Flight Advisor Corner by Hobie Tomlinson

December 2011 Transition to Experimental or Unfamiliar Airplanes ~ Part III

This month we will continue our look at Advisory Circular (AC) Number 90-109, *Airman Transition to Experimental or Unfamiliar Airplanes* which was published by the FAA's Flight Standards Division (AFS-800) on 30 March, 2011.

We will pick up our December discussion with the subject of **Stability and Controllability** as well as take a look at the FAA's **Special Airworthiness Information Bulletin (SAIB)** CE-11-17, issued on 18 January 2011.

Stability, Controllability, and Maneuverability are aviation engineering concepts which are not often well understood by pilots. I would even go as far as to say that we in the flight instruction community have not done a stellar job of instructing our students in the area of aerodynamics!

Stability is an airplane's tendency to remain at its current, steady state flight condition or to return to its steady state flight condition after it has been disturbed by outside forces (i.e. control inputs, turbulence, etc.) *Stability can be thought of as the inverse of maneuverability.* The more stable an airplane is, the less maneuverable it tends to be; conversely, the more maneuverable and airplane is, the less stable it tends to be. Modern fighter aircraft are designed for extreme maneuverability and are so naturally unstable that they cannot be flown without using the artificial stability provided by their fly-by-wire, flight-control computers.

- **Airplanes that exhibit** strong static stability are reluctant to change their flight condition. High static stability – low maneuverability – is a desirable trait in transport airplanes.

- **Over Stability** can cause an airplane to have high control forces and will make it difficult for the pilot to make changes in the airplane's flight path.

- **Under Stability** can make an airplane feel "twitchy" or over sensitive to control inputs and/or atmospheric upsets, such as wind gusts. This can make the airplane difficult to fly precisely. High maneuverability – low static stability – is a desired trait in aerobatic airplanes. *It is a very undesirable trait when flying instruments*.

- **An airplane's stability** increases as its Center of Gravity (CG) moves forward. *The forward CG limit in your aircraft is the point at which its maneuverability will no longer be adequate for all flight conditions*. This usually means the inability to rotate the aircraft to the proper lift-off attitude at the appropriate speed or the inability to adequately flare the aircraft during a full flap landing. The infamous "Platinum Jet" CL601 accident in KTEB a few years back was caused by an attempted take-off with the aircraft's CG well forward of the maximum allowable by the aircraft's CG envelope. The result was that the elevator control did not have sufficient authority to lift the nose wheel off the runway at the proper rotation speed (over stability). This *"surprise"* resulted in an aborted takeoff attempt – well above the maximum abort speed. The aircraft departed the end of the runway at high speed, crashed through the airport fence, crossed a busy road, and crashed into a factory building. Think of your aircraft's forward CG limit as its *"Minimum Acceptable Maneuverability"* limit!

- **An airplane's stability** decreases as its Center of Gravity (CG) moves aft. *The aft CG limit in your aircraft is the point at which its stability is no longer adequate for all flight conditions*. The airplane's control forces become lighter and its attitude/flight path will change easily, which makes the airplane become increasingly prone to being stalled unintentionally. I personally think one of the reasons that we typically see unintentional stall accidents in 4 and 6 seat airplanes is that most of the training completed in those aircraft is usually done at (or near) the forward CG location. Pilots then get into trouble when flying with an aft CG. *FAR Part 23 multiengine aircraft seem especially prone to this Loss Of Control – In Flight (LOC-I) symptom when loaded toward their aft CG limit – especially during single engine emergency operations*.

- ***The vertical lines*** *(fwd. and aft CG limits) in your aircraft's CG envelope* *can be thought of as controllability limits*. Exceed the forward line (CG limit) and maneuverability becomes unacceptable. Exceed the aft line (CG limit) and stability becomes unacceptable. *Take both of these lines (CG limits) very seriously*!

Controllability is the ease (or difficulty) experienced in changing an airplane's flight condition. Proper controllability is achieved by the correct blending of stability and maneuverability. Controllability is enhanced by achieving a good blend of control forces (required to maneuver) and control harmony (balance between the flight controls).

Maneuverability describes how quickly an airplane's flight condition can be changed. Maneuverability requirements typically dictate the size, control displacement, and effectiveness required from the airplane's flight controls. Aircraft designed for high maneuverability (i.e. aerobatic aircraft) are typically designed with large, effective control surfaces, light control forces, and low-to-neutral stability.

