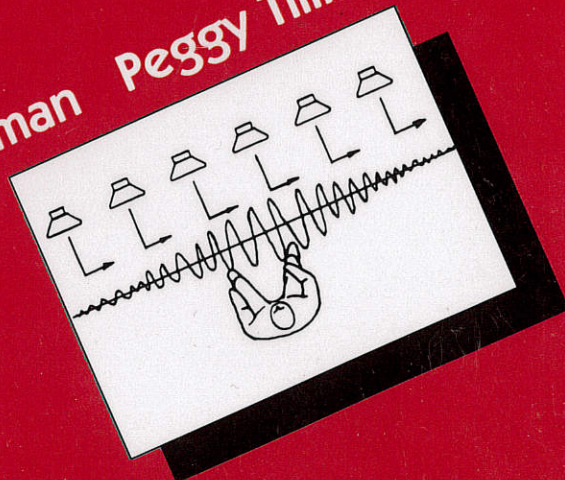
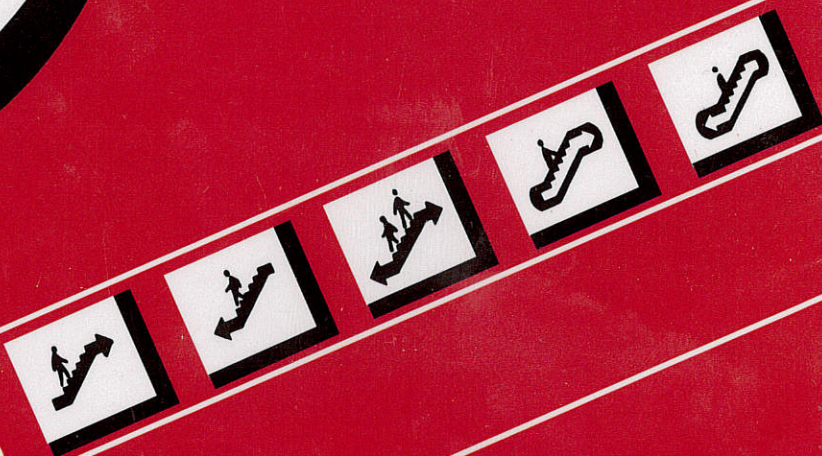


HUMAN FACTORS DESIGN HANDBOOK

SECOND EDITION

Wesley E. Woodson Barry Tillman Peggy Tillman



Bus Driver Work-Station Geometry

The accompanying illustrations show the key geometric and dimensional features required to provide a work station that is compatible with the range of adult drivers from a 5th-percentile female driver to a 95th-percentile male driver. The criteria represent a more or less ideal design that would not be restricted because of other factors such as structural thickness and curvature. Because one cannot attain these ideal geometries, these criteria should be looked upon as a guide; i.e., one should develop an adjustable mockup of the proposed work station using these data, but adjusting them as necessary to fit within the existing constraints.

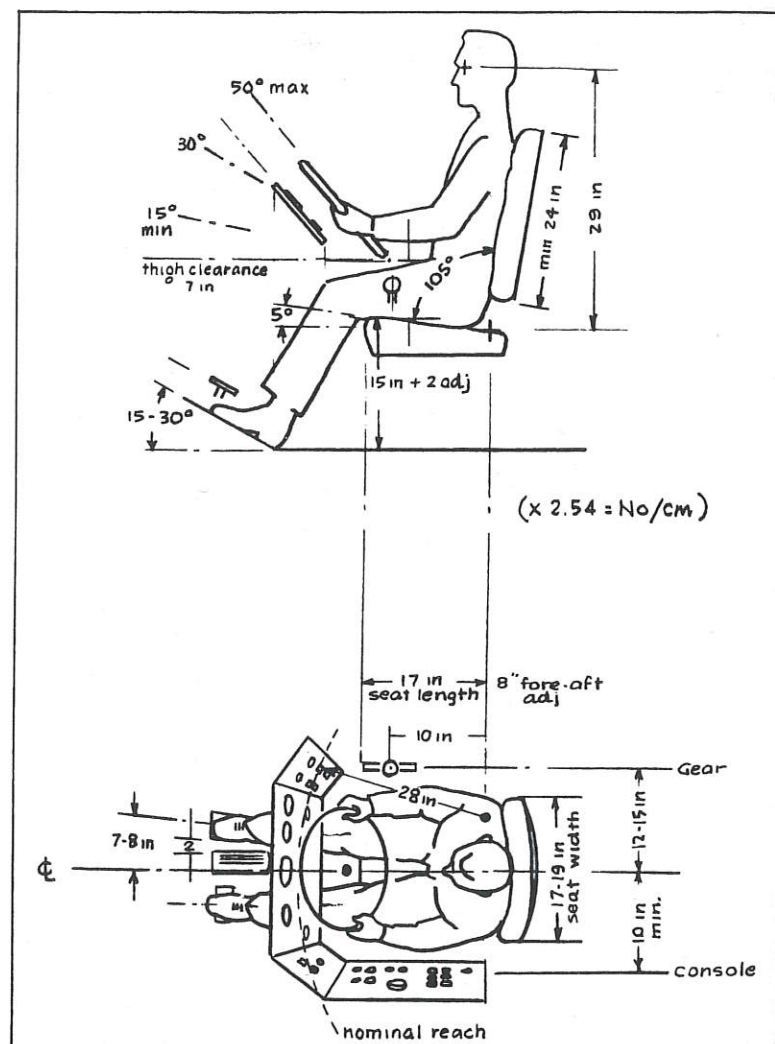
Consider these factors:

1. Continuous, extending reaching increases driver fatigue.
2. A pedal may not be pressed as hard, or far, if it is at the limits of the driver's leg-foot reach.
3. Holding one's foot at an awkward angle (as on the accelerator) tires the driver overall, not just his or her foot or ankle.
4. A steering wheel which is too big or which is positioned in such a way that the driver has to go through drastic torso and arm motions to turn corners not only tires the driver but may also encourage "sloppy" steering.
5. An optimally designed seat, even one that appears to be too upright or too firm, may in the long run minimize fatigue with long usage periods. A seat that is too soft often adds to fatigue because it fails to provide support and because of the "bunching" it causes. Proper seat-pan angle and seat-pan-to-backrest angle are the most important contributors to fatigue minimization. A straight, rather than contoured, seat pan and back cushion are preferred. The backrest should, however, have a slight concavity in order to counteract the effects of sideways.

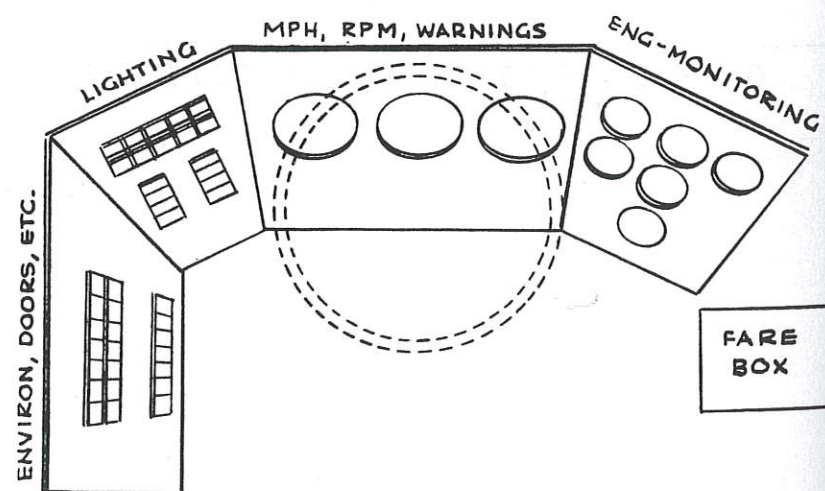
A lap belt be provided for the driver and the belt be anchored to the seat in such a way that the belt geometry will stay constant regardless of where a particular driver adjusts his or her seat.

