Spin-Resistant Airframe (SRA)

ICON Aircraft

What is a Spin?

A spin is a dangerous combination of a stall and yaw. Spins occur when a stalled aircraft experiences too great a yaw rate, which can be the result of an incorrect rudder input or a pre-existing yawing moment as would occur if an airplane is stalled while performing an uncoordinated turn. During the ensuing spin, an aircraft rapidly loses altitude as it rotates about its spin axis, driven by an asymmetric stall condition between the two wings. The pilot often loses the ability to control the aircraft because of disorientation or loss of control authority, making spins dangerous and harrowing. During a spin, the aircraft experiences low airspeed and a high angle of attack. It is worth noting that this is different from a spiral dive in which an aircraft experiences high airspeed and a low angle of attack, and during which more control authority is preserved. Some spins are recoverable by experienced pilots, but this requires high situational awareness, proper training, and often more than 1,000 feet of altitude. Other spins are unrecoverable, even by the most experienced pilot.

Stalls/spins are a significant source of serious accidents in General Aviation accounting for 41% of fatal accidents that occurred because of “pilot-related factors,” according to the Aircraft Owners and Pilots Association (AOPA) Air Safety Institute’s 2010 Nall Report. Pilot-related factors are responsible for 70% of all accidents, with the remainder being mechanical, unknown, or undetermined in cause. Stall/spin accidents are particularly dangerous because they usually occur at low altitude and low airspeeds, such as in the traffic pattern during maneuvering when the pilot’s attention is diverted from maintaining sufficient airspeed by other tasks. In fact, 80% of stall/spin accidents occur at 1,000 feet AGL (above ground level) or below. Surprisingly, the highest portion of stall/spin accidents happened to private and commercial pilots and not to students, likely because of students’ close supervision and the fact that more experienced pilots may have grown complacent in their skills.

History of Spin-Resistance

The earliest attempts to create a spin-resistant aircraft date back to the early days of flight, well before World War II. The ERCO Ercoupe was developed in an attempt to be safer than comparable aircraft by being less susceptible to spins. Through the simple measures of limiting control-surface deflection and center-of-gravity range, the aircraft was certified as “characteristically incapable of spinning” by the Civil Aeronautics Administration (predecessor to today’s FAA). However, to achieve this, the Ercoupe did not have rudder pedals, which prevented the pilot from actively controlling aircraft yaw. An aircraft’s tendency to spin is extremely sensitive to the location of its center of gravity (CG), which is the result of how much weight it is carrying and where the weight is located. The farther back the CG, the less effective the horizontal tail is at providing longitudinal stability and the more likely the plane is to spin.

In the 1970s and 1980s, researchers at NASA’s Langley Research Center studied spin resistance in depth, with a focus on aerodynamic characteristics and techniques to make aircraft more resistant to spins without highly unconventional approaches like the Ercoupe’s elimination of rudder pedals. They performed extensive modifications to four existing General Aviation aircraft and flew thousands of test flights to determine how changes to the airframe would affect spin characteristics. They discovered that small changes could dramatically affect performance during spins. They were able to create an aircraft that “gives plenty of warning, lots of buffet, very little roll-off laterally – a long period of telling the pilot ‘Hey, you’re doing something wrong,’” according to NASA experimenters. This work eventually evolved into techniques to make aircraft that are resistant to entering spins.

One of the key findings of the NASA studies was that a critical component of spin resistance is controlling the way the wing stalls. They concluded that having the stall initiate near the root of the wing (where it attaches to the fuselage) while the outboard panels of the wing continue to fly is ideal because it prevents the stall from ever fully developing or “breaking” because the outboard panels are still generating lift. Without a stall, a spin cannot initiate. This progressive stall is achieved with a wing cuff, or a discontinuity on the leading edge of the wing that separates the wing into two distinct parts. The outboard segments of cuffed wings have a different airfoil with a drooped leading edge, compared to the main wing, which causes that portion of the wing to stall later than the inboard part of the wing as angle of attack increases. Because the ailerons are located on the outboard panel which is still flying, roll control is preserved even after the inboard panel of the wing has stalled. The FAA recognized the significance of the introduced standards for spin-resistance for Part 23-certified aircraft in 1991. The standards carefully define what the behavior of an aircraft under specific tests should be in order for it to be considered spin-resistant, with five maneuvers completed across the entire center-of-gravity range of the aircraft, and across the full spectrum of configurations, including landing-gear position, power setting, and flap setting. Depending on the complexity of the aircraft, it must past hundreds of test cases to be considered spin-resistant by the FAA.

