SATURN Requirements

1. THE WRITTEN PHASE

The cadet is required to pass an examination on how to determine a model rocket's altitude at the apogee of its flight. The cadet is required to pass a second component of the examination that deals with model rocket engines.

2. THE OFFICIAL WITNESS LOG (OWL) AND TESTING

The Squadron Testing Officer (STO) must administer the written examination and once passed, sign the OWL for the cadet.

3. THE HANDS-ON PHASE

The cadet is required to build one of the following options:

a. The cadet may elect to build a two-stage rocket that requires two engines to reach altitude.

b. **OR** The cadet may elect to build a model rocket that is capable of carrying a payload of at least 3 ounces to an altitude of 300' or more.

c. **OR**..If the cadet lives in an area where solid-fuel rockets are banned, he/she may elect to take the Air Power Option. If this is the case, the cadet is required to scratch-build a model rocket that works on a commercial launcher (like one of those featured in the Titan section). This rocket must achieve an altitude of at least 100 feet and proof must be given by either mathematical calculations or an altitude tracking device.

d. OR..If the cadet is taking the Air Power Option, he/she must also build a static plastic model of a rocket that was significant in aerospace history. This rocket and a short presentation must be made to the squadron.

e. All cadets in this program must have a working knowledge of the NARs Safety Code.

4. THE OFFICIAL WITNESS LOG FOR FLIGHT AND RECOVERY OF MODELS

A Qualified Senior Member must witness the launch of all flights. Once it is determined, by the QSM, that the cadet has met the requirements, he/she will sign the OWL for the Hands-On Phase.

5. THE ROLE OF THE SQUADRON COMMANDER

The Squadron Commander will sign the OWL and in an awards ceremony, present the cadet with the Model Rocketry Badge.

Model Rocket SAFETY CODE

This official Model Rocketry Safety Code has been developed and promulgated by the National Association of Rocketry.
(Basic Version, Effective February 10, 2001)

1. MATERIALS. I will use only lightweight, non-metal parts for the nose, body and fins of my rocket.

2. MOTORS. I will use only certified, commercially-made rocket motors, and will not tamper with these motors or use them for any purposes except those recommended by the manufacturer.

3. IGNITION SYSTEM. I will launch my rockets with an electrical launch system and electrical motor igniters. My launch system will have a safety interlock in series with the launch switch, and will use a launch switch that returns to the "off" position when released.

4. MISFIRES. If my rocket does not launch when I press the button of my electrical launch system, I will remove the launcher's safety interlock or disconnect its battery, and will wait 60 seconds after the last launch attempt before allowing anyone to approach the rocket.

5. LAUNCH SAFETY. I will use a countdown before launch, and will ensure that everyone is paying attention and is a safe distance of at least 15 feet away when I launch rockets with D motors or smaller, and 30 feet when I launch larger rockets. If I am uncertain about the safety or stability of an untested rocket, I will check the stability before flight and will fly it only after warning spectators and clearing them away to a safe distance.

6. LAUNCHER. I will launch my rocket from a launch rod, tower, or rail that is pointed to within 30 degrees of the vertical to ensure that the rocket flies nearly straight up, and I will use a blast deflector to prevent the motor's exhaust from hitting the ground. To prevent accidental eye injury, I will place launchers so that the end of the launch rod is above eye level or will cap the end of my launch rod when it is not in use.

7. SIZE. My model rocket will not weigh more than 1500 grams (53 ounces) at liftoff and will not contain more than 125 grams (4.4 ounces) of propellant or 320N-sec (71.9 pound-seconds) of total impulse. If my model rocket weighs more than one pound (453 grams) at liftoff or has more than 4 ounces (113grams) of propellant, I will check and comply with Federal Aviation Administration regulations before flying.

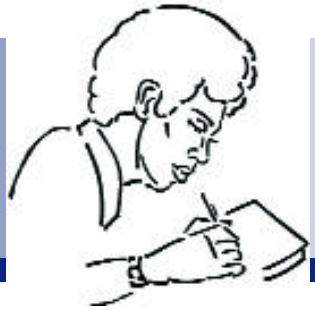
8. FLIGHT SAFETY. I will not launch my rocket at targets, into clouds or near airplanes, and will not put any flammable or explosive payload in my rocket.