Control and Display Layout

Although various bus configurations vary in terms of the subsystems that have to be monitored and controlled by the driver, all layouts can and should be organized by system function. As noted in the accompanying illustration, electrical and environmental systems should be located on the left of the driver because these are the first systems he or she activates and checks before moving the bus; i.e., since one normally proceeds sequentially from left to right, the first elements to be used are placed on the left. The central panel contains those instruments (and related controls) that are monitored most often as the driver is maneuvering the bus; i.e., although they are not the second step in precheck-out, they occupy a preferred position relative to the nominal in-motion driving task. The other subsystems, including engine, brakes, fuel, etc., are located on the right-hand panel. Finally, the fare box is placed at the most obvious driver-customer interface point.



GUIDELINES FOR BUS DRIVER STATION LAYOUT



BUS CONTROL AND DISPLAY LAYOUT

Pertinent Federal Aviation
Administration Regulations¹⁵

Before beginning the design of any commercial aircraft, the designer should review FAA requirements pertaining to crew and passenger accommodation, such as the following.

Criteria for determining minimum flight crew. The following are considered by the FAA in determining the minimum flight crew under § 25.1523:

- a. **Basic workload functions.** The following basic workload functions are considered:
 - (1) Flight path control.
 - (2) Collision avoidance.
 - (3) Navigation.
 - (4) Communications.
 - (5) Operation and monitoring of aircraft engines and systems.
 - (6) Command decisions.

- b. **Workload factors.** The following workload factors are considered significant when analyzing and demonstrating workload for minimum flight crew determination:

- (1) The accessibility, ease and simplicity of operation of all necessary flight, power, and equipment controls, including emergency fuel shutoff valves, electrical controls, electronic controls, pressurization system controls, and engine controls.
- (2) The accessibility and conspicuity of all necessary instruments and failure warning devices such as fire warning, electrical system malfunction, and other failure or caution indicators. The extent to which such instruments or devices direct the proper corrective action is also considered.
- (3) The number, urgency, and complexity of operating procedures with particular consideration given to the specific fuel management schedule imposed by center of gravity, structural or other considerations of an air-worthiness nature, and to the ability of each engine to operate at all times from a single tank or source which is automatically replenished if fuel is also stored in other tanks.
- (4) The degree and duration of concentrated mental and physical effort involved in normal operation and in diagnosing and coping with malfunctions and emergencies.
- (5) The extent of required monitoring of the fuel, hydraulic, pressurization, electrical, electronic, deicing, and other systems while en route.
- (6) The actions requiring a crewmember to be unavailable at his assigned duty station, including: observation of systems, emergency operation of any control, and emergencies in any compartment.

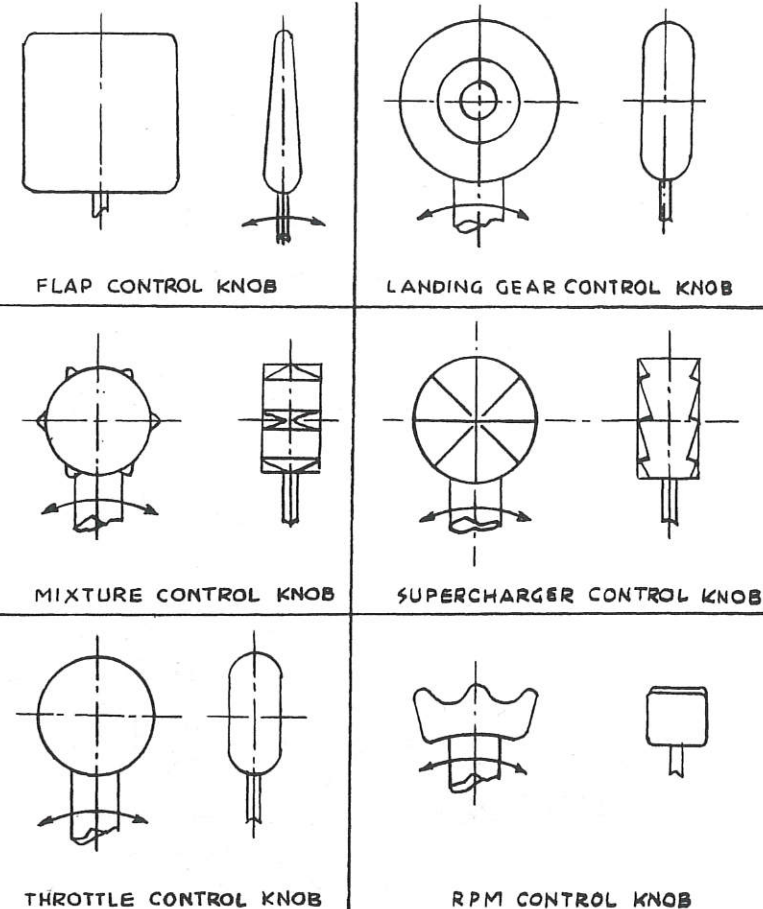
(7) The degree of automation provided in the aircraft systems to afford (after failures or malfunctions) automatic cross-over or isolation of difficulties to minimize the need for flight crew action to guard against loss of hydraulic or electric power to flight controls or to other essential systems.

(8) The communications and navigation workload.

(9) The possibility of increased workload associated with any emergency that may lead to other emergencies.

(10) Incapacitation of a flight crewmember whenever the applicable operating rule requires a minimum flight crew of at least two pilots.

- c. **Kind of operation authorized.** The determination of the kind of operation authorized requires consideration of the operating rules under which the airplane will be operated. Unless an applicant desires approval for a more limited kind of operation, it is assumed that each airplane certificated under this Part will operate under IFR conditions.



§ 25.781 Cockpit control knob shape.

