



AEROSPACE RECOMMENDED PRACTICE

ARP5764™

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Aerospace Active Inceptor Systems for Aircraft Flight and Engine Controls

RATIONALE

Active Inceptor Systems are a class of pilot cockpit controllers that include a programmable servo actuator controlled feel-force system, and are being developed and flight tested for both fixed and rotary wing aircraft, some of which are entering service. This Aerospace Recommended Practice fulfills the need for a document which defines the general characteristics and requirements for these feel-force control systems.

FOREWORD

Advances in flight control technology have helped optimize the performance of modern aircraft, and include selectable changes in aircraft configuration and extensive flight control system augmentation. Pilots require uniform and predictable aircraft response during changes in the configuration and flight conditions. This requirement is being addressed by active cockpit controllers, also known as Active Inceptors, which function as programmable, servo actuator controlled, feel-force systems. Active cockpit controllers may include a variety of pilot controls; side sticks, center sticks, engine controls, yaw controls, and cyclic and collective controllers.

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1. SCOPE

1.1 Purpose

The purpose of this document is to develop the general characteristics and requirements for feel-force control systems for active cockpit controllers, also known as Active Inceptors. The document presents technical material that describes the recommended key characteristics and design considerations for these types of systems. Where appropriate, the effects of platform specific requirements (e.g., single axis/dual axis, single seat/dual seat, civil/military, rotorcraft/fixed wing aircraft, etc.) are clearly identified.

The material developed will serve as a reference guide for:

- a. Aircraft prime contractors who want to understand active cockpit controller technology and develop their own set of requirements;
- b. Suppliers that develop active cockpit controller equipment and;
- c. Regulatory Authorities who will be involved in the certification of these types of systems.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

ARP4386	Terminology and Definitions for Aerospace Fluid Power, Actuation and Control Technologies
ARP4754	Guidelines for Development of Civil Aircraft and Systems
ARP4761	Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment
AS94900	Aerospace - Flight Control Systems - Design, Installation and Test of Piloted Military Aircraft, General Specification For

2.1.2 RTCA Publications

Available from RTCA, Inc., 1150 18th Street, NW, Suite 910, Washington, DC 20036, Tel: 202-833-9339, www.rtca.org.

RTCA DO-160	Environmental Conditions and Test Procedures for Airborne Equipment
RTCA DO-178	Software Considerations in Airborne Systems and Equipment Certification
RTCA DO-254	Design Assurance Guidance for Airborne Electronic Hardware

2.1.3 ATA Publications

Available from Air Transport Association of America, Inc., 1301 Pennsylvania Avenue, NW, Suite 1100, Washington, DC 20004-1707, Tel: 202-626-4000, www.airlines.org.

MSG-3: Operator/Manufacturer Scheduled Maintenance Development

2.1.4 U.S. Government Publications

Available from the Document Automation and Production Service (DAPS), Building 4/D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-6257, <https://assist.daps.dla.mil/quicksearch/>.

MIL-STD-1797	Flying Qualities of Piloted Aircraft
MIL-F-83300	Flying Qualities of Piloted V/STOL Aircraft
DOD-HDBK-743	Anthropometry of U.S. Military Personnel
MIL-STD-882	Standard Practice for System Safety
MIL-STD-883	Test Method Standard Microcircuits
MIL-HDBK-5400	Military Handbook Electronic Equipment, Airborne, General Guidelines for
MIL-STD-810	Environmental Engineering Considerations and Laboratory Tests.
MIL-STD-461	Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment
MIL-STD-1367	Military Standard Packaging, Handling, Storage, and Transportability Program Requirements (for Systems and Equipment)
MIL-STD-973	Military Standard Configuration Management

Available from US Army Aeroflightdynamics Directorate (AFDD) Mail Stop 243-11 Moffet Field, CA 94035:

ADS-33E-PRF	Aeronautical Design Standard Performance Specification Handling Qualities Requirements for Military Rotorcraft
MIL-STD-1472	Design Criteria Standard Human Engineering

2.1.5 FAA Publications

Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591, Tel: 866-835-5322, www.faa.gov.

14 CFR Part 23 Code of Federal Regulations, Part 23 Airworthiness Standards: Normal, Utility, Acrobatic and Commuter Category Airplanes

14 CFR Part 25 Code of Federal Regulations, Part 25 Airworthiness Standards: Transport Category Airplanes

14 CFR Part 27 Code of Federal Regulations, Part 27 Airworthiness Standards: Normal Category Rotorcraft

14 CFR Part 29 Code of Federal Regulations, Part 29: Airworthiness Standards: Transport Category Rotorcraft

2.1.6 EASA Publications

Available from European Aviation Safety Agency, Postfach 10 12 53, D-50452 Koeln, Germany, Tel: +49-221-8999-000, www.easa.eu.int.

