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AEROSPACE FLUID POWER AND CONTROL/ACTUATION SYSTEM GLOSSARY

1. PURPOSE:

This aerospace information report contains in a single document terms relevant to high performance flight control actuation systems with fault-tolerant capability. It represents the United States recommendation to the International Organization for Standardization (ISO).

2. SCOPE:

General terms peculiar to aerospace fluid power and control systems are defined in this glossary. Relevant terms have been excerpted from the referenced documents and listed as aerospace terms that are believed to be most useful as a reference for future air vehicle fluid power and control actuation system designs. This is a systems document and the only component-related terms are those significant at the systems level.

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3. REFERENCES:

ARP243 - Nomenclature, Aircraft Hydraulic and Pneumatic Systems

ARP1181 - Terminology for Redundant Flight Control Systems

AIR1799 - Missile Flight Control Actuation Terminology

DIS 5598 - Hydraulic and Pneumatic Fluid Power - Vocabulary, ISO/TC131

DP 8625 - Aerospace Fluid Power and Control System Glossary

ISO 6771 - Pressure and Temperature Classifications - Fluid Systems and Components - Aerospace

MIL-STD-721 Definitions of Terms for Reliability and Maintainability

CHAPTER 1 - GENERAL PRESSURE TERMS AND DEFINITIONS

TERMS	DEFINITIONS
Absolute Pressure	Pressure value using absolute vacuum as a reference.
Ambient Pressure	The static pressure surrounding a component.
Atmospheric Pressure	Absolute pressure of the atmosphere at a given location and time.
Breakout Pressure	The pressure required to overcome static friction in a component.
Burst Pressure, Actual	Pressure at which a component bursts, exhibits massive leakage due to permanent or non-permanent structural failure, or due to structural deflection.
Burst Pressure, Minimum (Ultimate Pressure)	Pressure during burst pressure testing up to which no externally visible bursting and no significant external leakage occurs. Deformation and permanent set are permitted. Function may be impaired.
Certification Pressure	The authorized pressure for formal acceptance tests.
Class of Hydraulic System	A pressure standard for a military aircraft hydraulic system based on the nominal pump output pressure or other supply pressure, defined in ISO 6771.
Control Pressure (Pilot Pressure)	The pressure required to control or influence any motion or change in motion.
Cracking Pressure	The pressure at which a valve becomes unseated and begins to pass fluid.
Cut-out Pressure	The pressure at which the sequence of reduced flow of a component or system begins.
Differential Pressure	The difference in value between two functionally related pressures occurring simultaneously at different points, such as at opposite sides of an actuator piston.

TERMS	DEFINITIONS
Dynamic Pressure	That portion of the local pressure in a fluid, which is recovered when the fluid is brought to rest.
Flushing Pressure	Pressure required to flush a system at defined conditions (for instance: at defined flow).
Gauge Pressure	Absolute pressure minus atmospheric pressure.
Idling Pressure	Pressure required to maintain a system or component at the idling speed, or flow.
Inlet Pressure (Supply Pressure)	Pressure at the inlet of a component.
Internal Pressure	The pressure inside a system or component.
Maximum Pressure	The highest transient pressure that can occur temporarily.
Minimum Operating Pressure	The lowest pressure at which a system or component must function.
Minimum Pressure	The lowest transient pressure that can occur temporarily.
Maximum Permissible Pressure	The highest pressure that is permitted for safety reasons.
No-Flow Valve Pressure Gain	Ratio of change in controlled pressure to the corresponding change of a controlling variable at no flow.
No-Load Pressure	Pressure required to maintain a system at a specified speed with no external load.
Nominal Pressure (System Pressure) (Rated Pressure)	The general pressure setting of the system.
Operating Pressure	The pressure available to a component or system during normal operation.
Opposing Load Pressure	Pressure acting to oppose operating pressure.
Outlet Pressure	Pressure at the outlet of a component.
Peak Pressure	Maximum pressure, usually of short duration.

TERMS	DEFINITIONS
Precharge Pressure (Inflation Pressure)	The pressure at which a component is initially charged or inflated.
Pressure	Pressure is defined as fluid force per unit area. Pressure in a fluid at rest is equal in all directions.
Pressure Curve	Pressure variation, expressed graphically in relation to another variable, for example, time.
Pressure Droop	Change in pressure from a higher level to a lower level with flow of a pressure-compensated pump or regulator.
Pressure Fluctuation	Variation of pressure with time, usually occurring randomly.
Pressure Gradient	The change in pressure value with distance in a steady-state flow.
Pressure Head	Equivalent height of a column of liquid required to produce a given pressure.
Pressure Impulse	A rapid rise and fall of pressure, or vice versa, of extremely short duration.
Pressure Loss (Pressure Drop)	Pressure loss is the reduction in pressure caused by resistance to flow or by any extraction of energy that is not converted into useful work.
Pressure Pulsation (Pressure Ripple)	Periodical variation of pressure in synchronism with the operating speed of rotating equipment.
Pressure Ratio	Numerical ratio of the value of two pressures.
Pressure Rise	Change in pressure from a lower level to a higher level (due to energy addition or kinetic energy recovery).
Pressure Surge	Pressure rise and fall over a period of time.
Pressure Transient	Pressure rise or drop, or both, of extremely short duration with negligible energy.
Pressure Under Load (Load Pressure)	The pressure reacting to a static or dynamic load.

TERMS	DEFINITIONS
Pressure Wave	A cyclic variation of pressure with relative low amplitude and long period.
Proof Pressure	Pressure above nominal system pressure of the component or system the application of which, at defined test conditions, must not lead to external leakage, permanent deformation, or any detrimental influence on function.
Rated Pressure	See nominal pressure.
Reference Pressure	The pressure established as a reference value.
Reseat Pressure	The pressure at which the valve is reseated and flow is interrupted.
Response Pressure	The pressure at which a function is initiated.
Return Pressure (Back Pressure)	Pressure caused by resistance to flow in the return line or by precharged reservoirs, or both.
Set Pressure	The pressure which a component is designed to provide for a defined operation.
Standard Atmospheric Pressure	Mean atmospheric pressure related to sea level (corresponding to the definition for the physical atmosphere 1013.25 mbar).
Static Pressure	The local pressure in a fluid that has no element due to velocity of the fluid.
Suction Pressure	Atmospheric pressure minus absolute pressure for values below atmospheric pressure.
Switching Pressure	The pressure at which a system or a component is activated, deactivated, or reversed.
Total Pressure	The sum of the static and dynamic pressures at a location.

