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Advisory Circular

Subject: Controls for Flight Deck Systems

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This advisory circular (AC) provides guidance for the installation and airworthiness approval of flight deck system control devices, from primarily a human factors perspective. It does not address primary flight controls, secondary flight controls, or controls that are not located in the flight deck. This AC addresses traditional dedicated controls such as physical switches and knobs, as well as multifunction controls such as touch screens and cursor control devices.

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Chapter 1. General Information

1-1. Purpose.

a. We, the Federal Aviation Administration (FAA), wrote this AC for aircraft and avionics manufacturers and designers of systems that are installed on the flight decks of any aircraft type certificated per Title 14 of the Code of Federal Regulations (14 CFR) part 23, 25, 27, or 29. This AC provides general guidance for the design, installation, integration, and approval of controls for flight deck systems.

b. This AC is not mandatory and does not constitute a regulation. This AC describes an acceptable means, but not the only means, to demonstrate compliance to controls-related requirements. If you use the means described in this AC, you must follow it entirely. The word "must" is used to express a regulatory (mandatory) requirement.

c. This material does not change, create any additional, authorize changes in, or permit deviations from, regulatory material.

1-2. Audience. This AC is for applicants seeking a type certificate (TC), supplemental type certificate (STC), amended type certificate (ATC), and amended supplemental type certificate (ASTC) for the installation of flight deck system controls.

1-3. Scope.

a. Controls are the components of a flight deck interface that allow pilots to provide information to an aircraft system. Example control functions are to operate, configure, and manage systems. This document addresses controls on civil aircraft flight decks from primarily a human factors perspective.

b. For the purposes of this AC, "controls" covers both the hardware and software components of the input device (e.g., button) and its identifier (e.g., label), as well as any other components related to its intended function. This AC also covers components of other systems that affect controls and control-related information.

c. The guidance in this document applies to the approval of:

- Controls for avionic systems in the flight deck;
- Dedicated controls (e.g., physical switches, knobs); and
- Multifunction controls (e.g., cursor control devices, touch screens).

d. The guidance in this document does not address:

(1) Primary and secondary flight controls, including:

- Yoke,
- Side-stick,
- Rudder pedals,
- Throttle levers and related powerplant controls, and
- Flaps.

(2) Controls located outside the flight deck;

(3) Controls installed in the flight deck that are not intended for use by the flightcrew (e.g., controls supporting airplane maintenance activities);

(4) Aircraft performance responses to manipulation of the “in scope” controls;

(5) Control failure analysis or control behavior in the presence of other system failures (system safety analysis);

(6) Detailed design guidance (e.g., knob resistance); and

(7) Controls guidance not related to usability or human performance.

e. If there is guidance in other ACs for specific aircraft categories (parts 23, 25, etc.), equipment, and systems, that specific guidance has precedence if a conflict exists with the guidance provided in this AC.

1-4. Regulatory Requirements.

> **Note:** In the following sections, the notation "2x" is used for brevity to indicate multiple regulations, as applicable, in 14 CFR parts 23, 25, 27, and 29.

a. A system must comply with the full text of all applicable regulations in 14 CFR. When the system includes flight deck controls, include special consideration of the following regulations: 14 CFR 2x.671, 2x.771, 2x.777, 2x.1301, 2x.1322, 2X.1381, 2x.1523, and 2x.1555. These are the regulations that are related to human factors. They address separate but related topics, including the following human factors topics associated with controls:

- Minimum crew;
- Accessibility;
- Concentration and fatigue;

- Convenience and ease of operation;
- Identification and marking;
- Confusion and inadvertent operation;
- Unrestricted movement; and
- Intended function.

b. This AC provides compliance guidance related to human factors topics concerning controls in the flight deck. Appendix B, in this AC, provides a tool that applicants can use to organize their design and compliance effort. Appendix C, table C-1, provides a quick reference that maps these topics to their associated regulations.

1-5. Background. Flight deck controls can present unique opportunities and challenges to the design and certification process. In particular, showing compliance with regulatory requirements related to the latest flight deck controls has been subject to various degrees of interpretation by applicants and the FAA. Whereas traditional controls are typically dedicated hardware components, such as single-function knobs, modern controls are often highly software-based, multifunctional, and integrated with displays and other systems. A key challenge is to interpret and comply with the regulations consistently and appropriately, across the design spectrum of flight deck controls.

Chapter 2. General Controls Guidance

2-1. General Controls Design Philosophy.

a. If you are an applicant, document and follow a design philosophy for controls, which supports the intended functions (14 CFR 2x.1301). The documented design philosophy may be included as part of a system description, certification plan, or other document that is submitted to the FAA during a certification project. The design philosophy should include a high level description of controls features, such as labeling, feedback, automated behavior, and error recovery. Also include a high level description of human performance considerations, such as flightcrew workload, error potential, and expected training requirements.

b. Apply a particular design philosophy consistently throughout the flight deck to the greatest extent practicable.

2-2. Environment and Use Conditions

a. Consider a variety of environments, use conditions, and other factors that can impact flightcrew interaction with controls during aircraft operations that can be reasonably expected in service, including:

- Appropriate representation of pilot population;
- Bright and dark lighting conditions;
- Use of gloves;
- Turbulence and other vibrations;
- Interruptions and delays in tasks;
- Objects that may physically interfere with the motion of a control;
- Incapacitation of one pilot (multi-crew aircraft);
- Use of the non-dominant hand; and
- Excessive ambient noise.

b. Since all possible environment and use conditions cannot be specifically addressed, develop a representative set that includes nominal and worst cases. These cases should cover the full environment in which the system is assumed to operate, given its intended function. This includes operating in normal, non-normal, and emergency conditions. The following paragraphs describe the above list of environment and use conditions in more detail.

c. Appropriate Representation of Pilot Population. Controls are designed with an assumption of a certain range of pilot attributes. These assumptions may include physical attributes, such as body size and proportion, and non-physical attributes, such as experience with a given type of controls.

(1) Design the controls to provide acceptable performance for a broad range of pilot physical attributes. The appropriate pilot representation is key in demonstrating compliance to the applicable regulations. For example, buttons that are too small for a given finger size can be prone to usability problems, such as finger positioning errors, finger slippage, inadequate feedback, insufficient label size, and inadvertent operation.