Dynamic Stability comes into play when an airplane is disturbed from its steady state condition. *Airplanes with positive stability will return to their pre-disturbed flight condition upon removal of the disturbing influence*. This return (to the pre-disturbed flight condition) can happen slowly (or quickly) and may occur with (or without) oscillations. *An airplane displaying negative dynamic stability will develop larger and larger deviations from its original flight condition when that condition has been disturbed*. This *"divergence"* can happen slowly (or quickly) and may occur with (or without) oscillations. Obviously, an airplane with negative dynamic stability will be difficult (or impossible) to control, depending on the amount and rate of divergence occurring. *An aft CG exceedance will rapidly progress from neutral stability to a* *negative dynamic stability with uncontrollable divergence*! **Take aft CG limits very, very seriously!**

RV-8 ~ Example of High Inertia and/or Low-Drag Airplane

RV-8 photographed at Smith Falls, Ont. on 21may06 ***Wikipedia Commons Image***

Some Typical Stability Modes (along with their piloting effects) are as follows:

- **Negative Longitudinal Static Stability** is when an airplane deviates from its trimmed airspeed and the deviation continues to increase (or decrease) until the airplane either exceeds its never-exceed speed (Vne ~ i.e. "Red Line") or it stalls. *Negative longitudinal static stability requires the pilot to continuously monitor the airspeed indicator and immediately make the required pitch correction, control inputs needed to correct any airspeed deviations*.

- **Negative Longitudinal Dynamic Stability (Phugoid**) is when an airplane deviates slower (or faster) than its trimmed airspeed and then begins to oscillate by accelerating and decelerating beyond its trimmed airspeed by wider and wider margins. These ever increasing deviations (both in amplitude and rate) continue to increase in both airspeed and altitude until the airplane stalls, exceeds Vne, or impacts the ground. *The pilot cannot rely on the airplane to self-correct even minor airspeed deviations caused by control* *inputs, wind gusts, thermal activity, etc*. At the very least, this can result in extreme pilot fatigue, as the pilot must continuously monitor and suppress the excursions.

- **Negative Longitudinal Dynamic Stability (Short Period)** is a pitch oscillation caused by a change in Angle of Attack (AOA) during which the excursions grow larger with each oscillation. Unlike the Phugoid, these oscillations can occur very fast with each cycle taking only one to two seconds to occur. Due to their high frequency and short period, these rapid pitch direction reversals are felt as G-load excursions, which can rapidly become intolerable, despite the seemingly small initial pitch attitude changes. These excursions will continue to increase with every cycle until the airplane either stalls or exceeds its structural limits. (This is not a Pilot Induced Oscillation – PIO – as the airplane will continue its oscillations without any pilot control input.) Suppressing a negative, short period oscillation is extremely challenging due to the requirement for perfectly-timed, counter pitch control inputs of the proper size. This one is extremely serious and will probably result in structural failure of the aircraft**. Fortunately, there are no known experimental airplanes that exhibit this behavior**; however, *the possibility of short period oscillations is one very good reason to wear a parachute during all experimental airplane test flying*!

- **Negative Spiral Stability** is when an airplane in a bank will continue to increase its bank angle unless the pilot prevents it by applying opposite roll control. This is a particularly dangerous trait in airplanes that are flown during night or instrument meteorological conditions (IMC). *This trait requires the pilot to closely monitor the airplane's attitude when turning*. The "roll-off," which occurs due to this characteristic, is usually subtle, thus depriving the pilot of clues such as rolling motion, changes in wind noise, cockpit control position, etc. *Wing dihedral is used to provide spiral stability in airplanes***. Most Type Certificated (TC'd) airplanes** display spiral stability in shallow banks, degrade to neutral spiral stability in medium banks, and display negative spiral stability in steep banks. (*Negative spiral stability during a steep bank is what produces the infamous graveyard spiral*.)