CS-23 Certification Specifications for Normal, Utility, Aerobatic and Commuter Aeroplanes

CS-25 Certification Specifications for Large Aeroplanes

CS-27 Certification Specifications for Small Rotorcraft

CS-29 Certification Specifications for Large Rotorcraft

2.1.7 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM G85 Standard Practice for Modified Salt Spray (Fog) Testing

2.2 Definitions

2.2.1 Cockpit Controllers

INCEPTOR: A device that is used to provide pilot control inputs and covers a variety of aircraft pilot controls: side sticks, center sticks, pedals, engine controls and rotorcraft cyclic and collective controls.

PASSIVE INCEPTOR: A passive control inceptor uses mechanical devices such as springs and dampers, sometimes in series with low bandwidth actuation, to generate the control forces felt by the pilot.

ACTIVE INCEPTOR: An active control inceptor uses high bandwidth actuation to generate the primary control forces felt by the pilot and thereby provide augmented control. This augmentation may include tactile pilot cues in real-time, such as variable spring gradients, force breakouts, detents, ramps, gates and soft stops, to warn of mode engagements or impending operating or envelope exceedances. Actuation backup may be provided by parallel springs and dampers in the event of a loss of active capability.

2.2.2 Specific Inceptor Terms

The following terms are used to define inceptor performance throughout this publication. Figure 1 illustrates the application of most of the terms to a two-axis inceptor.

1. **Reference Plane:** The plane that contains both the pitch and roll axes of a two-axis inceptor.
2. **Pivot Point:** The point about which the inceptor rotates, also known as a center of rotation. For the two-axis inceptor shown in Figure 1, the pivot points for both the pitch and roll axes coincide.
3. **Grip Reference Point (GRP):** The point on the controller/inceptor through which the pilot inputs all forces. These force inputs are input perpendicular to a line connecting the GRP and pivot point in the plane of motion (pivot arm). The GRP on most grips is usually taken as the center of the middle finger position when on the grip.
4. **Pivot Arm:** The distance between the GRP and the pivot point in the plane of motion.
5. **Pitch Axis:** Axis about which the inceptor rotates when the grip is deflected in the pitch direction.
6. **Roll Axis:** Axis about which the inceptor rotates when the grip is deflected in the roll direction.

7. Heave Axis: Axis about which the inceptor rotates when the grip is deflected in the up/down (heave) direction. This is often applicable to single axis rotorcraft collective controls (collective inceptor type).
8. Plane of Motion: The plane described by the rotation of the grip about the relevant axis (i.e., Pitch Plane of Motion). A 'Pitch Plane of Motion' would be perpendicular to the pitch axis and the reference plane.

