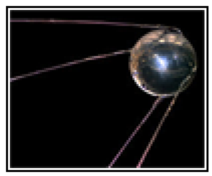
A History of the Lakeside Rocket Society

by Nym Park '64

WITH THE PRESS OF A BUTTON, the rocket motor bolted to the test stand came roaring to life, emitting a white-hot plume of smoke and flame; the oscillograph trace recording the motor's thrust spiked upward. Then the combustion chamber and nozzle parted company. The shuddering roar of the rocket motor became a thunderous explosion that shook Seattle's North End. Police phone lines lit up with calls from worried neighborhood residents wanting to know what was going on. No, it wasn't a broken gas main or the start of WW III. A Rocket Society test firing had, ah, exceeded parameter. But for the members of the LRS, myself included, this was heady stuff. "Doc" Morris and Mr. Dougall sure knew how to make rocket science interesting and exciting!

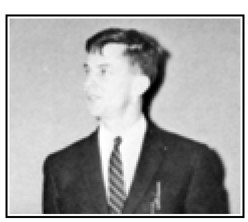


Sputnik 1

According to McCuskey's "Lakeside History," "on October 4, 1957, two earth-shaking events took place: the first earth satellite was launched, and the Lakeside Rocket Society was born; the formal, authorized Rocket Society, that is."[1, 2, 3] Brent Logan '59 was the "main power" behind the creation of the student organization.[4]

The Rocket Society was proud that the first earth satellite was launched on its birthday. "The impetus of the space age launched the society on weekly meetings, technical research and rocket tests."[5] As McCuskey went on to note, there had been "earlier informal, unauthorized playing with high explosives–(the concrete on the back wall of McAllister still bears the scars of that explosion.)" Boys will be boys even at Lakeside.

Between its founding in 1957 and its demise in 1966, the Lakeside Rocket Society attracted students inspired by America's space program.[6] (Notice the photograph of an Apollo launch above the work bench at which Eric Swanson '63 is working.)[7] Their enthusiasm was captured by this entry in the 1959 *Numidian*: "AS THE NUMIDIAN went to press, the Lakeside Rocket Society, under the guidance of its chairman, Brent Logan, was racing to achieve its first static rocket motor firing for this year. Now completing its second year, the LRS has concentrated on the construction of a most elaborate amateur static test site, equipped with complete electronic instrumentation, an underground control bunker, and a static test cell." Lakeside School had entered the Space Age.



Mr. Dougall

The Rocket Society was unique in the history of Lakeside School. For nearly a decade, the LRS flourished under the guidance of faculty advisers Dr. Morris, Mr. Dougall and Mr. Goldsmith.[8] The scientific knowledge and technical skills of many Lakeside students, combined with their hard work and dedication, contributed to the success of the Lakeside Rocket Society.

According to the *Tatler*, the founding members of the Rocket Society were mostly boarders.[10] As a result "meetings were no problem and organization, to say the lest, elementary."[11] Despite the Rocket Society's informal initial organization, its members were serious about learning rocket science. From the beginning, the LRS was dedicated to amateur experimental rocketry, specifically the design, construction and testing of solid propellant rocket motors.[12]

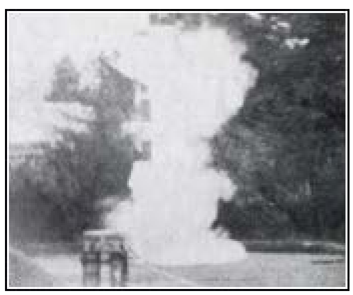
Why did the Rocket Society concentrate on static tests rather than building flight vehicles? "Each member is more interested in seeing just how his own particular part of the project functions, rather than seeing the spectacular flash and roar of a flight vehicle. On the basis of this, the members ask why they should spend all their time and money on a flight rocket, where thrust, pressure, temperature, etc. cannot be recorded, and when the end of a flight finds a missile destroyed. A great deal more can be learned by strapping the rocket motor to a static test stand and recording the motor's functions, thus testing each member's skill by having him work on a particular part of the project that is based on his knowledge of math, chemistry, physics, etc. Each member hopes that this testing of his school knowledge will lay the groundwork for a future career in science."[13]

Much of the Rocket Society's success can be traced to its group oriented dedication to serious, scientific inquiry — *Rocket Boys*, Lakeside style.[14]

<u>1957 - 1958</u>

LRS "proving ground" c. 1958

The Rocket Society, under the guidance of Chairman Brent Logan, held four successful static firings at its "proving ground," located on a vacant lot across the street from Parsons Field. One motor produced 207 pounds of thrust.



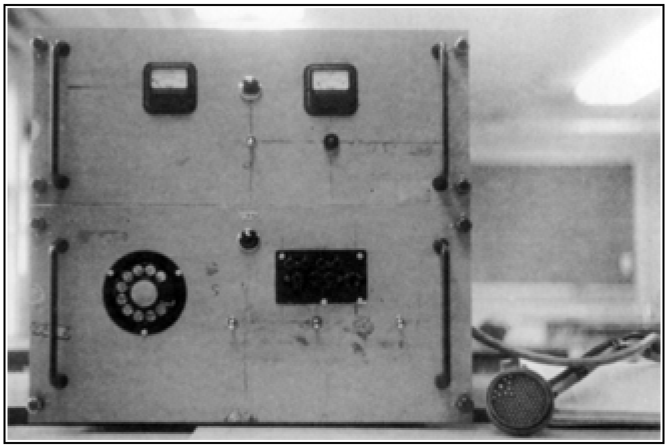
Static test firing c. 1958

The list of future projects included building a multi-stage rocket using "one of the most modern solid-propellants."[16]

<u>1958 - 1959</u>

The members of the LRS devoted their energies primarily to building and instrumenting their "most elaborate amateur static test site." A building permit was obtained for construction of the underground control bunker, test cell, etc. — one of the more unusual building permit applications received by the City of Seattle.[17]

As the year wore on, however, the members agitated for a firing. "Consequently the XLR-2b was constructed and fired in May 1959, in the new test cell. Although again using the zinc-sulfur fuel, this engine was considerably larger (18 inches long and 2 inches in diameter) than its predecessors.[18] The results of this firing were stupendous. "Although the burning time of the fuel was less than one-half of a second, the motor developed enough thrust to bend a one by three-eights of an inch iron thrust-guage bar into an S-shape. Logan calculated the thrust at between eight hundred and one thousand pounds."[19] The XLR-2b (unofficially) broke the national amateur single-chamber solid propellant thrust record of 800 pounds set at the end of the previous school year.[20]



Firing panel

1959 - 1960

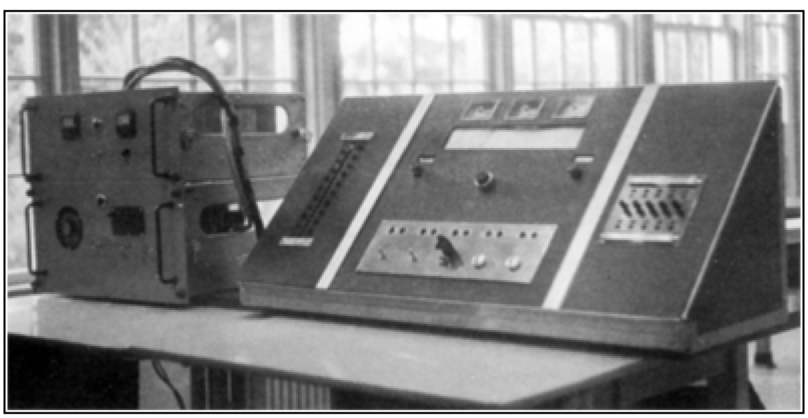
With chairman Alan Legge '60 and Bruce Thelen '62 leading the way, construction of the improved test site was completed in March 1960, the culmination of three years of hard work.[21] While ground support crews worked on site improvements, the Design and Propulsion divisions worked on designing and building more powerful and sophisticated rocket motors; George Cook '60 (Garfield High School) and his crew built the instrumentation set-up.

On April 1, 1960, Dr. Walter Hiltner, Chief of Boeing's Space and Information Systems Unit, addressed the Lakeside student body in McKay Chapel on the subject "Your Future in Space."[22]

Mr. Dougall and Dr. Morris "displayed the same enthusiasm as the Rocket Society members."[23] The faculty advisers made sure the educational aspects of the LRS were not neglected. There was plenty of challenging R & D work to be done for those who could handle the math, physics and chemistry. Those who could not, and otherwise lacked a special skill such as electronics or photography, were relegated to support status and doing grunt work. This eventually lead to organizational problems that clouded the future of the Rocket Society.

"AFTER a successful firing on April 7, 1960, the Lakeside Rocket Society, under the guidance and chairmanship of Allan Legge, began its spring test series. The primary purpose of this series was to evaluate the effectiveness of ammonium perchlorate as a propellant."[24] The announcement of perchlorate propellant testing was premature. Technical problems related to the development of an ammonium perchlorate based propellant delayed the start of 200-series testing until May 1964.

The propellants used by the LRS will be discussed later.



Master timer and power supply

1960 - 1961

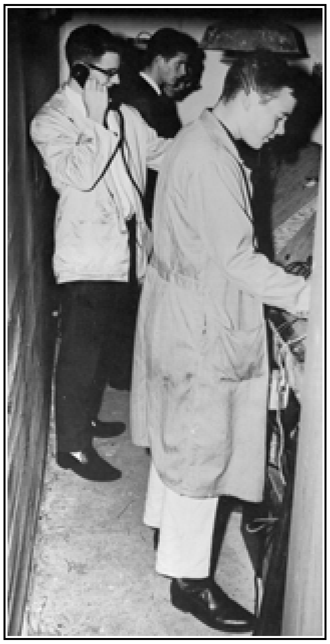
Among the Rocket Society's primary achievements were "an intensive study of a zinc-sulpher propellant, an increase in the reliability of instrumentation, the improvement of the observers' bunker and of the test cell, the acquisition of city electricity at the test site, and the design and construction of a thousand pound trust motor."[25] Chairman Bruce Thelen, Al Perthou '61, John Hager '62, Jim Winton '62 and Art Yengling '62 are credited with "increasing [the Rocket Society's] role as one of Seattle's leading amateur organizations in the field."[26]

At least two firings took place during the school year. The first, on December 16, 1960, was a "foot-long unit fueled with zinc-sulfur."[27] The motor fired successfully. Unfortunately, the generator powering the instruments ran out of gas at X+1 seconds and no instrument recordings were obtained. By other methods, the thrust was approximated at 300 pounds.[28]

The second firing took place on January 28, 1961, and involved two motors. The first blew up and the second failed to ignite.[29] In the words of the *Tatler*, "the January firing while not spectacularly successful, served a valuable purpose. First, it was proved that the system [and test cell] could safely withstand an explosion" . . . "Secondly, it is hoped that the explosion served as an illustration of the fact that the LRS is not handling mere skyrockets, but vehicles that can become lethal bombs. Thus the need for elaborate safety measures about which some members grumble.[30] Thirdly, the firing demonstrated the unreliability of the rockets — they don't all function properly."[31]

The *Tatler* neatly summed up the checkered results of LRS test firings in three headlines: "SSSSS:LRS," "BOOM:LRS,"and "PFFF:POP."

<u>1961 - 1962</u>



On October 14, 1961, motor XLR-4A was test fired. The zinc-sulfur grain had been cast in May, intended for firing in June. However, technical problems forced postponement of the firing until the following school year. The motor spent the summer locked safely in the LRS blockhouse.[32]

The firing was a qualified success. The XLR-4A motor produced 1,350 lbf. peak thrust and 823 lbf.-sec. (1,224.76 Newton-sec.) total impulse, smashing the national amateur single-chamber solid propellant thrust record of 800 pounds set in 1958.[33] However, erosion destroyed the nozzle.[34]

"Following this initial effort, the fall and winter months were occupied with theoretical studies, the designing of new motors, and the improvement of the site."[35] R. R. McAusland of the Boeing Company was scheduled to attend a LRS meeting on February 21, 1962, at which he would show movies relating to Boeing projects of interest to Rocket Society members. (*LRS Bulletin*, February 13, 1962.) No record can befound of McAusland's appearance at the LRS meeting but the event is presumed to have taken place. Whatever knowledge of rocketry and astronautics the members of the Rocket Society acquired from participation in LRS activities, they certainly learned the value of patience, dedication, teamwork — and just plain hard work.

