

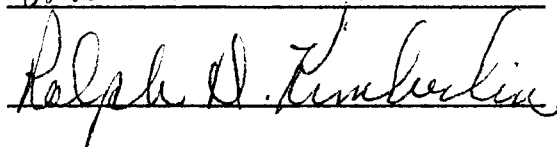
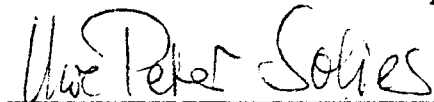
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I am submitting herewith a thesis written by Harry M. Robinson, Lieutenant Commander, United States Navy entitled "Techniques for Performing Human Factor Evaluation of Aircraft Controls and Displays". I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Aviation Systems.



R. Richards, Major Professor

We have read this thesis
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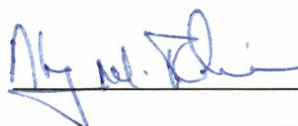
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TECHNIQUES FOR PERFORMING HUMAN FACTORS
EVALUATION OF AIRCRAFT CONTROLS AND DISPLAYS

A Thesis
Presented for the
Masters of Science
Degree
The University of Tennessee, Knoxville

Harry M. Robinson
Lieutenant Commander
United States Navy
December 1992

ABSTRACT

Modern aircraft are composed of various sub-systems which provide the means to execute the mission for which the vehicle was designed. Flight controls, aircraft configuration, navigation, detection and tracking, armament, and environmental systems require manipulation by the aircrew. Aircraft, in general, are manually operated and therefore must provide interfaces between the human operator and the individual systems. In the design process, human factors engineering principles can be utilized to optimize this interface. Recent advancements in technology have improved aircraft system performance and agility; however, the operator has become the limiting factor in design complexity.

The purpose of this thesis is to develop standardized procedures for conducting human factors evaluation of aircraft systems controls and displays. Initially human factors considerations and guidelines are presented. The thesis will then document test methodology to be utilized by test aircrew or engineers to perform both ground and flight evaluations. The scope of these tests is to provide a foundation to identify system human factors deficiencies, analyze their conformance with applicable design specifications, and determine their affects on the capability of the aircraft to accomplish the designed mission.

PREFACE

This manual has been designed for use depending upon the reader's prior knowledge in Human Factors and flight test procedures.

An individual with only a limited background in aviation should read through the entire manual. Individuals with a firm understanding in Human Factors design guidelines can proceed directly to the sections dealing with test and evaluation. Evaluators who are familiar with both topics, may only require the use of tables and data cards presented in the appendix sections.

In the attempt to make this manual as gender free as practicable, pronouns such as "his" or "her" have been removed where the readability of the text allows. Additionally, no distinction is implied or should be inferred between the terms pilot, aircrew, or operator and cockpit, crew station, or work station.

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CHAPTER 1

HUMAN FACTORS APPLICATIONS TO AIRCRAFT OPERATION AND DESIGN

BACKGROUND

Each aircraft is designed to accomplish a specific mission or task. Whether that mission is in support of military or civilian operations, it is essential the aircrew be provided with the means to direct the aircraft through its route of flight and perform the required mission. The primary means by which the aircrew receives information concerning aircraft and system performance is through displays. Likewise, the aircrew is provided with controls to manipulate the aircraft and operate the systems required for mission execution. Cockpit located controls and displays provide the means for aircrew interface with the various aircraft systems.

EARLY AIRCRAFT

Early aircraft were equipped with minimal controls and displays required for flight. Flight and power plant controls were supplemented by rudimentary instruments. The pilot received information concerning aircraft operation primarily through visual reference to the earth. Performance feedback was transmitted directly to the pilot through sensory inputs from control forces, gravitational pull, engine and airframe noise, and the feel of the airstream on the body in

an open cockpit. Technological advances in aircraft flight control, power plants, environmental controls, navigation instruments, detection and tracking systems, and armament systems required additional provisions to display information to the aircrew and allow for operator manipulation of the various aircraft sub-systems. Additionally, demands to conduct flight in all-weather conditions dictated equipping aircraft with the means to display and control the aircraft's attitude and flight path with respect to the earth.

COMPETITION FOR SPACE IN THE COCKPIT

Eventually, increasingly numerous aircraft system controls and displays began to compete for the limited space within the cockpit. Basic rules were developed to prioritize their location. Schemes were used by design engineers to determine the optimum placement for various controls and displays dependent upon their operation (e.g. safety-of-flight) and utilization frequency.

STANDARDIZATION BETWEEN AIRCRAFT

A further consideration for aircraft control and displays was standardization between different aircraft. Pilots transitioning from one plane to another expected to find similarly grouped cockpit controls and displays to be located in the same relative position and operate in the same

manner. Control location, coding, and manipulation which was not standardized often resulted in incorrect operation and in some cases destruction of aircraft and loss of crew.

LIMITATIONS TO AIRCRAFT ADVANCEMENTS

Aircraft modernization produced improved performance (higher altitudes, greater speeds, enhanced maneuverability) and increased combat induced hazards, placing additional stress on the aircrew. As the number of aircraft systems increased, the aircrew's capability to manage their operation remained fixed. This effectively compressed the time given to the pilot to interface with any one system. The limitation of serial processing by humans impeded pilots in reacting to critical events, especially when they occurred simultaneously. Technological advances which led to exceptional air vehicle performance, agility, and complexity resulted in making the operator(s) the weak link, the limiting factor of the combined aircraft system.[7, p. i] Improvements were required so aircraft and aircrew interface design provided for optimum use.

HUMAN FACTORS APPLICATION

Aircraft design found itself ripe for application of Human Factors engineering principles. Human Factors is the study of the capacities and limitations of man and/or woman

meeting environmental demands.[9, p. 19] Additionally, the related field of study, Ergonomics, was applied to aircraft design. Ergonomics is defined as the scientific study of the relationship between operator and working environment including anatomical, physiological, and psychological aspects of workers in their working environment with the object of optimizing health, safety, comfort, and efficiency.[4, p. 4] A depiction of interrelationships involved in Ergonomics applications is shown in figure 1.

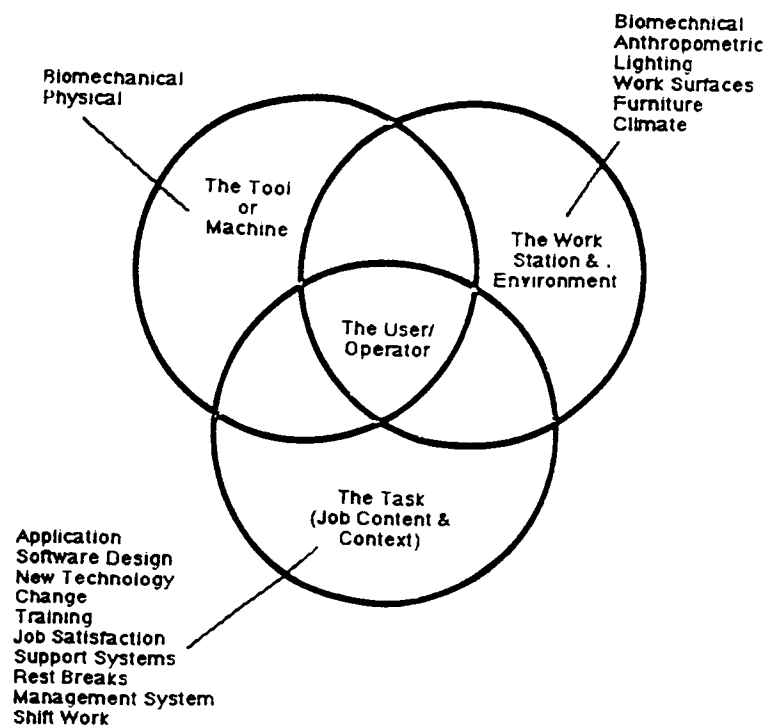


Figure 1
ERGONOMIC FACTORS AND RELATIONSHIPS

[21]

ENGINEERING GOALS

The cockpit became the focal point of the aircrew-aircraft interface, and it was this area which received the maximum human engineering design emphasis. Engineers were joined by psychologists, physiologists, and other professionals in an attempt to design hardware subsystems so human abilities could be complimented and human limitations compensated.[5, p. 1] Through the application of Human Factors principles, the identification of design induced errors led to improved safety and performance. Two primary engineering goals were to permit optimal human functioning in the kinds of tasks performed by the aircrew, and at the same time provide maximum system efficiency in attaining the goals for which the system was conceived. Criteria for Human Engineering design are defined as,

The summation of available knowledge which defines the nature and limit of human capabilities as they relate to the check out, operation, maintenance or control of systems or equipment, and which may be applied during engineering design to achieve optimum compatibility between equipment and human performance.[20, p. 12]

DESIGN STANDARDS

Incorporating of Human Factors engineering became a requirement in the procurement of military aircraft. Standardization of controls, displays, marking, coding,

labeling, and arrangement schemes provided the means to ensure uniform and common functions for all equipment. The military standard, Human Engineering Design Criteria (MIL-STD-1472), set forth guidelines concerning application of Human Factors into equipment procured by the government. Its objective was to ensure a work environment to foster effective procedures, work patterns, and personnel safety and health, and to minimize factors which degraded human performance or increased error. Additional objectives included designs in which operator workload accuracy, time constraint, mental processing and communication requirements did not exceed operator capabilities. Designs were to minimize personnel training requirements within the limits of time cost and performance trade-offs. The stated purpose of this detailed standard was to:

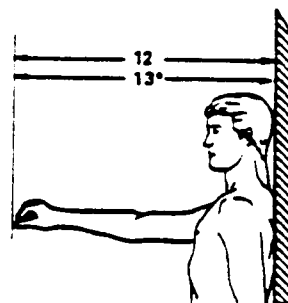
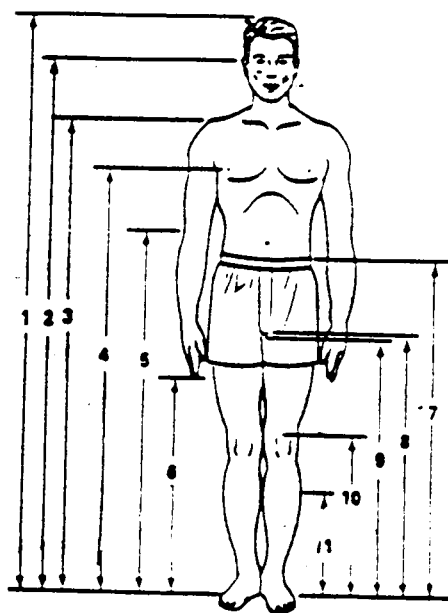
Present human engineering design criteria, principles, and practices to achieve mission success through integration of the human into the system, subsystem, equipments, and facility, and achieve effectiveness, simplicity, efficiency, reliability, and safety of system operation, training, and maintenance.[20, p. 1]

The use of design standards provided both manufacturer and customer a measure by which an aircraft could be evaluated. Aircraft performance and related efficiency were evaluated and documented to ensure the manufacturer would meet the necessary requirements for mission accomplishment. Design

standards were not used as the only criteria by which to evaluate aircraft. Functional utility of a system was considered just as important as meeting design specifications. The fact that an airplane met the requirements of pertinent specifications may have been of secondary importance if any performance characteristic degraded the airplanes normal operation in its planned environment.[16, p. I-3]

ANTHROPOMETRY

An associated field concerning Human Factors is Anthropometry, the study of human dimensions such as different body lengths, widths, weight, and strength. Within the human population exists an entire range of anthropometric measurements. By applying statistics to the population, the range can be defined by percentiles of minimum and maximum dimensions. Use of these dimensions in the aircraft design process ensure controls are accessible to the aircrew for the required force application during all phases of flight. Since aircrew do not come in standard sizes, design engineers are required to ensure a certain specified group of the population are provided functional access to the desired equipment. Figures 2 and 3 depict many anthropometric dimensions for both the seated and standing body.

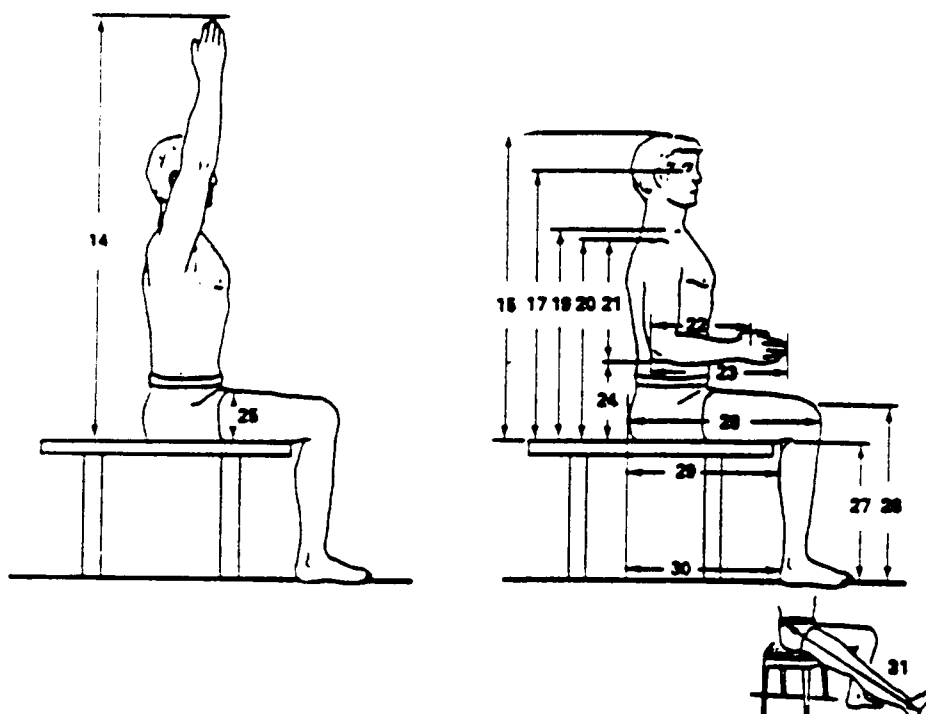


*SAME AS 12. HOWEVER,
RIGHT SHOULDER IS EXTENDED
AS FAR FORWARD AS POSSIBLE
WHILE KEEPING THE BACK OF
THE LEFT SHOULDER FIRMLY
AGAINST THE BACK WALL.

- | | |
|---------------------------------|--------------------------|
| 1. Stature | 8. Crotch height |
| 2. Eye Height (standing) | 9. Gluteal Furrow height |
| 3. Shoulder (acromiale) height | 10. Kneecap height |
| 4. Chest (nipple) height | 11. Calf height |
| 5. Elbow (radial) height | 12. Functional reach |
| 6. Fingertip (dactylion) height | 13. Functional reach- |
| 7. Waist height | extended |

Figure 2
STANDING ANTHROPOMETRIC BODY DIMENSIONS

[20, p. 130]



- | | |
|------------------------------------|------------------------------|
| 14. Vertical Arm reach-
Sitting | 22. Elbow-grip length |
| 15. Sitting height-erect | 23. Elbow-fingertip length |
| 16. Sitting height-relaxed | 24. Elbow rest height |
| 17. Eye height-sitting erect | 25. Thigh clearance height |
| 18. Eye height-sitting-
relaxed | 26. Knee height-sitting |
| 19. Mid-shoulder height | 27. Popliteal height |
| 20. Shoulder height-sitting | 28. Buttock-knee length |
| 21. Shoulder-elbow length | 29. Buttock-popliteal length |
| | 30. Buttock-heel length |
| | 31. Functional leg length |

Figure 3
SITTING ANTHROPOMETRIC BODY DIMENSIONS

[20, p. 132]

A more detailed explanation of anthropometry specifics and their applications is addressed in Chapter 5, Test and Evaluation Basics.

ENGINEERING ANTHROPOMETRY

Engineering anthropometry deals with the application of scientific physical measurement methods to human subjects for the development of engineering design standards or specifications. Use of anthropometry in human factors ensures proper form, fit, and function of operator-work station interfaces. Measurements of human size, lengths, and reaches provides designers with limitations and guidelines for proper placement of associated system controls and displays.

WORK STATION ANALYSIS

The investigation of the application of anthropometry at the point of the operator-machine interface is defined as a work station analysis. This is a tool by which actual and potential ergonomic hazards are recognized, identified, and evaluated.[4, p. 62]

SYSTEMS

The combination of both controls and displays compose a system, which is defined as an aggregate of interactive components operating together to perform a function. Systems

are broken down into two basic groups: open loop and closed loop. The distinguishing factor between the two is system feedback. Closed loop systems provide feedback to the operator, where open loop systems do not. Feedback is critical for providing two-way communications between the pilot and the specific system and establishing in the pilot both confidence and satisfaction with the system.[3, p. 13] A schematic of both system types is displayed in figure 4.