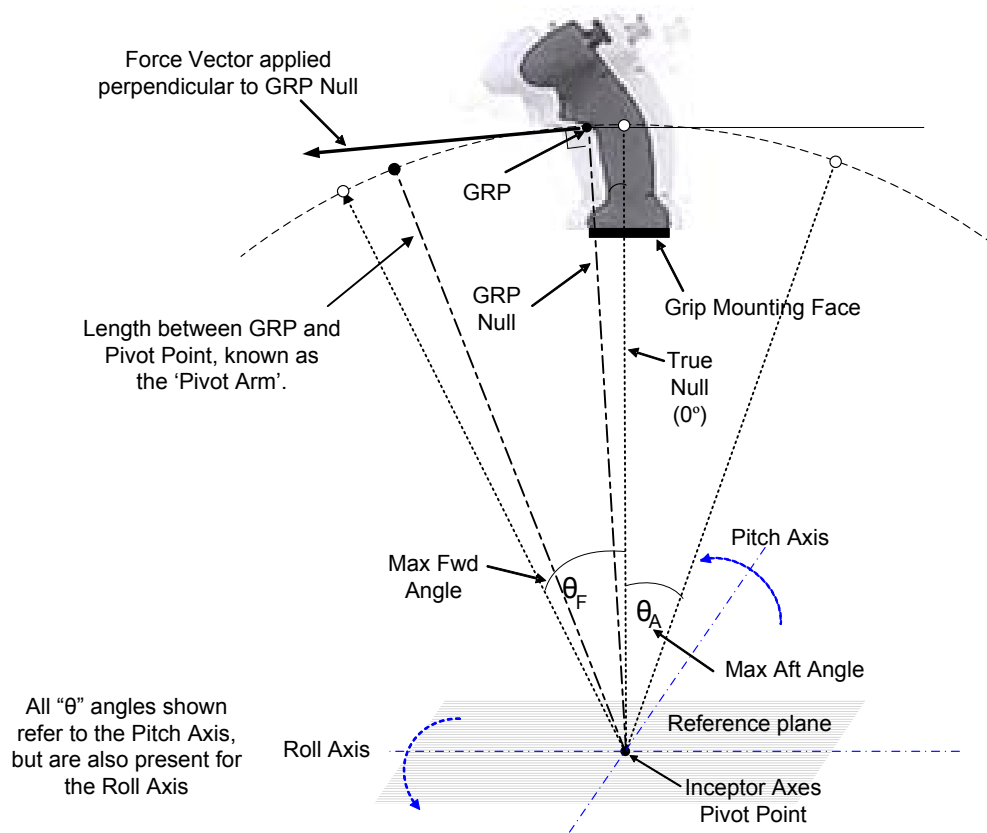


FIGURE 1 - PITCH/ROLL INCEPTOR GEOMETRY DEFINITIONS

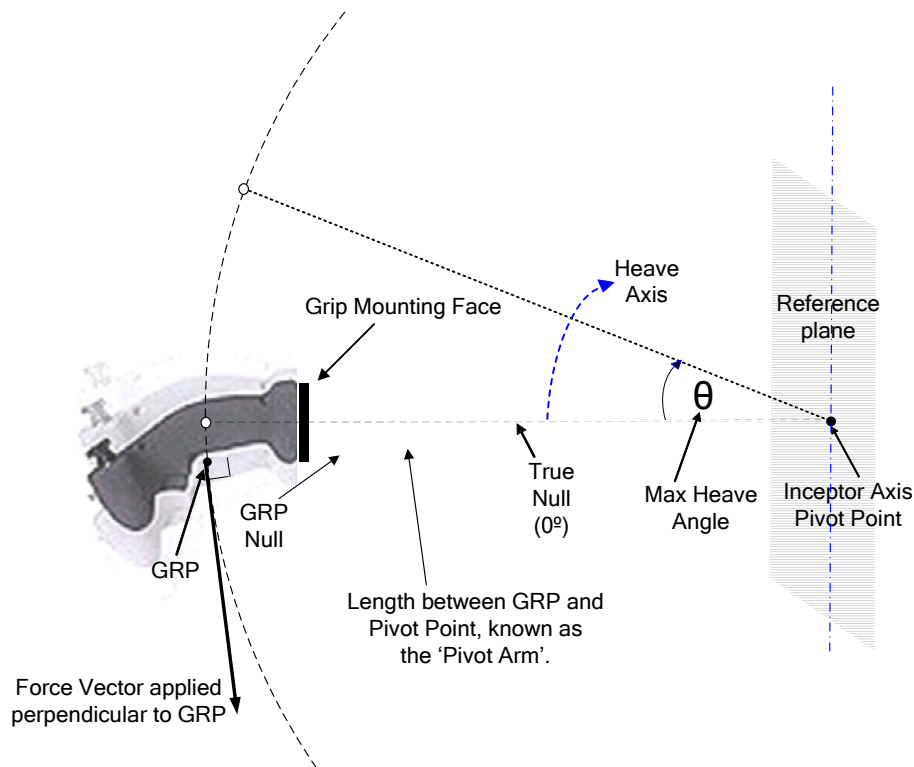


FIGURE 2 - HEAVE AXIS INCEPTOR GEOMETRY DEFINITIONS

9. True Null: This is the geometric null position of the inceptor and is described by a line perpendicular to the reference plane which connects the center of the grip mounting face and the pivot point. For the two-axis inceptor shown in Figure 1, this will correspond to zero displacement in the pitch and roll axes. For the single axis heave inceptor (Figure 2) the lowest inceptor position (at the bottom of the travel) may actually be greater than 0 degrees from 'horizontal', dependent on the aircraft type and specific requirements.
10. GRP Null: This is described by a line drawn between the GRP and the pivot point when the relevant axis is at True Null.
11. True Position: Rotational displacement about the relevant axis from the true null in the plane of motion.
12. Reported Position: The displacement about the relevant axis reported by the position sensors.
13. Zero Force Null Band: The range of inceptor displacement, with no applied force, over which the inceptor is statically stable. The Zero Force Null Band is typically determined by gradually releasing the inceptor without assistance from the deflected position in both directions, and determining where it comes to rest. This is defined in terms of reported position.
14. Zero Force Null: The geometric center of the Zero Force Null Band.
15. Breakout Force: The force required at the zero force null position to initiate movement away from this position.
16. Position sensor hysteresis: The difference in reported position (position sensor output) when at the same true position when approached from opposite directions.
17. Position sensor nonlinearity: The maximum deviation between the Reported Position and the True Position.

18. Position sensor gain/sensitivity: The slope of the best fit straight line through a series of sensor outputs corresponding to known sensor positions covering the sensor range.

