Slide Rules for Rocketeers

Michael Konshak

It is 1961, three years after the Soviets launched Sputnik into orbit on October 4, 1957. A rocket is mounted vertically on its launch pad, pointed to a brilliant blue sky. As the impending countdown is about to commence, two tracking stations turn toward the launch site, focusing on the projectile. Alignments have been checked, the equipment has been calibrated.

The designer of the rocket is apprehensive, though confident that her calculations and preparations have given this bird the best chance of success. But... will there be a rare catastrophic failure? Will the sensitive payload within the capsule survive the forces of the flight? Will the recovery system perform as planned?

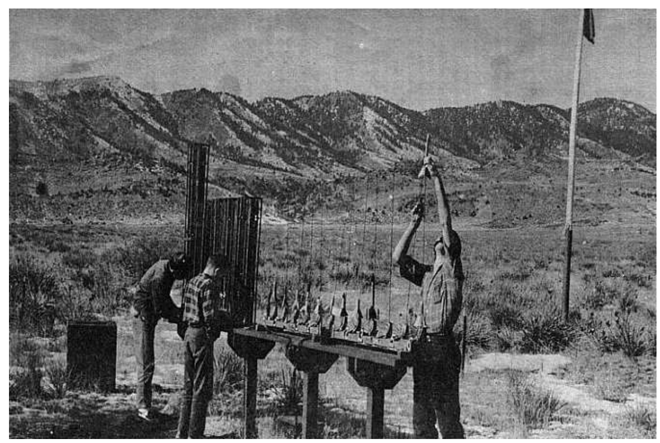
The RSO or *Range Safety Officer* scans the sky one last time for encroaching aircraft, then broadcasts over the radio "Range is clear, Tracking One?" "Ready" is heard over the speaker. "Tracking Two?", the RSO calls. A pause. "Tracking Two?" "Hold a sec, we have a problem with the azimuth... OK, we got it. Ready!" The RSO double checks the sky, the speaker blares "Launch is ready", he flicks a toggle switch and a red light flashes on. Spectators turn toward the pad. With finger poised over the ignition button, the RSO calls out in a steady voice, "Panel is armed, 5... 4... 3... 2... 1... Zero".

As soon as the button is pressed, the rocket instantly ignites and propels itself skyward with a WHOOSH. The gallery of onlookers bend their necks backward, hands shielding their eyes from the bright sun, as the missile's trajectory makes a slight weather cock into the wind. With the propellant expended, the rocket now drifts upward on its own momentum gaining more altitude, yet decelerating as it approaches the apogee of the flight. The designer watches in anticipation, not wanting to lose sight of her creation as the rocket starts to bend toward earth. "C'mon!" she declares. Suddenly a puff of smoke is seen followed by a delayed audible "POP". The RSO calls out over the radio "MARK!" The trackers lock the elevation of their respective theodolites onto the small cloud that has dotted the clear sky. A parachute appears overhead, the rocket safely dangling underneath. A "whoop" from the designer draws smiles from the crowd of onlookers.

This could be a scene from a NASA launch except for the teenagers running through the Colorado prairie, dodging yucca plants to chase down a 12-inch-long, brightly colored, fluorescent pink rocket with a bulbous nose cone. "There it is!" Panting, the girl picks up the rocket, careful not to catch the thin plastic parachute on the nearby prickly pear cactus. She inspects the payload, and turns back toward the launch site. "I think it's OK" she says, smiling to her friend.

Over the speakers, she hears "Tracking One, elevation 40 degrees, azimuth 55 degrees"; then "Tracking Two, elevation 35 degrees, azimuth 43 and one-half degrees".