(2) In some cases, certain attributes of the pilot population are addressed within controls-related regulations. For example, 14 CFR 2x.777 requires controls to be located and arranged in a manner that provides full and unrestricted movement of controls.
Title 14 CFR 25.777 specifies a pilot population that ranges in height from 5’2” to 6’3”. Title 14 CFR 27.777 and 29.777 specify a pilot population that ranges in height from 5’2” to 6’0”. (Part 23 does not specify a pilot population.) To show compliance with this aspect of the regulation, show that all positions of the control fall within the reach envelopes of the intended pilot population.

(3) Since human dimensions can vary greatly, the environment and use conditions should account for such variations. Some acceptable means of accounting for human size variations include:

- Selecting individuals for testing based on reference to an anthropometric database. Anthropometric databases contain information collected from comparative studies of human body measurements and properties;

- Supplementing physical mock-ups with computer anthropometrically-based models; or

- Comparing physical measurements of control positioning relative to physical measurements in anthropometric databases.

(4) In addition to considerations for unrestricted movement of controls, anthropometric data is important for many other performance considerations, including inadvertent activation and physical workload. Controls-relevant anthropometric data also includes hand and finger size.

(5) Consider other pilot characteristics that are relevant to controls, beyond anthropometrics. Other important physiological pilot characteristics can include physical strength, visual acuity, and color perception. Pilot cultural characteristics are also relevant in the selection of graphical elements, word choice, and certain control features (e.g., menu structure). It is generally appropriate to assume minimal prior pilot experience with a given control.

(6) Environment and use conditions should cover a range of pilot characteristics relevant to controls in order to represent the intended pilot population. Show not only that the controls are acceptable over this range, but also provide data describing the range of pilot characteristics, and how this range represents the intended pilot population.

d. Bright and Dark Lighting Conditions.

(1) Controls should be operable under foreseeable lighting conditions. Labels and other information related to a control's function and method of operation should be readable over a wide range of ambient illumination, including, but not limited to:

- Direct sunlight on the controls;
- Indirect sunlight through a front window illuminating white clothing (reflections);
- Sun above the forward horizon and above a cloud deck in a flightcrew member's eyes; and
- Night and/or dark environment.

(2) Consider the above conditions when evaluating controls, and show that the controls are acceptable. Compensating factors such as tactile characteristics, can also be included as part of the environment and use conditions. Special consideration is needed for controls whose function is affected by illuminated information (see paragraph 2-9 in this chapter), such as lighted switches and soft keys on displays.

e. Use of Gloves. Pilots might wear gloves during operations, such as in cold weather. Design assumptions regarding skin contact (e.g., tactile feedback, system capacitive sensing), finger size (e.g., button spacing), and other finger characteristics alone might not adequately cover situations in which pilots wear gloves. Therefore, include gloved pilot operations in environment and use conditions. In cases where controls cannot be operated with gloves, clearly describe any limitations or methods for determining limitations, in the aircraft flight manual or flight manual supplement, as appropriate.

f. Turbulence and Other Vibrations.

(1) Ensure that controls are operable during vibrations. Vibrations affect not only the ability of pilots to intentionally activate a control, but also can affect inadvertent activation and awareness of activation. Vibrations can be caused by turbulence, propulsion systems, or other means.

(2) Title 14 CFR 25.771(e), 27.771(c), and 29.771(c) require that vibration and noise characteristics of cockpit equipment not interfere with the safe operation of the aircraft. Theoretical analysis alone is insufficient for demonstrating compliance, but it can be complementary. Therefore, also show through other means, such as test or demonstration, that

the control is acceptable over a range of vibration environments for the intended aircraft and operations. Multifunction controls tend to be particularly susceptible to vibrations (see chapter 3). For functions with multiple means of control access, ensure that at least one of the controls is operable during vibrations.

g. Interruptions and Delays in Tasks. Some control operations involve multiple steps such that interruptions and delays might affect successful completion. For example, pilots might forget to complete a task they started (e.g., air traffic control calls), or they might not understand how the system behavior accommodates unfinished tasks (e.g., data entry timeouts). In environment and use conditions, include interruptions and delays during pilot-system interaction tasks to understand if the controls' behavior results in any safety-critical consequences.

h. Objects that Can Physically Interfere with the Motion of a Control. Ensure the control motion is not obstructed by other objects in the flight deck. Title 14 CFR 2x.777 addresses unrestricted movement of each control without interference. Interference can potentially arise not only from other components of the flight deck and the flightcrew's clothing, but also from objects that are brought on board. Such objects include electronic flight bags (EFBs), headsets, pilot kneeboards, flashlights, and portable electronic devices (PEDs). Consider objects that might reasonably be in the flight deck for physical interference, state the objects considered, and show that the control is acceptable in the presence of these objects.

i. Incapacitation of One Pilot (Multi-Crew Aircraft). For aircraft that are designed for multi-crew operation, the incapacitation of one pilot must be considered in the determination of minimum flightcrew, per § 2X.1523. Any control required for flight crewmember operation in the event of incapacitation of other flight crew member(s), in both normal and non-normal conditions, must be viewable, reachable, and operable by flightcrew members, from the seated position (§ 23.777(b), § 25.777(c), § 27.777(b), and § 29.777(b)).

j. Use of the Non-dominant Hand. Controls should be useable by both left-handed and right-handed pilots. Give special consideration to controls that require speed or precision in force or motion (e.g., cursor control devices) and controls designed to be operated with one specific hand (e.g., controls that can only be reached with the right hand).

k. Excessive Ambient Noise. Controls should be operable during conditions of excessively high ambient noise (e.g., from engines, airflow). Make noise conditions represent what can reasonably be expected for the intended aircraft and operation. Excessive ambient noise interferes with the ability of pilots to hear aural feedback and other sounds important to control functions. In addition, excessive ambient noise can sometimes interfere with non-aural sensory modes. When aural feedback is a control feature, it may be necessary to incorporate other sensory feedback as well (e.g., visual, tactile).