19. Position sensor resolution: The smallest inceptor position change that the sensor can measure.

2.2.3 Control Systems for Active Inceptors

The general functional requirements for the electronic controller, servo actuation system, the passive spring assembly, and the force and position sensors may be common for several types of active inceptors. A functional diagram for a typical active inceptor is shown below:

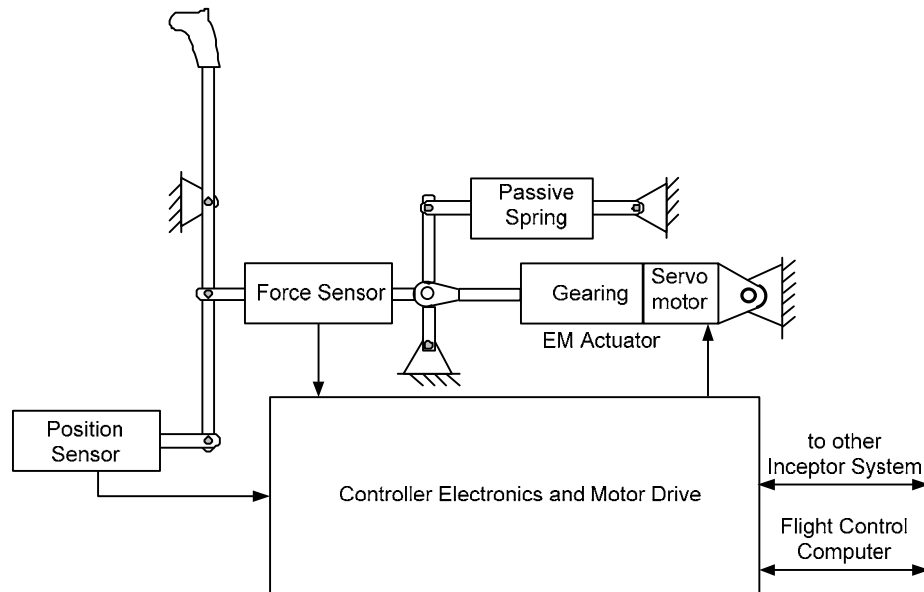


FIGURE 3 - INCEPTOR FUNCTIONAL DIAGRAM

An inceptor does not necessarily have to be a 'control stick' as depicted by this diagram. It could equally be a set of pedals or other general pilot-vehicle interface. It should also be noted that whilst the diagram shows a typical inceptor system, it does not show a minimum set of components for, or all components possible in an arrangement for any given air vehicle.

2.2.4 Types of Active Inceptor Systems

Active Inceptor Systems can cover a wide variety of controller types. These may range from short lever arm controllers (side sticks), long lever arm controllers (center sticks or rotorcraft collective levers), rudder pedals, and engine controls. These different types of force-feel controllers are described in more detail in the sub-sections below.

2.2.4.1 Side Stick Controllers

Side stick controllers are named as such because they are usually physically located to the side of the pilot seat, allowing the pilot to comfortably rest his or her hand on the controller hand grip, and allow a full range of axis travel without excessive arm movement. Cockpit installations often have adjustable armrests to allow optimal decoupling to be achieved between pilot pitch and roll inputs. They are usually 2 axis (pitch and roll), but could also be single axis or 3 axis (pitch, roll and yaw).

To achieve this, side stick controllers generally have a small pivot arm between the main rotational axis and the hand grip reference point. The pitch and roll axes generally coincide, though this is not always necessarily true. A small pivot arm allows the pilot to move the controller through a large angle whilst restricting the grip fore-aft/left-right movement to a small displacement. This allows the side stick physical throw, and thus the resulting hand movement to move the stick grip, to be minimized. This is necessary as typically the pilot will move the side stick with only the hand and wrist, with the forearm resting on an armrest. Typical pivot arms for side stick controllers can range from 4 to 8 in (102 to 203 mm), with pivot arms in excess of 10 in (254 mm) moving towards center stick applications.

Side stick force levels are generally lower than for a center stick application as they are designed for one handed operation. This results in typical maximum active force levels of approximately 30 lbf (133 N) at the grip reference point, rather than a range of 50 to 60 lbf (222 to 267 N) for center stick applications. However, installation geometry, pilot adjustment limits, and ergonomics also play a role in the typical operating forces for side stick controllers, as the pilot will typically be able to apply more force in the pitch (longitudinal) direction than the roll direction (lateral axis). A pilot will also be able to apply more force in the roll inboard direction than the roll outboard direction due to the anthropometry of the human arm. A typical force-feel characteristic will consist of a spring return gradient with dynamically alterable stop positions (described in 3.2.2.1 onwards).

A typical side stick assembly, with a pivot arm of between 5 to 7 in (127 to 178 mm) is shown in Figure 4.