9. LAUNCH SITE. I will launch my rocket outdoors, in an open area at least as large as shown in the accompanying table, and in safe weather conditions with wind speeds no greater than 20 miles per hour. I will ensure that there is no dry grass close to the launch pad, and that the launch site does not present risk of grass fires.

Installed Total Impulse (N-sec)	Equivalent Motor Types	Minimum Site Dimensions (ft)
0.00 - 1.25	1/4A,1/2A	50
2.26 - 2.50	A	100
2.51 - 5.00	B	200
5.01 -10.00	C	400
10.01 - 20.00	D	500
20.01 - 40.00	E	1,000
40.01 - 80.00	F	1,000
80.01 - 160.00	G	1,000
160.01 - 320.00	Two G's	1,500

10. RECOVERY SYSTEM. I will use a recovery system such as a streamer or parachute in my rocket so that it returns safely and undamaged and can be flown again, and I will use only flame-resistant or fireproof recovery system wadding in my rocket.

11. RECOVERY SAFETY. I will not attempt to recover my rocket from power lines, tall trees, or other dangerous places.



SATURN Written Phase

ALTITUDE TRACKING

It's great fun to launch and recover model rockets, but let's face it, after so many it "loses some of its excitement" and the average builder wants more. So what is the "next step?" Most model rocket builders advance to longer bodies, larger engines, multiple stages and various experiments with payloads. If you are short on cash and still have the excitement, there is another way to enjoy your current "inventory," yet still keep the interest alive.

It is recommended that you take the time to learn more about the science of model rockety. In other words, the cadet is urged to study performance variables. Two very important parameters are altitude determination and engine performance. Both are covered as part of the Written Phase of the Saturn Stage.

ALTITUDE DETERMINATION

By definition, apogee is the highest point in the flight of a model rocket. It is the point at which a rocket reaches its highest altitude and begins a return to Earth. There are several ways to determine the altitude at which a rocket reaches its apogee. The method described in *Aerospace Dimensions, Module 4, ROCKETS*, uses a sighting device called an "Altitude Tracker." It is part of Activity Three-Altitude Tracking. The cadet is urged to read the text, on pages 29, 30, 31, and to build the "Altitude Tracker" and use it as described. The cadet may also elect to purchase a commercially-built one like the Estes Altitrak™ (retails for around $24.00).

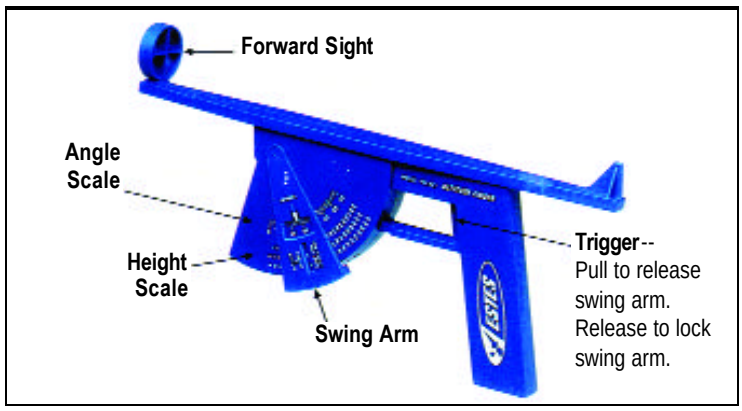
With permission from Estes, the author will explain how to determine the altitude of a model rocket using simple trigonometry. In the illustration "Using the degree scale to calculate altitude," first notice the term "baseline distance." This is essentially the base of a right triangle and the length is the distance from an observer to the launch pad of a model rocket. Refer now to number “1”, in their diagram that shows how to use the Altitrak. The observer is asked to pace off a distance of 500’, or in other words, make a baseline distance of 500' (150 meters). Once the observer is ready, he/she signals the launcher. The Altitrak™, or astrolabe as it is know in scientific terms, is aimed at the rocket. This is shown in illustration "2." As the rocket is launched it will climb to its apogee and then start a return to earth. The trigger is released and this will record the desired angle.