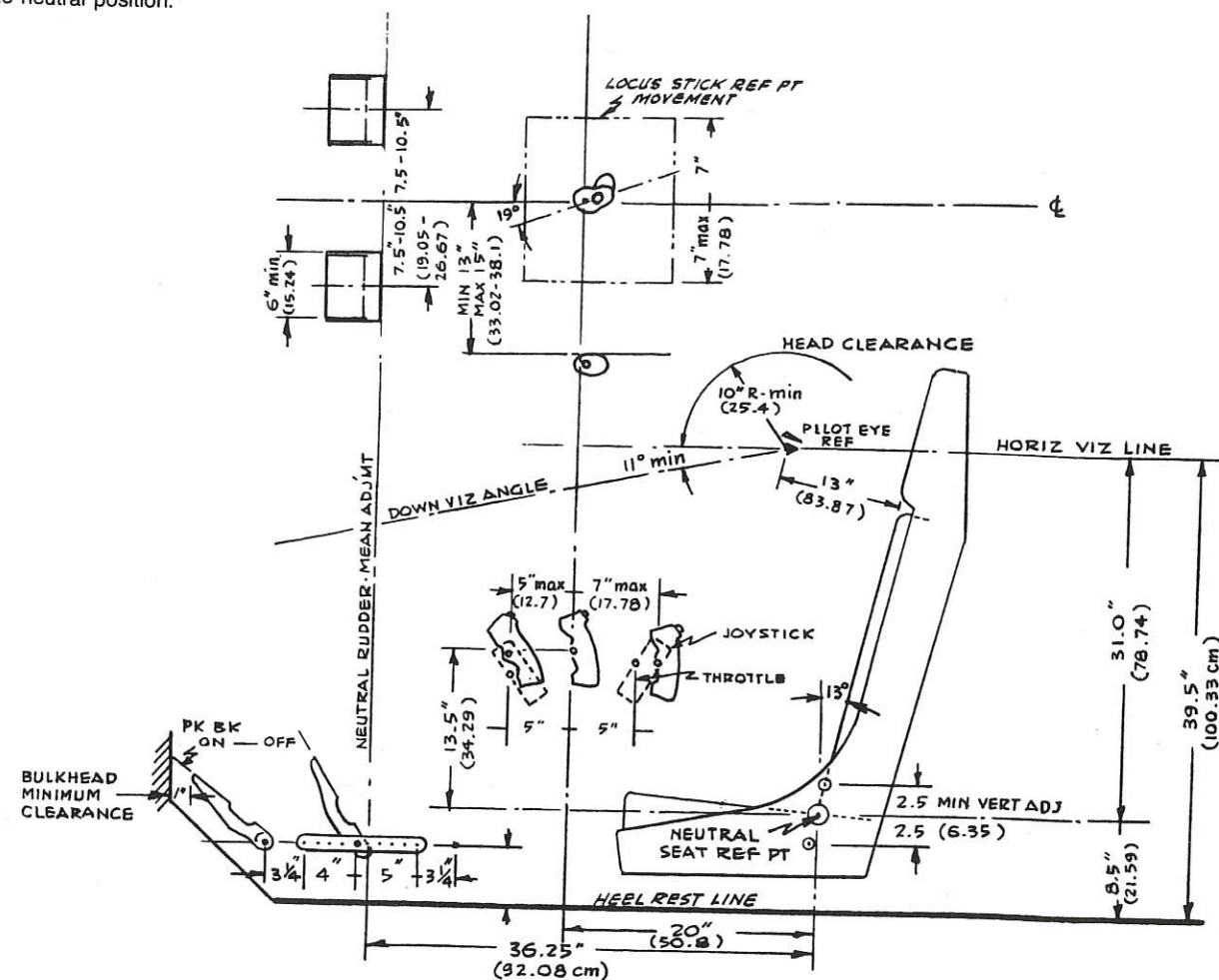
Cockpit control knobs must conform to the general shapes (but not necessarily the exact sizes or specific proportions) in the accompanying figure:

EXAMPLE OF FEDERAL AVIATION
REGULATIONS

¹⁵U.S. Department of Transportation, Federal Aviation Administration, Federal Aviation Regulations, vol. III.

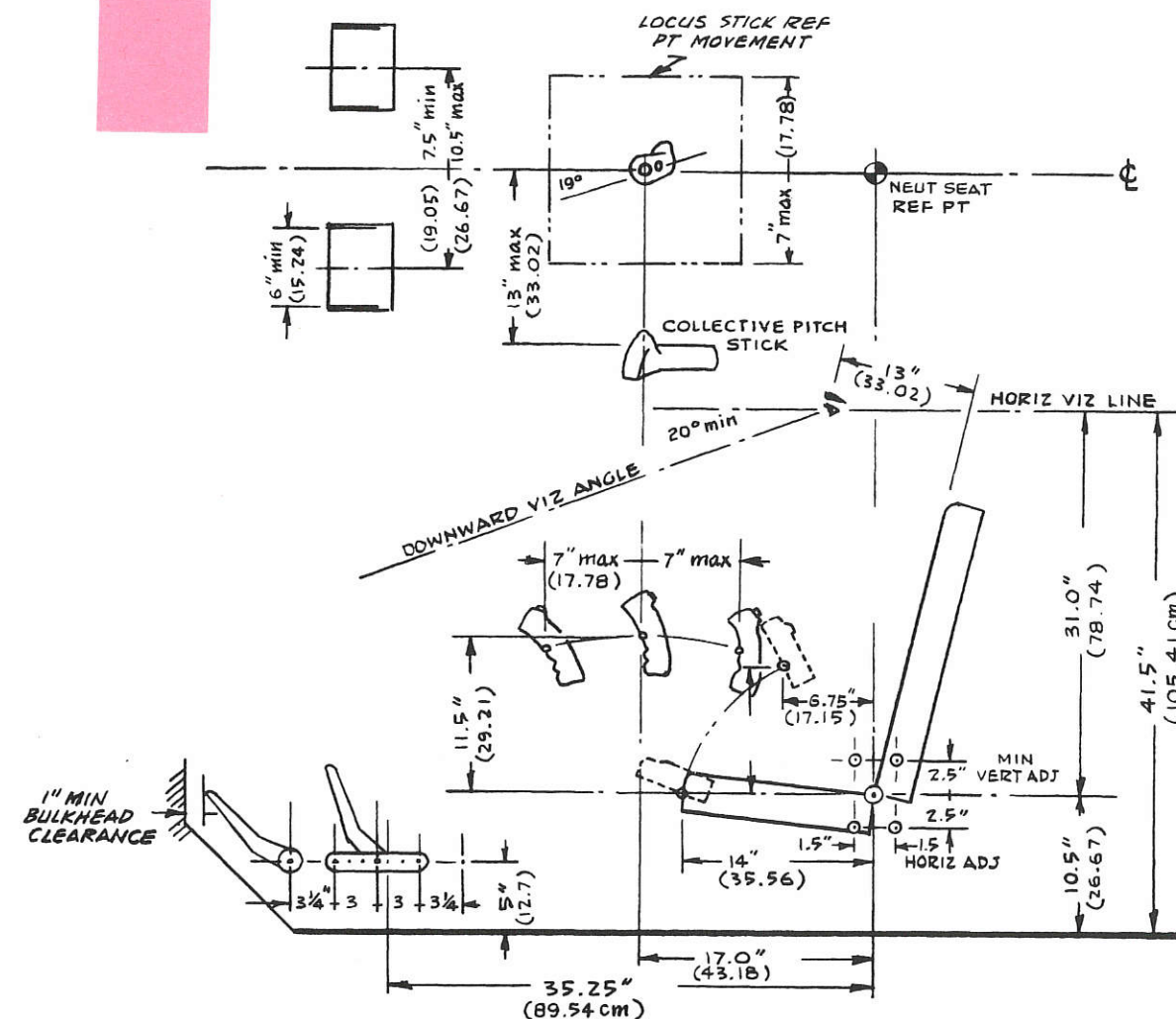
Military agencies are particularly adamant about cockpit standardization in order to minimize pilot confusion when transferring from one aircraft to another. Following are selected examples of U.S. Air Force standardization guidelines.¹⁶

1. The pedal "brake off" angle, with respect to the vertical shall remain constant throughout the entire rudder pedal travel.
2. Three inches of rudder pedal adjustment is acceptable when seats provided with ± 2.500 in of vertical and 1.500 in of fore and aft adjustments are utilized.
3. Rudder pedal adjustment shall be in increments of 1 in or less.
4. The stick and throttle reference point is defined as the point at which the pilot's second finger is in contact with the forward face of the control.
5. Reference spec MIL-B-6584 for brake pedal angles and dimensions.
6. All measurements are based upon the seat reference point at the centerline of the seat in the neutral position.