- **Negative Lateral-Directional Stability** leads to "Dutch Roll," which is a yawing, rolling oscillation, caused by sideslip (relative wind coming from either the right or left of the airplane's nose). These excursions grow larger in yaw, roll, or both with each oscillation and will increase with each cycle until the airplane either departs controlled flight or exceeds its structural limit. (Directional stability is usually provided/improved by adding either vertical stabilizer area or ventral fins. This is typically seen on seaplane conversions.) Suppressing Dutch Roll requires well-timed, properly sized counter control inputs. The most effective control is usually the rudder; however, in some airplane designs, ailerons may also be effective. *Dutch roll is a particularly pronounced characteristic of swept wing airplanes*. It is usually cured with a yaw damper. (Yaw dampers are an independent autopilot channel which is always engaged in flight and utilizes the rudder to prevent Dutch Roll. With some specific exceptions, even large aircraft autopilots are two-axis (pitch and roll). **There are presently no known experimental amateur-build airplanes which exhibit this behavior.**

Type Certificated (TC'd) airplanes must exhibit both positive and dynamic stability. Experimental airplanes may exhibit positive and dynamic stability, but they are not required to do so. Just because an experimental airplane shows positive stability traits during cruise flight does not mean that it won't become unstable in the landing pattern, or vice versa. A pilot does not necessarily notice a mildly unstable airplane because an attentive pilot is always making small control inputs to cure minor deviations – often without even realizing that he/she is doing so. The hazard of this type airplane develops when a pilot becomes inattentive due to a distraction and doesn't initially notice the deviation in altitude or flight path. He/she must then make a large correction that will cause a distraction from the other piloting responsibilities. *Some documented examples of instabilities with experimental airplanes in certain flight regimes are as follows*:

- **Following a small airspeed deviation** *slower* than the trimmed airspeed, the airplane will continue to decelerate until it stalls – unless the pilot intervenes. *This is an example of negative longitudinal static stability*.

- **Following a small airspeed deviation** *faster* than the trimmed airspeed, the airplane will continue to accelerate until it exceeds Vne, unless the pilot intervenes. *This is a second example of negative longitudinal static stability*.

- **Following a small rudder pedal displacement**, the airplane will continue to yaw to a larger sideslip angle, unless the pilot intervenes with opposite rudder pedal displacement. *This is an example of negative directional stability*.

- **Following a deviation in airspeed** (either faster or slower) the airplane alternates slowing down and speeding up – with each oscillation becoming larger than the previous one – until it either stalls or exceeds its Vne speed. *This is an example of negative longitudinal dynamic stability (Phugoid)*.

- **After establishing the airplane in a bank,** the bank angle continues to increase unless the pilot applies opposite aileron to stop the bank increase. *This is an example of negative spiral stability*.

These examples pertain to several experimental airplane designs of which hundreds have been successfully flying for years. This statement is not meant to minimize the safety concerns, but rather it is intended to illustrate that some experimental airplanes, which display minor, negative stability traits, can be kept in check as long as the pilot remains absolutely vigilant at all times. The big safety hazard is that the condition can rapidly lead to an emergency situation if the pilot allows himself/herself to become distracted.

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Negative stability is best illustrated by the example of balancing a broomstick in the palm of your hand. It is certainly possible, but doing so while distracted by the requirement to program a Global Positioning System (GPS) navigator is much more difficult. And just like a negative stability trait in your experimental airplane, if it diverges (tilts) too far, no amount of effort or concentration can save it. Another good analogy is the negative directional stability trait found during the landing of a conventional gear aircraft. *If a conventional gear aircraft is allowed to touch down with more than a miniscule amount of drift angle – the inevitable ground-loop is unpreventable!*

An Airplane's Control System plays a major role in the pilot's impression of its stability, controllability, and maneuverability. Airplanes with marginal stability, but high control forces, feel more stable than they actually are because the pilot has to apply a substantial control force pressure to cause even a small deflection of the control surface. However, if that small control surface deflection causes an unexpectedly large airplane response, the pilot will have to spend an inordinate amount of effort to keep the airplane responses manageable. Conversely, an airplane, which displays very low control forces combined with a highly maneuverable response (i.e. aerobatic airplanes), can easily lead to over-controlling. This leads to a series of alternating inputs as the pilot attempts to arrest the airplane's excursions. *Both of these scenarios of negative airplane-pilot coupling are examples of pilot induced oscillations (PIOs) and can rapidly escalate into an out-of-control situation.*

Freedoms Allowed in experimental airplane design and in individual builder's construction decisions may significantly influence the airplane's stability and controllability. *Some items which can have a potential effect ranging from negligible to disastrous are as follows*:

- ***Small errors in wing or tail incidence angles.***
- ***Irregularities in lifting surface finish.***
- ***Improper CG location or calculation***
- ***Addition of flight control gadgetry (i.e. springs, bobweights, or dampers).***
- ***Aileron-rudder interconnects***
- ***Addition of protuberances (i.e. antennas or scoops).***

If your airplane exhibits negative stability behavior, consult a reliable source (i.e. the designer or type club) to determine if this behavior is inherent in the design or particular to your individual airplane. Modifications may be available to minimize this undesirable characteristic. Be extremely careful about making changes to your airplane. If you do make changes, you must devise a thorough and well-conceived flight test plan. This is to adequately evaluate not only the characteristic you desire to improve, but also to verify that it did not produce unintended, undesirable changes to other existing characteristics.

