That Extra Little Lift

Willard Custer's Channel Wing looked like a mistake. Turns out his critics were the ones who were wrong

Air & Space Magazine
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Bob Englar revived the Custer Channel Wing for wind tunnel experiments directing airflow. (Tim Wright)

If Bob Englar is correct, he may be well positioned to breathe new life into an airplane design long abandoned as dead. "Good aero ideas recycle," says the engineer from his laboratory at the Georgia Institute of Technology Research Institute in Atlanta.

Englar is applying decades of his own research to an aeronautical oddity that hasn't always been recognized as a good idea: the Custer Channel Wing. The channel wing, which takes its name from the semicircular trough each wing forms below the engine, is a 1940s design that didn't get past a prototype. But the channels, which seem out of place, if not freakish, in an airplane's wing, generate high levels of lift, and that opens up all sorts of design possibilities.

Englar is combining the concept with other techniques to generate the extreme lift needed to raise a C-130-size transport off a 60-foot runway, or keep a futuristic personal air vehicle hovering above a suburban driveway. NASA funded his studies from a small program investigating novel ways to make aircraft more efficient.

Building deep channels into the wings of aircraft, dropping like twin smiles under the propellers, was the idea of Maryland inventor Willard Custer. Custer's insight was that the amount of lift generated can depend on the speed of air over the wing, not, as had been thought, solely the speed of the wing moving through the air.

"The beauty of the Custer Channel Wing is that we can generate lift at zero forward speed by using the engines to provide airflow," says Dennis Bushnell of NASA's Langley Research Center in Virginia, who is the primary force behind the research. "What you need is relative motion."

In addition, the shape of the channel deflects propeller thrust downward, as much as 26 degrees. With this extra lift, an aircraft with a channel wing is quickly airborne once it begins rolling and is able to maintain control at very slow speeds. Custer envisioned airplanes that could take off or land almost vertically, making him an early prophet of short-takeoff-and-landing aircraft.

The trouble with being a prophet is that people don't always listen. In 1943, Custer's first aircraft, the CCW-1, demonstrated STOL ability to the U.S. Army with a flight in Maryland. Despite interest by the media and some aircraft manufacturers, the CCW-1 was ultimately deemed impractical because it couldn't maintain control if it were to lose one engine and because it required an extreme nose-up attitude to land safely.

In 1959, Custer tested CCW-5 for the Marine Corps, and despite the aircraft's unique aerodynamic performances, it too was rebuffed. Part of the reason for these failures was that Custer was unable to adequately explain to the military the advantages his channel wing seemed to bestow.

But science may have caught up with the inventor. In 1995, Bushnell became the new research chief of the Langley center. Among the bundles of correspondence he inherited from his predecessor was a letter setting forth "technical quibbles" related to the testing of the Custer Channel Wing done in Langley's 30- by 60- foot wind tunnel in 1950s. Inspired by the letter, Bushnell "went to school" on the design, and grew impressed by the potential.

Years later, while driving home from his office, Bushnell was mulling over the growing demand for ways to get aircraft in tight spaces off the ground. The accepted methods, rotary wing and direct thrust, weren't enough. Then it hit him. If combined with "circulation control," a method of generating lift by using jets of air to improve the aerodynamic efficiency of wings the forgotten design could provide another option. "The channel wing couldn't do it, circulation control couldn't do it, but maybe they'd be able to do it together," Bushnell says.

Bushnell directed some money from his discretionary funds, reserved for high-risk, high-payoff projects, and "got back into it" with a program that lasted from 1999 to 2004. The grant money funded Englar's laboratory work at Georgia Tech. Since then, Bushnell and Englar have co-patented their marriage of circulation control and the channel wing, and Englar continues his work under the auspices of Georgia Tech.

Circulation control is based on the Coanda Effect, named for Romanian aviation researcher Henri Coanda, who in 1910 found that hot gas exiting a jet followed the contour of plates he had installed to deflect the exhaust. Coanda had inadvertently discovered the tendency of a pressurized gas to adhere to an adjacent curved surface. That tendency can be used to increase the lift created by an airplane wing if the exhaust is deflected downward by the wing's trailing edge.

Circulation control technology works by blowing compressed air—rather than Coanda's exhaust—over curved trailing or leading edges to achieve very high lift, where and when needed. Researchers believe that circulation control can one day make moving surfaces on aircraft obsolete. By replacing flaps and other mechanical lift maximizers with pneumatic air hoses, engineers can make airplanes lighter, quieter, and easier to maintain.

To find the ideal way to combine circulation control with Custer's design, Englar used the modern methods of computational fluid dynamics, including data from wind tunnel tests of sensor-studded models. One early goal was to prove that a channel wing with enhanced circulation control could turn a generic twin-engine transport into a super-STOL machine.

The wind tunnel model has an electronic motor that drives either two or three propellers. These can be positioned at various locations to test which placement generates the most lift. In a typical test from 2002, for example, various levels of prop thrust and blowing pressure were tested while the model was kept at a constant angle of attack. In other tests, the angle was changed while the other conditions remained constant.

The research confirmed the potential aerodynamic payoffs of the design in ways that Custer simply could not have. Says Bushnell, "You couldn't have computed it back then."

Custer understood that the airflow to generate lift could come either from the airplane's forward motion or from the engine. But the former auto mechanic and salesman didn't know—and given the technology of the time, couldn't have known, engineers now say—that his channel wing caused the air flowing over it to separate and become turbulent. At low speeds and smaller angles of attack, the flow of air detaches from the surface it is traveling across, leading to a loss of the pressure difference that causes lift. Custer could not determine when this would happen, or how to design around it. Also, he didn't have the digital design tools that could have shown him how to place the external struts of his aircraft without interfering with its aerodynamics.

Englar's task is to find a way to simultaneously use the channel wing's ability to generate a lot of lift while weeding out the problems associated with the design. To land, Custer's airplanes had to be flown at high angles of attack, a dangerous attitude because the pilot can't see over the nose of an airplane. Also, at a high angle of attack, the failure of one of the two engines could lead to dangerous rolls or stalls, with no way to compensate.

"We were trying to avoid all those problems" by using circulation control, Englar says. The blowing air increases the already considerable lift, eliminating the need to land at those high angles of attack. The pneumatic controls enable pilots to quickly compensate for engine failure or other dangerous asymmetries.

Like Custer, Englar fervently believes in his work despite the disappointment that his circulation control systems have not been adapted for production aircraft or for other vehicles beyond prototypes.

Englar shares some of the same frustration Custer felt when he was trying to convince the world to do something new. Use the word “curse” in relation to this grim similarity and Englar won’t object. “It takes a while for people to realize the potential,” he says. “And when they believe you, they say, ‘Well then why is it not being used in any production airplanes?’ ”

Circulation control, however, continues to attract attention. Engineers in Britain are designing an unmanned aircraft that would be controlled only by directed airflow and thrust vectoring, and the Navy is investigating the use of circulation control on Navy submarines, which could use water jets instead of dive planes and rudders. Englar’s extensive wind tunnel tests have also proven that circulation control can reduce drag on tractor-trailer rigs, improve traction on race cars, and help control high-speed race boats.

Meanwhile, Custer’s CCW-1 awaits restoration at the Smithsonian Institution’s National Air and Space Museum, and the CCW-5 sits forlornly on the tarmac at the Mid-Atlantic Aviation Museum in Reading, Pennsylvania. They have remained mere curiosities, but thanks to Englar, Bushnell, and renewed interest in short-takeoff-and-landing designs, the channel wing design may one day be transformed from a museum piece to a real, live flying airplane.