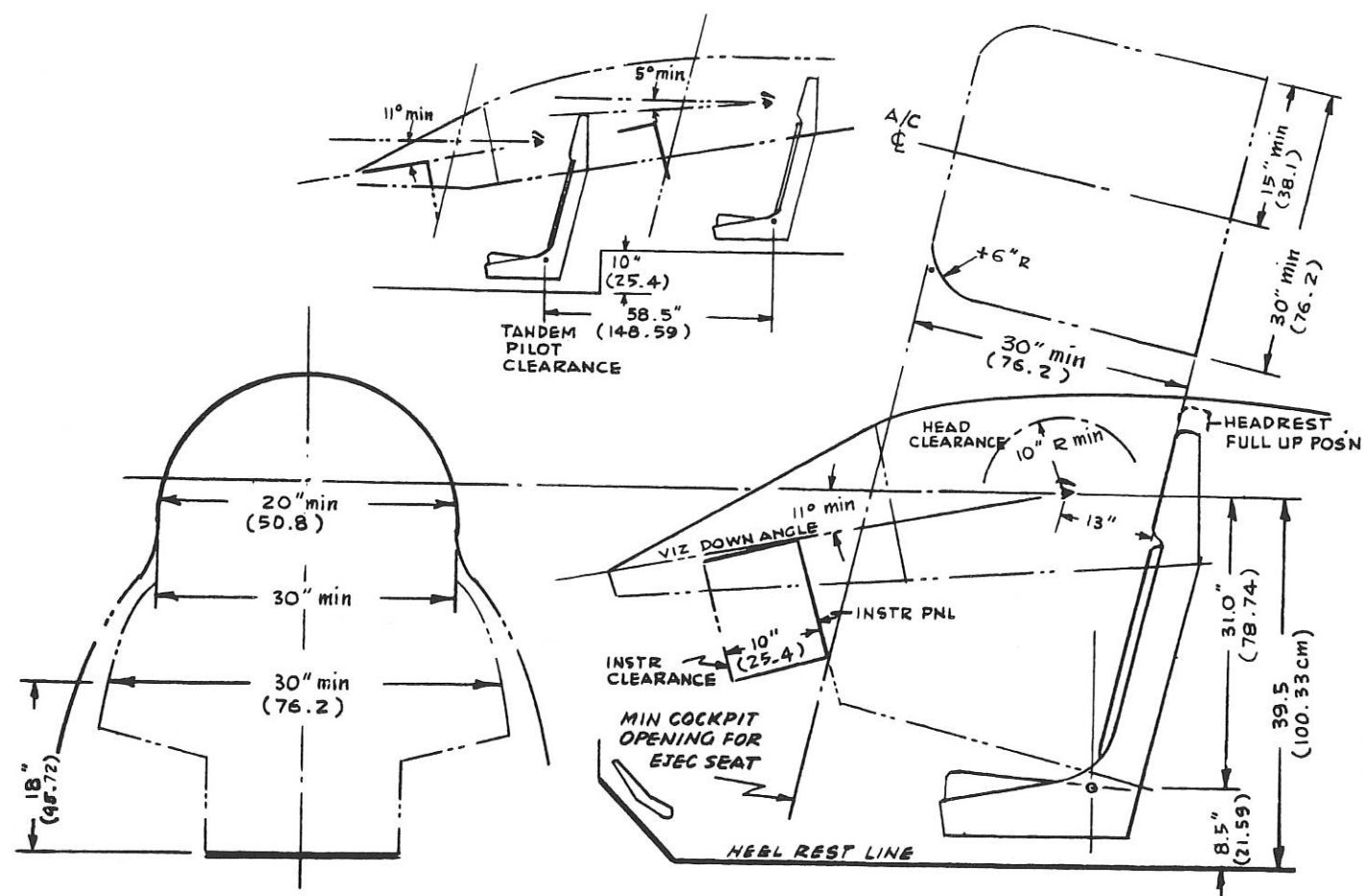
COCKPIT-BASIC DIMENSIONS, FIXED WING

¹⁶Crew Stations and Passenger Accommodations, AFSC DH 2-2, Design Handbook Series 2-0, Aeronautical Systems Headquarters, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio.