FIGURE 4 - EXAMPLE SIDE STICK INCEPTOR

2.2.4.2 Center Stick Controllers

Center stick controllers are so named because they are usually physically located to the front and center of the pilot seat, situated between the pilot and the instrumentation panel. The pilot will be able to grip the control stick with either one or two hands, depending on the type of control input being made, aircraft type, and the inceptor force-feel gradient. They are usually 2 axis (pitch and roll), and may have different pivot arms in the pitch and roll axes.

Center stick controllers typically have a larger pivot arm between the main rotational axis and the grip reference point than side stick controllers. This pivot arm allows the pilot to move the controller through large linear displacements with minimal rotational displacement.

Center stick force levels are generally higher than for a side stick application, as they are designed for one or two handed operation. This results in typical maximum active force levels of approximately 60 lbf (267 N) at the grip reference point, in comparison to 30 lbf (133 N) for side stick applications. Ergonomics also play a role in the typical operating forces for center stick controllers as the pilot will be able to apply more force in the pitch (longitudinal) direction than the roll direction (lateral axis). The pitch axis of a center stick controller will typically have a higher force requirement than the roll axis. A typical force-feel characteristic will consist of a spring return gradient with dynamically alterable stop positions (described in 3.2.2.1 onwards).

Typical center stick assemblies, with pivot arms of between 15 to 20 in (381 to 508 mm) are shown in Figure 5.



FIGURE 5 - EXAMPLE CENTER STICK INCEPTORS

2.2.4.3 Engine Throttle Controllers

There are several types of engine throttle controllers, such as:

- Rotary quadrant controllers: center mounted, typically used on 2 seat multi-engine aircraft.
- Left hand side rotary controllers, typically used in military fixed wing jets. A split grip may be present on twin engine aircraft to allow different engine settings.
- Left hand side linear throttle controllers, such as used on the F35 Lightning II.

Engine throttle controllers are usually single axis, or multiple single axis devices for multiple engine control. The concept of HOTAS (Hands on Throttle and Stick) is also supported by the grip configuration of many active engine throttle controllers in military aircraft, allowing the pilot to operate all aircraft functions without taking his/her hand off the stick and throttle grips. The pivot arms associated with rotary devices are usually similar to side stick controllers, at around 6 in (152 mm).

Engine throttle controller force levels are similar to side stick applications as they are designed for one handed operation. This results in typical maximum active force levels of up to 40 lbf (178 N) at the grip reference point. A typical force-feel characteristic will consist of a constant friction feature with superimposed throttle style features (gates, detents, stops and ramps, described in 3.2.2.1 onwards)

An example of an active linear engine throttle controller, in a cockpit installation, is shown in Figure 6.