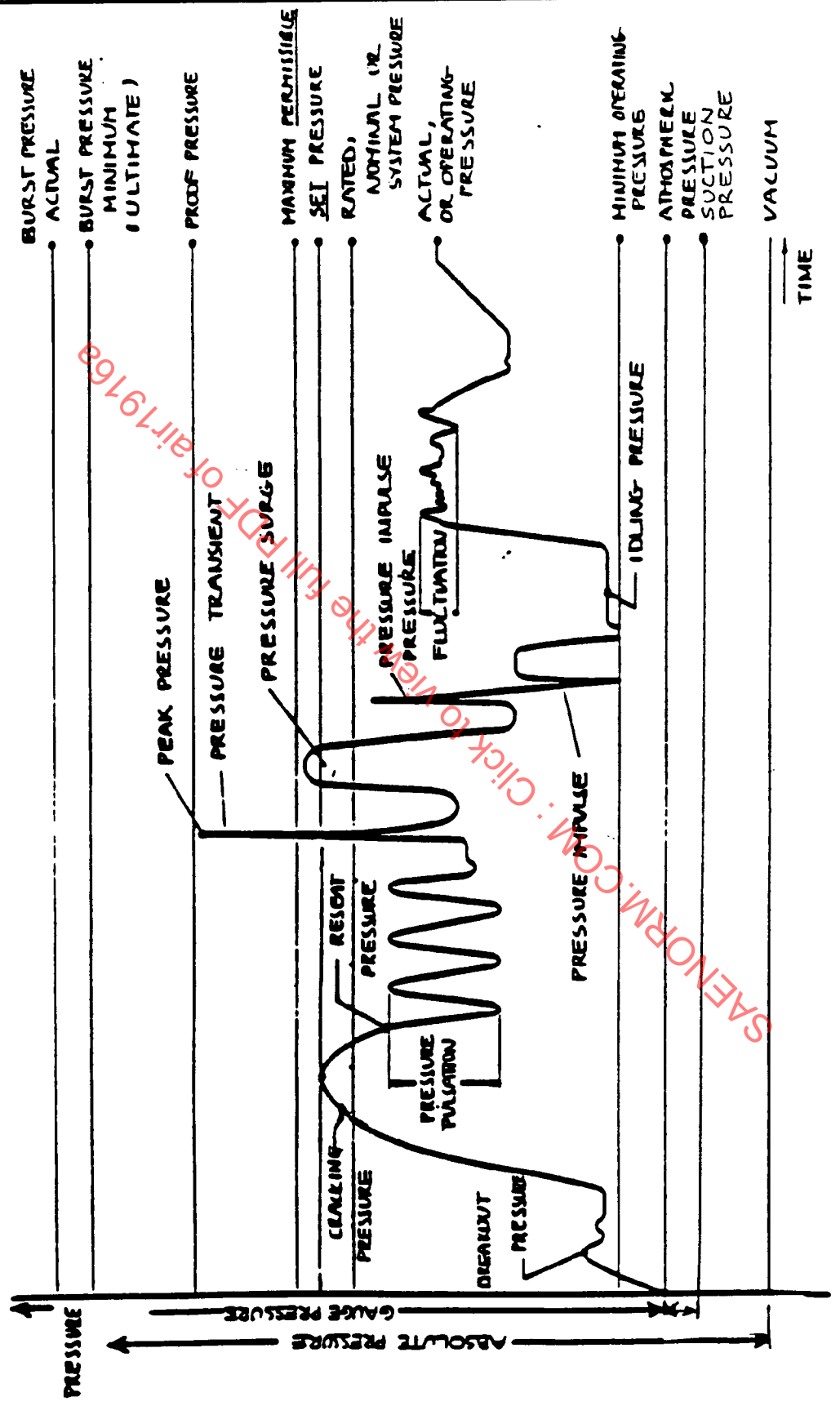


FIGURE 1 - Graphical Presentation of an Arbitrary Pressure Curve

CHAPTER 2 - GENERAL FLOW TERMS AND DEFINITIONS

TERMS	DEFINITIONS
Case Drain Flow	Cooling flow and internal leakage of a hydraulic pump or motor to the housing and out of the case drain port, not provided in all models.
Cavitation	Formation of cavities, either gaseous or vapor, within a liquid stream, which occurs where the pressure is locally reduced to vapor pressure of the liquid. It may include gas coming out of solution in the liquid as pressure is reduced (soft cavitation).
Choked Flow	Flow of a compressible fluid (gas), limited by the speed of sound in the fluid at the throat of a control section.
External Leakage	Leakage from the interior of a device to the exterior, other than out of the fluid ports.
Flow	Quantity of a fluid (volume or mass) crossing the transverse plane of a flow path per unit of time. Gas volume flow may be expressed at standard reference conditions of sea level atmospheric pressure and ambient temperature.
Flow Surge (Surge)	Temporary rise and fall of flow.
Internal Leakage	Leakage between internal cavities of a device.
Laminar Flow	Flow of a fluid characterized by the gliding of fluid layers (laminae) past one another in orderly fashion.
Leakage	Flow through a passage that is in a nominally closed position or at a location, which normally should permit no flow.
No-Load Valve Flow Gain	The increment of valve flow per change in valve input variable at no load across the output.
Null Leakage	Internal leakage of a valve when output flow is negligible.
Quiescent Flow	Total internal leakage of a complete hydraulic system or a branch of a hydraulic system at rest.

TERMS	DEFINITIONS
Rated Flow	Specified flow at steady-state conditions for a component or system.
Seepage	Occurrence of extremely slight fluid at the surface of a component or part of a hydraulic system, normally due to "breathing" of seals under cyclic pressure load. No drops are allowed over an extended period of observation.
Turbulent Flow	Flow of a fluid characterized by the random motion of fluid particles in directions transverse to the direction of the main flow.
Weepage	Occurrence of slight fluid at the surface of the sliding parts, such as piston rods, pump shafts, and valve spools due to wiping of fluid from the wetted surface by seals or scrapers. Drops of fluids may be formed after a number of actuation cycles, to be defined. If there is no relative motion, such as at parting lines, weepage must not occur.

CHAPTER 3 - GENERAL TEMPERATURE TERMS AND DEFINITIONS

TERMS	DEFINITIONS
Ambient Temperature	Temperature of the environment in which the apparatus is working.
Autoignition Temperature	Temperature at which the fluid flashes into flame without an external ignition source and continues burning. Actual value is to be determined by one of several approved test methods.
Cold Start Temperature	The temperature at which the hydraulic system will start to operate, but need not necessarily meet full performance.
Equipment Temperature	Temperature of the unit at a specified position and measured at a specified point, normally at the surface.
Flash Point	Temperature at which a fluid gives off sufficient vapor to cause it to ignite when a small flame is applied, under controlled conditions.
Fluid Temperature	Temperature of the fluid measured at a specified point in the system.
Inlet Temperature	Fluid temperature at the plane of the inlet port.
Maximum Fluid Temperature	Highest fluid temperature in the system at which the fluid is intended to be operated.
Normal Fluid Temperature	The stabilized fluid temperature normally reached during continuous operation.
Outlet Temperature	Fluid temperature at the plane of the outlet port.
Pour Point	Lowest temperature at which a fluid will flow under specified conditions.
Temperature Range of the Fluid	Specified range of fluid temperature that should not be exceeded for satisfactory operation of a system.

TERMS	DEFINITIONS
Type of Hydraulic System	A classification standard for a military aircraft hydraulic system based on minimum and maximum allowable fluid temperatures, defined in ISO 6771 as: Type I -54 to +71°C (-65 to +160°F) Type II -54 to 135°C (-65 to +275°F) Type III -54 to 232°C (-65 to +450°F) Note: The upper limit of Type III was reduced from +232°C (+450°F) to +199°C (+390°F) by the U.S. in recognition of hydraulic fluid limitations.

CHAPTER 4 - CONTROL/ACTUATION SYSTEM TERMINOLOGY

Control/actuation systems are used in aircraft, missiles, and other aerospace vehicles for actuating flight control surfaces, engine air inlets and exhaust nozzles, and other services that require precise positioning.

ABBREVIATIONS:

dB decibel

PWM pulse width modulated

LRU line replaceable unit

CONTROL SYSTEM CLASSIFICATION:

TERMS	DEFINITIONS
Adaptive Control	A control system that maintains optimum system performance by automatically changing system parameters.
Bistable and Tristable Control	A control system in which the power to control the load is fully "on" in either polarity (bistable), or fully "on" in one polarity, "off", or fully "on" in the other polarity (tristable). These systems are sometimes called "on-off" systems or "bang-bang" systems. When the time duration of the application of power is modulated by the input, the system is called pulse width modulated (PWM).
Closed-Loop Control System	A control system in which the command is compared with a measurement of system output and the resulting error signal is used to drive the load towards the desired output. Fig. 2 illustrates a closed-loop control system.
Command Input	An input that represents the desired output of the control system.
Control System	A system in which deliberate guidance or manipulation is used to achieve a prescribed value of a variable. A control system has at least one input and one output.
Error Signal	The output of the summing point where algebraic summation of two or more control loop variables is performed.