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Since the establishment of the Part 23 spin-resistance standards in 1991, a few aircraft companies attempted to produce aircraft that fully meet those standards; however, no conventional production aircraft without canards ever truly succeeded, either for technical reasons or because the aircraft was not successfully brought to market. It is worth noting, however, that both the Cirrus SR 20/22 models and Cessna Corvalis aircraft employed a cuffed wing design to

Top: One of NASA's spin-test aircraft, a Cessna 172 equipped with wing cuffs (in red on the leading edge of the outboard parts of the wing), in flight. Credit: NASA

Bottom Left: The ERCO Ercoupe is one of the earliest aircraft with spin-resistant characteristics, which were achieved by limiting the deflection of control surfaces (including the elimination of rudder pedals from the cockpit), as well as the location of its center of gravity.Credit: Smithsonian National Air and Space Museum

Above: James Patton Jr. (center) stands with James Bowman Jr. (left) and Sanger Burk (right) in front of a low-wing spin-research aircraft. A radio-controlled model and a spin-tunnel model of the same configuration are in the foreground. Credit: NASA.

advance stall and spin-resistance characteristics in General Aviation aircraft, although they did not meet the full Part 23 spin-resistance standards. The Jetcruzer, a canard airplane, is another aircraft that advanced spin resistance and was even certified as spin-resistant, although it never entered production. While the idea of controlling the stall is quite simple, it has proven extraordinarily challenging to get the exact airflow patterns required for a plane to pass the Part 23 standard completely.

Behind the Scenes of ICON's Spin-Resistance Program

ICON's engineers and management team were aware of the NASA work on spin resistance, as well as the sobering statistics around stall/spin accidents. Delivering an aircraft that provides both excellent control throughout the stall and resistance to entering a spin dramatically raises the bar for light aircraft safety by decreasing the likelihood of inadvertent stall/spin loss of control by the pilot. This is especially important at low altitude where the majority of sport flying occurs. To say that this was risky is a tremendous understatement. Not only had spin resistance (to the Part 23 standards) never been accomplished by legacy aircraft manufacturers on a conventional production aircraft, but ICON was a fledgling company that had not yet delivered any production aircraft. However, ICON management felt that the benefits of a spin-resistant aircraft were too great not to include, especially when considering that the A5 is intended to be used at low altitudes and low speeds, where a spin entry is especially unforgiving. They also trusted the competence of ICON's extremely talented engineering team to systematically approach the problem and deliver a production-ready solution.

The design process began with an all-new cuffed wing. All told, ICON's wing uses several different proprietary airfoils across its span. The resulting wing provides a stall that is more progressive than that of an aircraft not designed for spin resistance.

Collaborating with aerodynamicist John Roncz, ICON engineers designed a new wing and then built a physical subscale model, which they tested in a wind tunnel. The NASA studies had demonstrated an association between certain airflow patterns on the wing and spin resistance, so when engineers observed similar flow patterns on the ICON model in the wind tunnel, they were very encouraged.

The wing design was rapidly fabricated in full scale in ICON's shop and installed on the prototype aircraft. Initial validation flight tests were promising, and ICON began to prepare the aircraft for its full range of spin-resistance tests. Spin testing is one of the more dangerous types of testing and requires a pilot with considerable specialized experience and skills. Because of the possibility of entering an unrecoverable spin, the pilot must wear a parachute, and the aircraft itself is also fitted with a parachute to stop an unrecoverable spin, should one occur. Because ICON's usual testing occurs above Tehachapi, whose altitude is 4,000 feet, a special test site was selected with lower elevation to provide more space for the pilot to recover from a spin. Most tests were completed with a starting altitude of at least 8,000 feet above ground level.

