ISSUE 98 - FEB. 14, 2003

APOGEE

PEAK OF FLIGHT

NEWSLETTER

APOGEE COMPONENTS
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Apogee Components

RockSim Demo VIRTUAL ROCKET CONTEST RockSim

Whether you are just testing RockSim (Demo Version) or are power designer, you can participate in a new rocketry experience. Yes, participate in the Essence's Model Rocketry Reviews' "Virtual" Rocket Contest and win great prizes from Apogee Components.

Deadline: 3/9/03

RockSim Rocket Design Requirements:

- 18mm motor, single
- At least two diameters of body tubes for exterior body, One body tube must be at least 3x the length of the other
- The shortest body tube must be at least 3" in length
- There must be at least 2 sets of 3 or 4 fins, different shapes and the bottom of the root edge at a different place
- Materials must be standard weights that are in the rocksim database
- Materials must be standard thicknesses that are in the rocksim database
- Fins can not be any thinner than 1/16" of an inch
- Must include realistic recovery and launch lugs (motor hook is optional)
- NO CP Overrides, NO Mass Overrides
- NO Mass Objects for adjusting weight and CP other than normal required items like shock cord, eye-screws, etc.
- Must have at least 1 caliber of stability with an Estes C6 loaded
- Select the rocket part colors that your would like to see posted

Your rocket will be flown in (4) "contest" conditions events and will accumulate a total score:

- Versatility: your rocket will fly in "contest" conditions with (3) "contest" motors. The conditions and motors will not be disclosed. The placement score for each flight will be the Maximum Altitude (ft) * Rocket Weight (oz)
- Max Altitude: your rocket will fly with a "contest mass override", "contest conditions", and a "contest" motor. The placement score will be the Altitude (ft) .
- Slow and Low: your rocket will fly in "contest" conditions with (1) "contest" motor. The placement score will be based on highest Time to Apogee (sec)) and lowest Altitude (ft).
- Drag Race: your rocket will compete in a double-eliminate drag race in "contest conditions", with a "contest" motor. 3 points are up for grab for each flight. 1st) Fastest to clear launch rail (sec), 2nd Longest time to landing (sec), and 3rd Lowest Range (closest to pad in feet)

Time is running out, so check out all the contest rules at http://www.rocketreviews.com/specials2.shtml , or write nick@rocketreviews.com to get all the details!

Archives of this Newsletter

All the articles that have appeared in this newsletter are archived at http://www.apogeerockets.com/education/newsletter_archive.asp

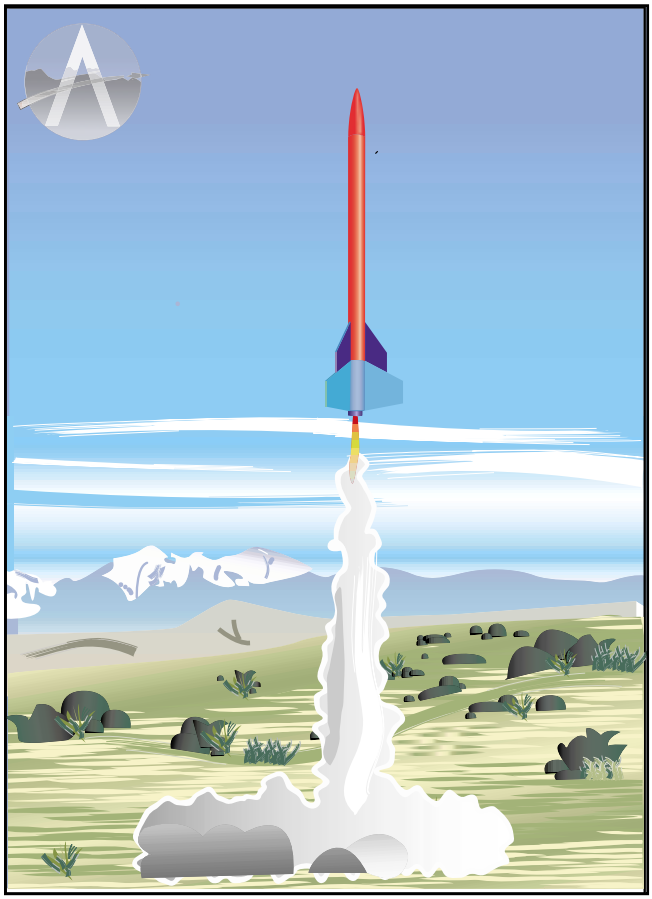
How Multi-Stage Model Rockets Work

Part 1

By Tim Van Milligan

Introduction: If you've been in rocketry for a while, then this article will be pretty basic; but you might learn one or two new things. It tells how two stage rockets work, and how to design your own multi-stage rockets. I've decided to write this article because people have been telling me that web based information is lacking on this subject. So hopefully this article will help someone that wants to build a two (or three) stage rocket.