As the designer walks up to the NARAM (National Association of Rocketry Annual Meet) Contest Director to present her rocket, she sees two older boys manipulating slide rules to perform trigonometric calculations that will tell her how high her entry has flown. The contest director watches as she separates the nose cone. Both peer inside the capsule. The egg is intact and unbroken. The contest director looks over at the finished calculations, then smiles at the young rocketeer, "Congratulations, it reached 579 feet." One of the boys leaves the table to go and prepare his contest entry, handing the slide rule to the girl. "Your turn, that one is going to be hard to beat." The girl proudly takes over the math chores for the other rocket enthusiasts.



There was a boom of interest in rocketry in the late 50s as the space race was just beginning to build up speed. Many backyard rocketeers were designing and building their own rockets, and there were continuous articles in newspapers mentioning that some youngsters had lost their fingers in an explosion while trying to build a rocket motor. Model rocketry was started in Colorado primarily through the efforts of G. Harry Stine who had contacted Vernon Estes to build safe, reliable rocket motors for use in model rockets. Stine and several other enthusiasts founded the National Association of Rocketry (NAR) in 1958, to help promote interest in rocket science and to provide a set of safety guidelines to protect the future aerospace engineers. Vern began producing the black-powder rocket motors, also called engines, in the backyard of his house in Denver, Colorado, then relocated Estes Industries to Penrose, Colorado, away from neighbors, selling rocket motors to NAR club members and rocketeers.

During the first couple years of the NAR, we rocketeers scratch-built our own rockets and hand made our own rolled paper tubes for bodies, cut fins out of balsa wood, and turned balsa nose cones on a lathe. As a 14-year-old in Colorado Springs in 1960, I remember spending many hours making up the materials to build rockets, guided by adult mentors in the Peak City club such as William S. Roe. The only other club in the nation at that time was the Mile-Hi club in Denver. We were not allowed to launch a rocket unless we could prove that we did our engineering correctly to show that the rocket would be aerodynamically stable. This was done by calculating the center of pressure and measuring the center of gravity of the rocket, after drafting a scale drawing of the rocket that also described its specifications. Later in life, I became a mechanical engineer, yet these were the first mechanical drawings I ever made. My best friend Steven Kushnir, who introduced me to the NAR, went on to become a nuclear scientist in Germany. It was a very inspiring sport for many kids.

1959 Ad

Slide rules were not only used in the field to calculate the apex of a rocket's flight, but were also used by many of the older rocketeers to determine the rocket design's predicted altitude beforehand. One class of competition was making scale models of real rockets and the slide rule's proportional capability made the task of reducing dimensions very simple. As the sport and science of rocketry progressed, Estes Industries started making components to provide to modelers, as there was a big demand for body tubes and nose cones. By 1964, kits of proven designs started appearing in Estes Catalogs as well as "Computing Equipment" in the form of slide rules, the Estes Altiscope (US patent 3,208,147), a 2-D Computer, and other charts and technical reports to aid the budding rocket engineers.

Five different models of slide rules appeared in Estes Industries Catalogs from 1964 to 1972, to be used with other "computing" equipment for calculating the altitude or apogee of a rocket. The 1964 catalog listed two slide rules on page 54. The first listing was for a five-inch pocket Mannheim slide rule made by Lawrence and sold for 40 cents.


Page 54

COMPUTING EQUIPMENT

2-D COMPUTER: Build your own easy-to-use altitude computer. Get this set of charts and instructions--everything you need except tape, thumbtacks and glue -- assemble the 2-D computer in a few minutes. Designed for use with one or two Altiscopes, easily used with other tracking systems. Shipping weight 2 oz.
Cat. No. 641-AC-1 $.25 each

5" POCKET SLIDE RULE: Ideal companion to the Altiscope. Find altitudes, solve problems in multiplication, division, proportions, reciprocals, etc. A,B,C,D,CI, and K scales accurately calibrated on white face of hardwood rule. Great for beginners. With easy-to-follow instructions. Shipping weight 4 oz.
Cat. No. 641-SR-1 $.40 each

