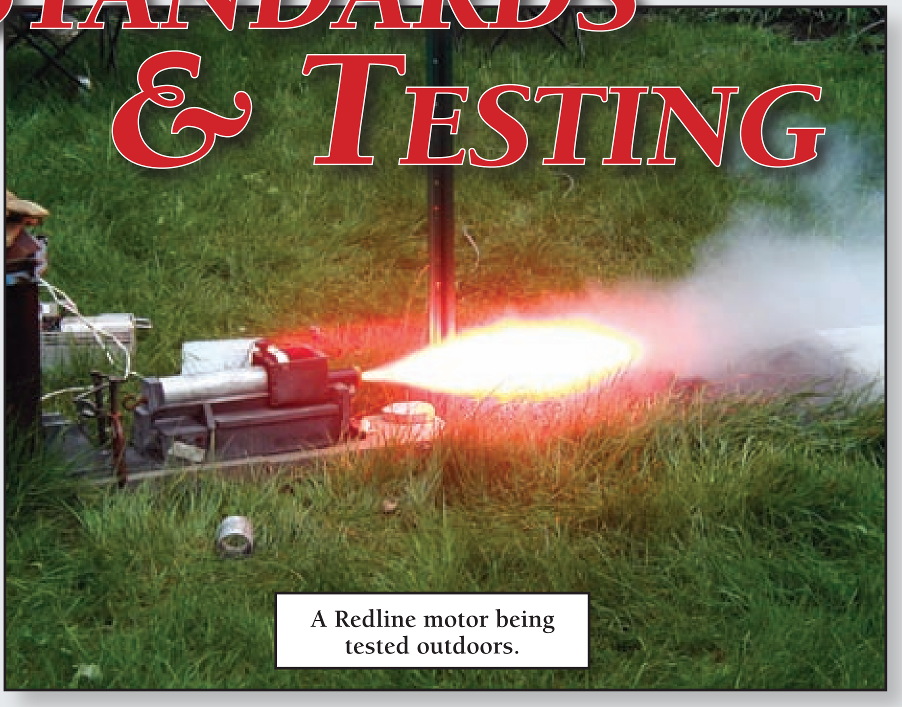
Standards & Testing



A Redline motor being tested outdoors.

National Association of Rocketry Standards and Testing Committee

We're not your mom, but we are trying to keep you safe. We are Standards and Testing (S&T), one of the NAR's oldest committees. We test rocket motors so that you (and your mom) will have some assurance that the rocket motors you buy are reliable and will perform as advertised.

Since S&T's creation, it has become the law in almost every state that rocket motor manufacturers must have their motors tested by an independent agency before they can be sold to the public. (Testing; it's not just a good idea, it's the law.) A manufacturer can pay thousands of dollars to a commercial testing facility to do the testing, or they can have us do it for 1/100th the cost and have the confidence that the those performing the testing are highly experienced in the assembly and use of the product under test. The NAR leadership views motor certification testing as a service to its membership and a benefit to all those who participate in hobby rocketry. By keeping the cost of motor certification low, the volunteer staff of NAR S&T makes it easier for new motor manufacturers to enter the marketplace, and existing manufacturers to expand their product offerings.

There are currently 16 members in the committee, split into two teams: East coast and West coast. We are a diverse group of rocketeers who fly everything from the smallest 1/8A motors up to Level 3. Long time NAR member Jack Kane heads East coast operations. NAR Board member John Lyngdal is in charge on the West coast. Bill Spadafora is secretary. Each test session usually involves between two and six people. The opportunity to spend a day burning someone else's motors tends to insure that there is no shortage of volunteers.

The committee's activities can be roughly divided into three categories: testing, monitoring, and publication. Testing activities include: testing a motor manufacturer's planned new product and, if it passes, certifying it; retesting and re-certifying motors that are still in production every five years; and performing ad hoc investigations at the request of the NAR board of trustees. An example of ad hoc testing is the testing we've done to characterize the sparks in a sparky motor: how long and how hot do they burn? This affects how likely they are to be burning when they hit the ground and how far from the launch pad this can happen. More details on testing are in the next section.