<u>1962 - 1963</u>

"This year like last, has been one of expansion for the Lakeside Rocket Society. Although firings were few, more has been done to secure sophisticated firing procedures than in any previous year. The most significant improvement has been the complete re-instrumentation of the firing site. The communications and public address system, the data acquisition system, and the hydraulic and mechanical support system have been improved upon. A propellant processing plant, a new building, a new instrumentation room and a new fence have recently been constructed. Chambers, nozzles and cooling jackets were procured for the new 200 testing series. New advances have also been made in the laboratory, especially on propellant processing techniques. Indications are that next year well be the most successful year of static testings in the Society's history" — *Numidian* 1963.

The Senate voted to give the Rocket Society a $200 research grant, a significant sum in those days.[36] The LRS took over a former darkroom in the basement of Bliss Hall for its headquarters/workroom.[37] The fence built to secure the LRS test site was 880 feet long.[38] The Rocket Society had effectively taken over an acre of the Lakeside campus!

Over a dozen companies donated materials, equipment and services to the LRS.[39] A Boeing representative made a presentation to Lakeside students aimed at stimulating their interest in future careers in aerospace.[40]

The Rocket Society had become a very successful student organization. Optimism about its future expressed in the *Numidian* was understandable.

Eric Swanson, who was chairman of the Rocket Society, is remembered as an inspirational leader.

<u>1963 - 1964</u>

By 1964, the Rocket Society had matured as a student organization. There were the usual problems of collecting dues and motivating volunteers encountered by most every student organization. In addition, the LRS had some problems uniquely its own. According to the *Tatler* ("The Woes of The LRS," January 10, 1964), the LRS had "advanced to such a degree of sophistication that only a few of the members, notably juniors and seniors, are capable of designing the nozzles, developing the propellants and, in general, doing all the most complex and interesting work. The remaining members either have a very special skill or are left out. Theoretically, we should be trying to educate those members through lectures, field trips, and practical experiences, but due to lack of time, reluctance of companies to allow a gang of high school students to run unchecked through their factory, and not enough basic math, physics or chemistry on the part of our younger members, we haven't been very successful." In other words, the Rocket Society was in danger of failing its underlying educational mission, a victim of its own success. "It has been suggested that the L.R.S. only accept juniors and seniors as members. This would eliminate the problem of keeping the younger members interested, and keep all members busy. Unfortunately this system would tend to bring in 'raw resulits' in the junior year who would have little or no experience. Another problem would, of course, be the drastic reduction in dues."

The Rocket Society was sufficiently concerned about the problem of how to keep all its members intellectually engaged and productively occupied that it sought suggestions from the Lakeside student body on how the LRS might do a better job, particularly in regard to the educational aspect of its activities. However, a better system of organization did not present itself during the remainder of the Rocket Society's existence.

Rocket Research, Inc. allowed members of the Rocket Society to tour its facility in Redmond, Washington, and offered several helpful suggestions.[41] Dr. George Sutherland, president of Rocket Research, seemed to feel that the LRS' perchlorate propellant was "fairly safe as to explosiveness."[42] This was encouraging as Sutherland was an expert on ammonium perchlorate composite propellant.

The same *Tatler* article reported that "Mr. Dougall has sent a nasty note to the appropriate governmental agencies, accusing them of obstructing education by not giving us a firing license." A touch of Cold War paranoia?

Despite the organizational quandary the Rocket Society was in and the destruction of an irreplaceable large motor, the LRS, under the leadership of Chairman Bruce LaZerte '64, continued to forge ahead. In May 1964, four years after ammonium perchlorate testing was announced, a motor using the perchlorate propellant (XLR-201) was finally constructed and taken to the LRS's test site.[43]


Sunday, May 10, 1964 The Seattle Times 61

SUCCESSFUL SOCIETY:

Lakeside Pupils' Solid Fuel 'Doesn't Blow Up' on Pad

—Times staff photos by Larry Dion.

From left—BRUCE LAZERTE, PETER ISAACSON and RANDY KAY

Lakeside Rocket Society members made final adjustments

According to LaZerte, here's what happed next: "Then it was insert the ignition wire, bolt on the nozzle, bolt the rocket to the test pad. And Peter Isaacson counting down 3-2-1.

"At first nothing happened. I recall somebody (Peter?) stepping out of the bunkers to see what if anything was going on, people (me?) screaming at him to get back in, then a god-awful noise and huge amounts of grey-white smoke pouring out of the cement block firing cabin.

"The noise really was deafening. We had no idea that it would be like that. We were completely stunned.

"And the amazing thing is that the rocket worked at all and didn't blow up. Whoever designed it knew what they were doing."[44, 45]

LaZerte and the other LRS members participating in the test firing were not the only ones who were stunned.

"First there were the police and fire trucks. And I'm sure the school received several irate letters. Then there was the article in a Seattle newspaper."[46]

Seattle Times reporter Marjorie Jones and photographer Larry Dion were on hand for the test firing.[47] Her article provides a detailed, first-hand account of the event – one of the most significant in the history of the Rocket Society.

Although the article makes no mention of police and fire trucks coming to the scene, it could have happened after Jones and Dion left to file their story.

With graduation approaching, LaZerte persuaded Robert McKibbin '65 to take over the helm of the Rocket Society.

1964 - 1965

The 1965 *Numidian* did not describe the activities of the school's clubs and organizations for the school year, the result of an unfortunate editorial trend at the yearbook.[48] The *Tatler* ("Member Calls 64-65 LRS a Failure," March 26, 1965) offers this picture of the Rocket Society: "The LRS is not dead - not quite. Although there has not been a meeting since last October or any work done on the site since November, this year's 'leadership' seems determined to finish off the LRS completely. . . . The site (opposite the tennis courts) has fallen into disrepair as has the LRS room itself. There is a list of 'things to be done' posted in there that was drawn up at the beginning of the year. Not a one of them has been done. . . . [A]ny enthusiasm left over from the LaZerte era [has slipped] quietly away until most of the members know nothing and care less." The "Member" who penned the article was Tony Mates '66.

Critics of the Rocket Society called for the group to disband and spare Lakeside and its student body from the burden of supporting a "do-nothing" organization. Headmaster Dexter Strong questioned the Rocket Society's continued existence as a sanctioned student activity.[49]

Prodded into action by Mates' *Tatler* article and the prevailing impression that the Rocket Society had become moribund, the membership rallied and a large motor using a perchlorate propellant was built and tested. "The Rocket Society was fading a bit but still managed a big boom at the range in May" (McCuskey's "Lakeside History"). According to *The Seattle Times* ("School-Built Rocket Goes Off Early," May 10, 1965), the explosion "rattled windows in homes throughout the North End about 11:30 o'clock Saturday night."[50] Patrolmen responding to the incident found "about a dozen pupils and a faculty adviser in a lot near the school, surveying the shattered remains of the 14-inch rocket." Headmaster Dexter Strong was quoted as saying, "Handbills telling of the firing had been distributed around the area. The trouble was in the timing. The countdown was late and the neighborhood had gone to sleep."

The following year, Mates became president of the Rocket Society and endeavored to breath new life into the moribund organization. The hope of sending up "a real rocket at the Takima [sic] Range one day" was kept alive.[51]

1965 - 1966

"The Lakeside Rocket Society can go either of two ways this year. Either we can stay with relatively small rockets and work to develop a reliable fuel, or, with sufficient improvements in our fuel, try to develop the large rocket we have worked with the last two years." — Tony Mates[52]

The explosive failure of a large rocket motor (the "big boom at the range in May") destroyed not only the motor but also a valuable thrust transducer, leaving the LRS with one large motor body and two stainless steel nozzles.[53] The former was incomplete; the latter, all but irreplaceable.

"I fear," said Mates, "the development of the large rocket may be impossible." However, he spoke too soon. Under Mates' leadership, the LRS held two test firings.[54] The first was filmed.[55] An audio recording was also made. (If any reader of this article knows the fate of either the film or audio recording of the test firing, please give that information to the Lakeside Archives office. These artifacts of the Rocket Society would be valuable additions to the school's archives.)

Although partial successes, the test firings proved critics of the LRS wrong.[56] The Rocket Society was not the moribund, do-nothing organization they claimed.

Mates was sufficiently encouraged by the results of the test firings that he wrote in the *Tatler* ("LRS Prepares Third Test Looks To Spring Flight," March 9, 1966): "Next time it shall burn faster, and hopefully break the national amateur rocket society thrust record of about 1300 pounds, set, interestingly enough, by Lakeside." However, the spring test firing did not take place (at least no record of it can be found).

In June 1966, Tony Mates graduated, depriving the Rocket Society of his leadership and energy. And "in May [1967] the earth movers were making good progress on Stimson-Carlisle Field," turning the Rocket Society's proving ground into an athletic field. (McCuskey's "Lakeside History.") The Lakeside

Rocket Society had nowhere to go except out of existence.

Members of the LS Model Rocket Club

Lakeside School Model Rocket Club, 1965 - 1967

Begun in 1965, the Lakeside School Model Rocket Club was a short-lived successor to the Rocket Society.[57] Two of the LMRC's original seven members, Bruce Brigham '68 and John Reynolds '67, were Rocket Society members. Another former Rocket Society member, Fred Hopkins '70, joined the following year. However, as its name implies, the Model Rocket Club was involved in the sport of model rocketry. The model rockets flown by members of the LMRC used commercially manufactured motors — a far cry from the high-powered, experimental motors built by the Rocket Society.

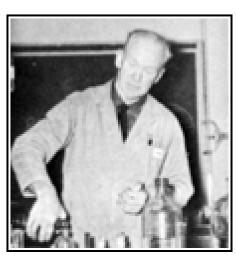
On February 19, 1967, the LMRC held its one and only recorded firing. The "event was supervised by Dr. Werner von Dougall, at the site of the Stanley Sayres Hydroplane Pit Parking Lot.

"Jamie Wedgwood's rocket was flown first and rose to the altitude of 1400 feet. This was the highest recorded flight of the day. One of Bruce Brigham's rockets rose 1100 feet and disappeared from sight. In Joel Lhamon's rocket a live payload was incorporated. A worm was chosen to have the honor of flying to 900 feet. A parachute brought worm and rocket safely back to earth. The firing wouldn't have been complete without the flight of Brigham's impressive looking three-stage rocket which fell apart as it left the launch pad. The crowning touch to the failure was added when he accidentally stepped on the rocket breaking all remaining parts. Also, Rob Stack's rocket rose to a record-breaking height of 75 feet. The rocket at this point overturned and shot into the center of a huge mud puddle.

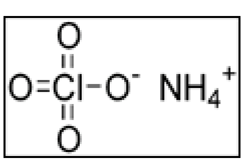
"The firing was a great success in spite of these incidents. The majority of the rockets flew properly and safely and all model rocketeers are anxiously awaiting another firing."[58]

The wait for another firing may have been a long one. As far as I'm aware, the LMRC lasted only two years before ceasing school sponsored activities (although its members may have continued to launch model rockets on their own). This statement is based primarily on articles in the *Tatler*. However, the digitized issues of the *Tatler* available to me ends with the June 10, 1967, issue so my impression of when the Lakeside Model Rocket Club held its last firing may be incorrect.

If so, I apologize. But I leave it to another Lakesider to write the full story of the Lakeside School Model Rocket Club and return to my subject, the history of the Lakeside Rocket Society, with a look at its advanced, high-energy rocket fuel and the motor built to test the powerful propellant.