From the book: *Model Rocket Design & Construction* (http://www.apogeerockets.com/design_book.asp), we see this definition: "A rocket having two or more engines, stacked one on top of another and firing in succession is called a multi-stage. Normally each unit, or stage, is jettisoned after completing its firing. The reason rocketeers stage models is to enable the uppermost stage to attain a very high altitude. This is accomplished by dropping mass throughout the burn so the top stage can be very light and coast a long way upward."



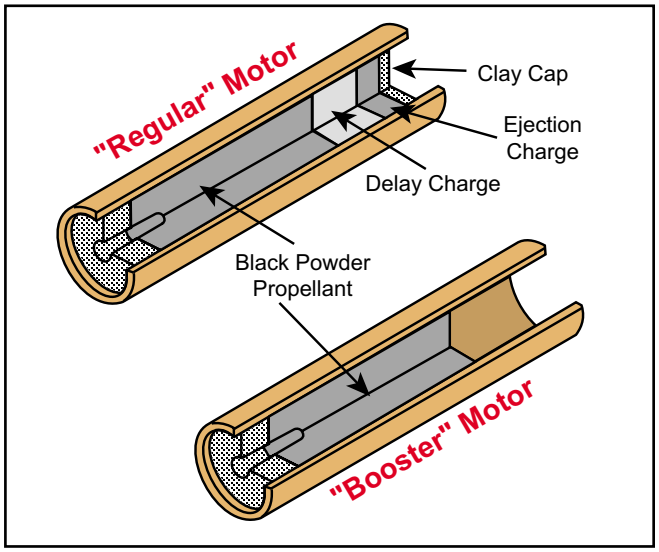
Direct vs Indirect Staging

There are two methods of staging rocket motor. They describe the way the upper stage(s) are ignited, and will be described in this article. The easiest method is called "direct" staging, where the lower stage motor ignites the upper motor. Most of this article will describe "direct" staging.

The second method is called indirect staging. In this method, the upper stage motor is ignited by some other device (not the lower stage). The device used to ignite the motor is a separate ignition system that is carried on the rocket. This method was discussed in Apogee e-zine newsletter 91 (Oct 28, 2002). http://www.ApogeeRockets.com/education/downloads/newsletter91.pdf.

Indirect staging is used on rockets that are larger than a D engine; because the availability of the special booster engines required for the direct-staging technique.

How Direct Staging Works



In direct staging, the lower "booster" stage motor ignites the top motor in the rocket. From the modeler's perspective, direct staging is simple and cheap. You don't need any complicated electronics or launch support equipment.

(Continued on Page 4)

Multi-Stage Rocketry

(Continued from page 3)

The reason it works is explained by the physical make-up of the rocket motors.

The illustration below shows a cut-a-way drawing of a typical black-powder propellant rocket engine. The typical rocket engine has a special slow-burning propellant that burns after the propellant is consumed. This is called the "delay grain." It burns slow, which allows the rocket to coast upward before the parachute is blown out of the rocket by the ejection charge. The delay also spews out a lot of smoke while it burns, which makes the rocket easier to track as it ascends into the air.

In the special "Booster" stage motor, there is no delay grain, nor ejection charge. It only contains the fast-burning propellant.

When the propellant burns upward toward the top of the motor, it throws a lot of heat and burning particles forward as it finishes its burn (see Figure 3). The hot gases and the burning particles go forward into the nozzle of the upper stage. There is so much heat that comes out of the booster motor, that the top stage instantly ignites (see Figure 4). It doesn't need a separate igniter, because the heat from the lower motor supplies the energy to get it to start burning.

How do booster motors differ from upper stage motors?

