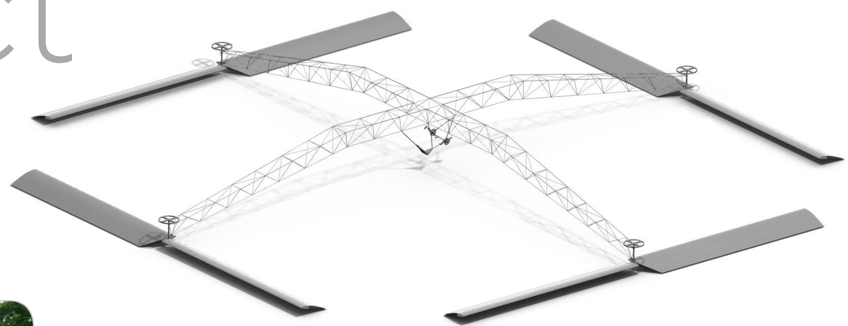
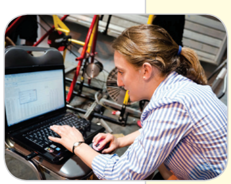
The Gamera Project

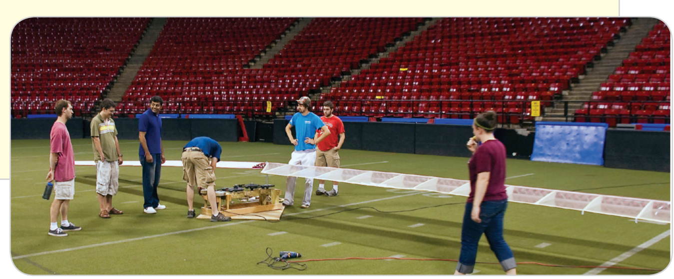
BUILDING A HUMAN-POWERED HELICOPTER AT THE CLARK SCHOOL OF ENGINEERING

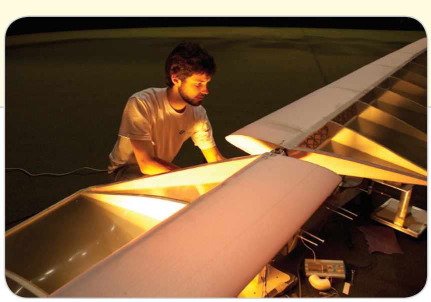


A team of 50 graduate and undergraduate students from the University of Maryland's A. James Clark School of Engineering has been working for two years to build and fly a human-powered helicopter. They have named their craft "Gamera," after a gigantic flying turtle in Japanese movies.



The team's goal? To succeed in one of aerospace engineering's most difficult challenges—and win the American Helicopter Society's famed Sikorsky Prize.





THE SIKORSKY PRIZE

The American Helicopter Society created the Sikorsky Prize, named in honor of helicopter pioneer Igor Sikorsky, in 1980. To win the $250,000 prize, a team must build a vehicle that:

- Obtains all of its power from a human pilot
- Achieves a 60-second hover while remaining within a 10-meter square and momentarily reaching a three-meter altitude.

Many attempts have been made to meet these requirements, but no team has ever fully succeeded. In fact, only two vehicles have risen off the ground, establishing record performances yet falling short of the prize.

SIGNIFICANT TECHNICAL CHALLENGES

Why is it so hard to fly a human-powered helicopter? Among the many technical challenges, the most significant are:

- Humans have very low power output for their weight, so the pilot must be extremely strong and fit, yet light
- Helicopters require much more power than airplanes, so the structure must be light, yet strong enough to withstand stress, and highly efficient aerodynamically and mechanically, especially in rotor design.

THE GAMERA DESIGN

Gamera has a rotor at each of the four ends of its X-shaped frame, with the pilot's module suspended at the middle. Each crossbar of the frame is 60 feet long, and each rotor is 42 feet in diameter. Yet, through the use of balsa, foam, mylar, carbon fiber and other lightweight materials, the entire vehicle weighs only 210 pounds, including the student pilot. All power comes from a combination of hand and foot pedaling, transmitted through chains, gears, and lightweight string to the rotors.

ROTORCRAFT EXPERTISE AT THE CLARK SCHOOL

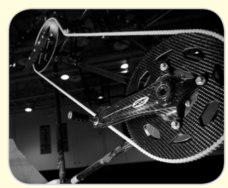
The Clark School's Department of Aerospace Engineering, chaired by Professor Mark Lewis, is one of the nation's top rotorcraft research institutions. Key to the department's strength is its Alfred Gessow Rotorcraft Center, directed by Professor Inderjit Chopra. Alumni have played leading roles in advancing rotorcraft design, including Ashish Bagai, Ph.D. '95, designer of the rotor for the 2011 Collier Prize-winning Sikorsky X2TD. Student teams have won the American Helicopter Society Design Competition 10 times in the last 13 years The Gamera-Sikorsky Prize team is advised by Senior Research Scientist V.T. Nagaraj, Professor Chopra and Clark School Dean Darryll Pines.

UNIQUE CHARACTERISTICS

GROUND EFFECT OPTIMIZATION: Ground effect is the increase in lift, for a fixed power, experienced by wings operating close to the ground. While ground effect is well known in conventional aircraft, few if any detailed studies have been conducted of "extreme ground effect"—in which the vehicle's wings or rotors are less than 10% of their length above the ground. Gamera operates initially within only 5% of its rotor length from the ground. The team spent more than a year in designing and building a ground effect test rig, with which they developed empirical models to optimize Gamera's rotor design and exploit extreme ground effect.

ULTRA-EFFICIENT COMPOSITE STRUCTURES: The main structural elements of the Gamera are carbon fiber composite trusses. Truss structures offer excellent structural efficiency, however they are typically very labor intensive to build and suffer from buckling failures when built to be as light as is required for a world record attempt. The team has developed two critical innovations to directly address these issues. First, a novel truss construction method has been developed that allows for highly optimized composite trusses to be built very quickly. Second, a truss-of-trusses design concept has been developed wherein the most critically loaded members in the airframe truss have been replaced with "baby trusses". These miniature trusses provide unmatched buckling resistance with significant weight savings—directly addressing the main failure mode of these ultra-efficient structures.

EXTENDED BLADE RADIUS: Gamera's rotor blades are 30% longer than those of the record-holding vehicle, resulting in an approximately 70% larger rotor area. All else held constant, the power required to hover reduces proportionally to the square root of the rotor area. While longer blades usually mean a heavier or overly flexible structure—which negates the advantage of reduced power requirements—the team's ground effect optimization, high stiffness composite truss spars, and careful material selection allow Gamera's rotors to be longer than the record holder's, while Gamera's total weight is nearly the same.



HAND AND FOOT PEDALING: Hand pedaling has not typically been incorporated in human-powered helicopter design because it increases mechanical complexity and is perceived to throw off the pilot's periodic motion. The Gamera team has determined that upwards of 10% of power can be gained by using the hands, and that by utilizing custom composite hand cranks, foot pedals, and transmission components, plus extensive pilot training, this additional power can be effectively captured with minimal weight penalty. The pilots have engaged in endurance, strength and co-ordination training for months, using a test rig built specifically to simulate the characteristics of the complete vehicle.

PHOTOS BY BRANDON BUSH, AB2 IMAGERY

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