We try to monitor how motors are performing in the field by asking you to file a Malfunctioning Engine Statistical Survey (MESS) form every time you have a motor fail. Failures include things like no ejection charge, weak ejection charge, inaccurate delay, nozzle blown out, and casing split or fragmented. Fill out the MESS form online at http://www.nar.org/NARmessform.html. We will notify the manufacturer if we see a lot of reports about the same motor, especially if they have the same production date. (Of course, you should also notify the manufacturer yourself if a motor fails because they might replace it.)

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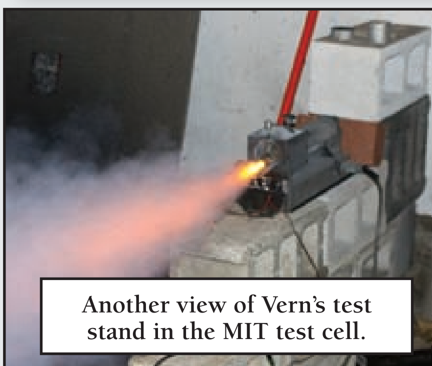
S&T has three publications: notices, approved motor lists, and motor testing results, which include the motors' thrust/time curves. The notices are issued as needed to inform members of S&T decisions. These are almost always announcements about motors: certifications, decertifications, and contest eligibility or loss of eligibility. Contest eligibility requires that the motors be both approved and widely available. After a new motor has been approved, we check around to see if it's available for sale. When we start seeing vendors with the motor in stock, we approve it for contest use. We email the notices to various organizations and provide them online at http://www.nar.org/SandT/STchrono.html.

S&T maintains a database of all approved motors, not only those we have tested, but also the motors tested by the Tripoli Rocketry Society and the Canadian Association of Rocketry. The NAR recognizes the motors tested by the other two organizations since all three have agreed to test to the same standards. A listing of the motors approved by S&T is available online at http://www.nar.org/SandT/NARenglist.shtml. A PDF file combining the motors approved by all three organizations is published twice a year in *Sport Rocketry* and is also available online at http://www.nar.org/SandT/pdf/CombinedMotorsByImpulse.pdf. Note that the online version of the combined list is updated continuously, so it will always have the latest information.

The NAR test stand designed and built by Vern Estes.



Another view of Vern's test stand in the MIT test cell.

Motor test results include the average thrust, the average delay length, and the motor's thrust time curve. The thrust/time curve represents how much force a motor was producing at a particular time during its burn. We collect all of a motor's test results into a single PDF file, which is linked from the motor's entry in the list of S&T approved motors online at http://www.nar.org/SandT/NARenglist.shtml. Note that the PDF contains an average thrust/time curve in WRASP format, which is the format used by rocket flight simulators.

How A Test Stand Works

The most important part of a static test stand is the load cell (Figure 1). A load cell is a chunk of metal (usually aluminum or steel) that has been machined so that it flexes slightly when a force, in this case rocket thrust, is applied. Attached to the metal of the load cell are strain gauges. Strain gauges (Figure 2) are serpentine wires mounted on a flexible backing. When the wire is stretched or compressed, its resistance changes slightly. Although you can make a load cell with one strain gauge, good ones have four. Load cells with four strain gauges have them located so that two are compressed and two are stretched when the load cell bends. The gauges are wired in a Wheatstone Bridge (Figure 3). A constant voltage is applied to two opposite corners of the bridge and the voltage across the other two corners is measured. This voltage is zero when there is no force on the load cell and increases (or decreases) as force is applied. The voltage is directly proportional to the force, so it's just a matter of converting the voltage to newtons to determine the thrust. Because this voltage is very small (millivolts) it must be amplified to reduce interference from outside sources. The amplifier (Figure 4) also provides the constant voltage to excite the strain gauge bridge. Years ago the output voltage would be sent to a strip chart recorder that drew a line on moving paper. Measuring the thrust or calculating the total impulse meant counting little squares on the paper. Now everything is digital so there's another black box involved called an analog to digital converter. It simply takes the analog voltage and changes it to a digital signal that a computer can understand. From there software is used to display the thrust time curve (Figure 5) and generate the various parameters that are used to describe the rocket engine's performance.