Dr. Morris



DURING THE 1950s AND 1960s researchers in the United States developed what is now the standard, high-energy solid propellant, Ammonium Perchlorate Composite Propellant (APCP).[59] Most composite propellants are based on a solid oxidizer and a curable liquid polymeric binder. The binder also serves as a fuel. Optionally, metallic fuels such as aluminum or boron may also be used.[60] APCP typically produces two to five times the Isp (specific impulse) of zinc-sulfur propellant.[61] APCP is also more predictable and hence safer than zinc-sulfur propellant.[62]

The original composite propellants, used in JATO units, contained an asphalt binder.[63] Since asphalt-perchlorate composites had poor performance, they were soon replaced with synthetic rubbers (polysulfide liquid polymers) in the binder system.[64] Polysulfides were the first binder elastomer fuel. Polysulfides, however, released water during combustion, a major drawback that limited their performance as a rocket fuel.[65] In the search for binder-fuels without the drawbacks of asphalt and polysulfides, polyurethanes (synthetic thermosetting or thermoplastic polymers) were found to have good performance and physical properties.[66] With these aluminium could be incorporated for higher specific impulse.[67] A polyurethane-perchlorate (PU/AP) propellant was used in Polaris missiles.[68, 69]

The composite propellant used by the LRS was based on ammonium perchlorate and Paraplex P-13, a flexible polyester resin.[70] Polyesters are used in polyurethane binder-fuels; a polyester-perchlorate composite could be classified as a PU/AP propellant. I was once shown a sample of the propellant by Mr. Dougall. It was a small, pinkish-gray cube having the rubberiness of an art-gum eraser.

Composite propellant formulations were military secrets until the 1970s and 1980s, when they were declassified and published.[71] As the *Tatler* noted, "little unclassfied information" was available on ammonium perchlorate.[72] Dr. Wernher von Braun discouraged amateur experimentation with rockets.[73] Government agencies were reluctant to grant necessary approvals for amateur test firings.

This raises an interesting question: How did the Rocket Society developed its own composite propellant?

In 1959 - 1960, the Rocket Society contacted a number of U.S. companies requesting information on ammonium perchlorate.[74] Thiokol Chemical Corporation in Utah, and the American Potash and Chemical Corporation in Los Angeles were promising sources of information on the high-energy oxidizer.[75] However, there was a slight catch to obtaining information from the latter. The LRS had to establish a "need to know clearance" with the company before they would provide information on ammonium perchlorate, not an easy thing for a group of high school students to do in the middle of the Cold War.[76]

Evidently, Thiokol and other companies were more forthcoming (less security conscious?) because information on ammonium perchlorate came "trickling in."[77] And Boeing helped, albeit indirectly.

During the course of his presentation, Boeing's Dr. Hiltner "demonstrated a solid propellant, potassium perchlorate, igniting a sample and passing several others around. Rocket models were shown and described."[78] The members of the Rocket Society's Propulsion Division would have been especially interested in the propellant samples. The chance to handle and examine samples of a reliable and proven rocket fuel made with potassium perchlorate (a chemical cousin of ammonium perchlorate) would have been quite informative. The look and feel of the stuff, the amount of smoke produced when burned, the quantity and appearance of the combustion residue all provided valuable insights into the characteristics of advanced composite propellants.

Other valuable insights were provided by Dr. Sutherland of Rocket Research, Inc. Sutherland had written his PhD thesis on "Mechanism of Combustion of an Ammonium Perchlorate-Polyester Resin Composite Solid Propellant."[79] While at Boeing before founding Rocket Research, Sutherland had coauthored a published paper on "Burning Mechanism of Ammonium Perchlorate Propellants," in which (Paraplex) P-13 is characterized as a binder-fuel.[80, 81] Sutherland was an expert on ammonium perchlorate - Paraplex P-13 (AP-P13) composite propellant. This was the same type of composite propellant used by the Rocket Society. A coincidence?

Based on evidence in *Tatler* and *Numidian* articles, the Rocket Society already knew about high-energy composite propellants prior to visiting Rocker Research in Redmond.[82] Whether this included a knowledge of AP-P13 propellant is unclear. Nonetheless, Sutherland would have been an invaluable source of information about such things as the safe preparation and handling of the propellant, a major concern.

Whatever the source of its knowledge of ammonium perchlorate composite propellant, the Rocket Society benefited from being located in Seattle, a national center of aerospace manufacturing and development. The opportunity for direct contact with experts in rocketry and aerospace was not something available to the members of many other amateur experimental rocketry groups.

"Seven months of research in the chemistry lab went into the development of the . . . 200 series [ammonium perchlorate based] fuel. Handling, processing, casting, and curing methods were investigated."[83] The development work on the 200 series fuel was carried out by Swanson, Charles Hagen '64, John Naiden '64 and Donald Schmechel '64 of the Propulsion Division.[84] Test batches of the rocket fuel were prepared in the laboratory and burned to see how it behaved during combustion. "Fun stuff!" recalls one former Rocket Society member.

Randy Kay '64 was also involved in development of the high-energy propellant. According to Kay, the basic formula was 65% ammonium perchlorate and 35% P-13.[85] A small amount of carbon black (1%) was added as an opacifier.[86] A catalyst, probably benzoyl peroxide (1%), was used to initiate polymerization.

Among his papers, McKibbin found an undated page of notes on propellant testing prepared while he was the Rocket Society's chief fuel chemist.[87] "No date, but I'm fairly sure these tests dictated the mix for the rocket that blew up," he wrote in regard to the May 8, 1965, test firing.[88] Based on his notes indicating which ammonium perchlorate fuel combinations worked best, the fuel used in the test firing was probably 74% ammonium perchlorate, 25% P-13, and 1% benzoyl peroxide. The propellant may have included a small amount manganese dioxide (0.5% Mn O2).

Eleven ammonium perchlorate fuel combinations were tested and evaluated by McKibbin, including four incorporating "Al dust." This shows a high degree of sophistication.

The LRS had previously experimented with the use of boron as a fuel. In one experiment, a boron compound was added to the basic zinc-sulfur propellant. The results were not encouraging.[89] "Al dust appeared to add only sparks to the [AP-P13] propellant," McKibbin noted.[90] However, this evaluation was based on burning a sample of the fuel in the laboratory and not in a rocket motor.

Had the Rocket Society been able to build and test additional perchlorate motors using the various fuel combinations McKibbin had investigated in the laboratory, including those containing powdered aluminum, the LRS might have hit upon something close to Polaris rocket fuel![91]

The Rocket Society's use of APCP was a decade or more ahead of most other amateur experimental rocketry organizations. It's AP-P13 propellant was highly advanced for its day.

Elaborate measures were devised for the safe preparation and handling of the AP-P13 propellant. Plans were made for using DRINAC to control the process.[92] A propellant processing plant was built on the LRS test site.[93]

These safety measures were not always followed in practice, however. The Rocket Society stored its supply of ammonium perchlorate at the Air National Guard Base at Paine Field. When the storage arrangement was canceled, the fiberboard drum containing about 250 lbs. of ammonium perchlorate — enough to blow up Bliss Hall — was transferred to a closet in Dr. Morris' chemistry lab.[94] There was a high tolerance for risk in those days.

The first batch of AP-P13 propellant tested in a motor (May 9, 1964) was prepared by LaZerte and John Black '64. The rocket fuel was cooked up, quite literally, in Mrs. LaZerte's kitchen. According to Black, the propellant mixture was heated in the kitchen oven to remove gas bubbles.[95]

Black recalls that a dowel was inserted into the motor before the fuel mixture gelled. According to Kay, it was a cone shaped wooden plug.[96] In any case, the piece of wood became stuck and had to be "towed" out using a chain and LaZetrte's GMC Suburban.

"It's a wonder we didn't blow ourselves up!" Black said, a remark frequently heard from former LRS members.

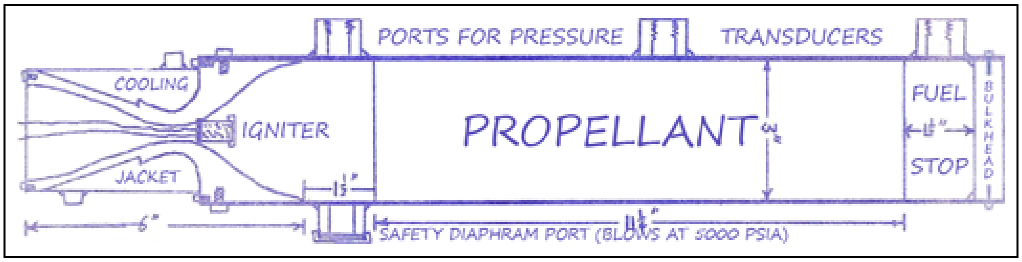
Despite the rough handling, however, the grain remained in tact and — to everyone's surprise — the motor fired successfully.

McKibbin and Paul Weston '65 prepared the motor test fired on May 8, 1965.[97] The batch of AP-P13 propellant was mixed up in the LRS workroom in the basement of Bliss Hall. The mixture had a "honey like consistency" or that of "runny cookie dough." The propellant mixture was spooned into the rocket body and tamped down to remove air bubbles. Then the rocket nozzle was screwed on and the grain cured in a hot water bath.[98]

When test fired, the motor exploded. McKibbin attributes the motor's failure to settling of the propellant mixture that occurred while the motor was lying/standing in the water bath.[99] Murphy's Law strikes again!

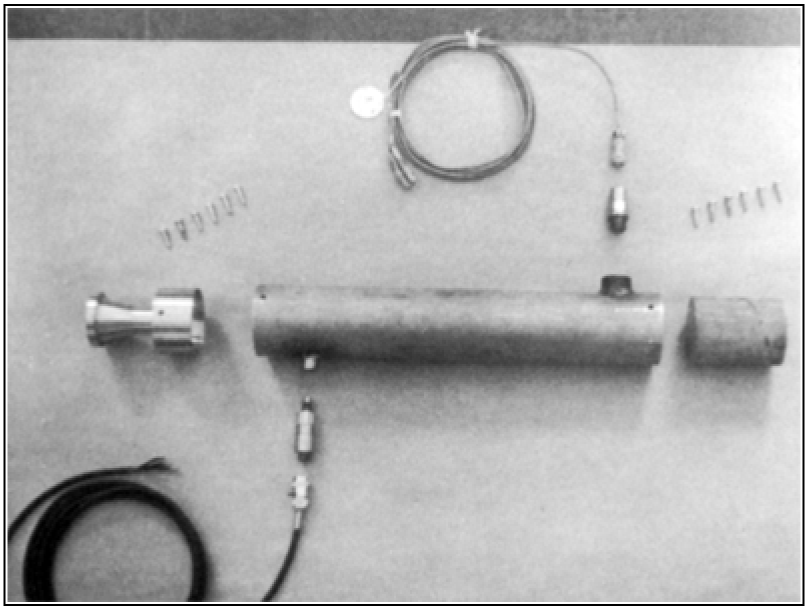
Two subsequent test firings, conducted while Mates was head of the Rocket Society during the last year of its existence, were described earlier in this article. Mates has a vague recollection of mixing up a batch of propellant in the LRS workroom in the basement of Bliss Hall -- "slacking off from study hall and creating a mixture that could have done some serious damage to the building."[100] "My guess about the make-up of the two shots in '65 would be Ammonium perchlorate/Paraplex fuel, mostly because I don't recall zinc being involved."[101]

The last 200-series motor tested fired by the LRS fizzled. The anemic firing marked the end of the Lakeside Rocket Society. Or, as headline writers at the *Tatler* might have put it: "SSSSS:LRS not BOOM:LRS!"