Really, the black-power propellant "booster" motor is exactly the same as an upper stage motor. The only difference is that the booster motor does not contain the special delay composition. If you look into the front end of a booster motor, you'll see the hard black surface of the propellant. In comparison, a regular rocket motor that has a delay will have a top end that is capped with grayish looking clay (see Figure 2).

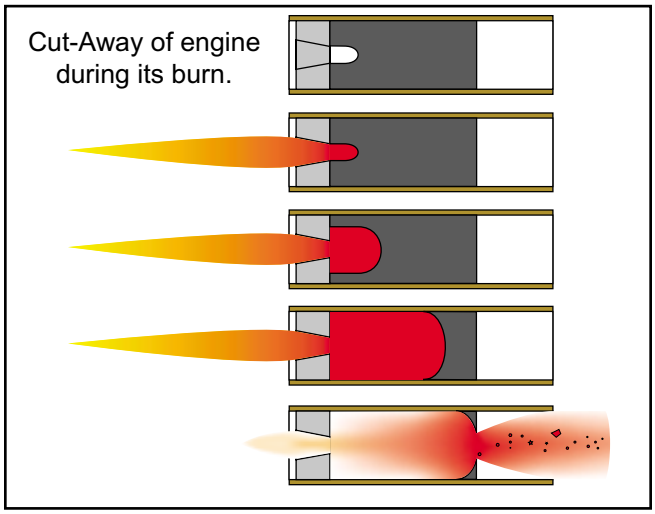


Figure 3: Series of images showing how a booster motor burns, and ejects hot gases forward when it breaches the upper portion of the propellant.

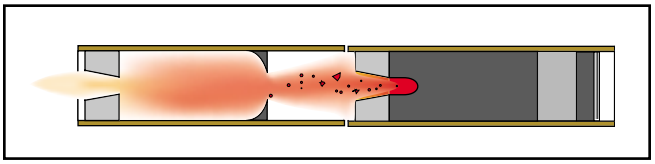


Figure 4: "Direct staging" uses the burn-through gases of the booster motor to directly ignite the upper stage motor.

By not having a delay element incorporated in the booster motor, we get ignition of the top stage nearly instantaneously after all the propellant in the booster has burned out. There is a good safety reason for this. If there were a delay between burnout of the booster, and ignition of the upper stage, the model could arc over. So it might not be pointed vertically when it ignites. This is a serious safety hazzard, and should be avoided.

Conditions for successful stating

For direct staging to work properly, there must be several conditions that have to be met.

To start, the two motors in the rocket have to use "Black Powder" propellant. Why? Because black powder motors burn linear; from the nozzle end toward the front end. This is important, particularly for the special booster motor. The propellant itself becomes a bulkhead; which is needed to hold the pressure inside the rocket engine. Without internal pressure, thrust wouldn't be created.

In a booster stage motor, the propellant that hasn't burned yet becomes the bulkhead that holds the pressure inside the motor. As it burns, the bulkhead becomes thinner and thinner. When the flame nears the top, bulkhead becomes so thin that it can't hold the pressure, and the bulkhead bursts. This is what throws the hot gases and the burning chunks of propellant forward (see Figure 3).

In a composite propellant motor, the actual propellant is soft and rubbery. It can't hold back any internal pressure. That means it can't be used as its own bulkhead like the rock-hard black powder propellant. Composite propellant motors always need to have a solid bulkhead made from another material to hold the internal pressure of the motor. This solid bulkhead prevents composite propellant motors from being able to be used as "direct" staging booster motors.

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Multi-Stage Rocketry

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Another problem associated with composite propellant motors is that they require high pressure to sustain the burning process. You've probably seen a cato of a composite motor that ruptures right at ignition. When this happens, the motor snuffs out. The remaining propellant doesn't burn. It just falls to the ground as a chunk of rubber.

What this means is that even if the propellant could act like a structural bulkhead, as soon as the flame reached the front end and broke through; it would immediately snuff out. The likelihood of hot gases and burning chunks being thrown forward out the top is greatly reduced.

Why black powder in the top stage?

The reason the top stage must have a black powder propellant rocket engine for direct staging to work is because the flammible substance inside the upper motor must be near the nozzle. The gases and the burning chunks eject forward from the booster motor have to come into contact with the propellant of the top stage. In a black powder motor, the propellant is right inside the nozzle opening.