10" TRIG SLIDE RULE: Perfect slip-stick for your rocket math. Durable plastic 10" rule has all nine basic scales: A,B,C,D, CI,K,S,T, and L. Do complex problems quickly and easily. Use it for math and science classes, designing and building rockets, and finding altitudes. Comes with protective carrying case and complete instructions. Shipping weight 9 oz.
Cat. No. 641-SR-2 $2.10 each

The listing for Cat. No. 641-SR-1 reads:

> 5″ POCKET SLIDE RULE: Ideal companion to the Altiscope. Find altitudes, solve problems in multiplication, division, proportions, reciprocals, etc. A, B, C, D, CI and K scales accurately calibrated on white face of hardwood rule. Great for beginners. With easy to follow instructions. Shipping weight 4 oz.

Because there were no S or T scales on this slide rule, which is necessary for the altitude equations, a trig table was generally supplied through the Estes TR-3 tech report. A Pickett model 120 Trainer was also listed for a price of $2.10. Cat. No. 641-SR-2 read as:

> 10″ TRIG SLIDE RULE: Perfect slip-stick for your rocket math. Durable plastic 10″ rule has all nine basic scales: A, B, C, D, CI, K, S, T, and L. Do complex problems quickly and easily. Use it for math and science classes, designing and building rockets, and finding altitudes. Comes with protective carrying case and complete instructions. Shipping weight 9 oz.

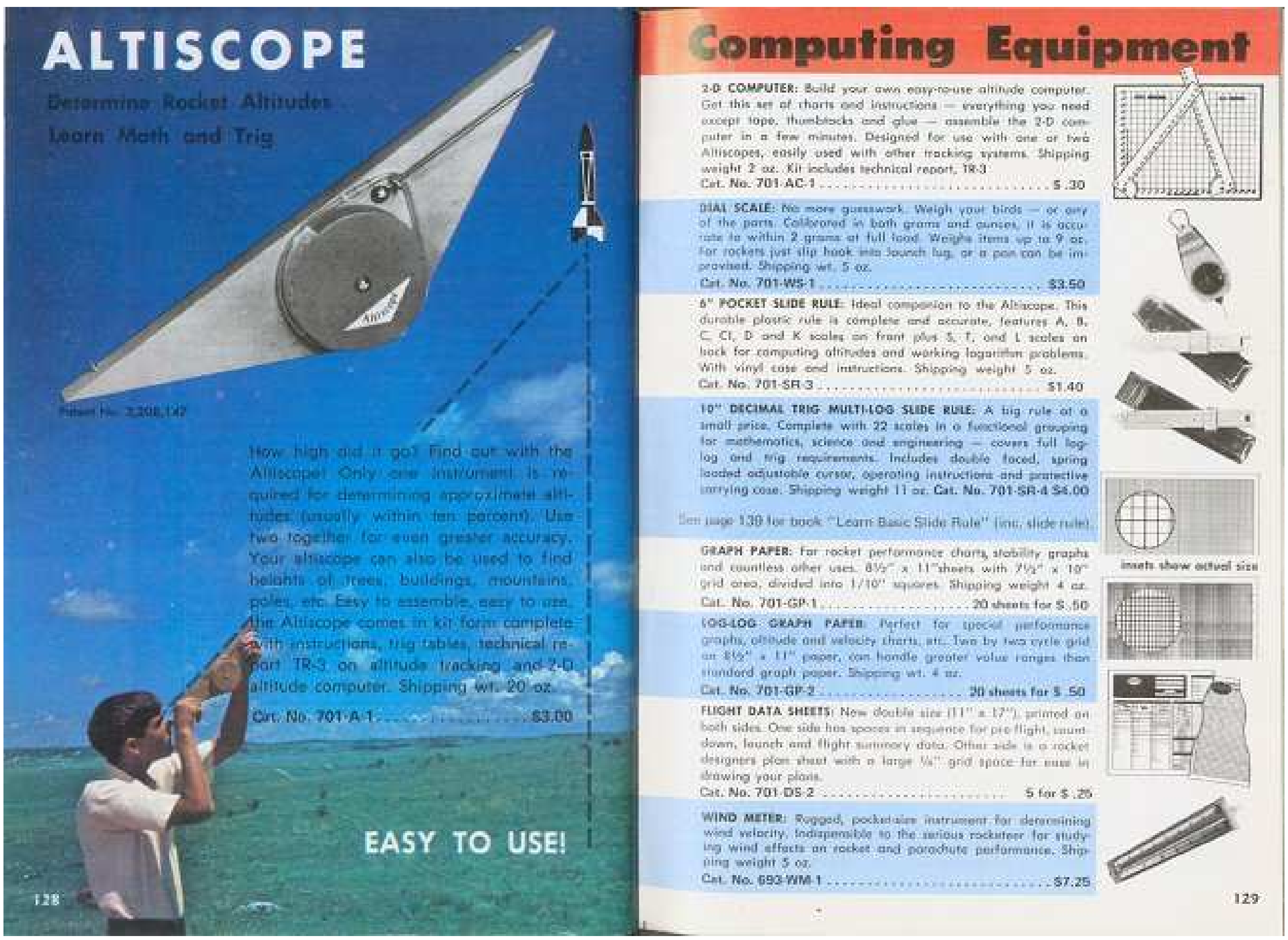
In 1965, four slide rules were listed, but the catalog pictures are not very clear. The 5″ Lawrence is again listed as SR-1 for 40 cents, and the SR-2 was a revised, totally white Pickett 120 with the molded end braces and still listed at only $2.10.