2-3. Controls Layout and Organization. Use the following guidance to the extent practicable (considering system tradeoffs) when developing a layout and organization scheme that will support pilot performance of system functions:

a. Group and arrange controls logically, such as by function or by sequence of use.

b. For functions that are frequently used by the flightcrew, controls should be readily accessible.

c. Position controls to allow a clear view of their related elements (e.g., displays, indications, labels) when in operation. In general, placing controls below the display or to one side of these elements will minimize visual obstruction during control operation.

d. Arrange controls to be easily associated with their related elements (e.g., displays, indications, labels). Ensure the association is readily apparent, understandable, and logical (e.g., line select function keys that align with adjacent text on a display). Give special consideration to large spatial separations between a control and its indication or display.

e. Position controls that are common to multiple tasks (e.g., numerical entry controls, “enter” or “execute” keys) to be easily accessible to the pilot and easily associated with their function(s). Position controls to prevent substitution errors, which can arise from inconsistent control placements.

f. Ensure that hand-operated controls are operable with a single hand. The remaining hand will then be free to operate the primary flight controls.

g. Ensure that maintenance functions or other functions not intended for pilot use are not readily accessible by pilots during operations.

2-4. Movement of Controls. Control devices typically transform their movement and/or force to achieve a control’s function. Ensure that the interaction between a control and its related elements (e.g., aircraft systems, displays, indications, labels) are readily apparent, understandable, logical, and consistent with applicable cultural conventions and with similar controls in the same flight deck. Table 1 provides examples of conventional relationships between the movement of a control and its function.

Table 1. Examples of Conventional Relationships between Control Functions and Movements.

Function	Direction of Movement
Increase	Up, Right, Clockwise, Forward, Push-in, Depress
Decrease	Down, Left, Counter-Clockwise, Rearward, Pull-out, Release
On Off	Up, Right, Depress, Clockwise, Forward Down, Left, Release, Counter-Clockwise, Rearward
Raise Lower	Up, Rearward, Pull-out Down, Forward, Push-in
Right Left	Right, Clockwise Left, Counter-Clockwise

a. Interpretation of the terms used in table 1 may be dependent upon the specific function, or upon the installation location of the control. For example, the interpretation of "increase" is dependent upon the parameter that the control modifies (e.g., magnification and range scale are inversely related, so as one increases, the other decreases). Or, a device with a linear movement might be oriented vertically, horizontally or in between, such that "pull-out" can result in an "up" or "down" component, depending on installation location in the flight deck.

b. The conventions in table 1 are examples only and might be conflicting or ambiguous due to installation location, cultural convention, flight deck consistency, or otherwise.

2-5. Sensitivity and Gain of Controls. Since many controls transform their movement and force to achieve a function, the gain or sensitivity is a key design parameter. In particular, it strongly affects the tradeoff between task speed and error. High gain values tend to favor pilot comfort and rapid inputs, but can also contribute to errors (e.g., overshoot, inadvertent activation). Low gain values tend to favor tasks that require precision, but can also be too slow for the task. Gain and sensitivity of the control typically need to be traded off to support the intended function. Give special consideration to variable-gain controls. Accurately replicate the response lag and control gain characteristics that will be present in the actual airplane, and show that gain and sensitivity of the control are acceptable for the intended function.

2-6. Feedback from Controls.

a. Design the controls to provide feedback to the pilot when operated. Feedback from controls provides pilots with awareness of the effects of their inputs, including the following effects, as applicable:

- Physical state of the control device (e.g., position, force);
- State of data construction (e.g., text string);
- State of activation or data entry (e.g., "enter");

- State of system processing;
- State of system acceptance (e.g., error detection); and
- State of system response (e.g., cursor position, display zoom, autopilot disconnect).

b. Feedback can be visual, aural, and/or tactile. If feedback/awareness is required for safe operation, it should be provided to inform the flightcrew of the following conditions:

- State of activation or data entry;
- State of system processing (for extended processing times); and
- State of system response, if different from the commanded state.

c. Provide clear, unambiguous, and positive feedback to indicate the successful or unsuccessful actuation of a control action. Feedback within the control device (such as the tactile snap of a switch) without any other system effect should not be the sole means of detecting the actuation of a control.

d. The type, response time, duration, and appropriateness of feedback will depend upon the pilots' task and the specific information required for successful operation.

e. The final display response to control input should be fast enough to prevent undue concentration being required when the flightcrew sets values or display parameters (§ 2X.771(a)). The specific acceptable response times depend on the intended function.

f. Once a control device is activated, if processing time is extended it might be appropriate to display progress to provide the pilot with a sense of time remaining for completion.

g. If control device position is the primary means of indicating the status of a function (e.g., switch in the Up position indicates that the function is On), the control position should be obvious from any pilot seat.

h. When a control is used to move an actuator through its range of travel, the equipment should provide operationally significant feedback of the actuator's position within its range.

i. Show that feedback is adequate in performance of the tasks associated with the intended function of the equipment.

2-7. Identifiable and Predictable Controls.

a. Pilots must be able to identify and select the current function of the control with speed and accuracy appropriate to the task, per § 2X.777(a). Make the function and method of operation of a control readily apparent (i.e., predictable and obvious), so that little or no familiarization is needed. Show that the intended pilot population can rapidly, accurately and consistently identify and execute all control functions, assuming qualified and trained pilots.

b. Controls can be made distinguishable or predictable by differences in attributes such as form, color, location, and labeling. For example, buttons, which are pushed, should be readily discernable from knobs, which are rotated. Control shapes that are easily determined with tactile senses can improve ease of operation, particularly during periods when pilot tasks require significant visual attention.

c. If color is used for coding task-essential information, use at least one other distinctive coding parameter (e.g., size, shape, label). Whenever possible, color coding should be consistent across all controls and displays. Consider the effect of flight deck lighting on the appearance of the label, and the use of colors throughout the flight deck (i.e., color philosophy).

2-8. Labeling of Controls.

a. Labels are the most common means used to identify and describe controls and other devices in the flight deck. They can be full text (e.g., “Standby”), abbreviated text (e.g., “STBY”), acronyms (e.g., “AGL” for “Above Ground Level”), as well as icons (e.g., ⏻ for “On/Off”).

