

IDD Aerospace

*Cursor Control Device
Human Factors and Technology
Considerations for Flightdeck Applications*

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1 Introduction

Competition is constantly driving cockpit avionics to be smaller, lighter, less expensive and more reliable. Beyond those competing qualities, customers want better ergonomics to reduce pilot workload and improve performance, and still offer an attractive package. Cockpits are evolving toward larger primary displays with fewer dedicated human interface panels, placing additional demands on cursor controls. The cursor control device (CCD) is an enabling human interface technology for the modern, display driven cockpit.

In 1954 Paul Fitts wrote that human motion, and especially pointing actions, could be predicted by mathematical law. This law came to be known as Fitts' Law. The law provides that human pointing accuracy and efficiency are governed by the distance between the starting point and the target, and the size of the target. The larger the target and the shorter the distance, the more efficient and accurate humans are at pointing at the target. Applying Fitts' Law to cursor control devices, the most efficient control devices are mice and pens. Both of these devices unfortunately require arm and shoulder movements, which are not well suited to the aircraft cockpit.

In high vibration and high acceleration environments, arm and shoulder movements can lead to errors, extended target acquisition times and cursor inaccuracy. In very high acceleration environments, an arm or shoulder movement may be prohibitive. This eliminates many mice and pens from consideration as control devices. Try keeping a mouse steady during severe turbulence. Control devices that isolate the hand and eliminate arm and shoulder movements, by providing a heel or wrist rest, are better suited to the aircraft cockpit.

The cursor control device can take several forms, each with advantages and disadvantages. Touch pads, trackballs, joysticks and cursor keys/multi-way rockers all have their merits and are considered here. This paper discusses the trade offs between different CCD technologies and how one technology may be more appropriate than another in a particular application. Not considered in this paper are mice, light pens, eye-cursor guided and voice guided cursor controls, which may be useful for more specialized tasks. The ubiquitous mouse is referenced in Fitts' target test comparisons.

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Cursor control devices can be stand alone units, or may be a component integrated into a larger human-machine interface LRU. Common interfaces include ARINC 429, CAN Bus, USB, and Ethernet or AFDX. ARINC 429 and CAN Bus provide a simple, real-time, reliable interface. Ethernet and USB provide greater bandwidth, but with greater complexity and overhead. ARINC 653 may be applied to partition integrated modular avionic implementations. This paper discusses the merits of different interfaces and the bandwidth/processing considerations for different CCD types.

2 Human Machine Interface (HMI) Considerations

2.1 Noise

Sample data noise is inherent with non-discrete or non-digital controls. Ideally noise is best resolved in the control head, prior to transmission to the host LRU, since data may be sampled at a relatively low sampling rate for transmission, giving fewer samples to average or smooth across. Noise may be random, or may be induced from an outside source, such as 400Hz power. Bandpass filtering and averaging need to consider desired signal and noise spectra.

Touch pads often start with rather small differential signals, which must be compared to determine whether the touch pad has been actuated, and whether movement has occurred. Averaging and filtering need to consider use and motion rate and also need to consider possible induced noise sources.

Users controlling trackballs tend to wander along the path from starting point to destination target. Some filtering and averaging, limiting the maximum rate of

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change in the data, may be applied to the sampled data stream, making the path information more linear.

2.2 *User Variability*

The response from some touch pad technologies can vary from user to user. These variations are mostly due to differences in total conductivity to ground. They can be influenced by the user's internal resistance, and the contact resistance from their finger to the touch pad. Low humidity and dry skin can increase the total resistance to ground. Some resistive touch pads can be influenced by contact pressure. The control system needs to consider these variations.

Trackball response can vary with variations in humidity and temperature. Friction between the user's finger and the trackball can decrease under some conditions, leading to some slippage and the need for the user to apply greater force.

2.3 *Control Acceleration*

Control acceleration may be used to improve transit times between the starting point and destination target. Acceleration increases the cursor velocity as the control is moved in the same direction. Acceleration may be applied in the cursor control device, or in the host LRU.

2.4 *Vibration and aircraft acceleration*

In high vibration and high acceleration environments, arm and shoulder movements can lead to errors, extended target acquisition times and cursor inaccuracy. In very high acceleration environments, an arm or shoulder movement may be prohibitive. Cursor controls that isolate the arm and shoulder, removing the user's body mass from influencing cursor movement, are most effective. Cursor controls that can be operated with finger or hand control, with the hand or wrist resting, are usually more successful. Devices that use detachable control components, such as mice and pen/tablet combinations, may be difficult to use in an aircraft cockpit.

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3 Cursor Control Devices

3.1 *Touch pad*

The touch pad offers a mix of good cursor stability, accuracy and ergonomics, along with reasonable pointer accuracy with superb long-term contaminant resistance. Some touch pad technologies can be affected by the presence of contaminants, but normal operation returns once contaminants are removed. Cursor movement can be rapid, but with less accuracy and precision than the reference mouse. This is truer for small test targets than large. Movement time to target is typically 50% greater than for the reference mouse.

Often the touch pad has greater user-to-user variability. Capacitive touch pads in particular are influenced by the conductivity of the user to ground. Some touch pad technologies can be influenced by contact pressure or force. Some touch pad technologies permit glove use, while some do not. If the system accounts for user variability, or if user variability is not a concern, the touch pad can be a very good choice.

3.2 *Trackball*

The trackball offers reliable cursor movement in severe moving environments, since movement is accomplished with finger movement, which allows full wrist and arm isolation. The trackball is significantly less efficient and accurate than the reference mouse, with slower target acquisition than mice, pen/tablet combinations, and joysticks. Software acceleration can improve movement rate, but improvement is limited due to angular inaccuracy or wander typical during use. In Fitts target tests, typical movement time to target is about four times that of the reference mouse.