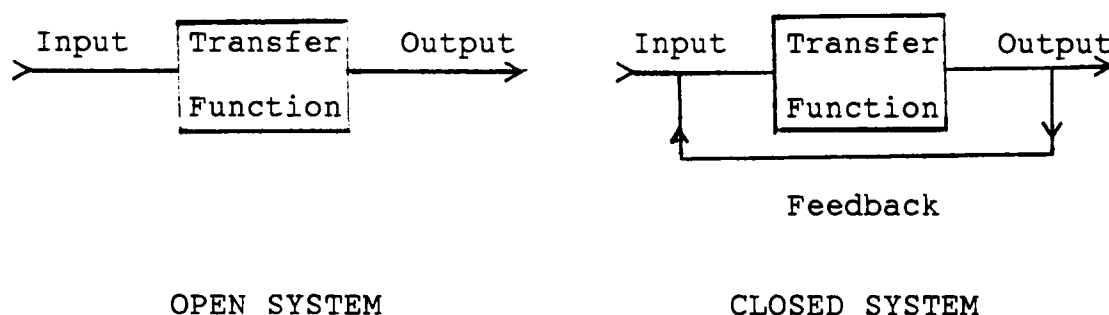


Figure 4
OPEN AND CLOSED LOOP SYSTEMS

The term system is used to describe various sub-components of the aircraft, and can be used to define the aircraft itself. Very simply stated, the aircrew provides input to the system through the controls and receives feedback through the displays. The net utility of an aircraft system will always be measured absolutely, by the ease with which the information generated by the system can be accessed, understood, and used by the operator.[6, p. 2]

SYSTEM ANALYSIS

Similarly to work station analysis, a systems analysis can be performed for Human Factors application. The steps include:

1. Define system mission and operational requirements.
2. Determine human versus machine allocation.
3. Ensure human-machine interface selection and design appropriate to physical and mental capabilities.
4. Provide for human-environmental compatibility.
[15, p. 215]

INTEGRATED AND STAND ALONE SYSTEMS

Aircraft systems may be integrated together as sub-systems which compose a larger grouped system or operate solely independent from each other. An example of an integrated system would be a navigation system which computes aircraft position based on inputs from self contained navigation components (e.g. inertial gyroscopes, Doppler) or radio navigation systems (e.g. OMEGA Worldwide Navigation System, Long Range Navigation - LORAN, and Global Positioning System - satellite navigation). Each sub-system may have its own organic controls and displays or may provide inputs and receive outputs from the integrated system via data communication networks. System analyses of stand alone and integrated systems are preformed similarly and require evaluation of the adequacy of the means by which the human-

machine interface is conducted. In order for the interface to be adequate and support the aircrew during execution of the mission, it must provide tactically usable information and the equipment to positively direct the systems operation with minimal effort and manipulation.

Although controls are usually provided for operator input to the system and displays are provided for system output to the operator, their uses should not be considered exclusively one way. Controls can be augmented with display features to provide feedback to the aircrew concerning aircraft or system performance. An example of this would be a rudder pedal whose operation directs flight control deflection and can be augmented with a "shaker" providing tactile cueing to alert the pilot of an impending stall. Likewise, displays can be augmented to provide the aircrew with a method to control systems operation. An example would be a touch sensitive display screen which provides the aircrew with an interactive interface for both system output and input. These factors must be considered during performance of system analysis.

CHAPTER 2

AIRCRAFT CONTROL DESIGN GUIDELINES

INTRODUCTION

The controls available to the aircrew provide the means to direct a specific action of an associated system. The engineering and design procedure should furnish the aircrew with the correct control for each required task to be accomplished and capitalize on a combination of human characteristics for ease and quickness of operation. Considerations in the design process include defining the control's purpose, location, operation, frequency of use, function, shaping and coding, and standardization with other associated controls.

POPULATION STEREOTYPES

An important consideration and guideline in the design of a control is the inherent stereotypes within the population of individuals who will operate the system. Certain expectations exist concerning control operation in that a group of people presume a control to operate in a known or learned manner. This is often referred to as motion expectancy. Common examples include the upward movement of a light switch to turn a light on, turning knobs clockwise to increase operational performance, and alphabetic keyboards

similar to a typewriter. Requirements in this regard are further detailed in the military standard, Aircrew Systems Controls and Displays (MIL-STD-203F) as follows:

Conventional Controls - shall be actuated in accordance with established custom or in direction of intended motion of the structure being controlled.

Performance Related Controls - adjustments which increase or decrease a component of aircraft performance shall operate such that increased actuation is forward, upward, and clockwise, while decreased actuation is backward, downward, and counterclockwise.[17, p. 6]

Most notable for aviators is the expectation for a flight control stick to control aircraft pitch up and down by aft and forward stick movement respectively, and roll left and right by left and right stick displacement respectively. Several similar stereotypes exist for a variety of control types.

Additionally, use of the preferred hand is a design factor. Studies have shown 90% of the population is right handed, and the preferred hand is 10% faster for reach-type motions.[4, p. 76-77] When possible, equipment should be selectively designed to remove the need for right or left handedness. However, the space limitations in the cockpit do not always allow for this possibility.

CONTROL FUNCTIONAL CRITERIA

Control function requirements should be based on the following considerations:

Speed - immediacy required to operate the control throughout its entire range.

Accuracy - degree of precision required for system operation.

Range - scope of action or extent of motion demanded of the control.

Force - required power and strength to manipulate the control.

CONTROL CATEGORIES

Five major categories exist to classify a control's requirement to command the system's operation. The categories provide a range of precision required for the control. In each case, a specific control classification type is optimum to ensure the aircrew are afforded sufficient operational authority without overburdening the aircrew with extraneous and superfluous control settings. In essence, if all that is needed for a control to operate properly is an on and off setting, then there is no reason to use a control with additional positions for adjustment. A brief description of control categories is listed below:

Activation - a control which initiates or terminates operation involving only two possible settings (e.g. on or off).

Discrete Setting - a control which possesses multiple preset distinct positional settings.

Quantitative - a control which offers a range of intermediate settings within a defined range.

Continuous - a control which offers several positional settings allowing for tracking of a time varying function.

Data Entry - a control such as a keyboard which provides for entry of alphanumeric characters as data.

CONTROL LOCATION

Another criteria governing application of human factors during the control design phase is determining the location for the various system controls. The actual location that an individual control is placed within the cockpit should be based on the following principles to ensure the optimum pilot-machine interface:

Frequency of use - number of times throughout the entire flight evolution or in any particular phase of flight requiring aircrew operation of a control.

Size of the control - actual physical size of the individual control required to implement desired system operation.

Type of control - Activation, Discrete Setting, Quantitative, Continuous, or Data Entry.

Number of controls - quantity of controls required for complete system operation.

Interlinkage of Controls - manner in which controls between interfacing systems are grouped.

The manner in which a system functions will dictate what controls are necessary for operation and how the controls are located. Controls should be located in a logical pattern to facilitate the correct sequence of operation. This decreases the time to perform and complete all required functions and reduces the probability of missing a step by using a fairly standard sequence of steps. An example would be sets of controls organized in a matrix which would be manipulated across (left to right) on the top row and then down to the succeeding rows.

Using functional grouping as a design principle provides the operator with a specific area for which to find the required controls for system operation. All controls for the associated system should be confined as much as possible to a specific panel within the cockpit. This arrangement ensures their association with the respective system is readily apparent and minimizes time required to locate, identify, and operate the desired control.

Controls which govern emergency operation require specific consideration for placement. The quick and accurate application of emergency controls demands special attention during the design process. Emergency controls should be located to allow minimum time to sight or operate during critical flight situations.

CONTROL CODING

Often systems will have multiple number of controls which operate in a similar manner such as switches, rheostats, and pushbuttons. In order to aid the aircrew in discerning the correct control to be manipulated, controls are coded to ensure correct identification. Coding requires either visual or tactile classification methods. The requirement for control coding is specified in the Aircrew System Controls and Displays military design standard as follows:

Controls within functional groups shall be selected to provide ease of identification and actuation for the operator. Shape coding, size coding or other coding techniques approved by the procuring activity shall be utilized as a necessary where tactile information for control selection and / or actuation is highly desirable. [17, p. 14]

Tactile cues reduce the requirement to visually identify the individual control. Use of tactile cues, such as size, shape, and range of motion provide the pilot with the means to locate the desired control without impacting visual scan outside the canopy or of displays within the cockpit. Tactile coding must be sufficient to allow the operator to discern the correct control by touch or feel with the pilot wearing normal protective flight gear such as fire retardant gloves and flight boots.

Control coding methods are discussed below:

SHAPE, TEXTURE AND SIZE

These provide the operator the means to distinguish controls exclusively by touch. This is useful for identification and standardization of functional groups. The number of distinct sizes which can be used for discrimination is limited. Shapes must be sufficiently different so as not to be confused with each other. Standardized shapes such as those shown in figure 5 have been adopted for use for flight related controls.

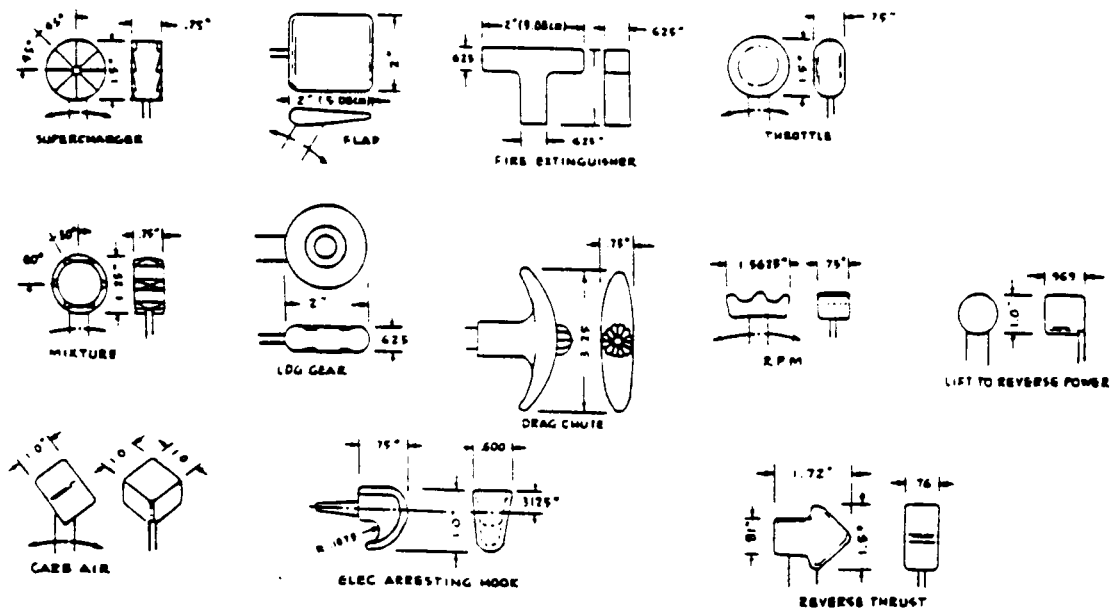


Figure 5
STANDARD AIRCRAFT CONTROL SHAPES

[15, p. 223]

LOCATION

Controls located in a standardized position among different airplanes serves to identify the control to the pilot. The location method should be sufficient to support a set of habit patterns for reaching and manipulation. Controls which are used most frequently should be placed in preferred locations and sufficiently close to the aircrew.

OPERATIONAL USE

Controls such as switches or levers that only move in certain planes permit the operator a means to distinguish individual controls. Operational coding also includes features such as providing audible or tactile clicks for switch operation. This gives the pilot feedback that the switch has been properly displaced and positioned.

LABELING

Alphanumeric or symbolic naming located on the control or on the panel immediately adjacent to the control aid visual identification of the desired control. This method requires the label to be viewed under adequate lighting and often requires extra space on a surface which may be restricted. Labeling should be placed so as not to be obstructed by control movement throughout its operational range.

COLOR

Use of color, intensity, and brightness permit quick visual acquisition of a desired control. This method is best used as supplementary coding since it requires adequate lighting conditions. A complete discussion of the application of colors is presented in Chapter 3, Aircraft Display Design Guidelines.

CONTROL TYPES

Several types of controls exist to provide the correct means to provide the operator the capability to select and govern system operation. Some of the more popular control types are discussed below:

PUSHBUTTON

Pushbutton controls are usually hand, finger, or foot operated and can be coded by shape, size, label, color and location. Their nature provides for quick operation. Pushbuttons are best used as activation category controls requiring high frequency operation.

TOGGLE SWITCH

Toggle controls are usually hand operated and allow for a minimum number of setting positions (usually 2 or 3).

Toggles can remain in displaced position or be momentary contact using self centering mechanisms. They are normally coded by label and best operated in the vertical plane to comply with perceived stereotypes and provide good visual indication of switch setting. These controls are normally used as activation or discrete setting controls. Coding requires labeling for several toggles located close together.

ROTARY SELECTOR SWITCH

The rotary selector switch is used when four or more detent positions are required for discrete functions. It normally has no more than 24 discrete settings with a minimum of 15 degrees between each setting, and is operated by the hand. Displacement to a new setting should have a tactile click or detent to facilitate correct selection. The control resistance should build up and then decrease as the switch seats to a new position. These controls usually have some sort of pointer and an increase in position occurs in a clockwise direction. These controls should have a discriminable pointing shape so the operator knows which end is the pointing end of the knob and have adequate depth to facilitate firm grip to turn the control. Rotary selector switches are excellent for discrete setting controls and normally use shape or size for coding.

CONTROL KNOB

The control knob provides the operator with a quantitative control to move a pointer on a display. Convention dictates the value of the pointer will increase with clockwise displacement of the control.

THUMBWHEEL / ROUND KNOB

A thumbwheel or round knob provides the operator with a continuously variable control such as a potentiometer which allows for precise analog settings. These controls should include the use of viscous damping to oppose static resistance and minimize inadvertent control movement. Round knobs are best applied for applications which require continuous and smooth rotation or when multi-revolutions are required. They are best used for non precise adjustments such as volume knobs. Coding may be accomplished by shape, size, and labeling.

CONTROL SIZE CRITERIA

The actual size of the control required should be determined during the engineering design stage. Both size and shape of a control can affect the ease with which an operator can manipulate the control. Some guidelines are listed below:

- When considerable force is required, diameter of the control handle should be large enough to allow maximum

application of force, but not so large to prohibit full grip.

-When finger or thumb activated switches are located on a handle or control stick, they should be positioned where the fingers naturally fall with normal direction of use.

-When precise knob rotation is required, the knob should be large enough to allow sufficient contact with both the thumb and forefinger.

-When several knobs are located close together, their shape should be sufficiently long enough to facilitate easy finger contact.

MULTIPLE CONTROL IMPLEMENTATION TECHNIQUES

When multiple controls are located within a limited area, the controls can be designed to operate in combination. By time sharing or combining the controls to provide specific governing of system operation, the limited space within the cockpit can be optimized. Examples of combination controls include:

Integrated - one control which can operate in several modes. An example would be a 4-way (x-y) switch which can also be pushed in (i.e., a toggle and pushbutton control).

Stacked - one or more controls can be mounted on top of one another. An example includes the placement of a trigger on the flight control stick or speed brake switch located on the throttle. Another case is concentric round knobs of smaller diameter mounted on top of larger diameter knobs. When stacked knobs are used, no more than two are recommended, and gross tuning should be assigned to the inner knob and fine tuning to the outer knob.

Multi-function - controls which perform separate operations at different times. An example would be pushbuttons surrounding a display which control various system operations depending on the menu displayed.

CONTROL DESCRIPTIONS

Certain specialized control types are often used in aircraft for operation of the various subsystems. Some of the more popular control descriptions and relative advantages or disadvantages are listed below:

JOY STICK

A joy stick is a control which allows for simultaneous two dimensional movement of a lever. Operator deflection from the origin is measured in two axes (usually X and Y) then translated to manipulate system performance in the respective planes. System response can be governed in accordance with respective time order functions (i.e., deflection magnitude will define system change in a direct proportion of distance, rate, or acceleration). Some aircraft system design considerations include:

Center Post Sticks

- Should allow for lateral clearance between pilot's legs.
- Height should not interfere with view of displays, but be sufficiently high to allow comfortable posture when gripped.

Side Stick

- Limited field of motion due to wrist constraints.
- Recommended forward and aft motion is + or - 30 degrees of center, and lateral motion is + or - 45 degrees of center.
- Force controllers allow use without arm movement.
- Good efficiency.
- Poor feedback.

Wheel Type Sticks

- Handles should be comfortably spaced to allow pilot to apply maximum pull and rotation force.
- Mounted to allow sufficient clearance for elbows when stick is at full aft deflection.
- Rotation movement input should be no more than + or - 40 degrees and not interfere with the knees.
- Straight line movement allows for easier pull than arc pattern.

Joy Stick Advantages

- Can be used comfortably with minimum arm fatigue.
- Capability to adjust the expansion and contraction of control response as directed by operator input.
- Allows for input to be displacement, rate, or acceleration controller.

Joy Stick Disadvantage

- Unless a large joy stick is used, inadequate input-to-output control ratio usually results in operator induced oscillations from overcontrolling positional inputs.

JOY BALL

A joy ball is a two dimensional control resting on a multi-turn potentiometer placed at right angles to each other such that turning the ball moves the potentiometers and is translated to control operations such as the placement of a cursor. Operation is very similar to a joy stick; however, the control does not possess an origin. Inputs are measured from the last known position. The control should be equipped with a separate switch to disengage the joy ball when not in use.

Advantages

- Very accurate with high resolution.
- Can be used comfortably with minimum arm fatigue.
- Capability to adjust the expansion and contraction of control response as directed by operator input.

Disadvantages

- Not capable for self-centering.
- Prone to having controller left in position which integrated display feedback (i.e., control cursor) is obscured from view.
- Inconvenient to have integrated trigger switch with ball.
- Ball is usually too slow for tracking.
- Ball used for computer "mouse" control requires additional work space surface.

KEYBOARD

A keyboard is the name for a control used for data entry composed of a matrix of pushtiles or pushbuttons, each labeled with an alphanumeric character or function name. Depression of a pushbutton allows for specific code to be entered or function to be initiated. Keyboards are often used for entering frequencies into radios or positional coordinates into navigation systems. Keyboard controls should provide the capability to backspace or clear entire character strings when errant inputs are entered. Keyboards for alphabetic characters are normally arranged similar to a standard typewriter. This layout is referred to as a QWERTY board (i.e., the first five letters on the top row of alphabetic characters). When insufficient room is available to use a QWERTY configuration, the controls are normally distributed in alphabetic order.

Numeric characters pushbuttons can be arranged in several patterns. When interfaced with an alphabetic keyboard, it is usually placed at the top of the board. When numerics are used without requirement for alphabetic entry, simple arrangements can be used such as shown below in figure 6.

7	8	9
4	5	6
1	2	3
0		

1	2	3
4	5	6
7	8	9
0		

Figure 6
NUMERIC KEYBOARD ARRANGEMENTS

The left and right arrangements are good for mimicking a calculator or telephone keypad, respectively. Whenever numbers are used for data, leading zero entries should be optional. The telephone arrangement can also be used for limited alphabetic entry as do letters on an actual telephone. Additionally, some letters such as the abbreviations for the cardinal headings should be incorporated when using navigational inputs. An example of this scheme is shown below in figure 7.