> **Note:** While a limited number of control functions might have icons associated with them that pilots would likely know, most functions have no universally accepted icons.

b. Control labels must be visible, legible, and understandable for the population of pilots that will use the controls, per § 2X.1555(a).

c. Unless the control function and method of operation are obvious or indicated through other means (e.g., form, location), the control labeling scheme should clearly and unambiguously convey:

- The current function performed by each control,
- The method for actuating the control when performing the current function.

d. Size control labels to be easily legible from the pilot’s normally seated position. SAE International, (SAE) Aerospace Standard (ARP) 4102/7, *Electronic Displays*, dated July 2007 provides guidelines on font sizes that are generally acceptable.

e. Use terms, icons, or abbreviations recommended in applicable FAA policy and other standards (e.g., International Civil Aviation Organization (ICAO), Document 8400, *ICAO Abbreviations and Codes*, Sixth Edition, date 2004 or SAE ARP 4105B, *Abbreviations and Acronyms for Use on the Flight Deck*, reaffirmed June 2004), for labels, when available. Otherwise, use labels that are in general use in aviation.

f. For controls using icons in lieu of text labeling, substantiate that pilots, with the minimum expected training program, can adequately perform their duties at an acceptable level of workload, as required by normal, non-normal, and emergency situations. If appropriate, consider incorporating icons in controls to complement rather than replace text labels (e.g., continuous text display, temporary “mouseover” display).

g. If multiple controls exist for the same function, clearly label all such controls. Exceptions can include alternate controls that provide flexibility to accommodate a wide range of pilots. For example, experienced users might choose less-intuitive methods in order to gain a performance advantage such as speed. Double-clicking or push-and-hold are examples that are generally not recommended as a sole method of operation, but may be acceptable as a secondary method (e.g., for advanced users). Show that multiple controls for the same function are acceptable, and do not result in confusion or inadvertent operation.

h. If multiple controls exist (multi-crew aircraft) for the same function, show that there is sufficient information or other means available to make each crewmember aware of which control is currently functioning.

i. Use only one abbreviation and/or one icon for labeling a function. This is to prevent confusion when a label appears in multiple locations.

j. Ensure that the labels resist scratching, hazing, erasure, disfigurement, and other legibility degradation that might result from normal use.

2-9. Controls Lighting.

a. For controls with visual markings that are intended for use in low-light conditions, the markings must be lighted in some way that allows them to be easily read, for compliance with § 2X.1555(a) and § 2X.1381(a). This lighting might be from an external source (e.g., cockpit) or from an internal source (e.g., backlighting or luminous controls). Controls should be visible over a wide range of ambient light conditions (see paragraph 2- 2d).

b. Ensure that lighting of controls is consistent with flightcrew alerting such as warning, caution, and advisory lights (§ 2X.1322).

c. For low-light conditions, make lighted controls dimmable to brightness levels commensurate with other flight deck instrument lighting. This allows for the flightcrew’s adaptation to the dark, so controls are legible, and outside vision is maintained.

d. Ensure that lighting of controls from an internal source is not dimmable to brightness levels so low that the controls appear inactive.

e. Ensure that lighting of controls from an internal source does not produce light leaks, bright spots, or reflections from the windshield that can interfere with pilot vision or performance.

f. Automatic adjustment of lighted controls may be employed. Consider preference differences in multi-crew operations.

g. Ensure that lighted controls intended for operation in a night vision imaging system (NVIS) lighting-modified cockpit meets (a) through (e) above, and are compatible with night vision goggles (NVG). For additional guidance see:

- AC 27.1, *Certification of Normal Category Rotorcraft*, refer to miscellaneous guidance (MG) 16,

- AC 29.2, *Certification of Transport Category Rotorcraft*, MG 16, or

- RTCA, Inc. (RTCA) document (DO) RTCA/DO-275, *Minimum Operating Performance Standards for Integrated Night Imaging System Equipment*, dated October 12, 2001.

Note: NVIS lighting must allow color transmission to meet aircraft certification regulations (e.g., §§ 2X.1381, 2X.1555). For controls that do not need color discrimination, NVIS A lighting can be used. For controls where color discrimination is needed, then NVIS lighting must (§ 2X.1555) allow the pilot to easily discern the required colors (typically accomplished using NVIS white). Make perceived color for reds, yellows (or ambers), and greens the same across the cockpit.

2-10. Preventing Inadvertent Operation of Controls.

a. Protect controls against inadvertent operation. This type of error can occur for various reasons, such as when a pilot accidentally bumps a control, or accidentally actuates one control when intending to actuate a different control.

b. Provide mitigation for inadvertent operation as appropriate. Consider these questions when designing and installing the control:

- Are there any safety-critical consequences if the pilot is not aware of the inadvertent operation?

- What will the pilot need to do to correct an inadvertent operation?

- Is the control designed to support “eyes free" use (i.e., when the pilot is not looking at the control)?

- Are there aspects of the design that will decrease the likelihood of inadvertent operation?

- Are there aspects of the design that will increase the likelihood of the pilot detecting an inadvertent operation?

c. The following paragraphs provide multiple methods that reduce the likelihood of inadvertent operation of controls.

(1) Location & Orientation. Title 14 CFR 2x.777 requires controls to be located to prevent inadvertent operation. Locate, space, and orient controls so that the operator is not likely to strike or move them accidentally in the normal sequence of control movements. For example, switches located close to a frequently-used lever could be oriented so the axis of rotation for the switches is perpendicular to the axis of rotation for the lever.

(2) Physical Protection. Physical obstructions can be built into the design of a control to prevent accidental actuation of the control. Examples include: recessed controls, shielded controls, flip-covers, and guards. Make physical protections so they do not interfere with the visibility or operation of the protected device or adjacent controls. Physical protections should be appropriately durable to ensure continued airworthiness.

(3) Slippage Resistance. The physical design and materials used for controls can reduce the likelihood of finger and hand slippage (especially in the presence of vibration). For example, buttons can be designed with concave, textured, or tacky upper surfaces to prevent finger slippage.

(4) Hand Stabilization. Provide hand rests, armrests, or other physical structures as a stabilization point for the pilot's hands and fingers when they are operating a control. This can be particularly useful for controls used in the presence of turbulence and other vibration, helping the pilot make more precise inputs.