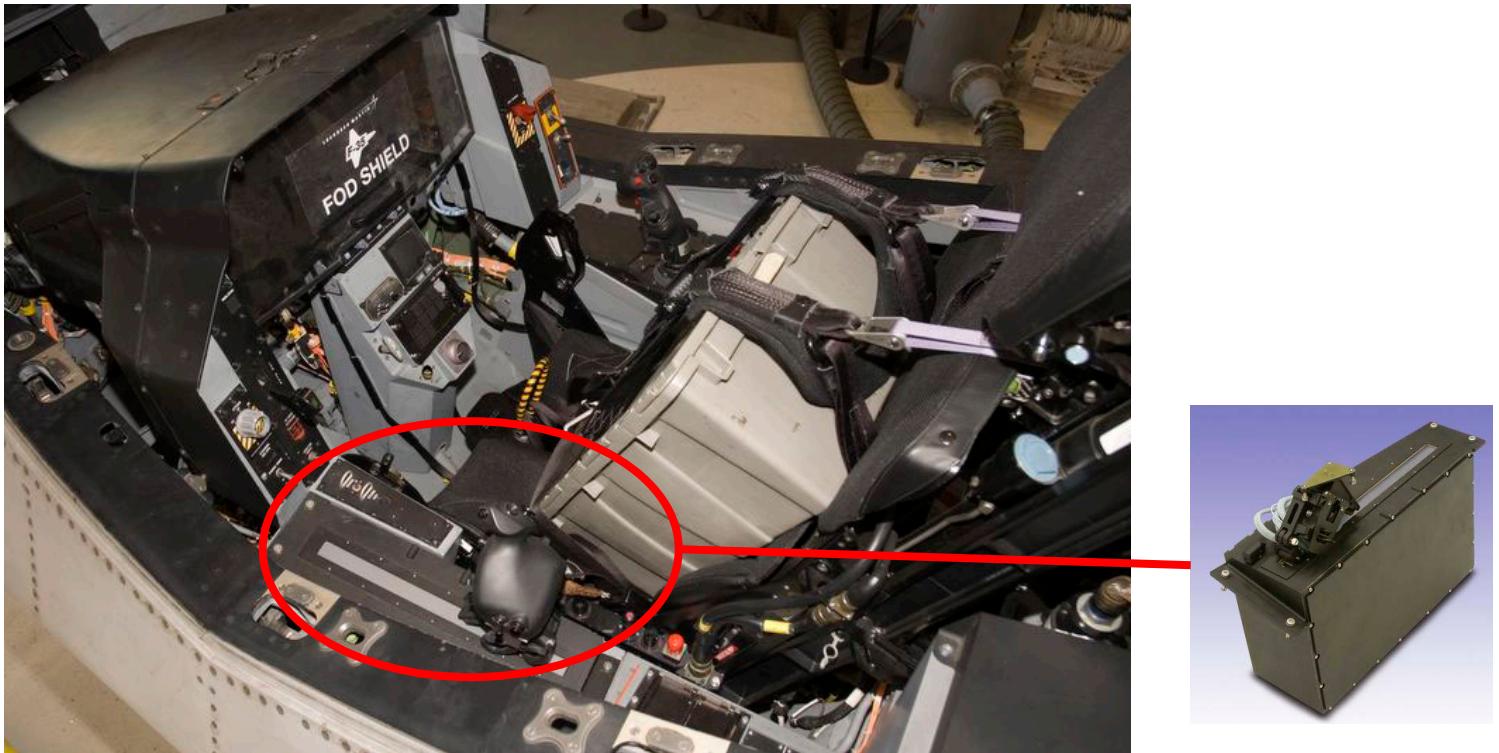


FIGURE 6 - EXAMPLE ACTIVE ENGINE THROTTLE CONTROLLER (LINEAR)

2.2.4.4 Rotorcraft Collective Controllers

Rotorcraft collective controllers are a single axis vertical controller, which moves in an up-down motion, generally situated to the pilot's left hand side alongside the seat. Rotorcraft collective controllers are considered a separate class of controllers from the engine throttle controllers as they control the collective pitch of the aircraft rotor blades, and sometimes have engine throttle functionality built in.

The pilot will grip the collective controller with one hand, so active force levels generated by the controller generally do not exceed 30 lbf (133 N) even though ergonomics dictate that much larger forces could be applied in the upward direction. A typical force-feel characteristic will consist of a constant friction with superimposed throttle style features (gates, detents, stops and ramps, described in 3.2.2.1 onwards)

Collective controllers typically have a large pivot arm between the main rotational axis and the grip reference point, of between 15 to 20 in (381 to 508 mm). However, shorter moment arm collective controllers are also possible.

A typical rotorcraft active collective controller, installed in a rotorcraft cockpit, with a pivot arm of between 15 to 20 in (381 to 508 mm) is shown in Figure 7.



FIGURE 7 - EXAMPLE ROTORCRAFT COLLECTIVE INCEPTOR

2.2.4.5 Directional Pedals

Active Directional Pedals (primarily yaw) may replace the traditional passive pedals in both rotorcraft and fixed wing aircraft, however, no flight worthy active pedal assemblies exist as yet. Pedal sets are typically configured to move in a fore/aft rotational movement about a fixed pivot above or below the pedal. If an active pedal system is incorporated within an aircraft, generally the envelope and pivot requirements for the active pedals will match the existing passive pedals.

Pedal force levels are generally much higher than hand controlled inceptors, as they are operated by the feet, with typical maximum active force levels of 200 lbf (890 N) at the pedal, though these levels will depend on the application and aircraft type. For example, the maximum force levels defined by ADS-33E-PRF for rotorcraft indicate that 75 to 125 lbf (334 to 556 N) of force is an acceptable maximum applied force to reach the displacement stops of a pedal inceptor assembly, however, the nominal maximum force values are often much lower at 30 to 40 lbf.

In summary, the design and installation of directional pedals is unique for each type and size of aircraft. When a need for the development of Active Directional Pedals is identified the prime contractor should specify the design and installation requirements. The requirements should include the integration of the directional pedals with the aircraft braking system.

3. REQUIREMENTS

3.1 General System Requirements

3.1.1 Safety and Operability Considerations

Safety and Operability considerations should use the references ARP4754 and ARP4761 and the Airworthiness Regulations as referenced by the FAA 14 CFR's (2.1.5) and/or EASA CS's (2.1.6) where applicable.

