What can carry on with you through life from the hobby of rocketry?

I was born in 1966 ten days before the Gemini 12 mission. So things were a flurry then. As a young child I assumed everyone had astronauts in their neighborhood.

Growing up in my little housing neighborhood of Bay Colony, I did not realize how lucky I was. We lived near the Johnson Space Center and several astronauts lived in our neighborhood. One of them was Robert Crippen. I mowed lawns when I was 14 and one of the lawns happened to be his. I found out while in Marine Corps Boot Camp that he had written a letter of recommendation on my behalf. I went to school with the youngest of their daughters from his family. My dad was a consulting engineer and did have some work with NASA along with other civil engineering jobs. On my seventh birthday, one of the neatest gifts was an Estes "Icarus" model rocket. It took me a while before it was built. However I thought it was neat because of its clear payload section.

In 1976 I was involved with Cub Scouts and we attended the Space-A-Rama event at the Johnson Space Center and it was really something. Everywhere at the center there were activities going on. R/C planes and gliders and the one that caught my eye were the rocket launch activities. There was a really well detailed Estes Maxi V-2 (which I have now in mint condition) that was gigantic for a model rocket back then.

Needless to say I was hooked. I later signed up with the NASA/Houston Rocket Club Section 365.

I did wander off from the hobby for a while. Joined the Marine Corps and made it a career for 20 years. The hobby did come back into my life after Desert Storm. A friend of mine in the service with me thought that if we got back alive, what is one thing that we would like to get re-involved with? We both said rocketry. That was in 1991. High Powered rocketry was starting to thrive in Southern California and I was hooked.

I was fortunate to have met Frank Kosdon. He was lucky enough to have met Werner Von-Braun in person.

Apogee Rocketry which has been around for some time and they provide great resources for educating people about the hobby. I kept a printed out laminated poster that I updated on our rocketry club web site. I passed it along to Tim Van Milligan and he wanted to know if I could elaborate on how I think what they identified on the poster is worthwhile. I thought I would take on the task of providing feedback.

Fifteen key subjects are covered, along with several sub categories below each one, totaling 136 items of discussion.

The first category is “Aerodynamics” and learning about aerodynamics can be a very fascinating subject. When you are a passenger on a plane getting ready to travel, the plane you are occupying depends on good aerodynamics.

Even if you at the present time have no interest in this subject, just making yourself aware of what aerodynamics is, will hopefully cause you to appreciate those who do.

1. **<u>Aerodynamics</u>**

Aerodynamic Stability: The key to stability is building a system that, when disturbed, returns to its original state. A stable system designed to return to the state it was in before something bumped it out of that state.

Bernoulli Principle: states that an increase in the speed of a fluid occurs simultaneously with a decrease in pressure or a decrease in the fluid's potential energy. The principle is named after Daniel Bernoulli who published it in his book Hydrodynamica in 1738.

Lift: is another component of the aerodynamic force, namely the projection onto the two directions perpendicular to the relative wind

Coefficient of Drag: The word “drag”, by itself, usually refers to a force (the force of drag). Similarly, the word “lift”, by itself, usually refers to a force. However, there are other ways of looking at things.

*   Coefficients: It is often convenient to write the drag force as a dimensionless number (the coefficient of drag) times a bunch of factors that characterize the situation:

Drag force = ½ρV2 × coefficient of drag × area

Where ρ (the Greek letter "rho") is the density of the air, V is your true airspeed, and the relevant area is typically taken to be the wing area (excluding the surface area of the fuselage, et cetera).

Similarly, there is a coefficient of lift:

Lift force = ½ρV2 × coefficient of lift × area

Friction: We can think of drag as aerodynamic friction, and one of the sources of drag is the skin friction between the molecules of the air and the solid surface of the moving rocket. Because the skin friction is an interaction between a solid and a gas, the magnitude of the skin friction depends on properties of both solid and gas. For the solid, a smooth, waxed surface produces less skin friction than a roughened surface.

Lift and Drag: For lift and drag to be generated, the rocket must be in contact with the air. So outside the atmosphere there is no lift and no drag. Aerodynamic forces are generated by the difference in velocity between the rocket and the air. There must be motion between the rocket and the air. If there is no relative motion, there is no lift and no drag.

Nose and Tail Spins: This topic can be considered in different way. Most rockets need a nose and fins for a stable flight. If you look up the history of rockets (such as the X-17), some rockets utilize spinning for a stable flight or for testing different application. The other interpretation is that the rocket could go into a nose or tail spins because of instability.

Reynolds Number: (Re) is an important dimensionless quantity in fluid mechanics used to help predict flow patterns in different fluid flow situations. It has wide applications, ranging from liquid flow in a pipe to the passage of air over an aircraft wing. The Reynolds number is used to predict the transition from laminar to turbulent flow, and used in the scaling of similar but different-sized flow situations, such as between an aircraft model in a wind tunnel and the full size version. The predictions of onset of turbulence and the ability to calculate scaling effects can be used to help predict fluid behavior on a larger scale, such as in local or global air or water movement and thereby the associated meteorological and climatological effects.

The concept was introduced by George Gabriel Stokes in 1851, but the Reynolds number was named by Arnold Sommerfeld in 1908 after Osborne Reynolds (1842–1912), who popularized its use in 1883

Streamlining: Another word for this is **free stream**, meaning the flow far away from a moving body. Much is intuitive (streamlined shapes, smooth contours), but advanced analysis can yield optimal designs

Subsonic vs. Supersonic: Subsonic: designed to operate at speeds below the speed of sound, this at standard conditions is 343.2 m/s (1,126 ft. /s or better known as 767.71654 miles per hour). This avoids the supersonic shockwave.

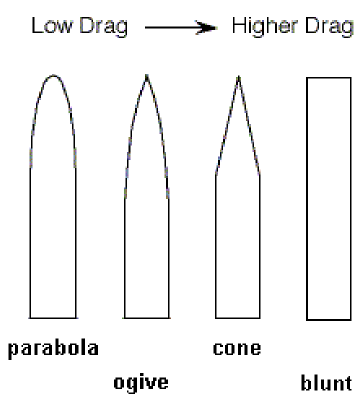
Supersonic: Supersonic flight puts many stresses on an airframe. The shock-wave coming off the nose can cause the airframe to crumple. The fins can succumb to flutter (Just what it sounds like; an uncontrolled flexing that, at best, will cause drag, and at worst, will tear the fins right off!). The drag goes way up as the speed approaches Mach one (768 miles per hour), further increasing stress on the vehicle and requiring even more thrust to overcome.

Subsonic flight: Less than Mach 1. This is the speed traveled by most of the commercial airplanes that carry people and cargo.

Transonic flight: At or about Mach 1.

Hypersonic flight: Greater than Mach 5. This is more than five times the speed of sound. It is the speed traveled by rockets and the space shuttle as they go into orbit.

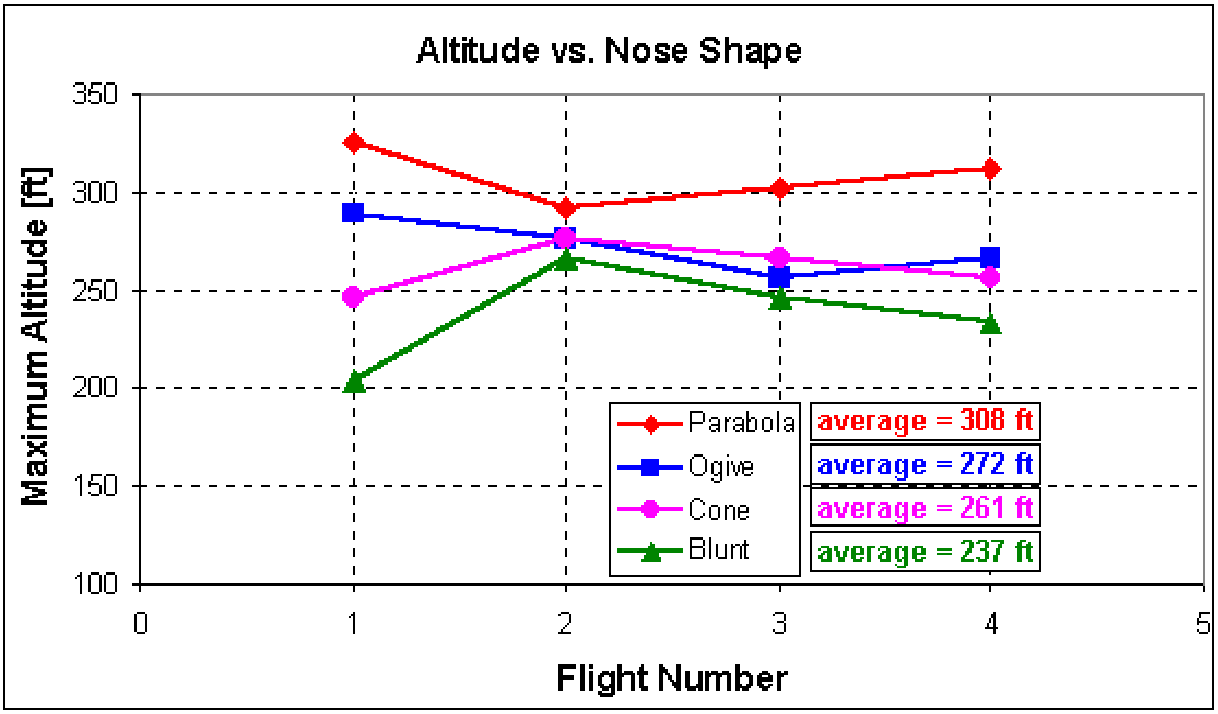
Airflow: Drag is minimized when the air flowing past a flying object is smooth because less energy is imparted to the airflow when it is smooth than when it is turbulent. Molecules are free to move from layer to layer, causing the air flow to randomly speed up in some places and slowdown in others. The end result is a chaotic and unpredictable pattern of air that creates greater drag than a smooth, laminar airflow.



Many factors of rocket design can increase the drag it experiences in flight. One of the most important of these factors is the shape of the nose. The ideal aerodynamic nose shape is primarily related to the speed at which the rocket flies. Moreover, the same principles hold true for aircraft, missiles, bombs, and other flying vehicles as well. In fact, it is often possible to tell what speed regime an aerial vehicle was designed to fly in simply by observing the shape of its nose.

For example, the ideal nose shape for vehicles that fly at subsonic speeds, defined as less than the speed of sound, is more rounded. That is why commercial aircraft like the Boeing 777 usually have rounded noses called parabolic nose shapes.

All tests were conducted using the same rocket body and using solid propellant motors of equal thrust. In addition, each nose was adjusted to the same length and weight to ensure that only the nose shape would vary from flight to flight. A ground-based altitude tracker based on simple trigonometry was used to measure the maximum altitude achieved on each flight. The results of the study are illustrated in the following figure.



Source: http://www.aerospaceweb.org/question/aerodynamics/q0151.shtml

2. Engineering

Laws of Motion:

1st Law- first law states that every object will remain at rest or in uniform motion in a straight line unless compelled to change its state by the action of an external force.

2nd Law- A force to be equal to the change in momentum with a change in time. Momentum is defined to be the mass m of an object times its velocity V. Force = mass x acceleration

3rd Law- For every action (force) in nature there is an equal and opposite reaction. In other words, if object A exerts a force on object B, then object B also exerts an equal and opposite force on object A. Notice that the forces are exerted on different objects.

Law of Thermodynamics: There are 4 laws to thermodynamics, and they are some of the most important laws in all of physics. The laws are as follows

Zeroth law of thermodynamics – If two thermodynamic systems are each in thermal equilibrium with a third, then they are in thermal equilibrium with each other.

First law of thermodynamics – Energy can neither be created nor destroyed. It can only change forms. In any process, the total energy of the universe remains the same. For a thermodynamic cycle the net heat supplied to the system equals the net work done by the system.

Second law of thermodynamics – The entropy of an isolated system not in equilibrium will tend to increase over time, approaching a maximum value at equilibrium.

Third law of thermodynamics – As temperature approaches absolute zero, the entropy of a system approaches a constant minimum.

What is Entropy? - Entropy is a very important thing in the realm of thermodynamics. It's the core idea behind the second and third laws and shows up all over the place. Essentially entropy is the measure of disorder and randomness in a system. Here are 2 examples

Let's say you have a container of gas molecules. If all the molecules are in one corner then this would be a low entropy state (highly organized). As the particle move out and fill up the rest of the container then the entropy (disorder) increases.

If you have a ball flying through the air then it will start off with its energy organized i.e. the kinetic energy of motion. As it moves through the air however, some of the kinetic energy is distributed to the air particles so the total entropy of system has increased (the total energy is conserved however, due to the first law). For more details you can check out the following web site: http://physicsforidiots.com/physics/thermodynamics/

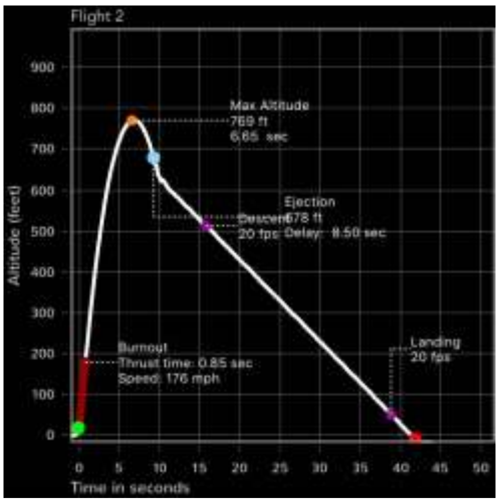
Lightweight Structures: The hobby of rocketry, aviation and aerospace utilizes light weight and strong material to make structures. You will learn a lot in this hobby. Rocketry competition is very, VERY popular in foreign countries and if you have ever heard of the World Space Modeling Championships, which is like the Olympics of rocketry, European countries take this seriously and so does the United States. It takes place every two years. More of the events take place in Europe; however America has hosted several of them throughout the years.

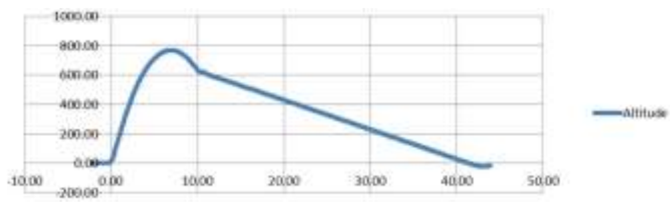
Tim Van Milligan gave a great presentation at the 2017 NARCON event on how to make your own lightweight body tubes that weigh hardly anything.



You will learn about composites and other aspects as well that will carry on through others aspects besides just rocketry from learning about structures.

Electrical Devices: If you are a computers wiz or just interested in it, then this hobby will be a treat. There are a plethora of cool electronic devices now easily and economically available for rocketry. You can place within your rocket a system for on board camera/video recording, altitude data analysis and electronic dual deployment for your recovery system.





You can be your own aeronautical engineer with designing your own prototype with rocket design software such as RocSim, or OpenRocket software. Launch it and get results from the flight which can easily be emailed to yourself or others for immediate analysis. Launch the rocket again with a different fin design, weight, or nosecone design and different motor or same motor and see what happens.

They have so many electronic systems now that you can configure too, such as the Arduino board or Raspberry devices and more.

Aerodynamic Stability: By using the devices and by also using that traditional Theodolite, you can visually witness if the rocket you engineered is aerodynamically stable. Conduct calculations and improve its stability.

Purpose: Often times you may not have a set purpose for what you are doing, and later on during your time will discover a purpose during your scientific interest. I was attracted just by the excitement of the liftoff of rockets, and then later on I wanted to work on a really nice lightweight, strong and efficient rocket design. That was a purpose that I discovered from the excitement of the hobby. Portland State Aerospace Society has a very strong engineering department involved with rocketry and is getting ready to launch CubeSat's. They designed a rocket with spin stabilization. This provided efficiency as well as stable video:

https://youtu.be/YUP2_m3gPiM

http://psas.pdx.edu/launches/

This is just one example. There are a lot of programs and universities available if you are interested to pursue this hobby as a profession.

Efficiency: Rocket launch vehicles take-off with a great deal of flames, noise and drama, and it might seem obvious that they are grievously inefficient. However, while they are far from perfect, their energy efficiency is not as bad as might be supposed.

The energy density of a typical rocket propellant is often around one-third that of conventional hydrocarbon fuels; the bulk of the mass is (often relatively inexpensive) oxidizer. Nevertheless, at take-off the rocket has a great deal of energy in the fuel and oxidizer stored within the vehicle. It is of course desirable that as much of the energy of the propellant end up as kinetic or potential energy of the body of the rocket as possible.

In a chemical propulsion device, the engine efficiency is simply the ratio of the kinetic power of the exhaust gases and the power available from the chemical reaction.

Time/Thrust Curves: When I was in high school I competed in a science fair (Circa 1983). It was in designing an aerodynamically efficient rocket. This caused me to have to study graphs. This involved researching not just the thrust curves for rocket motors but also the graphs dealing with time. The creators of Thrustcurve.org were not around back then.

http://www.thrustcurve.org/motorstats.shtml I needed to research direct from the current rocket motor vendors. Estes, Centuri and FSI were known back then. The Handbook of Rocketry from G Harry Stine was my main source.