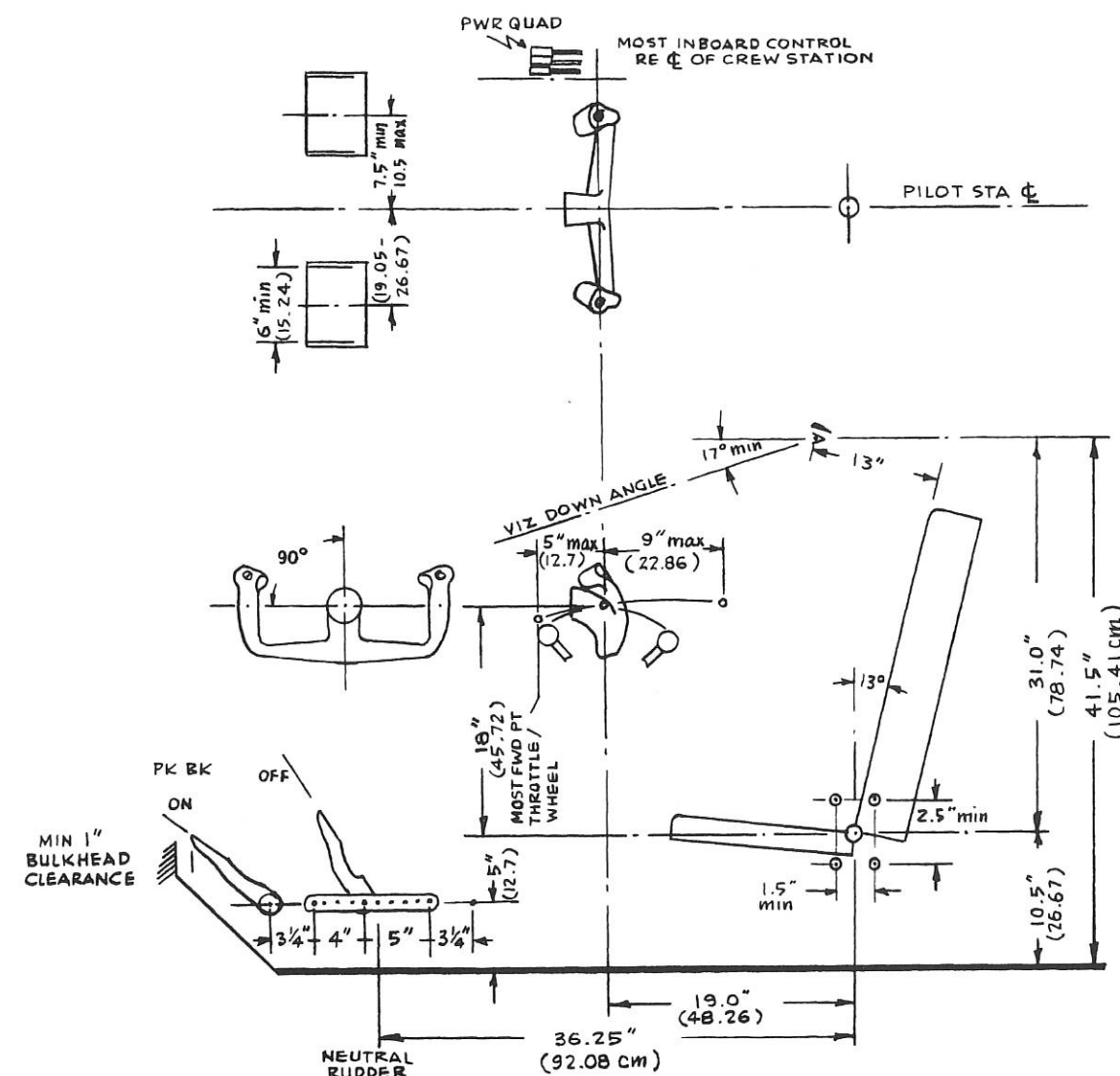
COCKPIT-BASIC DIMENSIONS, HELICOPTER

1. Adequate clearance shall be provided to allow unrestricted operation of the rudder pedal throughout the full range of travel.
2. The pedal "brake off" angle with respect to the vertical shall remain constant throughout the entire rudder pedal travel.
3. The collective pitch stick travel shall not exceed 12 in from pull-down position of the grip.
4. The seat shall be provided with fore and aft and vertical adjustment independent fore and aft and vertical adjustment is desirable. However, diagonal adjustment is acceptable.
5. Rudder pedal adjustment shall be in increments of 1 in or less.
6. The stick reference point is defined as the point at which the pilot's second finger is in contact with the forward face of the stick grip.
7. Reference spec MIL-B-6584 for brake pedal angles and dimensions.
8. All measurements are based upon the seat reference point at the centerline of the seat in the neutral position.



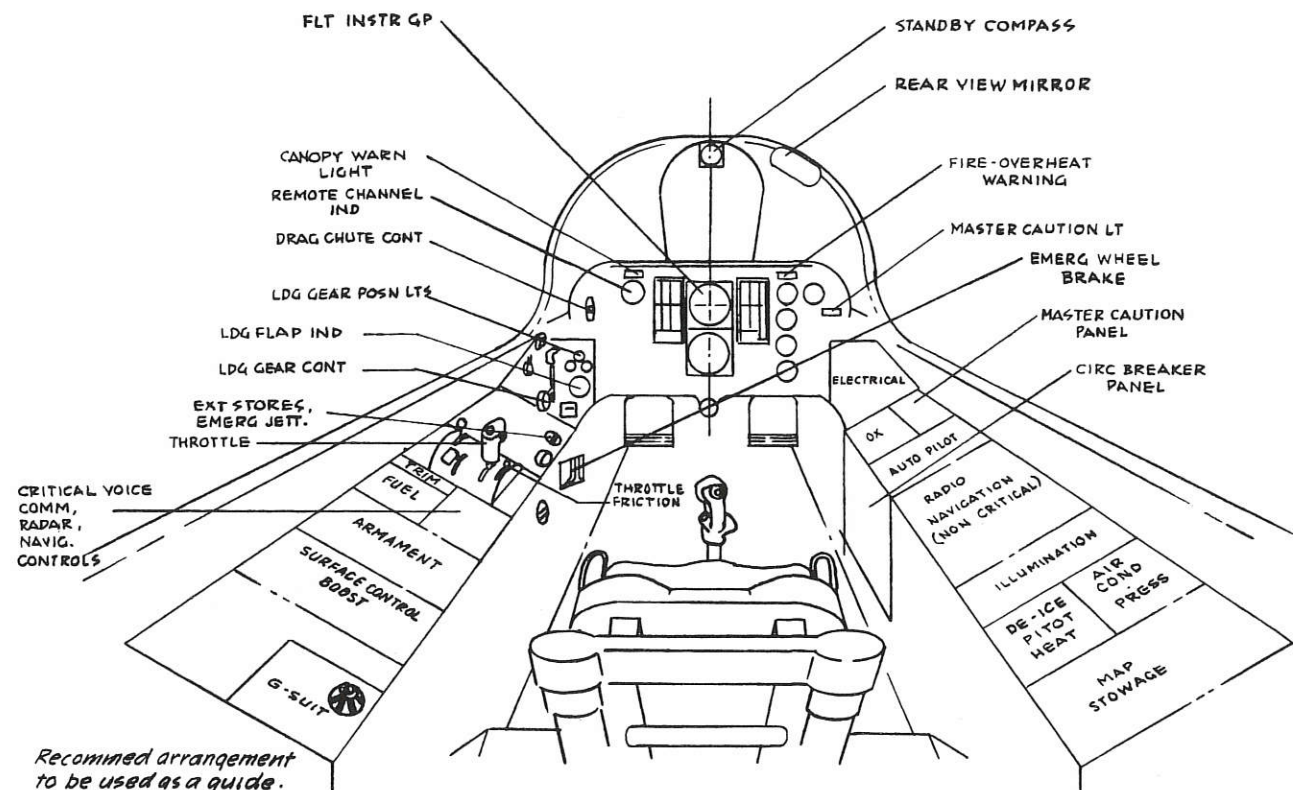
COCKPIT-CLEARANCE DIMENSIONS, EJECTION SEAT

1. There shall be no projections such as the throttle, landing gear control, instrument panel, etc., into the ejection seat envelope that would interfere with seat ejection.
2. All measurements are based upon the seat reference point at the centerline of the seat in the neutral position.
3. The 30-in minimum ejection clearance line (parallel to the ejection path and measured perpendicularly to the plane of the seat back) shall be provided from the seat reference point. For airplanes not requiring ejection seats the minimum cockpit opening shall be 24 by 24 in.
4. The seat shall be provided with vertical adjustment as shown.