The underlying principles of the System Safety Assessment are defined within ARP4761 and are summarized here for information:

- Functional Hazard Assessment (FHA) for both System and Aircraft level (A/C level to be undertaken by the Prime Contractor), carried out during the Concept Development of the aircraft and Preliminary Design stage of the Inceptor System;
- Preliminary System Safety Assessment (PSSA) and System Safety Assessments (SSA), again for both System and Aircraft level, should be carried out. The PSSA comprises Fault Tree Analysis (FTA), the SSA should include Failure Mode and Effects Analysis (FMEA) and further FTA. The PSSA should be carried out during the Preliminary Design stage of the system. The SSA should be carried out during the Detailed Design, and Validation/Verification stages of the Inceptor system design;
- Common Cause Analysis (CCA) should support the development of the specific system architecture and that of related events by evaluating the overall architecture sensitivity to common cause events. These common cause events are evaluated by performing Particular Risk Analysis (PRA), Zonal Safety Analysis (ZSA) and Common Mode Analysis (CMA).
- Further analysis if required, such as Modal Analyses and the analysis of Exchange Functions within the system should be carried out (interaction between the Aircraft level systems and the Inceptor System under consideration). These activities should be carried out during both the Preliminary and Detailed Design stages of the Inceptor system and also during the Validation/Verification stage.

3.1.1.1 Quantitative Flight Safety (PLOC - Probability of Loss of Control)

The Flight Control System (FCS) PLOC is based on the aircraft loss rate due to relevant FCS failures including all flight critical components and subsystems and the consequence of a single failure or multiple failures. The FCS PLOC is specified by the procuring activity. The prime contractor will allocate the appropriate portions of the FCS PLOC to FCS components and subsystems.

Inceptor failures which can cause or contribute to loss of control are considered catastrophic and must be mitigated with appropriate levels of redundancy and independence.

3.1.1.2 Failure Immunity and Safety

Flight safety assessments should be conducted in a manner similar to conventional controls but with an open mind to the failure possibilities inherent with active controls and Fly by Wire (FBW) based control position reporting.

The flight safety assessment should include the analysis detailed below:

3.1.1.2.1 Safety Analysis

3.1.1.2.1.1 Functional Hazard Assessment

A Functional Hazard Assessment (FHA) should be carried out which considers the functions of the Inceptor System. It identifies and analyzes failures of these functions and classifies the probability and severity of the failures. Where the probability and severity is unacceptable, the FHA identifies recommended mitigation and classifies the probability and severity of the failures after the mitigation has been taken into account. The FHA should also be linked to a list of Exchange Functions. An Exchange Function is a function of an external system (in the case of an inceptor system it is the Flight Control System of the platform it will be installed on) that is relied on for the overall aircraft safety. The crew reactions to failure events should also be considered as part of the Exchange Functions.

The FHA may be presented in tabulated format, with the following items addressed: hazard identifier, a description of the failure mode, operational state, effect of the failure, a reference to the applicable section in the aircraft level SSA, initial hazard risk assessment (severity, frequency, Hazard Risk Index (HRI)), recommended mitigation, target hazard risk assessment (severity, frequency, HRI), and requirements traceability.

Typical hazards to be considered, generally associated with an inceptor system include:

- Loss of motion, or 'free' motion (i.e., loss of feel, under damped response) - no response to pilot input when operating in 'active' or 'passive' modes:

Mitigated through redundant pilot/co-pilot stations if a dual cockpit system, or through multi-redundant processing and sensing if a single cockpit inceptor system. Typically an inceptor system would have triplex or quadruplex redundant sensing and processing. If the mechanism is jammed, the force signal may be used to allow the aircraft to be flown, if the signal has suitable integrity and availability.

- Runaway inceptor causing a 'hard over' condition:

A runaway condition may cause a large transient position to be reported to the FCS, which in turn can propagate through the aircraft control system. Mitigation should be through multiple redundant sensors, processing and actuation drive train, in tandem with monitoring schemes to allow errant servo demands to be detected and isolated before a significant transient occurs.

- Loss of reported position, when operating in 'active' or 'passive' modes:

Loss of the inceptor reported position will make the inceptor unable to control the aircraft. Mitigation should be through multiple redundant position sensing and processing. There should also be a multiple redundant communications link to the aircraft FCS to mitigate potential failures in the communications link. A multiple redundant communications link mitigation only applies to systems where the inceptor position is sent to the FCS over a digital link.

- Incorrect position feedback, when operating in 'active' or 'passive' modes:

This failure condition is similar to the above condition, except that position signals continue to be fed back to the aircraft FCS even though they are incorrect. The degree of degradation of the position signal can vary, so mitigation of this condition is through multiple redundant position sensors, channel cross comparison monitoring, and internal system performance monitoring. Multiple redundant communications links to the aircraft FCS also mitigate corruption of the position signals during transmission to the FCS.

- Loss of reported force, if operating in a 'jammed' or reversionary mode of operation:

Loss of the inceptor reported force will make the inceptor unable to control the aircraft if another failure has already occurred which makes it necessary to operate the inceptor using its force output only (i.e., a jam condition in the mechanism). Mitigation should be through multiple redundant force sensing and processing. There should also be a multiple redundant communications link to the aircraft FCS to mitigate failures in the communications link. However, a condition that also needs to be prevented is a force sensing failure causing an erroneous entry to Jam Operation.

