NASA
National Aeronautics and
Space Administration

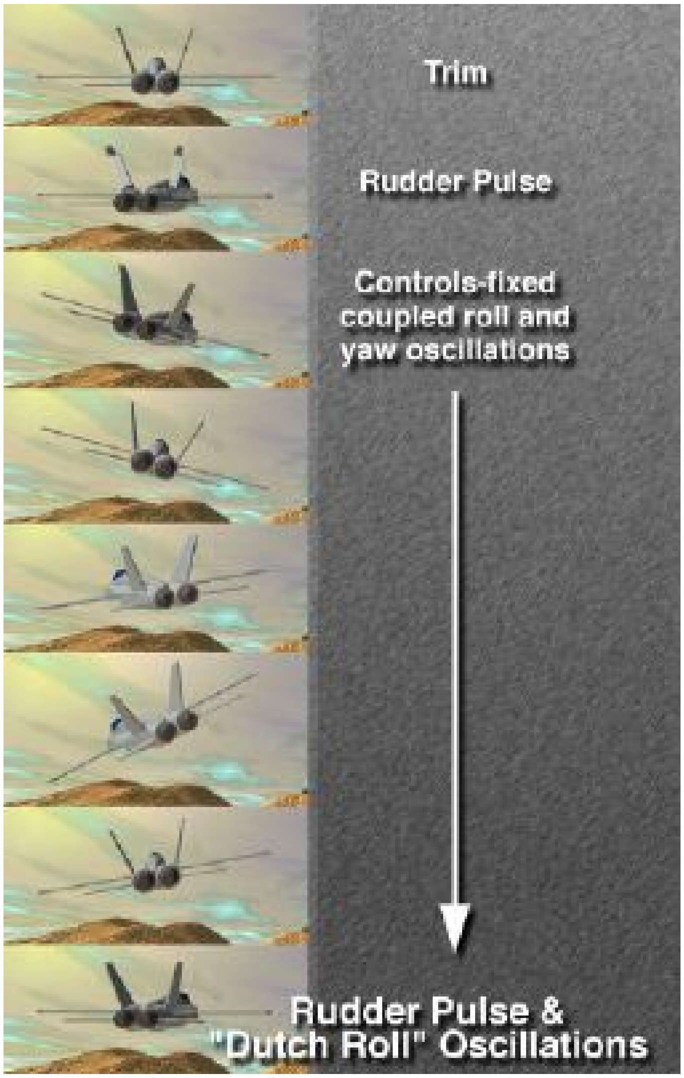
Information Summaries

IS-97/08-DFRC-C1

Control Pulse

Background

One of the most important stability measurements for an airplane is the determination of dynamic response. For a stable airplane dynamic response is the measure of the frequency and damping of the oscillatory motion. For an unstable airplane it is a measure of the time for the divergence to double in amplitude. In order to measure the dynamic response, the aircraft must first be disturbed from trimmed flight. The control pulse is the primary method of initiating this disturbance.



Control pulses can be introduced in either the pitch, yaw, or roll axes by abruptly moving either the elevator, rudder, or aileron controls. If the intent of the pulse is to disturb one of the oscillatory modes, the control input is fairly large and rapid. The control is released after the pulse to allow the airplane to oscillate freely without pilot inputs.

As more sophisticated mathematical analysis programs were developed, the purpose of the "pulse" changed slightly. Parameter Identification (PI) methods could identify not only the frequency and damping, but could also identify the control effectiveness and other more subtle features of the mathematical model that described the motions of the airplane (stability and control derivatives). When the pulse is to be used for PI analysis, the control input is usually very abrupt and is usually a doublet (that is, the control is moved sharply in both directions before release). A sharp doublet for PI analysis is much quicker than the standard dynamic response pulse and, if done properly, will induce only a small amount of oscillatory motion.

Frequency and damping measurements do describe the response of the airplane, but tell the engineers very little about how to solve a problem if the response is not as expected. PI analyses will provide a complete breakdown of the various features contributing to the observed response and are usually quite helpful in solving problems. PI analyses are used to update simulators and thus improve the overall understanding of the airplane's dynamics.

Since the roll and yaw axes are coupled through sideslip, the pulses are usually described as either "pitch" pulses (using the elevator control), or "lateral-directional" pulses (using either the rudder or the aileron controls) to initiate "Dutch Roll" oscillations.

In some cases a special sequence of control inputs may be used, such as a rudder doublet followed immediately by an aileron doublet, to enhance the PI analysis.–

1. Specific Objective of the Test

Determine the dynamic response (frequency and damping, or divergence rate) of the airplane in either the longitudinal or lateral-directional axes for a particular flight condition. For PI-type pulses, determine the set of stability derivatives that define the airplane's dynamic response at a particular flight condition.

2. Critical Flight Conditions

Dynamic response varies with the following variables:

- Airspeed
- Altitude
- Mach number
- Angle of Attack
- Configuration (flaps and landing gear position)

Critical flight conditions for dynamic response testing are highly dependent on the individual airplane and not easily generalized. Caution is usually exercised in the high Mach number region or transonic region where directional stability levels could be low, and in the high altitude, low speed region where damping in all axes could be low.