Note: ***Pilots transitioning to experimental airplanes must be aware that the habits and reflexes they learned from flying TC'd airplanes may lead to hazardous results when used in experimental airplanes!***

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Design Maneuvering Speed (Va) is the subject of FAA Special Airworthiness Information Bulletin (SAIB) CE-11-17, issued on 18 January 2011. It was issued as a result of the investigation into American Airlines Flight 587 crash, which occurred shortly after takeoff from KJFK on 12 November 2001. In that accident, the First Officer started "walking" the rudder in response to a perceived airplane upset condition that resulted from entering the previous departure's wake turbulence. The resultant "rudder wagging" induced a vertical stabilizer failure at 200 percent of the design load, subsequently causing the loss of the aircraft. This occurred even though the airspeed at the time was well below the aircraft's equivalent Va speed.

Va is applicable to airplanes certified under 14 CFR, FAR Part 23, the previous Civil Air Regulations (CAR) Part 3, special light-sport category airplanes (S-LSA), experimental light-sport airplanes (E-LSA) and experimental amateur-built airplanes. Va is determined by the stalling speed which corresponds to a particular design limit G-load. This is a design G-load of 3.8 Gs for a **normal category** aircraft in positive G-load flight at max gross weight and with the pilot only pulling the stick or yoke (single control).

It was revealed that many pilots have a misunderstanding of what Va (design maneuvering speed) represents and that they mistakenly believe that they can make any control inputs they desire below Va speed – without undue risk or harm to the airplane. **This, unfortunately, is simply not true!**

Design Maneuvering Speed (Va) is the speed below which you can move **a single flight control**, **one time,** to its full deflection, for **one axis** of **airplane rotation only** (pitch, roll, or yaw), in **smooth air**, without risk of structural damage to the airplane. It is not valid for multiple control deflections, control reversals (doublets), or multiple axes control inputs!

Even though experimental airplanes may not have a published Va, they will all have some maximum maneuvering speed associated with the maximum structural design loads. Pilots must be aware of this speed and adhere to the guidance contained in SAIB CE-11-17. The regulations governing design strength requirements for airplane structures requires adequate strength for a one time, single axis, full control deflection at Va. However, they do not require adequate structural strength to withstand a full control input, immediately followed by a full control input in the opposite direction (termed a doublet). Neither is the aircraft structure required to be strong enough to withstand full control deflections involving multiple axis's at Va (i.e. both full elevator and full rudder or aileron – used during aerobatics to induce a "snap roll, " but at slower speed than Va).

Published Va is for maximum gross weight. Because Va is directly related to the stalling speed at a given G-load (and stalling speed decreases with weight), thus Va must decrease as weight decreases. Another way of looking at this is that the aircraft's inertia lowers as its weight decreases. This lower inertia allows any given control input to produce higher G-loads at the lower weight. To counter this effect, the Va speed must decrease proportionally.

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The FAA wants to impress on all pilots the necessity of knowing the maneuvering speed for their individual airplane and while maneuvering at (or even below) Va, adhering to the following recommendations:

- ✓ **Do Not** apply a full deflection of any control then immediately follow by applying a full deflection of the same control in the opposite direction.
- ✓ **Do Not** apply full multiple control inputs simultaneously (i.e. pitch, roll, and/or yaw simultaneously), or in any combination thereof.
- ✓ **Reduce Va** when operating at less than maximum gross weight.
- ✓ **Be careful** not to confuse design maneuvering speed (Va) with operating maneuvering speed (Vo) in newer designs.

This looks like a good place to break for this month. Next month we will look at ***Transition Training***. The thought for this month is "**Chains of habit are too light to be felt until they are too heavy to be broken." ~ W*arren Buffett / American Businessman***

So, until next month be sure to **"Think Right to FliRite!"**

Merry Christmas!

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2009 Christmas Tree ~ Rockefeller Plaza, NYC

Image by Hobie Tomlinson

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