ICON engineers designed, built, and installed a boom to mount the spin parachute on the back of the A5 prototype and also retained globally recognized spin-test pilot Len Fox to put the aircraft through its spin-resistance testing regimen. Fox has nearly 40 years of experience and has flown almost 200 aircraft types. He was a United States Naval Aviator for 20 years, flying 17 military types including F-15, F-16, and FA-18. He has completed spin testing for 25 different types, which made him ideally suited for spin-resistance testing of the A5.

The FAA Part 23 spin-resistance standards require tests across the range of configurations and center-of-gravity (CG) locations that the aircraft will fly with, and the tests become progressively more difficult as the CG moves aft. For each configuration, the aircraft must successfully complete five different maneuvers ranging from a relatively mild wings level or coordinated turning stall to an aggressive abused input (uncoordinated with full deflection of elevator, full rudder, and full aileron input opposite to rudder), which must be held for seven seconds without a spin initiating. With all configurations and permutations, the A5 was subjected to over 360 test cases.

During the testing process, the A5 was continuously optimized. As the tests became more difficult, it became necessary to make a variety of aerodynamic changes, which were iteratively flight tested. After several weeks of iterations and testing, the A5 finally passed its last and most difficult test, the 7-second “abused controls” or “pro spin” test (control inputs of rudder and aileron that would promote a spin) at aft CG.
It was a momentous day at ICON, representing the successful completion of the riskiest and most technically ambitious part of the entire development program. When ICON Aircraft VP of Engineering Matthew Gionta and COO Steen Strand called the entire company together to announce the news, a spontaneous celebration erupted in a moment of elation, a reflection of the extraordinary challenges and risks the team had taken on to achieve such an ambitious goal. “I’m incredibly proud of our engineering and fabrication team,” said ICON Aircraft CEO Kirk Hawkins. “While creating a full-envelope spin-resistant airplane was extraordinarily difficult and took longer than we expected, it was absolutely the right thing to do for safety and is a game-changing innovation. Delivering an aircraft that provides excellent control throughout the stall while being resistant to entering a spin dramatically raises the bar for light aircraft safety by decreasing the likelihood of inadvertent stall/spin loss of control by the pilot. This is especially important at low altitude where the majority of sport flying will occur. This is just another example of ICON going above and beyond the call of duty to deliver not only the world’s coolest sport plane, but also one of the world’s safest.”