- Failure to enter 'active' or 'passive' modes, when operating in 'passive' or 'active' mode:

A failure of this type may cause degradation of the pilot's ability to fly the aircraft, as the inceptor will not be exhibiting the expected force-displacement feel characteristic. Mitigation should be through multiple redundant processing, and multiple redundant communications links to the aircraft FCS.

- Loss of correct active feel, when operating in 'active' mode:

A failure of this type may result in an inceptor that responds to pilot inputs in an unexpected manner, or provides a degraded mode of operation that affects the pilot's ability to control the aircraft. Mitigation should be through multiple redundant processing and sensors.

- Uncommanded movement associated with acceleration acting on masses sensed by the force sensor:

Certain types of inceptor may not be perfectly mass balanced, this may in turn lead to uncommanded movement due to acceleration forces acting on the mass above a force sensor. This should be mitigated through mass balancing of the mechanism, and appropriate programmed cueing features.

- Transients when moving from 'active' to 'passive' models, and vice versa:

When transitioning between modes, either from 'active' to 'passive', or 'passive' to 'active', a transient effect may occur in the position of the control lever. This is typically due to the driving actuator engaging or disengaging as the control mode is changed. Mitigation should be through alignment of the control system parameters with the passive characteristic as the mode is changed, thus resulting in a minimal transient.

3.1.1.2.1.2 Hazard Log

A Hazard Log should be produced which contains similar information headings as that contained within the FHA, except that it applies to 'Operationally Induced' or 'Maintenance Induced' hazards (or 'non-functional' hazards). Examples of these hazards considered for Active Inceptor systems include:

- Unexpected movement resulting in injury to crew hand/arm/wrist:

Mitigated through velocity limiting and monitoring of internal system control law states. For linked systems (dual cockpit systems), pilots should be made aware that an inceptor could move unexpectedly if an input is applied to the other inceptor.

- Sharp corners and edges injuring (maintenance) personnel:

Mitigated through rounding of edges and corners.

- Smoke and Fire due to electrical malfunction:

Low voltage (<50 Vdc typically) system, and safe materials should be used that conform to environmental specifications.

- Weight, causing maintenance personnel injury - an inceptor designed for flight should not be excessively heavy. Features for utilizing external lifting devices may be required to be designed into the inceptor structure for heavier units (i.e., for inceptors that weigh more than 25 lbf (11.4 kg)).
- Application of excessive forces to inceptor grip/pedal or the inceptor housing.

The inceptor system should be designed to withstand a substantial limit load in line with the likely accidental forces that may be applied to the inceptor system. Excessive force could be applied when a pilot accidentally kicks or steps onto an inceptor grip or housing during ingress and egress. Limit loads should be specified to be withstood without the unit incurring damage. Ultimate loads at 1.5x limit load allow damage to occur but must safely allow a return to base.

3.1.1.2.1.3 Software Safety

Software hazards should be mitigated by the software safety activities performed at the following levels:

- Analysis of software requirements, or the analysis of modified or bespoke software requirements if inceptor system software is re-used from a previous program.
- The production of each software lifecycle stage governed by procedures embodying safety rules and constraints designed to prevent the introduction of further hazards.
- Carry out a Software Failure Mode, Effects and Criticality Analysis (FMECA) to determine software resilience to hardware interface anomalies and the operational impact of software responses to hardware failures.
- Failure Mode and Effect Tests shall be conducted by fault insertion to cover all functional blocks to determine correct system detection and response to failures. Correct fault isolation will also be verified.
- Perform a code level analysis to ensure that safety requirements have been successfully mitigated by the software design.
- Validation and verification of the software, usually defined by a Software Verification and Validation Plan.

The system software safety requirements should be consistent with the prime contractor's Software Development Plan and RTCA-DO-178.

3.1.1.2.1.4 Exchange Functions

The Exchange Functions should be defined with the following items addressed: Inceptor System output (define the erroneous output), FCS function (the expected FCS reaction to the erroneous output), and the assumed crew reaction to these events.

3.1.1.2.1.5 Fault Tree Analysis/FMEA

The Fault Tree Analysis (FTA), and Failure Mode and Effects Analysis (FMEA) methods in ARP4761 should be used as a guide. The relationship between the FHAs and FTA/FMEAs are described in ARP4761, Figure 2.

3.1.1.2.2 Inceptor System Safety Engineering

The inceptor equipment should be designed to include safety features, which eliminate or control potential hazards to personnel and equipment without impairing equipment performance or the operational capabilities of the aircraft system. Electronic equipment should be designed considering the guidelines of MIL-HDBK-5400 and the relevant FAR requirements, and shall meet airworthiness and flight safety qualification criteria. Design of equipment for safety should proceed from one order of precedence to another only when one method is shown to be impossible or economically impractical. The order of precedence is as follows: