



# AEROSPACE RECOMMENDED PRACTICE

ARP60494™

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## Touch Interactive Display Systems: Human Factors Considerations, System Design and Performance Guidelines

### RATIONALE

Touch screens were introduced in the early 1990s in military cockpits to perform simple functions and more recently in commercial avionics both for installed and non-installed devices such as Portable Electronic Devices hosting Electronic Flight Bag applications. Touch screens are widely used in consumer electronics (e.g., tablets and cell phones) leading to novel human machine interfaces and interactions. However, the guidelines and recommendations for touch screens from the consumer industry are not sufficient to cover their implementation in cockpits/flight decks and hence this ARP is needed to ensure that the continued implementation of touch interactive display capabilities to be used by pilots will be acceptable. Guidance material on the integration and use of touch interactions for cockpit display systems is essential to address the new benefits and issues raised by introducing the touch modality into the cockpit. Certification Review Items have been issued by the European Aviation Safety Agency during the introduction of touch screens in commercial or helicopter cockpits. While the Federal Aviation Administration has included high level guidance for the introduction of touch screens into the electronic displays in AC 20-175 "Controls for Flight Deck Systems", specific recommendations on how to meet that guidance are missing. More specific guidance and recommendations will be useful to the industry to ensure that touch screens developed for use by pilots will consistently and effectively meet the regulatory rules and high level guidance. Human machine interaction factors such as single pilot versus dual pilot interaction, touch feedback, erroneous action and crew workload are addressed in this document.

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## 1. SCOPE

This Aerospace Recommended Practice (ARP) addresses direct touch interactive electronic display systems installed in the cockpit/flight deck for use by pilots. Direct touch refers to interactivity where the display screen is the input surface. This entire direct interactive electronic display system is referred to as the touch system throughout this document and covers those items related to direct interactive touch on display devices. In cases where only the display and touch device are being considered, this is referred to as the touch screen. The ARP covers system design guidelines as well as the considerations and recommendations for system performance and human factors. This ARP is intended to cover systems installed in 14 CFR Part 23, 25, 27, and 29 aircraft.

NOTE: Within this document, the term cockpit is used to refer to both flight decks and cockpits.

As an ARP this document collects what are considered good practices by developers, users, and regulators of touch systems. The state of touch technology and the application of that technology is still evolving. As a result, it is premature to develop quantitative guidance for some key touch characteristics. In addition to the recommendations, this document provides considerations to address these cases by listing the issues that need to be assessed in a specific application.

This ARP only applies to touch systems that are part of the installed equipment in the cockpit. However, the tendency for non-installed devices, such as Portable Electronic Devices (PED) hosting Electronic Flight Bag (EFB) applications, to move into a primary role in the cockpit should not be ignored whether or not the function is regulated. In this regard the ARP may provide useful information for the designers of PED type devices, especially those hosting EFB applications.

### 1.1 Additional Background

System design and human factors considerations covered in this document include: identification of the types of functions that could use and benefit from touch interactions, the pilot and cockpit environment characteristics that impact usability, and specific pilot interface characteristics such as single and multi-touch applications, feedback, latency, potential human error, and secondary means of interaction. Also addressed are criticality of function, workload, fatigue, and transition from hard to soft control considerations. Also covered are the operational aspects related to hardware considerations and performance when a display unit has a touch screen.

The specific guidance information in this document can be found in Sections 3 through 6. Section 3 covers system design topics, Section 4 covers general human machine interface topics, Section 5 covers touch interaction functions, and Section 6 covers hardware operational topics. In each section, the material is generally organized under the following categories: Background (where appropriate), Considerations, Recommendations, Recommendations from Other Sources (where appropriate), and Example Testing (where appropriate).

## 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 and other publications shall apply except in cases where the referring section of this document call out specific versions. 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](http://www.sae.org).

