

Flightlab Ground School

11. Some Differences Between Prop Trainers and Passenger Jets

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For Training Purposes Only

As we work through our flight test and upset maneuvers, keep in mind the possible differences between our aircraft and the one you normally fly. Below is a quick review of some of the differences between typical aerobatic prop trainers and passenger jets.

Although they are different in quickness and in attainable rates of roll, pitch, and yaw, different in stability versus maneuverability, and different in control forces and gradients, *aerobatic trainers and passenger aircraft still follow the same set of rules*. If you exclude prop effects for our trainers and various inlet and thrust effects for jets, each “calculates” the same basic matrix, constantly working out a balance between the forces of lift, weight, thrust, and drag, and between the opposing moments generated about the aircraft’s axes. One can observe these basic forces and moments in any aircraft.

However, that doesn’t mean that they actually *have been observed* during flight test to anywhere near the same extent in all aircraft. For example, flight-test requirements for an FAA spin approved trainer take it to much higher combinations of angle of attack, α , and sideslip, β , than required for passenger jets. The demonstrated ability to recover from a six-turn spin is required of the former. Adequate stall warning and the demonstrated ability to recover from a stall without needing extraordinary pilot skill are required of the latter. Between the one obligation and the other lies plenty of unexplored territory.

Accordingly, when we do our maneuvering exercises in our trainers at high α and β , we’ll be in a regime where the behavior we observe will not be the same for all aircraft. That won’t invalidate our observations, or the principles of aerodynamics they illuminate, but it will make us think.

What happens if you simply scale up an aircraft, keeping the proportions and the wing loading constant? Aerodynamic moments increase approximately as the third power of aircraft

dimension. But moments of inertia increase as the fourth power—which slows down aircraft response.

Maneuvering

If you normally fly a people-hauler, you’ll immediately notice a livelier feeling in our aerobatic trainers:

In pitch, *short period* response will be faster than you’re accustomed to (your instructor will demonstrate short period response, and we’ll cover it in ground school). For our purposes, short period response is essentially a measure of aircraft quickness—how rapidly an airplane can respond to a control deflection in pitch. Our aircraft have high short period frequencies, and are also quick to respond in roll and yaw. The significance is that you’ll be learning maneuvers in an airplane that’s more instantaneously responsive (higher initial accelerations) around its axes than the one you normally fly, and can build up higher rates of rotation about those axes, as well. As a result, you may tend to overcontrol at first.

But once you get accustomed to the training aircraft, your response expectations may then become unrealistic in terms of what your own aircraft can do. Your own aircraft might also feel somewhat out of phase during upset maneuvers compared to the trainer. It might respond to the controls at different rates around each axis. Control forces may not be as nicely harmonized, which can make it more difficult to coordinate unusual-attitude control inputs in a smooth manner.

Stability and maneuverability mark the opposite ends of a continuum. Passenger aircraft designed with the geometry and mass distribution for high longitudinal stability (or equipped with control systems that produce high stability artificially) are reluctant to maneuver. As the center of gravity shifts aft, stability relaxes, maneuverability increases, and required elevator

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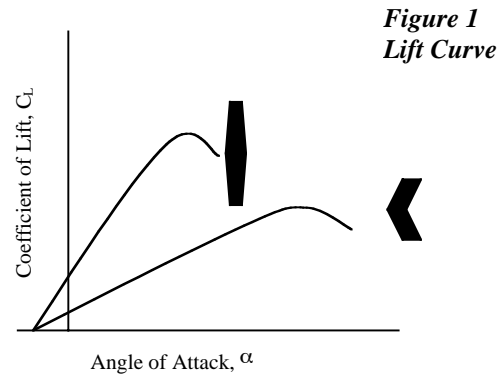
deflection and control forces diminish. An aft center of gravity also means that less down force has to be generated by the horizontal stabilizer to trim the aircraft, and there's less accompanying drag. Any down force at the tail in effect increases the weight of the aircraft, and so more lift is required of the main wing, which then has to operate at a higher angle of attack, again adding to the total drag necessary to trim. Transports designed with "relaxed" longitudinal stability can take advantage of lower drag, but require control systems that augment stability. If stability augmentation fails at aft loadings, the pilot needs to keep control movements in check, since response will be livelier.

Maneuvering produces loads. While our trainers are designed for maneuvering and built for the high g-loads that maneuvering entails, passenger aircraft are designed for a narrower maneuver envelope. Because aggressive maneuvering could produce excessively high structural loads, low-g passenger aircraft require higher control forces and steeper gradients of stick-force-per-g to discourage the pilot from exceeding structural limits. Aircraft stressed for higher g need lower pitch control forces and shallower gradients to avoid exceeding a pilot's strength during highly accelerated maneuvers. A 2-g pull in our aircraft will require much less force than in yours.