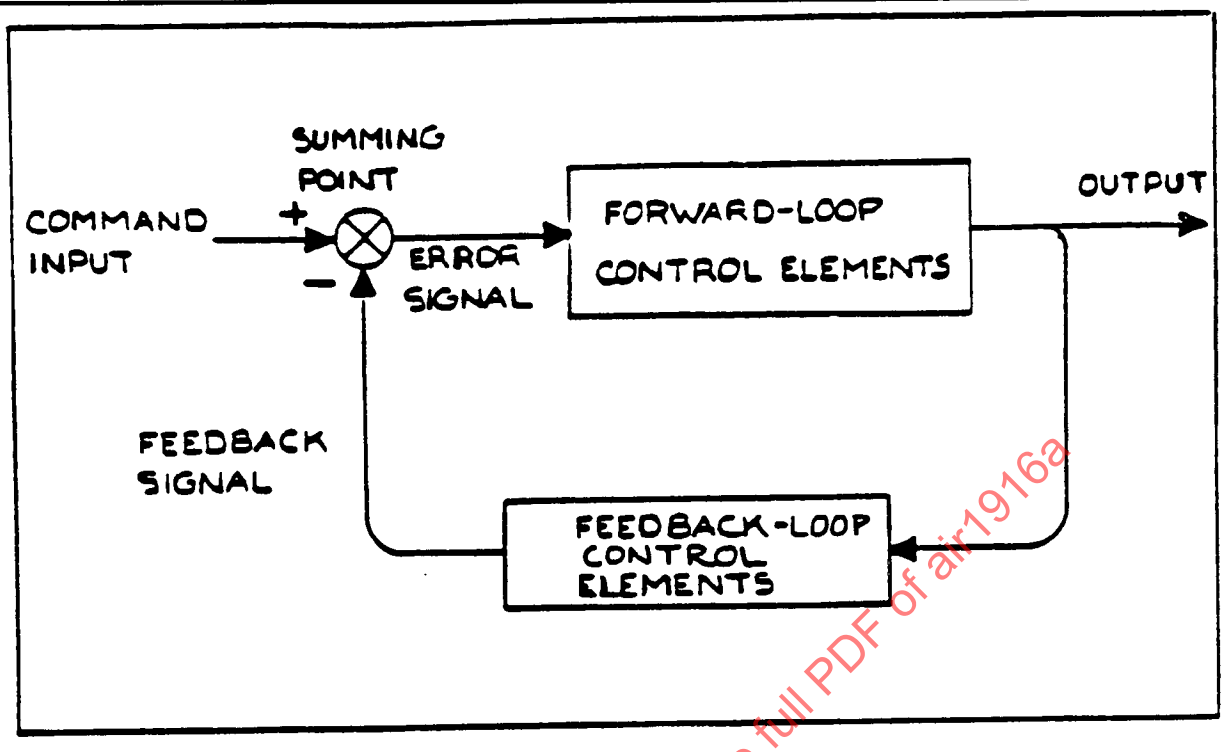


FIGURE 2 - Closed-Loop Control System

TERMS	DEFINITIONS
Feedback-Loop Control Elements	Elements in a closed-loop control system that provide the feedback signal of the output, or a function of the output that can be compared with the reference input.
Feedback Signal	The signal used to cancel further action when the command is carried out.
Forward-Loop Control Elements	Elements situated between the error signal and the output of the control system.
Integral Control (Type 1, 2, ...)	A control system that uses integration in the control loop elements to provide an output in response to an error signal. This is referred to as a Type N system, where N is the order of the integration. For more complete explanation refer to text books.
Loop	The signal path in a closed-loop control system beginning with the error signal and ending with the resultant feedback signal that functionally interconnects the forward-loop and feedback-loop elements.

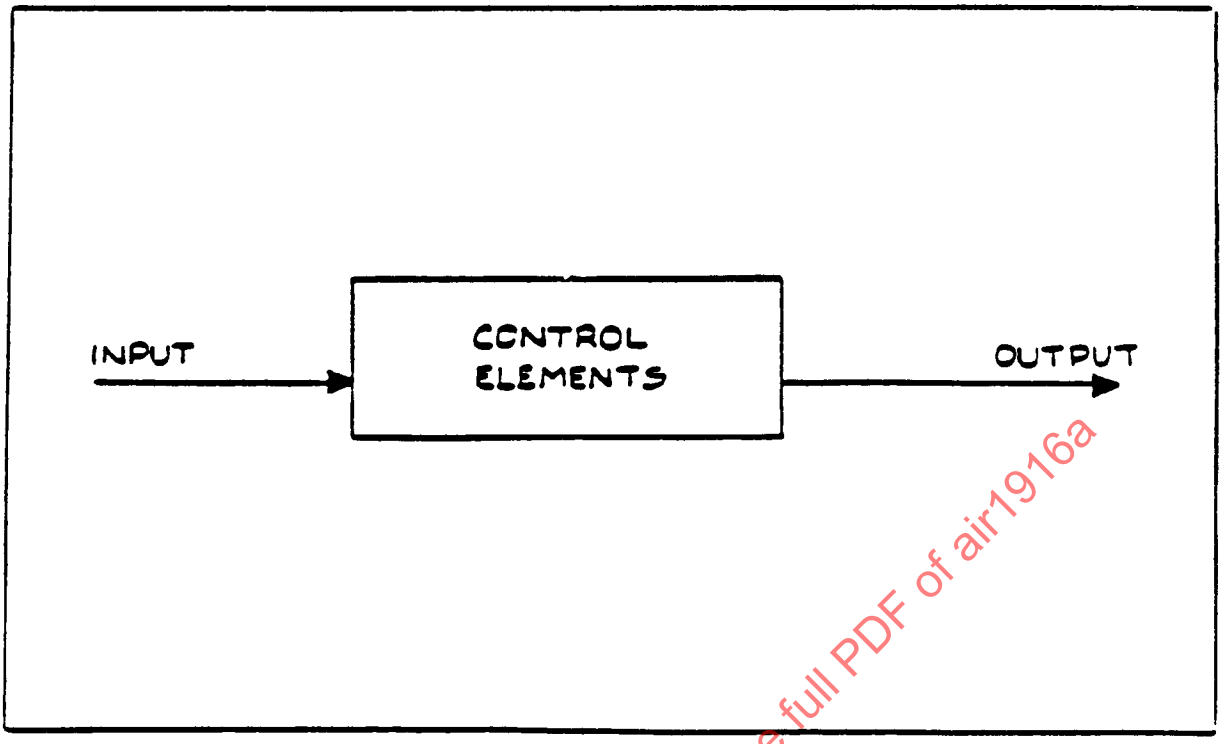


FIGURE 3 - Open-Loop Control System

TERMS	DEFINITIONS
Open-Loop Control System	A control system in which gain and power elements are used to provide an output in direct response to a command without feedback comparison. Fig. 3 illustrates an open-loop control system.
Output	The controlled variable resulting from activity of the control system.
Proportional Control (Type 0)	A control system that uses proportional forward and feedback control elements to provide an output in response to the error signal. This is referred to as a Type 0 control system.
Summing Point	Any point in a control system where an algebraic summation of two or more control-loop variables is performed.

CONTROL SYSTEM TECHNOLOGY

An actuation system is a means of power utilization for controlling a specific output variable. Actuation systems include a power source, power converter, controller, power modulator, actuator, and feedback element (if used). Fig. 4 illustrates a complete servo actuation system including controller and power modulator, or both. The controller is basically electronics and is not included in the servoactuator. Fig. 5 shows a simple servo actuation system without a separate controller, such as a simple hydraulic power boost cylinder.