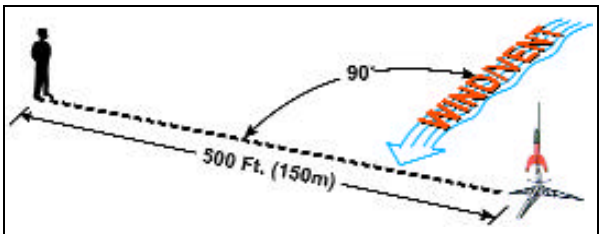
Refer now back to "Using the degree scaled to calculate altitude." Once this angle is known, the observer, or team, looks up the corresponding tangent on the Angle Tangent Chart. The altitude at which the rocket reached its apogee is found by:

Baseline Distance X Angle Tangent = Altitude.

Example: Baseline Distance is 500'; Angle observed is 50°; Tangent number from chart 1.19.

500' x 1.19 = 595' altitude at apogee

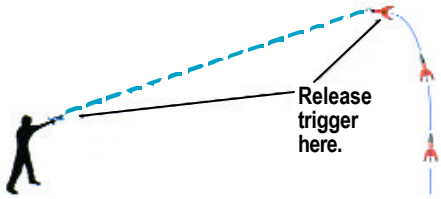




1. Pace off 500 ft. from launch pad at a right angle to the wind. (A pace equals the average walking stride of a 10-12 year old - approximately 2½ ft.)

NOTE: For low altitude rockets, pace off 250 ft. and divide height by 2. For high altitude rockets, pace off 1,000 ft. and multiply height by 2.

2. Hold the Altitrak™ at arm's length, pointed at rocket. Pull & hold trigger then signal for launch.



3. Track rocket through forward sight. When rocket reaches apogee (maximum altitude) release the trigger. Read the height indicated on swing arm.

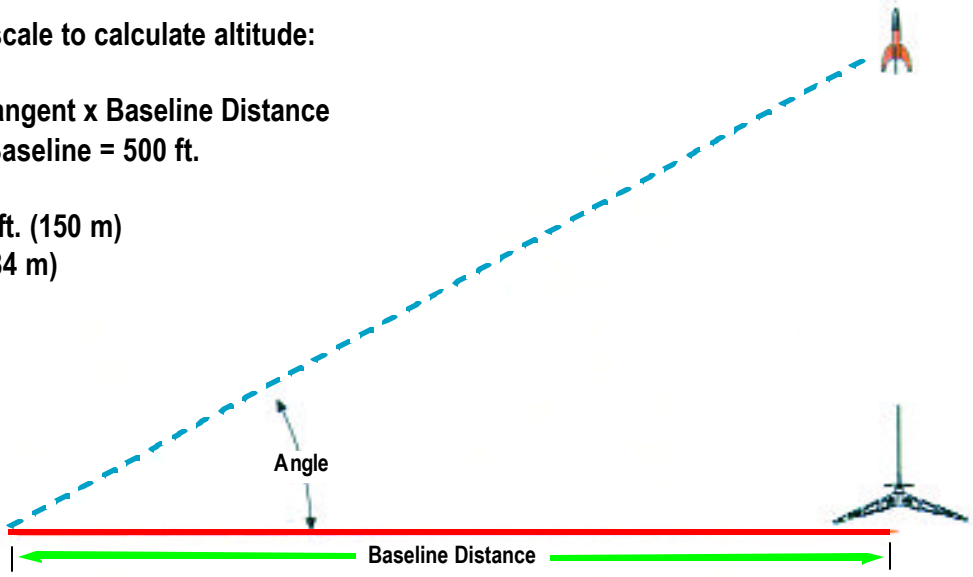
To convert feet to meters: 1 foot x 3.28 = 1 meter

Using the degree scale to calculate altitude:

Altitude = Angle Tangent x Baseline Distance

30° Angle = .58, Baseline = 500 ft.

