Flightlab's Upset Recovery and Basic Aerobatics Program
Understanding the Aerodynamics of Maneuvering Flight

Summary

Flightlab's Upset Recovery and Basic Aerobatics Program provides intensive ground school and flight training in aerobatics and unusual-attitude/upset recovery for flight crews, flight instructors, and individual pilots of all experience levels. Our ground school features a comprehensive but nonmathematical review of aerodynamics—taught using digital wind tunnels and flight-dynamics software designed for analysis and comparison of aircraft response. In the air, we use actual engineering flight-test procedures to demonstrate upset aerodynamics, and training disciplines from competition aerobatics to teach attitude perception and recovery skills. Because flying different aircraft reinforces the ability to adapt recovery techniques learned in one cockpit to another, students compare the unusual-attitude characteristics of two aerobatic aircraft: an Air Wolf M-26 and a Zlin 242L.

Course duration is typically three days, but can be extended over a longer period. Total flight time is approximately four hours. Students receive a detailed training record for insurance and employment purposes, and extensive ground school notes. The course can also include a complex/high-performance checkout and Biennial Flight Review.

Pilots will gain:

- A significantly increased understanding of maneuvering aerodynamics.
- The ability to recognize and track aircraft motion paths and energy transitions during unusual attitudes.
- Inverted-flight experience under real g forces in a true dynamic environment.
- Control skills necessary to recover from unusual attitudes and energy states.
- Strategies for dealing with flight characteristics following control failures.
- Enhanced confidence and safety.

Ground School Topics

Pilots can choose among a variety of ground school sessions and subjects, including:

The Aerodynamics of Lift and Control:

Angle of attack and pressure patterns.
Boundary layer and separation.
Wing planform: Stall pattern and vortex effects.

Aircraft Dynamics and Upset Recovery:

Aircraft axes and derivatives.
The nature of stability and control.
The aircraft's natural modes.
Lateral/directional coupling.
Roll dynamics.
Recovery procedures.
Flying qualities: Differences between prop trainers and passenger jets.
Limitations on the use of rudders for large aircraft.
FAR certification requirements.
Simulator alpha/beta envelopes.

Spin Dynamics:

Departure, incipient phase, steady state, recovery.
Inertial and aerodynamic moments.
Aircraft mass distribution and recovery techniques.

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Upset Causes:

NASA vortex studies and encounter dynamics.

Basic Aerobatic Maneuvers and Techniques

Introduction

Welcome to the program. The following pages describe our training goals, and provide the introduction to the Maneuvers and Flight Notes you and your instructor will use during your flights and briefings.

We developed our training program over many hours of flying with test pilots from NASA's Langley Research Center, the Empire Test Pilot School (U.K.), and the National Test Pilot School (U.S.A.), with fighter pilots and military instructors, and with International Aerobatic Club competition pilots, including members of the United States Aerobatic Team. Each discipline brought its own perspective. At NASA, we flew with experts on aircraft wake vortices to explore training methods based on recent studies of vortex encounters. We talked to experts about the limitations in using simulators for upset training. We worked on ways to help pilots safely translate the skills learned in straight-wing aerobatic aircraft to swept-wing transports.

Our program is unique in combining the aerobatic competitor's and military pilot's emphasis on attitude awareness and maneuvering airmanship with the test pilot's knowledge of aircraft dynamics. And we've introduced to aviation training the use of flight-test methods as cockpit teaching tools.

To gain a sense of where you're headed, take a look at the Maneuvers and Flight Notes before we fly. Review as much of our text material as you can, but don't be concerned if you can't get through everything, or intimidated when things get technical. We'll cover the essentials in our aerodynamics presentations. Aerobatics and unusual-attitude training both require and provide the ideal time for aerodynamics training. Our program is designed to help you understand the aerodynamics of upset and wide-envelope maneuvering, and to lay the groundwork for future study in general. You'll be on the right track if you ask lots of questions and then follow up on the reading when the course is over.

Our job is to answer those questions and to make the flying informative, appropriately challenging, and—this is important—enjoyable. Elevated anxiety shuts down the learning process.

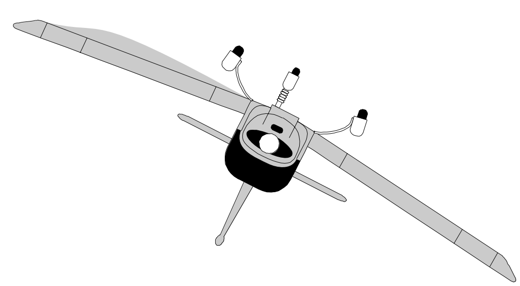
Your job breaks down into three closely linked tasks: ***We want you to increase your understanding of maneuvering and departure aerodynamics, become familiar with the stimulus environment generated by unusual attitudes, and develop the control skills necessary for recovery.***

During your flights, the instructor will read out the checklist for each maneuver, then guide you through the steps, demonstrating first when necessary. We follow a consistent maneuver format, with each pilot receiving the same core training necessary for crew coordination and for developing a CRM approach to unusual attitudes. Beyond these basics, we'll adapt to your background and skills. The flights will be an opportunity to practice assertive stick-and-rudder flying—the kind not possible in most daily operations but fundamental in emergencies.

You'll begin the first flight by observing the classical *free response* modes around the aircraft's axes, and the aerodynamics of high angle of attack (high α, pronounced "alpha,") and high sideslip (or high β, pronounced "beta"). The flight also includes the first set of 360-degree rolls. During this and later flights you'll learn to recognize and recover from an increasingly challenging range of unusual attitudes, both with full controls and during simulated control failures. You will also begin to fly basic, controlled aerobatic maneuvers.

Each maneuver set in the program builds on the previous ones, so we want to try to fly them in order, weather (and stomach) permitting. But we'll adjust the sequence to your rate of physiological adaptation. If you have doubts about motion sickness, a cautious start and a night's sleep between the first and second flights can be surprisingly helpful.

If your motion tolerance is low, we'll emphasize aerodynamics in your flight program and go a little lighter on unusual attitudes.



Because you might be reading this while still deciding whether to take an unusual-attitude program, the following contains some points worth considering, as well as a general description of what to expect in our program.

Our Training Aircraft

You'll have up to two flights each in an Air Wolf M-26 and a Zlin 242L. Both are Lycoming-powered, with FAA Airworthiness Certificates in the Utility-Aerobatic Category, and built to satisfy military training requirements. Because the aircraft have tricycle gear and don't require tailwheel experience, students can do all the flying. The flight instrumentation allows unusual-attitude practice in simulated IMC, and the low wings allow tufting for airflow visualization. The aircraft are responsive, fully aerobatic, and capable of outside maneuvers (including outside loops), plus tail slides and sustained inverted flight.

We chose these aircraft partly because they demonstrate aerodynamic coupling in yaw and roll.[1] This characteristic is key to understanding the dynamics of unusual attitudes. Yaw/roll couple is typical of the general and especially the swept-wing fleet, but largely absent in aerobatic aircraft certified under the lateral stability exemption of FAR Part 23.177(c). Our aircraft also have flaps, which allow us to analyze changes in span loading and downwash. While our aircraft can't achieve the rapid roll and pitch rates possible in such aircraft as the Extra or Pitts, those rates are in fact undesirable. Moderate rates, more pronounced coupling, and higher stability margins and control forces are far better for unusual-attitude training and aerodynamics demonstration. Plus our cockpit environments are much more comfortable!

In addition to being more fun, flying different aircraft as part of your unusual-attitude training allows you to make comparisons that illustrate the variables behind aerodynamic behavior. It reinforces your ability to adapt to those variables and transfer recovery techniques learned in one cockpit to another. ***Confidence in the ability to adapt what you've learned is crucial to reaction time, and thus essential in a future upset emergency in your own aircraft.***

What's an Unusual Attitude?

Some pilots prefer the term "unusual attitude," others prefer "upset." We use them interchangeably. Here's the definition of aircraft "upset" from the *Airplane Upset Recovery Training Aid* (or AURTA, first released in 1998 and developed jointly by government agencies and an industry-wide group of airlines, aircraft manufacturers, and training providers). The AURTA (page 1.1) definition takes the aircraft as the starting point:

"Airplane upset is defined as an airplane in flight unintentionally exceeding the parameters normally expected in line operations or training.

While specific values may vary among airplane models, the following unintentional conditions generally describe an airplane upset:

- *Pitch attitude greater than 25 deg, nose up.*
- *Pitch attitude greater than 10 deg, nose down.*
- *Bank angle greater than 45 deg.*
- *Within the above parameters, but flying at airspeeds inappropriate for the conditions."*

The attitudes given above do set appropriate limits for most aircraft and operations, but they're very narrow in terms of the possible attitudes a pilot can experience. This reflects an observation made by many professional pilots: after the maneuvering lessons of primary training and perhaps time spent as a flight instructor, as hours and aircraft size increase, maneuvering opportunities tend to diminish and proficiency tends to atrophy. There can be an inverse or at least no positive relationship between flight hours and wide-envelope maneuvering ability. In the absence of in-flight training, aggressive maneuvering ultimately becomes a simulator exercise, with the limitations that simulation implies.

While we take the AURTA definition as a start, we expand it in our program to underscore the aerodynamics behind upsets. Here's an addition:

In an unusual- attitude situation there's also typically an "unusual" relationship going on (or

[1] In a coupled response, rotation around one axis causes rotation around another. Aircraft can have both aerodynamic and inertial couples.

about to start going on) around the aircraft's axes. It's unusual in the sense that the opposing moments around those axes—which in a trimmed airplane normally find balance and keep things roughly straight and level—start to shift in ways that produce divergent results.

The above gets into technicalities and will take some explaining! Don't worry; you'll get a handle on it during our flights and ground-school briefings, as the examples unfold.

We should also expand the AURTA definition in terms of situational awareness: *It's fair to call an unusual attitude anything that a pilot can't immediately recognize: that is, whenever there's a loss of correspondence between what the aircraft is doing and what the pilot perceives.* The disconnection can be essentially cognitive, where a pilot just can't figure out what he's seeing, or take the form of spatial disorientation provoked by the vestibular system, where he can't *believe* what he's seeing because of conflicting motion cues. The resulting loss of "sense security" can produce panic in even the most experienced pilot.

Choosing an Instructor

There are no FAA regulations specifically governing curriculum or special instructor qualifications for unusual-attitude training. While there are guidelines, like the *Airplane Upset Recovery Training Aid*,[2] it's up to the training provider to define the tasks and training style in a manner that leads to an effective program. For safety, all instructors should be *current* in advanced aerobatics well beyond the maneuvering needs of the program itself.

Instructors in aerobatic or unusual-attitude programs typically have backgrounds in civilian competition aerobatics or are former fighter pilots. While both backgrounds can produce highly qualified instructors, remember that military and civilian aerobatic training and flying techniques are not always the same. The same laws of nature and aerodynamics apply, but, because of differences in mission and machinery, those laws are frequently invoked in different ways.

As a result, civilian aerobatic and military pilots can develop different skill sets and ways of thinking about aircraft maneuvering. Not surprisingly, each tends to *teach as they've learned*, sometimes inappropriately. Early in the development of airline unusual-attitude programs, for example, former fighter pilots—whose generation of swept-wing fighters relied on the rudder pedals for lateral control at high α—encouraged far more aggressive use of the rudder than airliner manufacturers thought safe. This led to what many regarded as "negative training," a situation in which the pilot was less safe after the training than before. Yet an aerobatic instructor with a competition background would have been just as likely to make the same training mistake regarding rudder use, although for different reasons. Don't let yourself be too impressed by an instructor's credentials—even the most veteran instructor has a point of view limited by his or her own training and maneuvering experience.

One way to counteract this is by introducing a wider, more integrated point of view—the test pilot's. By virtue of the job, test pilots have the techniques necessary to evaluate aircraft characteristics, and the experience to know how those characteristics can vary. Our ground school contains elements of the actual training a test pilot receives. Our flight program begins with basic "flying qualities" test procedures that reveal the fundamental mechanics of aircraft behavior—and builds from there.

Wide-Envelope Aerodynamics

Whether you receive instruction in flight or in a simulator, in any form of unusual-attitude training you're going to find yourself placed in upset attitudes (often while your eyes are first closed) from which you'll be expected to recover using the proper control movements. We'll do the same, but build to it in steps. First, we'll use our flight-test tools to illustrate the aerodynamics learned in ground school. *We'll examine the nature of stability and the conditions that lead to departure* by flying the aircraft carefully through the boundaries of the normal attitude envelope (but *well within* speed, recovery, and g-limits) while analyzing its behavior in both controlled and "free" response. This means flying at combinations of high angle of attack and high sideslip (α and β) where coupled behaviors can

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[2] The *Training Aid* was itself a product of debate. See "Airbus Industrie Presentation at 10th Performance and Operations Conference." www.ntsb.gov/events/2001/AA587/exhibits/240005.pdf

predominate, and at attitudes where the aircraft's inherently convergent, back-to-normal stability characteristics start producing undamped, divergent responses. It also means flying at energy states where you'll first need to reestablish dynamic pressure and reattach airflow before control can return. We'll emphasize that the underlying aerodynamic conditions—and not merely the aircraft's attitude—determine the inputs necessary to regain control.

As a result of this demonstration approach you'll gain a better understanding of aircraft dynamics, and of the circumstances that actually produce unusual attitudes, than you would if we began our work by placing you in already-developed attitudes and then just coached you through textbook recoveries. To start, we'll tuft the wing to see how airflow, and thus control effectiveness, changes as the aircraft enters and recovers from stalls.

As an additional way of understanding aircraft characteristics, we can also review the flying qualities mandated by FAR certification requirements.

Accidents

Many of the training tasks in our program are drawn from both recent and historically typical unusual-attitude accidents. Some examples are essentially aerodynamic in provocation, like vortex encounters, stalls, and spins. Other accidents stem from mechanical or control system failures. Although the engineering causes of system failures might be specific to aircraft type, there's usually an accompanying aerodynamics lesson that's applicable in general. That's why, for example, we'll have you examine the aerodynamics of rudder hardovers—the bane of the Boeing 737—even if you think it could never happen on your aircraft.

When we practice intentional unusual attitudes, briefed and prepared, it's easy to forget how unintentional attitudes often happen. Sudden catastrophes aside, they evolve. They're often the culmination of a chain of events that typically starts while the aircraft is still under normal control. Problems appear, the workload goes up, the pilot enters an overload state and fails to monitor attitude, and a departure from the normal envelope begins. Pilots who've experienced the alarming physical sensations of spatial disorientation can almost always look back and trace the bad *decisions* that set the seeds.

The National Transportation Safety Board's website www.ntsb.gov contains statistics on loss of control accidents, updates on current investigations, and detailed final reports.

Simulators for Upset Training?

Kinesthesia is the term for the sensation of the body's position, weight, and movement, as conveyed through our muscles, tendons, and joints. Both the vestibular (inner ear) and kinesthetic systems are components of *proprioception*, the general term (although usage varies) for all the non-visual systems involved in providing information on the orientation and movement of the body.

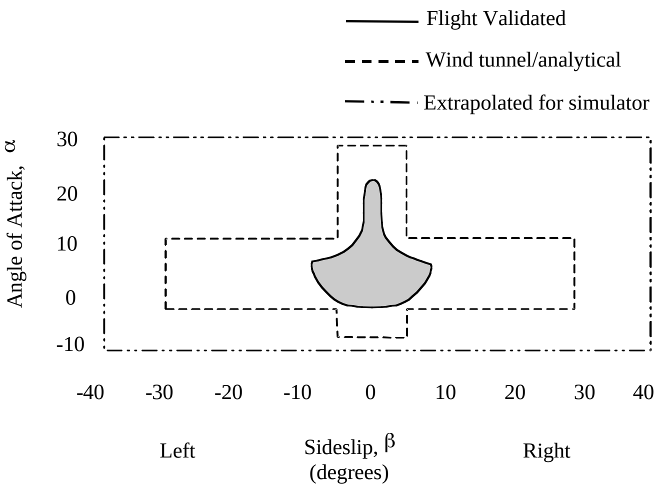
The proprioception of aerobatic flight involves sustained rotation and sustained g forces. But even the best six-degree-of–freedom simulator can only supply momentary cues. You won't feel a continuous 2 g during a simulated 60-degree banked turn, for example.

When a simulator can't provide a reasonably seamless motion environment in which to learn, and toward which to adapt, simulator based unusual-attitude training is limited to drills and procedures. The simulator can't provide equivalent *experience*, as it can in other flight regimes and emergencies involving less extreme motion. And if the simulator gives a false impression of how vision and proprioception match, it may actually lay the groundwork for even greater confusion during unusual attitudes in flight, when visual cues are combined with more challenging proprioceptive inputs than the simulator's motions allowed.

In addition to their limited ability to produce the physical sensations of aerobatic flight, the computers that drive simulators have flight model limitations. Both civilian and military aircraft are flight tested for their intended use, with some additional level of control abuse. Manufacturers of non-aerobatic aircraft are not required to develop actual extreme-attitude flight-test data. It would often be unsafe. As an example, the illustration shows the extent of the 737 flaps-up, flight-validated envelope. Note how combinations of high sideslip and high angle of attack are

737 Flaps Up Alpha/Beta Envelope

Adapted from AURTA, App. 3-D.



avoided. Behavior in these flight regimes simply isn't *known*. According to AURTA, App.3-D.1:

"From an aerodynamic standpoint, the regimes of flight that are usually not fully validated with flight data are the stall region and the region of high angle of attack with high sideslip angle where there may be separated airflow over the wing or empennage surfaces. While numerous approaches to stall or stalls are flown on each model (available test data are normally matched on the simulator), the flight controls are not fully exercised during an approach to stall or during a full stall, because of safety concerns. Also, roll and yaw rates and sideslip angle are carefully controlled during stall maneuvers to be near zero: therefore, validation of derivatives involving these terms in the stall region is not possible. Training maneuvers [in the simulator] in this regime of flight must be carefully tailored to ensure that the combination of angle of attack and sideslip angle reached during the maneuver does not exceed the range of validated data or analytical/extrapolated data supported by the airplane manufacturer."

It's worth noting that this doesn't preclude simulated rolling maneuvers at bank angles and attitudes outside flight-test parameters, but within α/β limits. Again from AURTA:

"Values of pitch, roll, and heading angles, however, do not directly affect the aerodynamic characteristics of the airplane or the validity of the simulator training as long as angle of attack and sideslip angles do not exceed the values supported by the airplane manufacturer. For example, the aerodynamic characteristics of the upset experienced during a 360-deg. roll maneuver will be correctly replicated if the maneuver is conducted without exceeding the valid range of angle of attack and sideslip."

You can see that limitations in the flight model beyond certain α/β values should be taken into account when simulators are used to re-create and study upset accidents. The same caution is necessary when simulators are used to *develop* unusual-attitude recovery techniques—a somewhat abused practice in the past. Be suspicious of simulation at high α and β, especially beyond stall.

But also put the limitations of a non-validated flight model into perspective. An aerobatic aircraft isn't going to "model" precisely the kind of aircraft the AURTA is concerned with, either. In-flight unusual-attitude training is illustrative. It can take you into, and show you how to get out of, all sorts of territory. It produces true sensations. Yet it can only provide for the transfer of general principles and fundamental skills.

Unusual-Attitude versus Aerobatic Training

In typical aerobatics courses you'll learn to fly a standard set of maneuvers: roll, loop, hammerhead, Cuban-eight, Immelmann, spin, etc. It's valuable training and worth encouraging, but not always the best approach for a pilot whose first concern might be to learn unusual-attitude aerodynamics and recovery skills for use in non-aerobatic aircraft.

One problem is that aerobatic training focusing on perfecting standard maneuvers tends to be inherently aircraft-biased in the way muscle memories are developed. Although the basic aerobatic techniques aren't appreciably different between aircraft, if you want to keep your instructor happy, and get the maneuvers right, you'll have to match your control inputs to the characteristics of the trainer you fly. In a very responsive aerobatic aircraft, such as an Extra or a Pitts, a little bit of input will produce a lot of maneuvering. You'll learn a light touch—otherwise you'll have a rough ride.

Unfortunately, those light control forces (which include the initial breakout force necessary to deflect controls from neutral) can lead a pilot to an unrealistic set of motor skills and response expectations if applied to less nimble, non-aerobatic aircraft in unusual-attitude situations. There a light touch might take a long time getting noticed.

Another drawback to standard aerobatic training is that the maneuvers, properly taught and flown, don't present all of the control issues that an unusual attitude program really needs to address. Although the *attitudes* may be new to the pilot, if the aerobatic maneuvers have been entered correctly the aircraft will be in an *energy state* well within the envelope of positive and immediate control. The pilot will have seen only part of the problem.

As a matter of fact, you have to fly aerobatic maneuvers badly in order to take them to the regions of the attitude/energy envelope where they start to provide the most complete training opportunities for unusual-attitude recovery. In a standard aerobatics course, a good instructor will set up bad maneuvers for just that reason. Even so, the experience may still be somewhat off the mark as unusual-attitude training, because the attitude emergencies a student will face in cross-country flying won't originate from a botched hammerhead or a sloppy Immelmann, but typically from such things as turbulence, ice, wake encounter, or systems and control failures.

We've created a maneuver sequence that addresses the aerodynamics of attitude, energy, and basic upset response more completely than a typical spin-loop-roll aerobatics course, using aircraft chosen to relate as well as possible to the general fleet. You'll start with stability and control demonstrations adapted from flight test procedures, begin to develop unusual attitude recovery skills, and then move on to the classic aerobatic maneuvers.

Wide-Envelope Attitude Awareness

You're going to be in for trouble in an upset situation unless you can visually track rapid and complex changes in aircraft attitude. Tracking information can come to you in three ways: by looking at the scene out the window, looking at the attitude and performance instruments in the cockpit, and by scanning inside and out. In VFR, this all happens within a wide-angle visual field that can develop rapid *peripheral rotations* that profoundly affect perception of the scene. In IFR, the angle narrows and potentially helpful peripheral cues are missing. And all of this occurs while your body is contending with abrupt and perhaps contradictory vestibular stimulation.

This environment is confusing at first. The perceptual skills that prevent it from remaining a blur take practice to develop. The forces are disconcerting and the usual references can disappear. Experience shows that the best way to enter it is in increments that provide a gradual exposure to increasingly unfamiliar aircraft attitudes and motions, while maintaining a comfortable sense of aircraft control. In addition to building understanding, the aerodynamics observations we'll be making in the first flight are designed to help you relax and develop confidence in the aircraft, while gaining the tracking ability necessary for more complex maneuvers later on.

As our maneuvering increases, you'll become more familiar with the aircraft's attitude cues and typical motion paths. You'll build a mental image, or model, of the aircraft's motions, as if visualizing the aircraft from outside. You'll also begin to acquire what aviation physiologists call ***earth-stationary perception***: You'll start to gain *the perceptual ability to fix the plane of the earth and horizon in place* during unusual attitudes, just as you do in normal ones, and you'll begin to experience and anticipate the motion of the aircraft against that stationary reference. The ability to imagine aircraft motion correctly in three axes supports the ability to perceive attitude in earth-stationary terms, since the internal model acts as a bridge during intervals when horizon reference is temporarily lost.

Although this learning occurs in VFR, you'll find that it applies to instrument interpretation in IFR, as well. Unusual-attitude instrument indications are easier to decipher when you can associate them with dynamics you've already seen outside. Interpretation can be very difficult otherwise. We'll start you on outside references, and then bring your focus inside.

Control Skills

Mantras: Because we want you to develop core response habits based on earth-stationary perception, we don't rely heavily on mantras, meaning memorized control sequences or control inputs remembered through acronyms. Mantras for guiding the hands and feet are fine—*as long as they're acted out in phase with the aircraft's attitude*. The trouble comes when a pilot loses or lacks earth-stationary visual tracking, applies sequenced inputs out of phase with the maneuvering requirements, and then becomes confused when the aircraft responds unexpectedly. Confused pilots often freeze. Aerobatics instructors see this all the time.

Also, in some cases maneuvers are actually easier to master if the necessary control motions are learned out of sequence. The flexibility necessary for this in training makes mantras inappropriate, and often irrelevant once the student catches on. This is the case in learning to roll an aircraft with integrated rudder and elevator inputs. (See "Slow Roll Flight Dynamics" in the Maneuvers and Flight Notes.)

We think mantras can be helpful, but as ways to summarize and seal the control skills you've learned, not as a primary training technique.

Airline training for unusual attitudes often relies on standardized "flow response" or "rule-based" performance.[3] The pilot learns to interpret flight instruments in the sequence necessary to determine aircraft attitude and perform the right control inputs. Pilots are trained to recognize the situation, confirm it, and then take the prescribed steps. This approach is based on instrument flying and suits the airline and FAA preference for uniform procedures. If the pilot follows the procedure correctly, he or she is considered trained.

Our program is different. We strive for "skill-based" performance and will encourage you to *fly in direct response to the visual cues*, mediated as little as possible by mental checklists designed to tell you what to do with your hands and feet. Direct response is how experienced aerobatic pilots fly. This approach isn't meant to replace procedural flying where procedures are necessary. The skills gained should make upset "procedures" easier, because you'll be able to take in attitude information more efficiently.

That said, a case where talking yourself through a memorized control sequence can work best, as both a learning and a survival technique, is during a spin recovery—especially once a spin develops and the wrong sequence can delay or prevent recovery.

The Debate over Spin Training

The then CAA (now FAA) removed the spin requirement from the private pilot flight test in 1949, but the arguments over spin training never let up. There were even Congressional hearings, in 1980, in which the Subcommittee on Investigations and Oversight of the House Committee on Science and Technology, clearly wowed by a witness list of famous test pilots, recommended that spin training be restored—a recommendation the FAA did not follow.

Under FAR Part 61, an applicant for a private pilot certificate is required to receive only ground instruction in "stall awareness, spin entry, spins, and spin recovery techniques." A candidate for flight instructor must demonstrate ground "instructional proficiency" in the same areas, and receive actual spin flight instruction. The flight instructor requirements can be satisfied with a logbook endorsement from a current CFI after just one spin-training flight.

The result is often a new instructor who speaks from limited direct experience.[4] Unfortunately, he'll be speaking to his eventual students about flying's most complex dynamic event—an event that can quickly deteriorate to the point where training restricted to ground instruction, however informed the instructor might be, won't prove much help. Pilots learn spins through their hands, feet, and eyes. Not only do they have to learn the correct recovery response, they have to filter out the impulsive and incorrect. That's not a ground-based academic task.

Over the years, some authorities have argued that stall avoidance training is the real answer to spin

[3] Human factors experts distinguish between skill-based, essentially automatic performance, and more cognitive, if-then, rule-based performance.

[4] Patrick R. Veillette, *Re-Examination of Stall/Spin Prevention Training*, Transportation Research Record, No. 1379, National Research Council, Transportation Research Board, 1993.

accidents. They cite as evidence the accidents that occur during spin training itself, and the statistics that show that most fatal stall/spins happen during takeoffs and landings (or during buzz jobs), at altitudes too low for recovery in the first place.[5] Their argument ignores the fact that only spin accidents get recorded, while there's no way of knowing how many people spin training has actually saved at recoverable altitudes, *or prevented from making mistakes* at low altitude by virtue of a better understanding of how things can go wrong. It's also a self-fulfilling prophecy: If you avoid spin training because you think recoveries from developed spins are statistically unlikely below standard traffic pattern altitude, as the Air Safety Foundation has asserted, you probably won't have the skill to recover from an initial spin departure, either.[6] Yet, with training, recovery from the initial wing drop that signals the beginning of autorotation is possible in many light aircraft, at least above 500 feet. So the question for the individual pilot becomes: Do you resign yourself to statistical outcomes—or do you try to beat them through training that takes you beyond stall avoidance and into actual spin departures and recoveries?

Some aircraft put up a good barrier between stall and spin. Stick shakers and pushers on turboprops and jets make it difficult to get into the territory necessary for a spin. Modern wing, empennage, and aileron designs make inadvertent spins less likely than in the old J-3 Cubs, Cessna 120/140s, and Aeroncas in which civilian spin instruction was once given. It was their departure characteristics that the classic, stall/spin-training scenarios were designed to reflect. Although their stall behaviors were often gentle, they had significant adverse aileron yaw and powerful elevators and rudders—a combination that affords plenty of pro-spin opportunity if a pilot misapplies the controls. The ease with which these aircraft (and many other pre- and World-War-II trainers and especially fighters) could spin if mishandled made spin training necessary. Later generations of aircraft were harder to provoke. Making them that way was part of the reasoning behind the removal of the private pilot spin requirement. As long as spins were required, manufacturers had to produce trainers that were easy to spin. Without the requirement, more spin-resistant designs became marketable.

In our training program we'll concentrate first on post-stall departures and incipient spin entries, where aerodynamic moments predominate and emergency recoveries should occur. When you're comfortable, the training moves to spins in which the aerodynamic and inertial moments are approaching balance, and incorrect control movements can delay recovery. You'll find that the stick forces necessary for recovery tend to increase as a spin develops, and spin rate can temporarily increase after recovery inputs. These are essential points to demonstrate, because their misinterpretation can cause a pilot to panic and misuse controls.

It's important to note that practice spins at safe altitudes, while necessary for learning spin dynamics and recoveries, don't recreate the mental state in which many spin accidents are likely to occur. Spins particularly happen down low, when an anxious pilot attempts to increase a turn rate while fighting a growing sink rate. Prime examples are turn-backs due to engine failure on takeoff, and skidding turns when low and tight on base to final. Pilots who claim they'd never mishandle an aircraft in this way simply don't realize how powerful the impulse becomes when the ground starts rising and there's unfriendly terrain ahead. In fact, spins aren't just fatal at low altitude: low altitude literally provokes departure if a pilot responds to the unexpected ground threat with visceral but inappropriate control movements. For the untrained pilot, the visceral response—stick back, opposite aileron—is pro-spin. If spin training up high fails to accomplish a safer outcome down low, it's a good bet that the instructor failed to point out that spin training is also crash training! It's certainly better to crash under control in a more or less level attitude than in the sudden-stop, nose-in-the-dirt vertical attitude of a low-altitude spin departure.

Also remember that the differences between aerobatic and non-aerobatic aircraft can be substantial. The FAR Part 23 one-turn spin recovery requirement for normal category certification can produce a much less predictable aircraft than one certified under the six-turn requirement for aerobatics and spin-approved utility. Part 23 twins and large aircraft certified under Part 25 have no spin recovery requirements at all. Consequently, it's dangerous to venture far-reaching predictions about the spin behavior of a

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[5] Especially Leighton Collins, *Air Facts*, vol. 36, June 1973, pp. 80-96.
[6] www.aopa.org/asf/ntsb/stall_spin.html

non-aerobatic aircraft based on one's experience in well-mannered aerobatic trainers alone. Our ground school takes this into account.

But the good news is that spin departures are essentially alike. Aircraft have different susceptibilities, but they go into spins or post-stall gyrations for the same underlying reason: failure of lateral/directional stability at stalling angle of attack. As a result, learning to enter into and recover from spins in any one aircraft gives you the basic lessons needed to keep them from happening in most others. By opening your eyes to both spin causes and consequences, spin training can build more ingrained and technically proficient stall avoidance. That's of course the foundation on which the argument for spin training ultimately rests: Spin training should make emergency spin recoveries unnecessary. The training doesn't have to be hair-raising and the airmanship benefits, once you've experienced them, are too genuine to ignore—a big chunk of mystery and vulnerability will be gone.