Propeller Effects

Propeller effects include spiraling slipstream, p-factor, precession, and torque. These tend to make the nose wander on an aerobatic aircraft in response to changes in power (slipstream effects), changes in angle of attack and sideslip (p-factor), and changes in pitch and yaw rates (precession), and can introduce rolling moments (torque). Lacking such annoyances, jet's track straighter and require much less attention to rudder for yaw control during normal aerobatics. In fact, the most-welcome discovery in the transition from aerobatics in a propeller aircraft to aerobatics in jets is the absence of the footwork associated with a prop, and the lack of directional trim change due to speed change that propeller effects require.

On the other hand, the least-welcome discovery is the loss of on-command airflow associated with a prop. At low speeds, prop-induced slipstream over the wing and tail surfaces helps maintain longitudinal and directional control.



The enhanced airflow over the wing can decrease power-on stall speed by a considerable amount, and by decreasing effective angle of attack over the wing roots tends to increase the overall deck angle at which stalls occur. The effects of power increase on stall speed and recovery control are more immediate and pronounced for propeller-driven aircraft than for jets, which don't see a marked induced airflow with power application but instead have to accelerate to build up the dynamic pressure necessary to reestablish lift and control authority. And propellers provide almost immediate thrust, while jets spool up and generate thrust and aircraft acceleration more slowly. These differences are especially important during the approach phase of flight, when speed control and engine rpm management become critical in jets. Excessive sink rates that require only a power increase for immediate correction in a prop aircraft take more time to correct in a jet.

Lift and Drag

Lift curve slope affects stall behavior. Wing sweep has the result shown in Figure 1. When slope is reduced, C_L varies less rapidly with angle of attack, α. For a straight wing, small differences in angle of attack produce notable changes in lift and potentially a quicker stall recovery when the nose goes down. Swept wings stall at higher angles of attack, and the stall and recovery may not be so well defined—more a mush than a break. Induced drag is also higher in the stall region with swept wings.

At idle, a propeller creates substantial drag, while a jet still manages a small amount of thrust. The ability to produce parasite drag with the prop one moment, and thrust the next makes speed control an easier matter. In a jet, with its relative lack of parasite drag to slow things down

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and its delay in thrust to speed things up, plus greater inertia to overcome, speed control using throttle requires more anticipation and planning

Because of the high induced drag at low speed, shallower lift curve peak, greater aircraft inertia, and longer spool-up time, stall recovery with minimum altitude loss can be touchy in jets. The method usually taught is to set the nose close to the horizon, add full power, and regain flying speed at as high a coefficient of lift as possible— C_L then being gradually reduced as airspeed builds. However, high-altitude recoveries may require putting the nose down to compensate for deficiencies in thrust. Transport pilots have been known to apply power during a recovery at altitude, *but attempt to hold the nose level*, allowing the stall to persist, even through repeated pitch breaks and buffet, until the airplane loses lateral control before hitting the ground. (Airborne Express, Douglas DC-8-63, Narrows Virginia, 12/22/96.)

The Rudder

On jets, the rudder is secondary to aileron and elevator. Without the various propeller effects to tame, rudders are used for countering asymmetrical thrust during engine failure and for directional control in crosswind landings. Pilots otherwise tend to keep their feet on the floor and let the yaw damper maintain turn coordination, especially in swept-wing aircraft that Dutch roll in response to sideslip. As a result, jet pilots often have to rediscover the rudder when learning unusual-attitude skills in aerobatic trainers (just as prop pilots have to learn to stop playing with their feet when transitioning the other way). In transferring those rudder skills back to their normal flying, jet pilots need to consider that the vertical fin and rudder structure and the rudder limiting system in their own aircraft may not be designed for the loads that poorly executed or maximum performance recoveries might generate or require. They'll also need to remember that, compared to a straight-wing trainer, in a large, high-yaw-inertia swept-wing aircraft it can be difficult to apply the rudder in phase to augment roll rate. Possibly, at first nothing happens, then too much happens and the aircraft over-rotates and begins a Dutch roll cycle. We'll need to keep this in mind throughout our flights, as we think about how (or if) specific techniques learned in the trainer should be transferred to other aircraft.

Speed and Altitude

Other differences between aerobatic trainers and jets include the latter's greater speed and altitude envelopes. Our trainers can't go fast enough and climb high enough to become involved with Mach-induced buffet and trim effects, or with the narrowing speed band between Mach buffet and low-speed stall (the "coffin corner"). Nor can they climb high enough to experience the change in stability and flying qualities caused by the reduction in aerodynamic damping due to decreased atmospheric density.

Finally, because of their lower speeds, at a given g-load our trainers will fly much tighter radii than jets during looping maneuvers or pull-up recoveries from nose-down attitudes. They can pull to higher limiting g-loads than passenger jets, as well. For a given g the radius of a turn (or of a pull-up) at any instant varies directly with the square of the true airspeed. Double the speed means four times the altitude consumed. As a result, the altitude required during maneuvers in the vertical plane will be much less in an aerobatic trainer than in a jet. The latter needs exponentially more sky.