XLR-200 series rocket motor cross section

THE XLR-200 ROCKET MOTOR was the culmination of years of work by the Design and Propulsion divisions. The motor was designed to produce average thrust of 500 lbf. for 2 seconds using a perchlorate propellant.[102] Drumheller is credited with devising a scheme for testing the propellant's effectiveness, e.g. the effect of imperfections in the grain on "pressure-time, and hence thrust-time, histories during the firing of the motor."[103, 104] Another 200-series motor was designed to study heat transfer.[105, 106]

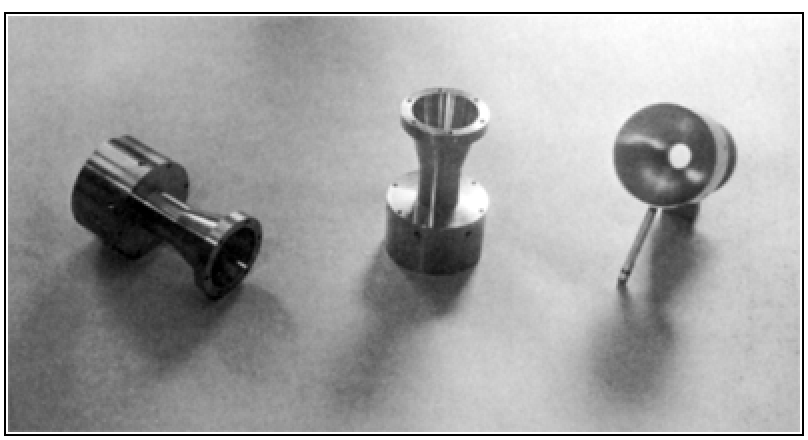


Disassembled XLR-201 motor

These were technically sophisticated projects; the Rocket Society was not simply about building bigger, more powerful rocket motors. However, a zinc-sulfur motor designed to produce 2,000 lbf. thrust was on the drawing boards.[107]

The business end of a rocket motor is the nozzle. The Rocket Society's XLR-1a through XLR-4a nozzles were made of either copper or brass and were used with zinc-sulfur propellant.[108] However, at least one nozzle, XLR-2a (?), was stainless steel.[109] Chrome plating was used to prevent "weakness," a problem that became apparent during the XLR-2a series of test firings.[110] This method of hardening nozzles against erosion met with limited success. The XLR-4A nozzle was made of brass completely covered in .063 inches of chrome.[111] During the record setting test firing of the XLR-4A motor, 2,600 degree Fahrenheit exhaust gases blasting through the nozzle at 2,000 feet per second eroded away the throat of the nozzle and it ended up in two pieces.[112, 113]

Loss or destruction of nozzles during test firings was a common occurrence. In the course of three years, five nozzles met with "unfortunate fates."[114] Obtaining replacements at little or no cost to the Rocket Society was a constant problem.



XLR-201 nozzles

The XLR-201 was a de Laval nozzle.[115] The XLR-201 nozzles and matching cooling jackets were fabricated for the Rocket Society by "a Seattle firm."[116] As can be seen from the above photograph, these stainless steel nozzles were a marvel of the machinist’s art.

What became of the Rocket Society's XLR-201 nozzles is an open question. The Rocket Society had at least two of them on hand when the LRS came to an end. If any reader of this article knows what happened to the XLR-201 nozzles or surviving motor parts, please give that information to the Lakeside Archives office. Any artifacts of the Rocket Society would be valuable additions to the school's archives.

THE LAKESIDE ROCKET SOCIETY did not achieve all that it set out to accomplish. What student organization ever does? Despite ambitions of one day sending up a multi-stage rocket using an advanced solid-propellant, the Rocket Society never launched a flight vehicle. Nor did the LRS publish its findings in research papers available to the space systems engineering community and amateur rocketry organizations.[117] The long delayed testing of motors using perchlorate propellant ended almost before it began, marking the end of the Lakeside Rocket Society itself. But these were comparatively minor failures.

During the nine years of its existence, the Lakeside Rocket Society test fired at least sixteen rocket motors designed and built by Lakeside students.[118] At least one motor set a national thrust record. Members of the Rocket Society developed an ammonium perchlorate composite propellant and successfully tested the propellant in a motor. All this was accomplished at a time of official skepticism and occasional outright hostility toward the Rocket Society's activities.

However, time was not on the side of Lakeside's *Rocket Boys*. As the decade of the 1960s wore on, the success of the Apollo Program made it increasingly clear who was winning the Space Race. The United States would be the first nation to plant its flag on the Moon. The Buck Rogers allure of rocketry remained, of course, but fresh new challenges were capturing the interest and imaginations of technology-minded Lakesiders.

Television images of Apollo mission controllers seated at banks of computer monitors were a harbinger of things to come — not just in science and industry but in everyday life as well. Drumheller was not the only Lakesider to become interested in computers. As a sophomore, Swanson had also built his own computer. By 1966, when the Rocket Society came to an end, Lakesiders were already exploring this new, digital frontier. Others would soon follow, Paul Allen '71 for example.

The Rocket Society was defunct by the time Allen entered Lakeside. But like many others who grew up during the heady days of the Apollo Program, Allen was influenced by the experience. "When I was growing up, America's space program was the symbol of aspiration," Allen said in a recent interview. "For me, the fascination with space never ended. I never stopped dreaming of what might be possible."[119]

Today, the dramatic count-down that preceded a Rocket Society test firing would probably be simulated on a computer — as would the entire test firing itself. Technologically interesting, yes. But there's nothing like the pungent smell of burning zinc-sulfur and the visceral roar of barely contained energy to get a boy dreaming of space travel and flights to the stars!

I WISH TO THANK the following individuals for their assistance in the preparation of this article: John Black '64, Bill Carter '63, Betty Drumheller, Dorothy Drumheller, Pat Dunn '65, Chuck Hagan '64, Peter Isaacson '64, Randy Kay '64, Bruce LaZerte '64, Kitandgary Maestretti, Mike Mates '64, Tony Mates '66, Bruce McCaw '64, Robert McKibbin '65, Tym Park '66, Craig Stewart, Ross Whitney '63, and Dee Wyman.

I especially want to thank Leslie Schuyler, Archivist at Lakeside School, for her invaluable assistance. Schuyler and her student volunteers digitized the *Tatler* issues for the LRS years, making this article possible, and helped research Seattle newspaper articles on the Rocket Society. I am indebted to "Rocket" Raul Cabrera, creator of the Vulcan Shuttle rocket car, for technical information on ammonium perchlorate - Paraplex P-13 propellant.[120]

Lastly, this article is dedicated the John Drumheller, an inspiring member of the Rocket Society, and Eric Swanson, whose leadership and dedication helped build the Lakeside Rocket Society into one of the most successful armature rocketry organizations in the United States.

FOOTNOTES

1. C. L. "Mac" McCuskey taught Latin and English at Lakeside School from 1937 to 1977. His "Lakeside History" is an account of the school's history during his half-century teaching career.

2. The launch of Sputnik 1 came as a shock to America. Americans had taken for granted our technological superiority over our Communist rivals; the faint, mocking beeps transmitted by the tiny earth satellite were deeply wounding to America's pride. Uncle Sam had been bested by the Russian bear — and in rocket science, a field of strategic importance during the Cold War; fears were raised of Soviet world domination. It was a wake-up call to the nation. Overnight, schools began emphasizing math and science eduction; the fledgling U.S. space program received a boost; and "students of America, always ingenious, stopped building their radios and model planes, and started building and experimenting with model rockets." ("An Invitation to the L.R.S.," *Tatler*, September 14, 1966.)

On July 7, 1958, Lakeside began an advanced Summer Workshop in Science and Mathematics. The workshop was under the direction of Mr. Jean A. Lambert (Ass't. Headmaster, Mathematics) and was open to boys and girls, bringing co-education to the Lakeside campus for the first time. ("Lakeside Offers Advanced Summer Workshop In Science, Mathematics: Co-education Comes to Campus; Mr. Lambert Leads New Project," *Lakeside School* News *Bulletin*, July 1958.) Support for the fledgling Rocket Society was not the school's only response to America's "Sputnik moment."

3. The first amateur group devoted to the modern sport/hobby of rocketry was formed in Germany in 1927 and was called *Verein für Raumschiffahrt* ("Spaceflight Society"). The Spaceflight Society established a long tradition among amateur rocketry groups of designating themselves "societies," e.g. American Interplanetary Society, British Interplanetary Society, Southern California Rocket Society, Chicago Rocket Society, M.I.T. Rocket Research Society, Philadelphia Astronautical Society and many others including the Lakeside Rocket Society. (C.L. Strong, "About the activities and the trials of amateur rocket experimenters," "The Amateur Scientist," *Scientific American*, June 1957, 174.)

4. "L.R.S.," *Tatler*, October 29, 1959.

5. "The Lakeside Rocket Society," *Numidian* 1958, 35.

6. While appearing before a special joint session of Congress on May 25, 1961, President John F. Kennedy declared, "I believe this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to Earth. No single space project in this period will be more impressive to mankind, or more important in the long-range exploration of space; and none will be so difficult or expensive to accomplish." Not since construction of the Panama Canal had the United States undertaken so large, costly and technically challenging a project in peacetime; the Apollo Program was the peacetime equivalent of the Manhattan Project. (NASA History Office, "The Decision to Go to the Moon: President John F. Kennedy's May 25, 1961 Speech before a Joint Session of Congress," accessed February 27, 2012, http://history.nasa.gov/moondec.html.)

The Apollo Program's mission of putting an American on the Moon and bringing him home safely became a national passion. The Apollo astronauts were heroes — men who had the "right stuff" — and became international celebrities.

John Drumheller '60 was so enthusiastic about amateur rocketry that he boarded at Lakeside during the summer in order to be involved in the Rocket Society and to build his famous computer.[6.1] (See footnote 92).

6.1. "The Thinker," *Tatler*, November 15, 1958.

7. Mercury 8 (?).

8. Dr. Daniel Morris taught physics, mathematics and chemistry at Lakeside School from 1951 to 1983. William S. Dougall taught physics at Lakeside School from 1957 to 1995, and served as Socratic Mentor to Lakeside faculty from 1996 until 2009. Keith Goldsmith taught biology and chemistry at Lakeside School from 1949 to 1960.

9. The LRS had approximately 80 members during its existence. George Cook, who attended Garfield High School in Seattle, was also a member of the Lakeside Rocket Society. ("L.R.S.," *Tatler*, October 29, 1959.)

10. "The Woes of The LRS," *Tatler*, January 10, 1964.

11. Ibid. The Rocket Society was organized along functional lines: Design Division, Instrumentation Division, Propulsion Division, Photography Division, and de facto Ground Support and Business divisions. The Design and Propulsion divisions attracted the brainer members, proficient in calculus and chemistry. Assignment to the Instrumentation Division was for electronics wizards and "gym-flakes." Unassigned members — mostly underclassmen — who did not participate in work details and Ground Support activities (and anyone without a parental permission slip on file) were denied the privileged of witnessing test firings from the Observer Section of the LRS test site.

12. The sport/hobby of rocketry is divided into three basic categories: model rocketry, amateur experimental rocketry, and amateur high power rocketry. Model rocketry, as its name implies, involves constructing and flying model rockets built from kits produced by Estes and other manufactures. Amateur experimental rocketry, the type pursued by the Lakeside Rocket Society, involves the research, engineering, design and construction of rocketry related projects. Amateur high power rocketry falls somewhere between model rocketry and NASA.

"Model Rocketry and High Power Rocketry are best suited to those who wish to make and fly rockets, and Experimental Rocketry is perhaps best suited to those who rather wish to *make rockets fly*" — Richard Nakka (Richard Nakka, "Amateur Experimental Rocketry ?," accessed February 26, 2012, http://www.nakka-rocketry.net/index.html.)

13. "Large-Scale Testing To Begin," *Tatler*, October 8, 1958.

14. In his memoir, *Rocket Boys*, Homer Hickam, describes the development of amateur experimental rocketry during the Sputnik era. The movie *October Sky* is based on Hickam's memoir.

15. The 1958 *Numidian* says "four successful static firings" took place during the school year. According to the *Tatler* (October 29, 1959), the LRS "conducted a total of five static firings" during its brief existence, one of which took place in May 1959. However, the *Tatler* goes on to describe four static firings, all but one during the 1957 - 1958 school year. It may have been that one of those firings involved two sections: a low-power firing to test the instruments; and a "program" firing described by the *Tatler*.