1	2/N	3
4/W	5	6/E
7	8/S	9
0		

Figure 7
GEOGRAPHIC / NUMERIC KEYBOARD

Advantages

- Can be located close at hand if the operator is typing.
- Satisfactory for text editing.
- Conforms well to population stereotypes.

Disadvantages

- Limited control in most cases, usually in increments of one character.
- Alphanumeric keyboards require sufficient room for placement on a panel.
- High error rate.

CONTROL OPERATIONAL CONSIDERATIONS

CONTROL ERRORS

Application of Human Factors principles during the engineering design stage is not only critical to maximize the aircrew - system interface, but also to prevent errant control operation. Control errors include:

- Confusing one control for another due to improper arrangement or coding.
- Manipulating a control in the wrong direction.
- Forgetting to use a particular control.
- Inability to reach a control.

This inadvertent operation of a control is often attributed to design induced error which is concerned with

whether or not the control configuration allows the aircrew to perform all necessary operations. Specifically, the aircrew is not prevented from operating controls in such a way that the system responds in the manner desired, to the required level of accuracy, within the allotted time and with an acceptable error rate.[7, p. 3] Additionally, control confusion is exacerbated when aircrew is under high stress or during rapid operation.

CONTROL GUARDS

Safeguards are used to protect aircrew from inadvertent control use. This requirement is directed by the military standard for Aircrew Systems Controls and Displays as follows:

All controls, the inadvertent actuation of which could or would produce a dangerous situations, shall have guarded or safety detent design features.[17, p. 14]

Design applications such as electronic circuitry or mechanical guards are commonly used to minimize incorrect activation of controls. Examples of these applications in aircraft include weight-on-wheels interlocks which prevent dumping fuel or landing gear retraction when the aircraft is on deck.

CONTROL TASK AUTOMATION

The requirements to operate all the necessary controls for the various sub-systems within an aircraft can overburden a pilot, especially during critical flight phases. Reducing pilot workload is accomplished through automating task activities or shifting parts of the task to more task-free times in the mission. The reduction in mental operations required to perform a task by using automated systems also leads to a decrease in the control error rate and provides the operator with greater situational awareness. Automation should be compatible with the pilot's mental representation of the task to be performed.[7, p. 28]

CHAPTER 3

AIRCRAFT DISPLAY DESIGN GUIDELINES

INTRODUCTION

The aircraft cockpit is equipped with displays to supply feedback to the aircrew concerning the various sub-systems' performance. Individual displays should be developed to provide the pilot information transmittal, distribution, and acquisition in a rapid, accurate, and reliable manner. Information transfer concerning a system is received by the aircrew via the human senses. Most modern displays capitalize on the use of sight, hearing, and touch to provide feedback to the pilot. Displays which attempt to pass information through taste or smell are beyond the scope of this manual. The critical consideration factor for the proper design and engineering of displays is how best to impart the necessary information and orientation to the pilot. Displays should not present so much information that the [aircrew] must sort out needed information or too little information as to cause the [aircrew] to have to supply ungiven information.[5, p. 6]

FEEDBACK

Closed loop systems are distinctive in the use of providing feedback to the aircrew. Display designs should ensure the feedback furnished is unambiguous. When displays

are used in conjunction with related system controls, the feedback should indicate in which direction to operate the control. Additional information required includes when, how much, and for how long to move the control.

DISPLAY TYPES AND CATEGORIES

PRECISION CLASSIFICATION

Display design requirements should be based on the precision of the feedback to be provided to the pilot. Classification categories include:

Representational - present a picture or model display as feedback to the aircrew.

Qualitative - display feedback through a limited number indications within a defined range. Used commonly for systems requiring limited feedback such as whether a component is on or off. Additionally used when the primary interest is approximate values, trend, or rate of change of a continuously changing variable.

Pseudoquantitative - non-numerical comparative data used to indicate a function which has a limited number of predetermined ranges. An example would be a visual flap indicator which displays flap deflection position on an uncalibrated dial between full up and full down.

Quantitative - display data provided in numerical values. Numerical precision is provided through either an analog or digital source. Analog indicators are easier to assimilate represented data and display trends, but they are less precise than digital sources.

INFORMATION CLASSIFICATION

The means by which the information is displayed for interpretation by the aircrew defines the display type.

Display type classifications are listed as follows:

Real - displays information directly to the aircrew. An example would be the actual movement of windshield wipers when turned on.

Artificial - displays information via symbolic representation or numerical indicator.

Static - a display which does not change. Static display examples include information placards or instructions for system operation.

Dynamic - a display which responds to actual system operation by indicating current performance as it changes.

SENSE CLASSIFICATION

Another consideration is the human senses to be targeted by the display for the transfer of information.

Auditory

Auditory displays provide the capability to transfer information without normally requiring the pilot to pay detailed attention to the display. Auditory signals can be either transmitted as tones or speech. An auditory display is often used to transmit an attention demanding signal to attract pilot attention and identify a general category of information. Use of an auditory display does not impede the aircrew from accomplishing other mission related tasks;

however, they are not very practical for passing simultaneous data concerning separate systems and can be masked by organic aircraft noise.

Tactile

Tactile displays normally use kinesthetic motion which is perceived by the aircrew's nerves as the sense of touch. The capability of the senses to distinguish heat is not normally used as a display means. Tactile display signals are often used as warnings such as a rudder pedal shaker which vibrates as the aircraft approaches critical angle of attack for stall. Use of tactile displays does not obstruct the aircrew from gathering information from other displays, but requires sufficient force as to be discriminated from any normal aircraft vibrations during both ground and flight operations.

Visual

Primarily, most displays require the use of visual senses to transfer signals from the system to the aircrew. The human eye is very capable of discerning small amounts of movement, color and shades while operating in a wide variety of background light conditions. All visual displays require the aircrew to sight the information being passed. Visual displays compete for the aircrew's attention and the requirement to visually scan outside the cockpit. Operator

attention can be obtained using flashing lights placed within the aircrew's primary line of sight or in the areas of peripheral vision to direct the operator towards the source of the display.

DISPLAY FUNCTIONAL CRITERIA AND CONSIDERATIONS

For each type of display, there is an optimum means by which to transfer and direct system feedback to the aircrew. Additionally, each sub-system's information must be prioritized to minimize the operator's workload in attempting to amass all the data which can be presented. Data fusion overload will prevent the aircrew from obtaining critical data from other less significant information when the pilot is overwhelmed with feedback.

FUNCTIONAL CRITERIA

When functionality principles are applied on a smaller scale, the design process should determine individual system display requirements. The display functional criteria dictates determination of the following:

- The manner in which a display should reflect any relevant change in system activity.
- Minimum accuracy presentation to be displayed.
- Minimum system change required to initiate a display change.

-Nature of the variable or function to be displayed (value, time rate of change of value, frequency rate of change of value).

-Total range of variables or functions.

-Maximum speed of information transfer. (How quickly must feedback be displayed?)

-Maximum equipment error rate.

-Distance between user and display. (Required to determine magnitude of signal for information transfer.)

VISUAL DISPLAY CONSIDERATIONS

Additional considerations and guidelines which focus primarily on visual displays include:

Content - provide the aircrew with only that feedback required to make a decision. Signals should not be too complex that they require deciphering or too little that they are insufficient.

Precision - the less precision required by the aircrew to interpret a given message, the faster the response to the change in displayed data. The degree of precision required should be optimized to reduce aircrew fatigue and mental stress.

Format - the signal should be transmitted using expected standardized formats accepted as population stereotypes. Data displayed in this manner should not interfere with established habit patterns.

Redundancy - use of additional transmission or coding methods to ensure feedback is obtained.

Failure - use of a signal to inform the aircrew if a display has failed. A common example is an off flag which is presented when a display becomes unreliable or a display discrepancy is determined.

A summary of guidelines for use during the display design process to chose display types is shown below in table I.

Table I
GUIDELINES FOR DISPLAY TYPES

Auditory or Tactile	Visual
1. The message is simple.	1. The message is complex.
2. The message is short.	2. The message is long.
3. The message will not be referred to later.	3. The message will be referred to later.
4. The message deals with events in time.	4. The message deals with location in space.
5. The message calls for immediate action.	5. The message does not call for immediate action.
6. The visual system of the person is overburdened.	6. The auditory or tactile system of the person is overburdened.
7. The receiving location is too bright or dark-adaptation is necessary	7. The receiving location is too noisy or subject to too much vibration.

[7, p. 17]

DISPLAY DESIGN ERRORS

Dependent upon the success of the display design and engineering process, aircraft display feedback may be incorrectly interpreted. Displays which cause the aircrew to receive erroneous information cause omission or late actuation of required controls and may lead to safety of flight hazards. Some display errors are listed below:

-Legibility errors due to improper marking or excessive parallax.

-Substitution errors from mistaking one display for another or confusing which set of equipment is being referred to.

-Reversal error due to incorrect interpretation of display (examples include roll angle shown by flight indicator or turn direction as shown on a wet compass).

-Use of an inoperative instrument in attempt to gain valid information.

-Scale interpretation errors causing incorrect interpolation.

-Signal interpretation error from failure to see or notice a display.

-Index error due to ambiguous or improper indication from a pointer on a display (common to multi-revolution dials).

VISUAL DISPLAYS

The remainder of this chapter will deal with design guidelines and principles concerning visual displays and application of Human Factors principles for their use. Visual displays in the cockpit are often referred to as instruments which may be exclusively mounted on panels or placed in conjunction with adjacent controls. Instruments should be positioned perpendicular to the pilot's line-of-sight and present minimum parallax. Multiple displays should be grouped functionally as much as practicable with priority given to the most important instruments as determined from the aircraft's primary mission. A critical principle for instrument location

is to ensure the principle viewing task is confined within a 30 degree cone around the primary line of sight.

When ... an operator is expected to visually monitor a primary display for a great share of the time, that display should be located for maximum comfort, usually directly in front of the operator and approximately at eye level or slightly below.[15, p. 397]

Instruments may be used to serve the following purposes:

- Check system performance to assure operation at normal or desired level.
- Display qualitative reading to indicate deviation from normal or desired level.
- Display quantitative reading to show exact scale value.

REFERENCE DISPLAYS

When a display is provided to indicate current system performance in comparison to a known or desired standard, two methods can be used to present this data. These displays types are often used with associated controls which allow the operator to manipulate system operation to the desired level.

Pursuit Displays

Pursuit displays present two indices, one is desired performance and the other is actual performance on a standard background scale. The display receives input to present system error as the distance between actual and desired

performance. The aircrew is required to manipulate system controls which results in a change in the actual performance index. The display provides the operator with the information to cause the performance index to move towards the desired performance index. Course deviation or airspeed indicators which allow for a setting of a desired figure and indicate current heading or aircraft speed, respectively are examples of pursuit displays.

Compensatory Displays

Compensatory displays use only one moving index and a fixed reference point. The distance between the index and the reference point represents the error between desired and actual performance. The aircrew is required to manipulate system controls which result in a change to the moving index. The display should provide unambiguous information to direct control movement to null out the error between the fixed reference point and the moving index. Instrument landing system displays which present deviation from glide slope or a Fresnel lens optical landing system are examples of compensatory displays. Compensatory displays used to indicate aircraft position can be divided into two general categories dependent upon the choice for the fixed reference.

-Inside-out displays fix the aircraft as the reference point and adjust the display to represent the aircrew's perspective. An example is an artificial horizon on an attitude indicator which tilts the horizon to illustrate how the aircrew views the actual horizon.

-Outside-in displays use an external reference and adjust the display to represent the airplane orientation with respect to the given perspective. A bank indicator which fixes the horizon and alters the rotation of the aircraft symbol on its roll axis is an example of an outside-in display.

If the field of view from the aircrew station prohibits sight outside the aircraft, the outside-in display format is better. However, if the operator may switch from the instrument to an actual outside view, it is best to use the inside-out format.[15, p. 538]

VISUAL DISPLAY CODING

Coding methods are required to provide the means for the aircrew to visually distinguish between multiple displays. Individual or multiple coding techniques can be applied to displays. Display coding techniques include:

Color - use of different colors can be used to allow the operator to visually identify and distinguish various data.

Shape - use of different symbols, geometric or pictorial shapes. Icons are often used for coding to trigger responses more quickly and more accurately than a set of corresponding words. Display icons should be developed to be highly discriminable and simple. They can replace strings of sentences or characters (alone or in text) to optimize display space.

Location - by placing displays in expected or known positions, the operator is provided with means to distinguish between displays.

USE OF COLOR FOR VISUAL DISPLAYS

As mentioned above, color is often used as a coding technique to supplement the information transfer to the aircrew. The examples are numerous from using colors to reinforce normal or abnormal system performance to using multi-color electronic displays to provide additional coding to discriminate various symbols. Use of color provides the potential for greatly increasing information coding capability and provides color contrast to improve visual acquisition of data on the display. Additionally, color coding is used often to aid in the visual acquisition of aircraft controls. Color coding guidelines discussed below apply to both controls and displays.

Use of Color as a Redundant Coding Feature

Color is best used as a redundant coding feature to improve the aircrew's receipt of system performance information. As a redundant feature, color coded data will provide an increase in signal detectability, enhance discrimination among many symbols, and provide an alternative method of obtaining information. Types of redundant coding schemes include:

Total Redundant - when color coding provides the same information as available from another means of coding.

Partial Redundant - An overlap between color coding and using another means of coding, but where some information is only coded with color. This scheme is used to categorize more than one level of specificity and to convey specific information which can not otherwise be conveyed.

Non-redundant - when color coding is the only means to discern among various data.

Human Eye

The eye focuses light energy received through the lens on the retina which contains optic sensors. These sensors transmit visual signal via optic nerves to the brain. The optic sensors on which light is directed are called rods and cones. Rods react primarily to distinguish black and white and provide the capability for low light vision adaptability. The capability of the human eye to distinguish color is due to the number and distribution of cone receptors in the retina. A blind spot exists in each eye where the optic nerve attaches to the retina in which no rods or cones are located in this area. Figure 8 illustrates the normal distribution of both rod and cone receptors in the retina.

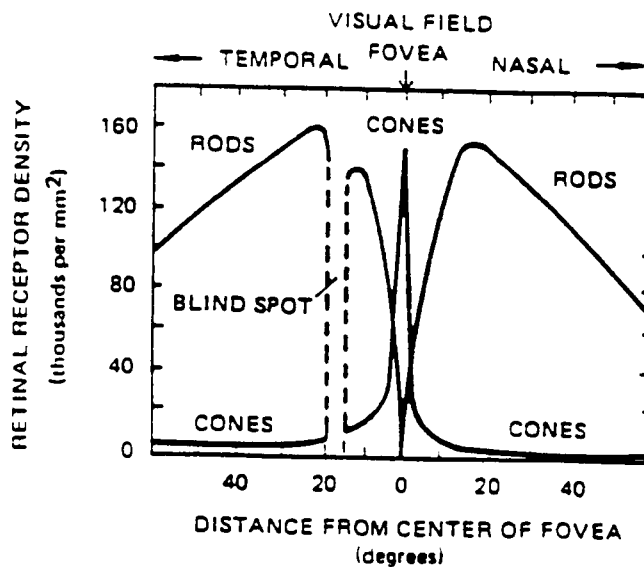


Figure 8
DISTRIBUTION OF ROD AND CONE VISUAL
RECEPTORS THROUGHOUT THE RETINA

[10]

The figure shows the capability to distinguish black and white and perform visually in low light conditions is low at the zero degree point, builds up rapidly just off center and tapers off gradually in the periphery. The primary area for color perception is located close to the zero degree point and then tapers off significantly to a relative uniform value for peripheral vision. The fovea contains the greatest color sensitivity and is the area used for direct viewing. The fovea is contained within the primary line of sight, which is approximately a 30 degree cone. Since peripheral vision does

not focus light on the fovea, color should generally not be used for coding outside the 30 degree cone. The distribution of cone and rod receptors makes for three major classifications of eye sight regions on the retina:

Photopic regions - correspond to high ambient light adaptation where color discriminability is sharp.

Scotopic regions - corresponds to low ambient light (i.e., dark) adaptation where color discrimination is minimal or does not exist.

Mesopic regions - an area of transition between photopic and scotopic regions where poor color discrimination capability exists.

Design engineers need to consider these facts when determining when to use color coding and where to physically locate the displays with relation to the pilot's primary line of sight.

Color Vision Deficiency

There exists within the human population those individuals who do not possess sufficient numbers and distribution of visual cone receptors to distinguish colors. This deficiency is normally either the inability to discriminate between red and green or blue and yellow. A very small percentage of the population possess insufficient cones for any color perception. Color perception deficiencies affect a total of approximately 8 percent of the male population and 0.4 percent of the female population. Table II

shows the incidence of color vision deficiencies.

Table II
INCIDENCE OF COLOR VISION DEFICIENCIES FOR MALES AND FEMALES

Preferred designation		Color dis- criminations possible *	Population Incidence (%)	
By number of components	By type		Male	Female
Trichromatism (normal or color weak)	Normal	L-D, Y-B, R-G	---	---
	Protanomaly (red weak)	L-D, Y-B, weak R-G	1.0	0.02
	Deuteranomaly (green weak)	L-D, Y-B, weak R-G	4.9	0.38
Dichromatism (partial color blindness)	Protanopia (red blind)	L-D, Y-B	1.0	0.02
	Deuteranopia (green blind)	L-D, Y-B	1.1	0.01
	Tritanopia (blue-yellow blind)	L-D, Y-B	0.002	0.001
Monochromatism (total color blindness)	Congenital total color blindness (cone blindness)	L-D	0.003	0.002

*: L-D = Light-Dark, Y-B = Yellow-Green, R-G = Red-Green

[12, p. 10]

The incidence of color vision deficiencies within the population is one reason why design engineers should use color as a total redundant coding feature. This ensures information coded in some format is available to all members of the general population. An example of redundant coding for color is the use of light positions on a vertically hung traffic

light: red is at the top, yellow in the middle, and green at the bottom.