(5) Logical Protection. Software-based controls and software-related controls may be disabled at times when actuation of the control would be considered inappropriate, based on logic within the software. Make disabled (inactive) controls clearly discernable from active controls.

(6) Complex Movements. The method of operation for a control can be designed so that complex movement is required to actuate it. For example, a rotary knob can be designed so that it can only be turned when it is also being pulled out. Double-click or push-and-hold methods are not recommended methods of protection.

(7) Tactile Cues. The surfaces of different controls can have different shapes and textures, supporting the pilot in distinguishing different controls when operating in a dark or otherwise "eyes free" environment. For example, most keyboards have a small ridge on the "J" and "F" keys, cuing the user to the proper placement of their index fingers. Similarly, 14 CFR 25.781 and 23.781 requires specific shapes for certain cockpit controls.

(8) Locked/Interlocked Controls. Locking mechanisms, interlocks, or the prior operation of a related control can prevent inadvertent operation. For example, a separate on/off control can activate/deactivate a critical control, or physically lock it in place.

(9) Sequential Movements. Controls can be designed with locks, detents, or other mechanisms to prevent the control from passing directly through a sequence of movements. This method is useful when strict sequential actuation is necessary.

(10) Motion Resistance. Controls can be designed with resistance (e.g., friction, spring, inertia) so that deliberate effort is required for actuation. When this method is employed, the level of resistance cannot exceed the minimum physical strength capabilities for the intended pilot population.

d. Any method of protecting a control from inadvertent operation should not preclude operation within the required pilot task time, or interfere with the normal operation of the system. If a control is inadvertently operated, multisensory information can assist pilots in detecting the error. Feedback can include one or more auditory cues, tactile cues, or visual cues. As a general rule, the greater the consequence of an unintended operation, the greater the prevention method needed, and the more salient the cues that should be provided for detection.

2-11. Controls for Data Entry.

a. Numerous flight deck tasks require some form of data entry, such as entering the airport code or radio frequency. Some controls lead pilots to enter data through compact devices (e.g., knobs that scroll through the alphabet), which might result in increased workload and head-down time. Controls for data entry must support the pilot when entering required data to support the intended function, per § 2X.1301. Show that the controls are acceptable for data entry speed, accuracy, error rates, and workload.

b. If data entry involves multiple steps, make sure that each step is clearly discernable. For example, pilots should be aware that the first step is to construct a string of multiple characters and the second step is to enter the string into the system.

c. During data construction, ensure that automatically constructed data is clearly discernable from manually constructed data. Regardless of how the data was constructed, the system should allow pilots to readily determine the data that is entered into the system.

d. Data entry controls should allow pilots to easily recover from typical inputs errors, such as a simple keyboarding error or an incorrect auto fill.

e. Previously approved controls for data entry have used physical configurations and design features based on the following:

(1) Letter keys that are arranged in a QWERTY format (preferred) or alphabetically.

(2) Numeric keypads that are arranged in a 3x3 matrix with zero (0) at the bottom.

(3) Concentric knob assemblies that contain no more than two knobs per assembly.

(4) Cursors that are automatically placed in the first data entry field.

(5) Data entry fields that are large enough to show all of the entered data without scrolling.

(6) Partitioning of long data items into shorter sections for both data entry and feedback.

f. Time-outs (e.g., from interruptions in the pilot's data entry task) and related automated data entry features should be predictable and easily recognized by the pilot.

2-12. Continued Airworthiness.

a. Title 14 CFR 2X.1529 requires instructions for continued airworthiness of equipment. Include any limitations or considerations for the conditions in which controls are operated, replaced, or serviced. For example:

- How should controls be serviced to ensure continued compliance with 14 CFR 2X.671, requiring easy, smooth, positive operation?
- Will controls need cleaning from skin oils and perspiration, in order for labels to be legible?
- What type of interference may impede safe operation?
- Is the control susceptible to failure if exposed to liquids (e.g., spilled coffee or soda)?
- What maintenance or inspection should be conducted over a given time interval?

b. Design controls to minimize degradation (e.g., scratching, hazing) from operational use.

c. Define a reasonable maintenance and inspection interval for each control, along with verification tests that are conducted at each interval in the instructions for continued operational safety.

Chapter 3. Additional Guidance for Multifunction Controls

3-1. Multifunction Controls—General. This chapter provides additional guidance that is specific to multifunction controls. The general guidance in chapter 2 still applies to multifunction controls.

a. Unlike a dedicated control, which performs a single function, multifunction controls can control multiple functions. This is enabled primarily through the use of electronic displays as a means for control. This AC covers the following multifunction controls:

- Cursor control devices,
- Touch screens,
- Menu-based controls, and
- Voice recognition and voice activated controls

Note: This chapter focuses on the first three items, so that "multifunction controls" does not necessarily include voice operated controls, unless specifically noted. However, some of the multifunction controls guidance may still apply to voice operated controls, and/or to electronic displays that are part of the voice-recognition control system.

b. Through the use of electronic displays as a means for controls, multifunction controls can be reconfigured by the system software, which creates opportunities for unique human-system interface strategies that are currently not possible with traditional dedicated knobs, switches, controls, and physical hardware. As a result, their introduction creates a fundamental change in the design characteristics of the pilot/system interface and the methods pilots use to perform different tasks.

c. Multifunction controls therefore provide unique opportunities and challenges to designers. For example, a large number of traditional controls can require a significant amount of dedicated area in the flight deck. With touch screens, cursor, and menu-based controls the dedicated area can often be reduced to the size of the electronic display. But, this space-saving advantage typically comes at a cost of accessibility and workload, as pilots might have to navigate multiple electronic pages or menu layers to access functions. What once required a simple button push at an easily memorized location might now require a sequence of multiple steps, with many steps needing visual attention.

d. If a multifunction control replaces the function of a conventional control, make a comparison between the two to determine if replacement results in changes in performance and safety, relative to well-understood devices. Show that multifunction controls do not result in unacceptable levels of workload, error rates, speed, and accuracy.