Altitude = .58x500 ft. (150 m)
= 290 ft. (84 m)



ANGLE TANGENT CHART

Angle	Tan.	Angle	Tan.	Angle	Tan.	Angle	Tan.
1	0.02	21	0.38	41	0.87	61	1.80
2	0.03	22	0.40	42	0.90	62	1.88
3	0.05	23	0.42	43	0.93	63	1.96
4	0.07	24	0.45	44	0.97	64	2.05
5	0.09	25	0.47	45	1.00	65	2.14
6	0.11	26	0.49	46	1.04	66	2.25
7	0.12	27	0.51	47	1.07	67	2.36
8	0.14	28	0.53	48	1.11	68	2.48
9	0.16	29	0.55	49	1.15	69	2.61
10	0.18	30	0.58	50	1.19	70	2.75
11	0.19	31	0.60	51	1.23	71	2.90
12	0.21	32	0.62	52	1.28	72	3.08
13	0.23	33	0.65	53	1.33	73	3.27
14	0.25	34	0.67	54	1.38	74	3.49
15	0.27	35	0.70	55	1.43	75	3.73
16	0.29	36	0.73	56	1.48	76	4.01
17	0.31	37	0.75	57	1.54	77	4.33
18	0.32	38	0.78	58	1.60	78	4.70
19	0.34	39	0.81	59	1.66	79	5.14
20	0.36	40	0.84	60	1.73	80	5.67

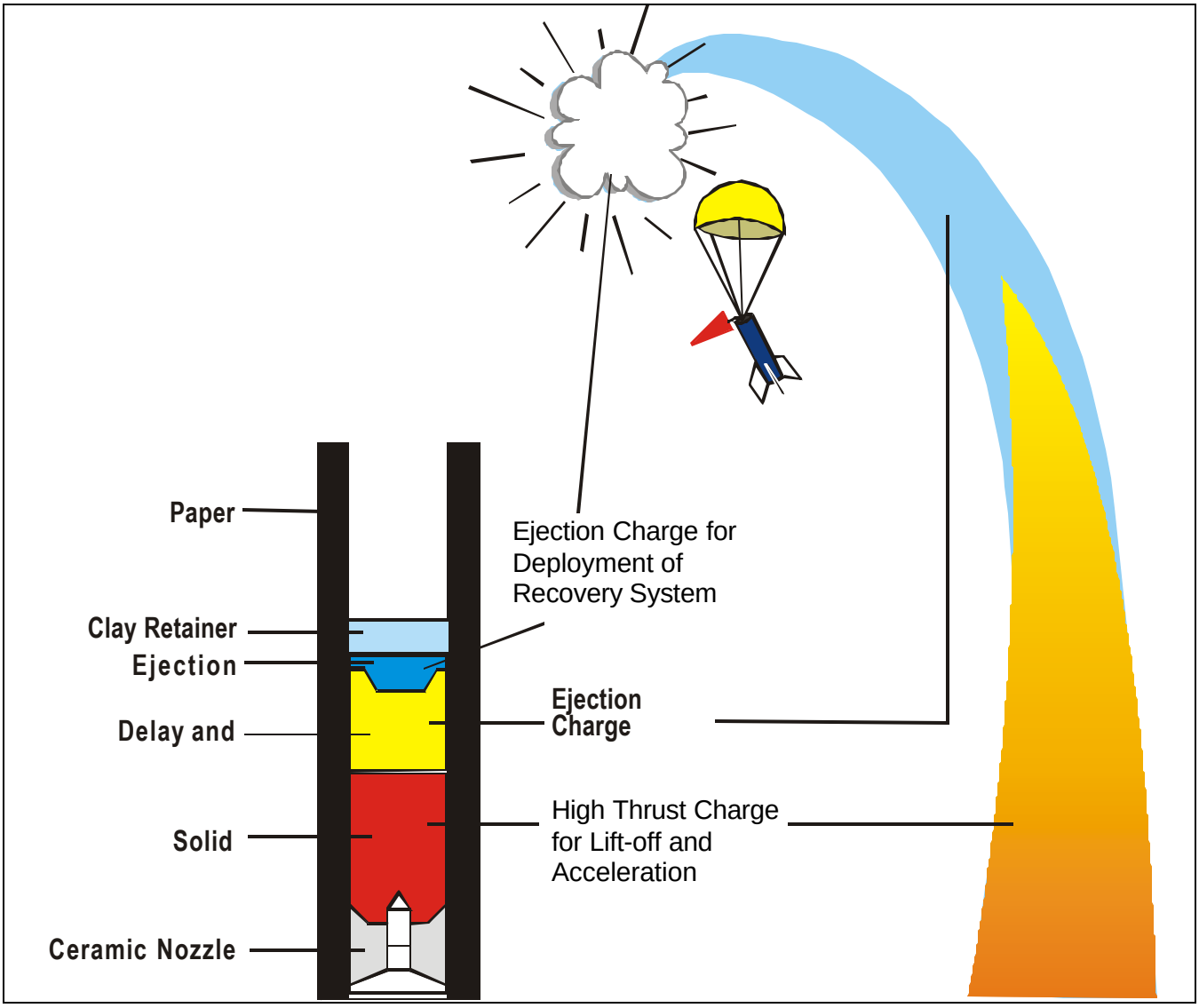
Cadets Brandon Ybarra and Bronson Montield demonstrate the use of the Estes Altitrak™