Color Coding Guidelines

Color coding offers several advantages over monochromatic displays and uses the aircrew's potential to visually perceive and distinguish color to enhance acquisition of system data.

Color coding of displayed information when applied correctly and systematically, offers the greatest potential for enhancing operator performance in complex, high workload situations and in severe dynamic operational environments.[1, p. 1.2]

Displays should have sufficient symbol-to-background contrast to ensure adequate color distinction cues are provided. Use of color in displays is irrelevant when it is used in a random fashion to simply brighten up the display. Excessive color has distracting effects, increases workload and degrades overall performance.[1, p. 4.1-4.2] Some guidelines for when to use of color are listed below:

- When high density information is displayed in a random format.
- When aircrew must search the display for relevant information.
- When information is to be coded in qualitative rather than quantitative form.
- When attention must be drawn away from other visual

tasks.

-When symbol legibility may be degraded or different zones of information are difficult to distinguish solely on the basis of luminance.

-When color is logically related to the aircrew's tasks.

Number of Colors

The numbers of colors presented on a given display effects the operator's capability to quickly discriminate the exact colors; therefore, the number of colors should be based on the performance demands for absolute discrimination. Color augmentation for coding should provide the means for the aircrew to compare colored display symbology instead of requiring the aircrew to obtain the information simply based on the symbol's color code. Use of too many colors can induce stress and increase both error rate and detection time. "It is easier, more accurate and reliable to discriminate colors based on comparison then for the situation requiring absolute color judgements." [10, p. 53] Recommended maximum numbers of colors to be used for coding are four for operational color displays and seven when absolute color judgement is required.

Meaning of Colors

Population stereotypes have resulted in an accepted standardized use of colors in displays. When color coding is applied to the cockpit, the scheme should be consistent

throughout. Although some particular color coding techniques are peculiar to different branches of aviation (e.g. the use of black and yellow striped handles to designate emergency flight controls in military aircraft), a few of the more popular color meanings for displays are listed below:

White - used to display alternative function or transitory conditions.

Green - monitored equipment is within tolerance or condition is satisfactory.

Yellow - used to advise aircrew of a condition exists which is marginal, caution, recheck, or delay.

Red - used to alert the aircrew of system performance outside of safety limitations. Flashing red lights should only be used to inform the aircrew concerning an emergency condition.

Blue - used as an advisory light but preferential use of blue should be avoided.

ILLUMINATION FOR VISUAL DISPLAYS

General

In order for the human eye to react to the information presented on a visual display, sufficient light must exist to allow for optic responses to pass the visual signal to the brain. Illumination requirements vary dependent upon whether the crew station is exposed to outside ambient light or is artificially lighted. Guidelines for the use of night vision devices is outside the scope of this manual. Display illumination should be adjustable to allow the aircrew to

control the amount of light required to optimize optic performance to visually acquire display data and scan outside the cockpit. No standard lighting conditions exist for all tasks. Although a general guideline suggests more display lighting is usually better than less, too high an illumination level can reduce information transfer. Some other principles for crew station illumination include:

- Illumination of displays should be engineered so the aircrew's eye is not exposed to the light source.

- Similarly grouped instruments and displays should be lighted at the same intensity, equally balanced from off to full bright.

- Attention gathering lights can not outshine the sun when the cockpit is subject to direct natural light. Illumination of an attention gathering light should not blind the aircrew.

- Floodlights for all control panels and displays should be provided so the aircrew will not suffer from hallucinations. Features which provide the aircrew the capability to adjust illumination throughout the range of expected ambient light conditions.

- Thunderstorm floodlights should be provided to illuminate the crew station for flight through thunderstorm conditions which will ruin dark adaptation.

Night Lighting

A special consideration is correct illumination of displays during flight in low ambient light circumstances. These situations exist during flight at night or in Instrument Meteorological Conditions. The requirement exists to visually

obtain information from cockpit displays and locate various controls while scanning outside the cockpit for landmarks and other aircraft. These requirements come into conflict if the area inside the cockpit is well lighted to find the necessary controls and displays, the resultant illumination will interfere with the aircrew's low light visual adaptation. "Minimum lighting combined with high contrast is desirable because it minimizes the decrement in dark adapted vision for outside cockpit vigilance." [7, p. 23]

Dark Adaptation

The capability to visually discriminate objects in low ambient light conditions depends largely on the rods, as cone receptors which are responsible for color perception lose their sensitivity. Color perception is very limited under low light conditions. Time is required for the human eye to dark adapt after a switch from bright ambient light to low ambient light. During this transition period, the residual effect of light stimulation to the eye's nerve receptors are diminished, allowing rods the capability to distinguish an object's luminance in low light conditions.

In order to foster dark adaptation, cockpit lighting may use either dim white light, or colored lighting (usually red or blue-green) for illumination of cockpit controls and displays. No one choice of light is correct for all

circumstances. Dark adaptation with red light is faster than with dim white light. However, evidence exists red light may not be the most effective color for illuminating displays which must be read under low luminance conditions.[1, p. 3.3] If the primary task is to view outside and perform monitor functions inside the crew station, red light illumination of the displays is recommended. However, if the primary task is to monitor cockpit controls and displays and dark adaptation for scanning outside the cockpit can be compromised without danger, then white light as a primary source should be used. [5, p. 21]

The convention for using blue-green light for illumination has demonstrated the eye is more sensitive to this colored light and less luminance is required to maintain display legibility. To maximize the use of both red and blue-green lighting, some aircraft allow for cockpit lighting systems which can be switched between the two.

Illumination Guidelines for Dark Light Conditions

During the engineering and design process, the following principles should be considered:

- The surface color of the instrument should remain discernible under different lighting conditions.

- When mission requirements demand maximum level of aircrew dark adaptation, use red lighting for crew station displays.

- For missions requiring less stringent dark adaptation requirements, the hue of any color display illumination is acceptable.

- Display color illumination should not be considered independently of the area illuminated since both factors influence dark adaptation.

- Backlit displays should be used to minimize illuminated areas. However, excessive use may result in the pilot's loss of frame of reference for the panel, and it may appear to float.

- Use light-on-dark display marking in order to reduce illuminated or reflected display area.

Glare

The reflectance of light from the glass instruments, windshield, and canopy should be minimized to reduce directing the light back to the aircrew. Guidelines for reducing glare are:

- Use minimum illumination level while maintaining adequate visibility of displays.

- Use a glare shield in natural ambient light path to block light reflected from the windshield.

- Position artificial lights and lighted surfaces such that reflection is not directed back towards aircrew.

- Use dark, matt surfaces in surrounding area around displays.

ENVIRONMENTAL EFFECTS ON DISPLAYS

Certain conditions inherent to flight operations affect the aircrew's capability to retrieve data presented on displays.

Acceleration

As g-forces due to aircraft acceleration in the z plane (N_z) increase, blood pressure in the aircrew's head decreases. The lower blood pressure and flow results in tunnel vision or loss of peripheral vision. At about 4 g, gray-out occurs, in this state, the aircrew is still conscious but has suffered a severe loss of visual acuity and the ability to perceive color. Above 5 to 6 g, the aircrew can lose consciousness and black out. Negative g forces can cause difficulties with visual acuity as the eye becomes abnormally full of blood at level of -2 to -3 g.

Vibration

Visual acuity is significantly degraded due to vibration, especially in the vertical plane.[1, p. 3-27] Effects from vibration are most severe in the 1 to 30 Hz range. A 50 % increase in symbol size may be necessary to compensate for the influence of vibration on display legibility.

Hypoxia

The eyes require a steady inflow of oxygen from the blood to perform optimally. A lack of oxygen in the bloodstream due to hypoxia impairs both color vision and dark adaptation.

ALERT LIGHTS

A special category of visual displays are those which are used to alert the aircrew concerning abnormal system performance.

Emergency , Warning, Caution, and Advisory Alerts

When system operation deteriorates so it creates a dangerous condition which will adversely impact the safety of flight or aircrew, the pilot must be alerted immediately. Indicators which transfer this information are emergency alerts. Warning and caution alerts are used to inform the aircrew concerning operational deterioration that may cause system failure or destruction. These alerts are used to display an impending dangerous condition requiring attention but not necessarily immediate action. The last category of alert indicators are advisory alerts which serve to notify the aircrew of some non-standard condition which may affect system performance.

Alert information should be provided to the aircrew as soon as practicable dependent upon the condition of severity. Additionally, the position given to the different categories of alert indicators should also be based upon condition of severity. In order to provide functional grouping of all the various sub-system alerts, the displays are normally collocated on alert panels which are divided into separate

sections for emergency, warning or caution, and advisory indications. The normal convention is to use an annunciator panel which is subdivided into individual alert signal lights which can be illuminated to display the applicable system condition.

Detectability of these signals will depend on the size, amount of light emitted, and duration of exposure of the alert. Alert lights should be illuminated by steady light and normally use red light for emergency, warning, and caution alerts and amber or green light for advisory alerts. Since the color red is a difficult color to detect in the periphery, red lights placed outside the primarily line of sight may be augmented by a flashing aid to cue the pilot. Additionally, lights placed in the periphery should have their size and symbol presentation amplified to maintain a high level of accuracy in information transmittal when displayed.

Master Caution Alert

In order to ensure the aircrew's attention is immediately directed to the specific alert indicator, cockpits should be equipped with a single master caution light. This discrete indicator is placed within the aircrew's primary line-of-sight and is often augmented with an aural alert signal. Activation of the master caution alert indicates one or more specific warning or caution lights has been actuated. The master

caution alert should not be lit in conjunction with an advisory alert since the aircrew is not required to perform immediate procedures in response to this type of alert. By prioritizing use of the master caution light, aircrew can be assured of the importance of the alert and determine what response is required by the amplifying emergency, warning, and caution signal(s).

Master caution lights normally use a red flasher to aid in gaining the immediate attention of the aircrew. Use of flashing lights should be reserved for emergency use only and should use a cycle rate between 3 to 10 flashes per second with 4 per second being optimum.[7, p. 13] Excessive flashing rates can result in flicker fusion, that is the frequency at which the human eye perceives the light to be continuous intensity (approximately 30 per second).

The master caution light should be equipped with a feature to permit the aircrew to extinguish the alert light. This serves to avoid further distraction after the corresponding alert has been identified and will allow the master caution light to illuminate again if a separate alert signal is subsequently actuated.

INDICATOR DIALS

General

A special category of instruments commonly found in aircraft cockpits are indicator dials. These are dynamic quantitative visual displays that use a reference scale to inform the aircrew regarding system performance. A few examples of indicator dial displays are shown below in figure 9.

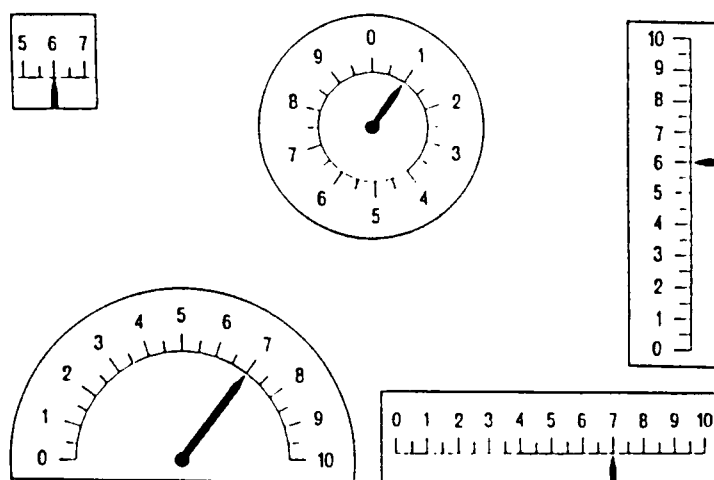


Figure 9
INDICATOR DIAL DISPLAYS

[21]

A dial uses a pointer as the moving index and scale markings as the fixed reference. The quantity on the scale aimed at by the pointer is the value which the display

indicates to the aircrew. Dials can support both analog and digital inputs; however, common practice is to display data in a analog format allowing for operator interpolation of readings between scale markings.

Dials can be used by the operator to ensure a system operational parameter is within a normal range, to display both quantity and rate of change, and provide means for extrapolation. Either pursuit or compensatory display schemes may be used for dials. To be in accordance with population stereotypes, the index should deflect in an up, right, or clockwise directions to indicate an increase in value.

Dial Scale and Design Principles

During the design and engineering stage for implementation of dials, the following design considerations should be determined:

- Range of values (minimum to maximum).
- Required display precision.
- Display format and terminology to be used.

Scale markings on the dial should be designed to promote the quick transfer of information. Spacing of the scale graduation marks should be sufficiently far apart to allow the aircrew to discriminate between marks. The number of marked divisions the scale uses is a compromise between required

accuracy to be displayed and speed to read the dial. Alphanumeric characters used to denote scale quantities should be placed outside the scale marks so the index will not cover marks or characters. Additionally, scale characters should be oriented to face upwards for round dials, not inwards. Areas of normal and abnormal system operation should be marked and coded for redundancy.

Scale Intervals

The proper use of scale intervals is required to optimize both display accuracy and time required to interpret the display. Recommended scale intervals are in increments of 1, 2, 5, or 10, with 10 being the primary choice. Other values should be avoided, especially increments of 3.

Scale Markings

The actual scale marking reference should be placed so as not to be covered by the moving index. The following scale marking techniques should be avoided as they result in design induced display errors:

- Use of dots instead of lines.
- Use of thick marks.
- Marks joined by a heavy base line.
- Long marks spaced closely together.

-Irregularly spaced marks about an arc which cause the aircrew to shift spatial reference.

-Uneven spacing which cause doubt in the aircrew as to the value of each mark.

-Significant spacing variation between the ends of the marks, which, because of the tight radius of the dial makes it hard for the eye to follow along the scale pointer axis.

Example of poor scale marking techniques are shown below in figure 10

following are some typical scale-marking errors to be avoided:

Dots instead of lines

Thick marks

Marks joined by a heavy base line

Long marks spaced close together

Irregularly spaced marks about an arc, which cause the observer to shift his or her spatial reference

Uneven spacing, which leaves the observer in doubt as to the value of each mark

Significant spacing variation between the ends of the marks, which, because of the tight radius of the dial, makes it hard for the eye to follow along the scale-pointer axis

.....

|||||

|||||

|||||

Numbers distorted
Too far apart
Too close

Irregular spacing

Wide
Narrow

Figure 10
POOR SCALE MARKING TECHNIQUES

[15, p. 530]

Pointer Design

The pointer used as the moving index should be shaped to promote the quick visual identification of the position on the scale it is pointing to. The pointer shape greatly affects this, and should be designed with a width at the end of the pointer which matches the scale markings. Pointer shape should be simple, possess a tail feature for circular dials, and avoid artistic variations or improvements.

Generally speaking, if a pointer has a tail on it, the observer can judge slight movements of the pointer better than if the pointer is tailless. The tail should not be more than $\frac{1}{3}$ the length of the pointing segment; otherwise, there may be confusion as to which end is the pointing end.[15, p. 533]

Examples of correct and poor pointer designs is shown below in figure 11.

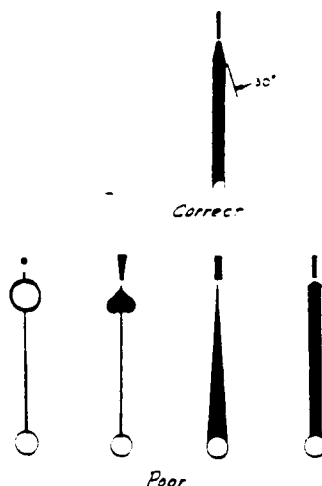


Figure 11
POINTER DESIGNS

[15, p. 533]

Multiple Grouped Dials

Multiple dials concerning various system parameters can be functionally grouped together. To promote quick visual scans of multiple dials and simplify check reading tasks, the indices should generally reside in the same place on each instrument. Horizontally distributed instruments promote a left to right scan and should have pointers at the 3 or 9 o'clock position. Vertically distributed instruments promote a top to bottom scale and their pointers should be at the 6 or 12 o'clock position. An example of this display scheme is shown in figure 12.

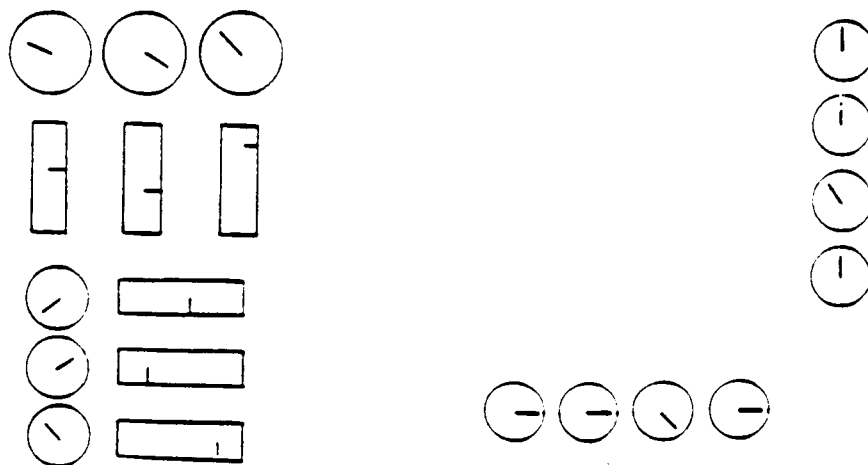


Figure 12
MULTIPLE DIAL DISPLAY TECHNIQUES

[15, p. 528]

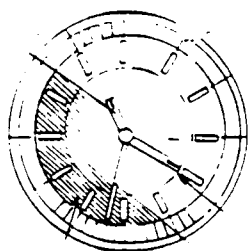
Dial Display Design Error

Incorrect design and engineering of dial displays may result in the aircrew misinterpreting the information being presented. Some examples are listed below:

Flopper - circular dials which use almost the entire available arc for scaling need to possess the capability to register flopper. That is a reading or value outside the normal minimum or maximum range. If the pointer is allowed to continue past the preset range, the pointer may indicate an erroneous quantity to the operator.

