# SPIN TESTING THE T-3A "FIREFLY"

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## Introduction

This paper will describe some of the recent spin testing performed on the USAF's newest training aircraft, the T-3A "Firefly." The testing was a joint effort between the USAF and the contractor (Slingsby Aviation of the United Kingdom) during a larger qualification test and evaluation (QT&E) program on the aircraft. A total of 4 spin sorties were flown from 25-28 Sep 93 at the contractor's production facility in Hondo, TX.

The T-3A is a single engine, reciprocating engine aircraft that is replacing the Cessna T-41's and will be used to screen all USAF pilots prior to Undergraduate Pilot Training (UPT). The Firefly represents a quantum leap in performance (260 HP vs 180 HP) and maneuverability (acrobatic category) over the T-41s. I'll be going over more specifics about the T-3A in just a bit, but suffice it to say it the Air Force traded in the old family station wagon for something with a bit more gusto.

After some background information on the program and the aircraft, I'll walk you through our test planning and test conduct for the spin tests. I'll show you our results--which held a surprise for everyone--and discuss the impacts for future testing of "off-the-shelf" aircraft.

## Background

### The Enhanced Flight Screener Concept

For many years the U.S. Air Force has been remodeling its UPT program to resemble a two-track system common to the Navy and other foreign services. As a part of this process, the USAF wanted a more effective way to screen candidates prior to UPT by introducing the fledgling pilot to the rigors of aerobatics, spins and higher g maneuvers. It was hoped this would reduce washouts, overall cost and produce better pilots. And so the idea of an "enhanced flight screener" was born.

In May 1992 the Slingsby T-3A "Firefly" was chosen by the Air Force to replace the aging Cessna T-41s and fulfill the enhanced flight screener mission. A total of 113 Firefly aircraft were contracted to replace the T-41s at both Hondo, TX and the USAF

Academy, CO.

The strategy for acquiring the T-3A centered around using a commercial, "off-the-shelf" aircraft that could be entered into military service with minimal developmental costs. (In the eyes of the bean counters, that also means minimal flight testing). Commercially certified variants of the Firefly had seen service in other European and Asian countries, as well as Canada.

Qualification Test and Evaluation (QT&E) on a production T-3A was a major milestone that had to be completed prior to putting T-3As "on the ramp." Because of its previous work with commercial aircraft buys--like the T-1A "Jayhawk" and Air Force One (Boeing 747) programs--the 4950th Test Wing at Wright Patterson AFB, OH was designated the USAF's Responsible Test Organization for the QT&E program. And because I was assigned to the 4950th at that time, that's also when all the fun started for me and my test team.

## The T-3A Aircraft

The T-3A is the military designation for the now commercially-certified T-67M260. The Firefly is manufactured by Slingsby Aviation. The basic design evolved over a 10 year period from a French wooden/fabric aircraft to the USAF T-3A. The principal dimensions and wing section are shown in Figure 1. There are horizontal strakes forward of the empennage for improved tail damping during spin recovery, and aileron winglets for better lateral-directional stability. Flaps are controlled by a direct drive, "parking brake" style lever between the pilots. The flight controls are fully reversible, with pitch trim provided by a small trim tab on the left elevator (remember that trim tab for later discussion!).

One of the most interesting features of the T-3A is its GRP (glass reinforced plastic) construction. Similar to high performance sailplanes, this type of construction means no rivets, incredible structural strength with minimal weight penalty, and low profile drag--except for the fixed gear!

Over the years, Slingsby gradually increased the engine size and maximum gross weight of the Firefly. Currently, they market several versions of the Firefly. Table 1 summarizes major changes to the Firefly from the first version in 1982 to the present day. The 260 HP engine (Lycoming AEIO-540) was installed exclusively to meet USAF performance requirements at both a low altitude and high altitude training location.

