



# Longitudinal Stability

*I am feeling more confident and in tune with my aircraft as I progress through these various tests. BJJ is becoming more and more an intimate part of me and a living entity rather than an inanimate object. As I fly the various maneuvers, I find that my control inputs become natural, an extension of myself rather than a conscious control input with feedback to mark appropriate secondary and tertiary responses.*

*I now want to explore the input/response arena. I want to investigate the details of flight control and the responses that my aircraft can return, so that I can fly safely, effectively and sensitively to everything it tells me; in the feel on the stick; the gravitational forces I feel; the sounds that I hear; and the sights that I see out of my canopy.*

**Static Stability;** is an aircraft’s tendency to return to an original condition after a disturbance. The disturbance can be caused by the pilot’s control input, or by an aerodynamic air-flow disturbance that kicks the aircraft off its current flight path and attitude.

**Dynamic Stability;** is whether the aircraft does return to its original flight condition and attitude, and how it does this. For instance, it may, or may not oscillate several times before it gets there.

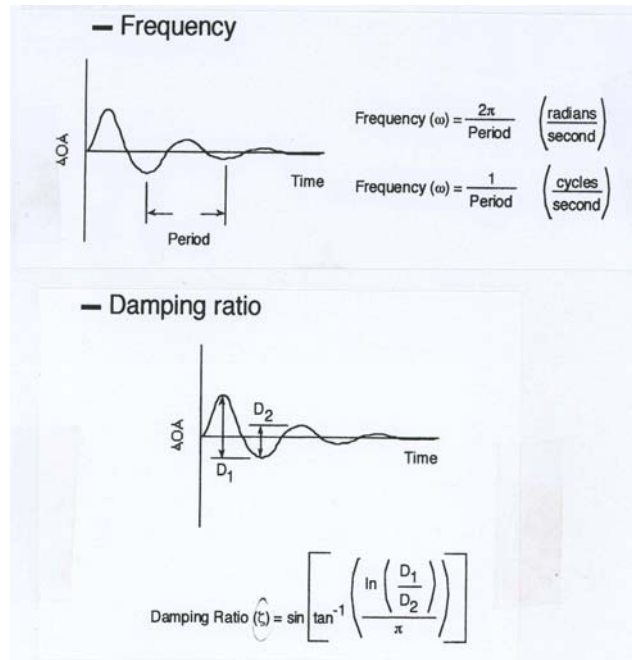
We will investigate two longitudinal dynamic modes:

- Short Period
- Long Period (Phugoid)

**Short Period:**

When we think of an aircraft, we expect the elevator to change and maintain the angle of attack (AOA). The horizontal stabilizer’s task

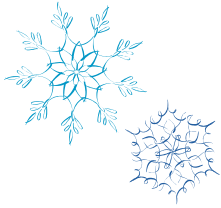
is to resist this change and to restore the aircraft’s flight path to the original. For a ‘stable’ aircraft the larger the AOA introduced, the greater will be the nose down moment when the elevator is relaxed. Similarly, the greater the decrease in the AOA, the greater the nose-up moment when the elevator is relaxed. The **short period** is defined by the frequency and the dampening ratio of the oscillations following a disturbance as described above.



It is interesting to note that the **frequency** varies directly with airspeed, whereas the airspeed has virtually no effect on the **dampening ratio**. For the mathematicians the formulas above describe these qualities:

So what does this mean to me the pilot? **Short Period** dynamic stability is of prime concern in maneuvering, as example, in a tight

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ILS approach, or in a precision landing flare. Consequently this flight quality will largely influence your ability to finesse precision maneuvers. The ideal aircraft will have balance between being responsive enough, but not too responsive.

A low short period frequency will result in a sluggish aircraft response, whereas a high short period frequency will result in an aircraft sensitive to control inputs.

In addition, you want your aircraft to have maximum dampening, but again without sacrificing maneuverability.

## Long Period (Phugoid):

This is a measurement of the aircraft's response to airspeed changes. In essence, it occurs when the aircraft is at one airspeed, but is trimmed for another. In flight, the aircraft trades altitude for airspeed over a sine wave flight path. (See illustration )

Two characteristics are noted: The AOA remains essentially the same throughout the cycles, and positive longitudinal dynamic stability is indicated, by the aircraft eventually returning to its original trimmed air-speed.

Long period (phugoid) dynamics are the same as those for short period. Both frequencies and

dampening ratios are calculated in the same manner.

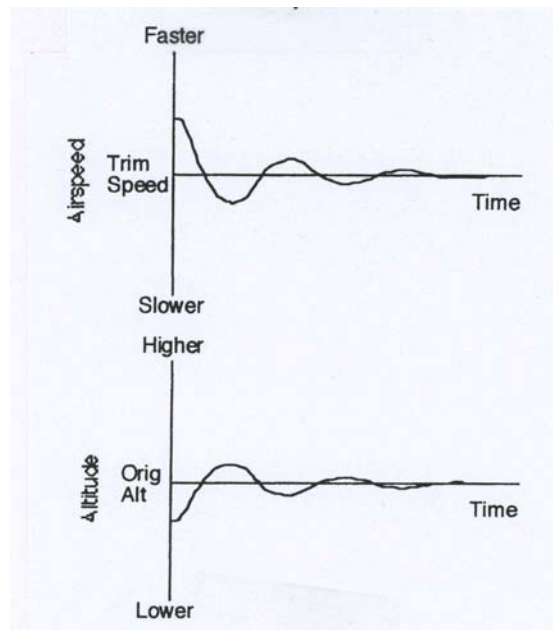
From the cockpit perspective, the **Long Period** dynamic stability affects the non-maneuvering tasks. For instance, under IMC or externally controlled flight parameters, altitude hold or trimming to eliminate nuisance flight characteristics will be more difficult, resulting in increased pilot workload. Corrective action to overcome these tendencies is limited, dependent mainly on aircraft design considerations.

