TE 336-Engineering II

Thrust, Balance, Pressure

TE 336-Thrust, Stability, Pressure

- As stated in Unit 5, **all bodies in motion have four principle forces acting upon them; gravity, thrust, lift and drag**.
- Scientists use a force known as Action-Reaction to move items and people out of earth's atmosphere.
- **Newton's third law of motion states for every action there is an equal and opposite reaction.**
- As hot gases escape the rear of a jet engine, a reaction is produced in the opposite direction. This reaction is called thrust.
- **Thrust is used to push the aircraft forward.** To fully understand thrust we must revisit fundamental physical science.

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- The reaction or thrust must be greater than the pull of gravity on the object and must overcome inertia in order for work to be done.
- Inertia is described as the tendency of a body at rest to remain at rest unless an outside force acts upon it.
- Before an outside force acts upon an object it remains motionless.
- It is said to have "**static inertia**", or the inertia of a non-moving body.

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- This is stated in *Newton's Third Law of Motion.* It partially states that a body at rest will remain at rest. Conversely, an object in motion will continue in the same direction and at the same speed unless a force is applied to it.
- This property of a moving body is sometimes referred to as **Kinetic Inertia** (of or resulting from motion.)
- A body in motion will remain in motion with constant speed in a straight line as long as no unbalanced force acts upon it.
- The force built up by the moving object is definable as momentum.
- It is determined by multiplying the mass of the object by the velocity.

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- **Momentum = Mass x Velocity**. Momentum is directly proportionate to the speed and or the mass of the object.
- Therefore, if the speed of an object is doubled the quantifiable momentum is also doubled.

Which has more momentum?

(1) A model rocket travelling upward at 100 miles per hour.
(2) The same model rocket traveling upward at 200 miles per hour.

How can you double the momentum of a model rocket?

(1) You can't
(2) Halve its speed
(3) Double its speed

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- Let us examine a model rocket as an illustration of these principles of thrust. That being the case, what factors or unbalanced forces must we be concerned with when designing our model rockets?
- The first is **Gravity** or mass of the rocket in comparison to the thrust of the engine.
- The second is **Drag** or wind resistance. These two forces reduce the amount of energy needed to produce momentum.

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- **The Law of Conservation of Energy** states that Energy is not created or destroyed, it simple changes from one form to another.
- In a model rocket, the chemical energy stored in the propellant of a model rocket engine is transformed into the mechanical energy of hot, expanding gases by its combustion.
- Part of the energy of these expanding gases is transformed into kinetic energy of the rocket's motion.
- Part of the energy is transformed into heat by the friction of the rocket moving through the air.
- Part of the energy is transformed into potential energy of the rocket as the rocket rises higher and higher. The portion of the energy in which we are most interested is that which is transformed into momentum of the rocket.

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- ***How high will the rocket go?***
- The height of the rocket depends upon the amount of energy needed to overcome static inertia, gravity and drag.
- In order to predict the height of a rocket it is necessary to determine the rockets ballistic coefficient.
- The ballistic coefficient is the ratio of the weight of the rocket divided by its drag form factor.
- The ballistic coefficient of any given projectile is a three digit decimal number assigned to it by virtue of its shape and weight.
- It is an indicator of how well the projectile will retain its initial velocity over any distance.

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- *Who likes to hunt?*
- Air is a resistant medium just like water.
- A heavier and more aerodynamically efficient projectile will have a higher ballistic coefficient (BC).
- Bullets are projectiles. A light .22 caliber bullet of 55 grains, while having a streamlined and pointed configuration, has a BC of .235-.243.
- A 7mm (.284 diameter) bullet of 162 grains in weight has a BC as high as .534.
- A blunt and cylindrical .357 caliber wadcutter has BC of .055.
- Spire point or Spitzer type rifle bullets will always have a higher

  BC than a round nose bullet of identical caliber and weight.