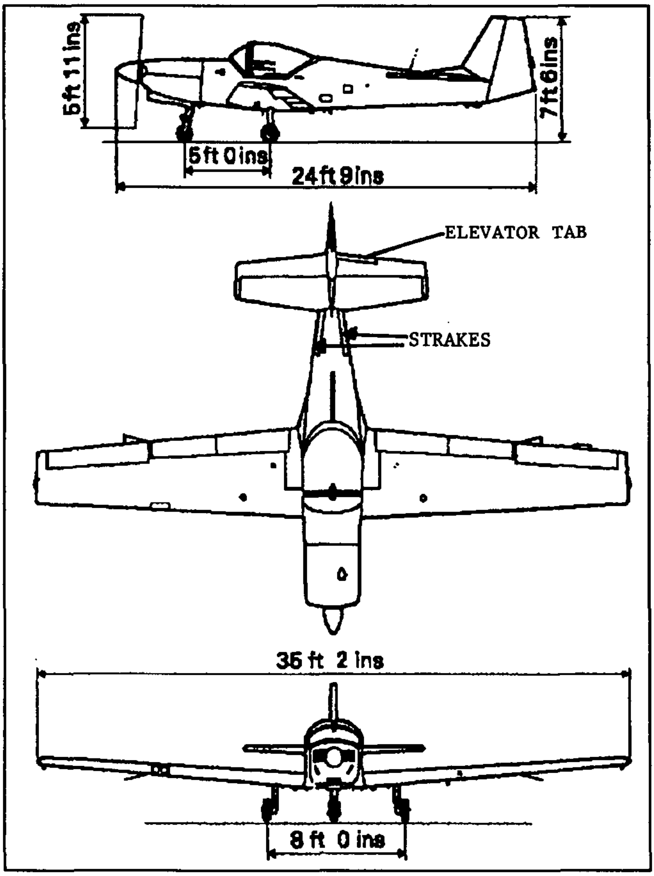


Figure 1: The T-3A Aircraft

| Firefly Version | Max Weight | Engine (Lycoming) | Propeller | $V_{stall}$ (full flaps) | $V_{never\ exceed}$ |
|---|---|---|---|---|---|
| T-67A | 1650 lbs | 120 HP | 2 blade, fixed pitch | 40 KIAS | 138 KIAS |
| T-67M200 | 2250 lbs | 200 HP | 2 or 3 blade, constant speed | 49 KIAS | 180 KIAS |
| T-67M260 (T-3A prototype) | 2450 lbs | 260 HP | 3 blade, constant speed | 52 KIAS | 195 KIAS |
| T-3A | 2550 lbs | 260 HP | 3 blade, constant speed | same as prototype | same as prototype |

Table 1: Firefly Versions

## QT&E Test Objectives and Spin Investigation

In conjunction with the contractor, the USAF's job during QT&E involved testing to meet three objectives: 1) ensure contractual specification compliance, 2) verify the flight manual, and 3) provide an initial operational assessment of the aircraft. At the time of the test, the T-3A was also undergoing commercial type certification by both the FAA and the British aviation authorities. Specifically, the USAF operational user (Air Education and Training Command) was very interested in the T-3A's spin characteristics, as they were planning to start spinning this new training aircraft almost immediately after we completed QT&E.

Slingsby had a lot of experience with the basic Firefly design, but the USAF's 260 HP was a relatively new animal. The new airframe/powerplant combination on the T-3A was less "off-the-shelf" than other versions of the Firefly. Once we sat down to plan the spin portion of the test, there was a concern on the USAF side that there still might be some gaps to fill in order to more fully characterize spins and departures.

Spin Test Planning & Development

Developing the spin matrix for this program required careful research. Unlike developmental programs, we had to rely on previous testing whenever possible (remember that thing about "minimal testing"?)

Contractor spin data came from earlier flights on pre-production and production T-3A models (which were virtually identical as far as spin characteristics). On the USAF side, we had to decide how much of this contractor data met our requirements for QT&E.

Next we had to look at the civilian certification process. As mentioned above, the T-3A was undergoing commercial type certification (both U.S. and British) concurrent with QT&E. In order to reduce duplication of testing, we had to understand what spin data were required by the FAA and British authorities for certification purposes.

Most importantly, we had to understand what data were essential to meet the user's needs. The user was concerned about student errors that would result in a departure or spin, as well as errors in recovery. These areas were not specifically addressed by either the contractor or the feds.

Our search also led us to ask "old head" engineers at NASA Langley and Edwards AFB about spin profiles. We looked at the Navy's spin testing on the T-34B to C conversion (another "bigger engine is better" program).

In the end, we found that there were some gaps that we needed to fill during the QT&E spin investigations to make sure the T-3A was ready for delivery:

--There had been no classification of the aircraft's basic departure/spin susceptibility along military guidelines (Phase A, B, C stalls).

--There needed to be a more complete verification of spin modes. We were particularly interested in an inverted mode and what type of departures or spins might result from a roll coupled entry. The FAA and British required Slingsby to demonstrate only the erect spin. Slingsby had not been successful spinning the aircraft inverted due to an apparent lack of elevator control power. Engineering analysis seemed to agree, but we wanted our own flight test assessment.

--Lastly, there had been no previous, in-depth look at student errors during spins and recovery. British certification did require the T-3A to be able to recover from an erect spin with a "reverse" recovery of forward stick followed by opposite rudder. Though a step in the right direction, we on the USAF side wanted to see for ourselves the various effects of power, controls, and flaps on recovery.

## Test Conduct and Instrumentation

Now that we had found work unique to our spin investigation, we had to blend it into the rest of the QT&E program. In a "non-developmental" test environment we did not have the luxury of very much instrumentation, test range support or time. The complete QT&E program was to be done at the contractor's plant in Hondo, TX within a three week period. We elected to place the spin investigation near the end of the program, after we had some experience with the aircraft.

The T-3A had no ejection seat or proven bailout capability. Nevertheless, as a way to enhance safety we chose to wear parachutes and established minimum entry and bailout altitudes for the spins.

Instrumentation for spins had to be simple, inexpensive, and reliable. We opted for video recording from a chase aircraft and a second, over-the-shoulder camera mounted in the cockpit. All other data for the spins would be hand-held. The USAF pilots received some pre-QT&E training flights in the T-34C, ASK glider, and even the test aircraft which enhanced our ability to collect data during spins. Lead ballast was fitted under the pilots' seats, which brought the CG towards the aft end of its operational range. This aft CG made the aircraft most susceptible to departures and spins.

## Test Results

### Departure/Spin Susceptibility

A thorough stall verification series revealed adequate basic stall characteristics with an easily recognizable, natural stall buffet about 5 knots prior to the stall. The aircraft's tendencies to depart or spin were evaluated using classic, 1 second (Phase B) and 3 second (Phase C) aggravated inputs of full aft stick and full rudder inputs at the stall. The aircraft was basically resistant to both departing and spinning, as most of the time a sustained input (Phase C) was needed to get things "out of control."

Inverted stalls were very benign. As seen from the cockpit during inverted flight, with full forward stick and about 15 degrees nose high, the nose gently dropped to the horizon at the stall and the aircraft rapidly gained flying airspeed. Any aggravated inputs with rudder or aileron did not develop enough yaw rate generate anything but a slow spiral. An inverted spin seemed difficult to achieve.

Following this, a total of 39 spin test points were performed, investigating the effects of various controls, power, and entry conditions on the spin and spin recoveries.

## Erect Spin Modes

The entry conditions varied from wings level, power off to highly dynamic entries with maximum power. In all cases evaluated, if the pro-spin inputs (full aft stick, neutral ailerons, and full rudder) were sustained, within two turns the aircraft would end up in the normal, erect mode.

The standard erect mode was characterized by a stable, nose low attitude of 30 to 40 degrees. Each turn took a bit over 2 seconds (that's a little less than 180°/second) and lost 250 to 300 feet.

There were no apparent changes to these basic spin characteristics due to changes in CG (we moved fuel and/or ballast forward, aft and laterally), weight, or pressure altitude.

These results extended to the higher energy entries as well. These were entered from an accelerated, turning stall by applying full pro-spin rudder opposite the turn direction at the stall. Though initially an "E ticket" (fairly oscillatory) ride, within 2 turns things had stabilized into an typical spin. We saw this as a desirable characteristic for a basic trainer.

Pro-spin aileron usually caused a slight increase in rotation rate. Releasing controls resulted with the controls floating pro-spin, a slight increase in rotation rate, and no recovery from the spin.

The elevator was effective in a spin to vary angle of attack, and therefore rotation rate. An accelerated spin mode could be entered during an erect spin if the stick was brought forward while maintaining pro-spin rudder. This resulted in a marked increase in rotation rate (about 25% faster) and about 10 degrees lower attitude than with full aft stick. We noticed no tendency to "tuck under" to an inverted position, even if the stick was rapidly brought forward.

## Erect Mode Recoveries

The spin recovery recommended by Slingsby consisted of the following steps:

1. Throttle-idle
2. Flaps-raise
3. Stick full aft with neutral ailerons
4. Check direction of turn
5. Full rudder opposite spin direction
6. Pause momentarily, then move control stick, with ailerons neutral, progressively forward until spin stops
7. Recover from dive

This recovery took advantage of the T-3A's powerful rudder for anti-spin control, and we found it effective in all cases. Usually rotation stopped within 1 turn after applying opposite rudder. Spins to the left usually stopped rotation sooner than spins to the right--apparently, the spinning propeller's slipstream had a "blowing" effect on the rudder, enhancing its effectiveness when the surface was deflected right. A nominal, 3 g dive recovery took up to 1000 ft. In all, a typical 6 turn spin used from 2000 to 2500 ft, including the dive recovery. We saw this relatively small altitude block for spin training as another desirable characteristic.

Besides the recommended spin recovery, we looked at other types of recoveries. Opposite rudder without forward stick was successful from left spins only. As I mentioned earlier, the British aviation authorities required the T-3A be able to recover from a spin using a "reverse" application of forward elevator followed by opposite rudder. We verified this procedure as well. Though both the rudder-only and "reverse recoveries" took longer to stop the spin, they highlighted the rudder as the primary anti-spin control for the T-3A.

Student Errors Investigation

Remember I said that the user was planning to fly the T-3A with students almost immediately following our QT&E program? Much of our verification work was folded over into this student error investigation--departure susceptibility, effects of controls in spin, "reverse recoveries," and so on. Some other things we just had to botch up on purpose and see what happened!

Entering spins with full power, for instance, resulted in a flatter, initially more oscillatory, and faster spin than with idle power. During the recovery, full power enhanced rudder effectiveness (more "blowing effect"). This caused a reversal in spin direction if the pilot did not neutralize the opposite rudder quickly, or reduce the power to idle. In short, we found the first step in the standard spin recovery, "Power-Idle," was a critical one!

Spins with flaps full (40 degrees) were slightly more nose low and faster than with an intermediate setting (18 degrees) or clean. The contractor's spin recovery called for raising flaps as the second step following reduction of power. We found the human factors of the "parking brake" style flap lever made this a difficult task. As recoveries were achieved with the flaps down until dive pullout, we recommended Slingsby change this part of the procedure.

Spins from extreme nose high, erect attitudes did not transition to anything except the erect mode with a few more oscillations.

Inverted Mode Discovery

The possibility of an inverted spin seemed remote, due to the reluctance of the aircraft to depart or spin from an inverted stall. We tried roll coupled entries, but could not generate sufficient roll rate to translate to a yaw rate. The only card left unturned was the effect of the elevator trim (remember that trim tab)--could it make a difference?

We found with the elevator trim set full nose up, the aircraft would spin inverted in either direction. This was accomplished from an inverted stall, with full forward stick and full pro-spin rudder held throughout the incipient stage (1 to 2 turns) and the developed spin. The full nose up setting of the trim tab allowed an extra bit of elevator control power when inverted. This in turn, kept the angle of attack high enough to allow a yaw rate to develop. And as we know, stall plus yaw equals spin.

A total of three inverted spins were accomplished, two left and one right. The spin with left rudder appeared more oscillatory than with right. The developed spin was slightly flatter than the erect mode, characterized by about 20 degrees nose low, with standard rotation rate and altitude loss per turn. As soon as pro-spin controls were neutralized, the aircraft stopped spinning and recovered to an upright, nose low attitude.

The inverted spin discovery carried with it some good news and bad news. The good news was that the inverted spins we had done, though potentially disorienting to the pilot, had to be intentionally entered from an inverted stall, and appeared easily recoverable. The bad news was that this was a non-developmental program and it was up to the contractor to make sure we had not opened up a Pandora's box!

Follow-On Tests

Naturally, Slingsby wanted to further investigate the inverted spin mode. Their follow-on testing completed before delivery verified the importance of the trim tab for inverted spins. Expanding from the QT&E sorties, they looked at both forward and aft CG, as well as heavy and light aircraft weights. In all cases, once the trim was set more than half nose up, the propensity for inverted spinning increased. The aircraft was more susceptible to inverted spins with right rudder, though it could spin both directions once the trim was set to full nose up (as we had done during QT&E). Slingsby also found the neutral recovery to be most effective for the inverted spin. In the end, Slingsby recommended the aircraft not be certified in this area and for inverted spins to remain a "prohibited" maneuver. In part, this decision was an economic one, as travelling the certification highway can be a long and expensive journey. And on-time delivery of the aircraft was paramount to both the USAF and the contractor.

## Overall Assessment and Impact of Testing

On the USAF side, we were pleased with the Firefly's spin characteristics--how it spun when you wanted to and didn't when you weren't expecting it. The inverted spin potential seemed remote enough to eliminate most of the worry on part of the user. The T-3A had a no-nonsense, erect spin mode that would expose pilots to the spin environment in a safe and energy-efficient manner. As long as the pilot utilized rudder for primary anti-spin control, most mistakes during recovery could be tolerated.

The T-3A program taught us the importance of a thorough flight test investigation, as civil certification requirements do not always match military needs. We learned not to overlook even simple instrumentation such as a video camera and stopwatch. As a result from our limited test program, we succeeded in completing the spin picture so the user felt comfortable training from their first sortie.

While the idea of adapting "off the shelf" aircraft for military use is not new--take the Wright Flyer, for example--it is becoming an increasingly popular way to acquire primary training aircraft. The T-1A Jayhawk, a Beech business jet derivative, has been in service for more than two years training USAF tanker and transport pilots. The Joint Primary Aircrew Training System (JPATS) program will be bringing in a commercially certified aircraft to replace the USAF T-37 and the USN T-34 trainers. Like the T-3A, JPATS calls for minimal military flight testing. I hope the lessons from T-3A can be helpful to the spin testing of the JPATS aircraft.

As we have seen, military test pilots have an important role in the world of "non developmental" test. The challenge for each program is to define what unique level of testing will ensure a safe and mission-ready airplane.