The SR-3 was added to the list, selling for $1.10 each and was now being touted as "the perfect companion to the Altiscope", in place of the SR-1, as it had the requisite S and T scales to alleviate the need for the trig table. The SR-3 was an all-plastic 6-inch pocket slide rule with A, B, C, CI, D, and K scales on the front, plus S, T, and L scales on the back, and appears to be a Sterling 587. I thought it might be a Pickett 1200, but the Pickett did not have the L scale on the back.

The SR-4 was a multi-log and appears to be a Sterling 594 Decimal Trig Multilog Duplex with 22 scales and a spring-loaded adjustable cursor. Having these two slide rules (the SR-3 and SR-4) in the 1965 Estes catalog and later leads me to believe that they were Acumath models, as Sterling did not buy the Acu-Rule manufacturing company until 1968. The conundrum is that none of the Acumath models in 1965 match the scales as listed in the catalogs, so either Sterling was making slide rules prior to 1968 or Acu-Rule was supplying them as OEM products.

The 1967 catalog dropped the SR-2, now only listing three slide rules.

In 1968 the pictures began showing the SR-3 and SR-4 slide rules with leather (or leatherette) cases.



The 1968 through 1972 catalogs listed the Frederick Post 1447 slide rule, made by Sun-Hemmi in Japan, in the Books and Literature section that came bundled with the expansive manual *Learn Basic Slide Rule on Your Own, A Modern Programmed Instruction Manual,* by Cybern-Education, Inc., with which most slide rule collectors are familiar.

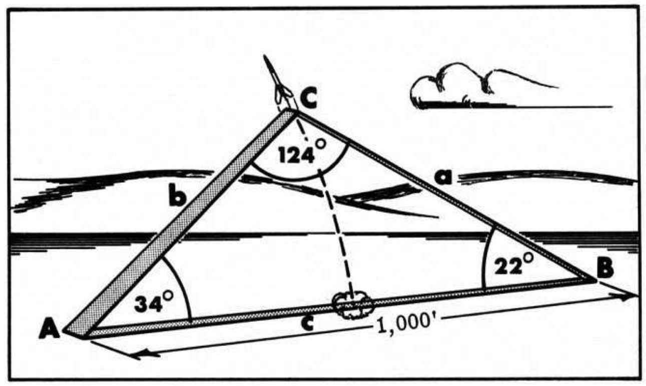
Conventional slide rules do not appear in 1973 and later Estes catalogs, possibly because Borden Chemical Company, who bought Sterling in 1970, stopped all slide rule production in 1972. The era of the electronic calculator was about to begin. An Estes ALTITUDE COMPUTER was introduced in 1973. It was basically a custom slide chart, that given the weight and frontal area of a rocket would predict the altitude that could be achieved with any given Estes motor.

