

Information Summaries

IS-97/08--DFRC-H1

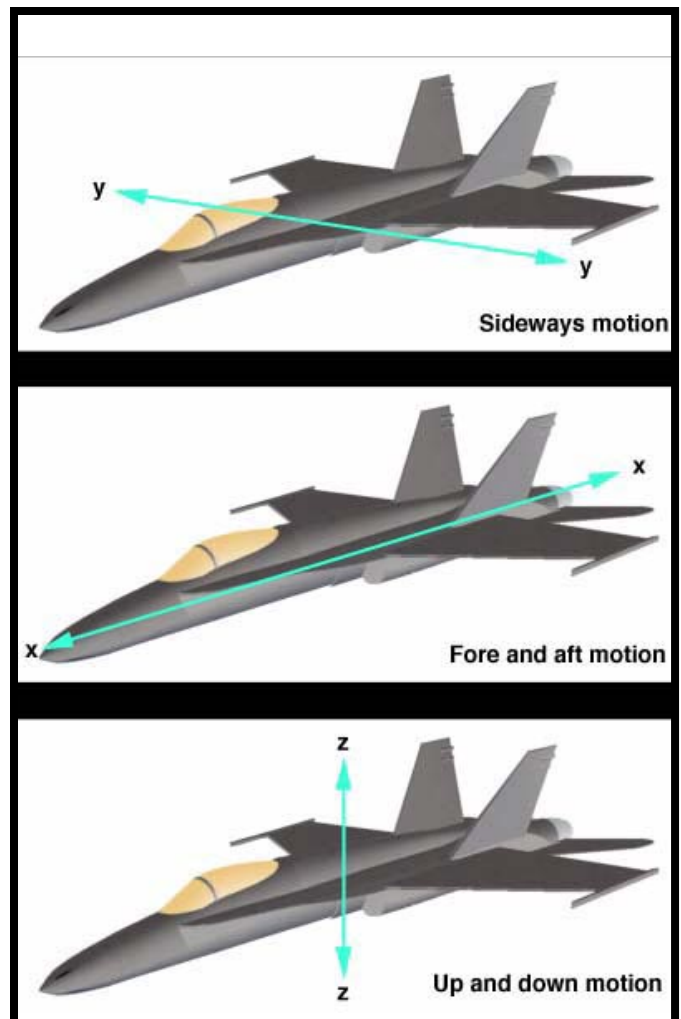
Introduction to Flight Testing

Flight testing is the process of gathering information (or data) which will accurately describe the capabilities of a particular type of airplane, and which can be used to accurately predict and optimize the use of all airplanes of that same type in future missions. Flight testing of research airplanes constitutes the gathering of data in regions of the flight environment where little past information has been obtained. This information is then used to design future airplanes which can operate safely in this new environment. The test maneuvers which are used to obtain this data are described in detail in sections that follow this introduction. There are some common elements and special terminology in these maneuver descriptions which will be introduced now to avoid duplication.

The Axis System

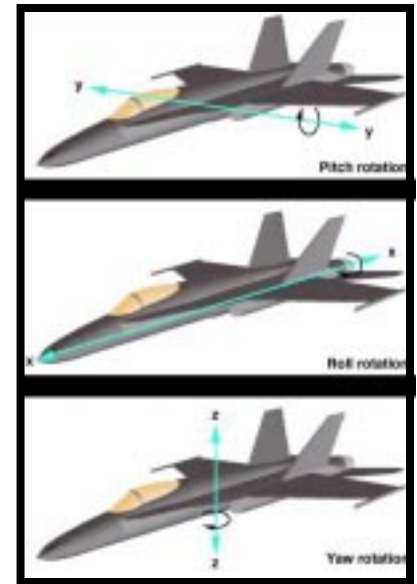
A good understanding of the basic axis system used to describe aircraft motion is necessary to fully appreciate flight test data, since all measurements are referenced to this axis system. Aircraft translational motion is described in terms of motion in three different directions, each direction being perpendicular to the other two (orthogonal). Motion in the X direction is forward and aft velocity. The Y direction produces sideways motion to the left and right, and up and down motion is in the Z direction

The rotational motion of an aircraft can be described as rotation about the same three axes; pitch rotation (nose up or nose down) is about the y axes, lateral or roll rotation (one wing up or down) is about the x axis, and yaw rotation (nose right or left) is about the z axis.