## Test Flights:

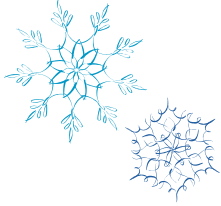
To test our aircraft, we will devise several test cards. First we will test for **Static Longitudinal Stability**, and then for **Dynamic Longitudinal Stability**. In this second series of tests, we will look at both the **Short Period** and the **Long Period (Phugoid)** stability qualities.

## Static Longitudinal Stability Flight Tests:

Test one will have us deflect the trimmed flight path, by pulling on the stick to reduce the airspeed by 10%. We should feel a definite stick force. We will then increase the pull force on the stick to reduce the airspeed by 20%. We will record our results.



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# Longitudinal Stability

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## Static Longitudinal Stability, Test 1

Forward C of G

6000 AGL

Trim aircraft for straight and level flight, target airspeed 130 mph

Pull (light) on stick to stabilize at 10% lower airspeed (117 mph) (Should require a definite stick force)

Comments:

*No noticeable change in stick pressure!*

Pull (additional) on stick to stabilize at 20% lower airspeed (104 mph) (Should require a definite **additional** stick force)

Comments:

*Small, if any increase in stick pressure noted at 110 mph, then some stick pressure. This would indicate a near 'neutral' stability.*

This test card and the recorded results are shown below:

Next, we repeated this test but using push forces on the stick to investigate the static

## Static Longitudinal Stability, Test 2

Repeat process of Test 1 with "push" forces

Forward C of G, 6000' AGL

Trim aircraft for straight and level flight, target airspeed 130 mph. Push on stick to stabilize airspeed at 10% higher (143 mph). (Should require a definite stick force)

Comments:

*Started light push pressure, then released stick. Aircraft nose continued downward with a resultant increase in airspeed up to 140 mph. Required pull back on stick to prevent nose from continuing its downward travel.*

Push on stick to stabilize airspeed at 20% higher (156 mph) (Should require a definite increased stick force)

Comments:

*Slight stick push required to reach 150 mph. Then definite stick pressure required to maintain 156 mph.*

stability resulting from the aircraft's return to its original trimmed flight path. These test results are shown below:

From the above data, we learn that CF-BJJ has very near neutral static longitudinal stability. The second 'push' test indicates that there is definite a positive trend, but I suspect the 'breakout' and 'friction' control forces almost match the positive stability forces, and the aircraft will not return to its trimmed flight path with small stick inputs or flight aerodynamic disturbances. Since the control forces on this aircraft are already 'light', this will tend to increase the pilot's workload, but at the same time make the aircraft more responsive.

## Longitudinal Dynamic Stability Flight Tests:

The **Short Period** longitudinal **Dynamic** stability tests were conducted as shown on the test card with comments below:

### Dynamic Longitudinal Stability, Short Period, Test 3

Do after confirming that the aircraft has positive static Longitudinal Stability.

Trim aircraft for straight and level flight (140 mph)

With smooth (fairly) rapid motion push stick down a few degrees

Quickly reverse the control input back to trim (start) position

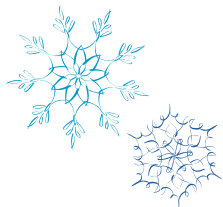
Release stick (but guard it)

Aircraft should oscillate briefly about trim position before stopping at trim position

Comments:

*With the initial push force on the stick, aircraft nosed down and upon release immediately returned to trim position. There were no oscillations. Test was verified three times. Aircraft displays positive longitudinal stability.*

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Finally we tested our aircraft for the **Long Period** or **Phugoid** longitudinal **Dynamic** stability. We trimmed the aircraft for straight and level flight, and then pushed on the stick to increase the speed by 5 mph. On releasing the stick we observed the aircraft's ability to return to the trimmed position and airspeed. We repeated the test with pulling on the stick as per above. The results are shown below:

#### Dynamic Longitudinal Stability, Long Period, Test 4

Trim aircraft for straight and level flight (140 mph)  
Push stick to increase speed by 5 mph (145 mph)

Release stick. Aircraft should oscillate around the trim position  
Several times before motion dampens out.

Comments:

*Aircraft showed a slow return to almost the trimmed condition (ie. 140 mph). Time of 1.5 to 2 minutes required to reach straight and level flight at 143 mph.*

Repeat with a pull force:

Comments:

*Again, a very slow return to trimmed flight. It took 3 oscillations before reaching it.*

#### Summary:

This RV-9A has positive longitudinal stability, both in the static as well as in the dynamic modes. In the static mode, this stability almost seemed to be neutral although I believe that the natural friction and control breakout forces tend to overcome what positive stability forces are available. In the dynamic longitudinal stability tests, 'BJJ' displays positive stability, but only very lightly so. This gives this aircraft excellent pilot response to elevator input, but also tends to overload the pilot when attempting to fly a specific altitude over

time. From experience, an autopilot with 'altitude hold' is a valuable flight companion when flying through controlled airspace and keeping an eye out for VFR traffic.

Perhaps this whole exercise is academic, since unless we compare these characteristics with another design with differing ones, we really can only surmise where we fit in the broad spectrum of aircraft. The benefit of this study is in better understanding the issues surrounding control input, response to control input, and our aircraft's ability to resume trimmed flight after a disturbance to its flight path.

In our next column we will continue to investigate this aircraft's stability parameters.

Acknowledgements:

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Jack Dueck, EAA HAC, FA, TC.