The 1972 Enerjet catalog, a competitor of Estes Industries, has a picture of a man holding a slide rule while others track a rocket's flight.

The NAR (www.nar.org) will be 50 Years old in 2008. I attended NARAM-2 and NARAM-3 in Colorado as a kid and am now planning on attending NARAM-50 which will be held in Virginia. They are having a reunion of old rocketeers, those with NAR numbers of 50,000 and lower. As NAR 896, I'm sure I'll qualify. I am building a bunch of rockets to take with me, and in so doing using my slide rule to recapture the effort we put into our scratch-built designs (and just in case running them through a rocket simulator program on my computer).

BARs (Born Again Rocketeers) have now moved into high-powered rockets which can achieve altitudes of 50,000 feet. Although I do not see slide rules at today's launch sites, as electronic altimeters are mounted on board, many of these people used them in the past.

Calculating the Altitude Using two Tracking Stations and a Slide Rule



To simplify the calculations on a busy launch day, the tracking stations were set up in line with the wind, equidistant on each side of the launch pad. This eliminated the need to factor in the azimuth as the rocket will always turn into or drift with the wind. Elevations within one degree were the norm. Once the scopes were locked on the maximum altitude the elevation angles were read and the sine of the angles were found, either using the two-digit trig table or from the slide rule, which offered more accuracy.

Sines and Tangents

∠	sin	tan	∠	sin	tan	∠	sin	tan
1	.02	.02	28	.47	.53	54	.81	1.38
2	.03	.03	29	.48	.55	55	.82	1.43
3	.05	.05	30	.50	.58	56	.83	1.48
4	.07	.07	31	.52	.60	57	.84	1.54
5	.09	.09	32	.53	.62	58	.85	1.60
6	.10	.11	33	.54	.65	59	.86	1.66
7	.12	.12	34	.56	.67	60	.87	1.73
8	.14	.14	35	.57	.70	61	.87	1.80
9	.16	.16	36	.59	.73	62	.88	1.88
10	.17	.18	37	.60	.75	63	,89	1.96
11	.19	.19	38	.62	.78	64	.90	2.05
12	.21	.21	39	.63	.81	65	.91	2.14
13	.22	.23	40	.64	.84	66	.91	2.25
14	.24	.25	41	.66	.87	67	.92	2.36
15	.26	.27	42	.67	.90	68	.93	2.48
16	.28	.29	43	.68	.93	69	.93	2.61
17	.29	.31	44	.69	.97	70	.94	2.75
18	.31	.32	45	.71	1.00	71	.95	2.90
19	.33	.34	46	.72	1.04	72	.95	3.08
20	.34	.36	47	.73	1.07	73	.96	3.27
21	.36	.38	48	.74	1.11	74	.96	3.49
22	.37	.40	49	.75	1.15	75	.97	3.73
23	.39	.42	50	.77	1.19	76	.97	4.01
24	.41	.45	51	.78	1.23	77	.97	4.33
25	.42	.47	52	.79	1.28	78	.98	4.70
26	.44	.49	53	.80	1.33	79	.98	5.14
27	.45	.51				80	.98	5.67

For angles of 81° through 89° the sine is .99, the sine of 90° is 1.00. Tangents over 80° are not given, as no sensible data reduction is possible for angles that great.

