STANDING WAVES & RESONANCE

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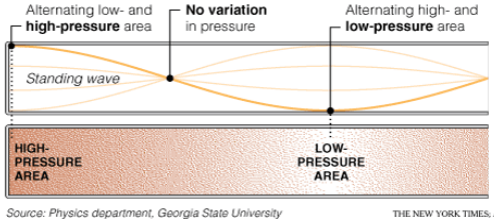
Whole Lot of Shaking Going On?

NASA engineers are examining potentially dangerous oscillations in the Ares 1 rocket. If vibrations in the booster were the right frequency to resonate through the entire rocket, they might be amplified enough to shake the crew module violently.

STANDING WAVES
At right, vibrations in a simple tube closed at one end and open at the other create a wave of alternating high- and low-pressure areas.

Solid rocket motors have more complex internal shapes, but vibrations in the combustion chamber can grow into similar standing waves.



Source: Physics department, Georgia State University

ARES 1
As the rocket's first stage burns solid propellant from the bottom up, it begins to act like a hollow tube.

Reusable solid rocket motor

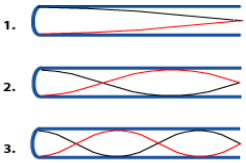
THE NEW YORK TIMES; ARES RENDERING BY NASA

NASA Insists It Can Fix Flaw in Rocket Design

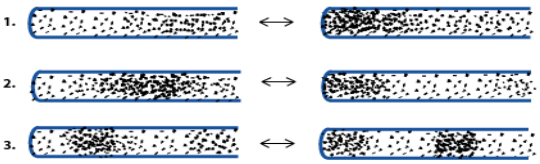
By KENNETH CHANG

Published: February 19, 2008 Preliminary calculations by NASA last summer suggested that the rocket it had on the drawing board to replace the space shuttle possessed a design flaw: ***vibrations in the booster*** might shake the top of the rocket so violently that any astronauts riding aboard would suffer severe, perhaps fatal, injuries. In 2004, NASA announced plans to develop a family of rockets, collectively known as the Constellation program, to replace the three-decade-old shuttles, due to be retired in 2010. The first, Ares I, is to have its first test flight next year. To understand the engineering challenge, here is the key thing to know: Unlike most space-bound rockets that use liquid oxygen and hydrogen for fuel, Ares' first stage will use solid rocket propellant, borrowing the design of the shuttle's solid fuel boosters.**With a solid-fuel rocket, the fuel burns outward from the center of its cylindrical core. When the fuel is gone, what is left is a hollow metal tube — one that behaves remarkably like an organ pipe**.The rich sounds of an organ result from the blowing of air through the pipes**. When the wavelength of the vibrations equals the length of the pipe, the vibrations are amplified and the resulting resonance produces the note.In much the same way, *the Ares I booster also resonates — at a frequency of 15 hertz, or 15 times a second.***

Pressure Waves



If you consider the standing waves as pressure waves rather than displacement waves, the nodes would be at the open end! This is because it is easy to change the pressure at a closed end, but impossible to change it at an open end. Pressure at an open end will always be room pressure, so standing pressure waves alternate between high and low pressure at closed ends.



Introduction: The fundamental frequency (or first harmonic) standing wave in a tube (like a hollow solid rocket cylindrical core) closed at one end is shown in the first pressure wave graphic labeled #1 above and to the left. The second harmonic is labeled #2 and is the same as shown in the graphic at the top of this page. The speed of a wave (like a sound wave) = [wavelength] x [frequency]. The Reusable

Solid Rocket Motor (RSRM) is actually five sections(spans) of solid rocket propellant with each section cylindrical spanning 18 feet. Question: Knowing the fundamental frequency's wavelength which causes resonance in the first 18 foot solid rocket empty hollow metal tube[wavelength= 4 x 18 feet length of each solid fuel span] find the resonant frequency of sound in this hollow empty solid rocket tube? Hint: The speed of sound is 1116 ft/s. Answer: ~ 15 Hz or cycles/second. Merely use the function….speed of sound = [wavelength of fundamental frequency which fits in the first hollow empty solid rocket tube] x [frequency of that first resonant frequency]. The unknown variable here is the frequency of the first resonant frequency.