Multi-revolution Dials - circular dials which use the entire arc and are designed to use a range of motion in excess of 360 degrees are multi-revolution instruments. In order to keep track of the number of unit pointer revolutions, a common scheme is to use a second pointer (or even third pointer). This is commonly seen on clocks, altimeters, and airspeed indicators.

As the units pointer completes a full revolution, there is often confusion as to exactly where the second or third pointer is pointing. The analog operation directs these pointers to approach the next highest scale unit which leads to misinterpretation of the data presented. A means to ensure proper display of the number of unit pointer revolutions is to use a digital counter within the dial display. Examples are illustrated below in figure 13.



Clock



Altimeter with digital counter

Figure 13
MULTI REVOLUTION DISPLAYS

ELECTRONIC DIGITAL DISPLAYS

General

This category is used to classify modern display methods such as Light Emitting Diodes (LED), Liquid Crystal Displays (LCD), and Cathode Ray Tubes (CRT). These dynamic presentations offer the advantage of quick updating and the capability to support various display schemes. Data transfer can be in the form of alphanumeric text, graphics, or pictorial displays. Engineering and design allows for individual electronic displays to support multiple functions as both a representational or a qualitative presentation. This form of visual display is quite versatile and can be designed to allow the aircrew to select the desired sub-system information.

Dynamic Display Characteristics

Electronic digital displays are capable of providing instantaneous feedback concerning system performance. The values presented can be updated faster than can be comprehended by the aircrew. Ideally, refresh rates should be controllable by the user and be set by the use to be made of the information. Alphanumeric strings should not be updated faster than 5 times per second and no slower than 2 times per second when required to provide real time information.[2, p. 1.2.2.6-1] Another recommended feature includes the

capability to freeze a given display to allow close scrutiny of any selected frame and allow resumption at the point of stoppage or at the current real time point.

Screen Layout

The design process should ensure the electronic digital display screen is maximized for quick data transfer and retrieval by the aircrew. If the entire screen is cluttered with information, excessive time is required to obtain desired information which impedes the aircrew's visual scan. The screen display should be structured to reduce error rates and diminish confusion. Two structuring schemes are to use perceptual organization of displayed data groups or sequential organization. Perceptual organization uses a specific structure such as a tree with branches which provides the aircrew with a conceptual scheme to locate data for retrieval. Sequential structures organize data using a scheme for sorting and retrieval such as alphabetical or numerical order. A common practice is to reserve certain areas of a screen for specific types of information. A list of guidelines for screen layout follows:

- In a list of options, place the most probable option at the top of the list. If no best option can be determined, list options sequentially.

- Avoid breaking up or chopping screen into multiple subdivisions (e.g. windows).

-Standardize organization of displayed fields within format.

-Directions to aircrew concerning system operation should precede list of choices.

Data Presentation

The presentation of alphanumeric strings or pictorial displays should be in a readable and usable form which allows the aircrew to take immediate action based on the system information. Guidelines listed below should be considered during the design process to maximize display use.

-Don't use strings of more than 5 alphanumeric characters.

-Present data fields in some recognizable order for ease of scanning and identification.

-Identical data types from various sub-systems should be presented to the aircrew in a standard and consistent manner.

-Don't change existing and accepted formats.

-Use vertically aligned lists with left justification for rapid scanning.

-Alphabetical character strings should be presented to be left justified in data fields.

-Numeric character strings should be presented to be right justified in data fields (especially tables).

-Don't assume aircrew can identify individual fields because of past familiarity.

[3, p. 7-8]

Display density is another important consideration for maximizing the presentation. Ideally no more than 60 percent of the available display fields for character strings should be used, and the number of separate items displayed simultaneously should be minimized. Control of the display density provides for data to be presented to the aircrew in a readily usable and readable format so the aircrew does not have to transpose, compute, interpolate or mentally translate into other units, numbers, bases or languages.

Electronic Digital Display Characteristics

Certain characteristics inherent to the use of these display devices should be engineered to minimize crew fatigue and promote accurate and quick information retrieval.

Flicker

The strobing caused by electronic digital displays as they update is perceived by the human eye as flicker. Flicker is a function of regeneration rate, screen phosphor persistence and chromaticity, and size of the display element. If the rate is sufficiently fast and flicker fusion is reached, the presentation is discerned as continuous. A perceptible display flicker can cause irritation and visual fatigue and may impair visual performance.

Color Contrast

The numbers of colors presented on an electronic digital display should be limited to ensure the aircrew can positively identify the color enhanced coding presented. Basic colors recommended for use are red, yellow, and green since they are highly discriminable from each other. The use of white tends to be confused with the color yellow, especially in direct natural light. Although blue is discriminable, its use results in poorer legibility than red, yellow, or green.[1, p. 3.11]

Resolution

The sharpness and clarity of the data presentation on the displays is referred to as resolution. This characteristic directly relates to legibility of information available and design display induced error. Measurements such as pixel size, scan lines per character height, dot matrix dimensions concern themselves with symbol resolution. Guidelines vary with visual task, type of display element, and element size.

Display Background

The color which is used as the background for electronic digital displays should be chosen to maximize the data transfer and optimize color discrimination of presented characters and symbols. The two prominent schemes are

discussed below:

DARK:

- Provides very high degree of local contrast.
- Individual colors are more visible on dark backgrounds.
- Causes display surround mis-adaptation due to very bright characters for non-display task involving dark backgrounds.
- Discrepant depth perception cues from the various colors may cause luminous symbols to appear to float.

MATCHED TO SURROUNDINGS OR LIGHT:

- Adaptation transients are minimized when sight is shifted between display and external visual tasks.
- Allows display of negative contrast (i.e., dark) information as well as positive contrast information.
- Facilitates color discrimination and reduces likelihood of possible color confusion.

Symbology Luminance

The displayed brightness of the characters or symbols should assure sufficient luminance differential is presented when compared to its background. This will ensure the observer's visual acuity is not impeded.

Surround Luminance

This area is defined as the entire field-of-view exclusive of the physical display itself. Luminance in this region is not normally under control at crew stations exposed to natural ambient light. Aircraft maneuvering may cause

large and rapid changes in surround luminance as solar shadows are altered.[1, p.2.3] Design and engineering should attempt to optimize surround luminance so as not to impede visual acquisition of the displayed information.

Display Labeling

The data fields located within the display are usually labeled to aid the aircrew in recognizing the data being transmitted. Guidelines for display labeling are listed below:

- Don't use unique words or messages.
- Labels should be chosen which are distinct, meaningful, and can be easily discriminated from surrounding labeled fields or messages.
- Avoid requirement for transposing, computing, interpolating, or mental translation into other units.
- Labels should avoid attempts at humor or punishment, their meaning should be simply informative.

CHAPTER 4

AIRCRAFT INTEGRATED INTERFACE DESIGN GUIDELINES

INTRODUCTION

Not all aircraft sub-system components which provide an interface with the aircrew can be exclusively classified as either a control or a display. There exists a general category of mediums which integrate both aspects of controls and displays. This overlapping of purposes allows for a single unit to affect or be used for aircrew input to the system and system feedback to the aircrew. The engineering process must capitalize on design guidelines for both aircraft controls and displays to maximize the integration of these combined interface units. The successful application of human factors considerations is critical for effective aircrew - system interface performance.

[Aircrew] can sometimes compensate for poor design with extra effort. Probably no single [aircrew] interface design flaw, in itself, will cause system failure. But there is a limit to how well [aircrew] can adapt to a poorly designed interface. As one deficiency is added to another, the cumulative negative effects that may eventually result in system failure, poor performance, or [aircrew] complaints.[11, p. 3]

INTEGRATED CONTROL - DISPLAY UNITS

Certain controls are designed to have a direct correspondence to an associated display and affect the presentation of information to the aircrew. These integrated controls and displays are often found within modern cockpits and are quite commonly identified with electronic digital displays. Associated controls for electronic digital displays normally command data entry and retrieval or direct the movement of a cursor about the display. The requirement for conformance of integrated control - display interface units is defined in Aircrew Systems Controls and Displays (MIL-STD-203F) which states:

The controls and displays must provide and integrated installation which will insure consistent operation, uniform actuation, and consideration for the operational complexity of the aircraft.[17, p. 4]

INTERFACE RELATIONSHIP GUIDELINES

The design process should construct a control - display relationship to augment the aircrew operation of the system and the system's presentation of feedback to the aircrew. This integration should produce a relationship which is immediately apparent and unambiguous to the aircrew.

CONTROL - DISPLAY UNIT DESIGN LOCATION PRINCIPLES

Design location guidelines for both controls and displays are both applied to interface units to optimize the functionality of a closed loop system. The engineering process should ensure attention and consideration is given to the following topics:

Functionality - interface control and display units which have similar functions or are part of the same sub-system should be grouped together on cockpit panels.

Importance - most critical controls and displays should be located in the easiest to see and easiest to reach locations.

Standardization - fundamental arrangements for integrated controls and displays should be similar between aircraft models.

Sequence of Use - placement of integrated controls and displays should be based on the sequence of required actions required to be taken and information to be retrieved by the aircrew.

Utilization Frequency - placement of integrated controls and displays should allow for preferential placement based on how frequent the items are used

Load Distribution - integrated controls and displays should be engineered to ensure one sense or body part is not over loaded.

Optimum Position - integrated controls and displays placement should be based on the nature of the task. Controls placement should be placed where sufficient force and dexterity can be applied. Likewise, associated displays should allow for unobstructed view. "Controls should be located adjacent to their associated displays and positioned so neither the control nor the hand normally setting the control will obscure the display."
[20, p. 21]

CONTROL - DISPLAY INTERFACE ADJUSTMENTS

The purpose of several controls is to have some affect on the display of information to the aircrew. Controls can affect sub-system performance such as operating modes or simply regulate the display of sub-system data. Regardless, the amount of change to the system operation or display as compared to the amount of control input is referred to as the control sensitivity or gain. This closed loop system approach allows the operator to observe the incremental variation in system performance.

Control - Display Ratio

Human Factors engineers use the inverse of control sensitivity called control - display ratio when defining the extent of control device movement required to direct the desired display change or movement. When control display ratio is applied to directing movement of a cursor about a display with a joy-stick or similar control a ratio of 1:1 is generally used. This means a full deflection of the stick translates to maneuvering the cursor completely across the display screen. When fine adjustments of the cursor a ratio of 3:2 or 2:1 provides for larger stick deflection to render small and precise cursor movement.[15, p. 590] Additional

considerations are travel time to move the control to an approximate position and adjust time required to move the control to the position required. Characteristics of small and large ratios are listed below:

Small Control - Display Ratios - increases the speed of the cursor movement but reduces accuracy. High sensitivity, low travel time, and high adjust time

Large Control - Display Ratios - cursor speed suffers, but a much higher degree of accuracy is achieved. Low sensitivity, high travel time, and low adjust time.

Control - Display Drift

The interface between integrated controls and displays should ensure the display cursor does not move without control input. This may be referred to as the stability of the cursor after a control adjustment is directed. The cursor should remain where it was positioned until its position change is directed by the aircrew. The control must have enough inertia so it does not move of its own weight, but not so much inertia that the aircrew has to make a deliberate effort to start it moving.[3, p. 25]

SOFTWARE

Computers require sets of algorithms to be executed which dictate what functions it is going to complete. These algorithms are usually referred to as software, and consists

of a set of coded program language which is compiled into a format executed by the computer's central processing unit. Computers use various software programs to support acceptance of input from either the aircrew or other sub-system, transmission of display data to the aircrew, and control of various sub-systems.

As such, computer software falls into the category of integrated control and display interfaces. As an interface between the aircrew and system, software applies to all aspects of system design that affect the system use and influence an aircrew's participation in information handling tasks.[11, p. 2] Software is an integral part of the interface that contributes significantly to effective system operation. It can not be used to decorate the display or added on at the end of system development. Its design should strive for consistency implying a predictability of system response to aircrew inputs.

A fundamental principle is some response should be received for each aircrew action. It is this feedback linking action to reaction that defines each discrete transaction and maintains aircrew orientation in the interaction with the system. Interface software objectives are listed below:

- Consistency of operational procedures.
- Efficient use of full system capabilities.

-Minimal learning time required by aircrew to become proficient in software use.

-Minimal memory retention required by aircrew for software use and predictable operation.

User interface software represents a sizable investment in programming effort during initial system development and later when a system is upgraded. Overall estimates is user interface software comprises 30 to 35 % of operational software.[11, p. 3] The requirement for software standardization compliance is recognized in Human Engineering Design Criteria for Military Systems Equipment and Facilities (MIL-STD-1472D).

SOFTWARE CONTROL OF DATA ENTRY

Software should be implemented to optimize the aircrew entry of data into the system. Objectives for software are:

- Consistency of data entry transactions.
- Minimal entry action by the aircrew.
- Compatibility of the data entry with data display.
- Flexibility of aircrew control of data entry procedures.

Additionally, the interface provided by the software should afford the aircrew with sufficient flexibility, but the specific means of achieving such flexibility must be determined during the design phase.

DISPLAY FEEDBACK

Computer execution of interface software also provides the means to direct feedback to the aircrew concerning system operation and transmission of data. Software design and implementation should support the use of positive feedback directed to the aircrew which indicates the acceptance or rejection of a data entry. The speed at which the feedback is directed is a requirement if the purpose of the feedback is to confirm receipt of a command or assist in selection of a various option. The reaction should appear to each entry in sufficient time so the aircrew does not have to guess as to whether the entry was received. Delays in feedback cause the aircrew to question the validity of input or the computers capability to execute an instruction.[2, p.2.4.1-1] A normal aircrew response to slow feedback is errant excessive data entries, further complicating aircrew - system interaction.

Prompts

One software interface between a system and aircrew which aids information transaction is a prompt. Prompting is the process in an interactive environment where the system requests additional or corrected information when an error is detected or insufficient input is entered.[3, p. 19] Prompts are used to display and explain commands, error messages, system capabilities, display format procedures, and data

sequences. Either text or symbology may be used to present prompts. They should be located in a significant and conspicuous position on the display and exhibit to the aircrew the optional parameters which indicate what is the valid field of entries. Functions or transactions requested by the aircrew should be confirmed by the system upon completion of the request. Use of prompts should be consistent in meaning and context, directing information to the aircrew's point of view and not the programmers.

Help

Similar to a prompt in many respects is the use of help, that is the presentation of additional information directed to the aircrew concerning how to correctly use software to obtain required system data. The amount of detailed help information should be selectable by the aircrew for complete explanation of the system error.

Frame Content

The quantity and quality of data presented on an integrate interactive display is critical for optimizing the data transfer between the system and aircrew. Some guidelines for implementation are:

-When implementing a list with mutually exclusive options, when one is selected, dim those remaining in the list or deselect them for display.

-System provided explanations should be of the quick reference type. It should not be a tutorial but should show how to use the system to complete the job.

-System should only supply the aircrew with information essential to making a decision and not overload the aircrew with extraneous data.

CHAPTER 5

TEST AND EVALUATION BASICS

INTRODUCTION

Prior to conducting a test of aircraft crew station controls and displays for human factors, the evaluator must have a firm understanding of the applicable design guidelines and considerations. A working knowledge of this information provides the test aircrew and engineers with only a foundation for conducting tests. Further understanding of aircraft test and evaluation fundamentals is required. This chapter will serve to offer an ideology and general methodology for the execution of aircraft related tests.

TEST PREPARATIONS

A proper and complete human factors evaluation can not be done simply by handing the "keys to the aircraft" to a pilot and having it wrung out in flight to find out what and where the design deficiencies exist. A certain amount of planning and consideration is required to ensure the aircraft or specific component under test is evaluated within the proper scope. The test process can be categorized into the following steps:

- Determine applicable aircraft or system specifications.
- Determine test requirements.
- Develop a detailed test plan.
- Arrange for test facilities, material, and manpower.
- Perform tests.
- Record data to include both quantitative measurements and qualitative observations, notable events, regardless of apparent significance.
- Process data.
- Analyze data.
- Document test results.[6, p. 5.6]

PURPOSE OF TEST

First, it is important to clarify the purpose of the human factors testing to be conducted. It is rare that flight or ground testing is limited to the exclusive evaluation of human factors applications. More often, human factors testing is performed in conjunction with aircraft or system performance and operational qualities evaluations. Testing may involve the entire crew station or simply be limited to a specific aircraft (sub) system. Determination of the purpose for the evaluation will define the type and manner in which the tests are to be done. An evaluation conducted to ensure specification compliance requires more quantitative tests, while qualitative observations may suffice for other evaluation needs.

AIRCRAFT MISSION

Additionally, the test aircrew and engineers must consider for which mission the aircraft or specific system is to be evaluated. The mission suitability reflects whether an operational characteristic degrades the airplane's normal operation in its planned environment. A navigation system which may suffice for the requirements of civilian airways navigation in a multi-crew station airliner may not be suitable for installation in a single seat jet aircraft for the conduct of night, all-weather bombing. Each component, system, or aircraft must be evaluated against the precise demands of the mission and in the operational conditions for which it is intended to be used.

INSTRUMENTATION

In order to collect test result data some instrumentation is needed. Instrumentation is used to provide quantitative data which may be used to support test conclusions and recommendations from both quantitative and qualitative testing methods. Some basic instruments for the conduct of human factors evaluation are listed below:

Tape Measure and Scale Rule - used to measure distances between objects. Recommended are a 1 foot rigid straightedge, 3 foot rigid straightedge yardstick, and flexible metal or cloth measuring tape.

Protractor - used to determine angles for line of sight and field of view measurements. It is primarily related to displays or visual acquisition of system controls. Strings attached to the origin may be used for measuring the angle of objects far away.

Force Gauge - for determining human strength required to deflect controls for system operation.