Compare this to a composite propellent motor. Here, the propellant has a hole right through the middle — from the nozzle all the way to the forward bulkhead. So there is less of a likelihood that the gasses are going to make it up into the motor. You'd think it would be possible to ignite, because the gases are so hot. But it doesn't.

An example is easily illustrated by blowing through a straw. If the straw is open all the way through, you can easily blow air through it. But if you block the front end, no matter how hard you try, you can't get any new air to go into it. This is very similar to a composite propellant motor. The hot exhaust gases coming up from the booster stage never make it into the middle of the motor. (Figure 5)

But a black-powder motor has propellant that is very close to the nozzle end. So some hot gases and burning chunks have a very high likelihood of making it into the top stage to ignite the propellant.

The other condition that needs to be met with direct staging to work is that the distance between the motors has to be fairly short. The hot gases from the bottom motor have to stay hot until it reaches the top stage. If the distance between motors is too great, the gases may cool to the point where it isn't hot enough to start the top stage burning. So the closer the motors are together, the easier it is to get a successful staging.

If the motors are in direct contact like shown in Figure 4, then it is customary to tape the ends of the motors together using celophane tape. This prevents separation of the motors for a split second, allowing the gases enough time to ignite the upper stage motor. When staging occurs, the tape simply melts apart, allowing the stages to separate after a successful ignition of the upper stage.

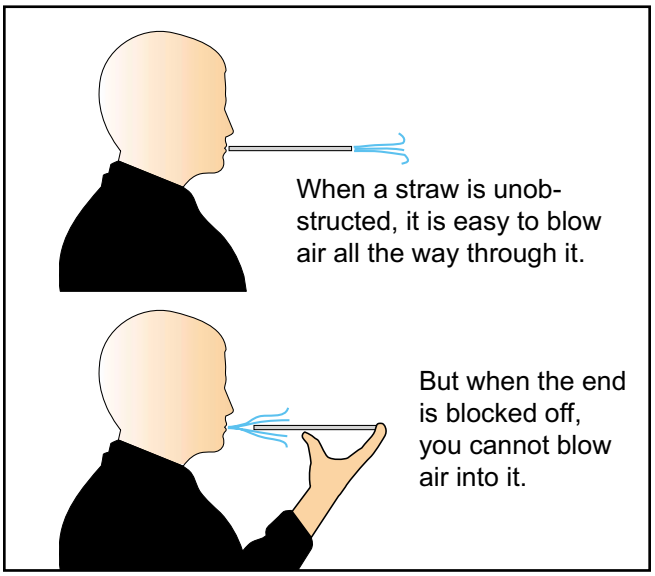

Figure 5: A composite propellant motor is a lot like a blocked tube, so it can't be used for direct staging.

Gap staging

It is still possible to get direct staging to work even if the stages are separated by 10 inches. What you need to do is to allow the gases in front of the lower booster engine to vent to the outside air. If you don't, the stages will separate without the upper stage motor igniting. This is because the hot air coming out the front of the booster engine is pushing the cool air in front of it. If there is no place for the cool air to go, it prevents the hot air from getting into the nozzle of the upper stage engine. Again, it is the blowing air through a blocked straw analogy (see Figure 6).

The vent hole should be about 6.35 mm (0.25 inches) in diameter, and even smaller if you use more than one hole. Place the hole as close to the bottom of the upper stage as possible. This will allow the hot gases to push all the cool air out of the inter-stage tube.

In a future issue, I'll talk about a few more important topics associated with multi-stage models. This includes: safety considerations, engine selection, how to couple the stages together, and flying strategies. If you want the information sooner, I suggest reading the chapter about multi-staging rockets in the book *Model Rocket Design & Construction.*

