



AEROSPACE RECOMMENDED PRACTICE

ARP6001™

REV. B

Issued 2012-07
Revised 2020-04
Reaffirmed 2026-05

Superseding ARP6001A

(R) Aerospace - Passive Side Stick Unit
General Requirements for Fly-by Wire Transport and Business

RATIONALE

The document has been updated to incorporate comments from the industry.

ARP6001B has been reaffirmed to comply with the SAE Five-Year Review policy.

A reaffirmed status is given to technical reports that have been reviewed by the technical committee and deemed to be current with no need for immediate revision. No changes have been made to this document as a result of this review.

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1. SCOPE

This SAE Aerospace Recommended Practice (ARP) provides recommendations for design and test requirements for a generic “passive” side stick that could be used for fly-by wire transport and business aircraft.

It addresses the following:

- The functions to be implemented
- The geometric and mechanical characteristics
- The mechanical and electrical interfaces
- The safety and certification requirements

2. REFERENCES

NOTE: A list of research publications related to human factors is provided in Appendix A.

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 +1 724-776-4970 (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

2.1.2 Transport Canada Publications

Transport Canada documents are available from Transport Canada, Tower C, Place de Ville, 330 Sparks Street Ottawa, Ontario K1A 0N5, Tel: 1-800-305-2059, www.tc.gc.ca.

Part V Airworthiness Manual Chapter 525 - Transport Category Aeroplanes

2.1.3 EASA Publications

Available from European Aviation Safety Agency, Konrad-Adenauer-Ufer 3, D-50668 Cologne, Germany (for visitors and for mail over 1 kg) and Postfach 10 12 53, D-50452 Cologne, Germany (for mail 1 kg or less); Tel: +49 221 8999 000, www.easa.europa.eu.

CS-23	Certification Specifications for Normal, Utility, Aerobatic and Commuter Aeroplanes
CS-25	Certification Specifications for Large Aeroplanes

2.1.4 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

Special Conditions No. 25-498-SC: Embraer S.A., Model EMB-550 Airplanes; Side Stick Controllers

Federal Aviation Administration (1995). FAA Policy Statement PS-ANM100-1995-00020: Policy Regarding Flight Control Jams for Normally Encountered Positions. Washington, DC: Federal Aviation Administration.

Federal Aviation Administration (2015). FAA Policy Statement (PS)ASW-27,29-09: Rotorcraft Advanced Flight Controls (AdFC) Handbook. Washington, DC: Federal Aviation Administration.

NextGen Final Report: Data for Updating 14 CFR Part 25.143 and Potential Reference Standards for Part 23, 27, and 29 Aircraft: An Evaluation of Muscular Force That can be Applied to Flight Controls.

2.1.5 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 Considerations in Airborne Systems and Equipment Certification

2.1.6 U.S. Government Publications

Copies of these documents are available online at <https://quicksearch.dla.mil>.

DOD-HDBK-743 Anthropometry of U.S. Military Personnel

MIL-E-5400 Military Specification, Electronic Equipment, Airborne, General Specification

MIL-F-83300 Flying Qualities of Piloted V/STOL Aircraft

MIL-STD-461 Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment

MIL-STD-810 Environmental Engineering Considerations and Laboratory Tests

MIL-STD-883 Test Method Standard Microcircuits

MIL-STD-1797 Flying Qualities of Piloted Aircraft

2.2 Definitions

2.2.1 Inceptors

INCEPTOR: This is a device that is used to provide pilot control inputs and covers a variety of aircraft pilot controls including:

- Side sticks
- Center sticks or central control wheel
- Pedals
- Throttles
- Rotorcraft cyclic and collective controls

PASSIVE INCEPTOR: This is a passive control inceptor system that primarily generates the artificial feel by passive mechanical elements like springs and dampers to achieve grip force profile gradients without active variation of grip feel forces or position (back drive function).

PASSIVE SIDE STICK: This is a passive side stick is a passive inceptor used for pitch and roll (or lateral) control without a back drive or active feel force mechanism.

2.2.2 Specific Side Stick Terms

The definitions of the angular positions/displacements of a left-hand side stick are provided in Figure 1.

