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TERMINOLOGY FOR FLIGHT CONTROL SYSTEMS

1. SCOPE: This ARP presents definitions of terminology used in conjunction with flight control systems. Terminology associated with fault-tolerant systems has been emphasized. No details of specific design approaches are given. Likewise, no recommendations are included for flight control system performance and design requirements.

2. ABBREVIATIONS:

ACT	-	active controls technology
AFCS	-	automatic flight control system
BIT	-	built-in-test
CAS	-	control augmentation system
CBL	-	control-by-light
CBW	-	control-by-wire
DFO	-	dual fail operative
FBW	-	fly-by-wire
FCS	-	flight control system
FS	-	fail safe
IAP	-	integrated actuator package
MFCS	-	manual flight control system
PBW	-	power-by-wire
SAS	-	stability augmentation system
SFO	-	single fail operative

3. TERMINOLOGY:

Active: An adjective which describes; A system or portion of a system which is in control in contrast to being in standby.

Active Controls Technology (ACT): 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/or Directional Stability Augmentation
Angle-of-Attack Limiting
Wing-Load Alleviation
  Maneuver-Load Control
  Gust-Load Alleviation
Flutter-Mode Control
Ride Smoothing

Automatic Flight Control Systems (AFCS): Automatic Flight Control Systems consist of electrical, mechanical and hydraulic components which 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, structural mode control and similar control mechanizations.

AFCS functions include:
- Airspeed Hold
- All-Weather Landing
- Altitude Hold
- Altitude Select
- Attitude Hold (Pitch and Roll)
- Automatic Carrier Landing
- Automatic Instrument Low Approach
- Automatic Navigation
- Automatic Terrain Following
- Automatic Vectoring/Traffic Control
- Heading Hold
- Heading Select
- Mach Hold

AFCS Pre-engage Synchronization: The process of biasing a new input signal to correspond with the AFCS output position prior to switching to the new input signal. The bias is ramped out after switching.

Analytical Redundancy: A concept wherein an estimate of a physical parameter (e.g. aircraft attitude, acceleration, etc.) is computed by combining and filtering information from other sensed data which have a known physical relationship to the signal of interest. In this way, a signal may be synthesized from other sensor signals rather than be obtained from direct measurement. In control systems, the synthesized signal can be used to add a level of redundancy.

Artificial Intelligence: A characteristic of a knowledge-based concept or process that involves decision making and reasoning based on stored knowledge. A system possessing such a characteristic is sometimes referred to as an "expert system", i.e., it uses knowledge and inference procedures to solve problems, or diagnose conditions by their symptoms.

Averaging System: The type of fault-tolerant system using two or more active channels wherein the individual channel outputs are summed to provide an average output. All channels are normally operative so performance degradation may occur after a failure. An example of an averaging system is the use of multiple control surfaces on an airplane, each individually actuated.

Backup System: A mode of control which is engaged upon failure of the primary operational system. Usually used to refer to a system which is as independent as possible from the primary system. Sometimes used as protection against multiple generic failures.

Built-In-Test (BIT): An operational status checkout or test system which is integrated into a control system or function. Usually used to verify operational status of as many aspects of a control function as possible within the limits of integrated test capability. May be initiated automatically or on command.

Channel: One signal or control path of a redundant set. A channel is an entity within itself and contains elements individual to that channel. A model may be used as a reference channel in a detection-correction system.

Channel Buffering: A technique used to minimize the possibility of a failure in one channel from inducing 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
Normal/Alternate

Channel Summing: The combining of multiple channels to provide a control function. Examples of channel summing techniques are:

Flow Summing
Flux Summing
Force Summing
Position Summing
Torque Summing
Velocity Summing

Control Augmentation System (CAS): A vehicle flight control system wherein the control system responds to the error between the commanded vehicle motion and the actual vehicle motion.

Control Authority: The amount of control surface or force effector 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, so as to be more explicit.

Control-By-Light (CBL) (Fly-By-Light) System: A flight control system wherein vehicle control information is transmitted by light through a fiber-optic cable.

Control-By-Wire (CBW) (Fly-By-Wire) System: A flight control system wherein vehicle control information is transmitted completely by electrical means.

Conversion: The process of changing from one type of control or operational state to another; e.g. from an active to a standby control or from a primary to a secondary system.

Detection-Correction System: The type of fault-tolerant system wherein a failure or out-of-operating tolerance condition is detected and corrective action is taken automatically. This may involve switching to a standby system; or, if two or more systems 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 and correction. With detection-correction systems, it is possible to use a model of an active system as a reference in order to extend the failure correction capability of the total system.

Dual-Fail Operative (DFO): A condition or requirement wherein 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 but non-simultaneous failures in two of its channels and continue to operate with no nominal loss of performance. Unless specifically stated, it is understood that no nominal loss of performance occurs after one or two failures.

Dual Load Path: A type of mechanical paralleling wherein 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, as a duplex valve, duplex actuator, etc.