SATURN Written Phase

MODEL ROCKET ENGINES

The model rocket engine is a very powerful, yet reliable source of thrust. Several companies market these engines including Quest, Estes and Pitsco. All engines comply with the National Fire Protection Association and are certified by the National Association of Rocketry (NAR).

The model rocket engine is made up of a ceramic nozzle, a solid propellant for lift-off and acceleration, a delay and smoke tracking chemical, an ejection charge, a clay retainer cap and all of this is enclosed in a heavy paper casing.



Thrust—Push Power!

The model rocket engine is designed to provide thrust and to provide forward motion. When the solid fuel is ignited, usually by electrical means, a chemical reaction occurs and the gases created in this reaction are forced out the nozzle. According to Newton's Third Law of Motion, this is an action and propels the rocket skyward as a reaction. The altitude, speed and weight-lifting capability is determined by amount of solid fuel and the duration of the chemical reaction.

The thrust that an engine creates is measured in terms of "Newtons" over a period of time in "seconds." When the two terms are spoken in terms of performance, it is said "maximum thrust was achieved in 'so many' Newton Seconds." Another term is total impulse and this is the total power produced by the engine. The engines are classified according to letters of the alphabet. The further into the alphabet, the more powerful. Here's how it works:

ENGINE	IMPULSE	ENGINE TYPES
1/4 A	0.313-0.625 (Newton-seconds)	Mini
1/2 A	0.626-1.25 (Newton-seconds)	Standard (also Mini)
A	1.26-2.50 (Newton-seconds)	Standard (also Mini)
B	2.51-5.00 (Newton-seconds)	Standard
C6	5.01-10.00 (Newton-seconds)	Standard
C11	5.01-10.00 (Newton-seconds)	In "D" size
D	10.01-20.00 (Newton-seconds)	D size
E	20.01-30.00 (Newton-seconds)	E size

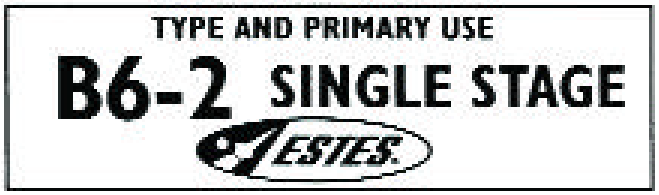
Using a common engine, the B6-4, let's investigate what the lettering on the rocket engine means:

The "**B" is the total impulse, or power,** (in Newton-seconds) produced by the engine. Each succeeding letter has up to twice the total power as the previous letter. An example of this is the letter "B." It has up to twice the power of an "A" engine and this, in turn, means that it should reach approximately twice the altitude, given the same rocket. In higher powered engines, for example, a "G" has 160 Newton Seconds of total impulse!

The **"6" shows the engine's average thrust, or how fast the engine powers the rocket.** This parameter is measured in just Newtons. It might be noted that the 4.45 Newtons = 1 pound of thrust, or 0.225 pounds equal one Newton.

The next letter, in this case the "**4" means the "Time Delay."** This number gives you the time delay in seconds between the end of the thrust burn-out and ignition of the ejection charge. It should be noted that **engine types that end in "O" have no time delay,** or ejection, and are used for booster stages only.

Engine Coding for Quick and Easy Identification



Material Courtesy Estes-Cox Corporation. Used with permission.

Label color indicates recommended use of the engine.

a. **Green**.....Single stage rockets
b. **Purple**.....Upper stage or Single stage, if used in very light rockets
c. **Red**.....*Booster and intermediate stages of multi-stage rockets
d. **Black**.....*Special plugged engines for R/C gliders

*These contain no delay or ejection charge.

TOTAL IMPULSE CLASSIFICATION

CODE	POUND-SECONDS	NEWTON-SECONDS
1/2 A	O.14 - 0.28	O.625 -1.25
A	1.26 - 2.50	1.26 - 2.50
B	2.51 - 5.00	2.51 - 5.00
C	1.12 - 2.24	5.01 - 10.00
D	2.24 - 5.00	10.01 - 20.00

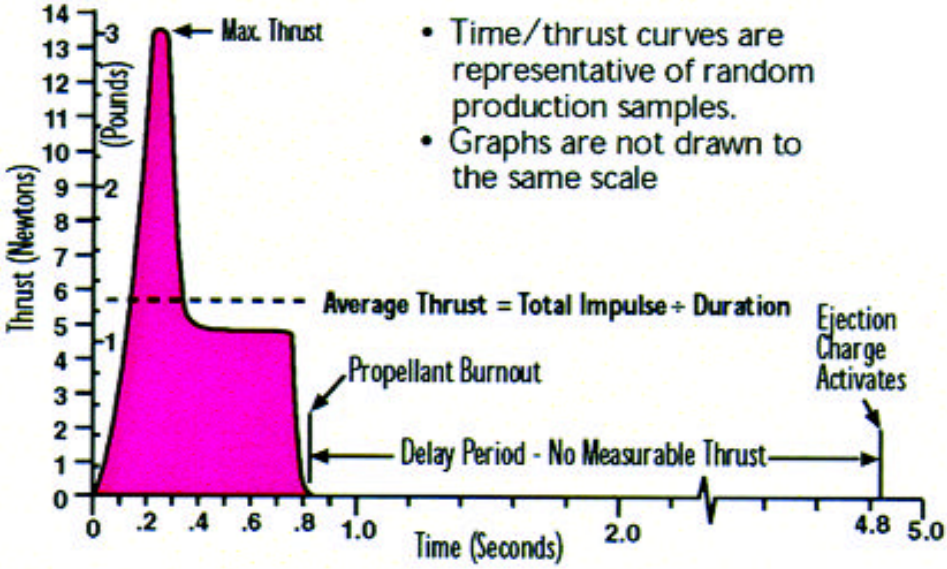
HOW HIGH WILL YOUR ROCKET GO?

The chart below shows the approximate altitudes that can be achieved with single stage rockets.

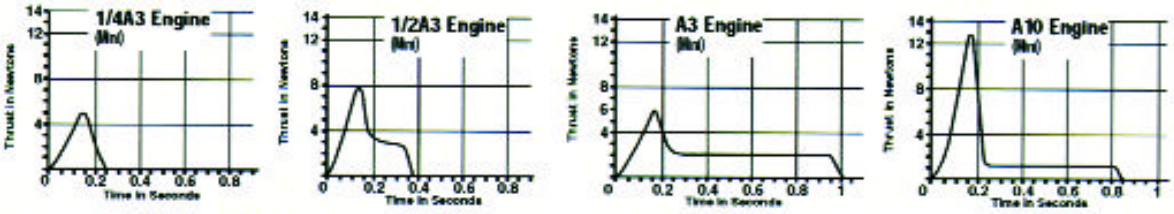
ENGINE SIZE	ALTITUDE RANGE DEPENDING ON ROCKET SIZE AND WEIGHT	APPROXIMATE ALTITUDE IN A TYPICAL
1/2A6-2	100' to 400'	190'
A8-3	200' to 650'	450'
B6-4	300' to 1000'	750'
C6-5	400' to 1500'	1000'
(Some high performance rockets will reach higher altitudes than shown above.		

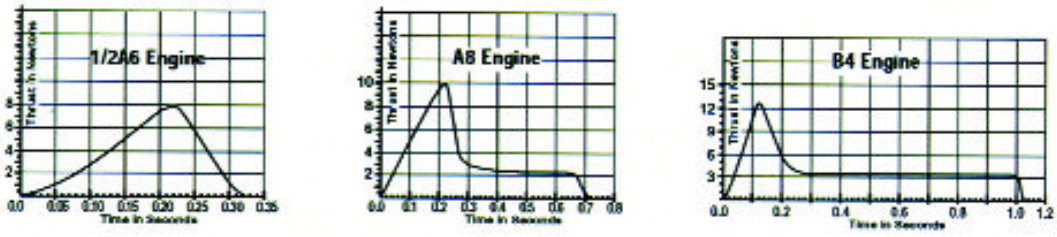
Material Courtesy Estes-Cox Corporation. Used with permission.

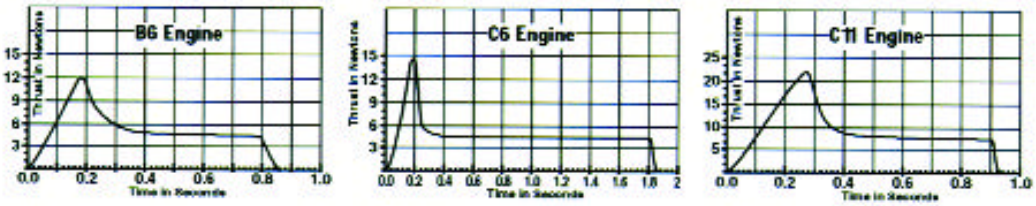
TIME/THRUST CURVES

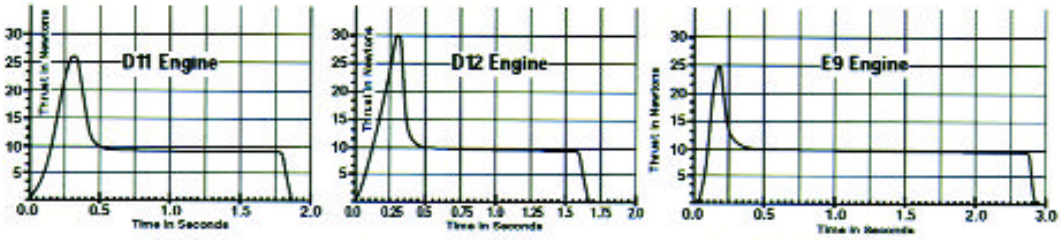


- Time/thrust curves are representative of random production samples.
- Graphs are not drawn to the same scale









This illustration was provided courtesy of Pitsco, Inc.

Safety First and Foremost

The model rocket engine of today is a very safe, reliable powerplant. Cadets, students, seniors and teachers must, however, take every precaution to maintain a high level of safety. The National Association fo Rocketry has eleven guidelines that will help promote safety in the building of model rockets. It is highly recommended that these rules be followed during every launch. The Model Rocketry Safety code is found on page 54.

ESTES® ENGINE CHART

- Delays have a tolerance of plus or minus 10% or 1 second, whichever is greater.
- All Estes® engines come complete with igniters and patented igniter plugs (Pat. No. 5,410,966 and 5,509,354). The Estes® Igniter Plug makes engine ignition extremely reliable.
- Do not fly a rocket/engine combination whose maximum lift-off weight exceeds the recommended maximum lift-off weight.

Prod. No.	Engine Type	Total Impulse	Time Delay	Max. Lift Wt.		Max. Thrust		Thrust Duration	Initial Weight		Propellant Weight	
		N-sec	Sec.	Oz.	g	Newtons	Lbs.	Sec.	Oz.	g	Oz.	g
SINGLE-STAGE ENGINES (GREEN LABEL)												
1502	1/4A3-3T	0.625	3	1.0	28	4.9	1.1	0.25	0.20	5.6	0.03	0.85
1503	1/2A3-2T	1.25	2	2.0	57	8.5	1.9	0.3	0.20	5.6	0.06	1.75
1507	A3-4T	2.50	4	2.0	57	8.5	1.9	0.6	0.27	7.6	0.12	3.50
1511	A10-3T	2.50	3	3.0	85	13.0	2.9	0.8	0.28	7.9	0.13	3.78
1593	1/2A6-2	1.25	2	2.0	57	11.8	2.7	0.3	0.53	15.0	0.06	1.56
1598	A8-3	2.50	3	3.0	85	11.8	2.7	0.5	0.57	16.2	0.11	3.12
1601	B4-2	5.00	2	4.0	113	13.2	3.0	1.1	0.70	19.8	0.29	8.33
1602	B4-4	5.00	4	3.5	99	13.2	3.0	1.1	0.74	21.0	0.29	8.33
1605	B6-2	5.00	2	4.5	127	12.1	2.7	0.8	0.68	19.3	0.22	6.24
1606	B6-4	5.00	4	4.0	113	12.1	2.7	0.8	0.71	20.1	0.22	6.24
1613	C6-3	10.00	3	4.0	113	15.3	3.4	1.6	0.88	24.9	0.44	12.48
1614	C6-5	10.00	5	4.0	113	15.3	3.4	1.6	0.91	25.8	0.44	12.48
1622	C11-3	10.00	3	6.0	170	22.1	4.9	0.8	1.14	32.2	0.39	11.00
1623	C11-5	10.00	5	5.0	142	22.1	4.9	0.8	1.18	33.3	0.39	11.00
1666	D12-3	20.00	3	14.0	396	32.9	7.4	1.6	1.49	42.2	0.88	24.93
1667	D12-5	20.00	5	10.0	283	32.9	7.4	1.6	1.52	43.1	0.88	24.93
1673	E9-4	30.00	4	15.0	425	25.0	5.6	2.8	2.00	56.7	1.27	35.80
1674	E9-6	30.00	6	15.0	425	25.0	5.6	2.8	2.00	56.7	1.27	35.80
UPPER STAGE ENGINES (PURPLE LABEL)												
1504	1/2A3-4T	1.25	4	1.0	28	8.3	1.9	0.3	0.21	6.0	0.06	1.75
1599	A8-5	2.50	5	2.0	57	13.3	3.0	0.5	0.62	17.6	0.11	3.12
1607	B6-6	5.00	6	2.5	71	12.1	2.7	0.8	0.78	22.1	0.22	6.24
1615	C6-7	10.00	7	2.5	71	15.3	3.4	1.6	0.95	26.9	0.44	12.48
1624	C11-7	10.00	7	4.0	113	22.1	4.9	0.8	1.22	34.5	0.39	11.00
1668	D12-7	20.00	7	8.0	226	32.9	7.4	1.6	1.55	44.0	0.88	24.93
1675	E9-8	30.00	8	15.0	425	25.0	5.6	2.8	2.00	56.7	1.2	35.80
BOOSTER STAGE ENGINE (RED LABEL)												
1608	B6-0	5.00	None	4.0	113	12.1	2.7	0.8	0.58	16.4	0.22	6.24
1616	C6-0	10.00	None	4.0	113	15.3	3.4	1.6	0.80	22.7	0.44	12.48
1621	C11-0	10.00	None	6.0	170	22.1	4.9	0.8	0.98	27.8	0.39	11.00
1665	D12-0	20.00	None	14.0	396	32.9	7.4	1.6	1.44	40.9	0.88	24.93
PLUGGED ENGINES - FOR USE WITH R/C ROCKET GLIDERS (BLUE LABEL)												
1669	D11-P	20.00	None	16.0	453	27.6	6.2	1.8	1.55	44.0	0.88	24.93
1676	E9-P	30.00	None	15.0	425	25.0	5.6	2.8	2.0	56.	1.27	35.80

The data listed above is from randomly chosen production samples.
NOTE: The "T" designates a mini-engine.