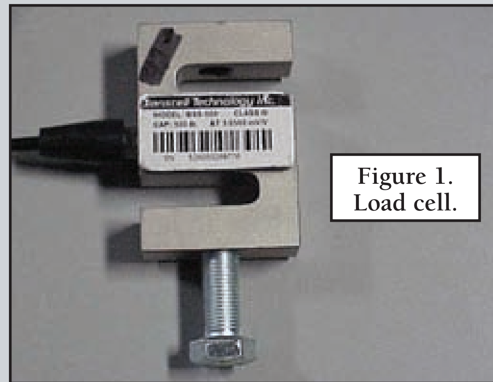


Figure 1. Load cell.

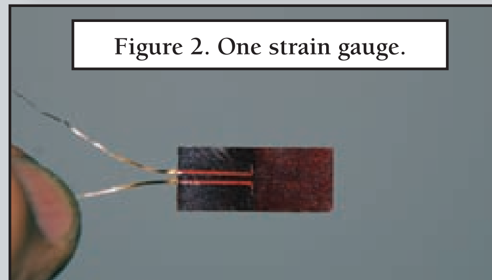


Figure 2. One strain gauge.

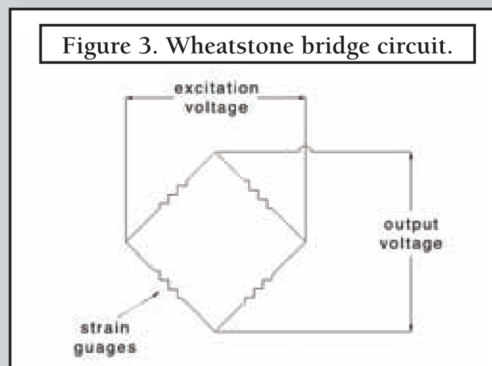


Figure 3. Wheatstone bridge circuit.

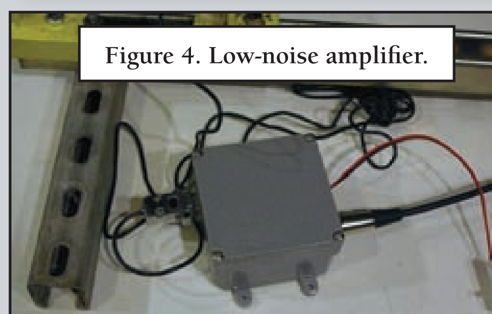


Figure 4. Low-noise amplifier.

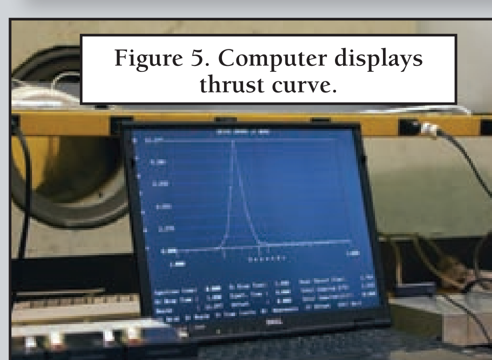
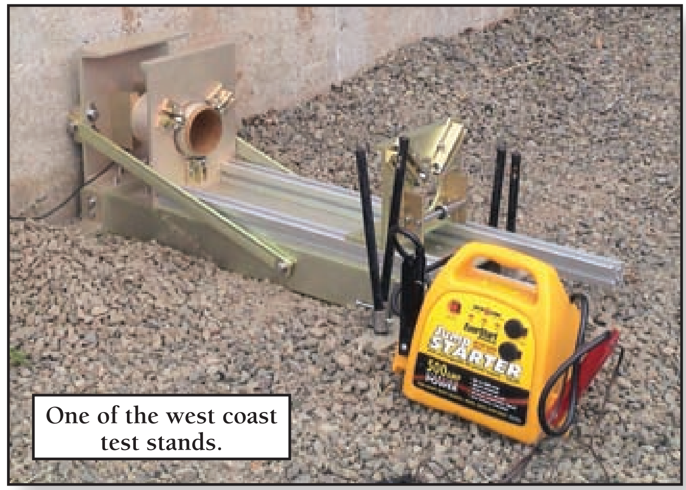


Figure 5. Computer displays thrust curve.