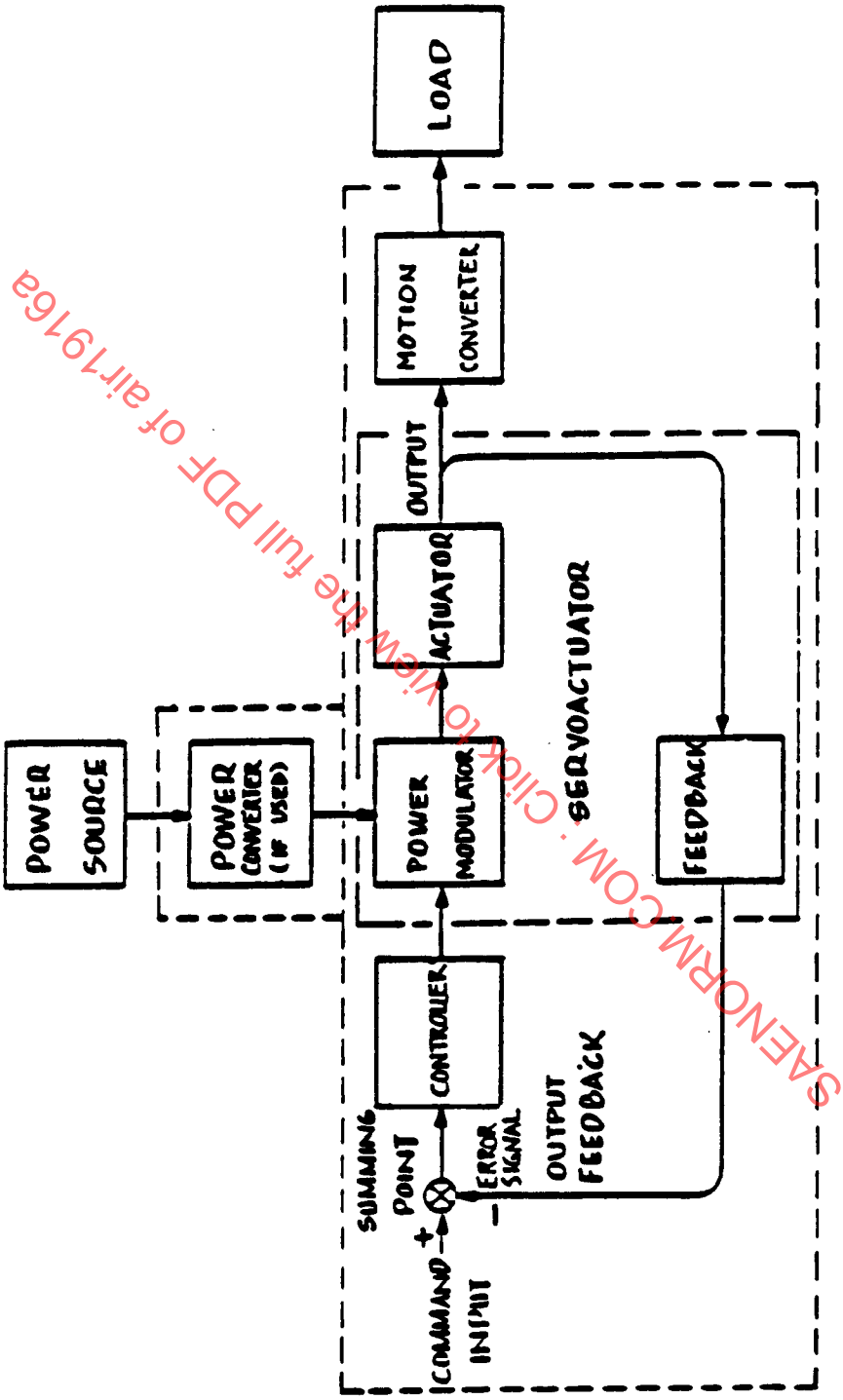


FIGURE 4 – Complete Servoactuation System

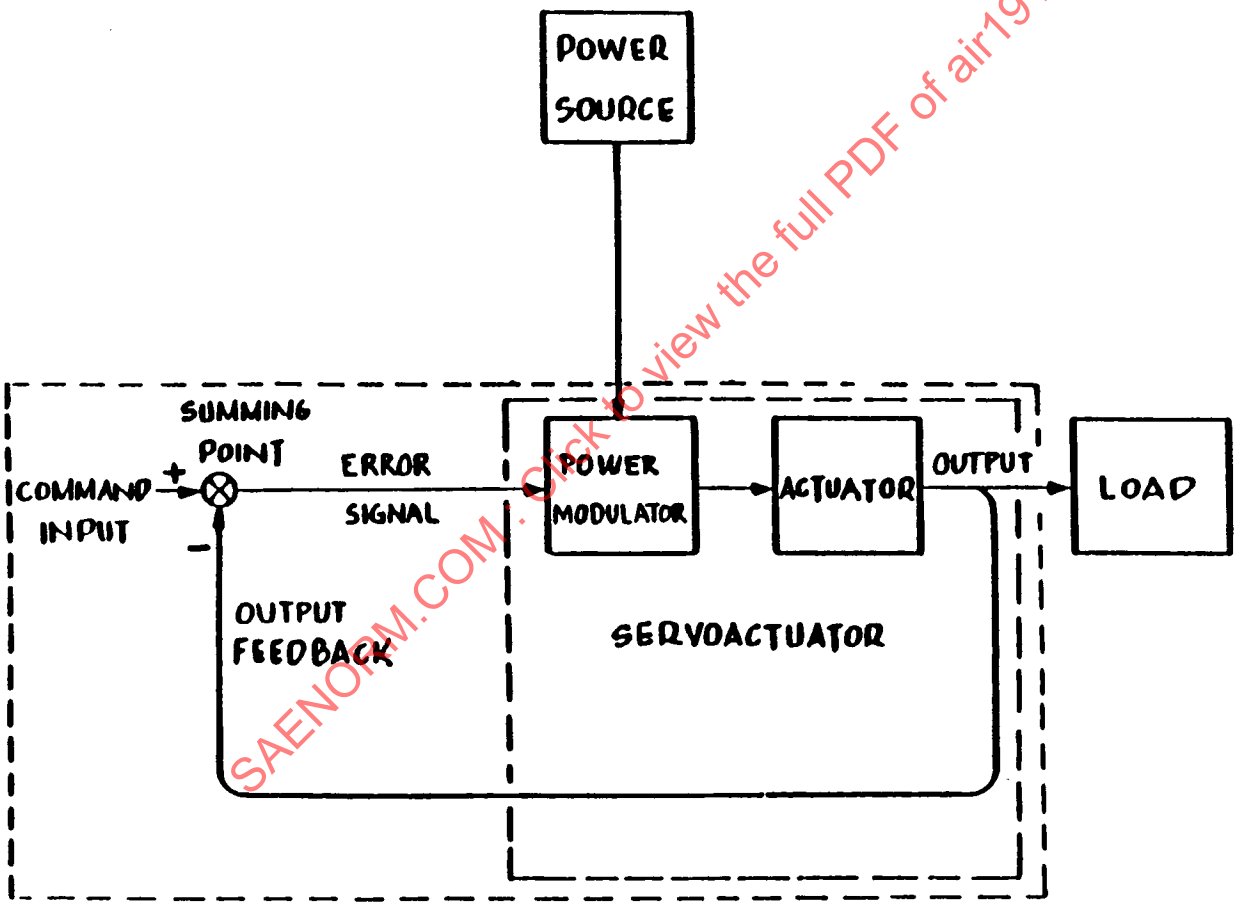


FIGURE 5 – Simple Servoactuation System

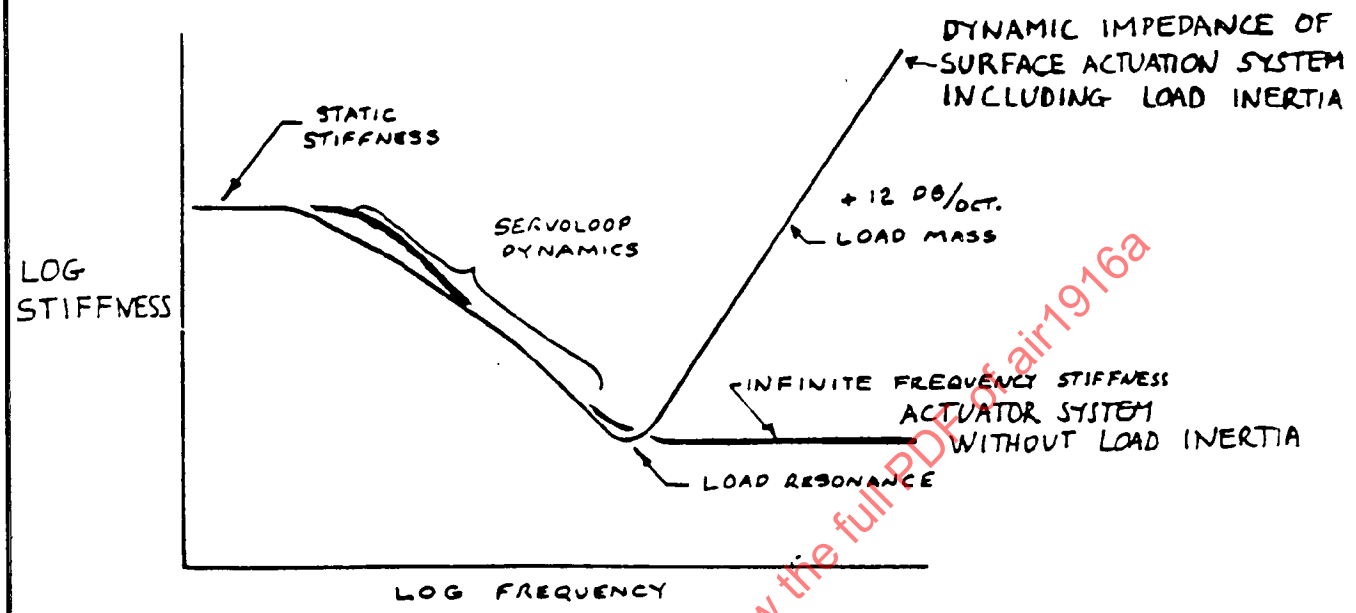
TERMS	DEFINITIONS
Actuator	The component of the actuation system that does work or dissipates energy to control a load. Actuator output is achieved by conversion of energy from the power system or load into mechanical work, torque, or force.
Controller	The component of the actuation system that controls the power modulator as a function of the command or error signal. Many of the electronic controllers have dynamic compensation as well as significant gain, so they must be recognized as separate components in the actuator loop.
Feedback Element	The component of the actuation system that measures the system output and transforms it in to a form compatible with the command signal.
Motion Converter	The component of the actuation system that converts the motion of the actuator in to the motion of the load. For example, a ball screw converts rotary motion into linear and a crank arm converts linear motion into rotary.
Power Converter	The component of the power system that transforms energy from the power source in to a form compatible with the servoactuator requirements.
Power Modulator	The component of the actuation system that regulates the potential energy of the power source to the actuator as a function of controller output. In a simple hydraulic power boost system, which has no separate controller, the power modulator controls the power to the actuator directly as a function of the command or error signal. See Fig. 5.
Power Source	The component that supplies energy for load actuation.
Power System	The power system generates, conditions, and distributes power to the servoactuator. It is not a part of the servo actuation system.
Servoactuator	An assembly of a controller, an actuator, and feedback element(s), typically packaged together as a single line replaceable unit (LRU).