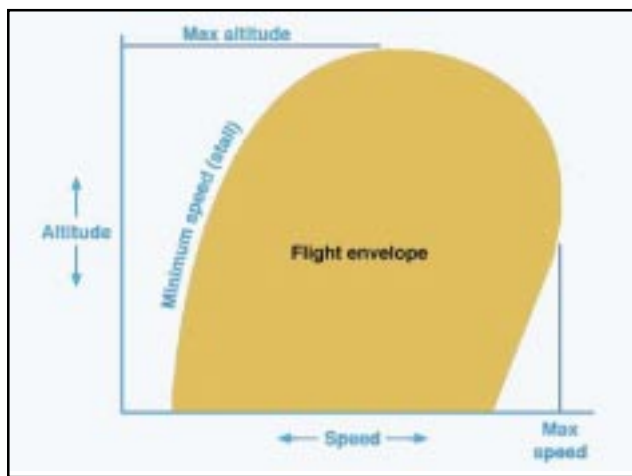
Translational Axes

There are several slightly different versions of the basic axis system just described. They differ primarily in the exact placement of the zero reference lines, but are generally similar in their directions. (For example, the body-axis system uses the fuselage center line as the x axis, while a wind-axis system uses the direction that the aircraft is moving through the air as the x axis.)



Performance

Performance generally refers to the motion of the airplane along its flight path, fore and aft, up or down, right or left. The term "Performance" also refers to how fast, how slow, how high and how far. It may also refer, in



Aircraft Performance

general sense, to the ability of an airplane to successfully accomplish the different aspects of its mission. Included are such items as minimum and maximum speed, maximum altitude, maximum rate of climb, maximum range and speed for maximum range, rate of fuel consumption, takeoff and landing distance, weight of potential payload, *etc.* There are specific maneuvers which are used to measure and quantify these characteristics for each airplane. In many cases, flight testing takes place in a competitive environment to select the best airplane for accomplishing a particular mission. Since all of these performance measurements are strongly affected by differences in the weather conditions (that is, temperature, pressure, humidity, winds),

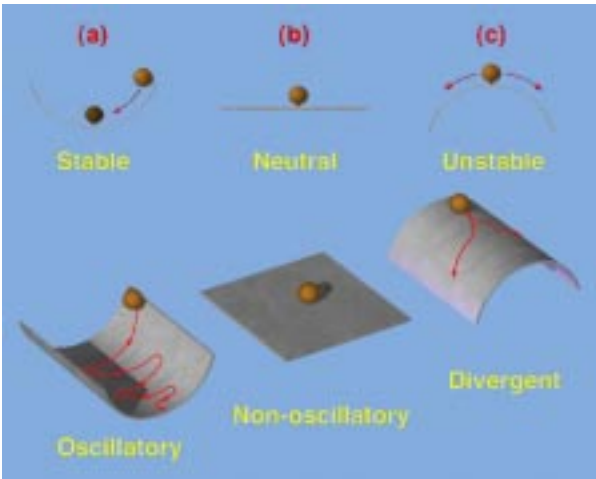
there are some very specific and complex mathematical processes which are used to "standardize" the test results. The "standardization" process corrects each of the test-day measurements to an artificially created standard-day condition. In this way valid comparisons can be made between airplanes that were tested on different days or at different atmospheric locations.

Stability

Stability refers in a general sense to the rotational motion of an airplane about its axes; roll, pitch, and yaw. "Stability" is defined as the tendency of an object to return to an initial rest or trim condition when it is disturbed. A marble placed in the bottom of a shallow trough is said to be stable to that trim condition .

Oscillatory

When disturbed it will tend to return to that resting place at the bottom of the trough. It may overshoot and oscillate back and forth, but it will continue to seek the lowest point in the trough. Static stability is a measure of the strength of that returning tendency. A trough with steep sides provides a higher level of static stability for the marble than one with shallow sides. The motion that results from a statically stable condition is called "oscillatory". If we set the marble on a flat table, there is no tendency for it to return to any trim point .



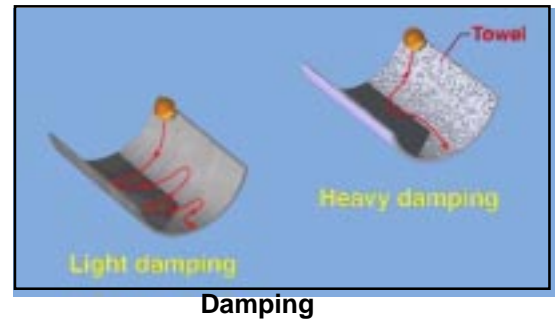
This condition is called "neutral stability". The motion resulting from a condition of neutral stability is called "non-oscillatory". If we turn the trough upside down, we can balance the marble at one point on the top of the trough, but when disturbed it will tend to move away from the balance point at an increasing rate.