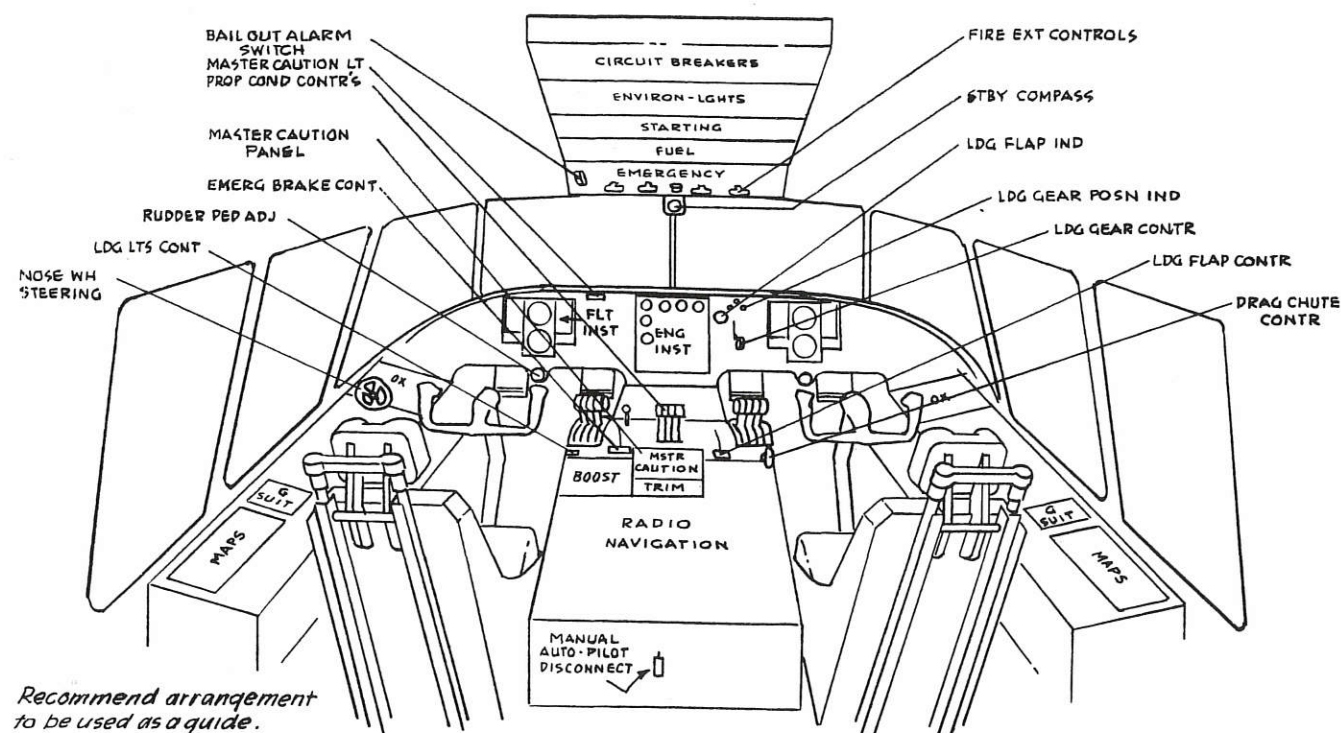


COCKPIT-BASIC DIMENSIONS, CARGO AND BOMBER

1. When ejection seats are required, the vertical seat adjustment shall be parallel to the ejection rails.
2. The rudder pedal "brake off" angle with respect to the vertical shall remain constant throughout the entire rudder pedal travel.
3. Rudder pedal adjustment shall be in increments of 1 in or less.
4. The wheel reference point is defined as the point at which the pilot's second finger is in contact with the forward face of the control wheel.
5. The seat shall be provided with fore and aft and vertical adjustment. Independent fore and aft and vertical adjustment is desirable. However, diagonal adjustment, as shown, is acceptable in lieu of vertical adjustment.
6. Reference spec MIL-B-6584 for brake pedal angles and dimensions.
7. All measurements are based upon the seat reference point at the centerline of the seat in the neutral position.

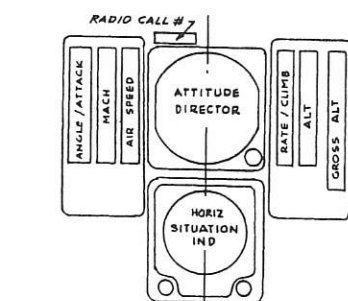


COCKPIT-TYPICAL ARRANGEMENT, SIDE-BY-SIDE, FOUR ENGINE

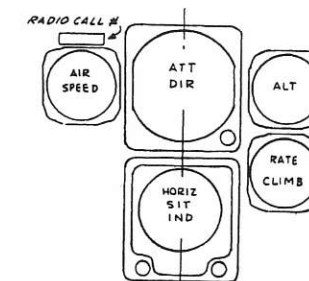


COCKPIT-TYPICAL ARRANGEMENT, FIGHTER TYPE AIRCRAFT

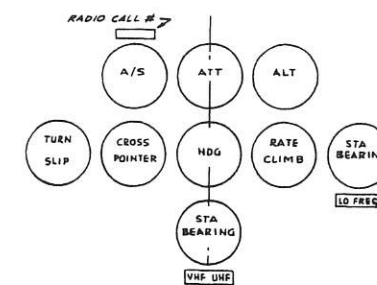
1. Vertical line through the directional indicator dial indicates centerline of pilot's head.
2. Other instruments not shown here, which are required, shall be located in the most convenient place to suit the particular design of each type airplane, and shall have engineering approval by the procuring activity.
3. Any deviation from the proposed instrument arrangement as shown on this drawing shall have engineering approval by the procuring activity.
4. The panels containing instruments, other than self-contained gyro instruments, may be inclined subject to approval of the procuring activity.
5. When advanced instrument Figs. 1 and 2 are provided only for the pilot, conventional instruments shall be arranged in accordance with Fig. 4.



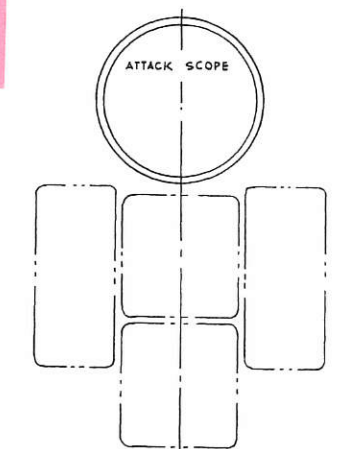
Standard basic advanced flight instrument arrangement (Fig. 1).



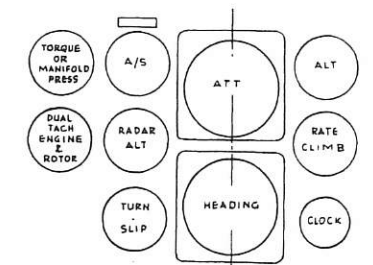
Standard basic advanced flight instruments with conventional indicators (Fig. 2).



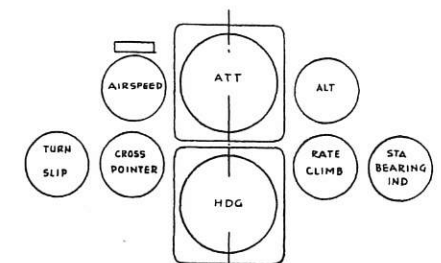
Standard basic flight instrument group with conventional instruments (Fig. 4).



Attack or radar scope location (Fig. 3).



Standard basic flight instrument arrangement for rotary wing aircraft (Fig. 5).



Standard basic flight instrument group with large heading and attitude indicator (Fig. 6).

INSTRUMENT ARRANGEMENTS

Wheel-Type Joy Stick

The wheel-type joy stick is generally used for most aircraft other than military fighters where lack of lateral space within the cockpit dictates a single lever-type joy stick.

The so-called wheel generally is configured as a half wheel in order that the pilot can see panel instruments beyond the wheel.