Acceleration: Acceleration is a measure of how much the speed increases each second. It can be calculated using the equation acceleration = resultant force (newtons, N) divided by mass.

G-Force: On the surface of the earth, its value is 9.8 meters per square second or 32.2 feet per square second. The weight, or gravitational force, is then just the mass of an object times the gravitational acceleration (W = mg)

Miniaturization: We live in such a great time where electronics and microprocessors are prevalent. Your cell phone that you possess in your hands is a prime example. The 1980s, the size of a cell phone was a brick, with just basic functions. The altimeters and other electronic devices are great. If you can imagine it, you can make it happen these days.

The 2g GINA controller board incorporates inertial sensing, processing, communications, and actuation. A MEMS accelerometer and gyros, a 2.4 GHz radio, and a connector to an actuator driver board are visible; the processor is on the backside of the board.

A prime example of some really amazing ideas was posted in the most recent Sport Rocketry magazine of May 2017: http://www.andrac.co/#specs

3. <u>History</u>

I really enjoy history. Without reading history you do not learn, grow, or progress forward. Every day you, yourself are alive, you are making history. Record what you do and learn in order to pass it on to others so they prosper. We as a nation would not be where we are today without reading the records of the past. Learning about key people in rocketry, aviation, or what interests you, we will not move forward. You will also learn about other people not so well known but have contributed to the cause. Below is just a small list of key figures.

Pascal: Blaise Pascal, Born 19 June 1623 Clermont-Ferrand, Auvergne, France. Died 19 August 1662 (aged 39) Paris, France. Pascal's work in the fields of the study of hydrodynamics and hydrostatics centered on the principles of hydraulic fluids. His inventions include the hydraulic press (using hydraulic pressure to multiply force) and the syringe. He proved that hydrostatic pressure depends not on the weight of the fluid but on the elevation difference. He demonstrated this principle by attaching a thin tube to a barrel full of water and filling the tube with water up to the level of the third floor of a building. This caused the barrel to leak, in what became known as Pascal's barrel experiment.

Bernoulli: (February 1700 – 17 March 1782) was a Swiss mathematician and physicist and was one of the many prominent mathematicians in the Bernoulli family. He is particularly remembered for his applications of mathematics to mechanics, especially fluid mechanics, and for his pioneering work in probability and statistics. His name is commemorated in the Bernoulli's principle, a particular example of the conservation of energy, which describes the mathematics of the mechanism underlying the operation of two important technologies of the 20th century: the carburetor and the airplane wing.

Newton: was an English mathematician, astronomer, and physicist (described in his own day as a "natural philosopher") who is widely recognized as one of the most influential scientists of all time and a key figure in the scientific revolution. His book "Mathematical Principles of Natural Philosophy", first published in 1687, laid the foundations of classical mechanics.

Ancient Fireworks: Like many inventions, firecrackers fireworks were created by accident... and by the search for immortality. Around 200 BC, the Chinese unintentionally invented firecrackers by tossing bamboo into fire, but it took another thousand years before true fireworks came alive. As the story goes, around 800 AD, an alchemist mixed sulfur, charcoal, and potassium nitrate (a food preservative) hoping to find the secret to eternal life. Instead, the mixture caught on fire, and gunpowder was born! When the powder was packed into bamboo or paper tubes and lit on fire, history had its first fireworks!

If you attended a fireworks show in 800 AD, it would be unlike anything we see today. Paper fireworks were used to scare evil spirits or to celebrate weddings and births and were simply thrown onto a fire, not blasted into the air. There were no added colors, so a "fireworks show" was just a series of small, noisy explosions. The chemistry was an accidental discovery, and there was still a long way to go.

Medieval missiles:

The trebuchet is a compound machine—a combination of simple machines. The trebuchet makes use of the mechanical advantage of a lever. Most trebuchets are powered exclusively by the force of gravity. Potential energy is stored by means of an extremely heavy weight box attached (by a hinged connection) to the counterweight portion of the throwing arm. This was one of the first recorded apparatuses which was required neither to launch missiles (aka rocks or balls of straw with tar and lit on fire).

WW II: Bazookas: Referred to as the "Stovepipe", the innovative bazooka was among the first generation of rocket-propelled anti-tank weapons used in infantry combat. Featuring a solid-propellant rocket for propulsion, it allowed for high-explosive anti-tank (HEAT) warheads to be delivered against armored vehicles, machine gun nests, and fortified bunkers at ranges beyond that of a standard thrown grenade or mine. The universally-applied nickname arose from the M1 variant's vague resemblance to the musical instrument called a "bazooka" invented and popularized by 1930s U.S. comedian Bob Burns.

During World War II, German armed forces captured several bazookas in early North Africa and Eastern Front encounters and soon reverse engineered their own version, increasing the warhead diameter to 8.8 cm (among other minor changes) and widely issuing it as the Raketenpanzerbüchse "Panzerschreck" ("Tank terror"). Near the end of the war, the Japanese developed a similar weapon, the Type 4 70 mm AT Rocket Launcher, which featured a rocket propelled grenade of a different design.

Buzz Bombs: The V-1 was developed at Peenemünde Army Research Center by the Nazi German Luftwaffe during the Second World War. During initial development it was known by the codename "Cherry Stone". The first of the so-called "Vengeance weapons" (V-weapons or Vergeltungswaffen) series designed for terror bombing of London — because of its limited range, the thousands of V-1 missiles launched into England were fired from launch facilities along the French (Pas-de-Calais) and Dutch coasts. The first V-1 was launched at London on 13 June 1944, one week after (and prompted by) the successful Allied landings in Europe. At its peak, more than one hundred V-1s a day were fired at south-east England, 9,521 in total, decreasing in number as sites were overrun until October 1944, when the last V-1 site in range of Britain was overrun by Allied forces. After this, the V-1s were directed at the port of Antwerp and other targets in Belgium, with 2,448 V-1s being launched. The attacks stopped only a month before the war in Europe ended, when the last launch site in the Low Countries was overrun on 29 March 1945.

V-2, Bumper, (July 24, 1950) a new chapter in space flight began in July 1950 with the launch of

the first rocket from Cape Canaveral, Florida: the Bumper 8. Bumper 8 was an ambitious two-stage rocket program that topped a V-2 missile base with a WAC Corporal rocket. The upper stage was able to reach then-record altitudes of almost 400 kilometers, higher than even modern Space Shuttles fly today. Launched under the direction of the General Electric Company, Bumper 8 was used primarily for testing rocket systems and for research on the upper atmosphere. Bumper rockets carried small payloads that allowed them to measure attributes including air temperature and cosmic ray impacts. Seven years later, the Soviet Union launched Sputnik I and Sputnik II, the first satellites into Earth orbit. In response, in 1958, the US created NASA.

Redstone>>Saturn V: If you ever have a chance to read or purchase Peter Always "Rockets of the World", please do. This will be the book to have and keep in the family. He did a great job with documenting a lot of rockets, some that I never heard of. I want to make a mid-sized scale rocket of the X-17. The rocket spins during lift off and was utilized to test different kinds of re-entry material in support of several aerospace ventures.

ICBMs & Politics:

The reality of an external threat is just as real today as it was during the 1950s. Recent test from the west coast proves that. ICBM test from Vandenberg May 3rd 2017.

Part of the initial politics surrounding the hype of the space race was to get a man into space. At first they wanted a non-military designed rocket. It was discovered that would take too long, so the rockets first used for the initial flights were ICBM booster rockets. The Redstone was a short range ballistic missile (SRBM) and Titan II an intercontinental ballistic missile (ICBM) were both originally designed for military purposes and were modified for one and two man capsuled space missions. That gave more time to build the Saturn 1B and Saturn V rockets. It was vital and essential.

Tactical Nukes: A tactical nuclear weapon (TNW) or non-strategic nuclear weapon is a nuclear weapon which is designed to be used on a battlefield in military situations, mostly with friendly forces in proximity and perhaps even on contested friendly territory. This is opposed to strategic nuclear weapons which are designed to be mostly targeted in the enemy interior away from the war front against military bases, cities, towns, arms industries, and other hardened or larger-area targets to damage the enemy's ability to wage war. Tactical nuclear weapons were a large part of the peak nuclear weapons stockpile levels during the Cold War.

Mutually Assured Destruction (MAD): A doctrine of military strategy and national security policy in which a full-scale use of nuclear weapons by two or more opposing sides would cause the complete annihilation of both the attacker and the defender. It is based on the theory of deterrence, which holds that the threat of using strong weapons against the enemy prevents the enemy's use of those same weapons. The strategy is a form of neutrality which no player has anything to gain. Once armed, neither side has any incentive to initiate a conflict or to disarm.

The Race to Space: Refers to the 20th-century competition between two Cold War rivals, the Soviet Union (USSR) and the United States (US), for supremacy in spaceflight capability. It had its origins in the missile-based nuclear arms race between the two nations that occurred following World War II, aided by captured German missile technology and personnel from the program. The technological superiority required for such supremacy was seen as necessary for national security, and symbolic of ideological superiority. The Space Race spawned pioneering efforts to launch artificial satellites, unmanned space probes of the Moon, Venus, and Mars, and human spaceflight in low Earth orbit and to the Moon.

The Space Race began on August 2, 1955, when the Soviet Union responded to the US announcement four days earlier of intent to launch artificial satellites for the International Geophysical Year, by declaring they would also launch a satellite "in the near future". The Soviet Union beat the US to this, with the October 4, 1957 orbiting of Sputnik 1, and later beat the US to the first human in space, Yuri Gagarin, on April 12, 1961.

The Space Race has left a legacy of Earth communications and weather satellites, and continuing human space presence on the International Space Station. It has also sparked increases in spending on education and research and development, which led to beneficial spin-off technologies.

The Race to the Moon: The race peaked with the July 20, 1969 US landing of the first humans on the Moon with Apollo 11. The USSR tried but failed manned lunar missions, and eventually cancelled them and concentrated on Earth orbital space stations.

A period of détente followed with the April 1972 agreement on a co-operative Apollo–Soyuz Test Project, resulting in the July 1975 rendezvous in Earth orbit of a US astronaut crew with a Soviet cosmonaut crew. The end of the Space Race is harder to pinpoint than its beginning, but it was over by the December, 1991 dissolution of the Soviet Union, after which true spaceflight cooperation between the US and Russia began.

4. Meteorology

The first television picture sent from space by TIROS-1 showed the coast of Maine and Canada's Maritime Provinces. Courtesy NASA

1960: NASA launches the first weather satellite, TIROS-1, from Cape Canaveral, Florida.

TIROS, for Television Infrared Observation Satellite, sent the very first TV images from space to the ground station at Fort Monmouth, New Jersey. The pictures clearly showed the New England coast and Canada's Maritime Provinces north to the St. Lawrence River. The photos were airlifted pronto to Washington, D.C., to be presented to President Eisenhower.

TIROS-1 was an aluminum-and-stainless-steel drum measuring 42 inches in diameter, 19 inches high and weighing 270 pounds. An array of 9,200 solar cells powered its two TV cameras: one high-res, one low-res. One antenna received control signals from ground stations, and another four transmitted TV images back to Earth. Two video recorders stored images when the satellite was out of range of ground stations.

The polar-orbiting craft was not constantly pointed at earth and could only operate in daylight, so coverage was not continuous. It functioned for just 78 days, but it sent back thousands of pictures of cloud patterns forming and moving across the face of the planet. And it proved the theory that satellites could effectively survey global weather from space.

The Environmental Science Services Administration (predecessor of the National Oceanic and Atmospheric Administration) launched more TIROS satellites with NASA in the next few years. But it wasn't until TIROS-9 in 1965 that the program achieved complete daily coverage of the entire sun-illuminated side of the planet.

April 1 has further import in the history of meteorology. It was this day in 1875 that Francis Galton (cousin of Charles Darwin) published the first newspaper weather map in The Times (London). Galton's chart of conditions in northwestern Europe on the previous day had virtually all the elements of a modern weather map: isobars (lines of equal atmospheric pressure), temperatures, wind speed and direction, and sky and sea conditions.

No fooling'. To date there are now 364 active satellites in orbit (this does not include classified satellites of course). 44 retired satellites, 48 deorbited satellites, 16 failed satellites, 13 geostationary satellites, 51 planned satellites, and 878 different satbeam channels being transmitted from the active orbiting satellites:

https://sattrackcam.blogspot.com/

http://satbeams.com/

Reports and Prediction: Hobby wise

With the hobby of rocketry you can create thousands of reports, hypothesis and predictions with rocketry. [The National Association of Rocketry]() now has an archive for NAR members* of all research and development presentations that have been conducted from other rocket enthusiasts. Beginning from the year 1972, there are more than 500 R&D reports to look through and read. There are a lot of amazing items discussed, and there is still more to research. Rocketry is more than just three fins and a nose cone. So much more☺

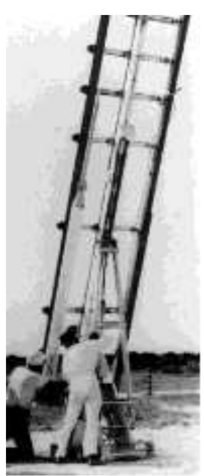
Thermals: Understanding thermals in the case of rocketry and rocket related contests are very valuable. Thermals are rising masses of air that rise because they are warmer than the rest of the surrounding air mass. This warming is generally the result of points on the ground such as dark plowed earth or asphalt paving that are being heated by sunlight. Thermals generally arise at increasing rates as the day moves from dawn to mid-afternoon, then subside as the ground cools toward sunset. They usually develop in some sort of interval that leads to “waves” of thermal activity that propagate downwind at a predictable periodicity that changes with the time of day and the wind speed. They can be detected with sensitive temperature-measuring devices that show warming air, with devices such as thin streamers on tall poles or soap bubble generators that show rising air, or by observing the flight of birds that use them to soar or the flights of other models already in the air. Thermals have both a horizontal and a vertical structure; a thermal detected at the ground may or may not mean that there is a thermal at that point which extends all the way to the flight altitude of a model that flies over that point at that time.

Flight performance in all duration events is heavily influenced by the degree to which models exploit and ride in thermals. A flier who can regularly detect and then launch reliable models into thermals will almost always do better than a flier who does not have this skill.

Another excellent resource is the DVD “Secrets of Thermal Soaring” available at http://www.radiocarbonart.com

http://www.nar.org/wp-content/uploads/2014/05/Detecting-Thermals-Gassaway-Mizoi1.pdf

(Source: http://www.nar.org/contest-flying/competition-guide/techniques-and-tips/detecting-thermals/)



Weather: Successful launching of a rocket has a great dependence upon the weather. Determining current and future weather conditions requires measurements of such things as temperature, wind direction and speed, barometric pressure to name only a few. These measurements must be made not only at ground level, but at many altitude levels as well.

All sorts of instruments are employed to aid meteorologists with their predictions. Balloons carry instrument packages to high altitudes and transmit measurements back. Conduct your own research or build a semi scale rocket of the Arcas or Loki.

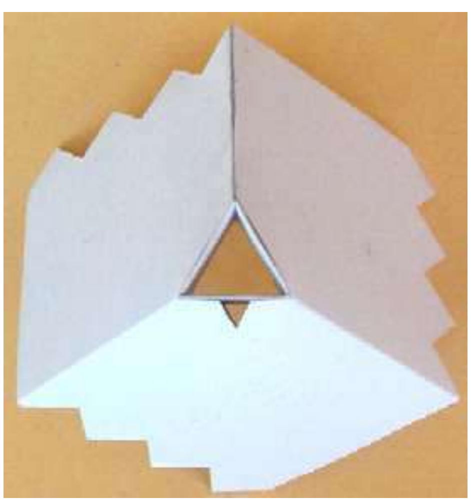
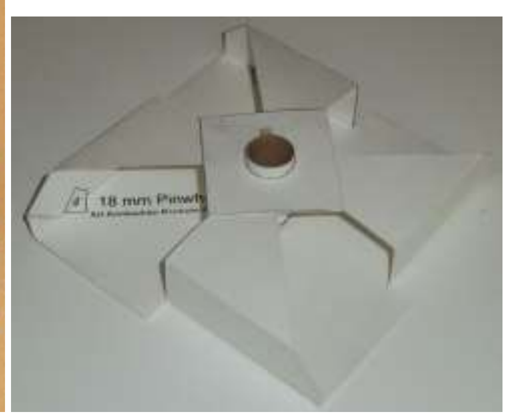
Observation of Wind: Understanding your site where you will conduct a rocket launch will depend on wind. Surveying your site and knowing where the prevailing winds are is a good thing. You will want to be aware of where your rockets will land. In flight, the rocket will not be traveling sideward, but with its nose pointed into the wind. The wind speed should be no more than 20 miles per hour.