This is an example of an unstable condition, or "static instability". The motion that results from static instability is called "divergence".

Damping

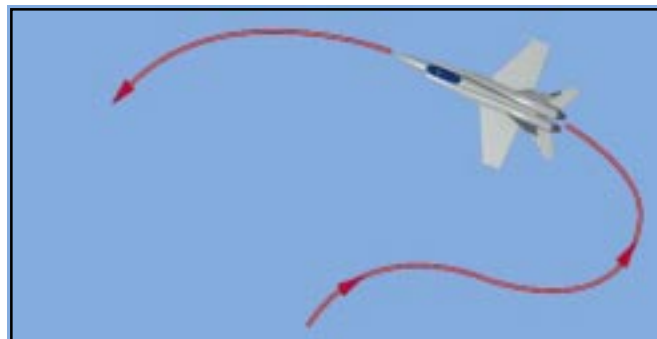
Damping is resistance to motion. Damping only exists when actual movement is occurring. For an airplane it is usually characterized as being proportional to the rate of movement, or velocity. (Note that "velocity" can be either translational - speed, or rotational - revolutions). Damping is usually related to some form of friction. If we line the trough referred to in the stability example with a towel, the marble will still seek the lowest point in the trough (still statically stable), but the towel has increased the friction between the marble and the smooth sides. The marble will not move as rapidly and will not oscillate back and forth as much as in the previous example. The towel has added damping to the motion of the marble.

The marble rolling back and forth in a trough is a demonstration of certain laws of physics. Engineers have applied the magic of mathematics to improve their understanding of many of these laws of physics. The mathematical equations which describe the motions of an airplane in flight, (or a marble in a trough) are called "differential equations" and they are based on an advanced mathematical concept called Calculus. By applying a marvelously simple mathematical trick, called the Laplace Transform, engineers can identify specific mathematical terms within the equations of motion which cause certain characteristics to occur in the observed motions. Once identified, these terms can be manipulated by altering the shape or location of various aircraft components (changing the size of the tail, for example). In this way the aircraft designer can produce an airplane that will have the desired levels of stability and damping.



Maneuverability

Maneuverability is defined as the ability to change the speed and flight direction of an airplane. A highly maneuverable airplane, such as a fighter, has a capability to accelerate or slow down very quickly, and also to turn sharply. Quick turns with short turn radii place high loads on the wings as well as the pilot. These loads are referred to as "g forces" is considered one measure of the force acting on the air- imposed by the gravitational a maneuver exerts 5 times the earth.



and the ability to "pull g's" maneuverability. One g is plane in level flight im- pull of the earth. Five g in gravitational force of the

Maneuverability

Flight Test Instrumentation

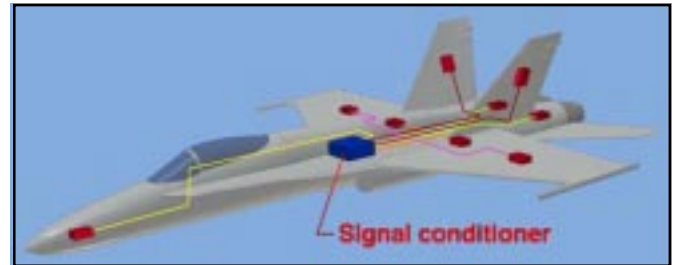
Gathering Data



Sensors (Transducers)