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

AS8034 Minimum Performance Standard for Airborne Multipurpose Electronic Displays

## 2.1.2 Regulatory and Government Guidance Material

Title 14 Code of Federal Regulations (CFR) Parts 23, 27, 25, and 29 and their accompanying regulations. Appendix B contains a listing of 14 CFR Parts 25, 27, and 29 that are related to touch screens. Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591, Tel: 866-835-5322, [www.faa.gov](http://www.faa.gov). For the current Part 23 rule, effective August 30, 2017 (Amendment No. 64), refer to <https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=ef385d6094cda0745af63bc4c719986c&pid=20170830&n=pt14.1.23&r=PART&ty=HTML>.

For a cross reference table showing former and current Part 23 regulations see Appendix 1 to the Preamble (in the PDF version) of the current rule at: <https://www.federalregister.gov/documents/2016/12/30/2016-30246/revision-of-airworthiness-standards-for-normal-utility-acrobatic-and-commuter-category-airplanes> ICAO Publications.

|                                |                                                                                                              |
|--------------------------------|--------------------------------------------------------------------------------------------------------------|
| Advisory Circular (AC) 20-175  | Controls for Flight Deck Systems                                                                             |
| Advisory Circular (AC) 120-76D | Authorization for Use of Electronic Flight Bags                                                              |
| MIL-STD 1472G, (2012)          | Department of Defense Design Criteria Standard: Human Engineering. Washington, DC: US Department of Defense. |

## 2.2 Related Publications

|                    |                                                                                                                                                 |
|--------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|
| AC 23-1311-1C      | Installation of Electronic Display in Part 23 Aircraft (2011)                                                                                   |
| AC 25-11B          | Electronic Flight Displays (2014)                                                                                                               |
| AC 27-1B, Change 7 | Certification of Normal Category Rotorcraft, Miscellaneous Guidance (MG) 19 Guidance on Electronic Display Systems & MG 20 Human Factors (2016) |
| AC 29-2C, Change 7 | Certification of Transport Category Rotorcraft, MG 19 Guidance on Electronic Display Systems & MG 20 Human Factors (2016)                       |

Appendix A "Additional References" contains a list of references cited in this document.

## 2.3 Definitions

When the following term is used in this document, it has the following meanings:

SHOULD: The word "should" is used to express a recommendation.

Appendix C contains a glossary of words used in this document.

## 3. SYSTEM DESIGN AND IMPLEMENTATION RECOMMENDATIONS

A touch system generally operates by: (1) registering the position information in response to a finger/stylus touch or movement on the device, and (2) establishing a direct relationship between the input action and corresponding outputs, which are presented on the display. In the context of this document the term "finger" encompasses all parts of the four fingers (e.g., fingertip, knuckle) as well as the thumb although in some cases "thumb" and "finger" are differentiated.

Different touch technologies (e.g., capacitive, resistive, and infrared) may be used to implement touch displays in the cockpit. Each technology corresponds to a singular way of performing a measurement of a certain physical quantity, which in turn corresponds to the user input itself, namely the user's touch. For example: (i) in the projective capacitive touch technology, the user input (the touch) that is sensed corresponds to a measurement of the change in the capacitances of the nearby electrodes; (ii) in the resistive touch technology, the user input corresponds to a measurement of the voltages of the nearby cells; (iii) in the infrared touch technology, the user input is detected when the input device interrupts the light beams generated by infrared sources located around the screen. It is important to identify the system safety, human factors, and operational environment aspects associated with the use of touch screens when considering the type of technology to be used. No existing touch technology is completely immune from the challenges presented by these aspects.

The technologies used to implement touch systems can have unique characteristics that make touch detection and identification different than other means of control. Touch devices are a particular form of soft or display-based controls. As such, many of the concerns are similar. Differences exist to the extent that touch screen devices can support selection and activation with a single action or can support multi-touch gestures. This ARP provides guidance for soft controls where touch specific differences are significant or where existing soft control guidance is missing or unclear.

### 3.1 Design and Implementation

#### 3.1.1 Considerations

##### 3.1.1.1 Feedback Considerations

Touch controls may be implemented using a variety of different system architectures. They range from self-contained designs with little processing capability at the control device level to architectures where the touch device is embedded within the system being controlled and has high-speed access to processing capability. All of these architectures can be used successfully if the touch control operational use is consistent with the limitations and capabilities of the architecture. The most significant system level characteristic of concern for a touch device is the latency of various types of feedback experienced by the user.