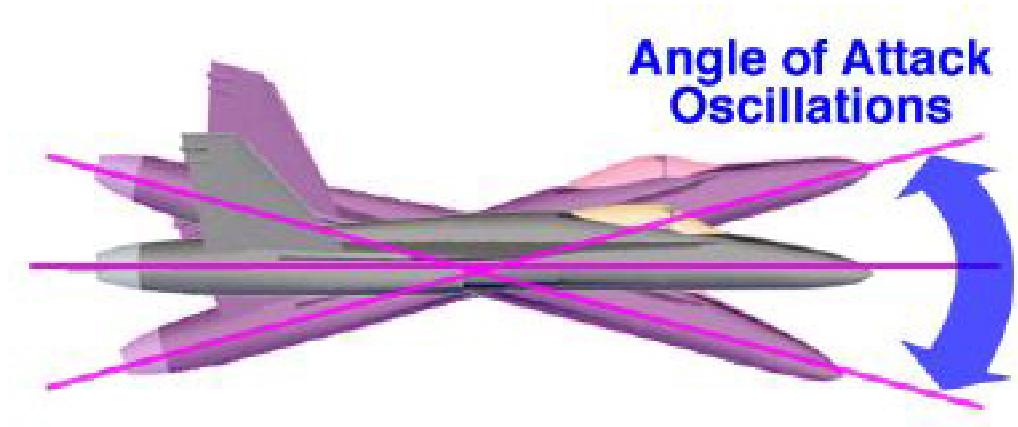
Although the primary variables of interest are angle of attack and dynamic pressure, the flight conditions are identified to the pilot in the more common terms of airspeed and altitude. Control pulses, like pushover-pullups, are very short maneuvers that do not need to start from precisely stabilized trim conditions. Most control pulse maneuvers are 8 to 12 seconds in duration. They are therefore of value in the testing of rocket-powered aircraft or fighters where stabilized flight test time is difficult to obtain.

3. Required Instrumentation

The parameters usually measured and recorded during a control pulse are shown in Table (1-1). Notice that this is a large list of measurements, including nearly all of the dynamic instrumentation on the airplane. Each measurement contributes to the understanding of the maneuver dynamics, and some of the subtle interactions that are defined by the PI process. If only frequency and damping are desired, they can be determined with only a few measurements, such as angle of attack and sideslip.

A continuous time history of these parameters is needed for the entire maneuver. A sampling rate of at least 10 data samples every second is necessary to accurately record the maneuver, and each data sample must be accurately time-correlated with the data samples of the other parameters. This is especially true if the maneuver is to be analyzed using a PI method. The PI process must be able to relate a particular measurement of angle of attack with a corresponding measurement of normal acceleration, pitch rate, and elevator position at the same instant in time.

Starting Trim Point
The control pulse will identify the frequency and damping data for one flight condition of Mach number and altitude. For PI analysis, the stability derivatives will be appropriate for the test angle of attack and Mach number. The flight test engineer will establish a table of flight conditions where control pulses are desired. This table usually calls for particular speeds, altitudes and aircraft configurations covering the entire flight envelope of the airplane. A typical sample table of flight conditions for control pulses is shown in Table (1-2). Notice that a control pulse does not have to start from a stabilized level flight condition. It can be performed during a climb or descent, or even during a turn. The only stipulation is that the airspeed be relatively constant at the beginning of the pulse.



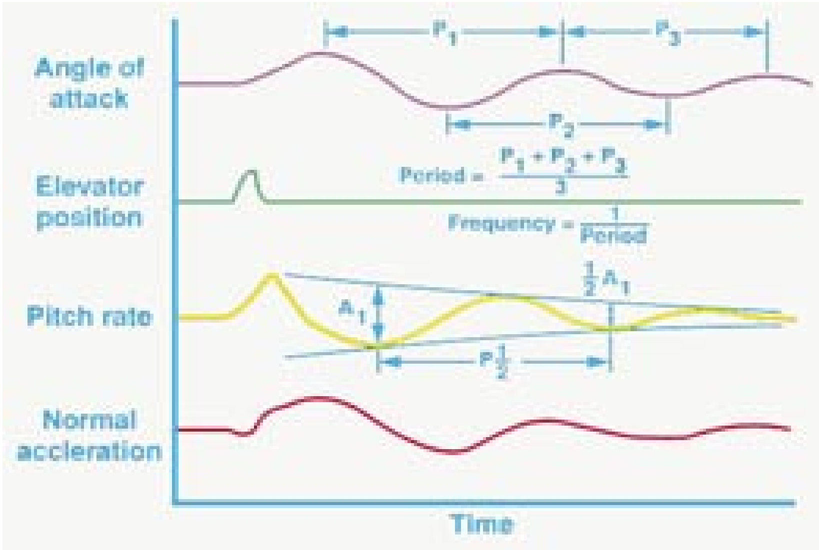
5. Description of a Control Pulse
The pilot establishes the airplane at the desired speed, altitude and starting angle of attack. The pilot will then trim the airplane and obtain a short "trim shot" before initiating the pulse. In many cases the aircraft may be decelerating or descending and the pilot merely starts the pulse when the speed or altitude passes through a desired test point. If the pulse is intended to initiate an oscillation for frequency and damping measurements, the pilot will move the flight control rapidly in one direction and will not release the control until the airplane has obviously been disturbed from its trimmed state. After the controls have been released, the pilot will allow the airplane to oscillate freely with his hands and feet off of the controls, until the motions have damped, or until the airplane deviates significantly from the desired flight condition.