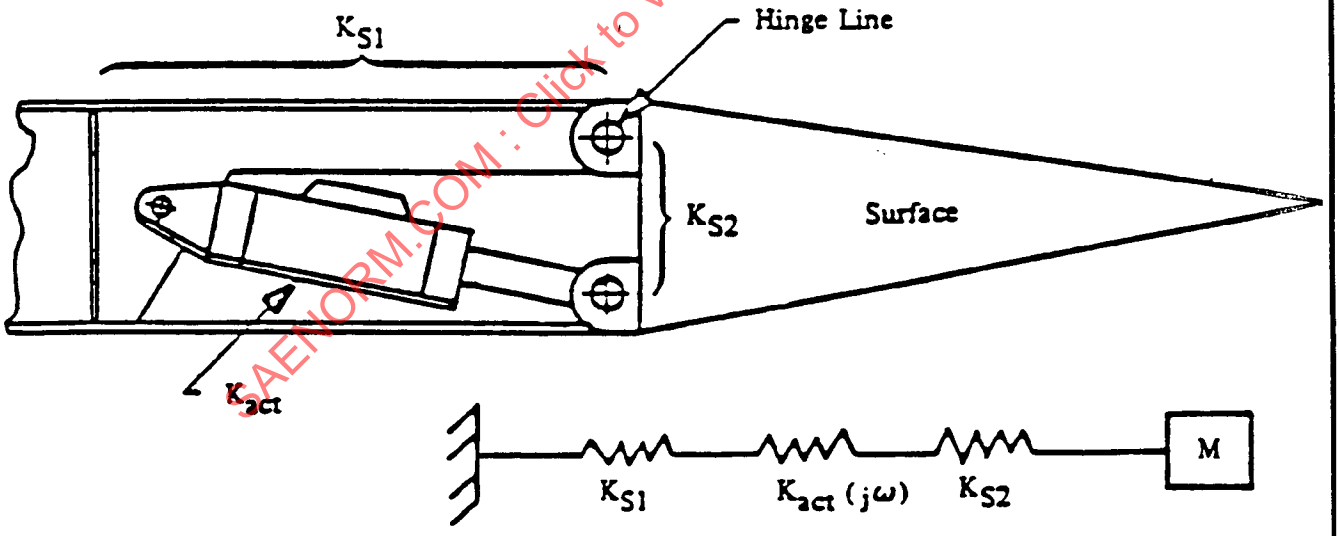
CONTROL SYSTEM PERFORMANCE

TERMS	DEFINITIONS
Aiding or Opposing Load	An aiding load is a force or torque on the actuator, provided by load restoration or inertia, or both, that acts in the same direction as the desired direction of load motion. A force or torque that acts in the direction resisting motion is called an opposing load.
Backlash	The uncontrolled load motion, due to clearance in actuation elements including the load attach point, and usually expressed in terms of absolute load motion.
Back-Up Stiffness	The mechanical stiffness of the actuator attach point(s) through which load reaction forces are transmitted.
Bandwidth (Bandpass)	The frequency range over which the actuation system has acceptable dynamic response. This spectrum extends from DC up to a specified frequency, which is usually the frequency where the open-loop amplitude ratio has unity gain (0 dB), and the closed-loop response is down 3 dB. For a first-order system the closed-loop response is down 3 dB with 45 deg phase lag.
Bias Load	A steady-state load that is unidirectional and constant over full load travel.
Closed-Loop Frequency Response	The frequency response between command input and control system output with the feedback signal summed with command. Actuation system response for a closed-loop system is usually specified as closed-loop frequency response.
Control Bandpass	See Bandwidth.
Coulomb Friction Load	A constant friction load opposing motion.
Decibel (dB)	A unit of measure used to express amplitude ratio of control input and output. Decibels = 20 $\log_{10}$ (Amplitude Out/Amplitude In).
Drive Stiffness (Actuator Stiffness)	The stiffness of the actuator between the mounting and output motion attach points. It is the resultant of the mechanical stiffness of the load carrying elements and of the actuation system stiffness.

TERMS	DEFINITIONS
Duty Cycle	A description of the load throughout the total mission time with sufficient detail to determine load velocity requirements, frequency of occurrence, and dynamic load characteristics. A complete duty cycle description defines the actuation energy required for the total mission.
Dynamic Impedance (Stiffness)	The impedance associated with the output deflections of an active closed-loop actuation system caused by externally applied dynamic forces (usually sinusoidal) over a specified frequency range. Dynamic impedance includes the load mass or inertia, load friction, system stiffness, and any other load-related compliance effects. Since it is a complex quantity, the term, Dynamic Impedance, is preferred to the term, Dynamic Stiffness.
Fluid Bulk Modulus (Bulk Modulus)	Fluid bulk modulus of a trapped fluid volume is: $$\beta = \frac{\text{incremental pressure}}{(\text{incremental volume/total volume})}$$
Fluid Stiffness	The pressurized fluid chamber on each side of the piston in an actuator contains a trapped volume of fluid when the control valve is at null. The trapped fluid exerts stiffness, opposing change in fluid volume, when an external load is applied to the piston.
Frequency Response (Bode Plot)	The complex ratio of the actuation system output to the command input, while the input is cycled sinusoidally and the frequency is varied. Frequency response is usually presented as a combined plot of normalized amplitude ratio in dB, and of the input to output phase angle, in degrees, versus the logarithm of frequency (called a Bode plot).
Gain Crossover, Phase-Margin Frequency	The point on the Bode plot of the transfer function at which the magnitude crosses over unity: $\text{Log}_m G(j\omega) = 0$ dB where ω is the oscillation frequency, in radians per second, and j is the square root of minus one. The frequency at gain crossover is called the phase-margin frequency.

TERMS	DEFINITIONS
Gain Margin	A measure of system stability defined as the reciprocal of the magnitude of the open loop gain at 180 deg of phase lag crossover frequency usually expressed in dB.
Hysteresis	The difference in actuation system input that yields the same output command level during a complete cycle of input command when cycled throughout the full range of travel. The cycling rate must be significantly below the control bandpass so that velocity error signals are not included in this parameter.
Inertia Load	A load opposing any change in the state of motion and proportional to load acceleration and inertia.
Infinite Frequency Stiffness (Frequency-Independent Dynamic Stiffness)	The stiffness associated with the output deflections of an active actuation system caused by externally applied loads where the frequency of the load disturbance is significantly above the bandpass of the actuation system. Since the system cannot actively react against high frequency load disturbances, this stiffness is identical to stiffness to ground at frequencies well beyond the system bandwidth. See Fig. 6, load inertia excluded.
Input/Output Curve	The graphic representation of actuation system output versus command input. This is usually a continuous plot throughout a complete cycle between plus and minus rated commands. The cycling rate must be significantly below control bandpass so that velocity error signal is not included in this parameter.
Linearity	The degree to which the normal output curve conforms to a straight line under specified load conditions, usually expressed as percentage of rated command.
Load Natural Frequency	The undamped resonant frequency of the load mass coupled with the load related stiffness.





where ω is the oscillation frequency of the applied forces, in radians per second, and j the square root of minus one.

FIGURE 6 - Actuator Stiffness Determination

TERMS	DEFINITIONS
Low Frequency Stiffness (Frequency Dependent Dynamic Stiffness)	The stiffness associated with the output deflection of an active actuation system caused by externally applied loads where the frequency of the load disturbance is within the bandpass (bandwidth) of the actuation system.
Misalignment Load	A force component perpendicular to the actuator output motion, which is the resultant of a load not in line with the actuation output.
No-Load Velocity	The output velocity of the actuation system measured with no external load. Maximum no-load velocity is determined with a saturation input to the power modulator.
Normal Output Curve	The locus of the midpoints of a complete input/output curve. This locus is the zero-hysteresis output curve.
Normal Output Gain	The slope of the normal output curve in units of output/input.
Open-Loop Frequency Response	The frequency response between command input and control system feedback signal with no feedback loop closure.
Overshoot	The increment by which the output exceeds the final value when responding to a step command, usually expressed as a percentage of the output.
Phase Crossover, Gain Margin Frequency	The point on the Bode plot of the transfer function at which the phase angle is -180 degrees. The frequency at which phase crossover occurs is called the gain margin frequency.
Phase Margin	A measure of system stability defined as the phase lag to be added to achieve 180 deg of phase lag at the open loop frequency response corresponding to 0 dB amplitude ratio.
Rated Continuous Power	The maximum power that can be delivered by the actuation system for an indefinite period without sustaining damage or reducing life.
Rate Limit	The maximum velocity of the control system output. Usually, rate limit is defined under aiding load condition with saturation signals applied to the servoactuator.