A simplified equation was used, which was reduced from a series of trigonometric formulas, and involves only two multiplications and one division, a very easy task for a slide rule. The calculation becomes even easier if the baseline distance c between the tracking stations is a power of 10 as in 1000 feet or meters. Angle C is derived by subtracting angles A and B from 180 degrees. If over 90 degrees you subtract the angle from 180 to get the supplement, which happens to be the same as Angle A plus Angle B in this case. In the above example the $\sin(124°) = \sin(180° - 124°) = \sin(56°)$.

$$Altitude = (c \times \sin A \times \sin B)/\sin C$$

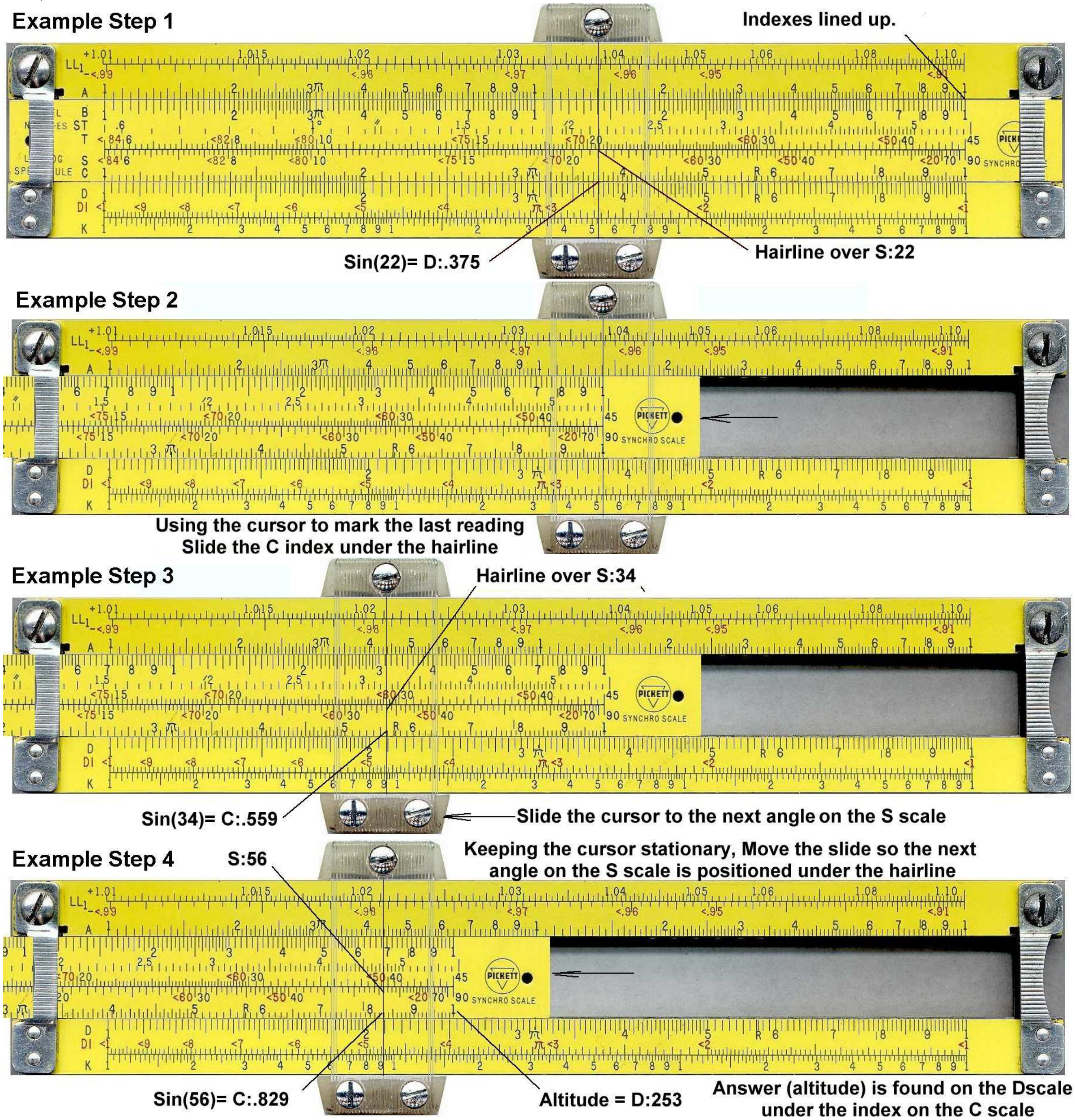
$$Altitude = (1000' \times \sin(34°) \times \sin(22°)/\sin(56°)$$