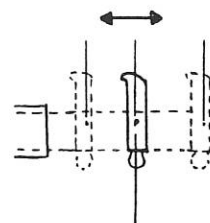
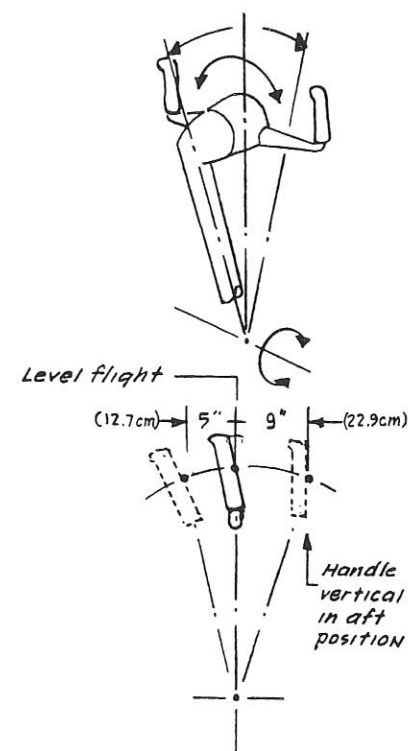
Key factors in designing and positioning the wheel control are the following:

1. Fore-aft excursion should be within comfortable reach of the pilot; the pilot should not have to lean forward for pitch-down movements or rear back for pitch-up movements, and his or her normal position for flight control should be comfortable (i.e., the upper arm should hang approximately vertically).

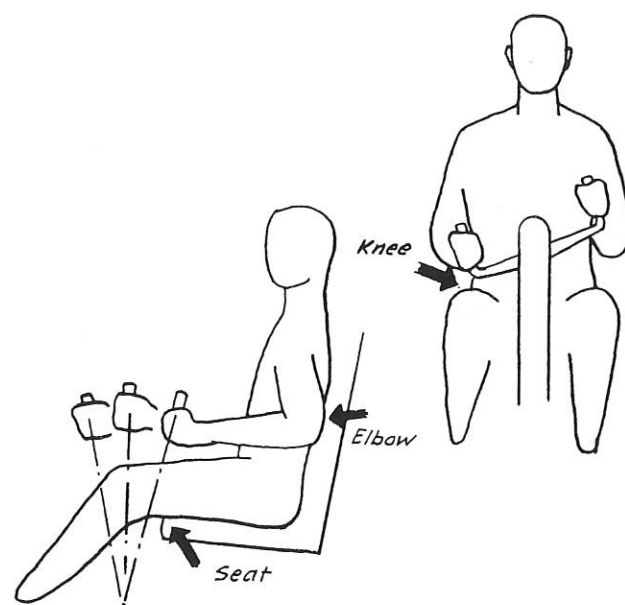
An arc pattern is acceptable, but a straight-line pull is easier for the pilot.

2. Clearance must be provided between the wheel and the pilot's knees and between the vertical control shaft and the pilot's seat, and there must be clearance aft of the pilot's elbow when pulling the wheel aft.

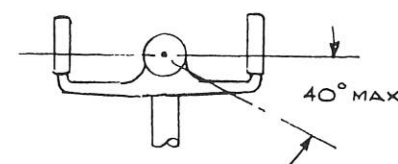
3. When possible, design the system so that full rotation is no more than 40°.



1. FORE AFT MOVEMENT WITHIN REACH OF PILOT

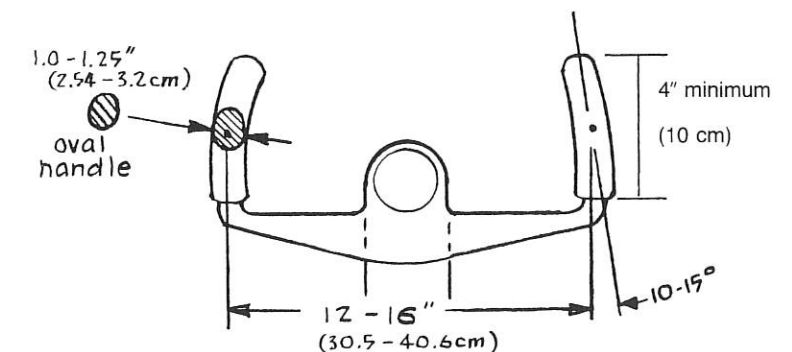


2. PROVIDE CLEARANCES

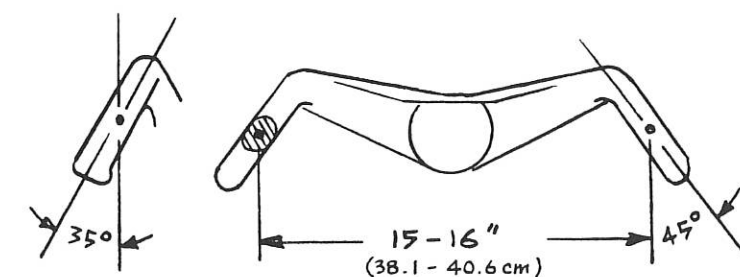


3. RECOMMENDED ROTATION LIMIT

4. For small aircraft, where a wheel of minimum size is desirable, be sure that the handles are at least 12 in (30.5 cm) apart. Handgrips should be round or oval. A 1.125-in (2.858-cm) diameter is optimum. (Oval dimensions are illustrated.) The handgrip should be at least 4 in (10 cm) long and should be tilted inward, as shown in the accompanying sketch.
5. A very effective wheel configuration is shown in the accompanying illustration. Not only is it very comfortable, but it also provides useful feedback in terms of control position. Note, however, that the lateral handle spacing must be at least 15 in (38.1 cm) to prevent the handles from striking the pilot's knees during a turn.



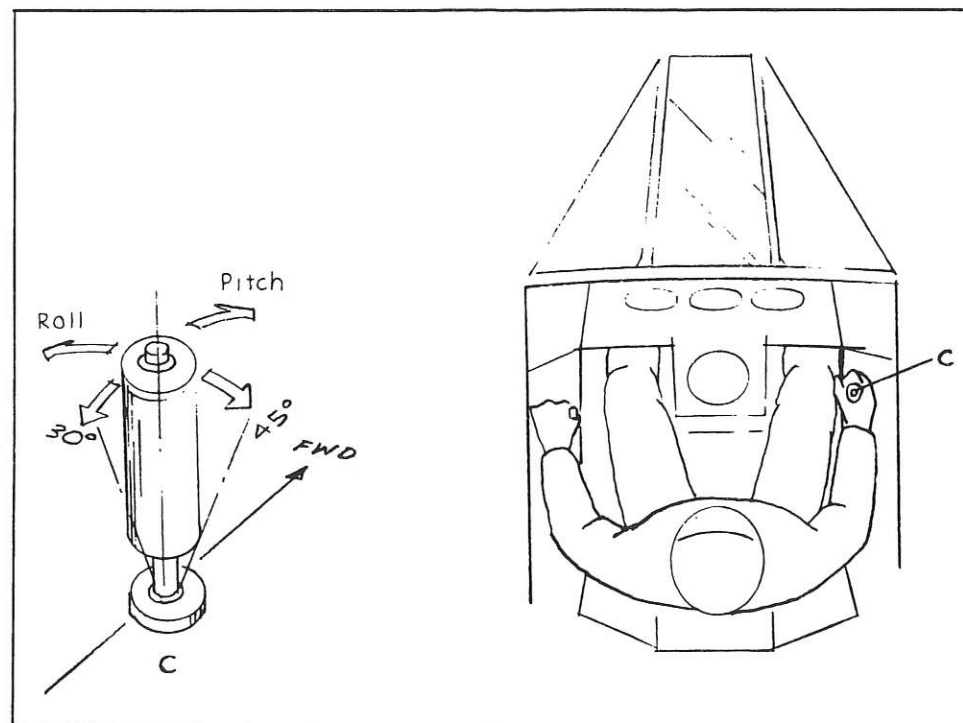
4. RECOMMENDED DIMENSIONS (FROM MIL-STD-1472 D)