Electrical Logic: Logic for mode switching or failure detection and correction performed with electronic or electrical components.

Equalization (Channel Balancing): The use of feedback to achieve close coincidence between the outputs of two or more elements or channels in a fault-tolerant control system. Equalization may be necessary to reduce the transient that could occur while shutting off a failed channel, or it may be necessary to minimize the adverse effects of normal tolerances.

Expert System: See Artificial Intelligence.

Failure: A noun describing the state of having failed. 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) Erroneous hardover conditions or loss of control intelligence at the signal input.

4) Any out-of-tolerance condition that exceeds normal operating limits.

Failure Mode: A manner in which a device can or did fail. Simple devices may have only one failure mode; whereas, more complex devices can have several failure modes.

Fail-Functional: A more limited case of fail-operative wherein performance is degraded following a failure.

Fail-Hardover: The type of failure wherein the output of the failed element is at an extreme condition (e.g. position, force, etc.). In cases having a polarity of output, a hardover failure may be of either polarity.

Fail-Neutral: A failure mode where the control device or system fails to a passive null or locked-at-null condition.

Fail-Open: The type of failure wherein 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.

Fail-Operative: A quality wherein a control device or system can continue operation after a failure or failures. A more explicit description is given by SFO or DFO. In a true fail-operative situation, a failure will cause no nominal loss of performance.

Fail-Passive: A quality wherein 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 a part of the system but acts only as an additional load. Sometimes referred to as Fail-Soft.

Fail-Safe (FS): A quality wherein the control device or system ceases to function but the conditions or consequences resulting from the failure are not hazardous and do not preclude continued safe flight. The condition following failure may be completely passive, or it may involve driving to a predetermined nonactive condition.

Flight Control System (FCS): A system which includes all aircraft subsystems and components used by the pilot or other sources to control one or more of the following: aircraft flight path, attitude, airspeed, aerodynamic configuration, ride and structural modes.

Fly-By-Light: See Control-By-Light.

Fly-By-Wire (FBW): See Control-By-Wire.

Hydromechanical Logic: Logic for mode switching or failure detection and correction, performed only with mechanical elements using hydraulic information in the form of hydraulic pressures or flows.

Integrated Actuator Package (IAP): An actuator package which has an energy source or power conversion unit, such as an electric motor/pump, within the package.

Isolation: A technique used in fault tolerant systems that removes the effects of a failure or prevents a failure from propagating or affecting the continued operation of the system.

Majority Voting System: A fault-tolerant system wherein the outputs of three or more signals are summed to provide a single signal representative of the majority of the individual signals, often providing detection logic for identifying a failed channel. (See voter.)

Manual Flight Control System (MFCS): A system which transmits manual pilot commands directly or generates and conveys commands which augment manual pilot control commands and thereby accomplishes flight control functions. The system may include electrical, mechanical and hydraulic components which provide means for transmission of manual pilot commands to the control function. This classification includes the longitudinal, lateral-directional, lift, drag and variable geometry control systems. Associated scheduling, limiting and control devices are included.

Model: A device used in a failure detection-correction system to simulate the performance of a component or 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 or a model. Cross-channel monitoring compares equivalent performance features of two or more channels.

Non-detectable Failure: A failure that, upon occurrence, is not recognized by the failure detection scheme(s) of a fault tolerant flight control system. Unless stated otherwise, a flight control system must maintain its fail-operative status after the occurrence of a non-detectable failure.

Parallel Actuators: Two or more actuators arranged in parallel to drive a single output or load. Usually, parallel actuators are physically separated, each with its own output connection, and are tied together by the load in a force or torque-summing fashion. Sometimes, referred to as side-by-side actuators.

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 which perform an alternate function to that of the pilot. The parallel servo output will drive both the pilot controls and the flight control system.

Passive Failure: The type of failure wherein the failed device or system has no effect on the operational performance of a fault-tolerant system even when it is commanded to function. Usually associated with standby or inactive features of a fault-tolerant system.

Passive Paralleling: The simplest and most common type of redundancy wherein two parallel functional devices are utilized such 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 fail passively, such as springs and linkages. When failure of one element occurs, there may be a change in performance or capability.

Power-By-Wire (PBW) Actuation: An integrated servoactuator which incorporates an electric motor to receive power from the aircraft main electric power system in lieu of an actuator connected directly to the aircraft main hydraulic system. Power conversion from electrical to mechanical may include mechanical devices such as ballscrews, gears, chains, cables, etc. or through a motor/pump and hydraulics. See Integrated Actuator Package.

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 capability such as SFO/FS, DFO or DFO/FS.

Quad Voter: A voter that selects one common output to represent the four input signals or values.

Reconfigurable: That characteristic of a fault-tolerant device or system whereby continued functional operation, subsequent to a failure, is provided by rearranging or recombining the surviving control elements. Sometimes referred to as self-repairing.

Redundancy Management: That portion of the system logic and control (hardware or software) which 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.