DEPARTURE

by Carl Risteen

Fleas, ants & the incredible shrinking Mustang
Why small is better

At the dawn of mankind, curious cavemen probably wondered how those pesky creatures that crawled over them performed such prodigious athletic feats. Fleas, for example, jump hundreds of times their own height. Ants snatch tasty morsels weighing a hundred times more than they do. In 1638, Galileo solved the puzzle by explaining the Square/Cube Law. Tiny creatures demonstrate it vividly.

Take a muscle, for example. Scale it down. Its cross-sectional area will be reduced in proportion to the *square* of its scale, while its volume and weight will be reduced in proportion to the *cube* of its scale. A human leg muscle downsized by a linear scale factor of 1,000 would retain only one-millionth of its cross-section area and strength, but since its length is also reduced by a factor of 1,000, its mass will be slashed by a factor of a billion. Its strength-to-weight ratio will thus be increased by a staggering factor of 1,000. Tiny *homo sapiens* could compete handily in the flea Olympics. On the flipside: an elephant-size mouse wouldn't even be able to stand.

Rolls-Royce Merlin Engine shot by JAW at Pearce Air Force Base, Western Australia, 2005, http://en.wikipedia.org/wiki/File:Rolls-Royce_Merlin.jpg.

U.S. Air Force photo by Tech. Sgt. Ben Bloker, http://commons.wikimedia.org/wiki/File:P-51_Mustang_edit1.jpg.

Performance-wise, many model airplanes effortlessly humble even their hottest full-scale brethren. Do their designers know something that the experts don't? Or is a fundamental law of nature asserting itself? Let's do some number crunching using, as a "template," the P-51D Mustang, which is beloved by modelers for its voluptuous contours and outstanding aerodynamics. How would an all-metal replica, faithful to every detail, including its engine, perform?

The full-scale P-51D weighs about 7,125 pounds empty. Born of computer-aided manufacturing magic, a 1/6-scale, 72-inch exact replica would weigh 1/6 to the third power, or 1/216 times 7,125—about 33 pounds. Slip in some radio gear, telemetry, and gasoline for a gross weight of about 40 pounds (ouch!)—just a tad heavy 6-foot airplane.

With its flush-riveted aluminum skin, working Oleo struts, hydraulic brakes and all, it is dazzling. Pop some cowl Dzus fasteners and behold its gorgeous engine—a 14-inch-long supercharged Rolls-Royce Merlin V-12 replica. The full-scale Merlin weighs 1,645 pounds; our 1/6-scale miniature tips the scales at 7.62 pounds. Since the torque of an engine of any given design is proportional to its cylinder displacement, it will produce about the same torque per pound as the original.

Power is an entirely different matter. Power is proportional to torque multiplied by rpm, and with only 1/6 the stroke, our miniature Merlin would contentedly scream at 18,000rpm. With 1/216 of full-scale torque and six times higher rpm, power becomes 1/36 of 1600 horsepower: 44.4hp—*six times* the power-to-weight ratio of the original! With less than a pound per horse, this beast would climb like a rocket accompanied by the ethereal music of 12 supercharged cylinders.

We have created a little 350mph monster that's suitable for flying only at a desert airport by a maestro pilot—hopefully, with onboard video and GPS navigation. Pull up hard immediately after the frantic takeoff, and the wild pony gallops at about 250mph straight up, thoroughly dusting the original, in which each horsepower is saddled with six times as much weight.

The little Mustang's hyper-performance and wing loading banish it as an RC model for almost anyone except the seriously insane. Let's delve into a subject of far more modest performance: the friendly Cessna 172 Skyhawk. Shrink the Skyhawk to a 72-inch-span all-metal replica, and we get a sweet-handling 8-pound gleaming bird. The maximum speed of the full-scale Skyhawk is about 150mph. The model, drag-hampered by its lower Reynolds number, would fly a bit more slowly at about 125mph–a little fast, but manageable.

Its intricate, flat-four 1.67ci engine should produce 4.44hp at 16,000rpm—hyper-power in such a light airplane. This produces sustained vertical climb at 1/2 throttle and blows the full-scale original into the weeds. But we modelers are used to such antics, aren't we?

Closing the circle: enlarging the full-size Mustang by six times drops a 217-foot span, 800-ton juggernaut into our lap. Its 58,000hp, 178-ton 500rpm engine would thunder fruitlessly but fail to urge this dinosaur to loftier aviatory achievement than a 500-pound canary would attain. Smaller wins again. ✪