16. Ibid. The "modern solid-propellant" was ammonium perchlorate composite propellant (APCP).
17. Obtaining a building permit for the Rocket Society's proving ground involved much red tape. ("L. R. S.," *Tatler*, February 12, 1960.) An eighteen month controversy with the City of Seattle delayed installation of electric power at the site until March 6, 1961. ("Mr. Hiltner Speaks," *Tatler*, April 29, 1960; "Canaveral Kids Annually AOK," *Tatler*, June 3, 1961.)
18. This description of zinc-sulfur propellant is from Gary Jacobs, "Types of Propellants," accessed February 29, 2012, http://www.jacobsrocketry.com/aer/propellant.htm.

> Zinc-Sulfur
>
> In the early days of experimental rocketry powdered zinc and sulfur were a common propellant. This was also referred as "micrograin." The optimum mixture was 2.04 parts zinc to one part sulfur by weight. Its burn rate depends on how small the particle size is for each and how much it is compressed. The more dense it is compacted, the slower the burn rate. Its burn rate is between 14 and 290 inches per second. At 160 lbs/ft3 and 1000 psi, the following has been measured*:
>
> Burn rate - 90 in./sec
> Flame Temp - 2600 F
> Effective Exhaust Velocity - 1490 ft/sec
> Specific Heat Ratio - 1.25
> Molecular Weight - 97.45 lbs / mole
> Specific Impulse - 45 sec
>
> * from "How to Make Amateur Rockets", John H. Wickman, 2nd Ed, (publisher CP Technologies, 1997) pg 3-3
>
> Because it is so difficult to compress the powder to a known value consistently, rocket motors made with this formula typically either don't have much power and may not get off the launch pad, or they blow up from over pressurization. It is not used by any serious rocketeers today.

19. "L.R.S.," *Tatler*, October 29, 1959.
20. The 800 pound amateur thrust record is mentioned in the 1959 *Numidian*. However, the yearbook notes on the Rocket Society did not claim it had broken the record based on the estimated thrust of the XLR-2b motor.
21. "Rocket Society," *Numidian* 1960, 30.
22. "Mr. Hiltner Speaks," *Tatler*, April 29, 1960.
23. "Rocket Society," *Numidian* 1960, 30.
24. Ibid. The *Numidian* reported that "the Lakeside Rocket Society . . . began its spring test series. The primary purpose of this series was to evaluate the effectiveness of ammonium perchlorate as a propellant." This statement appears to have discounted a number of unsolved technical problems, making it more of an announcement than a statement of fact. However, Bill Carter '63 recalls: "I remember going to a test firing but I wasn't involved with preparing the propellant, and all I know about it is that it was a solid and I think it was a mixture of some sort of salt (perchlorate seems reasonable) and some organic compound." (Bill Carter, e-mail to the author, September 17, 2012.)
25. "Rocket Society," *Numidian* 1961, 37.
26. Ibid.
27. "Rocket Society Blasts Two Thrust Buckets: LRS Fires Successfully," *Tatler*, February 24, 1961.
28. Ibid.
29. Ibid. Regarding the XLR-3A motor explosion, the *Tatler* reported: "At about four-tenths of a second after zero-time (3:15 PM) as shown by the oscillograph, a sudden thrust peak occurred, rising sharply to 510 pounds and then dropping back to zero at X+.65 seconds. This peak was accompanied by a loud report heard as far as Northgate, and a pinggg! As the nozzle bounced in front of the test cell and flew into the woods, the test cell roof rose about three inches, and clouds of white smoke billowed from all the roof’s cracks and joints." I witnessed that test firing and remember it vividly. So did Whitney, who recalls: "The explosion I witnessed, when I was a sophomore (I think), from the concrete bunker, was of a rocket motor exploding upon ignition. So far as I know, the nozzle was never found: it traveled that far into the woods. We were using a slightly twitchy compound." (Ross Whitney, e-mail to the author, September 17, 2012.)

Shortly after this incident, a sand filled blast deflector was constructed to prevent stray rocket nozzles and other detritus from explosive test firings being launched toward Northgate Mall.
30. "Firing Procedure Sheet: Rules of Conduct," undated, issued by the LRS. Perthau is named as one of the Range Safety Officers. Therefore, the "Firing Procedure Sheet" must predate his graduation in June

1961.

Rule No. 1: "The idea of personal safety and avoidance of injury must be uppermost in the minds of everyone at all times." The "Firing Procedure Sheet" contained eleven additional rules of conduct for participants in LRS firings.

31. "Rocket Society Blasts Two Thrust Buckets: Lakeside Rocket Society Scores On Second Successful Firing," *Tatler*, February 24, 1961.

32. "- A Publication of the Lakeside Rocket Society-," October 14, [1961].

33. Actually, this may have been the third record set by the Rocket Society, twice breaking its own record in the process. The XLR-2b, test fired on May 4, 1959, produced thrust of approximately 800 - 1,000 pounds. The XLR-2A, test fired on March 24, 1961, had a reported 1,200 pounds of thrust. However, no thrust / time record of the test firing was obtained. On the other hand, a thrust / time record of the XLR-4A test firing was obtained, documenting the motor's record-setting performance.[33.1]

Based on its total impulse of 1,224.76 Newton-sec., the XLR-4A motor would be in the "J" motor class (High Power, Level 2) under NAR Standard Motor Codes.

The National Association of Rocketry (NAR) is the governing body for the sport/hobby of model rocketry in the United States.[33.2] Established in November 1957 by Orville Carlisle and G. Harry Stine, NAR's mission is "to aid and encourage by all suitable means all people interested in model rocketry and its related sciences."[33.3]

Stine, a former safety officer at the White Sands Proving Grounds, wrote the safety code for the organized sport of model rocketry.[33.4] NAR also developed the Standard Motor Codes, based on total impulse, for sport rocket motors sold in the United States.[33.5] Today, most amateur rocketeers assemble their rockets from kits employing a motor (or, in some cases, motors) obtained from a commercial supplier. Some amateur experimental rocketeers do design and build their own motors, all but the largest of which fall within the established NAR classification system.

Under the NAR classification system, rocket motors are classified "1/8A" through "O." Motors in each class have double the power (upper limit) of motors in the preceding class; motors ranging from "G" to "O" are classified as high-power motors rather than model rocket motors. The classification system does not end at the letter "O," however. An amateur built, single-stage rocket powered by a "P" motor (total impulse > 40,960.00 N-sec.) reached the edge of space.[33.6]

33.1. "- A Publication of the Lakeside Rocket Society-," October 14, [1961].

33.2. Wikipedia contributors, "National Association of Rocketry," accessed February 28, 2012, http://en.wikipedia.org/wiki/National_Association_of_Rocketry.

33.3. Trip Barber, "How the NAR Works," *Sport Rocketry*, March/April 2009, accessed February 28, 2012, http://www.nar.org/pdf/How%20the%20NAR%20Works%20%28Mar%202009%29.pdf, 38.

33.4. "G. Harry Stine: Paying Forward," [n.d.], video clip, accessed March 1, 2012, YouTube, www.youtube.com/watch?v=yXmpnknOOlc.

33.5. National Association of Rocketry, "High Power Rocket Safety Code," accessed February 29, 2012, http://www.nar.org/NARhpsc.html.

33.6. Civilian Space eXploration Team, "Official Altitude Press Release," accessed February 29, 2012, http://ddeville.com/derek/CSXT.htm.

34. "- A Publication of the Lakeside Rocket Society-," October 14, [1961].

35. "Rocket Society," *Numidian* 1962, 45.

36."Senate Meeting," *Tatler*, May 31, 1963.

37. *LRS Bulletin*, Vol. V, No. 2, February 13, 1962.

38. "-A Publication of the Lakeside Rocket Society-," Vol V No 1, 10/22/62.

39. The following list of companies and individuals contributed materials, equipment or services to the Lakeside Rocket Society. The list was compiled from a variety of sources and may not be complete.

Alphabetically: Alaska Copper and Brass Company, Alleghany Ludlum Steel Co., American Standard Instrument Co. (a/k/a Norwood Controls Division of American Standard, a/k/a Norwood Products), Boise-Cascade Corp., Clark Laboratories (a/k/a Clark Electronic Labs), Consolidated Electrodynamics Corp., "generous doctor," Graystone, Isaacson Iron Works, John Drumheller's father, Kenmore Building Materials Company, Inc., Layrite Concrete Products, Houston Instrument Company, Mr. Isaacson, Mr. J.R. Stein, Young Iron Works (subsidiary of Isaacson Iron Works).

Their donations:

"Two generous companies [Greystone and Layrite Concrete Products] donated 360 concrete blocks for the static test cell, where the rocket motors are fired, and a generous doctor donated an electrocardiograph machine, which will be adapted to measure the rocket's thrust." ("Eventually," *Tatler*, March 5, 1959; "L.R.S.," *Tatler*, October 29, 1959.)

Kenmore Building Materials Company, Inc. donated six cubic yards of concrete. ("L.R.S.," *Tatler*, October 29, 1959.)

"The roof of the cell was built from railroad ties given by John Drumheller's father." (Ibid.)

"The Alaska Copper and Brass Company will donate the copper for the nozzles." ("L.R.S.," *Tatler*, March 11, 1960.)

Houston Instrument Company donated a recording oscillograph. ("L. R. S.," *Tatler*, June 4, 1960.)

"Thanks to the willing hands of Mr. J.R. Stein of Sitka, Alaska, the society obtained a new nozzle, thus putting the number of them in possession at this time at two." (Ibid.)

"A new system for retaining the rocket during firing, donated by Mr. Isaacson, was installed and tested." ("Lakeside Rocket Society Scores on Second Successful Firing," *Tatler*, February 24, 1961.)

Boise-Cascade Corp. donated 80 6"dia.x8' fence posts. ("-A Publication of the Lakeside Rocket Society-," Vol V No 1, 10/22/62.)

Norwood Products (i.e. Norwood Controls Division of American Standard) donated a pressure transducer. Consolidated Electrodynamics Corp. and Baldwin-Lima-Hamilton "indicated their willingness to donate pressure transducers to the LRS." (*LRS Bulletin*, Vol. V, No. 2, February 13, 1962.) Consolidated Electrodynamics Corp. followed through with the donation of a pressure transducer. The two transducers were valued at $150 each. ("Rocket Society Soundings," *Tatler*, January 7, 1962.)

Boeing calibrated the pressure transducers donated by Norwood Products and Consolidated Electrodynamics Corp.. ("President Maps L.R.S. Future In Tatler Letter," *Tatler*, September 13, 1965)

Clark Laboratories donated a thrust transducer. ("Rocket Society Soundings," *Tatler*, January 7, 1962.)

Graystone and Layrite Concrete Products each donated 100 8x8x16 inch concrete blocks. (*LRS Bulletin*, Vol. V, No. 2, February 13, 1962; "Pfff:Pop," *Tatler*, March 9, 1962.)

"So far it has managed to acquire four thermocouples for temperature measurement, some special lacquer for use in measurement of strain and stress, and one pressure transducer which will accurately measure pressure in the 0-2000 psia pressure range. Negotiations for the donation of other pressure transducers are still in progress." ("Pfff:Pop," *Tatler*, March 9, 1962.)

Young Iron Works donated a test stand for the rocket motors. (*LRS Bulletin*, Vol. V, No. 2, February 13, 1962.) Young Iron Works was a subsidiary of Isaacson Iron Works. (Peter Isaacson, e-mail to author, August 20, 2011.)

Alleghany Ludlum Steel Co. and American Standard Instrument Co. (Norwood Controls [?]) are credited with making unspecified donations to the LRS. ("LRS," *Tatler*, June 1962.)

Clark Electronic Labs donated a force transducer. ("- A Publication of the Lakeside Rocket Society-," October 14, [1961].)

40. See footnote 22.

41. "The Woes of The LRS," *Tatler*, January 10, 1964.

42. Ibid. This is a bit technical. Burn rate is profoundly affected by combustion chamber pressure in accordance with Saint-Robert's Law, $r = aP_c^n$ where r is the burn rate, a is the burn rate coefficient, n is the pressure exponent, and P_c is the combustion chamber pressure.[42.1] The values of a and n are determined empirically for a particular propellant formulation.[42.2] A low value of n (< 1) is critical for a safe propellant. For example, the value of n is 0.35 for the Space Shuttle Solid Rocket Boosters.[42.3] The pressure exponent for a typical ammonium perchlorate - polyester resin propellant is 0.51.[42.4] For an ammonium perchlorate - Paraplex P-13 propellant, the pressure exponent was 0.67.[42.5] The n value for AP-P13 propellant was substantially higher than for the typical ammonium perchlorate - polyester resin propellant but still comfortably below the critical value of 1.0, where the pressure exponent becomes very unforgiving.

42.1. "Basics of Space Flight: Rocket Propulsion," accessed September 24, 2012, http://www.braeunig.us/space/index.htm.

42.2. Ibid.

42.3. Ibid.

42.4. Francis A. Warren, Eugene L. Anderson, Ralph J. Wheeler and Robert J. Martin, "Chlorates and Perchlorates Their Characteristics And Uses (U)," accessed July 29, 2012, http://www.dtic.mil/cgi-bin/GetTRDoc?AD=AD318741&Location=U2&doc=GetTRDoc.pdf.

42.5. Martin Summerfield et al., "Burning Mechanism of Ammonium Perchlorate Propellants," in *Solid propellant rocket research: a selection of technical papers based mainly on a symposium of the American Rocket Society*, ed. Martin Summerfield (New York: Academic Press, Inc. 1960), 156-157.

43. Carter recalls going to a test firing of what may have been a perchlorate motor. See footnote 24. However, the May 9, 1964, test firing is the first test firing of a perchlorate motor that I was able to document.

44. "Lakeside's Own NASA: L R S '64 - '65," *Tatler*, October 27, 1964. Note: This article appears on page 3 of the October 27, 1964, issue of the *Tatler*. Pages 2 and 3 of the issue are erroneously dated "September 11, 1964."

45. Bruce LaZerte, e-mail to author, July 6, 2012.

46. Ibid.

47. Marjorie Jones with staff photographer Larry Dion, "Successful Society: Lakeside Pupils' Solid Fuel 'Doesn't Blow Up' on Pad," *The Seattle Times*, May 10, 1964, 61.

By Marjorie Jones

. . . . Three, two, one, zero, FIRE!

With a muffled roar, a whoosh and a cloud of steam which enshrouded the little testing cell, the solid fuel burned brightly and steadily in the rock core.

Another roar, this from the entire membership of the Lakeside Rocket Society, hidden under the protective covering of concrete and dirt-filled bunkers, proclaimed the firing a success.

"It was beautiful! It was lovely;" shouted mop-haired Bruce LaZerte, 17, chairman of the society.

"It didn't blow up! It didn't blow up!" Randy Kay, 18, one of the chief rocket-fuel testers, yelled.

"Now I can get some sleep," said sleepy Tony Mates, 15, who hadn't slept in 35 hours. Tony was the electronics technician.

THE SOCIETY, composed of about 20 pupils at the private school, has been operating since Sputnik was launched in 1957.

"We wanted to beat the Russians," quipped Peter Isaacson, 18.

The "launching site" is across the road from the school at the wooded corner of First Avenue Northeast and Northeast 145th Street.

From a one-button operation the society has developed fairly sophisticated testing apparatus.

YESTERDAY the boys, taking a solid-fuel, ammonium perchlorate, with polystyrene as a reducing agent, made a static test for thrust, pressure in the stainless steel rocket core and temperature. The rocket alone cost an estimated $500.

The rocket was strapped to a firing platform. The various tests were made through apparatus wired to register on an instrumentation panel in the firing cell, separated from the rocket by a concrete wall.

The firing was done from a concrete bunker about 100 feet away. It was filled with more instruments, including an oscillograph worth about $2,000, loaned by The Boeing Co., and countdown instrumentation, a public-address system and other equipment. Much of it was scrounged from the boys' father.

PICTURES were taken by cameras buried in bunkers. A major safety factor was a two-key system. Kay and LaZerte had different keys. Unless both keys were inserted there could be no firing.

Dr. Daniel Morris, chemistry instructor and faculty advisor on the rocket, said that precautions always are taken and that there never had been an accident.

For awhile it looked as if there wouldn't be a firing yesterday. Delay followed delay. Major systems all went well but faulty water-hose connections, needed for the cooling system, almost canceled the testing.

"We operate under Murphy's Law," Dr. Morris said smiling. "Murphy's Law says if something can go wrong, it will."

AFTER TWO HOURS of tinkering and frustration in a pouring rain, all systems were "go."

When the smoke and steam cleared, the little rocket sat on the platform in excellent condition.

"I'm very pleased," Dr. Morris said, smiling."It was perfect."

"Gee, maybe we'll get to go to Yakima yet," one of the boys remarked.

In two years the Rocket Society hopes to advance to the point where it can launch a real rocket from the Yakima Firing Range.

"We'll make it," another said with certainty.

48. Beginning in 1964, the *Numidian*'s coverage of student activities became increasingly pictorial. The pictures grew larger at the expense of the text, which shrank until the yearbook was little more than a photo album without picture keys, presenting the author with a challenging research problem.
49. Dr. Morris and Mr. Dougall were fans of the Rocket Society. Dexter Strong was, at best, tolerant of the LRS; its activities were problematic from a liability and community relations standpoint. The headmaster was probably glad to see the Lakeside Rocket Society fading away and was ready to pull the plug on the student organization.
50. The explosive May 8, 1965, test firing earned the Rocket Society two back-to-back articles in *The Seattle Times*: "Pupils' Test Rocket Is Loud Failure," May 9, 1965, p. 71, and "School-Built Rocket Goes Off Early," May 10, 1965, p. 6.

Both articles give the impression that a rocket was fired aimed "parallel to the ground." This was not the case. The motor was mounted horizontally on the test stand and remained stationary during the test firing. When the motor exploded, ejecting the nozzle, it became lodged in the blast deflector.

51. Although the Rocket Society had chosen test-stand rocketry over flight vehicles, the hope of one day building and flight testing a "real rocket" was perennial. Eastern Washington — specifically the Yakima Firing Range — was the presumed location of such a flight test.

52. "President Maps L.R.S. Future In Tatler Letter," *Tatler*, September 13, 1965. Note: When Mates speaks of "rocket(s)," he is referring to a rocket motor or motors and not flight vehicles.

53. "President Maps L.R.S. Future in Tatler Letter," *Tatler*, September 13, 1965.

54. "LRS Prepares Third Test Looks To Spring Flight," *Tatler*, March 9, 1966.

55. Ibid.

56. Ibid. "The first was a success in that it ignited and burnt and that all safety procedures and electronics were operative. Unfortunately, due to the confusion, weather, and wrath of God, someone (unnamed herein) forgot to turn on a rather essential power supply. As a result, the chamber pressure transducer failed to read." At the time, the LRS did not have a (working) force transducer; no thrust readings were obtainable. "At the second firing, the general procedure went much better, there being much less confusion, panic and wrath of God. Between the two we had acquired a force transducer, capable of measuring 0-5000 lbs. thrust. This we used on the rocket, in conjunction with the pressure transducer previously mentioned. Both were turned on this time, by the way, and for that matter everything else worked almost perfectly. Save for a recalcitrant Polaroid camera and a rather scratchy public address system, all was in good shape. The only problem was the rocket. It simply did not develop enough thrust to register on our transducer. Instead of burning for a fast 4 or 5 seconds, the rocket motor burned for 52 seconds." In other words, the motor fizzled.

57. A photograph of "LS Model Rocker Club" members appears in the 1966 and 1967 *Numidian*'s, implying the LMRC was started during the 1965 - 1966 school year.

58. "LMRC HAS FIRING!," *Tatler*, March 3, 1967.

AMMONIUM PERCHLORATE

59. Wikipedia contributors, "Rocket propellant," accessed February 27, 2012, http://en.wikipedia.org/wiki/Rocket_propellant.

60. Metallic fuels, usually powdered aluminum, are added to APCP to improve combustion characteristics.[60.1]

60.1. Boyd Hansen, Felix F. Chen and Michael D. McPherson, "Chemical Explosives and Rocket Propellants: Part II. Rocket Propellants," in *Riegel's Handbook of Industrial Chemistry*, 10th Edition, edited by James A. Kent, Ph.D., (Kluwer Academic / Plenum Publishers, New York, 2003), accessed February 27, 2012, http://books.google.com/books?id=j3AwCqvqIzEC&pg=PA1353&lpg=PA1353&dq=%22Polaris+propellant%22&source=bl&ots=3U8rJqiScS&sig=CNYhJtVAUWZ0D22yPyE2NN_JB6w&hl=en&ei=Yh_MTtOgErPUiALuxLn5Cw&sa=X&oi=book_result&ct=result&resnum=3&sqi=2&ved=0CDIQ6AEwAg#v=onepage&q=%22Polaris%20propellant%22&f=false,1348, 1349.

61. Jacobs, citing *How to Make Amateur Rockets* by John H. Wickman, 2nd Ed, pg 3-3, gives a measured Isp of 45 seconds as an example of zinc-sulfur characteristics. According to Vyverman, reports from the mid-nineteen-forties credit the propellant with a specific impulse ranging from 20 seconds to 150 seconds.[61.1] The Rocket Society's XLR-4A motor had an Isp of 89.3 seconds.[61.2]

By comparison, a castable composite of ammonium perchlorate (50% - 85%) and elastomer (50% - 15%) produces an Isp in the range of 175 - 240 seconds.[61.3]

The poor relative performance of zinc-sulfur is caused by its external combustion. Most of the propellant burns outside the combustion chamber, enhancing a rocket's display of tail flame but detracting from its performance.[61.4]

61.1. Tony Vyverman, "A brief history of zinc and sulfur propellants," accessed February 27, 2012, http://users.cybercity.dk/~dko7904/Notes/chapter_1_history.pdf.

61.2. "A Publication of the Lakeside Rocket Society," giving "DATA on the Oct. 14th. FIRING of the XLR-4A." The test firing of the XLR-4A motor was mentioned in the 1962 *Numidian* and took place on October 14, 1961. The *Numidian*, however, reported the motor's thrust incorrectly: "1150 pounds of thrust for one second" instead of the actual average thrust of 1,190 lbf.

61.3. Andre Bedard, "Composite Solid Propellants: The detailed chemistry and development of composite solid propellants," accessed March 3, 2012, http://www.astronautix.com/articles/comlants.htm.

61.4. Wikipedia contributors, "Solid fuel rocket," accessed February 29, 2012, http://en.wikipedia.org/wiki/Solid-fuel_rocket.

62. Wikipedia contributors, "Amateur rocketry," accessed March 1, 2012, http://en.wikipedia.org/wiki/Amateur_rocketry. APCP formulated using a suitable binder elastomer fuel can be made tough and rubbery. The propellant resists cracking under the shock of ignition, a major problem with zinc-sulfur propellant.

A zinc-sulfur grain can be "cold cast in the rocket" using either alcohol or acetone as a solvent.[62.1, 62.2] The zinc-sulfur grain of the record-setting XLR-4A motor was cast in the motor body; the grain configuration, "tubular, case-bonded."[62.3]

Although casting a zinc-sulfur grain was an improvement over packed-powder grain formation, the cast grain remained vulnerable to shock. The explosive failure of the XLR-3A motor (see footnote 29) was blamed on an "overpowered igniter which cracked or shattered the grain."[62.4]

62.1. "blast off," *Tatler*, October 5, 1960.

62.2. "Rocket Society Blasts Two Thrust Buckets: LRS Fires Successfully." *Tatler*, February 24, 1961.

62.3. "- A Publication of the Lakeside Rocket Society-," October 14, [1961].

62.4. "Rocket Society Blasts Two Thrust Buckets: Lakeside Rocket Society Scores On Second Successful Firing," *Tatler*, February 24, 1961; "Canaveral Kids Annually AOK," *Tatler*, June 3, 1961.

63 – 67. Andre Bedard, "Composite Solid Propellants: The detailed chemistry and development of composite solid propellants."

68. Cliff Lethbridge, "POLARIS A1 Fact Sheet," accessed May 23, 2014, http://www.spaceline.org/rocketsum/polaris-a1.html.

69. Matt Walker, "Solid Rockets & Aluminum," accessed May 23, 2014, http://www.aerospaceweb.org/question/propulsion/q0246.shtml.

70. Invented by Dr. Herman A. Bruson, Paraplex P-13 was a flexible polyester resin made by ROHM & HAAS. In addition to being used as a binder elastomer fuel in solid propellant formulations, Paraplex P-13 was adapted for potting and encapsulating electronic and electrical components. The following are selected properties of Paraplex P-13 drawn form a technical data sheet on the material ("P-Series, Polyester Resins, Technical Data, Pl-451a : Paraplex P-13") supplied by "Rocket" Raul Cabrera. (See footnote 120.)

TYPICAL PROPERTIES AS SUPPLIED IN LIQUID FORM

Monomer	**Styrene**
Polyester Concentration (%)	50
Viscosity (25°C.) Centipoises	415
Color – Varnish Color Scale (Gardner 1933)	3
Specific Gravity (25°C.)	1.02
Acid Number	5

SPI* REACTIVITY, CURING, STABILITY CHARACTERISTICS

Reactivity Tested in Water Bath @ 180°F.	**1% Benzoyl Peroxide**	**0.5% Benzoyl Peroxide**
Gel Time (minutes)	6.6	7.1
Time to Peak (minutes)	6.0	6.4
Peak Exotherm °F.	205	200
Catalyzed Stability, Days @ 25°C.	6	12

*The Society of the Plastics Industry, Inc.

Paraplex P-13 could also be catalyzed with methyl ethyl ketone peroxide accelerated with cobalt napthenate. The gel time of catalyzed, accelerated Paraplex P-13 ranged from approximately 45 minutes to approximately 110 minutes at 25°C. (77°F.).

TYPICAL PHYSICAL PROPERTIES OF UNREINFORCED CASTINGS
(At standard ASTM conditions 23°C [73.4°F.] unless noted)

Flexural Properties	
Elastic Modulus (psi)	6,400
Tensile Properties	
Ultimate Strength (psi)	1,600
Ultimate Elongation (%)	220
Hardness Shore "A"	80-85
Polymerization Shrinkage (Volume–%)	9.0
Specific Gravity (25°C.)	1.122
Water Absorption % wt.	

after 7 days immersion @ 25°C. 0.4

71. John Wickman, "Frequently Asked Questions on Making Your Own Rocket Motors," accessed February 27, 2012, http://www.space-rockets.com/faq.html.

For example, a document examined by the author in the preparation of this article, "Chlorates and Perchlorates Their Characteristics And Uses (U)," prepared for the U.S. Navy's Bureau of Naval Weapons by the Department of Chemistry and Chemical Engineering of Southwest Research Institute, was classified "confidential" on 15 May, 1960. The document was declassified by the DoDD on 31 May. 1972, and by the USNSSC on 5 September 1975.

72. "L. R. S.," *Tatler*, February 12, 1960.

73. Dr. Wernher von Braun "supposedly wrote a letter to a magazine(??) – apparently based on publicity or LRS (or other high school) activity regarding solid fuel development – saying that this is not for amateurs to mess with and they shouldn't be doing this kind of research.[73.1] This was 'common knowledge' at the time, and I assume that there was a factual basis for the claim (pre-internet urban legends more reliable, and I think Doc Morris mentioned it – with a laugh), but can't recall if I actually saw something in writing about it." (Randall E. Kay, e-mail to author, July 24, 2012.)

73.1. Dr. Wernher von Braun (1912 – 1977) was one of the most important rocket developers and champions of space exploration during the period between the 1930s and the 1970s. Von Braun was the leader of the "rocket team" which developed the V-2 ballistic missile for the Nazis during World War II. The V-2s were manufactured in a forced labor factory called Mittelwerk and employed against targets in Europe beginning in September 1944.

Anticipating the victory of the Allies over the Third Reich, von Braun engineered the surrender of 500 of his top rocket scientists, along with plans and test vehicles, to the Americans. For fifteen years after World War II, von Braun worked with the U.S. Army in the development of ballistic missiles.

In 1960, his rocket development center transferred from the Army to the newly established NASA and received a mandate to build the giant Saturn rockets. Accordingly, von Braun became director of NASA's Marshall Space Flight Center and the chief architect of the Saturn V launch vehicle, the superbooster that would propel Americans to the Moon. ("Biography of Wernher Von Braun," accessed June 2, 2014, http://history.msfc.nasa.gov/vonbraun/bio.html.)

During the era of the Space Race, Dr. Wernher von Braun personified "rocket science." However, his involvement in the activities at Mittelwerk remains a matter of debate to this day. Satirist Tom Lehrer wrote a song about von Braun, in which the former Nazi collaborator is described as "a man whose allegiance / is ruled by expedience." Von Braun's willingness to lend his considerable scientific and engineering talents to leading any military or civilian rocketry enterprise was captured by Lehrer in this memorable couplet: "Once the rockets are up, who cares where they come down. / 'That's not my department,' says Wernher von Braun."

74. "L.R.S.," *Tatler*, March 11, 1960.

75 – 77. Ibid.

78. "Mr. Hiltner Speaks," *Tatler*, April 29, 1960.

79. Sutherland, G. S., "Mechanism of Combustion of an Ammonium Perchlorate-Polyester Resin Composite Solid Propellant," Ph.D. Thesis, Aeronautical Engineering, Princeton, 1956. Sutherland's thesis is cited in Martin Summerfield et al., "Burning Mechanism of Ammonium Perchlorate Propellants," 161, footnote 11.

80. Martin Summerfield et al., "Burning Mechanism of Ammonium Perchlorate Propellants."

81. "The resin P-13 was chosen as one of many submitted by various companies because of the simplicity of processing, desirable physical properties, absence of personnel hazards, and because it is representative of a wide class of solid hydrocarbon fuels." (Martin Summerfield et al., "Burning Mechanism of Ammonium Perchlorate Propellants," 143-144.)

82. "L.R.S.," *Tatler*, October 29, 1959 [correct date], "L. R. S.," *Tatler*, February 12, 1960, "L.R.S.," *Tatler*, March 11, 1960, "blast off," *Tatler*, October 5, 1960, "The LRS," *Tatler*, October 16, 1963, "The Woes of The LRS," *Tatler*, January 10, 1964. *Numidian* articles: *Numidian* 1960 ("Activities"), 30; *Numidian* 1962, 45.

83. "L.R.S.," *Tatler*, May 31, 1963.

84. *LRS Bulletin*, Vol. V, No. 1, October 22, 1962.

85. Randall E. Kay, e-mail to the author, July 24, 2012. Working in the laboratory, McKibbin investigated numerous variants on the basic AP-P13 formula.

86. An opacifier is sometimes added to solid propellants to reduce infrared preheating during combustion.

87. A copy of McKibbin's notes on "Ammonium Perchlorate Fuel Combinations" is in The Lakeside School archives. The date of the notes is uncertain but they were apparently compiled in 1964 - 1965, while McKibbin was head of the Rocket Society and its chief fuel chemist.

VARIOUS AMMONIUM PERCHLORATE FUEL COMBINATIONS

compiled by Bob McKibbin

A: 5.0 gm. P-13
.2 gm. Benzoyl O_2
14.8 gm. NH_4NO_3

B: 5.0 gm. P-13
.15 gm. MnO_2
14.8 gm. NH_4NO_3

C: 5.0 gm. P-13
14.8 gm. NH_4NO_3

D: 5.0 gm. P-13
.2 gm. Benzoyl O_2
.1 gm. MnO_2
14.8 gm. NH_4NO_3

E: 5.0 gm. P-13
.2 gm. Benzoyl O_2
10.0 gm. Al dust
 4.8 gm. NH_4NO_3

F: 5.0 gm. P-13
.2 gm. Benzoyl O_2
13.6 gm. NH_4NO_3
 1.2 gm. Al dust

G: 5.0 gm. P-13
.2 gm. Benzoyl O_2
14.8 gm. $NaNO_3$

H: 5.0 gm. P-13
.2 gm. Benzoyl O_2
.5 gm. MnO_2
.5 gm. Al dust
12.4 gm. NH_4NO_3

I: 5.0 gm. P-13
.2 gm. Benzoyl O_2
14.8 gm. NH_4NO_3
10.0 ml. Acetone

J: 5.0 gm. P-13
.2 gm. Benzoyl O_2
.1 gm. Al dust
14.7 gm. NH_4NO_3

K: 5.0 gm. P-13
.2 gm. Benzoyl O_2
14.8 gm. NH_4NO_3
10.0 ml. CCl_4

Fuel combinations tried using NH_4NO_3 which was later found to be NH_4ClO_4. $NaNO_3$ didn't work at all. Al dust appeared to add only sparks to the propellant. Solvents for P-13 (acetone & CCl_4) left bubbles in the grain. Of all the compositions "D" appears to work best, with "A" following that.

88. McKibbin attached a note to the copy of his old notes on propellant testing that he sent to me on March 15, 2014. The note reads: "My notes on propellant testing. No date, but I'm fairly sure these tests dictated the mix for the rocket that blew up. Still had a lot to learn about scientific method and keeping good notes!"
89. "L.R.S.," *Tatler*, October 29, 1959.
90. McKibbin's notes on "Ammonium Perchlorate Fuel Combinations."
91. This is not as far fetched as it might seem. If the Rocket Society's fuel chemists had used McKibbin's formulation "F" as a starting point and varied the relative proportions of P-13 and Al dust (while keeping the amount of oxidizer fixed at 68%), they could easily have found the sweet spot at

14% - 20% aluminum content.[91.1]

91.1. Matt Walker, "Solid Rockets & Aluminum."

92. Drumheller won a prestigious Westinghouse Science Award for building "DRINAC" (Digital Relay Integrator, Numerator, and Calculator). (McCuskey's "Lakeside History.") Also called the "EMNIAC" for Electro-Mechanical Numerator, Integrator, and Calculator, DRINAC was built from toggle switches and surplus telephone company stepping relays.

Despite resembling Babbage's Engine more than an IBM main-frame computer, DRINAC was potentially powerful. "Eventually, the computer will handle advanced algebra, trigonometry, and calculus problems, and will be used by the Rocket Society to compute what the members can not. If your math course gets rough, see Drumheller and EMNIAC, Inc., 50¢ per problem." ("The Thinker," *Tatler*, [date ? - issue follows November 4, 1958])

93. "Lakeside Rocket Society," *Numidian* 1963, 39.

94. This was common knowledge among Rocket Society members at the time. McKibbin supplied a first-hand description of the ammonium perchlorate supply stored in Dr. Morris' chemistry laboratory.[94.1]

94.1. Robert McKibbin, telephone conversation with the author, March 4, 2014.

95. A low oven (200°F.) for 60 - 90 minutes would have cured the Paraplex P-13 binder elastomer fuel.[95.1] However, baking the rocket motor in the oven probably would not have degassed the propellant mixture.

Casting large amounts of solid propellant reliably and consistently involves an elaborate process, usually computer controlled. The blending and casting takes place under vacuum and the propellant blend is spread thin and scanned to assure no large gas bubbles are introduced into the motor. Solid fuel rockets are intolerant to cracks and voids and often require post-processing such as x-ray scans to identify faults."[95.2]

Manufacturing techniques suitable for building Space Shuttle boosters and large military rockets don't necessarily apply to small, solid fuel rockets. The successful firing of the Rocket Society's first 200-series motor proves that. But those elaborate and costly manufacturing techniques were developed for a reason: solid propellant grains must be virtually perfect for the rocket to work properly and not explode.

95.1. Battelle Memorial Institute, "Interim Report on The Development Of Laminated Body Armour," September 30, 1948, accessed March 19, 2014, http://www.dtic.mil/dtic/tr/fulltext/u2/a954855.pdf.

95.2. Wikipedia contributors, "Rocket propellant," accessed May 26, 2014, http://en.wikipedia.org/wiki/Rocket_propellant.

