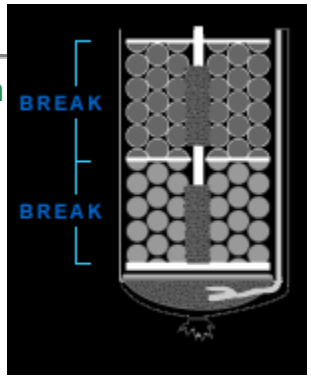
Anatomy of a Firework

Click on labels for details

When most of us think "fireworks," we think of brilliant bursts of light and color we've seen paint a night sky. But such bursts are merely the spectacular *end* of fireworks that likely took centuries of experience, weeks of planning, and hours of painstaking labor to fashion and fire. In this feature, pull back the wrapping on a typical aerial display shell and see what it looks like *before* its glorious denouement in the dark.

Click on the labels at left to learn more about them.

Break

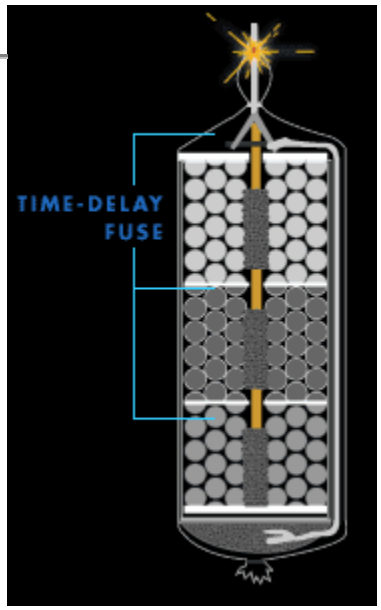


In a multi-break firework, stars are contained in separate cardboard compartments within the shell. Each compartment has its own bursting charge, which ignites and throws out the stars. In order to spread these decorations over a wide area of sky, the break must burst open with tremendous force. The more the compartment can resist the explosion and bottle up its force, the bigger the display will be. Resistance comes from the break's heavy wrapping, which momentarily keeps the gas and heat from reaching the bursting charge.

A firework's breaks may also contain sound charges, which result in the cracking bangs and thunderous booms that thrill audiences. To

make these loud explosions, which are usually accompanied by a bright white flash, firework manufacturers use mixtures of perchlorate, a different kind of explosive than black powder.
Back to main diagram

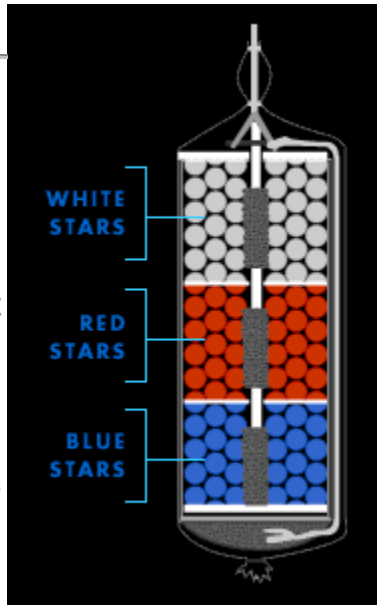
Time-delay fuse



As the firework ascends through the air, the time-delay fuse continues to burn. By the time the shell nears its apogee, the fuse has burned low enough to ignite the black powder in the first break (or compartment). Colored stars ignite in every direction. But the show isn't over yet. The fuse keeps burning, making its way toward the stashes of black powder in the second and third breaks.

Timing is critical. In a three-break firework, the middle break needs to ignite at the highest point in the shell's trajectory. Thus, the first break should blow a little before and the third break a little after. If the timing is off, the firework might detonate too close to the ground. Great care is used in designing the fuses and calculating their lengths.
Back to main diagram

Stars



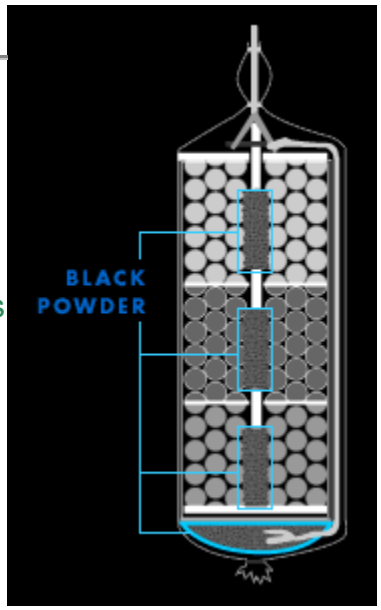
Stars are the precious cargo carried by "aerial" fireworks like the one depicted here. An unlit star isn't much to look at -- just a dull black lump about the size of a jawbreaker. But appearances can be deceiving. When ignited, stars create the breathtaking flashes of color and light that elicit "oohs"and "ahhhs" from even the most jaded spectators.