Stopwatch - provides capability to measure time required for aircrew actions or system responses. Allows for computation of time order derivatives (i.e., velocity or acceleration rates).

String and Plumb Bob - used to determine vertical plane or aid in measuring angles with protractor. Additionally, an Abney level and digital inclinometer can be helpful.

Voice Tape Recorder - allows evaluator to instantaneously record data and qualitative observations.

TEST PLAN

The actual conduct of the test should be strictly defined in the process of developing the test plan. It is during this period the aircraft or specific system is studied to determine the scope and methodology of tests to be performed. Additionally, proposed operating procedures can be examined to evaluate the functional utility of the complete system with respect to human factors applications. In order to tailor the test procedures, the test aircrew or engineer must be familiar with:

- Operational principles of the system to be tested.
- Mission requirements imposed upon the test system.

-General methods of testing applicable to that type of system.

-General principles of test and evaluation.
[6, p. 5.5]

The process of defining how and what tests are to be conducted requires the determination of a test methodology to be utilized. To be effective, the evaluation should be designed to ensure:

-Tests have a well-defined and specific objective.

-Parameters to be measured provide for unambiguous evaluation of the factor to be evaluated.

-Any interfering or obscuring parameters are controlled or measured.

-Test instrumentation provides sufficient accuracy.

-Test data which allows for statistical determination of the testing error dispersions.

-Sufficient number of measurements are made for the desired degree of confidence in the test results.
[6, p 5.8]

TEST PHILOSOPHY

The viewpoint of the individual conducting the evaluation is critical to ensure an unbiased and fair determination is made concerning the aircraft or system under test. Although an individual aircrew may possess excellent flight aptitude, the tested equipment must be evaluated with respect to the least capable person expected to fly that

aircraft. Experienced aviators are well adapted to compensate for aircraft or system deficiencies by use of their skill and experience.

The most important principle to keep in mind when performing any human engineering evaluation is the concept of individual differences. We tend to evaluate items such as controls and displays from a very subjective viewpoint, i.e., our own capabilities, limitations, and experience. The fact that pilots are all different must be thoroughly understood when evaluating cockpits. Test pilots in particular, are perhaps not always entirely objective when it comes to admitting that particular human engineering design deficiencies are a problem as far as they are concerned. [16, p. XV-2,3]

Each component under test must be evaluated against the entire population of expected users. Therefore, the test pilot or engineer must consider the proficiency and aptitude demanded of an individual possessing the minimum acceptable levels of talent and competence required to complete the desired mission.

Another important consideration for the evaluator is to ensure the system is tested throughout the full range of expected operational conditions. These should include all normal and emergency ground and flight procedures. At each phase, a "worst case" scenario should be used to ensure no deficiencies exist which will impede the aircrew from taking the necessary corrective actions.

As with all human engineering evaluations, anthropometry must be checked against 'worst case' conditions. An example...would be reaching a critical control such as the emergency stores jettison when fully restrained (shoulder harness locked) and when under a high-g condition such as a catapult launch.[16, p. XV-5]

QUALITATIVE RATING SCALE

During test execution two types of data, qualitative and quantitative information, should be obtained. Data in the quantitative format normally allows for an obvious analysis and conclusion regarding a deficiency. However, the significance of qualitative test results and observations are often more difficult to confer in documentation. One means to aid in defining qualitative system test issues is the use of the Operational Qualitative Rating (OQR) Scale. This assessment scale, similar in nature to the Cooper-Harper Rating Scale for flight qualities, provides the evaluator with a clear cut decision-tree methodology to determine the severity of a system characteristic. The evaluator is tasked to rate the level of workload or acceptability of workload for a particular system configuration. One caution is people who utilize rating scales can be biased by previous experience with a system which may cause an evaluator to underestimate the workload of a new but similar system.[7, p. 38] A rating from the scale provides the intended audience an explicit measurement regarding a system operational characteristic.

The scale is shown in figure 14.

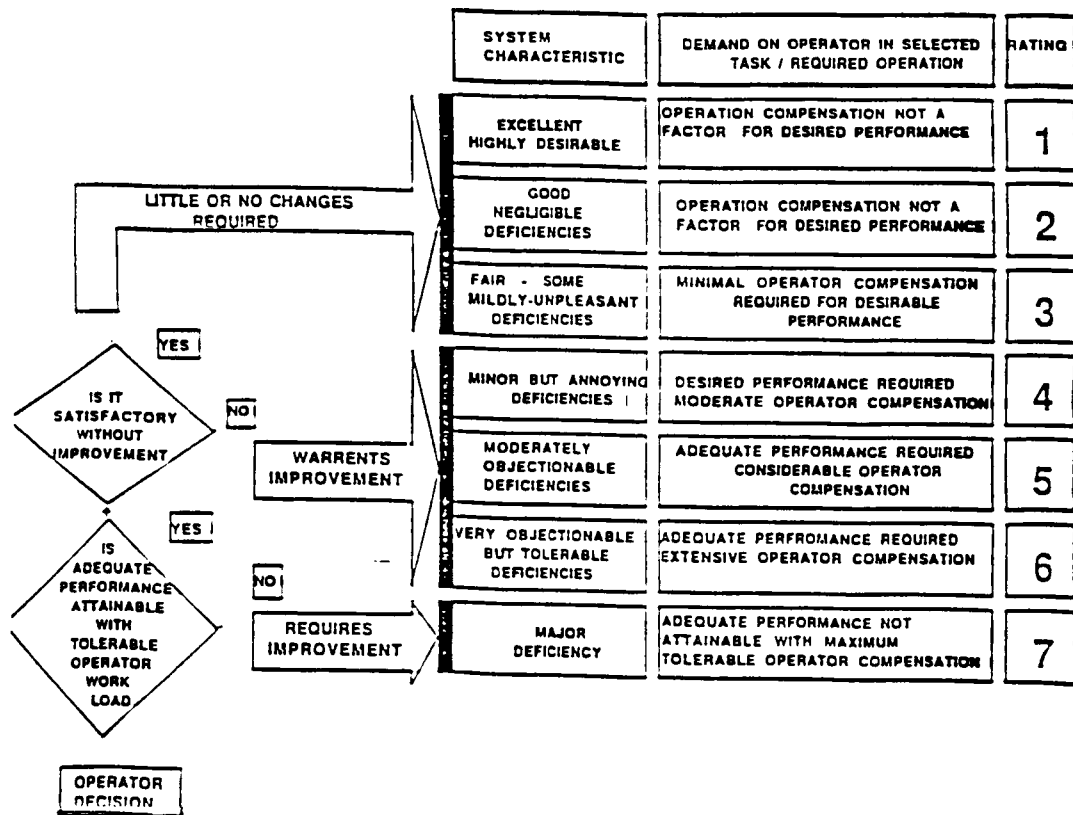


Figure 14
OPERATIONAL QUALITY RATING SCALE

[22]

MISSION RELATION

When a deficiency is discovered, its effect must be determined. The degree by which the deficiency degrades the system operation or impedes the aircrew from accomplishing the mission requires analysis. The evaluator should relate the consequence and result of the deficiency with regard to specific tasks required to be accomplished. This mission relation provides justification for the magnitude and significance of the deficiency.

RESULTS AND DOCUMENTATION

The end result of an evaluation is to confer the knowledge obtained by the evaluators to the parties which can take action to correct deficiencies. Additionally, the documentation can be used to inform other aircrew of aircraft or system characteristics and deficiencies prior to their first flights. When specification compliance is involved, the material from the evaluation needs to be transmitted to the contractor so measures can be taken to rectify deficiencies. "It is the nature of the testing process that the only product is the documentation.[6, p. 5.10]

GENERAL TEST PROCEDURES

SYSTEMS APPROACH

The evaluation of an aircraft cockpit or particular piece of equipment should be viewed as a system. Whether the system is open or closed, integrated or stand alone, the analysis of the controls and displays should include how they interact with each other and with the aircrew as the focal point.

Not until the working relationships of controls, displays, lighting and cockpit environment are analyzed can an intelligent evaluation be conducted. Regardless of airplane performance and flying quality potential, the man in the cockpit must accomplish the transfer function of changing the airplane's potential into reality. Important variables which control this function are (1) capabilities and limitations of the aviator and (2) the cockpit design which is the link between action and reaction performed by the pilot as a result of information received and processed.[16, p. XV-2]

FLIGHT GEAR EQUIPMENT

Both ground and flight evaluations should be conducted while attired in the complete flight gear. This requirement increases the validity of the tests. It also ensures proper accounting for possible interference from the flight gear for operating controls throughout their full range of motion or obstructions to visual acquisition of displays. Equipment used in flight such as kneeboards, watches, and flashlights should also be carried during the evaluation.

ANTHROPOMETRIC CONSIDERATIONS

A major part of the aircrew cockpit or station analysis is concerned with ergonomics. This ensures aircrew are located such that all controls are within functional reach and all displays can be visually sighted without obstruction. The first step for conducting a human factors evaluation of aircraft controls and displays is to perform an Anthropometric Accommodation Assessment (AAA).

AAA relates defined and readily obtainable anthropometric body measurements to the layout and operational considerations of each crew station in an aircraft. This is intended to provide a detailed description of which aircrew will encounter restrictions in an operational environment due to the interaction between anthropometric dimensions and crew stations layout. This is based on a comparison of each individual's anthropometric measurements to the anthropometric ranges determined from these procedures to be accommodated or not accommodated.[8, p. 1]

Execution of an AAA provides an initial view of the entire aircrew-aircraft interface and is designed to:

- Ascertain what access or clearance is provided for any given person.
- Determine the effects of a full range of anthropometric measurements against the crew station layout and operational constraints.
- Ensure sufficient work space volume and safe egress paths due not conflict with the goals of visual and functional access to associated controls and displays.

Anthropometric Measurements

The primary anthropometric dimensions applicable to aircraft design are:

- Total Sitting Height.
- Sitting Eye Height.
- Sitting Shoulder Height.
- Bideltoid Diameter (shoulder width).
- Functional Reach.
- Buttock-to-Knee Length.
- Sitting Knee Height.

Each evaluator should determine their individual dimensions and utilizing a guide such as Anthropometry of Naval Aviators (excerpts may be found in appendix A), ascertain the correct percentile ranking for that dimension. This information provides the evaluator with the knowledge that if a control is outside his function reach, aircrew with a lesser percentile functional reach will be prohibited from properly actuating the control. "Only by knowing your own various percentile ranks can you make relative judgements as to overall anthropometric accommodation of a particular cockpit...."[16, p. XV-4] A sample data card for recording anthropometric dimension data is located in appendix C, figure C-1.

Aircrew Accommodation

Aircraft cockpits and crew stations are designed to accommodate a representational cross section of the expected population. Current military standards require aircrew who fall between the 3rd and 98th percentiles be fully accommodated. However, there are some problems with this guideline.

No current anthropometric data base assessment has been established and the last major survey (Aerospace Crew Equipment Laboratory - Anthropometry of Naval Aviators) was conducted in 1964 consisting of all-male (mostly caucasian) aviators. Some work has been performed to account for the growing numbers of minorities and women; however, no formal data base readily exists to account for this larger population of aircrew.

Additionally, few (if any) individuals possess uniform percentiles across the entire spectrum of measurements. An aviator or test engineer may be short in overall stature but have a significantly different percentile sitting height or buttock-to-knee length. Differences in proportions must be properly accounted for. Toward this end, Anthropometric Artificial Manikins ("dummies") may be used to aid in the conduct of an AAA. The dummies may be manufactured to represent "worst case" aircrew and utilized to determine anthropometric accommodation deficiencies.

DESIGNED EYE POSITION

In order to account for the wide variety in anthropometric measurements of aircrew, seats are provided with the means for adjustment. This provides aircrew with the capability to ensure the body is located to place the aircrew's head at the Designed Eye Position (DEP). DEP is defined as the reference datum point based on eye location that permits the vision envelope to include the sighting of all displays and adequate exterior vision. It allows for posture slouch and is the datum point from which the aircrew station geometry is constructed.

Cockpit and Crew Station Seat Dimensions

The understanding of several key dimensions are important to ensure the evaluator has correctly determined and placed the seat to the DEP. These dimensions are graphically illustrated in figure 15.

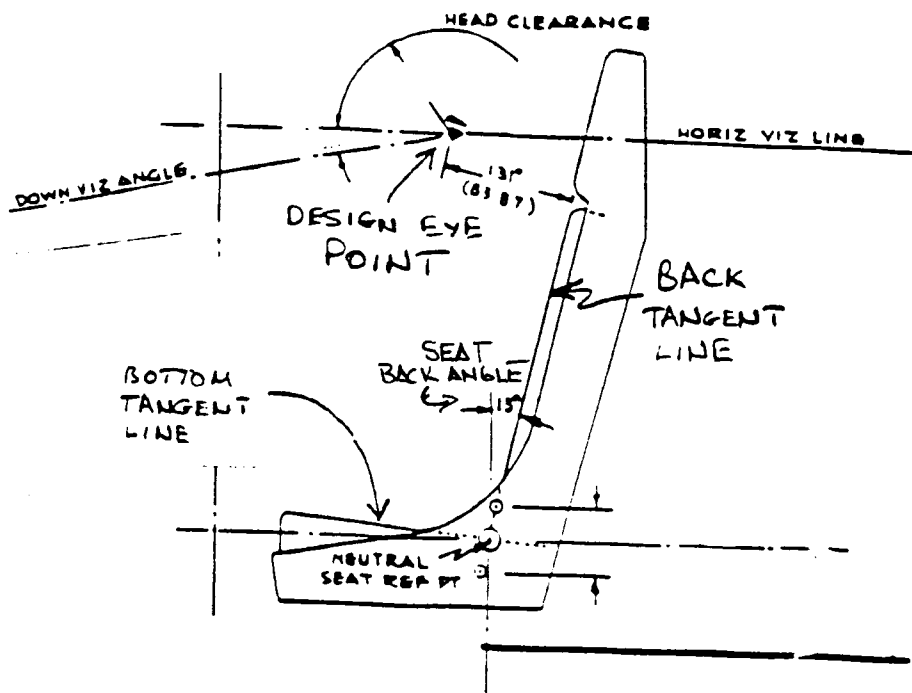


Figure 15
AIRCREW SEAT DIMENSIONS

[16, p. 10]

Back Tangent Line - A vertically inclined line tangent to the back of a seated aircrew at the thoracic region and buttocks.

Bottom Tangent Line - horizontally inclined line coincident with the upper surface of the seat

Seat Reference Point (SRP) - the intersection of back tangent line and bottom tangent line.

Neutral Seat Reference Point (NSRP) - location of the SRP when the seat is adjusted to the mid-point of vertical adjustment. This position will place the 50th percentile (seated height) male aviator with his eye at DEP.

Seat Back Angle - using the SRP as the origin, the angle subtended by the vertical and the back tangent line.

Steps to Place the Seat at DEP

The below listed steps should be followed to adjust the seat so the evaluator's eyes are at DEP.

Safety

In all testing, safety is paramount. Testing must be conducted in a manner so as to minimize the risks to all involved personnel. Toward this end, the evaluator must ensure all emergency controls (e.g. ejection seat initiators and canopy jettison devices) are deactivated or have safety pins in place prior to entering the cockpit. Additionally, evaluators must exercise extreme caution while conducting emergency egress procedures.

Ejection Seat versus Multi-Aircrew Seats

A major difference between ejection seats and multi-aircrew seats exist in ejection seats are not normally adjustable in the forward-aft direction. This is due to their mounting on a rail and associated rocket. Non-ejection seats, often found in multi-aircrew planes, usually provide for forward-aft adjustments and may be equipped to allow some degree of rotation for reclining.

In a multi-aircrew seat, the forward-aft setting should be set as far-forward as possible without impeding the aircrew from comfortable foot-pedal movements. Closest positioning of

the aircrew's eyes to the canopy will maximize exterior field-of-view. This must be balanced against providing adequate internal field-of-view for aircraft controls and displays. Seat rotation should be set to allow maximum comfort while not detracting either exterior or internal fields-of-view. These positions should be recorded.

Finding NSRP

1. Move seat full up and note vertical position of SRP.
2. Move seat full down and note vertical position of SRP.
3. Measure range between full up and down positions and divide by two. Position SRP to this distance above the full down position.

Adjusting for Evaluator's Sitting Eye Height

1. Determine difference between evaluator's sitting eye height and sitting eye height for 50th percentile aviator. (Male - 31.5 inches, corrected for slouch 31.0 inches.)
2. Adjust seat by difference. If evaluator has greater than 50th percentile sitting height, move seat down. If evaluator has less than 50th percentile sitting height, move seat up.

Correcting for Seat Back Angle

1. Measure seat back angle. Use table III below to determine Seat Back Angle Correction Distance.

Table III
SEAT BACK ANGLE CORRECTION DISTANCE

Seat Back Angle (DEG)	Correction Distance (IN)
10.0	7.7
10.5	7.4
11.0	7.1
11.5	6.9
12.0	6.6
12.5	6.3
13.0	6.1
13.5	5.8
14.0	5.5
14.5	5.3
15.0	5.0

[16, p. 11]

2. Find DEP by moving head forward correction distance for seat back angle from headrest or extended back tangent line when seated in seat with seat positioned to the adjusted NSRP.

The data for placing the aircrew seat so the evaluator is located at DEP should be recorded on the data card shown in appendix C, figure C-2. This will allow the evaluator to quickly position the seat to the correct settings during subsequent tests.

CHAPTER 6

TEST AND EVALUATION PROCEDURES

OVERVIEW

The individual tests procedures listed in this chapter present the evaluator with a detailed "cookbook" approach methodology to conduct a human factors evaluation of aircraft controls and displays. It is not necessary to conduct each test to complete an evaluation on a particular piece of equipment. Individual tests should be chosen to ensure the scope provides sufficient data to complete the requirements for the purpose of the evaluation.