For Parameter Identification control pulse maneuvers a control doublet is usually used. The pilot will abruptly cycle the control in both directions, then immediately release the control, regardless of the magnitude of the resulting upset.

6. Measures of Success
A successful control pulse will meet the following test criteria:

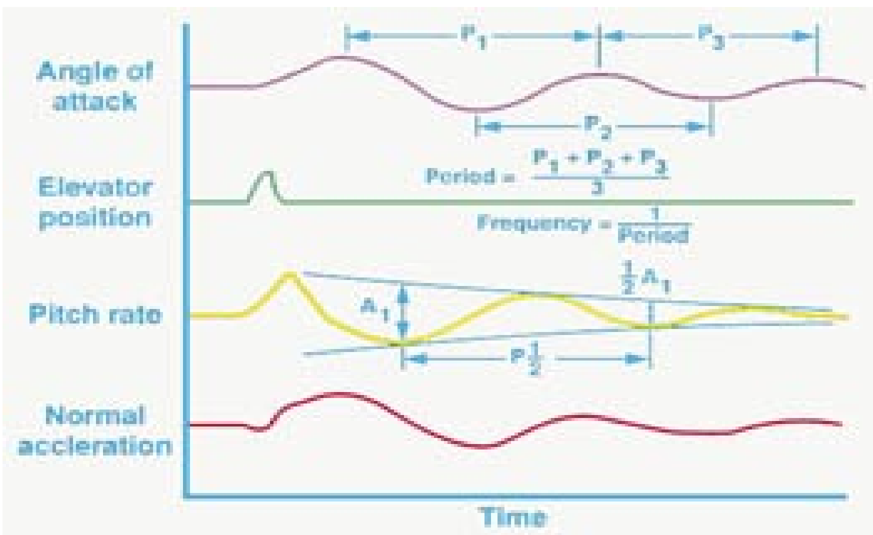
■All instrumented parameters were recorded properly. Table (1-1):
■Airspeed variations during the oscillations following the pulse were small (usually less than 10 knots).
■The oscillatory mode was disturbed enough to identify frequency and damping, or if the maneuver was for PI purposes, the control inputs were sharp and not cross-coupled (that is, an elevator pulse did not also result in a small aileron input).

Frequency can be determined by first marking the location of the peak values for one of the oscillating measurements as shown in Fig. PULS 3.



Averaging the time between the peaks on one side will produce the period of the oscillation or time for one cycle (seconds per cycle). Frequency is merely the inverse of this measurement (cycles per second).

Damping can be determined by first connecting the peaks with a smooth curve as shown in Fig. PULS 3.



Measure the distance between the two enveloping curves at a time shortly after the control was released (A1). Mark the time. Now find a later time where the distance between the two envelopes is exactly half of the first measurement (1/2 A1). Again mark the time. The time measurement between the first and second marks is the time-to-half-amplitude (T1/2) which defines the damping of the oscillation.

Table 1-1

Listing of Instrumentation Parameters

Parameter	Used for
Airspeed	Compute Mach and dyn. pres.
Pressure Altitude	
Outside Air Temperature	
Normal Acceleration	Compute normal force deriv. (PI)
Elevator Position	Identify start of free oscil.
	Compute elevator deriv. (PI)
Angle of Attack	Measure freq. and damping
	Compute AOA deriv. (PI)
Pitch Rate	Measure freq. and damping
	Compute pitch rate deriv. (PI)
Angle of Sideslip	Measure freq. and damping
	Compute sideslip deriv. (PI)
Lateral Acceleration	Compute side force deriv. (PI)
Yaw Rate	Measure freq. and damping
	Compute pitch rate deriv. (PI)
Roll Rate	Measure freq. and damping
	Compute pitch rate deriv. (PI)
Aileron Position	Identify start of free oscil.
	Compute aileron deriv. (PI)
Rudder Position	Identify start of free oscil.
	Compute rudder deriv. (PI)

Table 1-2

Table of Control Pulse Test Conditions

Config.	Alt.	Airspeed	(Mach)	Angle of Attack
Clean	10,000	140	.26	6.69
		200	.36	3.28
		250	.45	2.10
		300	.54	1.46
	20000	200	.44	3.28
		250	.55	2.10
		300	.65	1.46
		350	.75	1.07
	30000	200	.54	3.28
		250	.67	2.10
		300	.79	1.46
		350	.90	1.07
	5000	120	.20	9.90
Gear, Flaps		140	.23	6.69
		180	.30	4.04