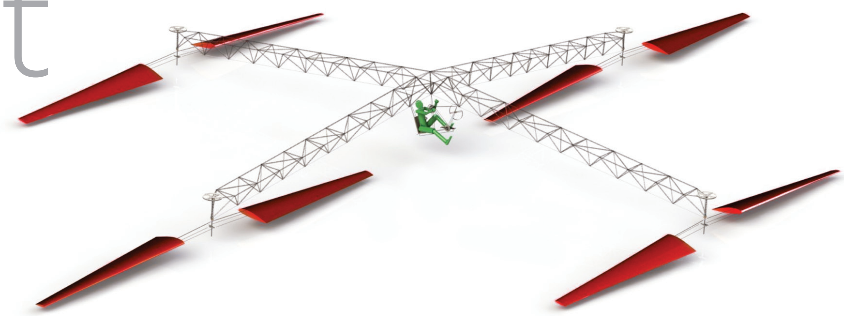
The Gamera Project

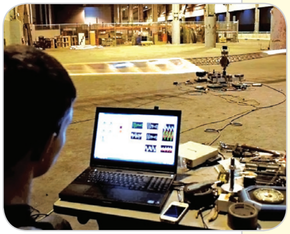
BUILDING A HUMAN-POWERED HELICOPTER AT THE CLARK SCHOOL OF ENGINEERING



UNIVERSITY OF MARYLAND

A PARTIAL PORTRAIT OF THE *GAMERA II* TEAM.

After setting flight duration world records in 2011 with *Gamera I*, our team of 40 graduate and undergraduate students from the University of Maryland's A. James Clark School of Engineering has returned to build and fly *Gamera II*. A lighter and more efficient refinement of the original design, *Gamera II* may take the team closer still to the American Helicopter Society's Sikorsky Prize.



TESTING *GAMERA II* ROTOR BLADES.

TESTING ARM AND LEG POWER OUTPUT.

GAMERA I SET WORLD FLIGHT DURATION RECORDS IN 2011.

JOINING *GAMERA II* TRUSS MEMBERS TOGETHER.

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.

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, 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 42.6 feet in diameter. Yet, through the use of balsa, foam, mylar, carbon fiber and other lightweight materials, the entire vehicle weighs only 71 pounds, excluding 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 Norman Wereley, 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 11 times in the last 14 years. The *Gamera* team is advised by Senior Research Scientist V.T. Nagaraj, Professor Chopra, Professor Gordon Leishman, and Clark School Dean Darryll Pines.

GAMERA DESIGN FEATURES

QUAD ROTOR CONFIGURATION AND GROUND EFFECT: The four-rotor *Gamera I* configuration, retained in *Gamera II*, increases vehicle stability while positioning the rotors as close to the ground as possible. This allows an increase in a phenomenon known as ground effect, a "free" increase in lift experienced by wings and rotor blades operating near the ground. The team spent more than a year designing and building a ground effect test rig and developed empirical models to optimize *Gamera's* rotor design to exploit ground effect.

ULTRA-EFFICIENT COMPOSITE STRUCTURES: Carbon fiber composite trusses are the main structural elements in *Gamera I* and *II*. The team developed a novel truss construction method that allows for highly optimized composite trusses to be built very quickly. The team also created a truss-of-trusses design wherein the most critically loaded members in the air-frame truss have been replaced with "micro trusses." These provide unmatched buckling resistance with significant weight savings.

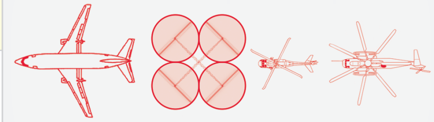
AERODYNAMIC AND STRUCTURAL OPTIMIZATION: During testing of *Gamera I* the team learned that the structural stiffness of the rotor blades (how much they flex upwards during flight) has a large impact on ground effect. For *Gamera II*, the team developed computer code to optimize the rotor blade aerodynamically and structurally, minimizing the power required from the pilot. Once built, all rotor blades were spun on a custom-built rotating test stand to measure actual flight performance.

MAXIMIZING HUMAN POWER OUTPUT: To extract every watt of power from the human engine during a 60-second flight, the *Gamera I* team explored using hand cranks in addition to the typical leg-crank bicycle mechanism. In testing *Gamera* pilots on a machine that measures both arm and leg power output, the team found an increase of up to 20% when using arms and legs versus legs alone, an advantage retained in *Gamera II*.

KEY CHANGES FROM *GAMERA I*: *Gamera II* leverages knowledge gained from *Gamera I*. While increasing the overall size of *Gamera II* might have improved efficiency, this was not an option because of indoor testing space limitations. However, while maintaining the *Gamera I* size, the team reduced *Gamera II* weight by 35 lbs, from 106 lbs to 71 lbs! This enormous reduction, combined with increased rotor blade aerodynamic efficiency, requires 44% less power from the pilot, crucial to achieving a 60-second flight duration.

GAMERA I vs. *GAMERA II*

	Gamera I	*Gamera II*
Configuration	Quad-Rotor	
Maximum dimension (ft)	105	
Rotor diameter (ft)	42.6 (x4)	
Disk area (ft^2)	5700	
Rotor RPM	18	20
Vehicle weight (lb)	106	71
Pilot weight (lb)	107-110	135-145
Power required to hover (2 ft altitude, 135 lb pilot)	770 W (1.03 hp)	460 W (0.62 hp)



BOEING 737 GAMERA UH-60A CH-53E

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