FIELDS OF VIEW

EXTERNAL FIELD OF VIEW (FOV)

Purpose

The purpose of this test is to assess the FOV outside the cockpit for the conduct of flight and ground operations.

General

This test is designed to determine the aircraft obstructions which prevent visual acquisition of objects (e.g. runway environment, other aircraft, and ground targets). The requirement for visual acquisition of particular objects is dependent on the aircraft's mission and the individual crew

station from which the test is being conducted. Restrictions to the external FOV impede aircrew from sighting both ground and airborne references adjacent to the aircraft.

Instrumentation

A cloth tape measure, protractor, string, and plumb bob are required for this test. A voice tape recorder, Abney level, and digital inclinometer are optional.

Data Required

Rectilinear graph presentation with obstructions labeled and qualitative comments.

Procedure

With the evaluator located at DEP, obstructions which limit the evaluator's sight of objects outside the cockpit should be charted. The obstructions should be defined in both the vertical and horizontal angles from DEP. Angles are measured using the protractor with the origin located at the eye. The plumb bob ensures proper orientation in the vertical plane. Any difference between the longitudinal axis and the horizontal plane when the aircraft is on the deck should be accounted for. Illustrations are shown in figures 16 and 17 for protractor use and accounting for aircraft longitudinal axis while on deck.

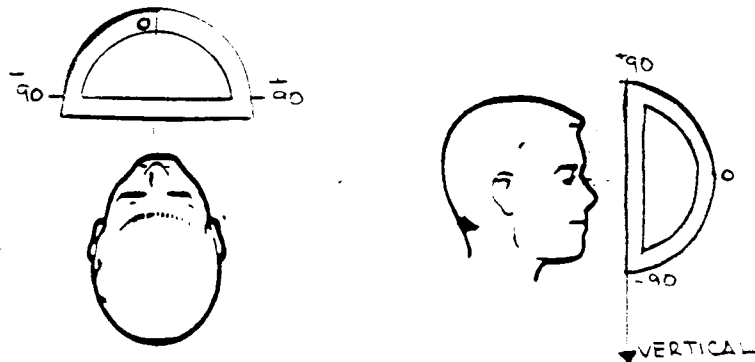


Figure 16
TECHNIQUE FOR MEASURING VERTICAL AND HORIZONTAL ANGLES

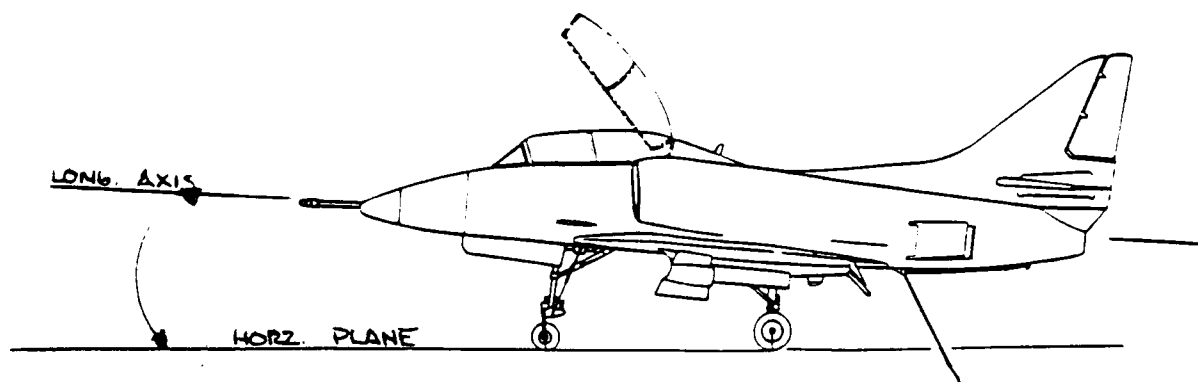


Figure 17
ACCOUNTING FOR DIFFERENCE BETWEEN AIRCRAFT LONGITUDINAL AXIS
AND HORIZONTAL PLANE

Attempts should be made to compensate for the fact that as the evaluator's head rotates, the eyes move from DEP. This is significant in attempts to acquire sight of objects behind the aircraft. The evaluator must strive to keep the shoulders pressed firmly against the backrest. Qualitative comments which describe the effect of the obstruction should be documented.

Data Analysis and Preparation

Obstructions to external FOV should be related to expected tasks required by the aircrew for the safe conduct and movement of the aircraft during both ground and flight operations. Expected procedures and maneuvers such as sighting ground personnel and following their direction, taxiing in close quarters, takeoff, landing, formation flight, weapons delivery, aerial combat, ground reconnaissance, in-flight refueling, shipboard flight operations, and visual target acquisition should be performed. Limitations to visual tasks performed outside the cockpit during all phases of flight and the respective impairment to the performance of required duties should be documented. Compensation required for task completion and the degree of impairment should be noted.

Data Cards

Sample data cards and rectilinear graph paper are presented in appendix C, figures C-3 and C-4, respectively. An example external FOV from the F-14B Radar Intercept Officer Crew Station is shown in figure 18.

- 1 - Headrest / Ejection Seat
- 2 - Canopy Rail
- 3 - Radar Intercept Officer Canopy Bow
- 4 - Mirror
- 5 - Pilot Canopy Bow
- 6 - Left Instrument Panel
- 7 - Right Instrument Panel
- 8 - Center Instrument Panel

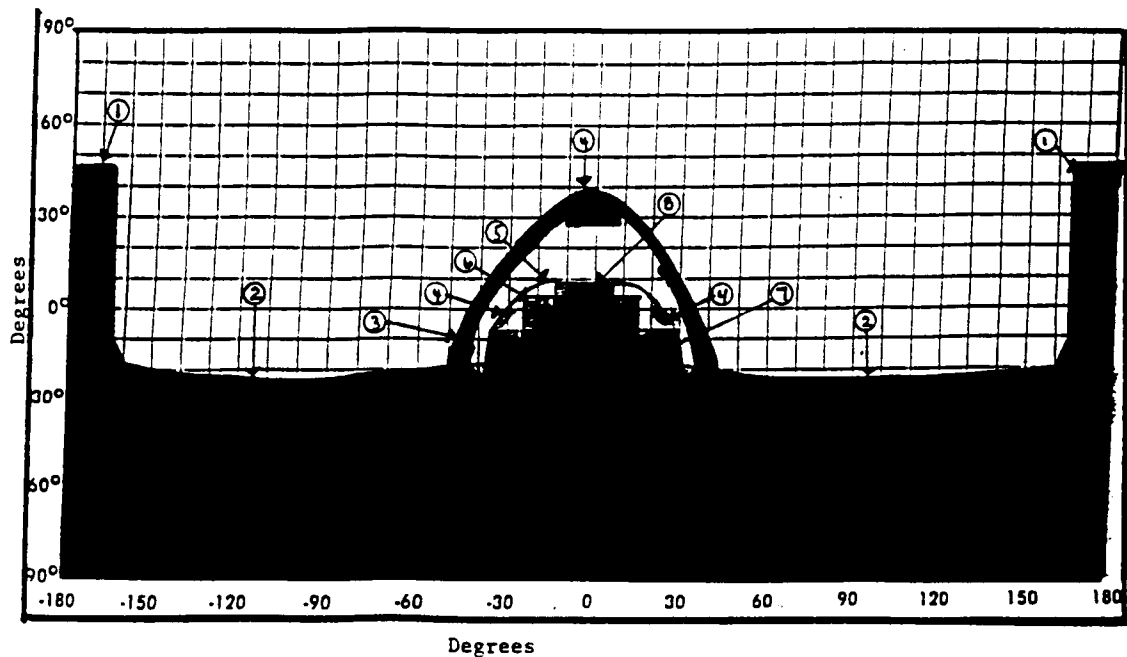


Figure 18
F-14B RADAR INTERCEPT OFFICER'S EXTERIOR FIELD OF VIEW

[23, p. 185]

INTERNAL FOV

Purpose

The purpose of this test is to assess the FOV inside the cockpit at the crew station for the conduct of flight and ground operations.

General

This test is designed to determine the obstructions which prevent visual acquisition of objects (i.e., controls and displays) inside at the crew station. Restrictions to the internal FOV impede the aircrew from sighting controls prior to manipulation and impede the transfer of system feedback.

Instrumentation

No instrumentation is required for this test. A voice tape recorder is optional.

Data Required

List the controls and displays obscured from visual acquisition, obstructions, and qualitative comments.

Procedure

With the evaluator located at DEP, obstructions which limit the evaluator's sight of objects inside the cockpit should be determined. This should include but not be limited

to aircraft panels or bulkheads which eclipse the view of controls and displays. Additionally, the placement of controls which obscure the associated or adjacent displays should be documented. Consideration should be given in multi-aircrew cockpits for controls and displays whose operation requires sighting by the individual or multiple aircrew. The amount of movement from DEP required to sight the particular control or display and the amount of degradation to both external and internal FOVs should be documented. Qualitative comments which describe the effect of the obstruction should also be recorded.

Data Analysis and Preparation

Obstructions to internal FOV should be related to expected tasks required by the aircrew for the expeditious sighting of controls and displays required for the safe performance of both ground and flight operations. Impediments which delay visual acquisition of controls and displays during transition between scanning outside and inside the cockpit should be described. Any obstruction to the internal FOV which impedes the performance of a required task should be documented. Compensation required for task completion and the degree of impairment should be noted.

Data Cards

A sample data card is presented in appendix C, figure C-5.

PRIMARY LINE OF SIGHT

Purpose

The purpose of this test is to assess the placement of controls and displays within the primary line of sight.

General

This test is designed to evaluate which controls and displays have been placed within the primary line of sight defined as a 30 degree visual cone originating from DEP. As discussed earlier, only those controls and displays of principal importance should be placed within the aircrew's primary line of sight. Additionally a balance between items located within the cockpit and the exterior FOV must be obtained to foster the aircrew's visual scan in this area.

Instrumentation

A cloth tape measure, protractor, string, and plumb bob are required for this test. A voice tape recorder, Abney level, and digital inclinometer are optional.

Data Required

Rectilinear Graph presentation with controls and displays labeled and qualitative comments.

Procedure

With the evaluator located at DEP, the evaluator should determine which controls and displays are located within the primary line of sight. The placement of these objects should be measured in both vertical and horizontal angles from DEP. Any obstructions to both internal and external FOVs should also be noted. Examples include canopy bows and dashboard glare shields. Qualitative comments should include descriptions of object's functional placement within the primary line of sight, frequency of use, relative size compared to other controls and displays, number, interlinkage, and importance.

Data Analysis and Preparation

The aircrew should evaluate whether those items mounted within the primary line of sight are most critical for aircrew control input and system feedback during both ground and flight operations. Since the aircrew's visual scan is concentrated in this area, placement of an object here should foster quick visual acquisition and transfer of data. Controls and displays in the primary line of sight should not

be so numerous and tightly compacted as to impede the aircrew from performing other tasks required for safe operations. Any obstruction in the primary line of sight which impedes the performance of a required task should be documented. Compensation required for task completion and the degree of impairment should be noted.

Data Cards

Sample data card and rectilinear graph paper are presented in appendix C, figures C-6 and C-7.

CONTROLS

PURPOSE

The purpose of these tests are to evaluate aircraft controls for accommodation and compliance with basic control design guidelines.

GENERAL

These tests are designed to investigate an individual control and the overall application of human factors principles to maximize its use to provide aircrew input to govern system operation. This micro approach will furnish the evaluator with the basis for introductory level analysis of a system's control. Deficiencies found during these tests when grouped together may reveal global human factors defects.

INSTRUMENTATION

A cloth tape measure, scale rule, force gauge, and stop watch are required for this test. Use of a voice tape recorder is optional.

DATA REQUIRED

The evaluator will be required to furnish details concerning control operation, classification, and functional criteria. Qualitative comments and OQR scale determinations will also be useful in documenting deficiencies.

PROCEDURE

With the evaluator located at DEP, and safety harness attached, an individual control should be selected for survey. The control should be evaluated against the design guidelines presented in Chapter 2. Specific measurements concerning functional reach, control motion and force requirements, and time required for employment will be required.

DATA ANALYSIS

For each deviation from human factors guidelines for controls, the evaluator should determine how the degradation will affect the capability to safely and successfully complete the required mission. Compensation required for task completion and the degree of impairment should be noted. The

capability of a control to provide the means for the operator to manage, regulate, supervise, or govern system operation should be appraised.

TEST SPECIFICS

The evaluator is responsible for choosing those tests which apply. When a sample data card provides a choice of responses for a particular data point, the option in capital letters indicates the response may be indicative of a design deficiency. If the capitalized selection is chosen (or circled) on the data card, the evaluator should consider whether an OQR value is applicable.

General Control Design Guideline Conformance

Specific data points for evaluating a control's design guideline conformance are detailed in the sample data cards presented in appendix C, figures C-8 through C-14.

Control Levers

Levers are normally used where large amounts of force or displacement, or multi-dimensional movement are required. Specific data points for evaluating control levers are detailed in the sample data cards presented appendix C, figures C-15 through C-18.

Rotary Selector Switches

Rotary selector switches are used for discrete function where three or more discrete settings are required. Specific data points for evaluating a rotary selector switch controls are detailed in the sample data cards are presented in appendix C, figures C-19 and C-20.

Switches

Switches are used for discrete function where three or less discrete settings are required. Switches will be considered to include simple on and off controls, pushbuttons, and toggles. Switches are used for controls when only momentary contact is required or for high frequency use. Specific data points for evaluating a switch controls are detailed in the sample data cards are presented in appendix C, figures C-21 and C-22.

Data Entry Keyboards

Data entry keyboards are used to provide for rapid information input and system control. Data is usually in the form of alphabetic or numeric characters. Additionally, data entry keyboards may serve to initiate function operation. Specific data points for evaluating a data entry keyboard controls are detailed in the sample data cards are presented in figures C-23 and C-24.

DISPLAYS

PURPOSE

The purpose of these tests are to evaluate aircraft displays for accommodation and conformance with basic display design guidelines.

GENERAL

These tests are designed to investigate an individual display and the overall application of human factors principles to maximize its use to provide feedback concerning system operation. This micro approach will furnish the evaluator with the basis for introductory level analysis of a system's display. Deficiencies, when grouped together, may reveal global human factors defects.

Display evaluation should ensure the information presented to each aircrew who operates a piece of system equipment is limited to information which is necessary to the specific actions or decisions requested. Feedback should be displayed to aircrew in a directly usable form without the requirement for decoding and interpolation.[15, p. 977]

INSTRUMENTATION

A cloth tape measure, scale rule, and stop watch are required for this test. Use of a voice tape recorder is optional.

DATA REQUIRED

The evaluator will be required to furnish details concerning display operation, classification types and categories, sense(s) targeted for information transfer, functional criteria, coding, illumination, and environmental effects. Qualitative comments and OQR scale determinations will also be useful in documenting deficiencies.

PROCEDURE

With the evaluator located at DEP, and safety harness attached, an individual display should be selected for survey. The display should be evaluated against the design guidelines presented in Chapter 3. Specific data concerning display presentation, format, coding techniques, and functional utility will be required.

DATA ANALYSIS

For each deviation from human factors guidelines for displays, the evaluator should determine how the degradation will affect the capability to safely and successfully complete the required mission. Compensation required for task completion and the degree of impairment should be noted. The capability of a display to provide adequate feedback to the operator should be appraised.

TEST SPECIFICS

The evaluator is responsible for choosing those tests which apply. When a sample data card provides a choice of responses for a particular data point, the option in capital letters indicates the response may be indicative of a design deficiency. If the capitalized selection is chosen (or circled) on the data card, the evaluator should consider whether an OQR value is applicable.

General Display Design Guideline Conformance

Specific data points for evaluating a display's design guideline conformance are detailed in the sample data cards presented in appendix C, figures C-25 through C-30.

Tactile or Auditory Displays

Tactile and auditory displays are normally used as attention gathering devices to provide aircrew with simple and quick feedback. Specific data points for evaluating tactile or auditory displays are detailed in the sample data cards presented in appendix C, figures C-31 through C-33.

Visual Displays

Visual displays are typically the most numerous type found in an aircrew station. They can be used to pass complex and detailed feedback concerning system operation. Specific

data points for evaluating visual displays are presented in appendix C, figures C-34 through C-36.

Color

Color coding techniques are used to supplement and reinforce visual feedback. Color applications provide the capability to improve visual acquisition on the display. Specific data points for evaluating the employment of color coding for visual displays are detailed in the sample data cards presented in appendix C, figures C-37 and C-38.

Illumination

Visual displays require sufficient lighting to allow for the eye to receive the presented feedback. Illumination requirements will depend upon whether the crew station is exposed to outside ambient light and the visual scan requirements outside the cockpit. Additionally, specific concerns for night lighting, dark adaptation, and glare should be investigated. Specific data points for evaluating display illumination techniques are presented in appendix C, figures C-39 through C-44.

Labels

Labels are a static type of visual display which are normally used to aid the aircrew in distinguishing and identifying both controls and displays. Specific data points for evaluating labels are detailed in the sample data cards presented in appendix C, figures C-45 and C-46.

Alert Lights

Alert lights are visual displays normally used to notify the aircrew concerning abnormal system performance which requires an immediate (corrective) response by the aircrew. Specific data points for evaluating alert light displays are detailed in the sample data cards presented in appendix C, figures C-47 through C-50.

Reference Displays

Reference displays are used to provide the aircrew with the means to compare system performance against a known or desired standard. Specific data points for evaluating reference displays are detailed in the sample data cards presented in appendix C, figures C-51 through C-53.

Gauges and Dials

Gauges and dials are instruments which are used to provide the aircrew with dynamic indications concerning system operation. These displays may also be used to provide aircrew with additional information in the form of advance warning, rates-of-change, and the opportunity to make cross-dial extrapolations. The size of the actual display should be dependent upon the number of scale markings and the distance between DEP and the display. Recommended instrument size is shown in table IV.