George Rachor, Gary Harris, and John Lyngdal of the west coast S&T team.

Testing

S&T's purpose is to provide the NAR with a prompt, reliable, and accurate capability to test and certify manufacturers' sport rocket motors for compliance with the performance and reliability standards established by NFPA 1122 (Code for Model Rocketry) and 1127 (Code for High Power Rocketry); and to provide technical analysis and recommendations to the NAR Board for any proposed changes to the NAR Safety Codes. This involves static testing all motors and compiling and maintaining a list of all the motors that are certified for use at NAR launches. Why is this necessary? The NFPA (National Fire Protection Association) codes are the law in many states and municipalities. They require third party testing of all rocket motors. S&T, along with our counterparts in the Tripoli Rocketry Association and Canadian Association of Rocketry, provides this testing at a low cost to the motor manufacturers. We can do this because we are all unpaid volunteers. This testing allows us to provide you with detailed performance and reliability data. NAR S&T certifications provide reliable, repeatable, regular testing to published standards. What are those standards? As codified in the National Fire Protection Association (NFPA) 1125 Code



One of the west coast test stands.

for Manufacture of Model Rocket and High Power Rocket Motors, S&T tests statistically-significant motor samples to insure they will not spontaneously ignite when physically shocked, heated, or exposed to water or radio energy; will reliably produce their rated total impulses, average thrusts, and ejection delay periods in static test firings; and comply with standards for casing temperatures, failure modes, packaging, and labeling.

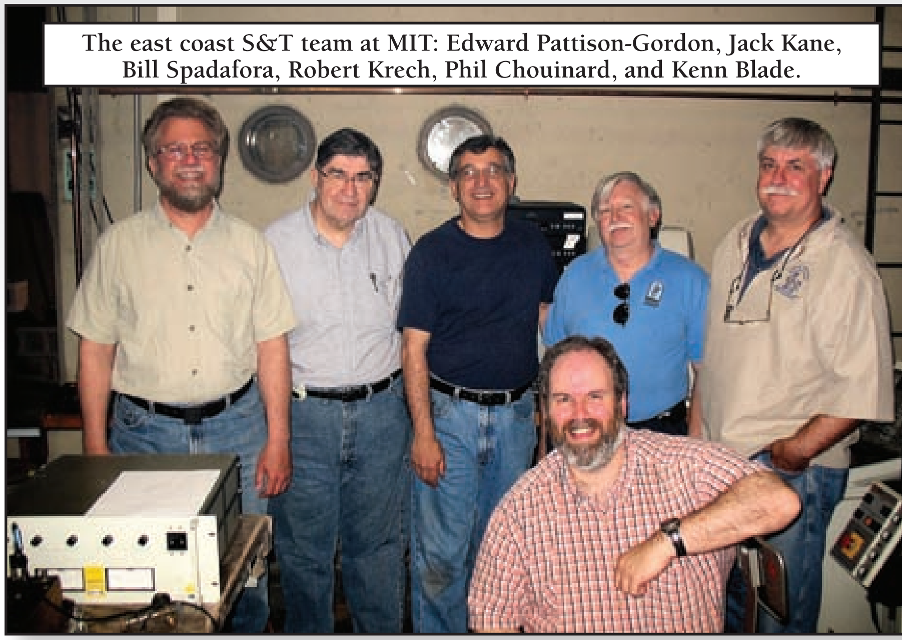
Most rocketeers want predictable total impulse and delay times. The key test parameters that address that requirement are that the standard deviation of the measured total impulse must be less than 6.7% of the mean, and measured ejection delays must not vary more than one second or 20%, whichever is greater, from the labeled delay. For further test parameter details, see the NFPA standards listed above.