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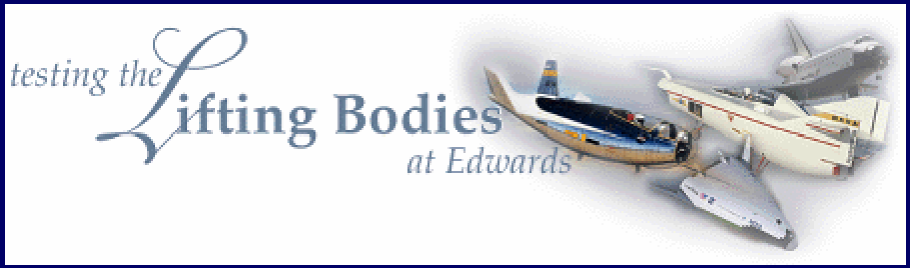

- A ballistic entry is one in which the force created is always parallel to the line of flight, that is, a "drag" force.
- Ballistic Coefficient = Weight/(Drag Coefficient x Area)

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- The drag form factor is determined by multiplying the drag coefficient (CD) (a measure of how easily a body moves through the air) by the frontal area (A).
- Frontal Area is the total area of all surfaces subject to drag. One important thing to remember is that a model rocket’s mass is not the same during the thrusting and the coasting phases of flight.
- A different ballistic coefficient is used for each of these two stages of flight.

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- Momentum = Mass x Velocity
- Work = Mass x Distance
- Ballistic Coefficient = Weight/(Drag Coefficient x Area)
- **Triangle Area Formulas:** 1/2 * ab * sin(c) where a and b are sides and c is the enclosed angle; 1/2 * hb where h is the height and b is the length of the base.
- **Circle Area Formula:** Pi r^2 where r is the radius
- **Pi = 3.14**
- What is the momentum of your rocket if it has a mass of 200 grams and a velocity of 150 miles per hour?
- What is the momentum of the same rocket with a speed of 75 miles per hour?
- If you pushed a 200 pound box 10 feet across the floor how much work was done?
- If you pushed the same box 5 feet, how much work is done?
- What is the ballistic coefficient of your rocket if it weighed 25 grams, had a 30 degree cone shaped nose and a diameter of .5 inches
- What is the ballistic coefficient of the same rocket with a hemisphere shaped nose cone?
- What is the ballistic coefficient of a rocket that has a 60 degree cone shaped nose, weighs 35 grams and a diameter of 2 inches?

- **The higher the sectional density (SD), the higher a projectile will rise.**
- In a bullet the deeper it will penetrate.
- Note that S.D. does not take into consideration the projectile's shape.
- Note, also, that no consideration is given to the projectile's construction.
- Both ballistic coefficient and sectional density of a projectile should be studied.

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- Thrusting Ballistic Coefficient (TBC) is equal to the initial weight (WI) less one-half the weight of the propellant (WP) divided by the drag form factor.
- This formula uses the average weight of the rocket during thrusting.