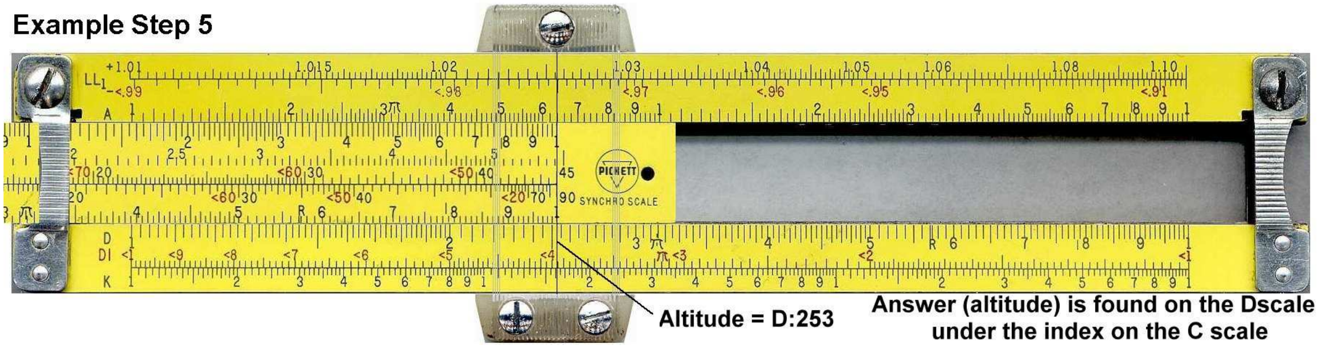
$$Altitude = (1000' \times .559 \times .375)/.829 = 253'$$

(Note: if your slide rule does not have S & T scales and the two-digit table is used, the answer comes out to 248′.)

It only takes four to five movements of the slide rule to perform a chained calculation to get the altitude. With the indices lined up, the sin of any angle is read on the C scale. The two multiplications and one division use the C and D scales so it becomes an easy task to complete the calculation without having to write down the intermediary steps. Ah, the beauty of logarithms and the slide rule. Built-in memory! Factoring in the 1000′ multiplication is simply a matter of locating the correct decimal point position in your head, at which all slide rule users are very proficient.

The following five figures show the movements in solving the above altitude calculation.





About the Author

Mike Konshak, as a 14-year old, joined the National Association of Rocketry in 1960 and was assigned NAR #896. He attended NARAM-2 (Denver, CO) and NARAM-3 (Colorado Springs, CO) and ended the competition season in 4th place over-all in the youth division. His exposure to aerospace kindled his involvement in later years to working on F4 Phantoms while in the Navy in Vietnam, and later as an instrument-rated private pilot. He became a mechanical engineer, graduating from CSU-Pueblo in Colorado and had the distinction of having one of his ruggedized optical disk designs sent up in the Space Shuttle and installed in the MIR space station. This unit was found in the remains of MIR after its fiery re-entry when the orbit collapsed, and because the drive was still operable, it was placed in the Smithsonian Museum. At age 60, and an avid slide rule enthusiast, Mike has rekindled his desire to fly competition rockets thus leading to the writing of this article.

References

1. 1972 Enerjet catalog, picture from page 16, scanned by Mark Johnson.
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3. 1964 Estes Industries Model Rocketry Supply Catalog #641, Page 54, scanned by Scott Rudisill.
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5. Telephone Interview with Vernon Estes, Canon City, Colorado, September 18, 2007.
6. Estes Industries *TR-3 Technical report,* Penrose, Colorado, Estes Industries, 1963.