TERMS	DEFINITIONS
Rated Load	A specified steady-state load applied to the actuator for determining rated velocity. Usually, rated load is an opposing load.
Rated Power	The power required at rated load and rated velocity, also called the power point. This point usually determines the maximum power required from the actuation system.
Rated Velocity	The required actuation system output velocity when the specified rated load is applied at the actuation motion attach point. Rated velocity can be determined at any load position.
Resolution	The accuracy with which the actuation system output can be positioned. Output accuracy is usually expressed in absolute terms; that is, a position resolution of 0.5 degrees.
Slew Rate	The steady-state output velocity of the actuation system in response to a step input command. Slew rate is usually determined by the average velocity between 10 and 90% of load position (so as to avoid actuator acceleration and deceleration effects) when both static and dynamic loads are imposed at the servoactuator output.
Spring Load	A load that varies proportionally with load position. This load may be caused by aerodynamic forces on a movable surface, or by thrust deflection reaction forces on a movable nozzle element. The load can be either opposing or aiding, depending on output position and motion direction.
Stall Load	The steady-state force or torque from the actuator at zero velocity, when the controller has a saturated input. It is the load that the servoactuator cannot overpower.
Stiffness	Force or torque per unit displacement.
Stiffness to Ground	The combined stiffness of all spring rates that determines the spatial reference of the load mass. This term is frequency dependent due to servoloop characteristics. Stiffness to ground, in conjunction with the load inertia, determines the load natural frequency. See Fig. 6.

TERMS	DEFINITIONS
System Resonance	The closed-loop resonant frequency observed with complete system operation. The system resonance is lower than the load natural frequency due to dynamic effects of system control elements, damping, and backlash.
Threshold	The increment of input required to produce a change of actuation system output. Threshold is normally specified as the input increment required to reverse the direction of output motion when the input is cycled at a rate sufficiently low to minimize dynamic effects.
Torque-to-Inertia or Force-to-Mass Ratio	The ratio of actuator shall load capability to rotary actuator inertia or linear actuator mass. This ratio determines the maximum actuator output acceleration.
Transient Response	The time response of the actuation system output, following a transient command input. Step response is usually specified as the time required to reach a particular percentage of the final output, along with limits on the percentage overshoot.
Velocity Gain	The proportional change of actuator velocity with error signal. This parameter is usually specified for no-load conditions and is usually measured open loop.
Velocity vs Force or Torque Characteristic	The curves of steady-state velocity vs steady-state force or torque when the actuator is driven by the power modulator with constant values of signal input.
Viscous Friction Load	A load opposing motion and proportional to load velocity.

CHAPTER 5 - FAULT-TOLERANT CONTROL/ACTUATION TERMINOLOGY

Terms and definitions peculiar to fault-tolerant control/actuation are presented in this chapter.

ABBREVIATIONS

ACT	active controls technology
AFCS	automatic flight control system
CAS	control augmentation system
CBL	control-by-light
CBW	control-by-wire
DFO	dual fail operative
FCS	flight control system
FS	fail safe
IAP	integrated actuator package
LRU	line replaceable unit
MFCS	manual flight control system
MTBF	mean time between failures
MTBR	mean time between removals
MTBJR	mean time between justified removals
SAS	stability augmentation system
SFO	single fail operative
TBO	time between overhauls

NORMAL OPERATION

TERMS	DEFINITIONS
Active	An adjective that describes: A system or portion of a system that is in control on line, in contrast to being in standby. The operational status of a servo control device after a failure if the device is activated or remains in control.
Active Controls Technology	An airplane design concept in which vehicle performance, weight, and economic characteristics are optimized through a reliance on automatic subsystems within the flight control system to augment the airplane's stability, to reduce the designing loads (through load reduction or redistribution and structural mode damping), and to manage the airplane's configuration for aerodynamic efficiency. Active control functions include: Pitch Stability Augmentation Lateral and Directional Stability Augmentation, or both Angle-of-Attack Limiting Wing-Load Alleviation Maneuver-Load Control Gust-Load Alleviation Flutter-Mode Control Ride Smoothing
Adaptive Flight Control System	A flight control system having the capability to vary its performance parameters in flight and thus adapt to the changing flight conditions so that the vehicle's structural integrity and stability limitations are not exceeded during critical phases of flight.

TERMS	DEFINITIONS
Automatic Flight Control Systems	Automatic flight control systems consist of electrical, mechanical, and hydraulic components that generate and transmit automatic control commands which provide pilot assistance or relief through automatic or semiautomatic flight path control or which automatically control airframe response to disturbances. This classification includes automatic pilots, stick or wheel steering, autothrottles, and similar control mechanizations. AFCS functions include: Airspeed Hold All-Weather Landing Altitude Hold Altitude Select Attitude Hold (Pitch and Roll) Autobrake Autoland Automatic Carrier Landing Automatic Instrument Low Approach Automatic Navigation Automatic Terrain Following Automatic Vectoring Modes Autothrottle Heading Hold Heading Select Mach Hold
Control Augumentation System	A function of the flight control system, including command shaping, sensors, actuators, etc., that perform in such a manner so as to augment the static and dynamic stability, and maneuver response of the aircraft. When considered as an entity it is essentially a closed-loop tracking control system, responding to pilot commands.
Control Authority	The amount of control surface or thrust vector deflection that can be produced by AFCS signals relative to the total available control deflection. This phrase is often preceded by the word electrical, or abbreviations such as CAS or SAS, in order to be more explicit.
Control-By-Light (Fly-By-Light) System	A control system wherein control information is transmitted by light through a fiberoptic cable. A true CBL system does not have CBW or mechanical backup, nor CBW or mechanical override.
Control-By-Wire (Fly-By-Wire CAS-By-Wire) System	A control system wherein control information is transmitted completely by electrical means.

TERMS	DEFINITIONS
Hydraulic Booster	The use of hydraulic power actuation to reduce the pilot effort needed for control of a vehicle wherein the actuator output force is in direct proportion to the manual input force.
Integrated Actuator Package	An actuator package wherein a power converter is contained within the package. Usually a servoactuator with an electric-motor-driven pump and fluid reservoir in a single LRU.
Manual Flight Control System (MFCS)	Manual flight control systems consist of electrical, mechanical, and hydraulic components that transmit pilot commands, or generate and convey commands that augment pilot control commands, and thereby accomplish flight control functions. This classification includes the longitudinal, lateral directional, lift, drag, and variable geometry control systems. In addition, their associated augmentation, performance limiting, and control devices are included. A manual flight control system does not include vehicle motion or flight path sensors.
Parallel Servo	A servo located in a control system so that the servo output drives in parallel with the major input. This arrangement usually is used with actuators that perform an alternate function to that of the pilot. The parallel servo output backdrives the pilot controls in addition to driving the actuator control valve.
Pseudo Fly-By-Wire	An FBW control system having a means to mechanically control or override the servoactuators.
Series Servo	A servo located in a control system so that the servo output adds to that of a major input. This arrangement is commonly used with SAS actuators to superimpose control on primary or parallel commands. The series servo output does not cause motion at the major input and may be introduced automatically without a pilot command.

TERMS	DEFINITIONS
Stability Augmentation System	A function of the flight control system, including sensors, actuators, etc., that perform in such a manner so as to augment the basic dynamic stability of the aircraft. When considered as an entity, it is essentially a closed-loop regulator control system. The SAS generally has limited authority. To prevent undesirable coupling between the SAS signals and the pilot inputs, SAS signals are normally introduced by a series servo that does not cause stick motion or forces.
FAILURE MODES	
Failure	A deficiency in system operation caused by a change in the functional characteristics of a system component. In dealing with fault-tolerant flight control systems, a failure occurs when a device within the system fails to function within prescribed limits without regard to the cause of the failure. Thus a failure may be: 1) Any loss of function of any element within the control system 2) Loss of supply power to the system 3) Uncommanded hardover conditions or loss of control intelligence at the signal input 4) Any out-of-tolerance condition that exceeds normal operating limits.
Fail-Functional	A limited case of fail-operative where performance is significantly degraded following a failure.
Fail-Hardover	The type of failure where the output of the failed element is at an extreme condition. In cases having a polarity of output, a hardover failure may be of either polarity.
Fail-Neutral	A specific case of fail-passive where the control device or system fails to a passive null or locked-at-null condition.
Fail-Open	The type of failure where the failed element disconnects the normal control path within a device. Such a failure either prevents the signal from passing or seriously alters the signal that passes through a system.

TERMS	DEFINITIONS
Fail-Operative	A condition or system where operation continues after a failure with either no loss, or an acceptable loss of performance.
Fail-Passive	A condition or requirement where the failed device or system ceases to create any active output. In the purest sense, a device that fails passively would simply remove its presence from the control system. However, a device is still considered fail-passive if it remains in the system but acts only as an additional load.
Fail-Safe	In any system or subsystem, the failure of any single element, component or connection during any one flight may occur, regardless of its probability. In a fail safe system, such single failure does not prevent continued safe flight and landing, or significantly reduce the capability of the airplane or the ability of the crew to cope with the resulting failure condition.
Failure Mode	The manner in which a device can or did fail. Simple devices may have only one failure mode; whereas, more complex devices usually have several failure modes.
Failure Rate	The probable number of times that a system or component fails during a given time or cyclic period of operation.