A great article from Apogee which was previously posted in the March 1998 issue of High Power Rocketry can be read at the following link:

https://www.apogeerockets.com/Wind_Caused_Instability

Sounding Rockets: A sounding rocket, sometimes called a research rocket, is an instrument-carrying rocket designed to take measurements and perform scientific experiments during its sub-orbital flight. https://sites.wff.nasa.gov/code810/files/SRHB.pdf

5. **Aesthetics (beauty)/Design**: Some rockets will be designed for certain purposes that may not look pleasing to the eyes of others, but with what a person (you) may want to achieve is something different. Some designs could be Monocopters. These items do not fit the design of a typical rocket: Non typical rocket designs

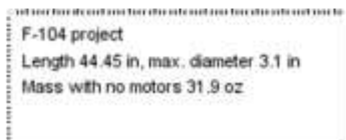
I myself like building rockets of history. Scale rockets such as the Mercury Atlas, the Saturn V. Those are aesthetically pleasing to me.

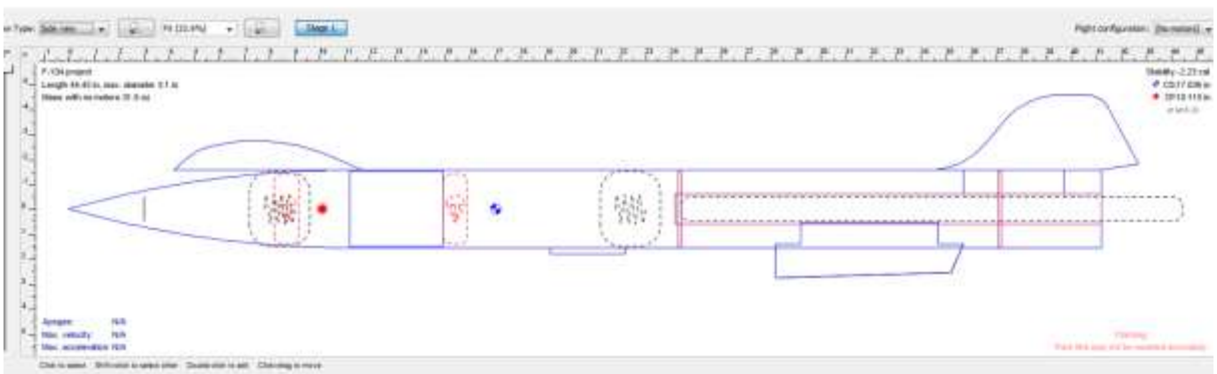
Art in science context: Science is an art within itself. Bill Nye the Science Guy stated it well:

http://www.npr.org/2017/04/22/525065105/in-a-new-anti-science-era-bill-nye-saves-the-world-with-same-optimism

Art and science are literally one. You will find yourself when designing your own rocket or looking up scaled detail on a rocket, it will require art. You may wonder why some details on a rocket are there and wonder why it was used.

Balance and Movement: If your rocket creation is deigned and balanced where is should be, it will move upward correctly:





Colors: there is a plethora of colors to choose from these days. You will learn new concepts in applying paint. You may even become interesting and gain a new talent with air brushing your rockets, model or other items. Air brushing will provide more details to your design and if weight becomes an issue, air brushing is better than spray painting. Even though there is more preparation time, it can prove to be rewarding.

Design and Style: You will learn new designs and styles.

Form and Function: You will discover in rocketry that the form causes an effect on the function of the rocket.

Historical Design: The earliest solid rocket fuel was a form of gunpowder, and the earliest recorded mention of gunpowder comes from China late in the third century before Christ.

Bamboo tubes filled with saltpeter, Sulphur and charcoal were tossed into ceremonial fires during religious festivals in hopes the noise of the explosion would frighten evil spirits.

It's probable that more than a few of these bamboo tubes were imperfectly sealed and, instead of bursting with an explosion, simply went skittering out of the fire, propelled by the rapidly burning gunpowder. Some clever observer whose name is lost to history may have then begun experiments to deliberately produce the same effect as the bamboo tubes which leaked fire.

Certainly by the year 1045 A.D.--21 years before William the Conqueror would land on the shores of England--the use of gunpowder and rockets formed an integral aspect of Chinese military tactics.

A point of confusion arises tracing the history of rocketry back before 1045. Chinese documents record the use of "fire arrows," a term which can mean either rockets or an arrow carrying a flammable substance.

By the beginning of the 13th Century, the Chinese Sung Dynasty, under pressure from growing Mongolian hordes, found itself forced to rely more and more on technology to counter the threat. Chinese ordnance experts introduced and perfected many types of projectiles, including explosive grenades and cannon.

Rocket fire-arrows were certainly used to repel Mongol invaders at the battle of Kai-fung-fu in 1232 A.D.

The rockets were huge and apparently quite powerful. According to a report: "When the rocket was lit, it made a noise that resembled thunder that could be heard for five leagues -- about 15 miles. When it fell to Earth, the point of impact was devastated for 2,000 feet in all directions." Apparently these large military rockets carried incendiary material and iron shrapnel. These rockets may have included the first combustion chamber, for sources describe the design as incorporating an "iron pot" to contain and direct the thrust of the gunpowder propellant.

Scale Modeling: Scale modeling may be one of the most popular activities in the hobby. The treasure for a lot of scale rocket builders is the Saturn V rocket. I myself have built three of them as well as the Mercury Atlas rocket, and the shuttle and more. It is great to read up on the history of each rocket built. The more accurate you are in the design, the better.

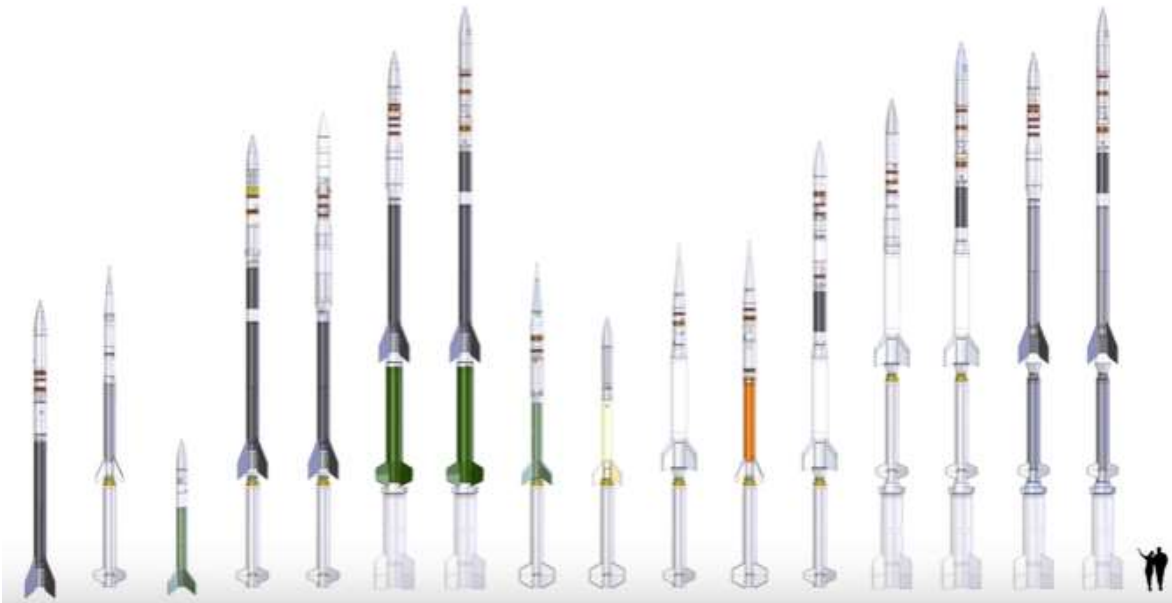
Shape and Area:

6. **<u>Big Rockets vs Micro</u>**

   Sometimes bigger is not always better, especially with rocketry. Sure as young adults we see the bigger rocket models as wow. However, a lot of the similar results conducted with smaller versions or designs will often have the same if not identical results.

   Making a bigger rocket, however does make assembly and construction a little easier. You do have to take in consider a bigger recovery system for the bigger system due to weigh and size.

   https://youtu.be/KyfQish8yqA



Technology: There have been so many nice advancements in technology. Rocketry has provided several advances throughout the years. http://www.greatachievements.org/?id=3642

The event was so draped in secrecy that, despite its historic nature, no pictures were taken. But no one who was there—nor, for that matter, anyone else who heard of it—would ever forget the moment. With a blinding glare and a shuddering roar, the rocket lifted from its concrete pad and thundered into the early evening sky, soaring up and up and up until it was nothing more than a tiny glowing speck. On the plains of Kazakhstan, on October 4, 1957, the Soviet Union had just launched the first-ever spacecraft, its payload a 184-pound satellite called Sputnik.

One Giant Leap: What does that word mean to you? Most people would associate it to the quote from Neil Armstrong when he landed on the moon:

"That's one small step for man, one giant leap for mankind". It was a poignant moment in 1969 when man had actually stepped on the moon. The technological advancements required to accomplish that moment is astonishing. I could not have imagined that we now take that achievement for granite.

We are still continuing to take giant leaps in space, more of the missions are robotic but are amazing none the same. Research what is going on with NASA or missions from Wallops island and other space agencies.

International: Japan has sent rovers to the moon and China is in the process of build their own space station. India recently launched the most CubeSat's on own rocket of their own.

https://www.theverge.com/2017/2/14/14601938/india-pslv-rocket-launch-satellites-planet-doves

Expeditions: Within the hobby of rocketry, YOU can be an explorer and conduct your own missions. You can read about other real world explorations wich can enhance what you may do in the future.

Here is a great pictorial link on expeditions:

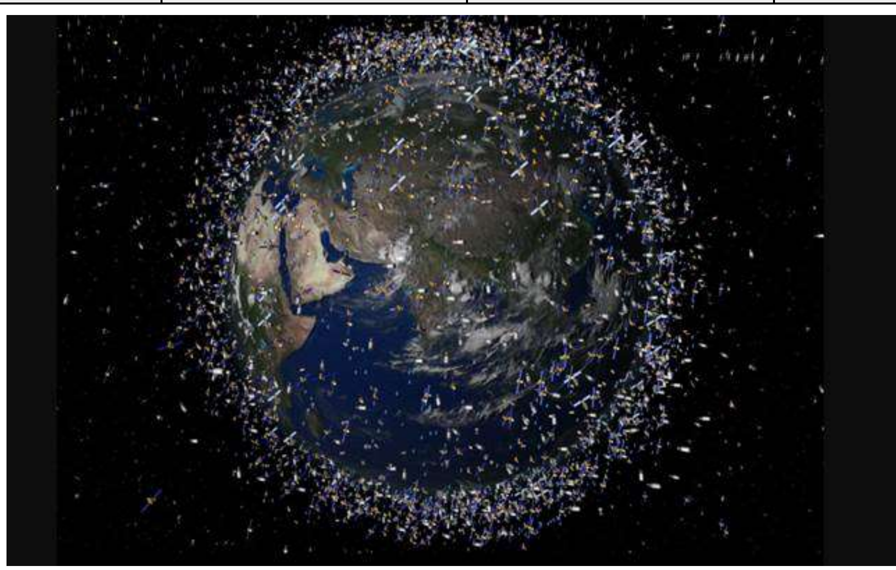
https://upload.wikimedia.org/wikipedia/commons/6/6b/Timeline_of_Solar_System_exploration.jpg

And more resources for expansion of learning:

https://en.wikipedia.org/wiki/Space_exploration

Commercial Satellites: There are many, commercial satellites in outer space now. http://www.satbeams.com/. There are 1,459 satellites currently orbiting Earth (http://www.ucsusa.org/nuclear-weapons/space-weapons/satellite-database#.WRtlb1XytQI).

Satellite Quick Facts *(includes launches through 12/31/16)*			
Total number of operating satellites: 1,459			
United States: 593	Russia: 135	China: 192	Other: 539
LEO: 803	MEO: 96	Elliptical: 38	GEO: 522
Total number of US satellites: 593			
Civil: 10	Commercial: 297	Government: 136	Military: 150



94 satellites listed with civil users: These tend to be educational institutes, although there are other national organizations also included. 46% of these satellites have a purpose of technology development, whilst Earth/Space science and observation account for another 43%.

579 with commercial users: Commercial organizations and state organizations who want to sell the data they collect. 84% of these satellites focus on communications and global positioning services; of the remaining 12% are Earth observation satellites.

401 with Government users: Mainly national Space organizations, together with other national and international bodies. 40% of these are communications and global positioning satellites; another 38% focus on Earth observation. Of the remainder space science and technology development have 12% and 10% respectively.

345 with military users: Again communications, Earth observation and global positioning systems are the strong focus here with 89% of the satellites having one of these three purposes.

Around 65 countries have launched satellites, although on the UCS database there are only 57 countries listed with operational satellites, again some satellites are listed with joint/multinational operators. The largest are:

USA with 576 satellites

China with 181 satellites

Russia with 140 satellites

The UK is listed as having 41 satellites, plus we're involved in an additional 36 satellites that the European Space Agency has. http://www.pixalytics.com/sats-orbiting-earth-2016/

https://orbitaldebris.jsc.nasa.gov/

Space Accidents:

Liberty Bell 7 (1961): Some may not consider this mission as an accident, since Gus Grissom did return, however his capsule did sink and was finally salvaged from the deep sea in 1999. There was always a cloud over Gus Grissom's reputation about losing the capsule to the sea. There was speculation that he hit the emergency release lever that deployed the capsule door too soon. It was discovered after the deep sea recovery that it did not get deployed by Gus.

Apollo 1 (1967): Sadly six years later after the Liberty Bell 7 and a Gemini mission, Gus Grissom, along with Ed White who was the first American astronaut to conduct a spacewalk and Richard

Chaffee who was a U-2 pilot and a rookie to the space program perished in a ground test in preparation for the first Apollo mission. A fire began under Gus Grissom's seat in the capsule. They were inside a capsule that was pressurized with 100 percent oxygen. The fire happened very quickly and they died within 14 seconds after the fire began. There was no way that they would have been able to get out due to the cumbersome design on the escape hatch.

http://www.space.com/14379-apollo1-fire-space-capsule-safety-improvements.html

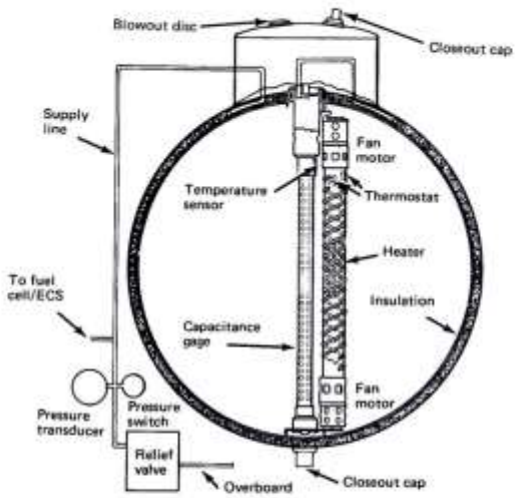
The accident was tragic and a lot of safety issues were quickly identified after a lengthy investigation. A lot of historical documents that you may read about this incident will state that there would have definitely been a death in space if this accident had not happened. Before this accident, all previous manned capsules were also utilized with pure oxygen. It was less tedious to work with that instead of an oxygen nitrogen mix. 100 percent oxygen also lowered the chance of the bends (a malady known as Decompression Sickness).

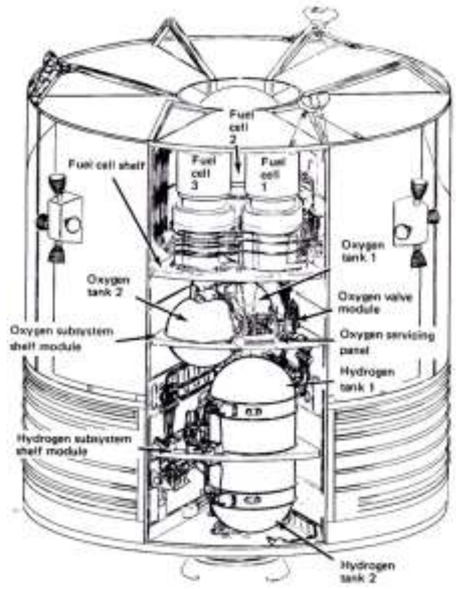
http://www.bishopmuseum.org/research/treks/palautz97/phys.html

Ultimately, though, while spacecraft safety has improved leaps and bounds since Apollo 1, the business of flying in space is still risky, and NASA aims to remember that. The Apollo 1 fire was not the last of NASA's deadly space accidents. Two fatal space shuttle accidents, one in 1986 and the other in 2003, killed 14 astronauts in all, forcing NASA each time to reexamine its spacecraft safety.

Apollo 13 (1970): Apollo 13 was one of the first near death missions after the Apollo 1 fire. The beginnings of the accident occurred prior to lift off. During one of the system checks before liftoff, a faulty sensor was no longer working with one of the oxygen tanks that normally gets stirred during traveling to the moon.