- WI-1/2WP
- TBC = ------------------
- CD x A

$$TBC = \frac{WI - 1/2\,WP}{CD \times A}$$

- We need to look at Solid Propellant Engines

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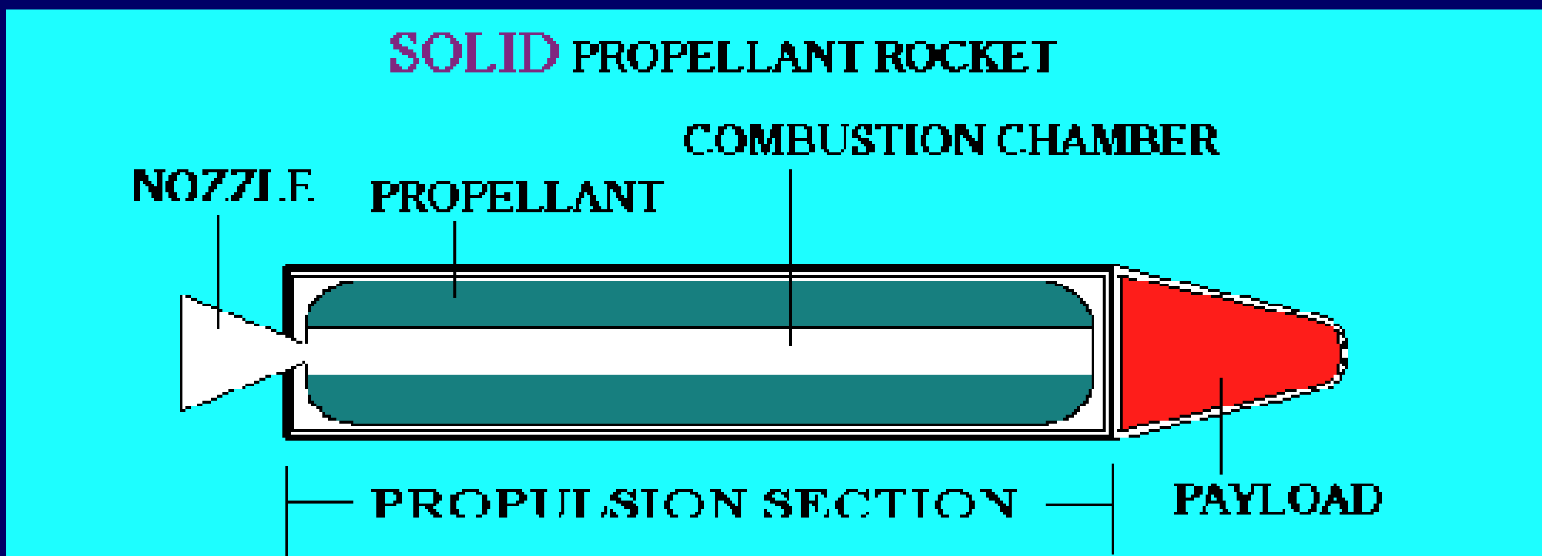

The payload usually comprises a small percentage of the actual craft or vessel. Most of the mass of modern rockets constitutes the propellant.

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- The propulsion section of the rocket includes the rocket propellant, the nozzle, the combustion chamber and the rocket motor outer structure.
- Two types of rocket engines are used:
  - Solid
  - Liquid.
- We will be using solid rocket boosters for this project.

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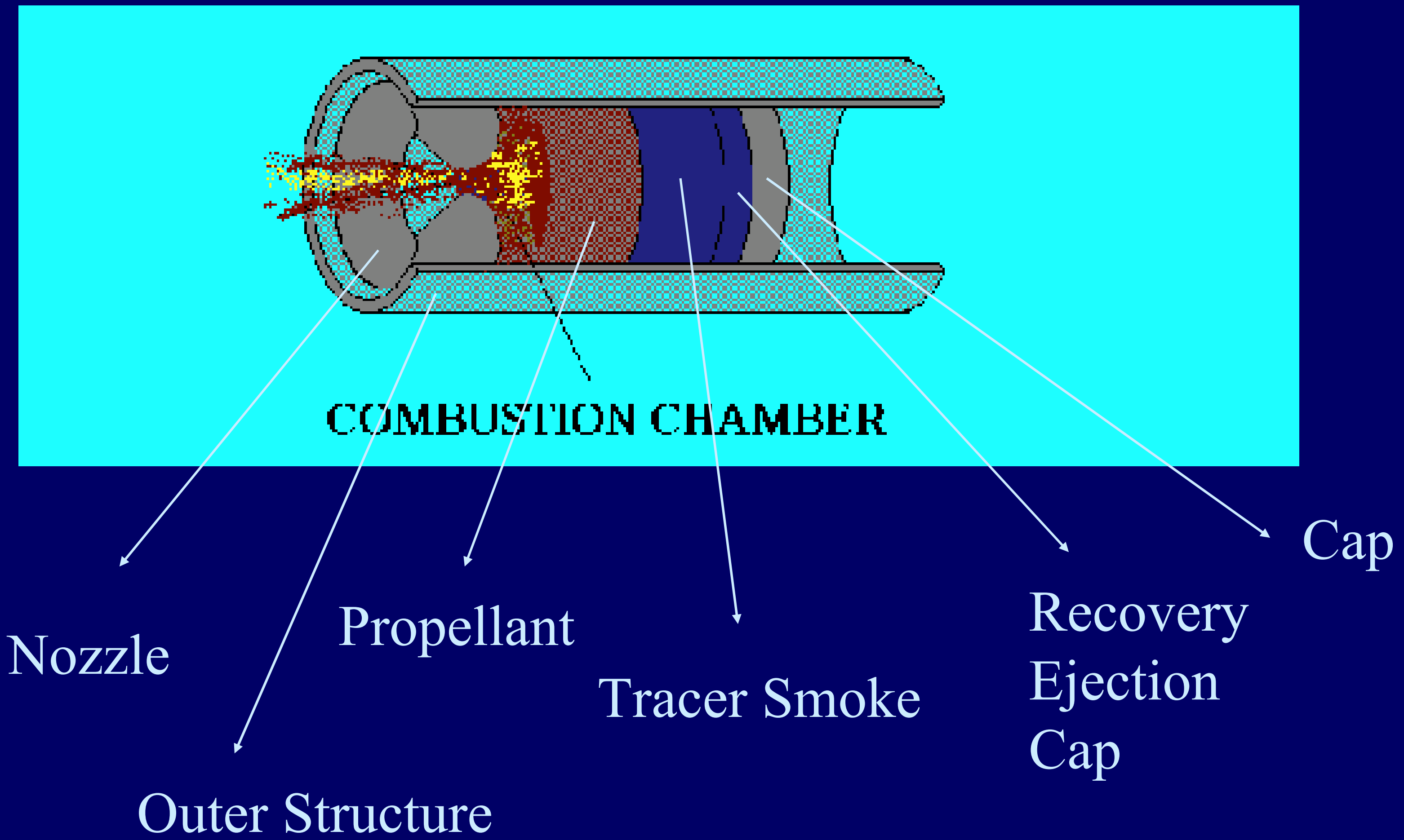

