Reaction Research Society's Mojave Test Area on 27 June 1970 (below).



June 1970. Launch preparations began with the set up of the tracking antenna and receiver station 200 feet behind the bunkers. This put the antenna some 550 feet from the launch tower. Transmitter and receiver tuning was accomplished shortly thereafter. The automated launch control equipment was set up in the bunker, but problems developed immediately. Although the panel was working well, the patchwork cable, forced by economic reasons, suffered broken connections and shorts. Although repairs were attempted, the cable could not be made to function properly within the time available. The launch system was bypassed and the launch was conducted from the blockhouse in the normal fashion.

Almost 160 pounds of the zinc/sulfur propellant used in this vehicle were mixed early that morning. Each of the first stage motors was fueled with twenty seven pounds of propellant and the upper stage required forty more. Two squibs were installed in each motor to insure simultaneous ignition. The motors were assembled into the first stage structure which was placed in the rack horizontally. The upper stage motor was then inserted into the staging adaptor and the tower was erected. The parachute section, payload and nose were assembled in the vertical position. The LDR system was armed along with the upper stage firing circuit and the parachute pod charges.

When communications were established between the blockhouse, bunkers and tracking, the rocket was fired. Simultaneous ignition of the four first stage motors had been a major concern during the design of the vehicle. However, first stage function was flawless. The flight was perfectly stable with absolutely no wobble or spin. Four distinct and symmetrical plumes could be seen at ground level as the vehicle rose from the tower.



The first stage after impact. Practically nothing remained of the second stage.

Although the first stage worked well, upper stage ignition failed to occur. The rocket continued up to peak at 11.6 seconds into the flight at an altitude of about 5000 feet. The vehicle pitched over and impacted the ground some considerable distance downrange. On contact, all the upper stage propellant detonated blowing the upper stage apart. The first stage was substantially intact, but the upper stage was completely destroyed.

Both first and second stage parachute systems failed to function as designed. The heavy payload section was retained in the parachute section by only a .75 inch long slip fit collar. This had worked with lighter nose sections, but at first stage burnout deceleration threw the nose clear of the rocket parting the firing cable to the piston charge. The first stage parachutes all deployed at lift off and were vaporized by the engine exhaust. These parachutes were designed to be ejected aft from the lower open end of the pod. The pods had no end caps and relied on the tight friction fit of the packed parachute for retention. This proved to be insufficient to withstand the acceleration at lift off.

The upper stage ignition failure was attributed to the use of redundant higher current squibs. Although the battery used to fire the upper stage was sufficient to fire a single squib, post flight ground testing demonstrated that a similar battery would not always fire two squibs in parallel. The graphite lined nozzles and motors of the first stage were recovered intact. The nozzles had worked extremely well and, unlike steel nozzles, suffered absolutely no erosion.

Although the use of multiple engines and several other features had been successful (graphite lined nozzles, multiple engines, large structure fabrication, etc.), the loss of the rocket constituted a major set back to the liquid rocket project. The design flaws uncovered during the flight test of the ER-16 could have been corrected in the planned ER-17, but time, money, and my entry into the U.S. Navy precluded its fabrication and flight. Nonetheless, the ER-16 demonstrated that larger, fairly sophisticated vehicles could be built with clustered motors and zinc/sulfur propellants. Rockets of this type could attain higher altitudes than could be achieved with smaller vehicles (assuming that the second stage functioned), and provided a stepping stone toward the much larger and more powerful liquid rockets to come. Although limited in performance and motor diameter, zinc/sulfur propellants could be used to advantage in other vehicle types. The Beta was not the limit of zinc/sulfur usefulness.