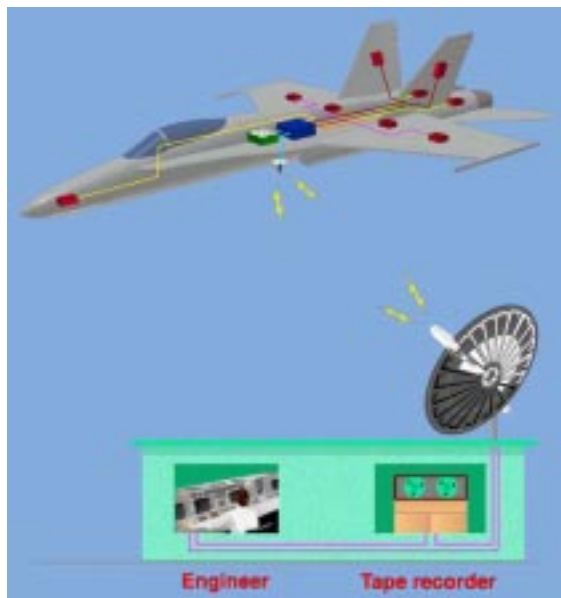
The purpose for flight testing is to gather data about the flight characteristics of an airplane and its subsystems for subsequent analysis on the ground. This data gathering process starts with sensors or transducers which have been mounted throughout the airplane. Transducers are devices which convert mechanical measurements into electrical signals. Different kinds of transducers are used to measure control positions, pressures, temperatures or loads.

The electrical signal from each transducer is routed through special instrumentation wiring to a central location in the airplane where it is connected to signal conditioning equipment. The signal conditioner "conditions" each transducer signal to a common format and organizes all of the signals for efficient recording. Many different terms are used to describe the various phases or processes that are included in this "conditioning", such as multiplexing, commutating, sub-commutating, digitizing, analog-to-digital converting, time-code generating, pulse-code-modulating, *etc.*



Wiring To Signal Conditioning Unit

The resulting organized stream of data is then transferred to an on-board tape recorder and also to



Ground Station and Control Room

a telemetry transmitter. The tape recorder records the data on magnetic tape in much the same way that music is recorded on a tape cassette. The telemetry transmitter transmits the same data stream from the airplane to a ground station on a selected radio frequency, in much the same way as a commercial radio station broadcasts music to our homes.

Recorder & Telemetry





The ground station receives the data stream and also records all of the data on another, ground based tape recorder. The ground station also converts portions of the data stream into electrical signals that can be displayed on indicators or strip charts in the ground control room. In this way engineers on the ground can monitor flight activities and can assist the pilot in the safe conduct of the flight.

If an aircraft is expected to remain within easy range of the ground station for all of its flights, it may not be equipped with an on-board recorder. This decision reduces complexity and saves weight. The data is transmitted from the airplane to the ground and the ground recorders are the only source of data for post flight analysis.

Ground Station and Control Room Without On-Board Recorder

Sensors

Nose Boom

Nose boom installations are fairly standard on test aircraft. The nose boom allows critical measurements of both pressure and the flow angles to be measured well in front of the fuselage where the measurements are not influenced by the shape of the aircraft.

Pitot-Static System

The pitot-static system is the basic measurement method for determining speed and altitude. It includes two pressure measurements. Total pressure (or pitot pressure) represents the pressure being applied to the front of the airplane as it moves through the air. It is measured by using a pressure transducer to measure the pressure inside a forwarding-facing tube at the front of the nose boom. Static pressure represents the undisturbed pressure of the atmosphere at the altitude that the airplane is flying. It is measured by side-facing tubes or holes on the top and bottom of the nose boom. The static pressure measurement can be related directly, through a mathematical formula, to the altitude that the airplane is flying. The difference between the pitot and static pressure can be related (through another mathematical formula) to the speed of the airplane through the air.



Nose Boom Pressure Sensors

sure of the atmosphere at the altitude that the airplane is flying. The difference between the pitot and static pressure can be related (through another mathematical formula) to the speed of the airplane through the air.

Angle of Attack and Sideslip Vanes

Immediately behind the total and static pressure tubes on the nose boom are two vanes (very much like miniature weather vanes) that pivot freely on posts extending vertically and horizontally from the nose boom. A transducer measures the position of these vanes relative to the fuselage centerline. The resulting angles are called angle of attack and angle of sideslip. Both are key measurements for determining the stability of an airplane.



Nose Boom Angle Sensors

Gyros and Accelerometers

Miniature gyroscopes (gyros) measure the rate of rotation about the three axes mentioned earlier (pitch rate, roll rate, and yaw rate). Accelerometers measure the linear acceleration along the same three axes (fore and aft - X, sideways - Y, and up and down - Z). The three accelerometers and three gyros are usually very carefully aligned and mounted near the aircraft's center of gravity, often on the same mounting platform.

Strain Gages

Loads are measured by mounting strain gages on the structural parts to be monitored. These sensors are very small wires which are bonded to the structure. When the structure is under load there will be a slight expansion or contraction of the part due to the load. This minute change in dimension is sensed by the strain gage which produces an electrical signal in much the same manner as the other transducers.