Fireworks masters manufacture their creations by hand, including the hundreds of stars that go into a single firework. They mix carefully measured ingredients like perchlorate and black powder with binding and coloring agents: magnesium or aluminum for white,

sodium salts for yellow, strontium nitrate or carbonate for red, barium nitrate for green, copper salts for blue, and charcoal or other forms of carbon for orange. The result is a huge slab of dough, which is then cut like a tray of brownies into half-inch cubes; these are then set out to dry.

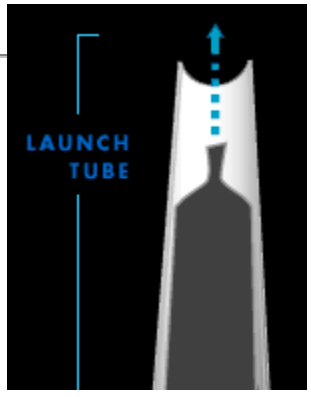
Stars can be extremely dangerous if not handled and stored with care. A sharp blow can detonate one. Oil from nearby machines can combine with certain chemicals to create an explosive gas. Even synthetic clothing, which generates static electricity, can create sparks capable of detonating the fragile shells. Firework makers must stick to wearing cotton -- all the way down to their underwear.
Back to main diagram

Black powder



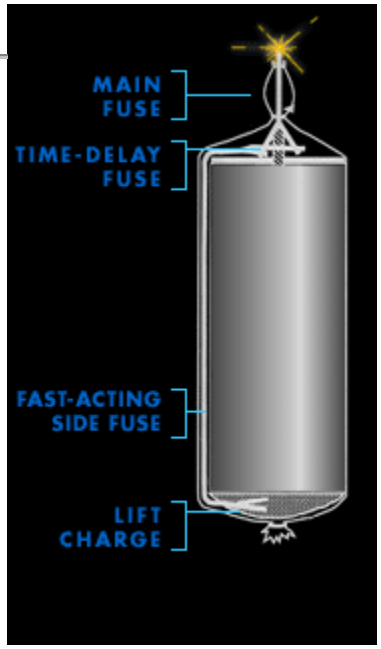
The recipe for black powder, or gunpowder, the basic material in all fireworks, has remained the same since it was discovered in China about 1,000 years ago: 75 percent saltpeter (potassium nitrate), 15 percent charcoal, and 10 percent sulfur. Black powder lends itself to fireworks because it's a "low explosive," meaning its detonation velocity is less than about 100 yards per second. ("High explosives" like dynamite have a velocity of detonation greater than 1,000 yards per second.) Fireworks makers can also control the powder's rate of burn in several ways. One way is by manipulating the size of its grains: Fine grains burn more quickly than coarse grains.
Back to main diagram

Launch tube



Most fireworks are launched from rows of steel tubes secured in troughs of sand. The tubes, or "mortars," are three times as long as the firework shells but have the same diameter. If a firework doesn't fit snugly into its launch tube, the pressure created by the lift charge will escape, and the firework can misfire.

Main fuse

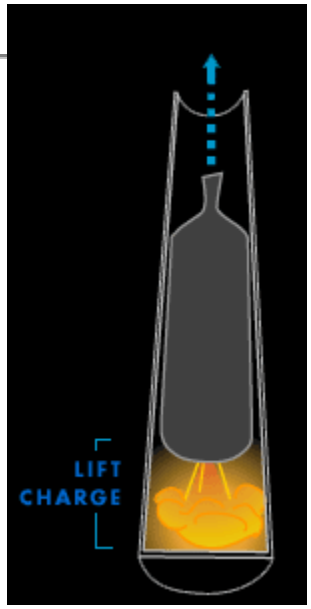


During the Renaissance, when fireworks as we know them were invented, pyrotechnicians lit their creations with tissue paper rolled around a trail of black powder. Later, string embedded with gunpowder was used. Today, electrical wires connect fireworks to a master control board. With the push of a button, an electrical current rushes through each wire and creates a spark at the point of contact on the main fuse.

The main fuse simultaneously lights two secondary fuses -- a fast-acting side fuse that ignites the lift charge, and a time-delay fuse buried inside the shell that leads to the heart of the firework.

Back to main diagram

Lift charge



When black powder burns in the open air, the heat and gas it generates quickly dissipate. But if the black powder is confined, say in a pouch at the bottom of a firework cylinder, the trapped heat and gas will push vigorously at the inside of the launch tube until an explosion results. This explosion will free the heat and gas and hurtle the firework shell as high as 1,000 feet into the air.

Back to main diagram

Printer-Friendly Format Feedback

Name That Shell | Anatomy of a Firework | Pyrotechnically Speaking | On Fire
Resources | Transcript | Teacher's Guide | Site Map | Fireworks! Home

Search | Site Map | Previously Featured | Schedule | Feedback | Teachers | Shop
Join Us/E-Mail | About NOVA | Editor's Picks | Watch NOVAs online | To print
PBS Online | NOVA Online | WGBH