What we test for is covered in NFPA 1125, but how we do it is covered in detail in our Motor Testing Manual that was written in 2008 in order to consolidate all our procedures in one easy to access place. That and other S&T documents can be found on the NAR website at http://www.nar.org/SandT/docs/index.html.

Manufacturers looking to have motors certified must fill out a simple form that tells us the expected motor performance data and that they have the required government approvals. That form along with the motors and a small fee gets the process started.

A typical test session begins with inventorying the motors to be fired. Reloadable motors are then assembled. Next they are weighed and measured. They are then put on the test stand and fired. After firing the motors are weighed again and the casings of reloadable motors are cleaned. The data is recorded on a laptop computer and is usually reduced later (even though it can be viewed in real time). The data consists of thrust values measured at a minimum of 500 times per second. Using a combination of spreadsheets and specialized software these numbers are used to calculate the total impulse, average thrust, peak thrust, and delay time. Assuming the numbers are within acceptable limits, the motor is certified and an Engine Data Sheet is created. These are available for every NAR certified motor at http://www.nar.org/SandT/NARenglist.shtml.

Occasionally motors do not get certified on the first try. Inaccurate delays, inconsistent total impulses, and failure of the motor casing are the most common causes. In such cases the manufacturers are provided with the data recorded and video and photos when available. Manufacturers may then make the necessary corrections and try again.



The east coast S&T team at MIT: Edward Pattison-Gordon, Jack Kane, Bill Spadafora, Robert Krech, Phil Chouinard, and Kenn Blade.

East coast testing is done indoors in a concrete test cell at MIT in Cambridge, Massachusetts. We have test stands capable of handling motors from 1/8A (or smaller) right up through K although the limitations of firing indoors makes anything bigger than J impractical. The test cell was designed to handle a small explosion but it wasn't designed for a day of continuous motor firing. In spite of phone calls and signs we've been visited by the fire department on several occasions when

The east coast S&T team doing an outdoor test.

concerned citizens have called in an alarm after seeing the cloud of smoke pouring out of the exhaust vent. We also have a vertical stand for hybrids. Out west the testing is done outside in two locations. Moderately sized motors are fired at a community airstrip in Hillsboro, Oregon. Large motors are fired in Amity, Oregon. We have stands that can handle motors with impulse classes from E through N on the west coast. All of our equipment has been made by NAR members and calibrated using NIST (National Institute of Standards and Technology) Traceable equipment. The workhorse stand on the east coast was built by Vern Estes and includes a custom-made load cell. A load cell is essentially a chunk of metal with strain gauges attached to it. The resistance of the strain gauges change as the metal bends and that change in resistance is used to measure the thrust. The other test stands use commercially made load cells and are configured to take motors of varying sizes.

The work of testing motors does not end with just firing motors. Data reduction as well as failure analysis often consumes significant manpower. Members see the results in the motor certification announcements together with data sheets published at the NAR website and through NARTS, but that is not the only output. NAR S&T also: manages certification of motors for NAR contest use; provides on-site testing for contest use when the Internats are hosted by the USA; retests all certified motors on a multi-year rotating schedule; reviews proposed NAR Safety Code changes; supplies proposals and reviews input to NFPA code revisions; and tracks motors failure reports.

This last service is important. S&T takes action, per NFPA standards, when the reported failures for any motor type exceed 20% of all reports in a twelve-month period. However, this task depends on help from all NAR members to be effective. Everyone should diligently report failures using the Malfunctioning Engine Statistical Survey (MESS forms) at http://www.nar.org/NARmessform.html.