3-2. Multifunction Controls—Inadvertent Operation. Multifunction controls present unique challenges for preventing inadvertent operation. For example, the use of electronic displays as a means for controls might not provide for motion resistance, tactile feedback, or physical protection against operation. Paragraph 2-10c., in this AC, provides multiple methods that have been shown to reduce the likelihood of inadvertent operation of controls. The following paragraphs provide additional methods that might be applicable to multifunction controls.

a. Controls should clearly indicate which areas of the electronic display are active for control functionality. Ensure that pilots can readily identify areas of active control functionality. Active areas should be sized and organized to permit accurate selection. Moving a finger or cursor to the intended active area should not inadvertently operate other active areas.

b. For controls functions that are accessible from multiple display pages or menus, place controls in a consistent display location, when appropriate. Inconsistent placement can disrupt pilot usage habits and lead to errors.

c. A confirmation step may be provided before activating a function, where appropriate, such as for safety critical functions. For example, when an approach has been activated in a flight management system (FMS), and the pilot changes the selected approach, the system might ask, "Are you sure you want to discontinue the current approach?" Consider the tradeoff between the need for confirmation steps and the increase in pilot workload.

d. Provide a means to reverse an incorrect activation or input, when appropriate. An example means is an "undo" or similar simple reversionary functionality in the system.

3-3. Multifunction Controls—Labeling. Labels for multifunction controls introduce different challenges than for traditional controls. For example, a multifunction control is not necessarily in a fixed location, and may need to be located by navigating through various pages or menus. Correctly identifying a multifunction control can require additional workload, time, and visual attention compared to traditional, dedicated controls.

a. Indicate a control's function in a manner that is readily discernable from the current state. For example, a button labeled "Track Up" should not represent the current display orientation of "Heading Up," but should instead change the display orientation to "Track Up" when selected.

b. Ensure that pop-up text that describes a control's function does not result in unacceptable distractions, interference, or clutter.

c. If a control activates several different functions based on sequential commands or selections, clearly label each of the functions.

3-4. Multifunction Controls—Cursor Control Devices (CCDs). CCDs provide a means for pilots to *indirectly* access controls on electronic displays. This is in contrast to touch screens, which allow pilots to directly access controls. Typical CCDs in the flight deck include trackballs, touch pads, and joysticks.

a. A key benefit of CCDs is their convenience; they are typically located on or close to the pilots' natural hand position, and often accompanied by a hand stabilizer or arm rest. This allows for convenient pilot inputs, particularly since hand and arm motion is minimized due to high device gain. However, CCDs can also lead to control errors, particularly when subject to vibration environments. Also CCD inputs are more likely to go unnoticed by other crew members because pilot inputs are typically accomplished with small finger motions on the CCD. Consider effects on flightcrew coordination in the environment and use conditions of CCDs.

b. Ensure that the cursor symbol is readily discernable from other information, and readily located on the electronic displays. This is particularly important if a cursor symbol is allowed to fade from a display. Some methods to enhance quick location of the cursor are “blooming” or “growing” it to attract the flightcrew’s attention.

c. If more than one cursor is used on a display system, provide a means to distinguish between the cursors.

d. Do not allow the cursor symbol to creep or move without pilot input. Exceptions can include automatic cursor positioning, if it can be shown that it does not result in pilot confusion or unacceptable task completion time.

e. Restrict the cursor symbol from areas of flight critical information, so it does not interfere with legibility. If a cursor symbol is allowed to enter a critical display information field, show that the cursor presence is acceptable.

f. In multi-crew aircraft, most applications will allow more than one flightcrew member to use one cursor. Establish an acceptable method for handling simultaneous “dueling cursors” that is compatible with the overall flight deck philosophy. Establish acceptable methods for other possible scenarios, including the use of two cursors by two pilots.

3-5. Multifunction Controls—Touch Screens. Unlike CCDs, touch screens control systems provide *direct* access to controls on electronic displays. Because of this, the input device is physically part of the display area. Touch screens utilize different technologies, such as resistive, capacitive, infrared, acoustic, and strain gauge (force-transducer) types. The specific technology affects performance and failures, and is therefore important to consider. For example, not all technologies accommodate the use of gloves.

a. Touch screens can be susceptible to control errors in part because the electronic displays (on which pilot inputs occur) typically are smooth and flat. Their surface offers little tactile feedback for determining finger position and motion, which can result in a greater need for visual attention. Therefore, consider integrating an associated support for stabilizing the pilot's hand, and for providing a reference point when positioning fingers, if appropriate. Ensure that touch screens do not result in unacceptable levels of workload, error rates, speed, and accuracy.

b. Ensure that touch screens resist scratching, hazing, or other damage that can occur through normal use. Demonstrate that the system will continue to provide acceptable performance after long-term use and exposure to skin oils, perspiration, environmental elements (e.g., sun), impacts (e.g., clipboard), chemical cleaners that might be used in the flight deck, and any liquids that might be brought onboard by flightcrew members (e.g., coffee).

c. If a touch screen's calibration can drift or degrade, provide touch screen calibration procedures and other maintenance-related items to ensure proper calibration and operation. Include these procedures in the instructions for continued airworthiness, per § 2X.1529.

d. The location of the pilot's finger touch, as sensed by the touch screen, should be predictable and obvious.

3-6. Multifunction Controls—Menus and Navigation. In menus, the layering of information should not hinder the pilot in identifying the location of the desired control. Location and accessibility are not only related to the physical location of the control function. They also include consideration of where the control functions are located within various menu layers, and how the pilot navigates through those layers to access functions.

a. For menu-based controls, ensure that the number and complexity of steps required to access and utilize a control is appropriate to the intended use of the control (e.g., frequently used controls and emergency controls should be available at top-level menus). The number of sub-menus should be designed to ensure timely access to the desired option without over-reliance on memorization of the menu structure.

b. Cockpit controls must be located and identified to provide convenient operation and to prevent confusion, per § 2X.777(a). Layer information on menus or hidden pages so it does not hinder the flightcrew in identifying the location of the desired control.

c. Fit top-level control menu pages (e.g., primary or "home" page) entirely on the display (i.e., do not require scrolling).

d. Make top-level control menus readily accessible. This is typically accomplished by continuously displaying the menu or menu access control in a fixed location (e.g., "home" page).

e. Provide feedback from page navigation that is an unambiguous indication of the current location.

3-7. Multifunction Controls—Voice Recognition and Voice Activated. Voice recognition and voice activated control systems in aircraft pose special challenges. Recognition accuracy of voice commands is less than perfect, and its performance is affected by pilot characteristics as well as the ambient noise environment. This section provides basic guidance and human factors considerations for voice recognition and voice activated controls, but it does not comprehensively address either.

a. Ensure that voice recognition and voice activated control systems consistently and accurately recognize and properly input verbal commands from pilots under expected flight and ambient noise conditions (see chapter 2, paragraph 2-2.k). Typical background aircraft noise, crew and passenger conversations, radio communication traffic, and sound from other sources should not impede the system.

b. Provide a simple and readily apparent means to deactivate the voice recognition or voice activated system.

c. Ensure that voice recognition and voice activated control systems do not interfere with normal pilot communication functions (e.g., air traffic control and other aircraft).

Appendix A. Related Documents and Acronyms

1. References.

a. AC 25-11A, *Electronic Flight Deck Displays*.

b. AC 23-23, *Standardization Guide for Integrated Cockpits in Part 23 Airplanes*.

c. AC 23.1311-1B, *Installation of Electronic Display in Part 23 Airplanes*.

d. AC 27-1, *Certification of Normal Category Rotorcraft*.

e. AC 29-1, *Certification of Transport Category Rotorcraft*.

f. RTCA/DO-275, *Minimum Operational Performance Standards for Integrated Night Vision Imaging System Equipment, October 2001*.

g. SAE ARP4102, *Flight Deck Panels, Controls, and Display,* July 2007.

h. SAE ARP4102/7, *Electronic Display*, July 2007.

i. SAE ARP4105B, *Abbreviations and Acronyms for Use on the Flight Deck*, reaffirmed June 2004.

j. FAA Policy ANM-01-03A, *Factors to Consider when Reviewing an Applicant's Proposed Human Factors Methods of Compliance for Flight Deck Certification, in Part 25 Airplanes.*

k. *Human Factors Design Standard for Acquisition of Commercial-Off-The-Shelf Subsystems, Non-Developmental Items, and Developmental Systems.* eds: V. Ahlstrom & K. Longo. May 2003. FAA Technical Center: Atlantic City, NJ. DOT/FAA/CT-03/05 HF-STD-001. http://www.hf.faa.gov/hfds.htm

l. International Civil Aviation Organization, Doc 8400, *ICAO Abbreviations and Codes*, Sixth Edition, 2004.

m. MIL-STD-1472F, *Department of Defense Design Criteria Standard: Human Engineering*, August 23, 1999.

2. How to Get Referenced Documents. You can get copies of FAA Advisory Circulars from our Regulatory and Guidance library (RGL) at www.airweb.faa.gov/rgl. On the RGL website, select "Advisory Circulars," then select "By Number." You can obtain a copy of Modification and Replacement Parts Association's (MARPA) guidance on continued operational safety (COS) at www.pmaparts.org/gvt/COSGuidance.pdf.

3. Acronyms.

AC	Advisory circular
AGL	Above ground level
ARP	Aerospace Recommended Practice
ASTC	Amended supplemental type certificate
ATC	Amended type certificate
CCD	Curser control device
CFR	Code of Federal Regulations
COS	Continued operational safety
DO	Document
DOT	Department of Transportation
EFB	Electronic flight bag
FAA	Federal Aviation Administration
FMS	Flight management system
ICAO	International Civil Aviation Organization
MARPA	Modification and Replacement Parts Association
MG	Minimum guidance
NVG	Night vision goggles
NVIS	Night vision imaging system
PED	Portable electronic device
RGL	Regulatory Guidance Library
RTCA	RTCA Inc.
RTCA/DO	RTCA Inc. Document
SAE	SAE International
STBY	Standby
STC	Supplemental type certificate
TC	Type certificate

Appendix B. Control-Function Matrix

1. Introduction.

a. This appendix provides a brief description of a “control-function matrix”. It is not required for compliance, but can be helpful as a method for development, and for sharing data with the FAA.

b. A control-function matrix primarily maps control devices (e.g., knob) to control functions (e.g., change radio frequency). The matrix also provides for an organization of controls-related attributes, such as those addressed in this AC. It is a tool sometimes used by applicants to organize their design and compliance effort.

2. Table B-1. Table B-1 provides an example template of a control-function matrix. The columns in table B-1 are described as follows:

a. Control: List each control separately in the table. Include traditional dedicated controls (e.g., knobs) and multifunction controls (e.g., software menus, touch-screen buttons) in the list.

b. Function Description Section: Group information that describes a function performed by a control in the matrix. In the table B-1 example, the function, criticality, frequency of use, and operational conditions are addressed.

(1) Function: Each function provided by a control is listed next to the name of the control. If a control provides multiple functions, list each function on a separate row, since the supplemental information may be quite different for each function.

(2) Criticality for Safety: This column provides relevant information about the criticality of a function from a system safety analysis. Criticality information can be helpful when considering implications associated with the possible inadvertent operation of a control (e.g., critical controls may need additional degrees of protection against inadvertent operation).

(3) Expected Frequency of Use: This column describes the frequency with which a function will be activated, deactivated, or manipulated. This information describes the function provided by the control. Frequency information can be helpful when considering the level of familiarity the pilot can be expected to have with a control, relative to its accessibility and complexity of operation (e.g., frequently used controls that are at the edge of a pilot’s reach envelope may not be compliant with 14 CFR 2x.777).

(4) Operational and Use Conditions: This column describes any operational use conditions that can impact the use of the control for that particular function. Operational and use conditions include those described in chapter 2, paragraph 2-2 of this AC, as well as flight phase. The information therefore establishes context in which the controls will be operated (e.g., functions that are regularly performed during final approach and

landing might need to employ a very simple method of operation to be compliant with 14 CFR 2x.771) and the acceptability of other features of the control's design.

c. Design Description Section: Group information that describes the physical design of the control and its associated elements into the matrix. The table B-1 example groups information about methods of operation, labels, protection against inadvertent actuation, feedback from control actuation, and location of the control when installed.