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Multi-Stage Rocketry

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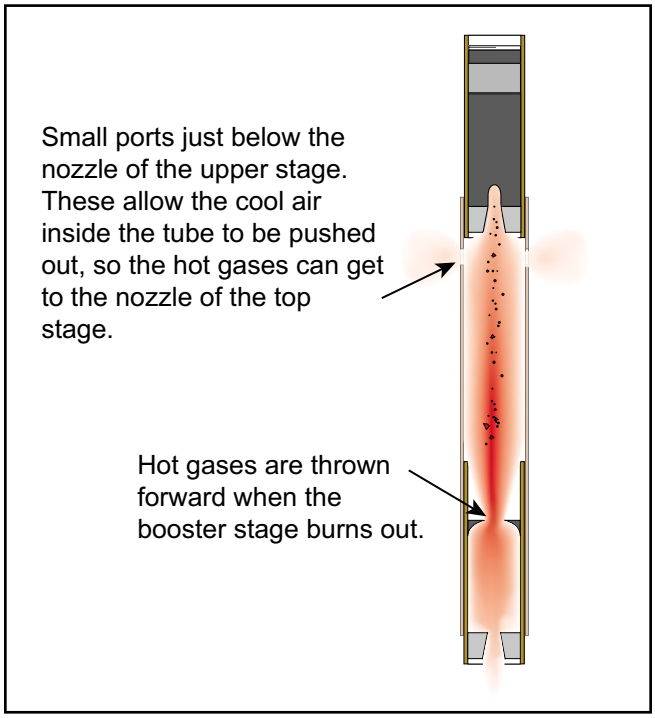

Figure 6: This illustration shows how you can get successful ignition of the top stage, even when the motors do not touch each other. This is called "Gap staging."

It should also be noted that we have previously discussed how to design the stage so it tumbles to the ground, and how big we can make the booster stage (in case we want to upscale an old design). These articles can be found listed in the bibliography at the end of this article.

Bibliography: Internet Resources:

Apogee's Educational Information - You should always start at this web site first. It has lots of links to other sites that have information about staging model rockets. http://www.apogeerockets.com/education/multi_stage.asp

Design, Construction, and Flying Strategies for Acheiving Maximum Altitudes. While this article doesn't directly deal with multi-stage rockets, it does have lots of information that carries over to multi-stage rockets. Apogee E-zine newsletter #75. http://www.ApogeeRockets.com/education/downloads/newsletter75.pdf

Electronic Staging of Composite Propellant Rocket Motors - This article explains how to do indirect staging Apogee E-zine newsletter #91. http://www.ApogeeRockets.com/education/downloads/newsletter91.pdf

How To Design Tumble Recovery Booster Stages - This article talks about how to arrange the parts so the stage will begin tumbling on its own. Apogee E-zine newsletter #96. http://www.ApogeeRockets.com/education/downloads/newsletter96.pdf

How To Design Tumble Recovery Booster Stages - Part 2 - This article shows you how to determine the rate of descent of the booster stage. It is particularly useful when upscaling old kits into larger high-powered rockets. Apogee E-zine newsletter #97. http://www.ApogeeRockets.com/education/downloads/newsletter97.pdf

In-line vs interdigitated fins: which is better for multi-stage rockets? Apogee E-zine newsletter #97. http://www.ApogeeRockets.com/education/downloads/newsletter97.pdf

Optimum Mass - Squeezing Out Every Inch Of Altitude. - This article talks about using the delayed staging technique to get higher altitudes out of multi-stage model rockets. Apogee E-zine newsletter #84. http://www.ApogeeRockets.com/education/downloads/newsletter84.pdf

Parallel Staging - Apogee E-zine newsletter #94. http://www.ApogeeRockets.com/education/downloads/newsletter94.pdf

Printed Materials:

Handbook of Model Rocketry By G. Harry Stine. Available from many online retailers, such as Amazon.

Model Rocket Design & Construction. By Timothy S. Van Milligan. Published by Apogee Components, Inc. ©2001. Available at: http://www.ApogeeRockets.com/design_book.asp

About the Author

Tim Van Milligan is the owner of Apogee Components (http://www.apogeerockets.com) and the new rocketry education web site: http://www.apogeerockets.com/education. He is also the author of the books: *Model Rocket Design and Construction, 69 Simple Science Fair Projects with Model Rockets: Aeronautics* and publisher of the FREE e-zine newsletter about model rockets. You can subscribe to this e-zine at the Apogee Components web site, or sending any message to: ezine@apogeerockets.com with "SUBSCRIBE" as the subject of the message.

Download the FREE RockSim Plans And Decal Artwork!

The data file you need is at:
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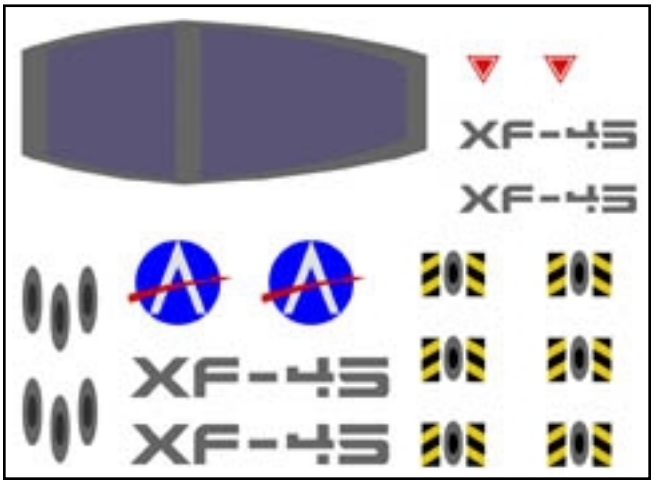
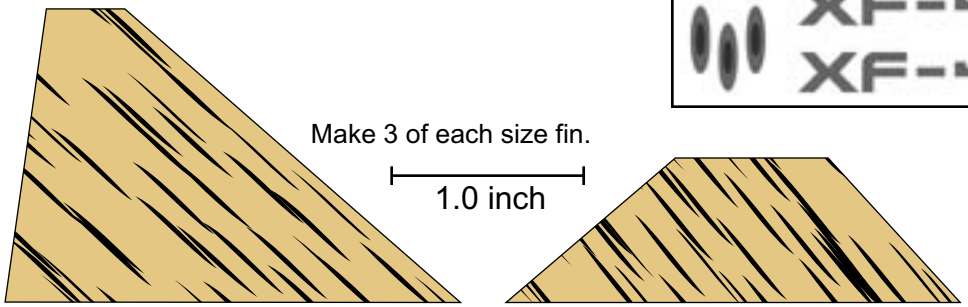
When you download the file, you'll get a RockSim design file (which can be opened in the FREE demo version of RockSim. Plus, you'll get color decal artwork that you can print out to put on your completed rocket!





A Tribute to The Astronauts On The Space Shuttle Columbia

February 1, 2003 will always be a date we rocketeers remember, as it is etched into our hearts as well as in our minds. The disaster of Space Shuttle Columbia left not only friends and family members of the seven noble astronauts in shock and sorrow, but it also directly affected us rocketeers. We have a direct connection to the space program, as we still firmly believe that "the first step into space is a model rocket." Many of NASA's astronauts first caught the "space bug" when they were introduced to it through model rocketry.

In memory of the seven astronauts that were launched into space on Shuttle Columbia, I commissioned Sara Danielson to create two tribute logos. I realize that many rocketry clubs throughout the world will pay respect to the astronauts by holding special rocket launches. So I thought it would be nice if modelers had special logos that they could put on their models. You are welcome to print these logos out and use them as decals on your rockets. If you would like us to print them out for you, just send me an email, and we'll work something out to cover the cost of postage.

Here is what Sara Danielson thought about when she created these two logos:

"Using the same outline template of the actual space shuttle patch that the astronauts wore on their uniforms, the two logos pictured below were created carefully not to copy the original design.

In the first logo design, a sense of patriotism was accomplished by creating a large flag in the central region of the patch. To place focus on each of the seven astronauts on Shuttle Columbia, their names were boldly displayed across the red and white stripes in the American flag. The flag was strategically placed in the center of the patch to separate the world (known as the starting point in Columbia's journey) and the blackness of outer space located in the bottom left corner of the patch design (the final destination). It is somewhere in-between where we lost and will remember the astronauts of Shuttle Columbia.

In the second patch design, less emphasis was placed on each of the seven astronauts. Instead, the seven white stars alone symbolize their courageous efforts. Notice again that a sense of patriotism is portrayed with the red and blue stripes representing America's well known flag. The world is this time placed along the bottom edge of the patch design and the gradient turning to blackness displays the unknown world of outer space.

Each of the logos below are made in memory of the astronauts America lost on Feb. 1, 2003. The astronauts are missed immensely and will be remembered forever."

Artwork Designs by Sara Danielson