96. The purpose of the dowel or cone shaped wooden plug was to form the grain geometry, either cylindrical (after the dowel was removed) or a solid block of propellant with a cone shaped depression in the end. Either geometry would increase the burning surface (as compared to a flat circle) and result in faster propellant combustion and higher motor impulse.

97. McKibbin could not recall for sure if it was Weston who helped him prepare the batch of propellant. The author was unable to contact Weston for this article.

98. Robert McKibbin, telephone conversation with the author, March 4, 2014.

99. Ibid. McKibbin recalled the motor being an end-burner, i.e. the burning surface was a flat circle the diameter of the grain. As the propellant mixture settled, it would have become lopsided. As a result, combustion would have progressed unevenly with unpredictable results. Moisture from the water bath may have seeped into the motor; the trapped moisture could have caused steam cracking of the grain during combustion.

100. Tony Mates, e-mail to the author, June 1, 2012 2:04 PM.

101. Ibid.

XLR-200 ROCKET MOTOR

102. The photograph of the disassembled XLR-201 motor shows a considerably simplified unit (as-built). Gone is one of the ports for pressure transducers. Also missing is the safety diaphragm port. In practice, the nozzle was the de facto pressure relief valve, the Achilles' heel of the design.

103. "Rocket Society," *Numidian* 1960, 30.

104. *LRS Bulletin*, February 13, 1962.

105. The nomenclature used by the LRS to designate motors and nozzles changed over time. The original designation of motors/nozzles followed this pattern: XLR-1a, XLR-1b, ..., XLR-2a, XLR-2b, ..., etc. through XLR3c. On January 28, 1961, the date of the XLR-1A firing, a new series of motors and nozzles was begun, starting with the designation XLR-1A.

Development of a perchlorate motor resulted in another change in nomenclature. "Henceforth, all ZnS motors will be designated as 100 series instruments. All perchlorate motors will be of the 200 series. The designs for the 101 and 201 motors have been worked out."[105.1]

105.1. *LRS Bulletin*, Vol. V, No. 1, October 22, 1962.

106. "Rocket Society," *Numidian* 1962, 45.

107. Ibid.
108. "- A Publication of the Lakeside Rocket Society-," October 14, [1961].
109. Based on a reading of "L.R.S.," *Tatler*, March 11, 1960, and "L. R. S.," *Tatler*, June 4, 1960.
110. "L.R.S.," *Tatler*, March 11, 1960, and "L. R. S.," *Tatler*, June 4, 1960.
111. "- A Publication of the Lakeside Rocket Society-," October 14, [1961].
112. Ibid. Preventing the throat of the nozzle from eroding during firings was a problem that occupied amateur experimental rocketeers. "The secret to our success in rocketry," said Homer Hickam of the *Rocket Boys*, "were the finely machined DeLaval nozzles produced by the mine machine shop experts that were then lined with a ceramic coating."[112.1] The nozzle of the Auk XXV, launched by the "Rocket Boys" in the spring of 1960, was covered with water putty as an ablative coating.[112.2]

Had the Rocket Society used the technique of coating nozzles with a ceramic material instead of chrome plating, fewer of its valuable nozzles might have met with "unfortunate fates."

Today, the nozzles would probably be made of graphite or glass-filled phenolic resin and would be more or less disposable.[112.3] How times have hanged!

112.1. Homer Hickam, "Did Auk XXXI break the sound barrier?" accessed November 8, 2012, http://www.imagiverse.org/questions/archives/aerospace_aviation1.htm.

112.2. Gary Bradshaw, "What's So Hard About Rocket Science? Secrets the Rocket Boys Knew," in [title], accessed November 11, 2012, http://repo-nt.tcc.virginia.edu/scitech_thinking/Bradshaw_11.pdf, 275.

112.3. Wikipedia contributors, "Ammonium perchlorate composite propellant," accessed March 1, 2012, http://en.wikipedia.org/wiki/Ammonium_perchlorate_composite_propellant.

113. "- A Publication of the Lakeside Rocket Society-".
114. Ibid.
115. Invented by Swedish inventor Gustaf de Laval in 1888 for use in steam turbines, the de Laval nozzle was implemented in rockets by Robert Goddard.[115.1] De Laval nozzles exploit the properties of supersonic flow to accelerate gasses beyond Mach 1, maximizing thrust. The de Laval (or convergent-divergent) nozzle is the most widely used design in rocketry applications.[115.2]

115.1. Dr. Robbert H. Goddard (1982 – 1945) was an American professor, physicist and inventor who is credited with creating and building the first liquid-fueled rocket, which he successfully launched on March 16, 1926. Goddard, after whom NASA's Goddard Space Flight Center is named, is considered the father of modern rocket propulsion.

115.2. Ivan Pandev, "A Brief Analysis of de Laval Nozzles and Nozzle Shocks," accessed December 4, 2012, http://cosmos.ucdavis.edu/archives/2011/cluster3/Pandev,%20Ivan
%20%28de%20Laval%20Nozzles%20&%20Nozzle%20Shocks%29.pdf.

116. "L.R.S.," *Tatler*, May 31, 1963. Unfortunately, the identity of that Seattle firm was not recorded for the sake of posterity. At least, I have not been able to find a record of it in the *Numidians* and *Tatlers* from that era, or in the archival materials on the Rocket Society. Peter Isaacson recalls that Isaacson Iron Works lathed the nozzles.[116.1] "Thelen had the metal stock and a drawing. The machinist made a jig from the drawing to run the lathe work. I gather it was a challenge."[116.2]

116.1. Peter Isaacson, e-mail to the author, August 20, 2011.

116.2. Peter Isaacson, e-mail to the author, August 21, 2011.

SUMMARY AND ACKNOWLEDGMENTS

117. "Rocket Society Soundings," *Tatler*, January 7, 1962.
118. These are the seventeen test firings that I was able to document. As noted, others may have taken place but were not reported in the *Tatler*, *Numidian*, *LRS Bulletin*, etc. On the other hand, the 6th and 7th test firings took place on the same day, December 16, 1960. Only sketchy details of the test firings were reported in the *Tatler*. It is not clear whether one or two motors were test fired that day.

> 1st test firing took place in February 1958. Motor: XLR-1a. Fuel: ZnS. Thrust: 50+ lbs. (*Tatler*, October 29, 1959.)
>
> 2nd: March 1958. Motor: XLR-1b. Fuel: ZnS + boron. A boron compound was added to the basic zinc-sulfur propellant with sub-par results. (*Tatler*, October 29, 1959.)
>
> 3rd: May 1958. Motor: XLR-2a. Fuel: ZnS. (*Tatler*, October 29, 1959.) Thrust: 207 lbs. (*Numidian* 1958.)
>
> 4th: May 1959. Motor: XLR-2b. Fuel: ZnS. Thrust, estimated at 800 - 1,000 lbs., bent the strain gauge. (*Tatler*, October 29, 1959.)
>
> Note: There is some confusion as to the number of test firings that took place

during the 1958 - 1959 school year. The *Tatler*, October 29, 1959, specifically mentions the XLR-1a (February 1958), XLR-1b (March 1958) and XLR-2a (May 1958) test firings. The XLR-2a test firing "completed the operations for the 1957 - 1958 school year."

In the same article, however, the *Tatler* states: "Since its formation, the society has conducted a total of five static firings," including the XLR-2b motor fired in May 1959. Further evidence of five test firings is "L.R.S.," *Tatler*, March 11, 1960, which refers to "the XLR-2a series last year." This suggests that the XLR-2a nozzle was used in more than one test firing. In the context of the March 11, 1960, article, "last year" would logically refer to 1959. The XLR-2b is the only recorded test firing that took place during the 1958 - 1959 school year. Therefore, despite the evidence that the 1958 - 1959 season ended with the LRS's fifth test firing, I have not added a possible second XLR-2a test firing to the total since no details of the test firing were recorded.

5th: April 7, 1960. "This test, though it did not meet expectations, was not a complete failure for through it the society gained much need[ed] information and experience." (*Tatler*, June 4, 1960.)

6th: December 16, 1960. Motor: XLR-3a (?) (*Tatler*, June 4, 1960). Fuel: ZnS. "Thrust was approximated at 300 pounds." (*Tatler*, February 24, 1961.)

"The Society has held four static firings to date, igniting a total of six sections." (*Tatler*, June 3, 1961.) The article provided details on the 7th through 12th test firings.

7th: December 16, 1960. Motor: XLR-1A. Thrust: 350 lbs. (*Tatler*, June 3, 1961) Same as 6th test firing?

8th: January 28, 1961. Motor: XLR-3A or XLR-3a. Fuel: ZnS. The motor exploded after producing 510 lbs. thrust. (*Tatler*, February 24 and June 3, 1961.) The nozzle flew into the woods, never to be found!

9th: January 28, 1961. Motor: XLR-1A. Fuel: ZnS. The motor misfired. (*Tatler*, June 3, 1961.)

10th: March 24, 1961. Motor: XLR-1A. Fuel: ZnS. Backfired (blew out fuel stop). The motor embedded itself in the blast deflector. (*Tatler*, June 3, 1961.)

11th: March 24, 1961. Motor: XLR-2A. Fuel: ZnS. Thrust: 1,200 lbs. (*Tatler*, June 3, 1961.)

12th: May 6, 1961. Motor: XLR-2A. Fuel: ZnS. The motor fizzled, the result of "chuffing" caused by a leaky fuel stop. (*Tatler*, June 3, 1961.)

13th: October 14, 1961. Motor: XLR-4A. Fuel: ZnS. Thrust: 1,350 lbs. (*Tatler*, November 3, 1961). This test firing set a national amateur single-chamber solid propellant thrust record.

Note: The two and one-half year gap in reported test firings, between the 13th and 14th test firings, may be the result of *Tatler* coverage (or lack of it) rather than a lack of actual events. "I remember going to a test firing but I wasn't involved with preparing the propellant, and all I know about it is that it was a solid and I think it was a mixture of some sort of salt (perchlorate seems reasonable) and some organic compound" — Bill Carter '63. (Bill Carter, e-mail to the author, September 17, 2012.)

14th: May 9, 1964. Motor: XLR-201(?). Fuel: AP-P13. First 200-series test; successful. (*Lakeside News Bulletin*, June 1964; *Tatler*, September 11, 1964.)

15th: May 8, 1965. Motor: XLR-201(?). Fuel: AP-P13. ("Pupils' Test Rocket Is Loud Failure," *The Seattle Times*, May 9, 1965, 71; "School-Built Rocket Goes Off Early," *The Seattle Times*, May 10, 1965, 6.) "The Rocket Society was fading a bit but still managed a big boom at the range in May." (McCuskey's "Lakeside

History.") The explosion destroyed "one of our large rockets," leaving the LRS with one 200-series chamber and two stainless steel nozzles. (*Tatler*, September 13, 1965.)

16th: 1965 - 1966 school year. Motor: XLR-202(?) Fuel: AP-P13(?). The motor fired successfully but no thrust readings, etc. were obtained due to a technical glitch. The test firing was filmed and a sound recording made. (*Tatler*, March 9, 1966.)

17th: 1965 - 1966 school year. Motor: XLR-203(?) Fuel: AP-P13(?). The motor fizzled. The burn lasted 52 seconds, producing no measurable thrust. (*Tatler*, March 9, 1966.)

119. Donna Blankinship and Seth Borenstein, "Bankrolling new operating system for space: High-tech tycoons take on the mantle of space exploration," *The Lewiston Tribune*, December 14, 2011, sec. 2C.

120. Built by Cabrera and partner Ron Poole, the Vulcan Shuttle was a Volkswagen Beetle with a rocket ship pierced through it. The Vulcan Shuttle reached speeds of 188 m.p.h.!

Cabrera has extensive knowledge of, and experience working with, ammonium perchlorate - Paraplex P-13 composite propellant, which he generously shared with the author.

TECHNICAL

This webpage was tested in the following browsers: Chrome 34.0, (Internet Explorer) Windows NT 6.3, Mozilla Firefox 5.0, Opera 21.0, and Safari 534.

VERSION

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