

# Keep It Simple

BETA Technologies' perfectly pragmatic approach

BY BETH E. STANTON



**FOR THE LAST FEW** years, BETA Technologies has been quietly developing an electric vertical takeoff and landing (eVTOL) vehicle at its headquarters at Burlington International Airport (KBTV) in Vermont.

According to founder Kyle Clark, EAA 1141386, it's not the technology that makes BETA innovative, but rather its simplicity.

"I have an appreciation for leaving things on the ground that don't need to be in the airplane," Kyle said. "We don't ask, 'What do I need to add [to] make this work?' but [rather], 'What do I actually need to subtract to make it work?'"

From both an aircraft design and business perspective, Kyle believes simplicity is pragmatic.

"This simplicity enables us to do things with a third of the people, a tenth of the money of our competition, and about a fifth of the time," he said. "When you've got a bunch of people who are not afraid to lie underneath the aircraft and fix stuff, they gain an appreciation for simplicity."

**PROTOTYPE AVA**

United Therapeutics (UT) is a pharmaceutical company founded by Dr. Martine Rothblatt that develops manmade organs for human transplant. Seeking a reliable, green mode of transport for this precious cargo, UT provided initial funding for BETA to develop an eVTOL.

"I gave Martine a high-five, and in 10 months, we took that sketch that I sent her to first flight," Kyle said.

BETA's prototype, Ava, is a heavily modified Lancair. RDD Enterprises in Redmond, Oregon, built the tail and wing. The BETA team put the rest together, including flight controllers, batteries,



motors, and inverters. Flight testing of Ava began in January 2018 to validate the propulsion and flight control systems. Ava featured eight 11-foot diameter tilt-rotors that articulated 90 degrees from pointing upward to pointing forward. However, the complex, heavy tilt-rotors violated Kyle's simplicity policy.

"I've got to learn these lessons like eight times, but you learn the simpler, the better," he said. "Give me a little more time and I'll make it even simpler."

CLEAN SHEET ALIA

BETA's clean sheet production model, ALIA, is a mathematical construct overlaid on the Arctic tern, the farthest migrating bird on earth. With his math background, Kyle likes to reduce to the minimum number of equations to solve for the variables.

"If you take the number of degrees of freedom that you're trying to achieve in an eVTOL aircraft and the minimum number of variables to solve for roll, pitch, yaw, and heave, the answer is some ultimate minima," he said. "The arrangement of ALIA's structure is a holistic optimization about minima and the physical limitations of technology today. It's not innovative; it's just brute force mathematical reasoning."

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Minimalist construction dictated a fixed-pitch, nontilting propeller design with four dedicated rotors for vertical flight and one pusher prop and 50-foot wing for efficient horizontal flight.



wing for efficient horizontal flight. The dedicated lift and pusher rotors allow for optimized pitch and size of the propellers for their specific task, which BETA found to be more optimal than tilting systems.

Forward flight efficiency required elegantly integrating systems that enable vertical flight. Tactics included mounting the quad-rotor configuration on two curved outriggers. To mitigate drag, the tail was split and the vertical stabilizers were offset from the outriggers. The large wing improved stability and efficiency at slower speeds.

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## MOTORS AND CONTROLS

The physics of electric motors and controls and the advantages and limitations of these technologies for aviation are still being explored. Kyle's expertise in power electronics and controls offers something unique in the industry.

"I think that's where BETA has a little inventive step," he said.

Since liquid-cooled motors aren't simple, the BETA team developed its own air-cooled electric motors.

"You just can't go out and buy an air-cooled motor that's 300 hp [for aviation]," Kyle said.

Each motor has dual power redundancy and feedback sensors and dual inverters, reducing the likelihood of a complete power loss. It is direct drive (no gearbox), which minimizes moving parts. BETA designed and manufactures its battery packs from commercially available lithium-ion cells.

This novel aircraft configuration and propulsion system have required multiple iterations of flight controls. ALIA's fly-by-wire control input system is a distant derivative of Kyle's Harvard thesis work rigging motorcycles with sensors to evaluate optimal pilot interface with an aircraft. The design philosophy behind ALIA's control inputs is similar to riding a motorcycle. X-Plane flight simulation helped develop and validate the control system, and X-Plane creator Austin Meyer is an integral part of the BETA team.

The control harmony connects the pilot with the airplane with a pressure-based stick, allowing the pilot to lean with pressure toward a direction as opposed to large stick movements.

"This control system is a paradigm shift because we no longer are limited by a mechanical flight control system, so we can make it simpler," Kyle said. "We can make it so that you're just kind of pushing the plane around the sky."

## FLIGHT TESTING

In June 2020, after 15 months of design and build, ALIA first hovered at Burlington airport. When this testing was complete, ALIA was airlifted by a Sikorsky S-61 helicopter from BETA headquarters in Vermont to Plattsburgh International Airport (KPBG) in New York for additional fixed-wing flight testing and has flown more than 200 flights.

The 6,000-pound maximum takeoff weight aircraft is larger than the handful of manned eVTOL aircraft currently flying, and Kyle is one of its primary test pilots.

"ALIA is a big, swoopy aircraft that flies like a glider," he said. "It's super, super docile. Although the batteries are consolidated near the center of rotational inertia, there are 3,000 pounds of batteries on your butt so it's super stable."

## PATH TO CERTIFICATION

Kyle believes that ALIA has a solid path toward certification due to its simplicity.

"We have a flight control system that operates without any state changes or need for the flight controller to be aware of the phase of flight, and only solid-state [inertial measurement unit] data is required for vertical flights," he said. "This is significantly simpler and more certifiable than relying on air data systems and complex data fusion for stable flight."

Developed for United Therapeutics, ALIA also may be adapted for commercial, industrial, and military use with its range of 250 nm and recharge time of 50 minutes. In cargo configuration, it can carry 200 cubic feet of cargo and has five-plus-one seats in passenger configuration.

In May 2020, BETA, along with Joby Aviation, advanced to the next stage of development in the U.S. Air Force's Agility Prime initiative to accelerate the development of domestic eVTOL aircraft. This collaborative "air race to certification" provides companies with resources as they work to certify their commercial vehicles.

Agility Prime partnership benefits include a more efficient contracting process, funding to develop aircraft for the Air Force, and partnerships with academia including Wichita State University.

"For a little company like ours to get access to that level of technology and people in the Air Force and academia is nearly unheard of," Kyle said.

## NEW TRAJECTORY

Kyle believes that pilots make better engineers because they intimately understand the practical aspects of flight firsthand. Everyone at BETA is either a pilot or becoming a pilot, and BETA covers flight training costs. Now 40 years old, Kyle had his first ride in an airplane as a teen with George Coy, EAA 278276, from Chapter 613 in Swanton, Vermont.

That flight changed the trajectory of Kyle's life.

"George took somebody who was limited to thinking about go-karts and motorcycles, and all of a sudden, I get to think about fun new things like airplanes," he said. "You don't know what you're doing to somebody's psyche or passion when they're 16 years old and show up to get an airplane ride. Twenty years later, they've founded an aerospace business because of that flight." *EAA*

**Beth E. Stanton**, EAA 1076326, majored in English because it involved the least amount of math. She finds it hilarious that now she is a pilot and writes stories about airplanes and technical stuff. She can be reached at [bethestanton@gmail.com](mailto:bethestanton@gmail.com).