NAR Standards and Testing also fields questions from manufacturers and members. Two often-asked questions are worth mentioning here. The first concerns thrust curves. It should be understood that rocket motor thrust curves are not certified; only total impulse and average thrust are certified. Thrust curves are variable, some more so than others. The motor data sheets published

Edward Pattison-Gordon and Kenn Blade weighing motors.

by S&T always contain a well-chosen representative thrust curve that matches the certified motor parameters. Secondly, the advent of altitude prediction programs for home computers often leads to requests for motor firing test stand data in the belief that it will improve prediction accuracy. This is a misconception because the thrust curves can be variable and point-to-point data exhibits quite a bit of noise.

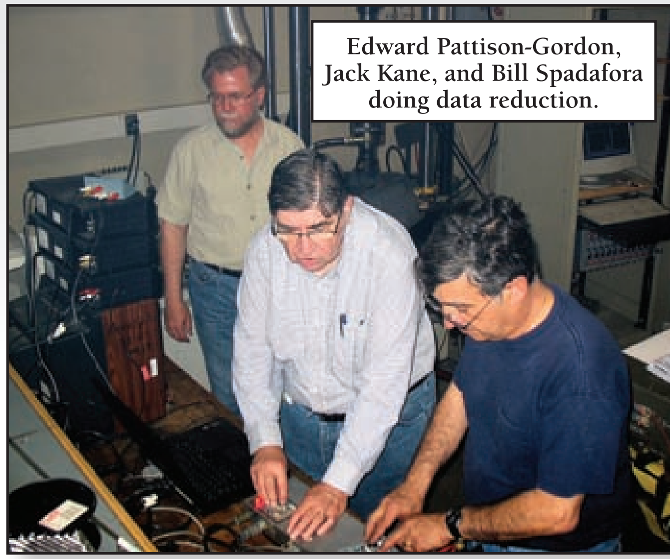
Manufacturers, Members, and Data

This section may answer a few questions that people have asked in the past. From our motor testing manual:

"The Committee shall serve motor manufacturers in a fair, impartial, and expedient manner. Two primary considerations shall govern their treatment by the Committee: the right of the association and its members to be accurately informed about the performance and reliability of products that are certified by the NAR for consumer use; and the right of manufacturers to maintain confidentiality of proprietary details of motor design and manufacture and/or corporate business plans and arrangements."

We don't talk about what testing we are doing or are not doing. If a manufacturer tells you that we are testing their motors and we are not, no comment from us. If a manufacturer tells you that S&T is giving him a hard time, no comment from us. If a manufacturer's motors are not passing our tests, no comment from us. If a manufacturer gives us data on a new propellant or future plans, no comment from us.

When it comes to the right of NAR members to be accurately informed about the performance of products, we think we have it covered. After the certification is complete a PDF of the certification data is put on the NAR web site. For example, if you go to the NAR motor page and pull up the sheet for the RoadRunner F35, at the very top you will see that the average total impulse is 76.49 newton-seconds. And the motor comes in two delays, 6 and 10 seconds. You can also find the case dimensions, propellant mass, initial mass, and mass after firing. In the middle of the page is again the total impulse and standard deviation. This shows that for this firing 68% of the motors had between 74.61 and 78.37 newton-seconds of total impulse. The curve at the bottom of the page is labeled as "typical." If you laid out the curves from all of the firings, this curve does have the shape of the typical curve. But this curve also has the max thrust, total impulse and burn time of the average of all the curves. If you think you need more data than that, go to the second page. This contains the total data from each of the motors tested. If you want flight simulation data, go to the third page; it contains the RASP.ENG data file. The bottom of the page contains the thrust-time curve from plotting the WRASP points. How accurate is the data? This data when run through a motor program (such as RASP.INFO) gives the same total impulse, max thrust, and burn time as is quoted on the first page of the PDF. The RASP.ENG data can be copied and pasted into a separate text file for use in a flight simulation program.


Edward Pattison-Gordon, Jack Kane, and Bill Spadafora doing data reduction.

In conclusion, we hope we've convinced you that we really are trying to keep you safe, and we hope we've convinced your mom, too.

This article was written with input from members of the S&T committee, all 16 of them.