ICON Videos

A5 Spin-Resistance Development
https://www.youtube.com/watch?v=bsQcfzNWJWc

ICON Spin-Resistance Reactions
http://www.aopa.org/asf/ntsb/stall_spin.html

Resources

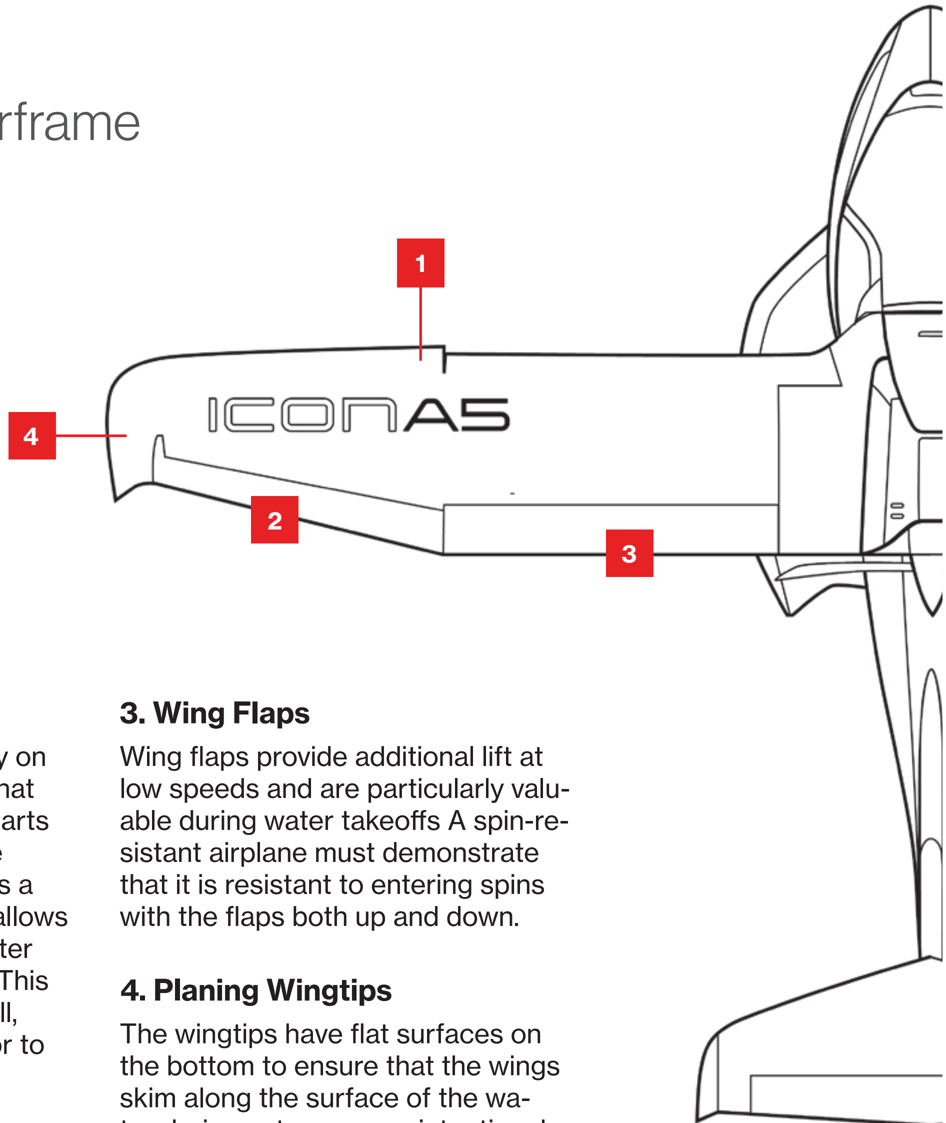
AIR & SPACE Smithsonian
http://www.airspacemag.com/flight-today/cit-bourque.html?c=y&page=5

AOPA
http://www.aopa.org/asf/ntsb/stall_spin.html

NASA
http://www.nasa.gov/centers/langley/news/researchernews/rn_halloffame.html

ICON A5

Spin-Resistant Airframe



1. Wing Cuff

The wing cuff is a discontinuity on the leading edge of the wing that separates it into two distinct parts that have different airfoils. The outboard panel of the wing has a drooped leading edge, which allows it to continue generating lift after the inboard panel has stalled. This gives the A5 a progressive stall, which is a signicant contributor to spin resistance.

2. Ailerons

Ailerons are located on the outboard panel of the wing, which continues to fly even while the rest of the wing is stalled. This ensures that the pilot maintains roll control during a stall. Control authority was not limited in any axis to achieve spin resistance.

3. Wing Flaps

Wing flaps provide additional lift at low speeds and are particularly valuable during water takeoffs A spin-resistant airplane must demonstrate that it is resistant to entering spins with the flaps both up and down.

4. Planing Wingtips

The wingtips have flat surfaces on the bottom to ensure that the wings skim along the surface of the water during extreme or unintentional water maneuvering. They also provide hydrostatic stability when the aircraft is not in forward motion.

iconaircraft.com

2141 ICON Way
Vacaville, CA 95688

825 Severn Ave
Tampa, FL 33606

learnmore@iconaircraft.com
707.564.4000