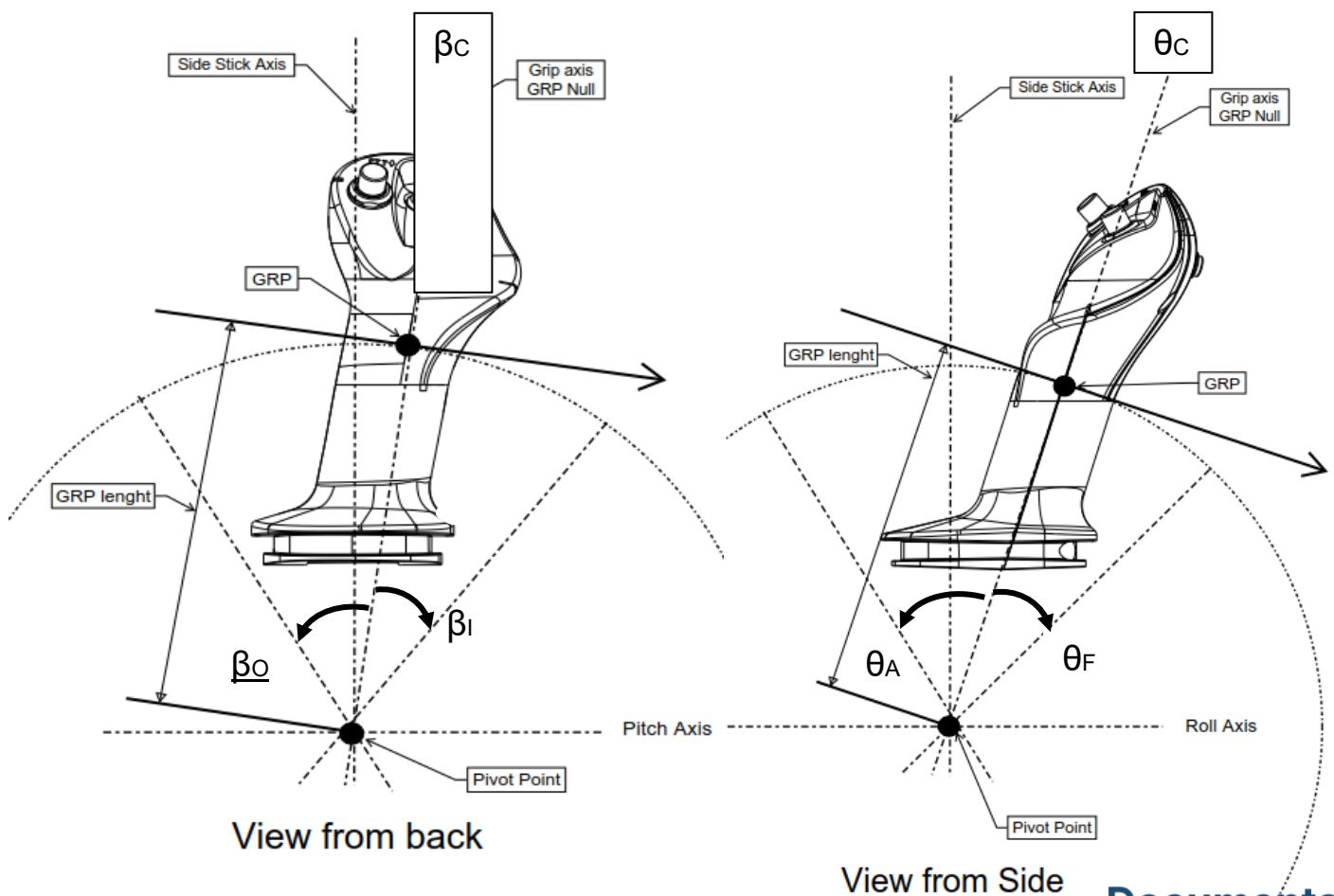


Figure 1 - Side stick geometry definitions at mechanical null

NOTE: ISO first angle projection.

Legend:

- θC GRP angle null position in pitch regarding the pivot point (null GRP pitch angle)
- θA Side stick angle displacement in pitch in aft direction, driving the aircraft nose up
- θF Side stick angle displacement in pitch in forward direction, driving the aircraft nose down
- βC GRP angle null position in roll regarding the pivot point (null GRP roll angle)
- βO Side stick angle displacement in roll in outboard direction, driving the aircraft on the left when apply by Captain (left hand)
- βI Side stick angle displacement in roll in inboard direction, driving the aircraft on the right when apply by First Officer (right hand)

GRIP REFERENCE POSITION (GRP): This is the position on the controller/inceptor defined on an interface control drawing, through which grip forces are measured.