FAILURE DETECTION AND MONITORING

Detection-Correction System	The type of fault-tolerant system where a failure or out-of-operating-tolerance condition is detected and corrective action is taken automatically. This may involve switching to a standby channel or, if two or more channels are normally operating, correction may involve switching out the failed channel. Inherent in this type of system is the existence of a finite time for detection-correction. With detection-correction systems, it is possible to use a model of an active channel as a reference channel in order to extend the failure capability of the system.
Fault Isolation	The process of determining the location of a fault to the extent necessary to effect a repair.

TERMS	DEFINITIONS
Fault Localization	The process of determining the approximate location of a fault.
Model	A device used in a detection-correction fault-tolerant system as a reference channel to simulate the performance of a channel used for control. Typical models are electrically implemented.
Monitor	A device used for sensing the operation of a component or channel such that failures may be detected. In-line and cross-channel are two forms of monitoring. In-line monitoring compares output performance to the command input. Cross-channel monitoring compares equivalent performance features of two or more components or channels.
Quad Voter	A voter that performs in a fashion to select one common output to represent the four signals or values.
Self Monitoring	The capability of a component to monitor itself without additional sensors or other devices.
Undetected Failure	A failure that is not identifiable until a second and detectable failure has occurred.
Voter	A logic element or device that compares the signal condition in two or more channels and changes state when a predetermined signal mismatch occurs.

FAILURE CORRECTION PROVISIONS

Averaging System	The type of fault-tolerant system using two or more active channels where the individual channel outputs are summed to provide an average output. All channels are normally operative so performance degradation will occur after a failure. An example of an averaging system is the use of multiple control surfaces on an airplane, each individually actuated.
Channel	One signal or control path of a redundant set. A channel is an entity within itself and contains elements individual to that channel. To achieve true fault-tolerance, each channel must be designed so that a failure in one channel does not cause failure in another. A model may be used as a reference channel in a detection-correction system.

TERMS	DEFINITIONS
Channel Buffering	A technique used in fault-tolerant systems that minimizes the possibility of a failure in one channel to induce a failure in another channel.
Channel Priority	The order of authority of the various channels in a redundant system where the channels are not equivalent. Examples of channel prioritizing are: Primary/Secondary Active/Standby
Channel Summing	The manner in which channels are combined to provide the control function. Examples of channel summing techniques are: Flow Summing Flux Summing Force Summing Position Summing Velocity Summing
Conversion	The process of changing over control from an active to a standby system or from a primary to a secondary system.
Dual-Fail Operative (DFO)	A condition or requirement where an active control device or system can sustain any two failures within the system and remain operative. It is implicit with DFO that the system be able to accept identical failures in two of its channels and continue to operate.
Dual Load Path	A type of mechanical paralleling where two separate load carrying paths exist from the control system input to the system output. Each load path is capable of carrying sufficient load such that failure of any one member will not jeopardize system performance.
Dual-Tandem Valve	A tandem valve having two separate control sections.
Duplex	An adjective meaning twofold such as a duplex valve, duplex actuator, etc.
Electrical Logic	Logic, as for mode switching or failure detection/correction, performed with electronic or electrical components.

TERMS	DEFINITIONS
Equalization (Channel Balancing)	The use of feedback to achieve close coincidence between the outputs of two or more channels in a fault-tolerant control system. Equalization may be necessary in order to reduce the transient that could occur with shutoff of a failed channel, or it may be necessary to minimize the adverse effects of normal tolerances. Sometimes this is referred to as channel balancing.
Hydromechanical Logic	Logic, as for failure detection or correction, performed with only mechanical elements where the information is in the form of hydraulic pressures or flows.
Isolation	A basic technique used in fault-tolerant systems that removes the effects of a failure from the system output when the failure is detected by the redundancy management portion of the system.
Majority Voting System	A redundant system where the outputs of three or more active channels are compared and the most often encountered is used as the selected output.
Manual Override	The capability of a flight control system to enable the pilot to override the AFCS through a cable and/or linkage system and exert control in excess of the AFCS authority or in opposition to the AFCS command.
Mechanical Reversion	The capability of reverting from fly-by-wire control to a state wherein the pilot's control is mechanically coupled to the actuator control valves.
Mid-Value Logic System	A fault-tolerant system having an odd number of active channels (usually three) where the system output is determined by the middle of the (three) input signals.
Passive Paralleling	The simplest and most common type of redundancy where two parallel functional devices are utilized so that if one fails the second is still available. This approach is limited to the more simple elements of the control system which can only failpassive such as springs and linkages. When failure of one element occurs, there is an acceptable change in performance or capability.

TERMS	DEFINITIONS
Quadruplex	An adjective meaning fourfold, as used for a four-channel system.
Quadruplex System	A control system containing four signal paths so as to provide multiple failure capabilty, such as SFO/FS, DFO or DFO/FS.
Redundancy Management	The portion of the system logic and control (hardware and software) that detects and isolates failures in a fault-tolerant system, and reconfigures the system after the failure is detected and isolated so as to maintain the same or a reduced level of operation.
Redundant	An adjective to denote the use of duplicate or alternate components for the purpose of improving the mission reliability and safety.
Reset	The process for returning a system to an operational state after a failure has occurred and has been corrected or isolated. Some systems have the capability for providing this function automatically.
Reversion	The process for changing over control from an active to a standby channel or from a primary to a secondary channel.
Ripstop	A mechanical design technique for achieving mechanical separation of hydraulic systems where more than one pressure source exists. If material fracture occurs in one portion of a ripstop design, the fracture cannot progress and causes the loss of two hydraulic systems. Thus, if two hydraulic supplies are used, they cannot enter the same body in a system designed to provide ripstop capability, unless the body is fabricated from two or more pieces of metal.
Simplex	An adjective meaning nonredundant.
Single-Fail Operative	A condition or requirement where an active control device or system can sustain any single failure and remain operative.
Standby	A term used to describe the normal status of a channel in a detection-correction fault-tolerant system that may be switched for control, in the event of the failure of a normally operating channel.

TERMS	DEFINITIONS
Tandem Actuators	Two or more coaxial actuators that are mechanically constrained to move together. A tandem actuator usually has two pistons on the same rod, carried in a single actuator cylinder housing. Separate cylinders (with a common piston rod) can be used to give partial ripstop protection.
Tracking Accuracy	The accuracy with which a channel output or combination of channel outputs match one another or the commanded output/outputs, or both.
Triplex	An adjective meaning threefold, such as a triplex valve, a triplex actuator, etc.
Triplex System	A fault-tolerant control system containing three signal paths.
Voter	A logic element or device that compares the signal condition in two or more channels and changes state when a predetermined signal mismatch occurs.

CHAPTER 6 - RELIABILITY AND MAINTAINABILITY

TERMS	DEFINITIONS
Accessibility	A measure of the relative ease of admission to the various areas of an item for the purpose of operation or maintenance.
Aircraft on Ground	AOG - Cannot fly until replacement parts are received to complete the maintenance action.
Aircraft Ground Equipment	Equipment required on the ground to support the operation and maintenance of an aircraft and its airborne equipment.
Alignment	Performing the adjustments that are necessary to return an item to specified operation.
Automatic Test Equipment (ATE)	Equipment that automatically carries out a program of testing for possible malfunction, with minimum reliance upon human intervention. The ATE should be self checking to ensure that the ATE itself does not lead to additional difficulty.
Availability	A measure of the degree to which an item is in an operable and committable state at the start of a mission when the mission is called for at an unknown (random) time.
Burn-in	The operation of an item under stress to stabilize its characteristics.
Check, Bench	A functional check of an item in the shop to determine whether the item may be returned to service, or whether it requires adjustment, repair, overhaul, or replacement.
Check, C	A heavy maintenance check. See letter check.
Confidence Level	The probability that a given statement is correct, usually associated with statistical predictions.
Confidence Test	A test primarily performed to increase the confidence that the unit under test is operating acceptably.

TERMS	DEFINITIONS
Condition Monitoring (CM)	(a) Process Condition monitoring (CM) is a data gathering, not a preventative maintenance, process. It allows failures to occur, and relies on analysis of operating experience information to indicate the need for appropriate action. If the removal rate is deemed to be excessive, the component may temporarily be assigned a hard time removal limit until corrective action can restore its removal performance to an acceptable level. (b) Item A CM item has neither hard-time removal nor scheduled test to determine its continued serviceability. All removals are for unscheduled cause. All units removed must, upon arrival in the shop, be given a check in accordance with the procedures in the appropriate shop manual. If the unit "passes", it is returned to service. Failure to pass the check requires the unit to be repaired to a state that it will pass and be serviceable.
Critical Item (Maintenance)	An Item: that has a limitation to warrant controlled surveillance under specified conditions. that is known to require special handling, transportation, storage, or test precautions. that does not have sufficient history of its own, or a similarity to other items that have the demonstrated high reliability to provide confidence in its reliability.
Criticality	A relative measure of the consequences of a failure mode.
Debugging	A process to detect and remedy inadequacies. With respect to software, it is the development process to locate, identify, and correct programming mistakes, including omissions in the software.

TERMS	DEFINITIONS
Dependability	A measure of the item operating condition and of the degree of which the item is capable of performing its required function at any (random) time during a specified mission profile, given item availability at the start of the mission.
Derating	(a) Using an item in such a way that applied stresses are below rated values, or (b) The lowering of the rating of an item in one stress field to allow an increase in another stress field.
Discrepancy	Any difference or inconsistency between a requirement for a characteristic of a material or an item, as specified in a contract, drawing specification, standard, test procedures, or other document and the actual characteristic of the material or item.
Error	A mistake in specification, design, production, maintenance, or operation that causes an undesired performance of a function.
Exposure Time	The period (in hours or cycles) during which a system, subsystem, unit, or part is exposed to failure, measured from when it was last verified as functioning to when its proper performance is or may be required.
Failure	The inability of a system, subsystem, unit, or part to perform within previously specified limits. Note that some failures may have no effect on the capability of the airplane and therefore are not failure conditions.
Failure Condition	A consequential airplane state that has an impact on the functional capability of the airplane or the ability of the crew to cope with adverse operating conditions, or that would prevent continued safe flight and landing. A failure condition can result from the occurrence of a specific single event or a combination of related faults, failures, errors, operating conditions, or environment. Postulated failure conditions are assessed for their impact on safety and assigned an appropriate probability classification. A defined failure condition provides the criteria for classifying system functions as non-essential, essential, or critical.

TERMS	DEFINITIONS
Failure Condition, Catastrophic	Failure conditions that would prevent continued safe flight and landing. A failure condition is considered catastrophic if more than a relatively few occupants incur serious injuries or fatalities.
Failure Condition, Major (Failure Condition, Hazardous)	Failure conditions that would reduce the capability of the airplane or the ability of the crew to cope with adverse operating conditions to the extent that there would be, for example: (a) A significant reduction in the safety margin (b) A significant increase in crew workload, or in conditions that impair crew efficiency (c) In more severe cases, adverse effects on occupants
Failure Condition, Minor	Failure conditions that would not significantly reduce airplane safety, and which involve crew actions that are well within their capabilities. Minor failure conditions may include, for example: (a) A slight reduction in safety margins (b) A slight increase in workload, such as routine flight plan changes (c) Some possible discomfort to occupants
Failure Effect	The consequences of item failure on system operation.
Failure, Dormant (Hidden)	A defect that is not visible, which cannot be detected and which does not cause failure under normal conditions, but can cause failure within the design envelope. In airline parlance this is usually called "hidden failure".
Failure, Expected	Expected failures are based on failure rates and exposures. The number is obtained by multiplying the official failure rate for each age interval by the exposures in the interval and then adding the results.

TERMS	DEFINITIONS
Failure Mode and Effects Analysis	A procedure by which each potential failure mode in a system is analyzed to determine the results, or effects on the system, and to classify each potential failure mode according to its severity.
Failure, Mission	Failure to complete the intended mission as a consequence of equipment failure.
Failure, Random	Failure of an item whose occurrence is only predictable in a probabilistic or statistical sense.
Failure Rate, Initial	An initial estimate of the expected failure frequency of an item, which may later be adjusted, as actual experience is gained.
Failure Rate, Smooth	Rates determined when sufficient failures and exposures per age intervals are available; enough to eliminate peaks and valleys from the data.
Failure, Wear-out	Failures that occur as a result of progressive deterioration and with a probability of occurrence that increases with the age of the device.
Fault	An undesired anomaly in the functional operation of a system, subsystem, unit, or part.
Ground Support Equipment	See Aircraft Ground Equipment
Inspection, Nondestructive (NDT)	A family of methods for investigating the quality, integrity, properties, and dimensions of materials and components, without damaging or impairing their serviceability through the use of dye penetrant, magnetic eddy current, ultrasonic, radiographic, infrared, etc. devices. Nondestructive testing (NDT) is widely used in aircraft structural inspection.
Inspection, Periodic	The periodic inspection is a thorough and close check of the overall aircraft. Each periodic inspection comprises all intermediate, pre-flight, thru-flight and post-flight inspections. It is repeated at regular intervals of calender time or hours of operation.
Inspection, Sample	The monitoring or withdrawl, or both, of random selected devices from assembly line or service to permit determination of their condition at predetermined progressive intervals.

TERMS	DEFINITIONS
Item, Critical	See Critical Item
Item, Completed	Items of equipment (including basic or end items, components, assemblies) that have been overhauled, modified, renovated, and completed in accordance with terms of contracts, project orders, or other work directives and authorizations, and are ready for their intended use after receiving final mechanical acceptance inspection.
Item Levels	Item levels from the simplest to the more complex are as follows: Part, Subassembly, Assembly, Unit, Group, Set, Subsystem, System.
Item, Life Limited	An item that must be removed from service and discarded before a specified time is achieved. It is referred to as a XXX time life part or component.
Item, Maintenance Significant (MSI)	Items identified by the manufacturer whose failure: - could affect safety - could be undetectable during operations, - could have significant operational economic impact - could have significant non-operational economic impact
Item, Serviceable	An item that can be returned to service with appropriate airworthiness documentation.
Letter Check	In airline industry, the alphabetic designations given to scheduled-maintenance packages. A maintenance package is a group of maintenance tasks scheduled for accomplishment at the same time. See Check, C.
Life, Useful	The length of time a population of items is expected to operate with a constant failure rate. This excludes infant mortality and wearout periods.
Line Replaceable Unit (LRU)	A unit that can be readily changed on an aircraft during flight line maintenance operations.

TERMS	DEFINITIONS
Maintainability Requirement	A comprehensive statement of required maintenance characteristics, to be satisfied by the design of an item (for example, Mean Maintenance Man-Hours per Flight Hour).
Maintenance	All action necessary to sustain or restore the integrity and performance of an item to a specified condition. It includes inspection, testing, servicing, classification as to serviceability, repair, rebuilding, and reclamation.
Maintenance, Condition Monitoring:	See Condition Monitoring
Maintenance Direct Costs	Maintenance labor and material costs directly expended in performing maintenance on an item or aircraft.
Maintenance, Direct (man hours per maintenance action)	A measure of maintainability that is the sum of direct maintenance man hours, divided by the total number of maintenance actions during a stated period of time.
Maintenance, Hard Time (HT)	See Maintenance, Scheduled
Maintenance Indirect Costs	Maintenance labor and material costs, not considered to be direct maintenance costs, that contribute to the overall maintenance program costs through overhead operations, administration, record keeping, supervision, tooling, test equipment, facilities, etc.
Maintenance, On Condition	A maintenance process, where a component's suitability for continued service is determined by periodic inspection or test, or both, in situ on the airplane. Such a plan gives full recognition to the fact that failure is random in nature and cannot be completely obviated by any known maintenance scheme.
Maintenance, Scheduled (Hard Time)	A maintenance process performed at defined intervals to retain an item in a serviceable condition.
Maintenance, Unscheduled	Corrective maintenance performed, as required by item condition.

TERMS	DEFINITIONS
Mean-Time Between Failures (MTBF)	A basic measure of reliability for repairable items. The main number of life units during which all parts of the item perform within their specified limits during a particular measurement interval under stated conditions.
Mean-Time Between Maintenance	A measure of the reliability taking in to account maintenance policy is the total number of life units expended by a given time, divided by the total number of maintenance events (scheduled and unscheduled) due to that item.
Mean-Time Between Removals	A measure of the system reliability parameter related to demand for logistic support is the total number of system life units, divided by the total number of items removed from that system during a stated period of time.
Mean-Time Between Unscheduled Removals	A performance figure calculated by dividing the total unit flying hours (airborne) accrued in a period by the number of unscheduled unit removals that occurred during the same period.
Mean-Time to Repair	The statistical mean of the distribution of times-to-repair is the summation of active repair times during a given period of time, divided by the total number of malfunctions repaired during the same interval.
Minimum Equipment and Dispatch Procedures (MEDP)	A supplement to the minimum equipment list (MEL) that also contains procedures to follow in order to dispatch aircraft with specific equipment that is inoperative. It may involve takeoff gross weight reduction.
Minimum Equipment List (MEL)	An approved list of equipment that must be operative for full mission capability. Any systems that are inoperative result in partial mission capable status. See minimum equipment and dispatch procedures (MEDP).
On Condition (OC)	An OC unit has no fixed restoration limit, but must be given a specific check at a prescribed frequency or interval. This check must be against specific, published requirements which determine that the unit is serviceable and airworthy and is reasonably certain to remain so until its next scheduled check. The degree of certainty required depends on the importance of the unit to aircraft airworthiness, available backup, and redundancy.