(1) Method of Operation: Describe the method of operation for a function. A control that provides multiple functions could have the same method of operation for different functions, or it could have different methods of operation for different functions. If a method of operation is difficult to describe in this matrix, it might also be difficult to perform for the pilot.

(2) Label: State the label associated with a function and method of operation. This information is useful to ensure that all functions are labeled and there is no inappropriate use of the same label for different functions, or different labels for identical functions. If no label is provided, make an assessment to ensure that the control is "obvious."

(3) Protection from Inadvertent Operation: This column captures descriptions of any design features that will prevent or reduce the likelihood of inadvertent operation of a function. This information might support compliance with 14 CFR 2x.777, requiring protection against inadvertent operation of controls.

(4) Feedback: This column captures information regarding feedback to the pilot during or following operation of a control.

(5) Location/Association: This column captures a description of the location of the control when installed. This information can be useful for understanding, for example, functional groupings and control-displays association.

d. Other Information Section: There may be several additional categories of information that are relevant to a function, the design of a control, factors that influenced the design decision process for the control, or the process of showing compliance. The table B-1 example uses a listing of related controls for each function, and a picture of the control.

Table B-1. Example Template for Control-Function Matrix

Control	Function Description				Design Description					Other Information	
	Function	**Criticality for Safety**	**Expected Frequency of Use**	**Operational and Use Conditions**	**Method of Operation**	**Label**	**Protection from Inadvertent Operation**	**Feedback**	**Location/ Association**	**Related Controls**	**Picture(s) of Control**
[Name of Control, or Reference # in Diagram]	[Name and Brief Description of Function #1]	[e.g., Catastrophic Function, OR Major Function, OR Minor Function]	[e.g., Multiple times per flight , OR Once per flight , OR Occasional use, OR Rarely used]	[e.g., Control will be used during high workload phase of flight, in cold weather, in high vibration conditions]	[Description of pilot actions required to perform Function #1]	[Text of Label; or "None"]	[Description of design features that prevent inadvertent operation, or "None"]	[Description of visual, aural, tactile, or other cues provided to indicate successful or unsuccessful operation of the control]	[Position of control relative to the pilot upon installation] (e.g., using a flight deck Zone reference)	[List of Names or Reference #'s for other Controls associated with Function #1]	
	[Name and Brief Description of Function #2]	[e.g., Catastrophic Function, OR Major Function, OR Minor Function]	[e.g., Multiple times per flight , OR Once per flight , OR Occasional use, OR Rarely used]	[e.g., Control will be used during high workload phase of flight, in cold weather, in high vibration conditions]	[Description of pilot actions required to perform Function #2]	[Text of Label; or "None"]	[Description of design features that prevent inadvertent operation, or "None"]	[Description of visual, aural, tactile, or other cues provided to indicate successful or unsuccessful operation of the control]	[Position of control relative to the pilot upon installation] (e.g., using a flight deck Zone reference)	[List of Names or Reference #'s for other Controls associated with Function #2]	

Appendix C. Regulations

Table C-1 provides a quick reference to some 14 CFR regulations that address controls. While many other regulations also apply to flight deck controls, as determined by the applicant's regulatory basis, this AC focuses on the regulations in table C-1 because they are strongly related to human factors, and have often been subject to interpretation during aircraft certification projects. Table C-2 lists additional regulations that were cited in the AC.

Table C-1. Quick Reference to Regulations for Controls Related to Human Factors.

Key Aspect of Regulation, From a Human Factors Perspective (In some cases, wording may be paraphrased for clarity. Consult regulations for exact wording.)	**14 CFR Regulations**
Each control must operate with the ease, smoothness, and positiveness appropriate to its function.	23.671(a), 25.671(a), 27.671(a), 29.671(a)
Controls must be located {*part 23 only*: arranged, and identified} to provide for convenience in operation.	23.671(b), 23.777(a), 25.777(a), 27.777(a), 29.777(a)
Controls must be located {*part 23 only*: arranged, and identified} to prevent the possibility of confusion and subsequent inadvertent operation {*part 29 only*: from either pilot seat}.	23.671(b), 29.771(b), 23.777(a), 25.777(a), 27.777(a), 29.777(a)
The pilot compartment must allow the pilot to perform his duties without unreasonable concentration or fatigue.	23.771(a), 25.771(a), 27.771(a), 29.771(a)
The aircraft must be controllable with equal safety from either pilot seat.	25.771(c), 27.771(b), 29.771(b)
Vibration and noise characteristics of cockpit equipment may not interfere with safe operation of the aircraft.	25.771(e), 27.771(c), 29.771(c)
Controls must be identified (except where the function is obvious).	23.777(a)
Controls must be located and arranged, with respect to the pilot seat, to provide full and unrestricted movement of each control without interference.	23.777(b), 25.777(c), 27.777(b), 29.777(b)
A control must be of a kind and design appropriate to its intended function.	23.1301(a), 25.1301(a)(1), 27.1301(a), 29.1301(a)
Controls must function properly when installed.	23.1301(d), 25.1301(a)(4), 27.1301(d), 29.1301(d)
For alerting lights, installed in the cockpit, the color red must be used for warnings and the color amber for cautions.	23.1322, 27.1322, 29.1322
Use of the colors red, amber, and yellow on the flight	25.1322(e)(1), (f)

deck for functions other than flightcrew alerting must be limited and must not adversely affect flightcrew alerting.	
Instrument lights must make each instrument and control easily readable and discernable.	23.1381(a)
Instrument lights must make each instrument, switch, and other device, easily readable.	25.1381(a)(1), 27.1381(a), 29.1381(a)
Instrument lights must be installed so that no objectionable reflections are visible to the pilot.	25.1381(a)(2)(ii), 27.1381(b)2, 29.1381(b)2
The minimum flightcrew must be able to access and easily operate controls required for safe operation.	23.1523, 25.1523, 27.1523, 29.1523
A cockpit control must be plainly marked as to its function and method of operation.	23.1555(a), 25.1555(a), 27.1555(a), 29.1555(a)

Table C-2. Additional Cited Regulations

General Topic	14 CFR Regulations
Cockpit control knob shape.	25.781, 23.781
Instructions for continued airworthiness.	23. 1529, 25.1529. 27.1529, 29.1529