NOTES:

1. This is defined by the customer.
2. These force inputs are input perpendicular to the planes defined by the GRP and the rotation axes.

SIDE STICK PITCH AXIS: This is the axis around which the inceptor grip rotates when the grip is deflected in the pitch direction.

SIDE STICK ROLL AXIS: This is the axis around which the inceptor grip rotates when the grip is deflected in the roll direction.

NOTES:

1. The pitch and roll axis are orthogonal and define the reference plane.
2. The specific aircraft application will determine the orientation of this plane relative to the aircraft structure.

SIDE STICK PIVOT POINT: This is the intersection of the pitch and roll axis.

SIDE STICK AXIS: This is the axis from the pivot point and perpendicular to the side stick reference plan.

GRIP AXIS: This is the axis through the grip reference position and intersects the side stick axis at the side stick pivot point

NOTES:

1. This is the center line of the grip.
2. This axis may or may not coincide with the side stick axis and may be at an angle to the side stick axis due to human factors considerations.

MECHANICAL NULL OR MECHANICAL NEUTRAL POSITION: This is the geometric null position of the side stick with no deflection in the pitch or roll axis.

TRUE POSITION: This is the grip angular displacement from the mechanical null.

REPORTED OR SENSED POSITION: This is the side stick positions measured by the position sensors.

ZERO FORCE NULL BAND OR NULL BACKLASH: This is the range of inceptor displacement, with no applied force, over which the side stick is statically stable.

NOTE: The zero-force null band is typically determined by releasing the side stick from deflected positions and determining where it comes to rest.

SENSED POSITION HYSTERESIS: This is the difference in sensor position signal at the same hand grip position when approached from opposite directions.

FORCE HYSTERESIS: This is the difference in hand grip force when reporting the same hand grip position when approached from opposite directions.

SENSED POSITION ERROR: This is the maximum deviation of the sensor position signal from the nominal sensor output as predicted from the side stick gain.

POSITION GRADIENT: This is the slope of the best fit straight line through a series of sensor outputs corresponding to known sensor positions covering the sensor range.

NOTE: Typically, the position of the grip sensed by the external sensors is compared to the sensed position of the side stick.

SENSED POSITION RESOLUTION: This is the smallest side stick position change that the sensor can measure.

HARD STOP: This is a mechanical stop which define the maximum displacement in pitch and roll for the grip.

NOTE: This stop should not be over path by the pilot and shall comply with certification loads.

SOFT STOP: This is an increase of pilot force feel gradient as shown in Figure 2.