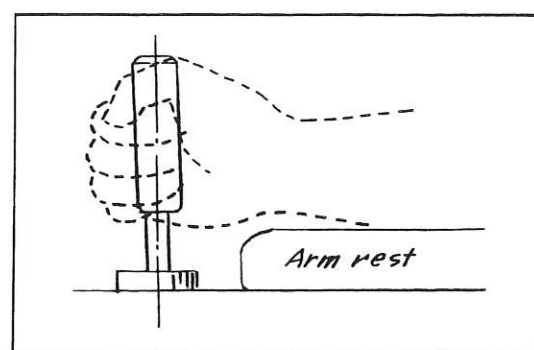
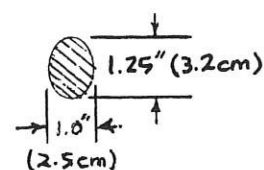
5. EFFECTIVE WHEEL CONFIGURATION

Side-Stick Controller

A side-stick type of joystick may be required when sophisticated display and control packages must be placed between the pilot's knees (thus eliminating the possibility of the normal joystick). Obviously, this greatly reduces the range of controller movement. Instead of full arm motions, pilots must rely almost entirely on wrist motion, which also reduces the amount of force they can apply. A typical electric stick is shown in the accompanying sketch. Fore-aft movement should be limited to plus or minus 30° and side-to-side motion to plus or minus 45°. Control movement resistance should range from 10 to 20 oz (283 to 567 g), and the control should be spring-centered so that it will return to the neutral position.


RECOMMENDED LIMITS OF WRIST CONTROL MOVEMENT

Theoretically, the most efficient side controller would be one that does not require the pilot to make any arm motion; i.e., the controller should be designed so that the pilot's arm can remain firmly on an armrest, with only natural wrist motions required to manipulate the controller.


USE REST TO SUPPORT ARM

**RECOMMENDED
CONTROL
HANDLE SIZE**

The shape and actual size of handles for side-stick controllers should be approximately the same as those suggested for the normal joystick (center type), as shown below.

PENCIL JOYSTICK

The pencil joystick gets its name from the fact that it is generally held like a pencil or pen. It is useful for console situations in which an operator manipulates cursors or other electronic graphics on a CRT display.

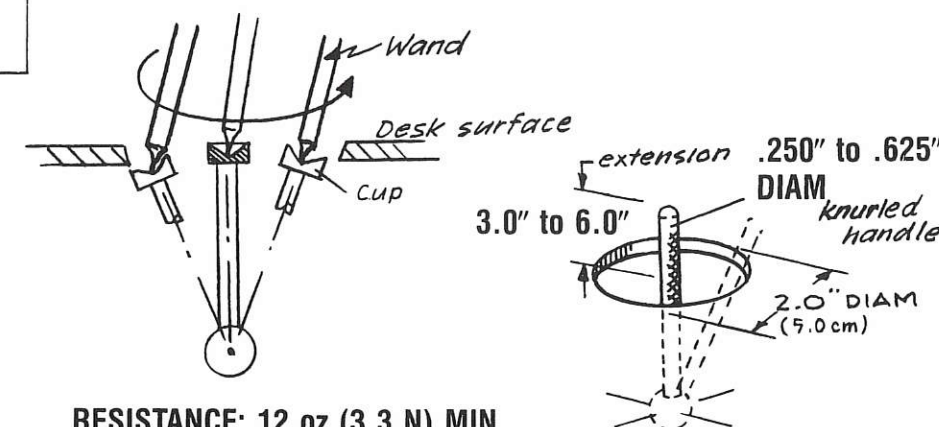
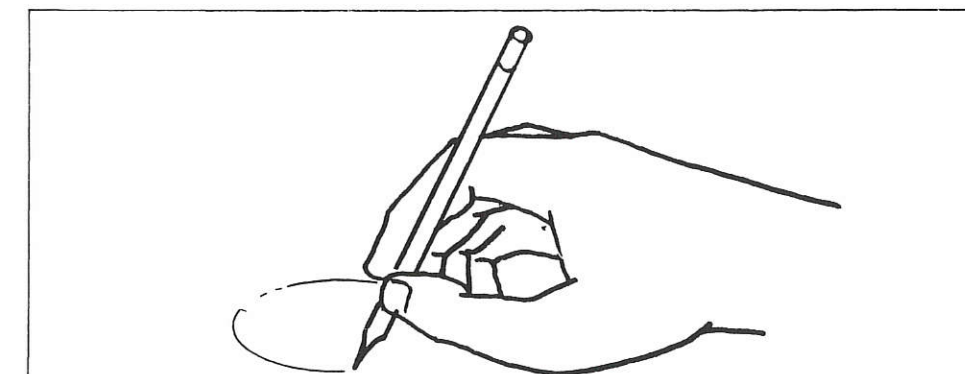
The more "pencil-like" the device is, the easier it is to operate. The accompanying sketch shows that the ideal approach would be to provide the operator with a "wand" with which the basic controller arm can be moved through a cone about 2 in (5.0 cm) in diameter.

A cup positioned approximately at desk surface height receives the wand, making it possible to "write" with the controller.

Perhaps the next best alternative is to place the control pivot point below the desk surface, as shown in the accompanying sketch.

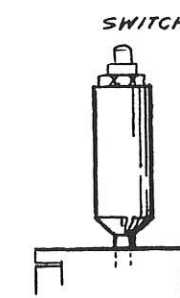
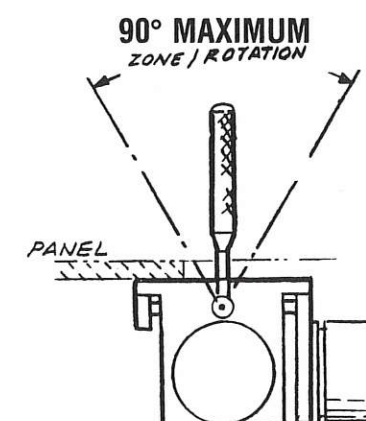
Various manufacturers offer other alternatives, as shown in the accompanying sketches. Although these do not provide the optimum "writing" characteristics discussed above, they are generally satisfactory. Avoid selecting devices that have handle diameters considerably different from those shown here.

Although the switch-handle configuration is acceptable, the smaller joystick with a separate, left-hand-operated switch on the console is preferred.



**RESISTANCE: 12 oz (3.3 N) MIN
32 oz (8.9 N) MAX**

Pencil joysticks should be self-centering



Least preferred - awkward, easy to disturb stick position while operating switch - place switch for operation with other hand.

PENCIL JOYSTICK DESIGN RECOMMENDATIONS