3.3 *Joystick*

A joystick is similar to a multi-way rocker switch with the addition of a control stick. Depending upon the design, the control may be actuated using finger or hand control, or may involve wrist or arm movement.

Many simple joysticks use four or eight pushbutton switches that detect stick actuation. Simple joysticks usually have either 90 or 45 degree angular resolution, so the user must approach the target with a combination of large angle movements. Some more complex joysticks use optical encoders or

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potentiometers to introduce an analog component that can be used to control cursor velocity, and to provide much greater angular resolution.



In Fitts target tests, typical movement time to target for simple joysticks is about 2.5 times that of the reference mouse. More complex joysticks, which introduce a velocity component and include better angular resolution, can come closer to the reference mouse.



3.4 *Cursor keys/multi-way rocker*

Cursor keys are probably the simplest form of cursor control device. Literally cursor keys are four key driven switches that correspond with up, down, left and right movements. Angular resolution is usually limited to 90 degree, since most implementations use four keys. Cursor keys perform somewhat like a simple joystick, but with reduced ergonomics, since the user has to locate and actuate each key individually.

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Multi-way rockers will usually be either a 4-way or an 8-way design. These function much like a simple joystick minus the stick. They offer better ergonomics than cursor keys for many applications, since the user only has to manage one control, instead of four keys. Control often permits finger actuation, without wrist, arm or shoulder movement, making these controls suitable for high acceleration and high vibration environments. Angular resolution is still limited to 90 or 45 degrees, depending upon whether a 4-way or an 8-way design is used. Angular resolution is less of a disadvantage with larger test targets.



Cursor keys and multi-way rockers can be very resistant to contaminants. These designs can be made waterproof, even during use. However, cursor keys and rockers must be carefully designed to work with gloved users. Reliability and robustness are these controls strongest advantages. Multi-way rockers are fairly small and can also serve a backup role as a secondary control device in the event another more capable primary device fails, and may be integrated into a primary device without requiring much additional space.

4 Interface Considerations

In most systems, the cursor control device connects with a host LRU with some form of serial interface. Practically any serial bus may be used to interface a cursor control device to the display LRU. Depending upon the control type, interface bandwidth may influence the signal processing required in the cursor control device prior to data transfer to the host LRU. In a minimalistic sense, some devices may be interfaced directly, with one line dedicated to each direction switch.

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4.1 *ARINC 429*

ARINC 429 is the well established workhorse of cockpit avionics. ARINC 429 is a low bandwidth, high reliability, predictive communication bus. It requires moderate overhead in the control head, and may require just an interface integrated circuit or an FPGA, and may not require a microprocessor and software. ARINC 429 is typically a one transmitter with one to many receiver communication bus.

4.2 *CAN Bus*

CAN Bus, or “Controller Area Network Bus” is a moderate bandwidth, reliable, robust, real-time communication bus. While not having the high bandwidth capability of Ethernet, it is faster than ARINC 429, and offers many of ARINC 429's advantages. CAN requires somewhat less overhead than Ethernet, though often will demand a microprocessor and software be utilized in the CCD control head. CAN is a truly predictive interface. CAN bus, like ARINC 429 and Ethernet, is capable of providing communication over 10's of meters. CAN can exist on a multi-node network or may be used between just two devices.

4.3 *Ethernet/AFDX*

Ethernet is a high bandwidth, reliable and robust communication bus. While being high bandwidth, it is not a truly real-time, predictive interface, so for time critical, or real-time control functions, it may present additional latency or sequence challenges. Latency guarantees can be improved by using QOS protocols. Ethernet generally requires a microprocessor and software, typically with a TCP/IP stack, and often an RTOS, be contained in the CCD control head. This addition may be moot if the CCD is of a type that benefits from signal processing prior to transport to the host, such as a touch pad. Ethernet is differential, and capable of providing communications beyond 100m. Typical speeds range from 10Mb/s to 1000Mb/s depending upon technology. In general Ethernet requires greater overhead in the CCD control head than other interface types. Ethernet may be a good option if the CCD control head is to exist on a network and is expected to control or communicate with multiple devices. Power over Ethernet may be implemented to power low-power control head devices, avoiding the need for separate control head power connections.

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4.4 *USB*

USB is the typical communication bus used for your PC mouse. While rather user friendly in an office environment, it is not particularly fault tolerant, and is limited to rather a short range connections of just a few meters. USB does have the advantage of providing up to 500mA of 5V power to the CCD, potentially removing the need for a line level power supply in the control unit. USB communications can be made more robust by using an embedded operating system, such as a micro kernel, that can restart drivers and applications without doing a full system reboot.

4.5 *Directly Connected*

Some cursor controls such as joysticks, cursor keys and multi-way rockers may be directly connected to their host. These control types usually involve several switch contacts, which limits the information communication demands. These control types are often discrete or digital, such that it is either actuated or not, without an analog component. Touch pads and trackballs usually involve an analog component, and often require some precommunication signal processing that precluded direct connections with these types. Some trackballs that just generate X and Y pulse data streams from a pair of optical encoders may be directly connected.

5 **Conclusions**

What works largely depends upon what is required of the cursor control device. If the device is required for a very precise function, an advanced joystick may be the best choice. The advanced joystick can also be a good all around choice. For high acceleration and high vibration situations, a trackball may be better. However, trackballs can have problems with contaminants. Trackballs and joysticks work fairly well for gloved users, while touch pads and cursor keys may not be effective. For simple functions in demanding environments, where robustness and reliability are key, cursor keys and multi-way rockers could be the best choice. These devices are also useful in a backup role to a primary control. A good all around choice, with good environmental resistance may be the touch pad. There is no one perfect choice.

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