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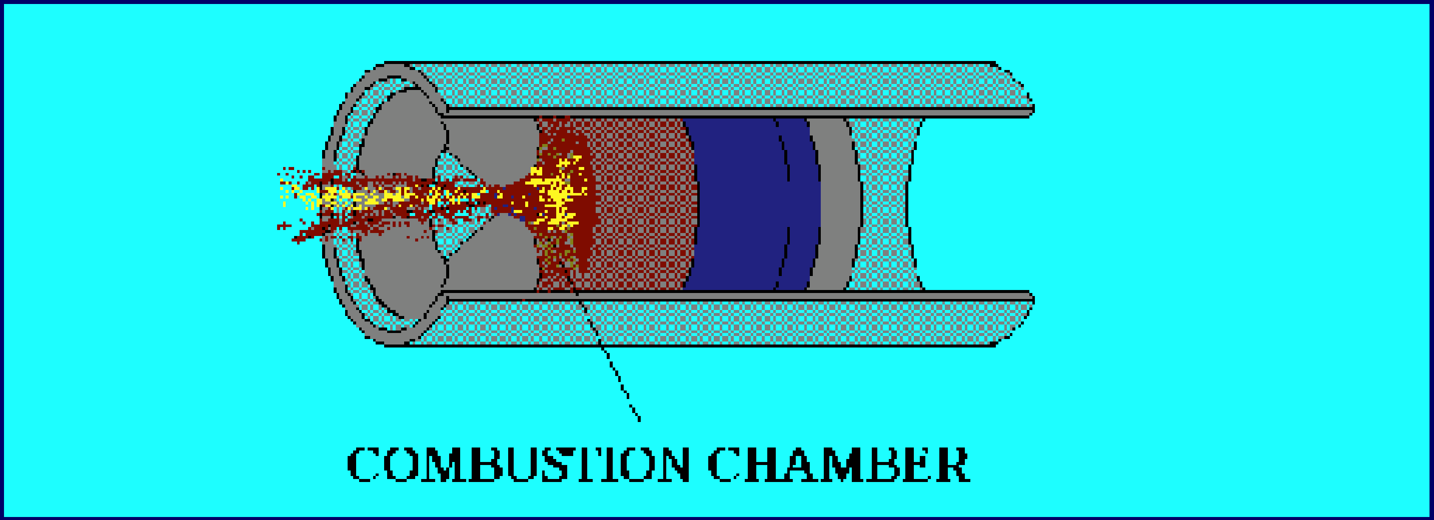

•Combustion produces hot gases.