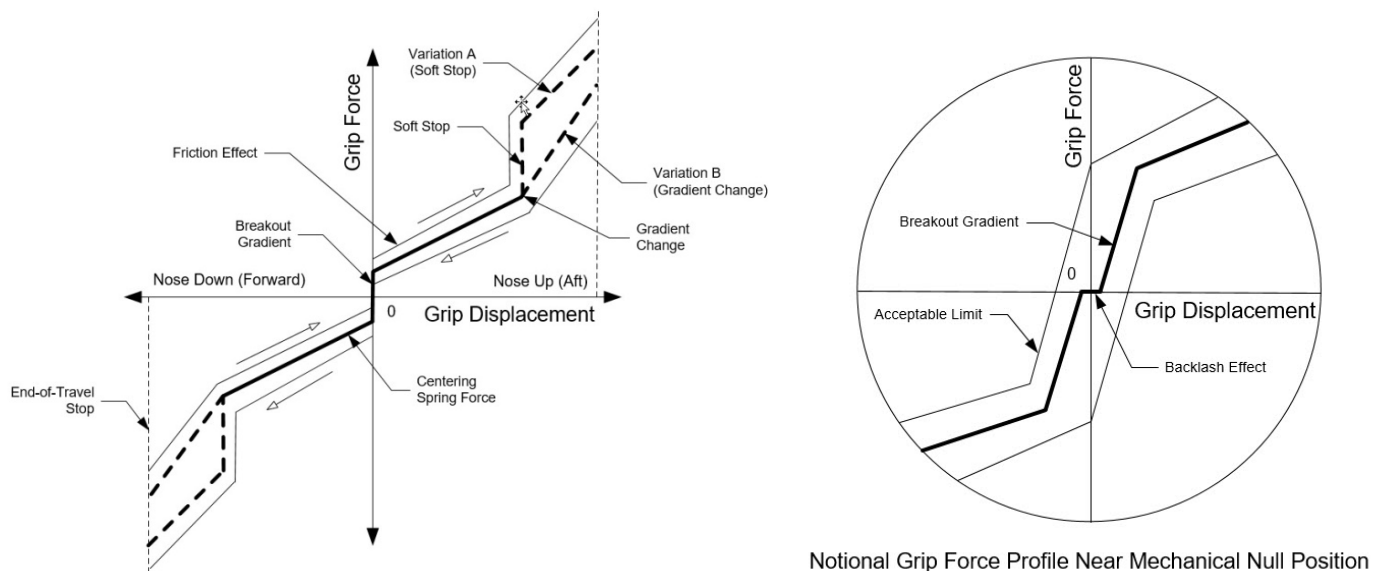


Figure 2 - Typical grip force profile in pitch

NOTES:

1. Variations A and B show typical force/displacement curve shape which might be achieved in a passive side stick.
2. The soft stop should allow the pilot to push through and continue the grip displacement after a clear increase load feel.
3. The indicated breakout gradient and backlash effect are a result of imperfections in typical centering mechanisms. It is generally desirable to maximize the breakout gradient and minimize backlash.

3. FUNCTIONS AND GENERAL DESCRIPTION

The passive side stick described in this document includes the following functions which might be included in the side stick customer specification, depending on the cockpit architecture and other factors.

- a. A handgrip which transmits the pilot commands to pitch and roll sensors. Pitch and roll movements can be combined.
- b. Position sensors for pitch axis, which provide increasing signals relative to the handle position to flight control computers, their number depending on the system architecture.
- c. Position sensors for roll axis, which provide increasing signals relative to the handle position to flight control computers, their number depending on the system architecture.
- d. Pitch and roll artificial feel and centering devices.
- e. Pitch and roll damping devices.
- f. An autopilot break out or a detent that keeps the handgrip at neutral to prevent inadvertent commands while autopilot is engaged. This may be a provision for the pilot to override this detent function by applying a given force.
- g. Switches in the hand grip.
- h. A redundant structure depending on the safety assessment.
- i. Segregated electrical harnesses including aircraft interface connectors.
- j. Protection devices against foreign object ingress.
- k. Mechanical stops in pitch and in roll axis.
- l. Balance mass.
- m. An access for a standard rigging pin to hold the handle in neutral position.
- n. A tactile indicator operated following a discrete input from flight control computers.

4. INTEGRATION IN THE COCKPIT

4.1 Location in Typical Two-Crew Cockpit

Figures 3 and 4 present a typical flight deck installation.



Figure 3 - Typical location of the side sticks in a flight deck

The Captain and the First Officer units have the same functionalities and are not mechanically connected.

The geometrical shapes of the Captain and the First Officer units are mirror images to suit left handed and right-handed operation, respectively.



Figure 4 - Typical installation of a side stick in the pilot's side console

Each side stick shall be located to provide convenient operation and to prevent confusion and inadvertent operation according to 14 CFR/CS 25.777 and 25.779. The integration in the cockpit should be such that there is full and unrestricted movement of each side stick without interference from the cockpit structure or any other equipment around each side stick (arm rest, steering wheel, etc.)

The two side sticks shall be installed to comply with 14 CFR/CS 25.1302.

The integration in the cockpit should also consider other objects like pens, phone, pad, camera, etc. which could be present in the cockpit and might create interferences with the side stick motion. Side stick design and side stick position on the flight deck should be defined by the aircraft manufacturer to mitigate risk of loss of full authority due to foreign object around the side stick.

4.2 Pilot hand position

When the flight crew is seated and belted, the Pilot' hand should be able to catch the side stick hand grip at the grip reference position.

A arm rest or similar design feature in the cockpit is recommended to provide to the pilot a reference position when the side stick is used.