During pre-flight testing, tank no. 2 showed anomalies and would not empty correctly, possibly due to the damaged fill line. (On the ground, the tanks were emptied by forcing oxygen gas into the tank and forcing the liquid oxygen out, in space there was no need to empty the tanks.) The heaters in the tanks were normally used for very short periods to heat the interior slightly, increasing the pressure to keep the oxygen flowing. It was decided to use the heater to "boil off" the excess oxygen, requiring 8 hours of 65 volt DC power. This probably damaged the thermostatically controlled switches on the heater, designed for only 28 volts. It is believed the switches welded shut, allowing the temperature within the tank to rise to over 1000 degrees F. The gauges measuring the temperature inside the tank were designed to measure only to 80 F, so the extreme heating was not noticed. The high temperature emptied the tank, but also resulted in serious damage to the teflon insulation on the electrical wires to the power fans within the tank.





https://nssdc.gsfc.nasa.gov/planetary/lunar/ap13acc.html

Luckily with the ingenuity of the ground control team and all of the contractors involved with the design of the Apollo rocket and missions, the crew returned home safely.

Challenger (1986): Like a lot of people, I can remember the day of where I was and what I was doing when news of the Challenger accident occurred. I was working near the Johnson Space Center in Texas on that day. I was working as a landscaper while waiting to join the Marine Corps the following year.

Worked had wrapped up and I was headed home. My dad notified me that there was an accident with the shuttle. I thought he was trying to pull me leg. Sure enough the news was everywhere announcing the tragedy. The following day Clearlake City Texas was a ghost town. President Reagan came to the Johnson Space Center for a memorial service which was heart felt. Most of the families were living near the Johnson Space Center. This is where all of the astronauts trained for missions. The investigation lasted for almost two years and the discrepancies with the mission as well as the design of the boosters were identified and fixed.

Luckily the shuttle system and its missions were back in business in 1988 with the STS-26 Discovery mission.

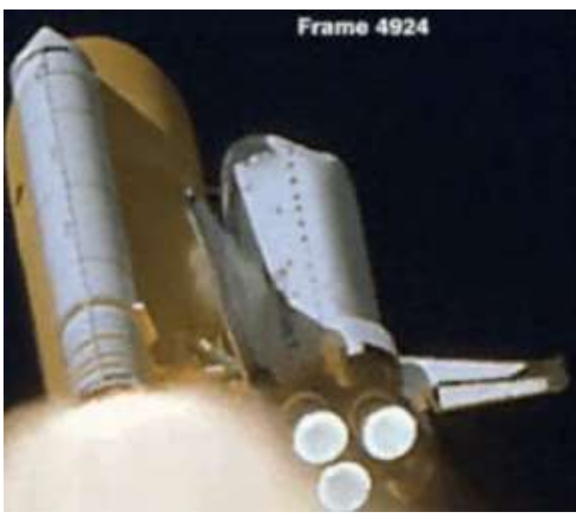
Every person involved with space missions know the risks and always try to implement every known safety measure. It does not mean accident will not happen. Those who venture into this field will still want to try to succeed. The rewards and discoveries could be amazing.

Columbia (2003): We had an imbedded reporter with us from the Wall Street journal while I was in Kuwait waiting to cross the line of departure to Iraq. Operation Iraqi Freedom was about to get very busy. I was with the 3rd Battalion 7th Marines Battalion. We were involved with getting prepared for what could happen once we cross into Iraq. I first stop would be in Al-Basrah Iraq and then continue north. The reporter gave us the news about the accident. It was a very sad day. A month later (March 19th, 2003) I was busy with the infantry battalion being active with current events. Nine months after returning back to the United States. I read further about the Columbia accident. It was interesting that the video showed large pieces of the foam from the external tank impacting the wing of the shuttle.

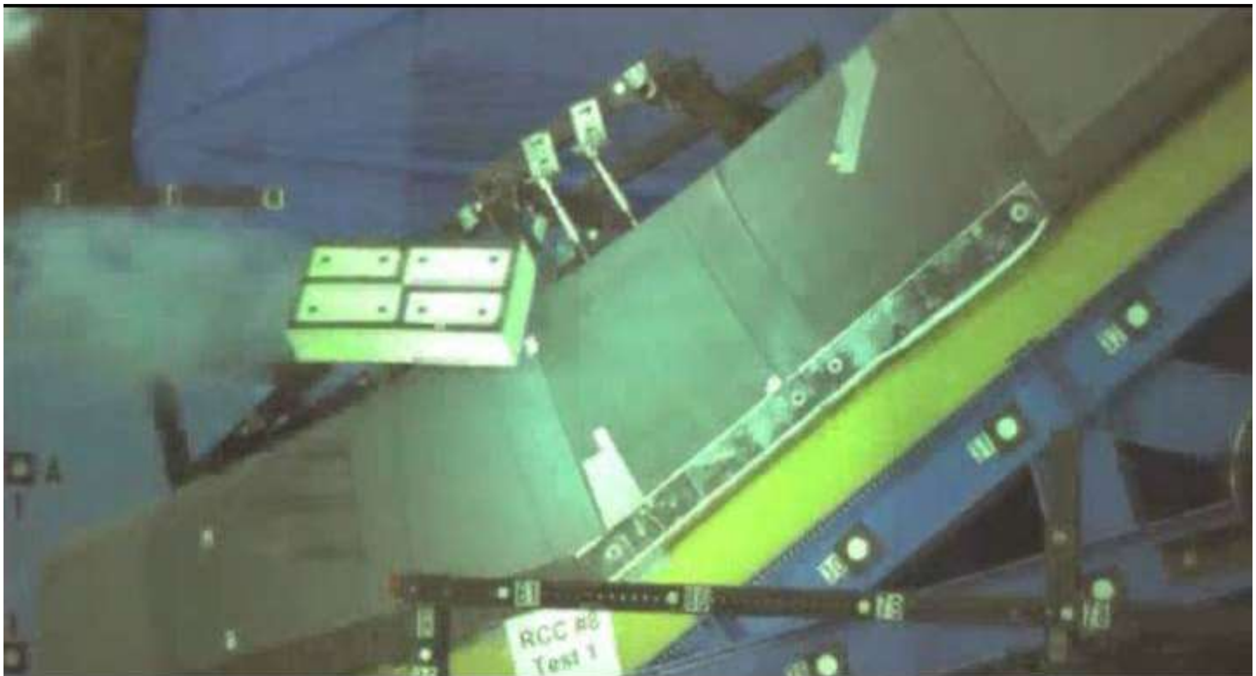
This is what was diagnosed as the point of failure.

There were a lot of afterthought questions of what could have been done to save the crew. This would be a great discussion with the classroom of what could have been done.

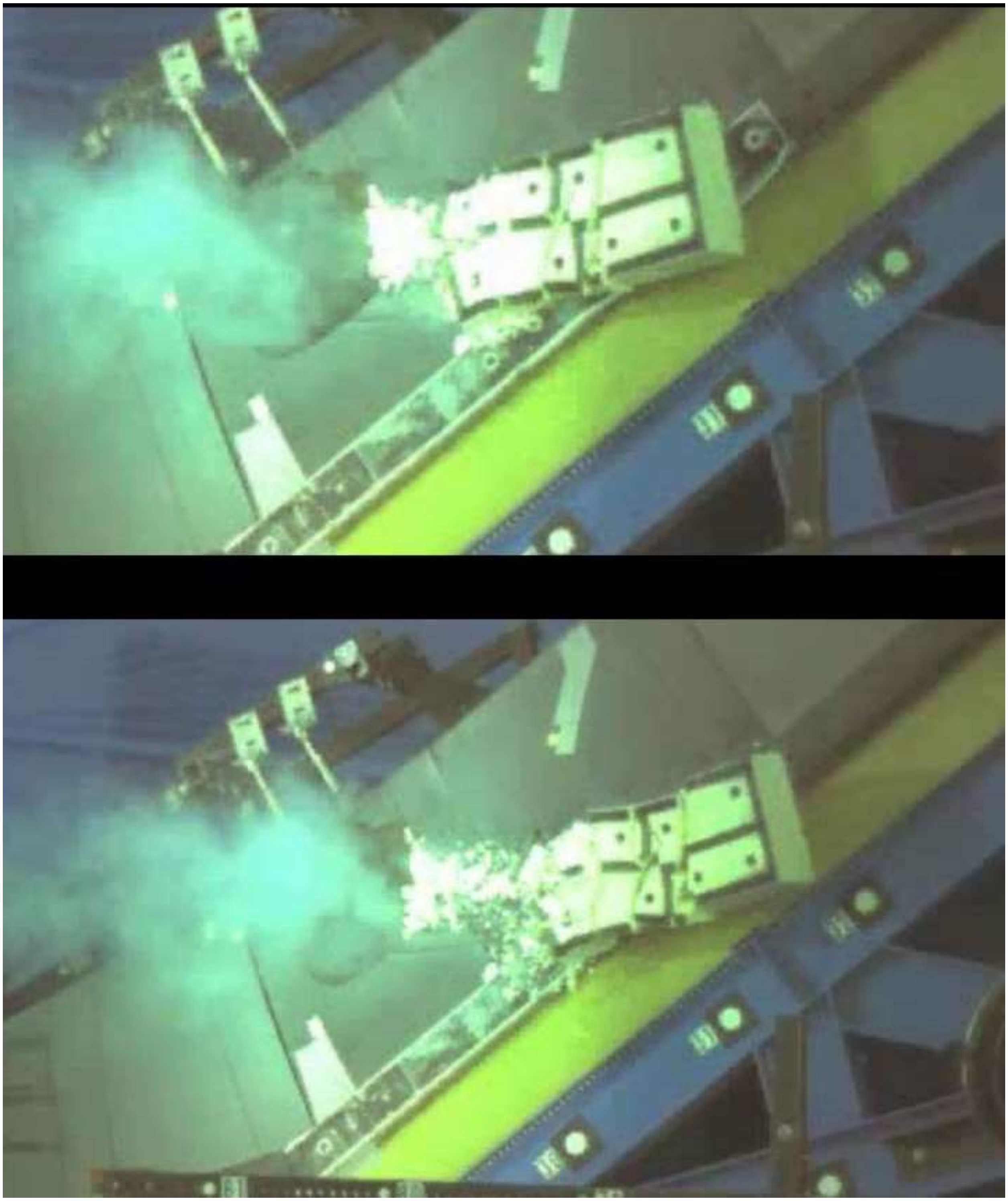
It is interesting to know that the paint that was applied only on the first shuttle mission of Columbia was intended as an application in order for preventing the possibility of foam coming off of the tank during flight. This added weight though, so it was later not applied.

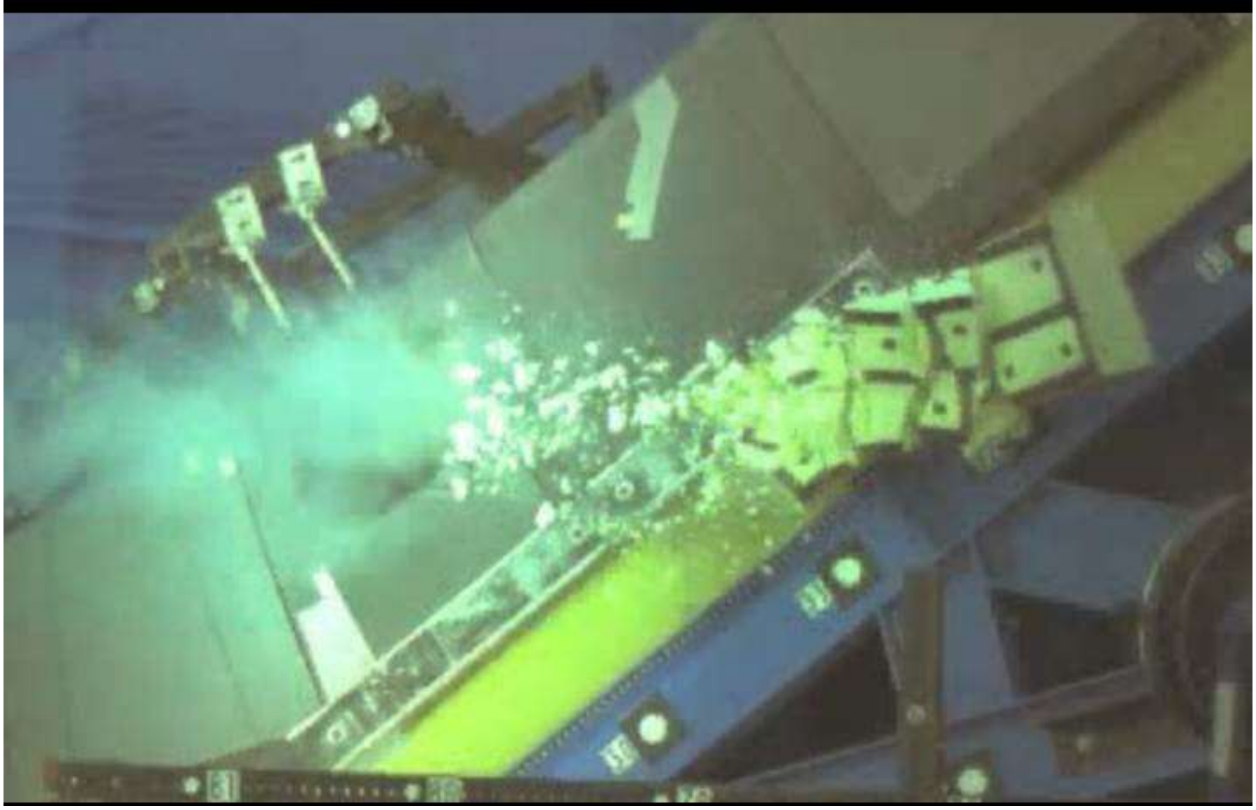


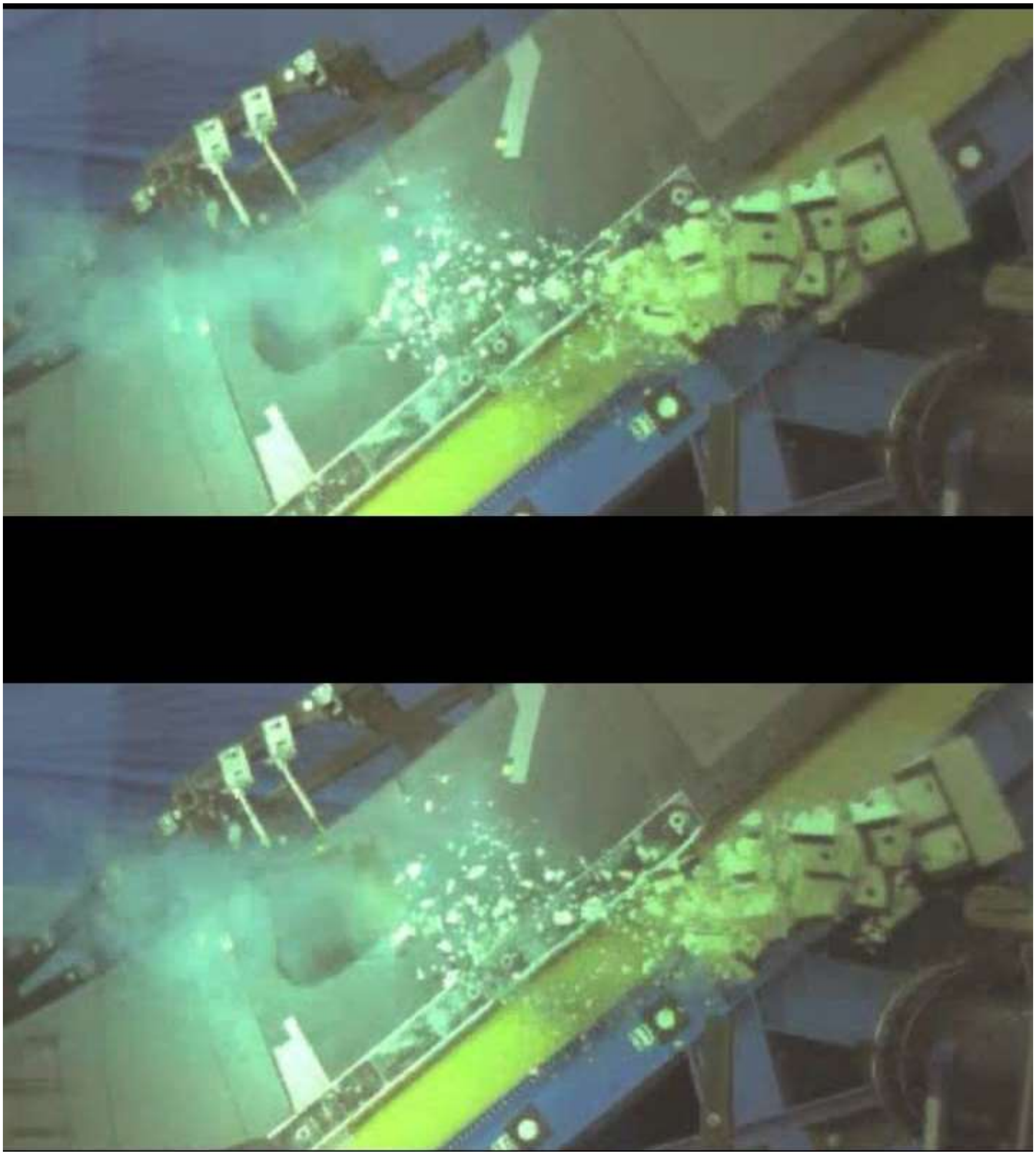
Below are slow motion shots from NASA investigation team. They implemented the same speed that the impact would have occurred during liftoff. A lot did not think how significant the impact could have been. After the test was conducted, they realized how severe the impact would have been.

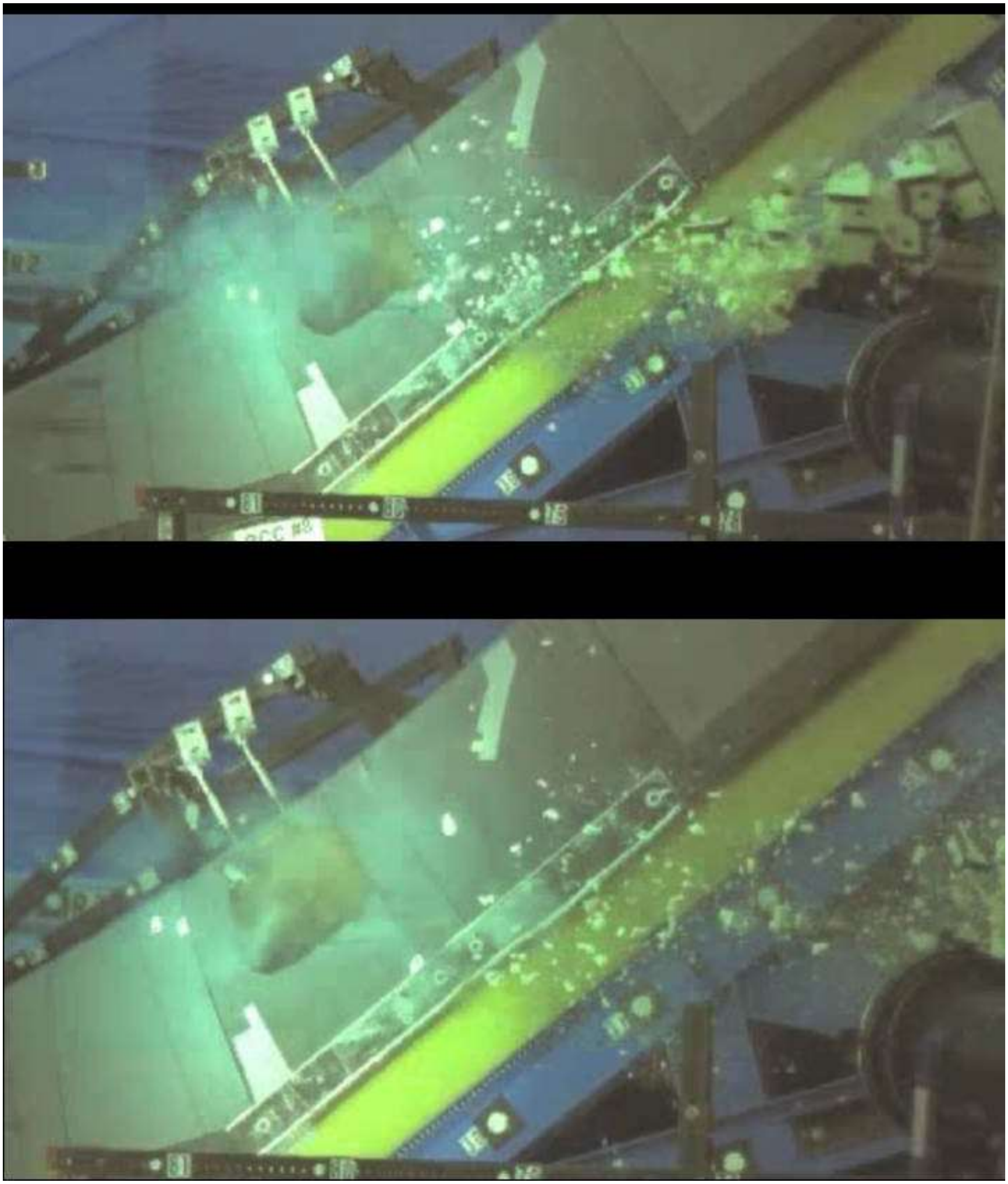

RCC #8
Test 1


RCC #8
Test 1









Source of video: Exploring Structural Dynamics April 2007 V1.1

http://www.aiaa.org or aiaasdtc_education@yahoo.com

7. Scientific Method

A way of doing something, especially a systematic way.

Model rocketry is an ideal tool for use with school science projects. It permits the student to conduct many repetitions of a flight experiment at a reasonable cost, and in the process of doing the experiment the student not only learns but also gets to do something that is a lot of fun—fly rockets! If the student understands the experimental method and uses rockets the right way for the right topics, a rocketry-based project can be an impressive entry in the Engineering or Physics category of a science fair at any grade level.

https://quizlet.com/33225625/sciencescientific-methodrockets-flash-cards/

In the movie October Sky, the scientific method has a very important role. The scientific method starts with a problem, and there are plenty of those in October Sky. While the main problem is getting the rocket to fly, the "Rocket Boys" run into several others along the way. The most serious of those is that they can't find one rocket and are accused of starting a forest fire. Using what he learns from a book about the flight of rockets, the Rocket Boys leader Homer develops a hypothesis. Based on this, using a formula and math, he figures out that the missing rocket should have landed about 6320 feet away from the launch pad. But when he and Quentin get to the predicted landing spot, the rocket is nowhere around! Homer backtracks and sits on a rock in a stream, trying to figure out where he went wrong. He realizes that something must be wrong with his hypothesis. What? He should have factored wind into his calculations, he decides, so he refines his hypothesis. He and Quentin agree that the wind that day most likely would have deflected the rocket slightly westward. He looks to the west, gets a big smile on his face, and we soon learn why: there's the missing rocket in the middle of the stream! Clearly, this rocket did not start the fire! (Later we learn that an aeronautical flare started the fire.) In the scientific method, you start with a problem, form a hypothesis, test it, and ask yourself if this hypothesis fits your data. If it doesn't, you keep refining and testing it until the hypothesis fits your data! October Sky provides good example of this process.

The Scientific Method

The first step of the scientific method is simply to come up with a question about the way something is or works.

Hypothesizing

Hypothesizing the outcome is the second step in the scientific method.

A hypothesis is a prediction of the answer to the question. Good ones are based upon research/previous observation.

Creating an Experiment

The next step is to create an experiment that will answer the question.

Performing the Experiment

The next step is to perform the previously developed experiment, ensuring all relevant data is gathered.

Analyzing Results and Reaching a Conclusion

The final step is to carefully analyze all the data gathered and use it to determine what happened during the experiment. Based on the observed result, and assuming the experiment was adequate in its ability to answer the question, the experimenter should be able to draw a clear conclusion that satisfactorily answers the question.

Social Skills:

All of the above items discussed for scientific method will require good social skills.

Teamwork: Working as a team can be fun and challenging and rewarding. The more complex you venture with the hobby, the better it is to work as a team. It helps with success, teaches patience and it makes the success overall, so much better. You can learn a lot from other people. Everyone learns differently and looks at challenges differently.

Leadership: Leadership is a talent and something that needs to be practiced by all. Sometimes you will be the leader of something and then sometimes you will have to be lead or follow someone else taking the role as lead. It requires patience and humility. This is not always easy, but definitely is invaluable.

Using Varied Abilities: Being a leader requires you to discover those working with you their talents. What are they good at and how can they help with what projects or tasks need to be accomplished.

Pleasing Varied Interests: Meaning displaying or characterized by variety; diverse. There is a variety of specialties within the hobby or rocketry. Some like to design and create, others like to delve in the variations of different payloads to place in a rocket, some like parachute recovery concepts, streamer duration ideas, tumble recovery launches, flex wing boost gliders, scissor-flop wing boost gliders, helicopter recovery designs, staging designs, two or three stage designs, radio controlled boost gliders and so on. There is not just one concept in this great hobby.

Non-Verbal Communication: Gestures and facial expressions, body posture, stance, and proximity to the listener, eye movements and contact, and dress and appearance. It's well known that good communication is the foundation of any successful relationship, be it personal or professional. It's important to recognize, though, that it's our nonverbal communication—our facial expressions, gestures, eye contact, posture, and tone of voice—that speak the loudest. The ability to understand and use nonverbal communication, or body language, is a powerful tool that can help you connect with others, express what you really mean, and build better relationships.

Speech and Public Address: Have you heard of Toastmasters? Toastmasters help you become a great or better speaker and presenter. You may be very smart and knowledgeable in your profession. If you are no able to convey what you know to others well, then you may not gain their interest in what you have to say.

It is a great skill to have the ability to speak publicly. There are a lot of people that get stage fright when they are requested or required to talk in front of a group, crowd or classroom. The more you practice talking and speaking in front of a crowd, the better you will become and you will gain the confidence you need to succeed.

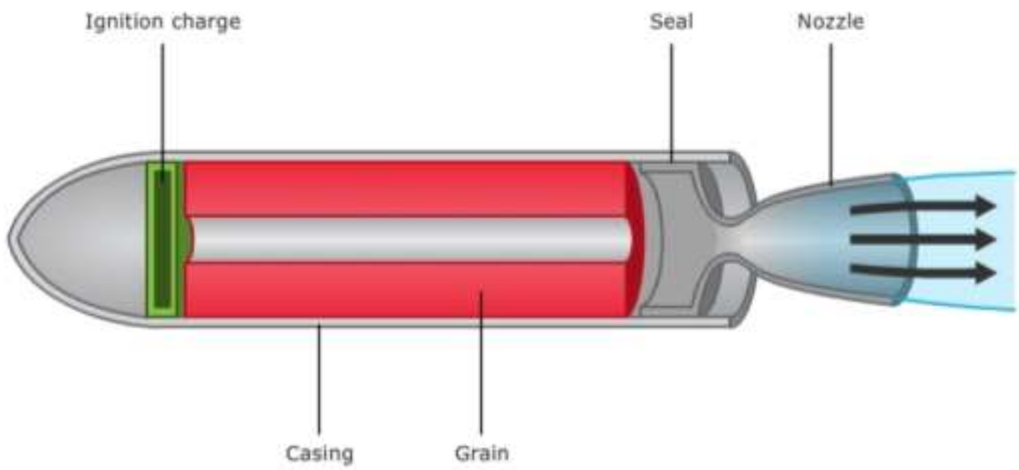
<u>Chemistry</u>

Chemistry is at the heart of making rockets fly. Rocket propulsion follows Newton's Third Law, which states that for every action there is an equal and opposite reaction. To get a rocket off the launch pad, create a chemical reaction that shoots gas and particles out one end of the rocket and the rocket will go the other way.

What kind of chemical reaction gets hot gases shooting out of the business end of a rocket with enough velocity to unshackle it from Earth's gravity?

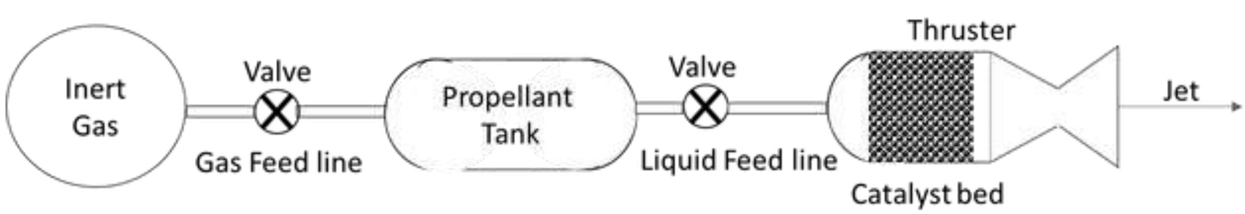
Combustion:

Whether it's your personal vehicle or a behemoth launch vehicle like the basics are the same. Combustion (burning something) releases energy, which makes things go. Start with fuel (something to burn) and an oxidizer (something to make it burn) and now you've got propellant. Give it a spark and energy is released, along with some byproducts.



Accelerants: Something to make it burn. Chemicals like Sulphur, powdered aluminum, or other easily oxidized metals. When lit, the fuel grain will burn energetically, releasing a large volume of hot gases that are used to provide thrust. https://youtu.be/uEAHMVhDAow

Catalysts: (often heated)

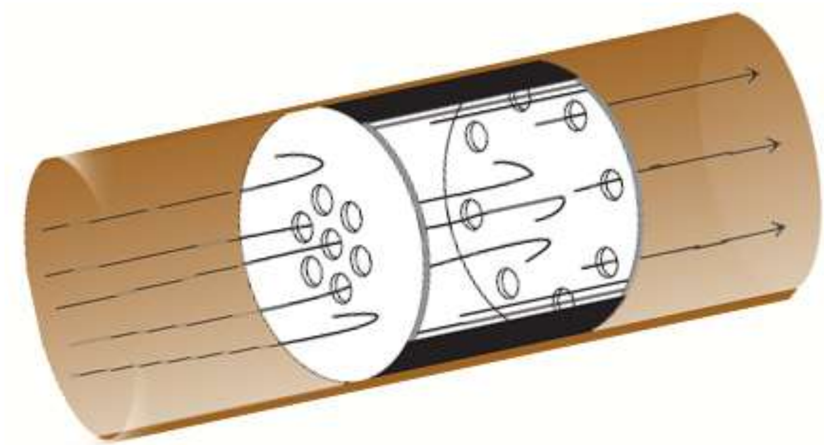


http://www.spacesafetymagazine.com/aerospace-engineering/rocketry/hybrid-rockets-overview/

https://youtu.be/nPfcwT4Fcy8

Combustion: In order to maintain a steady thrust the chemical reaction has to be energetic enough to maintain a high pressure inside the combustion chamber ('chamber pressure') while there is a continuous pressure-loss from the nozzle. The contents of a solid rocket are generally referred to as the 'fuel grain' and its rate and physical pattern of combustion is referred to as 'Regression'.

Flame and Retardants: In basic model rocketry, recovery wadding is utilized. The recovery wadding is a flame retardant. You can utilize a piston design instead of wadding. That can be considered a safer measure since some areas where rocket hobby enthusiasts launch are in areas near trees. Public Missiles Rocketry, better known as PML implement that design in their rocket kits. The piston design is one option. You can also use a baffle system. That has been implemented in other rocket kits. Baffles– Baffles are means of taming the hot ejections gases of the ejection charge. They can be made of steel wool, a mesh material or a series of mis-aligned tubes. The devices trap the hot gases while allowing the ejection pressure to continue through the containment.



Cellulose fiber– commonly known as Dog Barf. Probably the most widely used wadding. Used in both LPR and HPR. Sold as Cellulose insulation and readily available at your local hardware store. A $7 bail will last you a lifetime of rocketry. Cellulose is composed of 75-85% recycled paper fiber, usually post-consumer waste newsprint. The other 15% is a fire retardant such as boric acid or ammonium sulphate. Cellulose has the highest recycled content of any insulation available.

Glue and Cement: Glue and bonding to materials is a science of chemistry. Understanding how adhesives adhere to items is very useful. You may find that an epoxy you have been using for rocketry may soften up if exposed to the sun for a long time. They may not be a good thing if your fins soften up during a rocket launch. Some glue is also good for rocket motors.

High and Low Explosives:

High explosives are those that detonate. The reaction is defined as instantaneous combustion with speeds ranging from 3,300 to 29,900 feet per second (faster than the speed of sounds- 1,142 feet per second). High explosives have a more “shattering” effect rather than a “pushing” effect associated with low explosives. In general, high explosives must be initiated by the shock of a blasting cap.

Low explosives are those that **deflagrate:** the reaction defined as very rapid combustion from the surface inward as a reaction rate slower than the speed of sound. Low explosives have more of a “pushing” effect rather than the “shattering” effect associated with high explosives, so they are used primarily for propulsion. Low explosives can be initiated by a simple flame or acid flame reaction. They can also be initiated by shock or friction, but do not require the shock of a blasting cap. Examples of low explosives include black powder, smokeless powder, and solid rocket fuel.

Propellants/Oxidants:

Liquid Propellants

Fuel & Oxidizer stored separately

Liquid oxygen (LOX) and liquid hydrogen (Space Shuttle)

LOX-alcohol, LOX-kerosene (early ballistic missiles)

Combined in combustion chamber

Combustion pressure attained by

Turbo-pumps

Stored gaseous pressurant

Solid Propellants

Heterogeneous, aka composites, (modern ballistic missiles)

Oxidizer & Fuel, while mixed intimately, are stored as distinct molecules

Oxidizer (NH_4ClO_4) and fuel (Al) held in a rubber matrix (also fuel)

Black powder…this is what most model rockets use (10% powdered sulfur, 75% salt peter (KNO_3) & 15% powdered charcoal)…plus a teeny bit of binder

Homogeneous

Fuel & Oxidizer are part of the same molecule

During combustion, molecule decomposes and components burn

Gun cotton

Nozzles:

All modern rockets use a de Laval concept

Subsonic converging section

Sonic throat

Supersonic diverging section

Conical: easy to manufacture & ~98% efficient…this is what model rockets use

Bell: more difficult to manufacture & ~99+% efficient

Multiple cooling concepts

Regenerative: Propellant flows thru hollow nozzle walls until it's injected into combustion chamber

Ablative: Nozzle wall chars, & the char insulates the uncharred nozzle wall

Film: A thin propellant film coats the nozzle wall and insulates it

Heat sink: The nozzle just gets hotter during firing…this is what model rockets use

Thermoplastics (styrene)

Sometimes referred to as thermoplastic rubbers, are a class of copolymers or a physical mix of polymers (usually a plastic and a rubber) which consist of materials with both thermoplastic and elastomeric properties. While most elastomers are thermosets, thermoplastics are in contrast relatively easy to use in manufacturing, for example, by injection molding. Thermoplastic elastomers show advantages typical of both rubbery materials and plastic materials. The benefit of using thermoplastic elastomers is the ability to stretch to moderate elongations and return to its near original shape creating a longer life and better physical range than other materials. The principal difference between thermoset elastomers and thermoplastic elastomers is the type of cross-linking bond in their structures. In fact, crosslinking is a critical structural factor which imparts high elastic properties.

Thermosetting Plastics

Are synthetic materials that strengthen during being heated, but cannot be successfully remolded or reheated after their initial heat-forming. This is in contrast to thermoplastics, which soften when heated and harden and strengthen after cooling.

(Epoxy, polyurethane)

Epoxy resin is the best product for what we do, polyurethane resins are mostly used in casting and the resin can set pretty quickly and is a bit thick.

http://www.rocketryforum.com/attachment.php?attachmentid=311983&d=1487042214

http://www.rocketryforum.com/attachment.php?attachmentid=311982&d=1487042213

http://www.rocketryforum.com/attachment.php?attachmentid=311984&d=1487042214

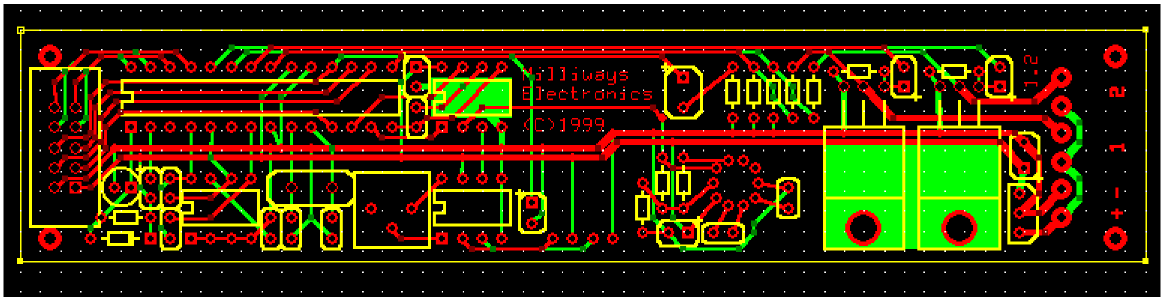
http://www.rocketryforum.com/attachment.php?attachmentid=311985&d=1487042215

http://www.rocketryforum.com/attachment.php?attachmentid=311986&d=1487042216

8. **Electronics**

   Trends in Rocket Electronics:

   https://www.youtube.com/watch?v=1OgUF-Ky-Os



Telemetry: Telemetry is the primary means of obtaining data from sounding rockets. The instrumentation system provided to the Principal Investigator (PI) depends upon the complexity of the experiment, the configuration of the detectors, and the size of the rocket. In some cases, a separate instrumentation package is best; in other cases, the instrumentation and detectors are fully integrated in the same housing(s). It can also be necessary to have a telemetry receiving and transmitting device in your rocket for better ability of acquiring and recovering your rocket. If you launch in rugged terrain, this item will be a necessity.

http://altusmetrum.org/

http://www.bigredbee.com/zc139/

Examples of Telemetry for real rockets:

https://youtu.be/ynMYE64IEKs

https://youtu.be/nNRs2gMyLLk

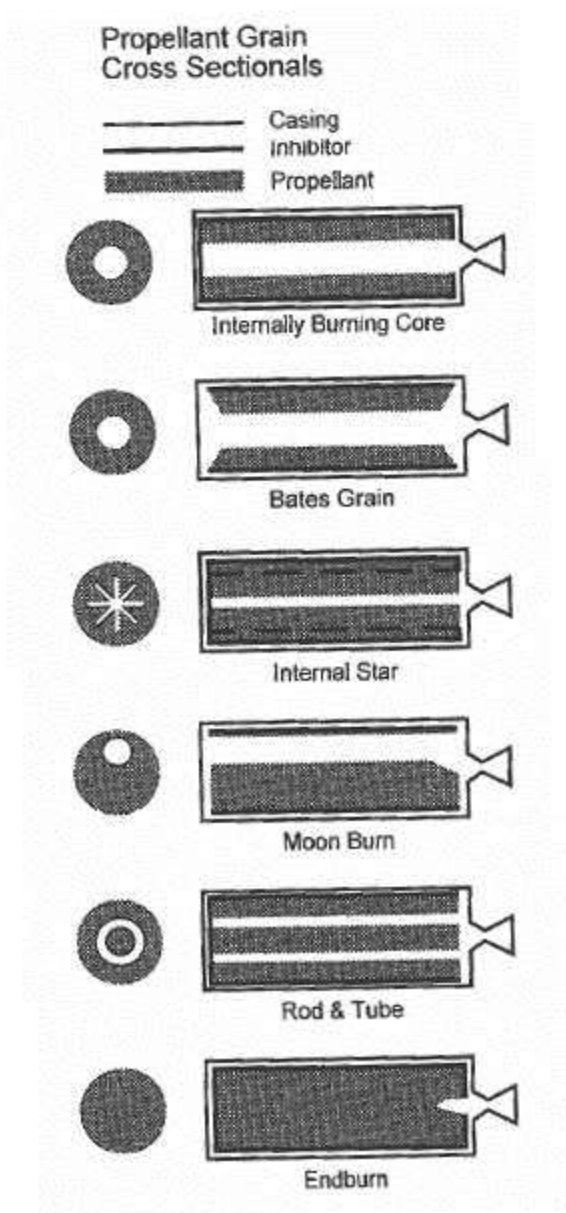
Computer data analysis: Computers are everywhere. It is a necessity and is a time saver for complex operations. You can create design and analyze rocket designs prior to building and launching.

Computer Programming: You may learn how to program items and create your own onboard payload for rocketry or other interests.

Instruments: You can learn a lot from this hobby with instrumentation.

Radio Remote Control: You may want to include with your rocket project a remote deployment system as a backup to the backup system in order to ensure recovery. You may learn to use a pager device to activate your deployment system. It is great how the electronics has become smaller and less expensive.

Ignition Systems: Understanding the ignition process for solid fueled or hybrid motors is interesting and educational. There are periodicals from the Journal of Pyrotechnics that talks and covers a lot of material of solid motors igniters.

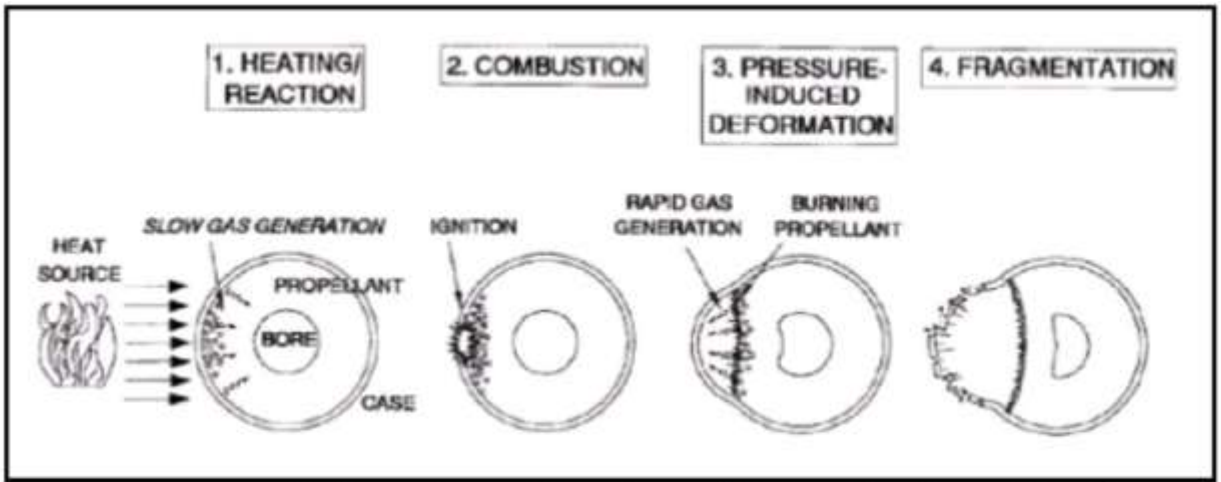


The reason why you may find this interesting is because not all solid motors are the same. There are different cores of motor grains for different effects of performance requirements. The same igniter may not work on the different motor.

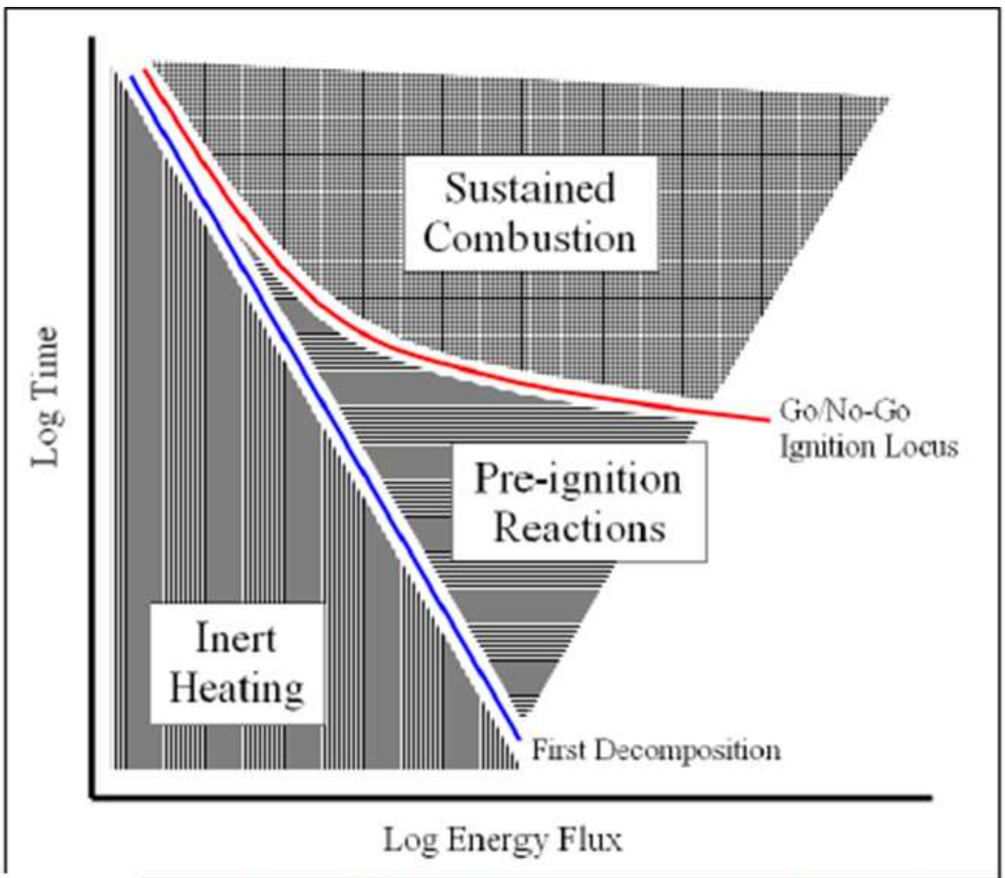
As you can tell by the example to the left, there are several to choose from.

https://www.nakka-rocketry.net/igniter.html

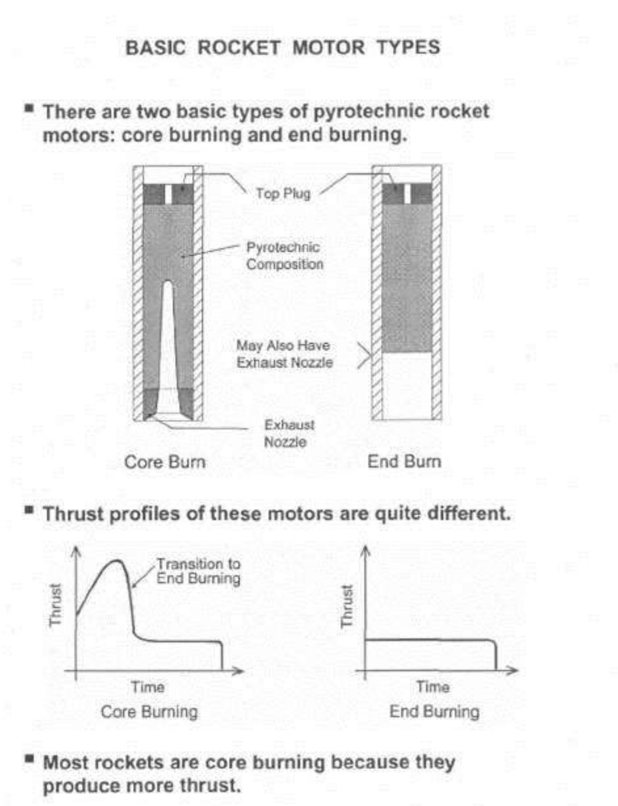
If you have ever witnessed a rocket launch (hobby related that is), you may notice that sometimes an igniter will spit out of a motor and the rocket will stay on the ground and not go up. That could be due to the fact that the igniter was too powerful and the surface area (grain) was small. This is what is called a chuff. Some igniters do not light as quickly as others. Why? Sometimes it takes a while for the fuel grain to ignite. Other types of grains will ignite without a problem. Understand the chemical composition of the solid fuel as well as what type of igniter you will need or have in your possession is helpful for better successful launches.

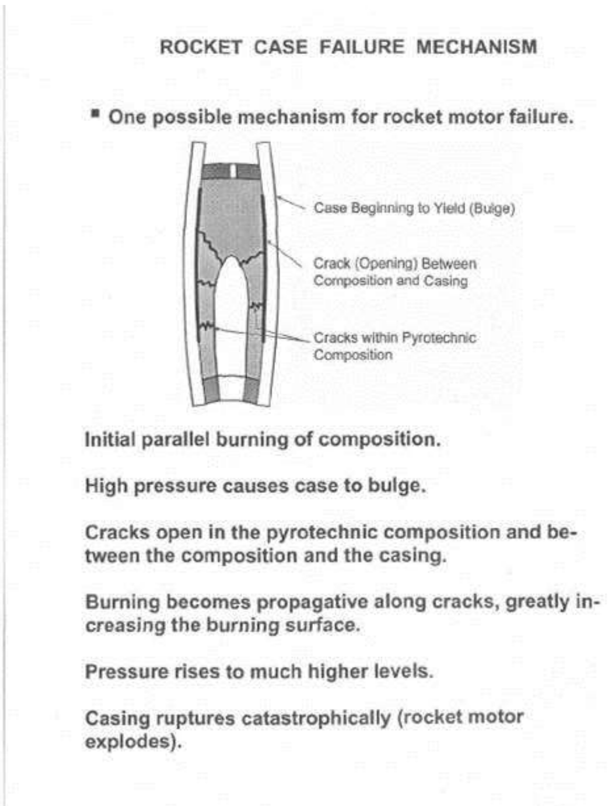


Deformation and rupture of fast-cookoff container[2]

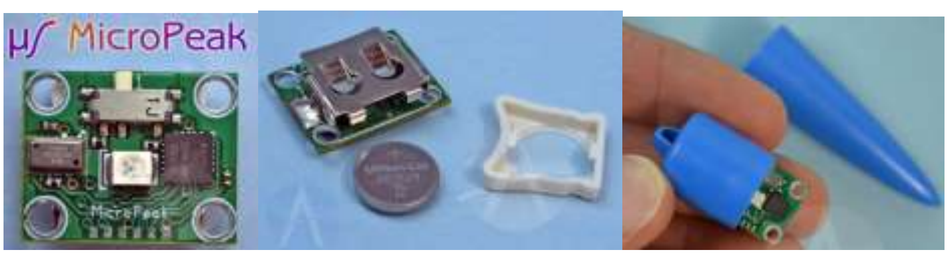


– General effect[65] of heat flux on time to ignition for propellants





Altimeters: Todays electronics are really amazing. They have become so small these days. You can almost place an altimeter in a 18mm rocket sized model. The limit now, is by the limit of your imagination.

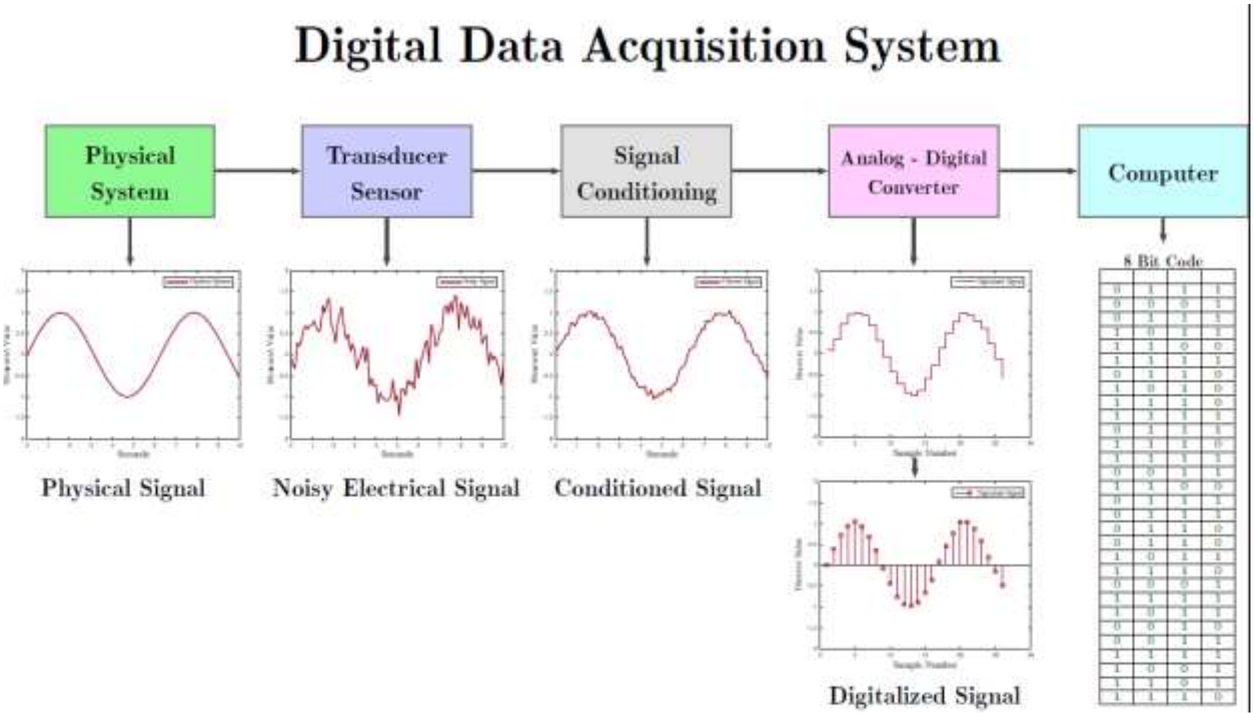


Accelerometers: You can add a small accelerometer to your rocket and get a great bit of data.

This can also be used to prove if your selected motor and the data prior to your launch that you may have are accurate or not.

An accelerometer is a device that measures proper acceleration. Proper acceleration, being the acceleration (or rate of change of velocity) of a body in its own instantaneous rest frame, is not the same as coordinate acceleration, being the acceleration in a fixed coordinate system.

Data Acquisition: (DAQ) is the process of measuring an electrical or physical phenomenon. It is the process of sampling signals that measure real world physical conditions and converting the resulting samples into digital numeric values that can be manipulated by a computer. Data acquisition systems, abbreviated by the acronyms DAS or DAQ, typically convert analog waveforms into digital values for processing.



Recording devices

Onboard cameras, still and Video: For those in their 50s or older you may recall the classic Cineroc kit (1970s era). This was one of the first systems specifically for model rocketry. There was also the Cam-Roc that was around in 1966Then there was the Astro-Cam 110 which used 110 film and took one snap shot photo at the rockets point of ejection. There was the Oracle which was a digital recording nose cone that would record video of liftoff for 30 seconds. It did not have sound.

ONLY
$4.75

CAMROC
ROCKET CAMERA

Lens opening — f-16
Shutter speed — 1/1600
Focal Length 3" (76 mm)

Launch your own aerial rocket camera! The Camroc automatically takes a photograph from hundreds of feet in the air and then returns safely. Uses a single exposure film disc mounted in a light-tight holder for quick and easy replacement in the field. Fits body tube BT-50. Negative is 1½ inches in diameter. In kit form with all parts and instructions for assembly and operation: 1 film holder loaded with unexposed film; 1 empty film holder and exposed film disc for practice loading and experimenting. Shipping weight 7.5 oz.

Cat. No. 701-C-1 .... $4.75

SPECIFICATIONS
Length.......... 5.3 in (13.5 cm)
Body Dia. .... 1.637 in (41.6 mm)
Weight .... 1.3 oz (37 gr)

RECOMMENDED ENGINES
Multi-Stage Flights
Booster B14-0 — Upper Stage B14-6, B14-7, C6-7
Single-Stage Flights
B14-5, B14-6, C6-7

SPECIAL OFFER
SAVE 50c
Complete Camroc kit plus the Astron Delta kit shown on page 42. This gives you the best basic outfit for making aerial photos. Engines not included. Shipping wt. 10 oz.
Cat. No. 701-RC-1 ..... $6.50

46 Patent Pending

CAMROC
OPENS NEW VISTAS TO THE ADVANCED ROCKETEER

Aerial photography has long been acknowledged for its value in map making, geographical studies, reconnaissance and related research fields. The Camroc aerial camera opens a new field of science studies to the rocketeer who wants to get a better understanding of the scientific uses of aerial photography. Recommended booster vehicle is the Delta. Other models can be adapted.

In addition to learning principles of camera construction and operation, many challenging aerial photographic projects can be developed.

Study space science reconnaissance techniques the practical way — over familiar terrain with known objects. Map your flight area with Camroc photos. Use photo pairs, which produce a stereoptic image when properly viewed, to emphasize geological features or estimate heights of different objects quite accurately.

Negative 1½" dia.
Print size . . 3" dia.

Processing information on page 48

47

Now in this era, they have small key chain cameras that can record the entire flight.

With the fun of 3D printers, you can create a nice holder for this key device and change it out between different rocket designs.

https://additive-aerospace.myshopify.com/collections/video-camera-shrouds/products/808-16-camera-shroud

9. Language Arts

Following Instructions: Following instructions can being easy, or hard. It would depend on your ability to comprehend and understand what is being directed to you. In order to succeed or achieve completing a task, you have to start at the beginning. Following instructions is fundamental.

Meetings: Everyone knows what a meeting is. Two or more people come together to discuss one or more topics, often in a formal setting. This is normally for the purpose of achieving a common goal through verbal interaction, such as sharing information or reaching agreement. Sometimes it is for informing those in attendance of what is going on. Meetings may occur face-to-face or virtually, as mediated by communications technology, such as a telephone conference call, a skyped conference call or a videoconference.

Reporting Experiences: Reports are used for keeping track of information, which may be used to make decisions. Written reports are documents which present focused content, generally to a specific audience. Reports are used in government, business, education, science, and other fields, are often to display the result of an experiment, investigation, or inquiry.

Speech: Being able to convey to others with speech is very valuable. When you first get involved with any activity, rocketry for example, you may at first feel intimidated by what other people involved in the hobby are talking about. You will learn a different kind of language for sure here in this field. You will hear a lot of people spit out numbers and formulas and more. These people enjoy sharing, and these people learned what they are talking about from others. If you ask them to explain what they are referring to, 90% of them if not all will be glad to take their time to talk about it. Often, this is intended as a way to verify what they have designed or created is correct as well. Feel free to ask them further about what you are unaware of. They most likely will even speak more about it.

Technical Jargon: This is a type of language that is used in a particular context and may not be well understood outside of it. The context is usually a particular occupation (that is, a certain trade, profession, or academic field), but any in-group can have jargon. The main trait that distinguishes jargon from the rest of a language is special vocabulary—including some words specific to it and, often, narrower senses of words that outgroups would tend to take in a broader sense. Jargon is thus "the technical terminology or characteristic idiom of a special activity or group.

Writings Instructions: Estes model rocket kits has about the best instruction format for building complicated kits. You do not realize how tedious it can be until you, yourself have to write or create instructions for a design. Talking about what to do is not as easy as a picture of schematic drawing. We are better at comprehending instructions with pictures more than words.

10. Self Confidence

Critical Assembly: Learning how to assemble and create is a great self confidence builder.

Handling Hazards: Understanding safety measures and precautions, is vital and essential in a lot of professions. Rocketry and aerospace is no exception. The more you understand and learn will enhance your understanding.

New Experiences: You will definitely experience something new at each launch. People in this hobby enjoy sharing.

Sharp Knives: Knives are always being used and utilized anywhere and everywhere. You will find that X-ACTO is a necessity in this hobby. Safety of use is vital. This thing is very sharp.

11. Economics

Budget: Any hobby can be expensive and economical. Learning how to budget your expenses anywhere is beneficial.

Cost vs Performance: Evaluating cost and performance will teach you to budget, manage and plan. Not just for this hobby, it will help you prepare for the future. It will teach you to plan and prepare.

Cost Effectiveness: What do you want to achieve with this hobby? To explore, or add instrumentation to your rocket? You can add things to your rocket project without spending a lot.

Materials: You will learn and explore using different materials for different functions and results with rocketry.

Organizational Budget: Being able to budget anything can be a large indescribable task. However, it is possible to manage and maintain it.

Pricing and Demand: The hobby can be inexpensive or can involve more if you so venture that way.

Product Development: You may even learn to create and develop something new as you create your own projects.

Tooling and Marketing: Are you familiar with Dremel's, drill presses or lathes? You may learn a new skill by utilizing tools such as these or even by using a 3D printer you can market parts for the hobby.

Event Planning: Are you a good event coordinator? If not you may soon learn that skill by helping to promote the hobby to teachers, mentors and educators. Patience and perseverance will be very valuable.

12. <u>Environmental</u>

Atmospheric Research: Scientists often use rockets to explore our Earth's atmosphere. Equipment such as barometers, cameras, and thermometers are carried into the atmosphere by sounding rockets, or alternatively called meteorological rockets. Information is collected by the instruments and sent back to the ground through radio.

Rockets are also used as a power source for experimental research airplanes to test how the planes fly in the atmosphere to help develop spacecraft. This kind of study on the rocket-powered X-1 and X-15 showed engineers how to control vehicles flying many times as fast as the speed of sound.

https://books.google.com/books?id=d5Ds1ZMSjIIC&pg=PA7&lpg=PA7&dq=Atmospheric+Research+in+rocketry&source=bl&ots=PtlrfJKz_n&sig=cLEdEyslhU2EQ1-twxEs7_qMNtc&hl=en&sa=X&ved=0ahUKEwijgqra8KzUAhVG8WMKHRZTBncQ6AEIXzAI

Balsa Wood, a rain forest: Balsa trees grow naturally in the humid rain forests of Central and South America. ... The scientific name for balsa wood is ochroma lagopus. The word balsa itself is Spanish meaning raft, in reference to its excellent floatation qualities. In Ecuador it is known as Boya, meaning buoy.

HOW DOES BALSA WOOD GROW?

There is no such thing as entire forests of balsa trees. They grow singly or in very small, widely scattered groups in the jungle. For hundreds of years, balsa was actually considered a weed tree. They reproduce by growing hundreds of long seed pods, which eventually open up and, with the help of the wind, scatter thousands of new seeds over a large area of the jungle. Each seed is airborne on its own small wisp of down, similar to the way dandelion seeds spread. The seeds eventually fall to the ground and are covered by the litter of the jungle. There they lay and accumulate until one day there is an opening in the jungle canopy large enough for the sun's rays to strike the jungle floor and start the seeds growing. Wherever there is an opening, made either by a farmer or by another tree dying, balsa will spring up as thick as grass. A farmer is often hard put to keep his food plot clear of balsa. As the new balsa trees grow, the strongest will become predominate and the weaker trees will die. By the time they are mature, there may be only one or two basa trees to an acre of jungle.

HOW LONG DOES IT TAKE A BALSA TREE TO GROW?

Balsa trees grow very rapidly (like all pesky weeds). Six months after germination, the tree is about 1-1/2 inches in diameter and 10 - 12 feet tall. In 6 to 10 years the tree is ready for cutting, having reached a height of 60 to 90 feet tall and a diameter of 12 to 45 inches. If left to continue growing, the new wood being grown on the outside layers becomes very hard and the tree begins to rot in the center. Unharvested, a balsa tree may grow to a diameter of 6 feet or more, but very little usable lumber can be obtained from a tree of this size. The basla leaf is similar in shape to a grape leaf, only a lot bigger. When the tree is young, these leaves measure a much as four feet across. They become progressivly smaller as the tree grows older, until they are about 8 - 10 inches across. Balsa is one of the few trees in the jungle which has a simple leaf shape. This fact alone makes the balsa tree stand out in the jungle.

THE PERFECT NURSE!

Nature evidently designed the balsa tree to be a "nurse tree" which would protect the slower-growing species of trees from the scorching jungle sun during their critical early years. For instance, in an area of the jungle that has been ravaged by a tropical storm or other natural disaster, the balsa trees will quickly sprout and begin to shoot up to impressive heights in a very short time. Their fast growth, and the extra large leaves they have in their early years, provide shade to the young seedlings of the slower-growing forest giants. By the time the seedlings are established enough to take care of themselves, the balsa tree is beginning to die. Undoubtably, the balsa tree's rapid growth, fast spreading crown of first very large and gradually smaller leaves, and it's relatively short life span were intended to make it the "perfect nurse" in the jungle ecosystem.

HOW ARE BALSA TREES HARVESTED?

While nature intended the balsa tree to be a short lived nursemaid, mankind eventually discovered that it was an extremely useful resource. The real start of the basa business was during World War I, when the allies were in need of a plentiful substitute for cork. The only drawback to using balsa was, and still is, the back breaking work that is necessary to get it out of the jungle. Beacause of the way the individual balsa trees are scattered throughtout the jungles, it has never been possible to use mass production logging procedures and equipment. The best way to log balsa trees is to go back to the methods of Paul Bunyan -- chop them down with an axe, haul them to the nearest river by ox team, tie them together into rafts, and then float the rafts of balsa logs down the river to the saw mill.

The logging team usually consists of two native Ecquadorians, each armed with a broad Spanish axe, a machete, and a long pole sharpened like a chisel on one end for removing the bark from the downed trees. Because of the hilly terrain, an ox team may only be able to drag two logs to the river per day. At the saw mill the raw balsa is first rough cut into large boards, the carefully kiln dried, and finally packed into bales for shipment to the U.S. via ocean freighter. Final cutting and finishing of our model aircraft balsa is done right here at the SIG factory. As a result of the balsa tree's fast growth cycle, both the quality and lightness of the lumber obtained from a balsa tree can vary enormously depending upon the tree's age at the time of cutting.

WHY IS BALSA WOOD SO LIGHT?

The secret to balsa wood's lightness can only be seen with a microscope. The cells are big and very thin walled, so that the ratio of solid matter to open space is as small as possible. Most woods have gobs of heavy, plastic-like cement, called lignin, holding the cells together. In balsa, lignin is at a minimum. Only about 40% of the volume of a piece of balsa is solid substance. To give a balsa tree the strength it needs to stand in the jungle, nature pumps each balsa cell full of water until they become rigid - like a car tire full of air. Green balsa wood typically contains five times as much water by weight as it has actual wood substance, compared to most hardwoods which contain very little water in relation to wood substance. Green balsa wood must therefore be carefully kiln dried to remove most of the water before it can be sold. Kiln drying is a tedious two week process that carefully removes the excess water until the moisture content is only 6%. Kiln drying also kills any bacteria, fungi, and insects that may have been in the raw balsa wood.

HOW LIGHT IS KILN DRIED BALSA WOOD?

Finished balsa wood, like you find in model airplane kits, varies widely in weight. Balsa is occasionally found weighing as little as 4 lbs. per cu. ft. On the other hand, you can also find balsa which will weigh 24 lbs or more per cu. ft. However, the general run of commercial balsa for model airplanes will weigh between 6 and 18 pounds per cu. ft. Eight to twelve pound balsa is considered medium or average weight, and is the most plentiful. Six pound or less is considered "contest grade", which is very rare and sometimes even impossible to obtain.

IS BALSA THE LIGHTEST WOOD IN THE WORLD?

No! Most people are surprised to hear that botanically, balsa wood is only about the third or fourth lightest wood in the world. However, all the woods which are lighter than balsa are terribly weak and unsuitable for any practical use. The very lightest varieties don't really resemble wood at all, as we commonly think of it, but are more like a tree-like vegetable that grows in rings, similar in texture to an onion. It is not until balsa is reached that there is any sign of real strength combined with lightness. In fact, balsa wood is often considered the strongest wood for its weight in the world. Pound for pound it is stronger in some respects than pine, hickory, or even oak.

SELECTING BALSA FOR MODEL BUILDING

Most hobby shops have a large rack of balsa sheets, sticks, and blocks that you can choose from if you are going to build a model airplane from scratch. Undoubtably, because of the nature of balsa, the actual weight of each piece of wood of the same size can vary slightly. When you select the pieces you want to buy you should keep their final use in mind. Logically one should select the lightest grades for the lightly stressed model parts (nose blocks, wingtip blocks, fill-ins, etc.) and the heavier grades for important load bearing parts of the structure (spars, fuselage stringers, etc.). To a large extent, this selection is already partly done for you. Here at SIG, we purosely cut up our lightest raw balsa into blocks, and our hardest raw balsa into sticks. Sheets are cut in the entire wide range of density.

COMMON MODELER'S TOOLS FOR CUTTING AND SHAPING BALSA WOOD

Balsa is a very "friendly" wood to work with -- so light, so soft, so easily worked into so many things. You don't need heavy-duty power saws and sanders like you would if working with a hardwood. In fact, even with an extensive power shop at their disposal, the professional model builders here at the SIG factory find that they still rely primarily on 4 or 5 simple hand tools for the majority of their work. If you are just starting out in the model airplane hobby, here are the tools that they recommend you get:

X-ACTO No. 1 knife with No. 11 blade for general cutting; X-ACTO No. 2 knife with No. 26 blade for carving; Razor saw for cutting thick sizes of wood; Razor plane for shaping; A knife or razor blade will work well for cutting balsa sheets and sticks up to 3/16". Always keep replacement blades on hand - blades do wear our and a dull blade can make it impossible to do a good job.

YOU WILL ALSO NEED SANDING BLOCKS

In addition to the cutting tools, you will need an assortment of different size sanding blocks. These are indispensable tools for model construction. You can buy ready-made sanding blocks or make your own. The most often used general-purpose sanding block in our model shop is made simply by wrapping a full 9" x 11" sheet of sandpaper around a 3/4" x 3" x 11" hardwood or plywood block. Use three screws along one edge to hold the overlapped ends of the sandpaper in place. Use 80 grit garnet sandpaper on the block during general construction. Another handy sanding block to have can be made by gluing 80 grit garnet sandpaper onto a 24" or 36" long piece of aluminum channel stock. Most hardware stores carry a rack of aluminum in various sizes and shapes. This long sanding block is very helpful for shaping leading and trailing edges, and other large pieces, accurately. Last but not least, glue sandpaper onto different sizes of scrap plywood sticks and round hardwood dowels. These are handy for working in tight places and for careful shaping where a big sanding block is too hard to control.

BALSA GRAIN -- LEARN HOW TO IDENTIFY ALL THREE GRAIN TYPES

In selecting balsa sheets for use in your model, it is important to consider the way the grain runs through the sheet as well as the weight of the sheet. The grain direction actually controls the rigidity or flexibility of a balsa sheet more than the density does. For example, if the sheet is cut from the log so that the tree's annular rings run across the thickness of the sheet (A-grain, tangent cut), then the sheet will be fairly flexible edge to edge. In fact, after soaking in water some tangent cut sheets can be completely rolled into a tube shape without splitting. If on the other hand the sheet is cut with the annular rings running through the thickness of the sheet (C-grain, quarter grain), the sheet will be very rigid edge to edge and cannot be bent without splitting. When the grain direction is less clearly defined (B-grain, random cut), the sheet will have most intermediate properties between A and C grain. Naturally, B-grain is the most common and is suitable for most jobs. The point to bear in mind is that whenever you come across pure A-grain or C-grain sheets, learn where to use them to take best advantage of their special characteristics.

A-GRAIN sheet balsa has long fibers that show up as long grain lines. It is very flexible across the sheet and bends around curves easily. Also warps easily. Sometimes called "tangent cut." DO use for sheet covering rounded fuselages and wing leading edges, planking fuselages, forming tubes, strong flexible spars, HL glider fuselages. DON'T use for sheet balsa wings or tail surfaces, flat fuselage sides, ribs, or formers.

B-GRAIN sheet balsa has some of the qualities of both type A and type C. Grain lines are shorter than type A, and it feels stiffer across the sheet. It is a general puropse sheet and can be used for many jobs. Sometimes called "random cut." DO use for flat fuselage sides, trailing edges, wing ribs, formers, planking gradual curves, wing leading edge sheeting. DON'T use where type A or type C will do a significantly better job.

C-GRAIN sheet balsa has a beautiful mottled appearance. It is very stiff across the sheet and spits easily. But when used properly, it helps to build the lightest, strongest models. Most warp resistant type. Sometimes called "quarter grain." DO use for sheet balsa wings and tails, flat fuselage sides, wing ribs, formers, trailing edges. Best type for HL glider wings and tails. DON'T use for curved planking, rounded fuselages, round tubes, HL glider fuselages, or wing spars.

http://www.mat.uc.pt/~pedro/ncientificos/artigos/techbal.html

13. Math

Altitude Prediction:

http://www.oldrocketplans.com/pubs/Estes/estTR-10/TR-10.pdf

http://www2.estesrockets.com/pdf/2844_Estes_Math_of_Model_Rocketry_TN-5.pdf

Area and Volume: The thrust that a rocket motor generates is proportional to the burning area at any particular instant in time. It is important to recognize that the burning area of a propellant grain is a key parameter in determining the performance of a rocket motor. The primary function of a propellant grain is to produce combustion products at a prescribed flowrate.

This is referred to as the instantaneous burning area.

Propellant grains are cylindrical in shape to fit neatly into a rocket motor in order to maximize volumetric efficiency.

https://www.nakka-rocketry.net/th_grain.html

Mass and Weight: Weight is the force generated by the gravitational attraction of the earth on the model rocket. The mass (and weight) is actually distributed throughout the rocket and for some problems it is important to know the distribution. But for rocket trajectory and stability, we only need to be concerned with the total weight and the location of the center of gravity. The center of gravity is the average location of the mass of the rocket.

Parabolic Trajectory: In astrodynamics or celestial mechanics a parabolic trajectory is a Kepler orbit with the eccentricity equal to 1. When moving away from the source it is called an escape orbit, otherwise a capture orbit. It is also sometimes referred to as a C3 = 0 orbit.

A Kepler orbit (or Keplerian orbit) is the motion of one body relative to another, as an ellipse, parabola, or hyperbola, which forms a two-dimensional orbital plane in three-dimensional space. (A Kepler orbit can also form a straight line.) It considers only the point-like gravitational attraction of two bodies, neglecting perturbations due to gravitational interactions with other objects, atmospheric drag, solar radiation pressure, a non-spherical central body, and so on. It is thus said to be a solution of a special case of the two-body problem, known as the Kepler problem. As a theory in classical mechanics, it also does not take into account the effects of general relativity.

Probability: http://www.nar.org/pdf/Safety_in_Sport_Rocketry_Tutorial.pdf

http://www.projectrho.com/public_html/rocket/calculators.php

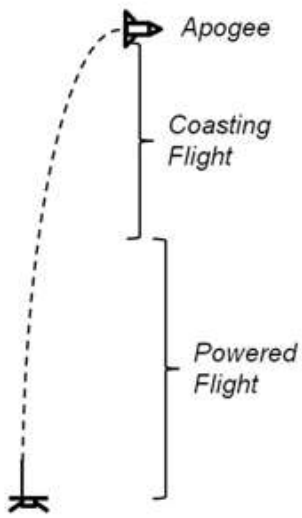
https://www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/media/AIAA-2007-6494-142.pdf

http://www.tc.faa.gov/its/worldpac/techrpt/cttn90-28.pdf

Statistical Deviations:
https://www.apogeerockets.com/education/downloads/Newsletter318.pdf

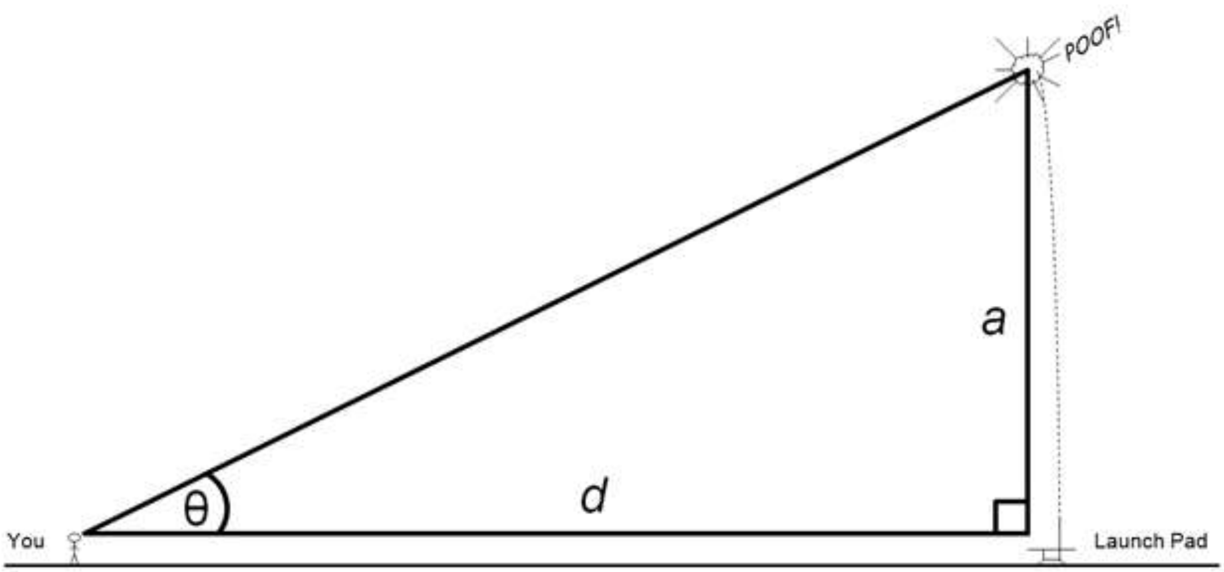
http://www.psc473.org/naram51/contest/NARTS_ED01.pdf

Trigonometric Tracking: To measure how well your rocket flies, you'll need to know how to measure the apogee of its flight. In rocketry, the apogee is defined as the highest point of the rocket's flight.



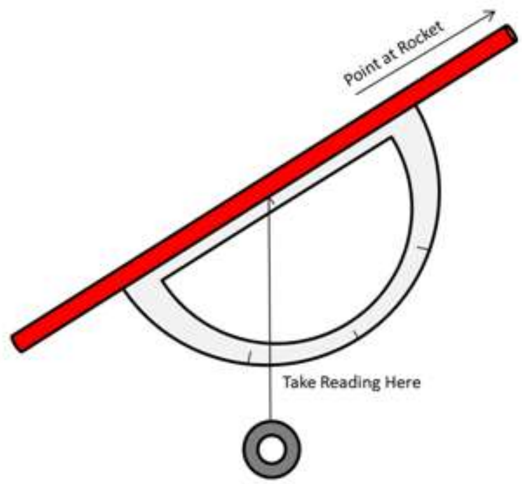
So, how do you go about measuring this point? Model rockets can travel for hundreds or even thousands of feet up in the air, so how on earth can we measure their maximum altitude? Fortunately, there are several methods for doing this and I'll explain a few of my favorites here.

The quickest and easiest way to determine your rocket's altitude with optical tracking is to use elevation-angle-only tracking. This is a very simple method and the amount of trigonometry isn't nearly as bad as I made it out to be. Let's begin with a diagram of the launch site. If we assume that the rocket travels reasonably straight up from the Launchpad, then we can draw ourselves a nice right triangle.



If we know the distance from our observation point to the launch pad (d) and the angle at which we can see the top of the rocket's trajectory (θ), we can calculate the altitude with the following equation:

$$a = d \times \tan(\theta)$$



If you’re using a calculator, make sure you’re in degree mode and not radian mode. Of course, this is assuming you measured the angle in degrees, although I don’t think I’ve ever met anyone who measured rocketry angles in radians. Measuring the angle can be done with an inclinometer. The Quest Skyscope and the Estes Altitrak are two types of inclinometers specifically designed for model rocketry. If you're in a pinch, you can make your own inclinometer with a protractor, a piece of string, a washer, and a straw.

Simply track the rocket to its highest point, tilt the homemade inclinometer so that you're looking at the apogee point through the straw, and pinch the string to the protractor once the string stops moving. Subtract the number on the protractor from 90 and you have the angle you need for your calculation! Here's an example of this type of calculation in action:

$$distance\ to\ launch\ pad = 300\ feet$$

$$angle\ on\ the\ protractor = 40^o$$

$$angle\ for\ calculation = 90^o - 40^o = 50^o$$

$$altitude = 300\ feet\ \times \tan(50^o) \cong 358\ feet$$

find that it's easier to find the ejection point of the rocket if I put a little colored chalk in with the parachute. Not only does the chalk prevent the parachute from sticking, but it also makes a nice visible cloud when the ejection charge goes off.

There are other methods of optical tracking that are a little more involved, but I've skipped them in this tutorial since this is more of an introduction to the methods of altitude tracking. For a quick and relatively accurate estimation of altitude, the elevation-angle-only method works well. Other methods, such as the alt-azimuth tracking method, often require multiple tracking stations and spotters.

Source: Stine, G. Harry, Handbook of Model Rocketry, Sixth Edition, John Wiley & Sons, Inc. New York, 1994.

http://www.hobbizine.com/rocketaltitude.html

https://er.jsc.nasa.gov/seh/Altitude_Tracking.pdf

Weight x Distance: The weight of your rocket can limit altitude. Weight is the force generated by the gravitational attraction of the earth on any object. Weight is fundamentally different from the aerodynamic forces, lift and drag. Aerodynamic forces are mechanical forces and the object has to be in physical contact with the air which generates the force. The gravitational force is a field force; the source of the force does not have to be in physical contact with the object.

Working with Formulae: Graphics are used to demonstrate how to rearrange a formula.

http://www.rocketmime.com/rockets/rckt_eqn.html

http://www.rocketmime.com/rockets/RocketEquations.pdf

Rocket Equations

mR = rocket mass in kg

mE = engine mass (including propellant) in kg

mP = propellant mass in kg

a = acceleration m/s 2

F = force in kg . m/s 2

g = acceleration of gravity = 9.81 m/s 2

A = rocket cross-sectional area in m2

cd = drag coefficient = 0.75 for average rocket

ρ = air density = 1.223 kg/m3

τ = motor burn time in seconds

T = motor thrust in Newton i.e. in kg . m/s 2

I = motor impulse in Newton . seconds

vτ = burnout velocity in m/s

hB= altitude at burnout in m

hC= coasting distance in m

14. Technique and Assembly

Subassembly: An assembled unit designed to be incorporated with other units in a finished product.

Care of Tools: Taking care of your tools will be cost effective and beneficial for long term use.

Craftsmanship: You can learn a trade by being a good craftsman.

Cutting: Accuracy and safety while cutting is a good thing to consider.

Drawing: If you ever opened up an Estes rocket kit, you will notice detailed drawings in support of the assembly instructions. Estes made some of the best instructions around. They had draftsmen draw these pictures which helped you as the builder understand how the kit went together. We are better at comprehending visual instructions more than written instruction. When we get older, written instructions are okay. I still enjoy visual instructions better though☺

Finish/Painting: Getting a well detailed paint finish on your project can be very important. Do you want to paint it with spray paint, or use an air brush? Sometimes if you are not familiar with the paint you are going to apply to your rocket could be a problem. Make sure to test the paint on something other than your built project first in order to familiarize yourself with how it will perform. Getting splotches on your finished rocket would not be very good. Having a smooth finish can very important for aerodynamics too.

Gluing & Cementing: Glue and bonding to materials is a science. Understanding how adhesives adhere to items is very useful. You may find that an epoxy you have been using for rocketry may soften up if exposed to the sun for a long time. They may not be a good thing if your fins soften up during a rocket launch.

Sources:

http://rocket.gtorg.gatech.edu/files/slides/Model_Rocket_Aerodynamics.pdf

Apogee Rockets

http://www.aerospaceweb.org/question/aerodynamics/q0151.shtml

http://physicsforidiots.com/physics/thermodynamics/

http://people.csail.mit.edu/mehtank/webpubs/fsr2013.pdf

Rottman, Gordon L. (2012). The Bazooka. Osprey Publishing. ISBN 978-1849088015

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Journal of Pyrotechnics, Issue No. 3, Summer, 1996.

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George P. Sutton, "Rocket Propulsion Elements", 4th ed., John Wiley & Sons, 1976

Richard B. Morrow, Mitchell S. Pines: "Small Sounding Rockets", Small Rockets Press, 2000

GUIPEP Propellant Evaluation Program

https://www.grc.nasa.gov/WWW/K-12/rocket/shortr.html

https://youtu.be/4DY10d8r5q8

https://youtu.be/XojbqTlC-j8

Good Movies to watch or purchase:

Orphans of Apollo

http://www.orphansofapollo.com/

Fight For Space:

http://www.fightforspace.com/

http://mircorp.org/