There is no one value for latency that will apply to all situations. The function being controlled and the urgency the user associates with that control are the primary determinants of the level of latency that will be acceptable. Some system architectures have longer latency than others and therefore, some actions that require fast user interactions may not be acceptable on all systems. In this document latency is not allocated to the various components that contribute to the touch feedback latency. It is up to the designers to establish appropriate user tasks and an associated latency budget. The breakdown for such a budget will depend on both the type of feedback needed and the system architecture in use or envisioned.

Touch control requires consideration of an additional level of user feedback that is inherent in most other control input devices. Specifically, this feedback provides confirmation that the user's intended touch target is the target detected by the touch system. For physical controls this step is accomplished tactilely and is so obvious that it is not consciously recognized in most circumstances.

In this document, feedback is characterized as falling into one of three types: 1) touch feedback, 2) command feedback, and 3) system feedback (see Figure 1).

1. Touch feedback: Confirmation to the user that a touch on an active area on the display has been detected. One type of touch feedback is making it clear to the user which control has been selected and will be actuated. Since the user will assume that the control pointed to, will be the one selected, the touch feedback needs to be fast with respect to the user's touch to be effective. A different type of touch feedback will be needed in the case of gestures. In addition to finger location, the fact that a gesture has been recognized by the touch device is at issue. A good touch feedback indication for a gesture may be the initial transformation (state, position, geometry, etc.) of the gesture target. In these cases the pilot is likely to be reacting and not consciously assessing the touch feedback. This causes the touch feedback latency performance to be compatible with pilot learned "automatic" response times. This form of human response time is faster than is typical for conscious response time situations. Excessive touch feedback latency can introduce errors if the pilot enters a new command before the system is ready to receive another touch command and has the potential to increase pilot workload if the pilot has to recheck whether the system has detected the touch command.
2. Command feedback: Confirmation to the pilot that the touch system has recognized a command action. Command feedback is most needed when the system response to the command cannot be completed fast enough to avoid command confusion on the part of the user. Excessive command feedback latency has the potential to cause the pilot to question whether or not the original touch event was recognized and may result in a duplicate input by the pilot. Touch and command feedback may appear similar. Indeed if command feedback is fast enough, separate consideration of touch feedback may not be necessary. Quantification of "fast enough" is dependent on the specific task assigned to the touch system. It has been determined that it is not practical to establish meaningful quantified guidance for all situations.

3. System feedback: Confirmation to the pilot that a commanded action has been completed by the controlled system. This feedback is not a touch specific issue but is an issue for all pilot controls. This feedback may happen after the touch event has been completed. There are various techniques available to address extended latency in this form of feedback e.g., a progress bar.

#### 3.1.1.2 Other Considerations

Touch screen controls can be applied to integrate functions which were previously independent, leading to new failure modes. For example, a touch screen could be designed to display and control all aircraft and engine icing controls on a single panel. In this case a touch screen failure would result in the loss of all icing controls if the touch screen is the only mechanism available to control the system.

Turbulence or maneuvering acceleration can induce relative motion between the touch surface and the pilot's finger or stylus resulting in inadvertent touch activation or touch motion.

An object other than the pilot's finger(s) could trigger an actuation event or events when none was intended (e.g., food, liquid, and inadvertent contact with other part of pilot's clothing or body). See 4.5 for additional information on inadvertent touches.

Some touch technologies may not be compatible with all glove types that could be worn by the pilot.

Large or centrally located touch screen devices could be utilized by multiple users at the same time or in rapid sequence potentially causing either the system or users to become confused by the multi-user inputs. In this case care is warranted in the system design to avoid touch interaction misinterpretation.

Touch screen control technology could be susceptible to degradation over time or with heavy use and without obvious indication of that degradation to the user until degraded to the point of adversely affecting the touch screen operation (e.g., number of touches exceeding touch sensor design life, coating degradation through normal use, etc.).

The differences between the various touch technologies may result in technology specific failure modes.

#### 3.1.2 Recommendations

##### 3.1.2.1 Latency Recommendations

Specific requirements for feedback latencies are highly dependent on the nature and criticality of the specific task. Therefore, usability testing is the recommended method for establishing whether the combination of touch and command feedback latency is fast enough to support the intended tasks. If the results are satisfactory there is no need to distinguish between touch and command feedback.

The methods outlined in AS8034 for latency testing can be used to measure either touch feedback or the combination of touch and command feedback.

The use case in Figure 1 illustrates visual feedback for a push-button action and activate on release, where command feedback is provided by highlighting the recognized command button.

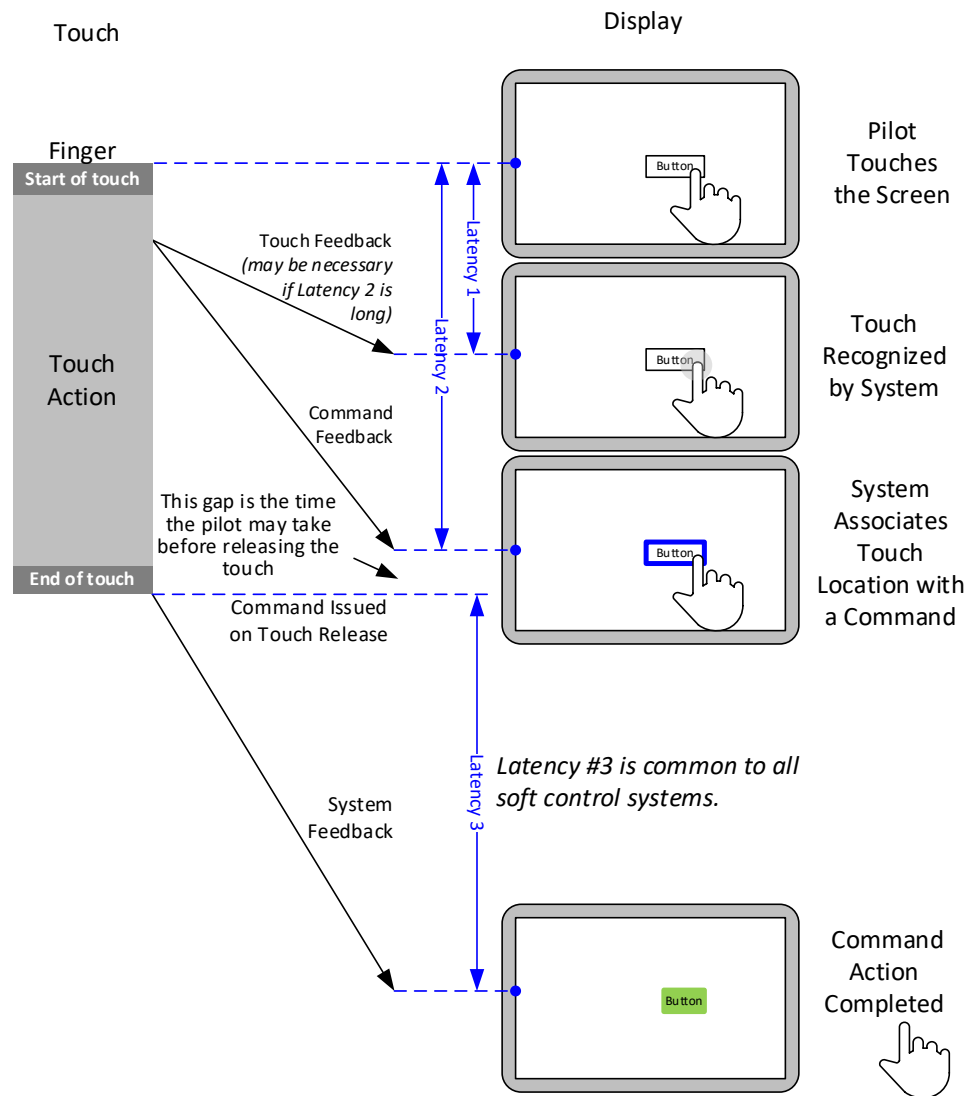


**Figure 1 - Representation of feedback latencies**

In Figure 1, if command feedback (latency #2) is fast enough, it can provide both touch and command feedback. For longer command feedback latency, explicit touch feedback (latency #1) may be necessary to reduce operator error.

Since acceptable feedback latency is heavily dependent on the specific user task, quantitative guidelines are not provided. Instead qualitative considerations are provided in Table 1. As a guide, latency should be assessed to confirm its suitability in a particular application. For those applications where very low latency is necessary, pilot in the loop testing may be appropriate.

**Table 1 - Feedback latency considerations**

| Feedback Type                  | When Needed                                                                                                                                                                                                                                  | Latency Considerations                                                                                                                                                                                                                                                                                                               |
|--------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1 - Touch feedback, controls   | <ul style="list-style-type: none"> <li>- The function to be controlled is not obvious to the user.</li> <li>- Touch is used to select one of many controls on a screen or one of many objects on a screen.</li> </ul>                        | If user task is time critical or the task is risky or difficult to reverse and touch feedback is needed, latency times consistent with the user's finger movement times will be best accepted by the user.                                                                                                                           |
| 1 - Touch feedback, gestures   | <ul style="list-style-type: none"> <li>- More than one gesture is supported by the touch system.</li> <li>- Completion of a gesture is dependent on a user characteristic (finger speed or direction).</li> </ul>                            | To be useful to the user this form of touch feedback needs to occur during the first portion of finger movement of the gesture.                                                                                                                                                                                                      |
| 2 - Command feedback, controls | <ul style="list-style-type: none"> <li>- Response to the command (system feedback) will be slower than the user's expectations.</li> <li>- Time critical tasks need to be carried out in succession by the user.</li> </ul>                  | <p>It provides awareness to the crew that the requested action is underway or will be triggered. Acceptable command feedback latency is highly dependent on urgency of the user task.</p> <p>This feedback is similar to "the time between object selection and indication of selection" defined in ARINC 661-6 (2016) standard.</p> |
| 2 - Command feedback, gesture  | <ul style="list-style-type: none"> <li>- User completion of the gesture is dependent on the extent of system or display action.</li> <li>- Response to the gesture (system feedback) will be slower than the user's expectations.</li> </ul> | If feedback is needed to complete the gesture, the user will need to perceive the feedback as concurrent with the user action. If not needed for gesture completion, acceptable command latency is highly dependent on urgency of the user task and the speed of the system feedback.                                                |
| 3 - System feedback, controls  | <ul style="list-style-type: none"> <li>- User needs confirmation that requested action has been completed.</li> </ul>                                                                                                                        | Depends on the function being controlled. Multiple techniques, often related to command feedback, are available to mitigate long latency for system feedback.                                                                                                                                                                        |

### 3.1.2.2 Other Recommendations

Touch controls may provide different opportunities and mechanisms for operator error and inadvertent operation than conventional mechanical controls. As a consequence, the system design should pay particular attention to error handling and recovery.

If the touch screens can be shared between pilots, care should be taken to define and assess all possible sharing situations that are allowed by the touch system design. For example, in the case of a shared display between two pilots (a display installed in the center of the cockpit), an interaction started by one pilot in a delimited area of the screen should neither prevent nor disturb interaction in another delimited area of the same screen at the same time by the other pilot if the cockpit concept allows these simultaneous interactions. If operating portions of shared displays are not delimited, the system needs to provide detailed feedback of recognized interactions to avoid pilot confusion.

All functions assigned to touch control should be assessed to determine the consequences of its loss, malfunction and error in the human-machine interaction. This is particularly important for touch implemented functions whose failure affects:

- Prevent continued safe flight and landing, or
- Cause a large reduction on safety margins, or
- Cause a large reduction on functional capabilities.

Mitigation should be provided when the touch system itself is not able to cope with the effects of the loss and malfunction of the function in question. Also, mitigation should be provided when considering the error in human-machine interaction. Some examples of mitigation strategies are:

- Other dissimilar device to act as a control input and possibly a display as well, if required by the intended function and its associated criticality
- An "undo/reversal button" to provide a means to reverse an inadvertent or incorrect input
- A "confirmation button" to confirm an input if it cannot be reversed and could have a safety impact if done in error.

Special attention should be given to the error mitigation applied to any touch function controlling significant aircraft actions that are difficult or impossible to reverse. As an example, a two-step operating procedure can add a confirmation prior to the system taking the indicated action. (See 5.4.2 for more detailed examples.)

If the use of gloves and/or alternate touch input device is incompatible in any way with the particular touch technology, the associated limitations should be included in the operating instructions for the touch system.

Where the use of gloves is not accommodated by the touch screen device, an alternative to the use of finger interaction with the display should be available.

If pilot or maintenance actions are required to avoid degradation of the touch system, the necessary actions should be stated in the maintenance or operating instructions for the touch system.

The design should be robust enough to protect against erroneous inputs from the pilot(s). Examples of robust design features include: hand rests, armrest, display bezels, or any other physical structures serving as stabilization points. Examples of erroneous inputs include those that may be committed during a high vibration environment due to engine failure or turbulence.

There should be a means provided for cleaning the touch surface without creating unintended actions.

## 3.2 System and Failure Mode

### 3.2.1 Considerations

Touch screens are subject to many of the same electrical and mechanical failure mechanisms as well as software problems that are common with other control devices. However, the use of touch screen, as compared to traditional control devices, such as knobs, buttons and levers, may introduce new failure modes and may adversely affect the pilot workload. The flexibility of touch controls suggests they will be applied to a wide range of functions. The criticality of the touch system will be governed by the highest criticality assigned to any of the touch functions or by the combination of criticalities of functions integrated within the touch system.

The touch screen is also a display, which provides graphical depictions of buttons, switches, textual information, and other items that are available for selection and/or manipulation by touching the screen.

Consider touch screen or touch controller failures where an area continues to send out erroneous touch signals.

### 3.2.2 Recommendations

Conventional design techniques (e.g., ARP4754A and ARP4761) should be used to address failures of the touch system. Touch systems may fail in a manner different from traditional devices and this should be considered when assessing and determining the safety objectives as part of a safety assessment per §§ 25.1309, 27.1309, 29.1309 and the equivalent Part 23 regulations.

The following touch system description should be included in appropriate documents such as Safety Assessment and Operating Instructions:

- Identification of the touch screen component with a description of touch functions and a description of the operation of the touch sensing/detection component, touch controller, and drivers
- Description of the internal design protection features used to ensure design integrity such as monitoring circuitry, power-up, user initiated and/or continuous built-in testing, etc.
- In order to ensure that the integrity of the touch screen control and display system will be maintained throughout the life of the aircraft, instructions for maintenance, calibration (if applicable), and performance evaluation should be provided.

Where needed to protect other touch functions or avoid erroneous touch, a failure of the touch screen (e.g., constant contact) should be detected and reported as a touch area failure and such touch area or entire touch function should be capable of being disabled with indication provided to the user.

#### 4. HUMAN MACHINE INTERFACE CONSIDERATIONS

##### 4.1 General HMI Items

##### 4.1.1 General Considerations

Touch screens may be used in support of a broad array of control and data manipulation tasks. The capability and flexibility of these types of control devices may allow currently unforeseen system configurations, interactions, and control features. Along with the potential for innovation in interface and menu structures, the potential benefit is also for touch screen control devices to reduce the number of separate control switches in the cockpit, and to allow multiple functions to be incorporated into a single control device.

Touch screens also have the potential to expedite and simplify pilot's actions, as the same interface can be used to input information, display data, select and switch applications, adjust avionics settings, and control aircraft systems. Nevertheless, touch screens may not be appropriate for all tasks or operating environments.

Generally accepted advantages of interacting with an application through directly touching graphical elements include a more "natural" and/or "compelling" approach than working indirectly with a mouse or other input device. The efficiency and accuracy of the direct touch input modality depends on the task (e.g., selection, data manipulation, data entry, scrolling through lists, and paging).

There are advantages and disadvantages for using touch systems in the cockpit. The following are some parameters to consider:

- Access to display and control of information
- Location of input to parameter being controlled
- Direct/indirect control of data
- Actions or gestures used for touch screen operation
- Accuracy of touch inputs including the effects of aircraft acceleration and environmental vibrations
- Functional reach to the touch screen
- Use of dominant versus non-dominant hand
- Ability to rest finger/hand on screen
- Ability to stabilize finger/hand during usage

- Physical obstruction of view of the display or other controls while using touch screen
- Touch target size related to finger use versus another type of entry device such as a stylus
- Touch target size related to touch screen location
- Increased occurrence of finger residue on display screen, potentially impacting display readability
- Ability to clean touch screen

Touch feedback is highly dependent on visual perception. Since touch systems provide new ways to present and manipulate information there is a potential to create clutter on the display as well as pilot distraction. See 4.7 on attention and distraction for additional considerations and guidance.

Simultaneous multiple users, human physical and cognitive capabilities, workload, and error potential are important aspects to be considered when using touch systems.

For latency considerations and recommendations see 3.1.1.1 and 3.1.2.1.

For general considerations and recommendations regarding gestures see Touch Interaction Functions in Section 5.

#### 4.1.2 Positive and Negative Transfer

The term transfer in this section refers to “the extent to which knowledge and skills acquired in one situation affect a person’s learning or performance in a subsequent situation” (Ormrod, 2014, p. 206). There are two types of transfer that can take place. Positive transfer occurs when something learned previously aids in learning at a later time. Negative transfer takes place when something learned interferes with learning at a later time.

##### 4.1.2.1 Considerations

Positive and negative transfer can have a significant effect on training needs, pilot workload, and errors. An example of positive transfer is when learning how to operate equipment on one aircraft makes it easier to operate similar equipment on another aircraft. The learning and practice gained on a given type of equipment transfers to operating the similar equipment on the other aircraft. However the error rates and/or training needs can be much higher when negative transfer occurs than when no previously learned behavior exists. For example, if a pilot already knows how to operate a piece of equipment and if negative transfer occurs, he or she may make more errors while learning to operate new equipment than a pilot who has never operated similar equipment before.

Adopting or adapting conventional touch interactions used in other domains for use in a cockpit environment might improve positive transfer while reducing training needs, workload, and errors.

For additional information on positive and negative transfer for touch systems see Mauney, et. al. (2010) and Sears, et. al. (1990).

##### 4.1.2.2 Recommendations

Paragraph 5.1 documents touch interactions and gestures that mimic interactions with conventional input devices such as one-finger touch for selection, activation, etc. Similarly, gestures like Swipe for paging, Pinch/Spread for zooming, etc., have been widely adopted from interaction with existing touch devices. In order to maximize positive transfer, it is recommended to use these common gestures to the greatest extent possible.

In case of conflicts in adopting/adapting positive transfer interactions, the desirable order for positive transfer should be the following:

- a. Interactions within the same display
- b. Interactions with installed equipment within the same cockpit
- c. Interactions in other contemporary cockpits

- d. Non-installed cockpit equipment, meant for flight operations such as PEDs with EFB applications
- e. Other widely used consumer devices where task association and potential for similarity relationship is high

#### 4.1.3 Cockpit Consistency

##### 4.1.3.1 Considerations

A cockpit design philosophy can be used to facilitate consistency across applications. It is noted that an entirely consistent pilot interface is not always possible, because of the inherent differences between soft and hard controls such as physical movement or tactile/haptic feedback of hard controls.

Touch systems can be introduced in the cockpit as retrofit to aircraft already in the existing fleet or as forward fit as a change to aircraft in the production stream as part of a “block-point” update. It is likely that retrofit introductions would be partial, i.e., touch interactive displays would coexist with “legacy” non-touch displays and their associated systems. Considering this type of partial introduction of touch systems, special care needs to be taken on maintaining a consistent cockpit philosophy despite the potential differences in both graphical designs and user interactions between the touch displays and the “legacy systems.” Note that the introduction of touch systems into forward fit applications or new cockpits also calls for an overall consistency whether or not the forward fit or new cockpit design operation mixes touch and non-touch interactive displays.

Considerations related to the integration of various direct touch devices:

- Integrating different touch technologies (e.g., capacitive, resistive, and infrared) into the cockpit may not provide a consistent user interface and could cause errors.
- Different touch characteristics (e.g., sensitivity, latency, touch feedback) with the same function on different devices may lead to errors or pilot confusion. For example, some touch screen devices may activate with certain gestures, such as a press and hold (see 5.1.1.2), while other devices may require a single tap.

##### 4.1.3.2 Recommendations

Positive transfer should be utilized when appropriate while negative transfer should be avoided to ensure consistency of touch screens with other interactive devices in the cockpit (see 4.1.2).

As part of achieving consistency and positive transfer within the same display, variations in layout of alphanumeric keys should be avoided unless they are designed to minimize workload or typing errors for specific data entry fields with a specific format. If only numeric entries are required by a displayed function on that display, then portraying just a numeric keypad may be appropriate.

For retrofit upgrades or forward fits, special consideration should be given to the consistency between the pre-existing cockpit interfaces and the new touch screens.

When multiple direct touch devices are installed in the cockpit, overall consistency in terms of sensitivity, latency, feedback, and multi-touch characteristics between all touch displays should be sought.

The mix of touch and other controls should always result in an acceptable level of workload.

##### 4.1.3.3 Related Recommendations from Other Sources

Whenever possible and without compromising innovation in design and use, EFB user interfaces should be consistent (but not necessarily identical) with the cockpit design philosophy (FAA AC 120-76D 12.2.2).

#### 4.1.4 Non-Finger Interactions

##### 4.1.4.1 Considerations

Non-finger direct touch input devices for touch screens can be with a stylus or a similar device.

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 have non-finger interactions (AC 20-175, 2-2.e).

A stylus is a portable device which can be lost if not suitably stored or can become entangled if secured by a lanyard or other means. A stylus may also be prone to slippage and inaccuracy in turbulent flight conditions.

##### 4.1.4.2 Recommendations

If a stylus is the sole means of input, it should be tethered to or near the display.

The touch screen should be resistant to scratching, hazing, or other damage that can occur through normal use of an input device including fingernails.

#### 4.2 Single and Multi-Touch Usage

##### 4.2.1 General Information

###### 4.2.1.1 General Considerations

Single touch refers to the response to one and only one touch point at a time by a touch sensor. Single touch systems can support certain gestures. Multi-touch refers to a touch system's ability to simultaneously detect and resolve two or more touch points. See 5.2 for more information on multi-touch gestures.

###### 4.2.1.2 General Recommendations

The operating instructions should describe the type of interaction, extent, and limitations of what to expect with the touch screen, e.g., single touch, multi-touch, gestures, and multi-users as appropriate.

Special consideration should be given to simultaneous multiple users, human physical and cognitive performances, workload, and error potential. How these aspects are considered should be substantiated.

##### 4.2.2 Single Touch

###### 4.2.2.1 Considerations

Single touch systems are intended to respond to a single finger or stylus at any one time. Single touch systems should consider multitouch input (e.g., simultaneous second touch) and how the system may react to the multitouch input to prevent erroneous activations.

###### 4.2.2.2 Recommendations

The equipment supplier should document the operating characteristics of the touch system such as what happens in a single touch device when multiple fingers are used.

##### 4.2.3 Multi-Touch

###### 4.2.3.1 Considerations

Multi-touch systems are capable of simultaneously tracking two or more independent contacts on the screen surface. Examples include one finger on one hand and one finger on the other hand, a single-handed operation where two fingers are used, or when a finger and a non-finger device (i.e., stylus) are used simultaneously. It is also possible to track independent contacts from multiple users.