•Gases are trapped in the combustion chamber by the sides of the motor structure and propellant.

•Only way to escape is through the ceramic nozzle.

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- **Where to find this information:**
- Estes Rocket Engines are printed with codes which gives them important data on the engine's performance capabilities. Us the following guide to interpret the code:
- C6-5
- The first letter indicates total impulse of total power produced by the engine. Each succeeding letter has up to twice the power of the previous letter. (Example "B" engines have twice the power of "A" engines.)
- The first number shows the engine's average thrust in Newtons or the average push by the engine.
- The final number gives you the delay in seconds between the end of thrusting and the ejection charge. This option allows you to choose the delay time you will need for any given flight. Engines with a number zero (0) in this position have no delay.

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- **Other important factors:**
- All matter, regardless of size, mass or shape, has a point inside called the center of mass (CM).
- The center of mass is the exact spat where all of the mass of that object is perfectly balanced.
- Center of mass can be found by trying to balance the object on your finger.
- When the object balances, this location is the center of mass.
- In rocketry the center of mass is about where the rocket starts to tumble freely in space.

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- In flight, spinning or tumbling takes place around one or more of three axis.
- They are called roll, pitch and yaw.
- The point where the three come together is the center of mass.
- Pitch and yaw are most important at keeping the rocket on course.
- Any movement will send the rocket off course.
- Roll is the least important of the three. Roll of the rocket can help the rocket achieve its goal. A slight roll makes the rocket more stable.

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- Fins make a rocket fly straight.
- A rocket without fins will tumble around its center of mass (CM) or balance point, when flying through the air like a balloon that is inflated and then let go.
- The balloon will fly erratically because it is uncontrolled.
- With fins a rocket has more surface area behind the balance point than in the front.

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- The purpose of all recovery system is to bring the rocket and payload safely back to earth by creating enough drag or lift to resist the force of gravity.
- Payload recovery is the most important part of the recovery system.
- The payload must sustain the liftoff and return in excellent condition.

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- The rocket engines starts the thrust in a straight line and Newton's First Law of Motion is restarted by the ejection charge of the engine.
- The rocket travels in a straight line until the charge is fired, then an unbalanced force stops the motion of a straight line.
- The rocket starts to fall back to earth with the force of gravity.
- Some type of recovery system must be in place to slow the force down on the return to earth.

- Six main types of recovery systems are used in model rocketry:
  - featherweight
  - tumble
  - streamer
  - parachute
  - helicopter and
  - glider.
- A parachute is recommended for the egg exercise. However, experimentation with different types is encouraged

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- Another important factor affecting the performance of a rocket is the Mass of the rocket.
- Mass of the rocket can make the difference between a great flight and not getting off the launch pad. If a rocket leaves the ground, its engine thrust must be greater than the total mass of the vehicle.
- Trim your rockets to the bare essentials for the most successful flight.

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- A total formula for mass looks like this:

- 91% propellant, 3% tanks, engine and fins, 6% payload. To determine the effectiveness of a rocket design, rocketeers speak in terms of mass fraction (MF). MF=(Mass of propellants)/(total mass). According to NASA, an MF number in the .80-.90 range is desired.

- This is a problem usually solved by running computer simulations
- *Mark Sullivan's Model Rocket Altitude* Predictor an outstanding, working online rocket simulator that does not require Java to run.

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- **State the Problem**:
- Farmer M. Brio has a problem. He would like to deliver his fresh eggs to his one and only customer, Mrs. Ima Eggeater. Mrs. Ima Eggeater and her sister, Anita Omelet, are two spinsters that live in a house built on a mountain exactly 50 feet from Farmer Brio. BUT there is one small problem. The 50 feet distance has a bottomless gorge. The only bridge is 150 miles south of the spinsters' locale. In the time it takes to travel the 300 miles down and around the other side of the mountain to deliver the eggs, the eggs are no longer fresh. In ordered to ensure the eggs are delivered fresh, Farmer M. Brio wants to use model rockets to deliver the eggs each day.

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- **Your engineering challenge**: You are an engineer with Space Age Eggsport, Inc. Your major objectives are to design and build a rocket type system that can:
  - .Load on small egg within two minutes of blast off.
  - .Carry one (1) fresh, raw egg safely into the air.
  - .The entire system must travel 250 vertical feet from the ground. (DY = 250 feet minimum).
  - .Return the egg to the earth completely undamaged. Cracks are considered damage.
  - .Land on the ground less than 90 feet from the launch pad.
  - .Have a fuselage, nosecone and recovery system of some sort all connected as one piece when it lands on the ground.
  - .Be pre-tested before the final flight.
  - .Remove the egg from the carrier within 2 minutes after recovery.

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- Notes:
- You will be provided the following materials: One (1) 3 inch maximum engine mount. One (1) C6-5 Estes Engine, One (1) launch lug, and One (1) small RAW grade A egg.
- Rules:
  - .For safety and liability reasons, the engine cannot leave school property.
  - .Further, the egg may not be tampered with in anyway (i.e., hardeners added to shell, hard boiling the egg, etc.)
  - .You may use only one engine in the design of your rocket.
  - .You may not acquire or purchase any portion of the rocket from a pre-assembled or non-assembled rocket kit. This is NOT a purchased unit contest.
  - .Test engines may be required. They are available at Wal-Mart very inexpensively.
  - .All tests must be performed with teacher approval.

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A portfolio will be required for this project. The portfolio must include

.**A colorful cover (20 pts)**. It must have the following elements: Your names, TE336-Engineering II, SGHS, Mr. Kachmar Instructor, Spring 2001. Colorful and well-planned covers will receive more points.

.**Section 1: Stating the Problem (5 pts)**

This section must include a copy of this problem sheet.

.**Section 2: Design Rationale (175 pts)**

This section must include a 2-3-page paper. This paper will address the following issues:

.The history of rocket science.(25)

.Given a C6-5 engine, what design considerations are you making to achieve the engineering goals.(25)

.Describe the shape of your nose cone and why you chose it. You must give dimensions verbally.(25)

.Describe the shape of your fuselage and why you chose it. You must give dimensions verbally.(25)

.Describe the shape of your fins, the number and placement of the same. Explain why you are using that shape number and the placement. You must give dimensions verbally.(25)

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.Description of recovery unit. (dimensions and materials used)(25)

.Plan on how you intend to safeguard the egg (carriage system).(25)

.Section 3: Mathematical and Simulator Analysis (150 pts)

On a separate sheet show the following efficiencies including all the work (formulas):

.CD (drag co-efficient) of your nose cone (25)

.Frontal area of your projectile (25)

.ballistic coefficient (25)

.thrust ballistic coefficient (25)

.Print off of data, estimated height and flight graph from the on-line simulator at http://www.execpc.com/~culp/Launcher/Launcher.html (50)

Section 4: Plan of Action (75 pts max)

.Three thumbnail sketches of the rocket. (15)

.Cad or mechanical drawing/sketch of the final proposed rocket with dimensions.(50 Cad, 25 sketch)

.Material list of all the items your will need in the construction of this rocket.(10)

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Section 5: Results (75)

This section will list the results of the flight. You must address:

.The flight path, by drawing it on a sheet of paper. Be sure to label the launch pad and the altitude from the altimeter gun.(15)

.Provide a written narrative of the flight from loading the egg to removal of the egg.(15)

.Report the distance the rocket landed from the launch pad.(15)

.Report the altitude achieved.(15)

.If your rocket encountered any problems of the challenge, describe what went wrong and what you would do differently to correct the problem(s).(15)

Section 6: Photographs (50 max. bonus pts)

Photograph you and your partner in each stage of development.(10 pts each)