Table IV
MINIMUM INSTRUMENT DIAMETER

NUMBER OF SCALE MARKINGS	VIEWING DISTANCE (IN)		
	20	36	72
50	---	1.3	2.6
100	1.4	2.6	5.0
150	2.0	3.9	8.0
200	2.9	5.0	10.0
250	3.5	6.4	13.0
300	4.0	7.7	15.0
350	5.0	9.0	18.0

[15, p. 531]

Specific data points for evaluating gauge and dial displays are detailed in the sample data cards presented in appendix C, figures C-54 through C-60.

Quantitative Readouts

These displays are generally used to provide the most rapid and accurate presentations of purely quantitative data. Specific data points for evaluating quantitative readout displays are detailed in the sample data cards shown in appendix C, figures C-61 through C-63.

Electronic Digital Displays

Electronic digital displays (EDD) are used to provide the aircrew with dynamic and versatile presentations concerning system operation. Their inherent flexibility allows for their operation to be tailored to the needs of the aircrew. Specific data points for evaluating electronic digital displays are detailed in the sample data cards presented in appendix C, figures C-64 through C-69.

INTEGRATED INTERFACES

PURPOSE

The purpose of this test is to evaluate aircraft integrated interfaces for accommodation and conformance with basic control and display guidelines.

GENERAL

Since integrated interfaces combine the aspects of both controls and displays, many of the applicable tests listed in those respective sections should be performed. This section will deal specifically with tests that apply to the interface.

INSTRUMENTATION

A cloth tape measure, scale rule, force gauge, and stop watch are required for this test. Use of a voice tape recorder is optional.

DATA REQUIRED

The evaluator will be required to furnish details concerning interface adjustments, control - display interactions, and software.

PROCEDURE

With the evaluator located at DEP, and safety harness attached, an individual interface should be selected for survey. The unit should be evaluated against the design guidelines presented in Chapter 4. Specific measurements concerning control motion, force requirements, time required for operation, and software functional utility will be required.

DATA ANALYSIS

For each deviation from human factors guidelines for integrated interfaces, the evaluator should determine how the degradation will affect the capability to safely and successfully complete the required mission. Compensation required for task completion and the degree of impairment should be noted. The capability of an interface unit to provide the means for the aircrew to manipulate system operation and receive feedback concerning system status should be appraised.

TEST SPECIFICS

The evaluator is responsible for choosing those tests which apply. When a sample data card provides a choice of responses for a particular data point, the option in capital letters indicates the response may be indicative of a design deficiency. If the capitalized selection is chosen (or circled) on the data card, the evaluator should consider whether an OQR value is applicable. Specific data points for evaluating an interface are detailed in the sample data cards presented in appendix C, figures C-70 and C-71.

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LIST OF REFERENCES

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APPENDIX A

EXCERPTS FROM ANTHROPOMETRY OF NAVAL AVIATORS - 1964

PERCENTILE LISTINGS

LIST OF TABLES

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A-IV.	Bideltoid Diameter (Shoulder Width)	133
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A-VII.	Sitting Knee Height	136

Table A-I
TOTAL SITTING HEIGHT

HEIGHT		PERCENTILE
INCHES	CENTIMETERS	
33.46	85.00	1 ST
33.76	85.75	2 ND
33.96	86.26	3 RD
34.24	86.96	5 TH
34.68	88.09	10 TH
34.98	88.86	15 TH
35.23	89.47	20 TH
35.43	90.00	25 TH
35.62	90.48	30 TH
35.79	90.92	35 TH
35.96	91.33	40 TH
36.11	91.73	45 TH
36.27	92.13	50 TH
36.43	92.52	55 TH
36.58	92.92	60 TH
36.75	93.33	65 TH
36.92	93.77	70 TH
37.10	94.24	75 TH
37.31	94.77	80 TH
37.56	95.39	85 TH
37.87	96.19	90 TH
38.36	97.43	95 TH
38.69	98.27	97 TH
38.95	98.92	98 TH
39.37	100.00	99 TH

Mean: 36.28 IN / 92.14 CM
Standard Deviation: 1.25 IN / 3.16 CM
Range: 32.19-41.62 IN / 81.75-105.65 CM

From: Anthropometry of Naval Aviators-1964

Table A-II
SITTING EYE HEIGHT

HEIGHT		PERCENTILE
INCHES	CENTIMETERS	
28.81	54.55	1 ST
29.19	55.03	2 ND
29.41	55.40	3 RD
29.70	55.95	5 TH
30.11	56.89	10 TH
30.38	57.56	15 TH
30.59	58.11	20 TH
30.77	58.58	25 TH
30.94	59.00	30 TH
31.09	59.39	35 TH
31.23	59.76	40 TH
31.38	60.11	45 TH
31.52	60.46	50 TH
31.67	60.80	55 TH
31.82	61.15	60 TH
31.98	61.50	65 TH
32.15	61.87	70 TH
32.33	62.26	75 TH
32.55	62.70	80 TH
32.80	63.21	85 TH
33.12	63.86	90 TH
33.61	64.87	95 TH
33.93	65.56	97 TH
34.16	66.10	98 TH
34.52	67.03	99 TH

Mean: 23.79 IN / 60.44 CM
Standard Deviation: 1.06 IN / 2.70 CM
Range: 20.02-27.49 IN / 50.85-69.75 CM

From: Anthropometry of Naval Aviators-1964

Table A-III
SITTING SHOULDER HEIGHT

HEIGHT		PERCENTILE
INCHES	CENTIMETERS	
21.48	54.55	1 ST
21.67	54.03	2 ND
21.81	55.40	3 RD
22.03	55.95	5 TH
22.40	56.89	10 TH
22.66	57.56	15 TH
22.88	58.11	20 TH
23.06	58.58	25 TH
23.23	59.00	30 TH
23.38	59.39	35 TH
23.53	59.76	40 TH
23.67	60.11	45 TH
23.80	60.46	50 TH
23.94	60.80	55 TH
24.07	61.15	60 TH
24.21	61.50	65 TH
24.36	61.87	70 TH
24.51	62.26	75 TH
24.69	62.70	80 TH
24.89	63.21	85 TH
25.14	63.86	90 TH
25.54	64.87	95 TH
25.81	65.56	97 TH
26.02	66.10	98 TH
26.39	67.03	99 TH

Mean: 23.79 IN / 60.44 CM
Standard Deviation: 1.06 IN / 2.70 CM
Range: 20.02-27.49 IN / 50.85-69.75 CM

From: Anthropometry of Naval Aviators-1964

Table A-IV
BIDELTOID DIAMETER (SHOULDER WIDTH)

MEASUREMENT		PERCENTILE
INCHES	CENTIMETERS	
16.59	42.13	1 ST
16.87	42.86	2 ND
17.05	43.30	3 RD
17.28	43.89	5 TH
17.63	44.77	10 TH
17.86	45.35	15 TH
18.03	45.80	20 TH
18.18	46.19	25 TH
18.32	46.53	30 TH
18.44	46.84	35 TH
18.56	47.14	40 TH
18.67	47.42	45 TH
18.78	47.71	50 TH
18.89	47.99	55 TH
19.01	48.28	60 TH
19.12	48.57	65 TH
19.25	48.88	70 TH
19.38	49.22	75 TH
19.53	49.60	80 TH
19.70	50.05	85 TH
19.93	50.61	90 TH
20.26	51.46	95 TH
20.48	52.02	97 TH
20.64	52.43	98 TH
20.90	53.09	99 TH

Mean: 18.78 IN / 47.00 CM
Standard Deviation: 0.91 IN / 2.30 CM
Range: 14.82-21.70 IN / 37.65-55.05 CM

From: Anthropometry of Naval Aviators-1964

Table A-V
FUNCTIONAL REACH

MEASUREMENT		PERCENTILE
INCHES	CENTIMETERS	
28.56	72.54	1 ST
28.87	73.34	2 ND
29.07	73.84	3 RD
29.33	74.51	5 TH
29.75	75.55	10 TH
30.03	76.29	15 TH
30.27	76.89	20 TH
30.48	77.43	25 TH
30.68	77.92	30 TH
30.86	78.39	35 TH
31.04	78.85	40 TH
31.22	79.30	45 TH
31.40	79.76	50 TH
31.59	80.23	55 TH
31.78	80.72	60 TH
31.98	81.23	65 TH
32.20	81.78	70 TH
32.44	82.39	75 TH
32.71	83.08	80 TH
33.03	83.89	85 TH
33.44	84.93	90 TH
34.04	86.46	95 TH
34.42	87.44	97 TH
34.70	88.13	98 TH
35.11	89.17	99 TH

Mean: 31.51 IN / 80.03 CM
Standard Deviation: 1.42 IN / 3.61 CM
Range: 27.26-36.31 IN / 69.25-92.15 CM

From: Anthropometry of Naval Aviators-1964

Table A-VI
BUTTOCK-TO-KNEE LENGTH

MEASUREMENT		PERCENTILE
INCHES	CENTIMETERS	
21.78	55.32	1 ST
22.08	56.09	2 ND
22.26	56.55	3 RD
22.50	57.15	5 TH
22.85	58.03	10 TH
23.08	58.61	15 TH
23.26	59.07	20 TH
23.41	59.47	25 TH
23.55	59.82	30 TH
23.68	60.16	35 TH
23.81	60.48	40 TH
23.93	60.79	45 TH
24.06	61.10	50 TH
24.18	61.42	55 TH
24.31	61.75	60 TH
24.44	62.09	65 TH
24.59	62.45	70 TH
24.75	62.85	75 TH
24.92	63.31	80 TH
25.13	63.84	85 TH
25.40	64.52	90 TH
25.80	65.53	95 TH
26.06	66.18	97 TH
26.24	66.65	98 TH
26.52	67.37	99 TH

Mean: 24.09 IN / 61.20 CM
Standard Deviation: 1.00 IN / 2.54 CM
Range: 20.73-27.81 IN / 52.65-70.55 CM

From: Anthropometry of Naval Aviators-1964

Table A-VII
SITTING KNEE HEIGHT

HEIGHT		PERCENTILE
INCHES	CENTIMETERS	
19.71	50.06	1 ST
19.93	50.61	2 ND
20.07	50.97	3 RD
20.27	51.48	5 TH
20.59	52.29	10 TH
20.81	52.86	15 TH
20.99	53.33	20 TH
21.15	53.73	25 TH
21.30	54.10	30 TH
21.44	54.45	35 TH
21.57	54.78	40 TH
21.69	55.10	45 TH
21.82	55.42	50 TH
21.95	55.75	55 TH
22.08	56.07	60 TH
22.21	56.42	65 TH
22.35	56.78	70 TH
22.51	57.17	75 TH
22.68	57.61	80 TH
22.88	58.12	85 TH
23.14	58.76	90 TH
23.50	59.70	95 TH
23.74	60.29	97 TH
23.91	60.72	98 TH
24.16	61.37	99 TH

Mean: 21.84 IN / 55.48 CM
Standard Deviation: 0.98 IN / 2.48 CM
Range: 19.00-25.13 IN / 48.25-63.75 CM

From: Anthropometry of Naval Aviators-1964

APPENDIX B
LIST OF ABBREVIATIONS

LIST OF ABBREVIATIONS

AAA	Anthropometric Accommodation Assessment
CM	Centimeter
CRT	Cathode Ray Tube
DEG	Degree
DEP	Designed Eye Position
E	East
EDD	Electronic Digital Display
FOV	Field of View
g	Acceleration due to gravity
ICS	Intercommunication System
IN	Inches
LBS	Pounds
LCD	Liquid Crystal Display
LED	Light Emitting Diode
LOS	Line of Sight
MIL STD	Military Standard
NATC	Naval Air Test Center
NSRP	Neutral Seat Reference Point
N	North
N/A	Not Applicable
Nz	Force due to acceleration in z-plane
OQR	Operational Quality Rating
OZ	Ounces
S	South
SEC	Seconds
SETD	Systems Engineering Test Directorate
SRP	Seat Reference Point
USNTPS	United States Naval Test Pilot School
W	West

APPENDIX C
SAMPLE DATA CARDS

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CARD NO _____
DATE _____

EVALUATOR

ANTHROPOMETRIC MEASUREMENT DATA

Characteristic	Measurement	Percentile
Sex		N/A
Race		N/A
Stature	IN	%
Weight	LBS	%
Total Sitting Height	IN	%
Sitting Eye Height	IN	%
Shoulder Height	IN	%
Bideltoid Diameter	IN	%
Functional Reach	IN	%
Buttock-to-Leg Length	IN	%
Sitting Knee Height	IN	%
QUALITATIVE COMMENTS:		

Figure C-1
EVALUATOR'S ANTHROPOMETRIC DATA CARD

CARD NO _____
DATE _____

EVALUATOR _____

DESIGNED EYE POSITION

Aircrew Station	
Seat Movement- Total Distance	
Up/Down	IN
Forward / Aft	IN
Tilt / Recline	IN/DEG
Rudder Pedals Full Throw Distance	IN
Forward/Aft Seat Placement	IN
Tilt / Recline Seat Placement	IN/DEG
Difference between Evaluator's Sitting Height and 50th %	(Subtract 31.0) IN
Seat Back Angle	DEG
Correction Distance (Use Table III)	IN
QUALITATIVE COMMENTS:	

Figure C-2
DESIGNED EYE POSITION DATA CARD

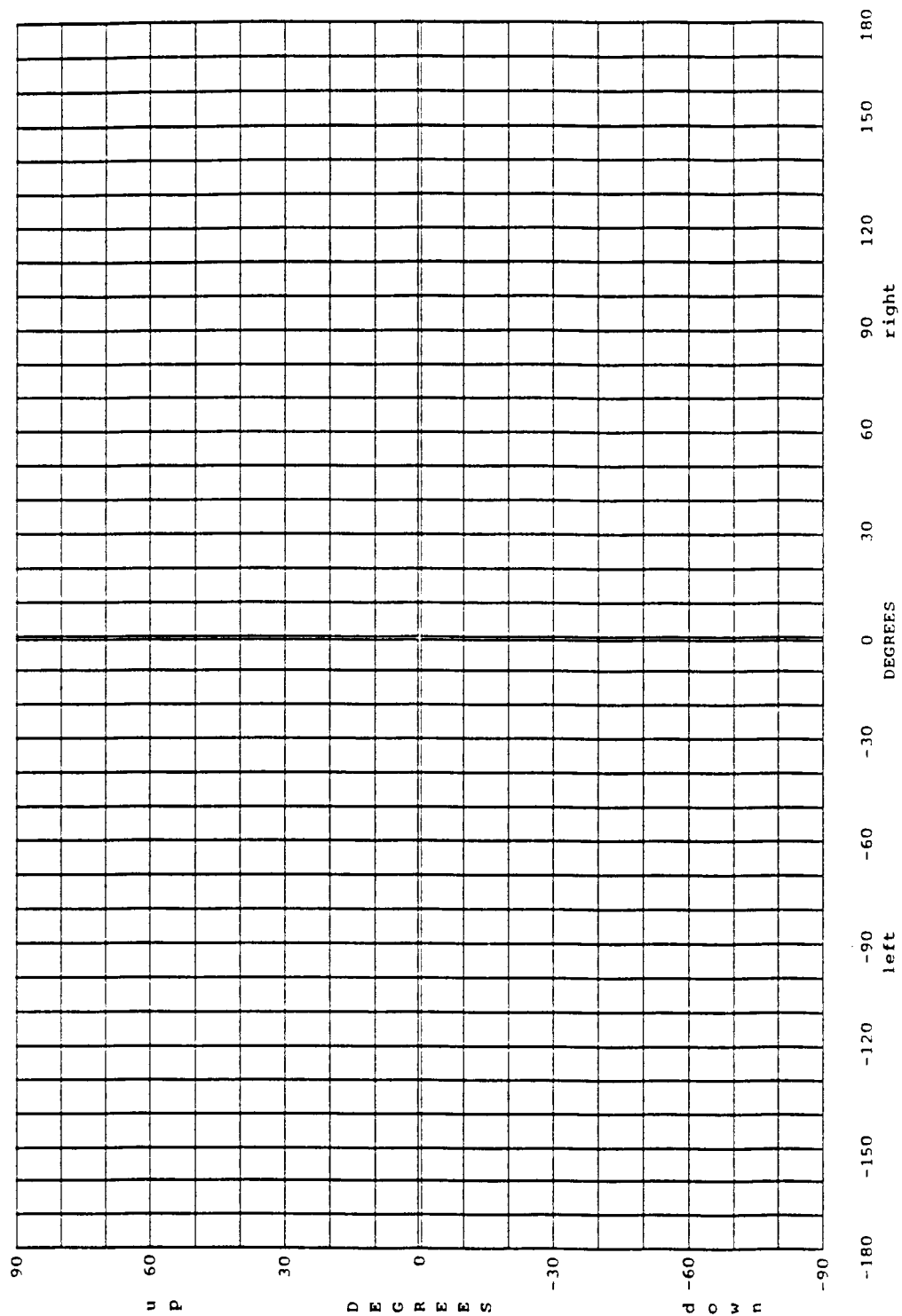
CARD NO _____
DATE _____

EXTERNAL FIELD OF VIEW

List obstructions to External FOV	Determine Degradation to Mission Conduct (include compensation required)
QUALITATIVE COMMENTS:	

Figure C-3
EXTERIOR FIELD OF VIEW DATA CARD

RECTILINEAR GRAPH



TOTAL VISION ENVELOPE PLOT

Figure C-4
EXTERIOR FIELD OF VIEW RECTILINEAR GRAPH

CARD NO _____
DATE _____

INTERNAL FIELD OF VIEW

List obstructed Control or Display	Obstructed by	Determine Degradation to Mission Conduct (include compensation required)
QUALITATIVE COMMENTS:		

Figure C-5
INTERNAL FIELD OF VIEW DATA CARD

CARD NO _____
DATE _____

PRIMARY LINE OF SIGHT

List Controls / Displays within 30 DEG cone of DEP	Critical for Operation? (Yes/No)	Obstruction? (Yes/No) Degradation and Compensation Required
QUALITATIVE COMMENTS: (Include functional placement, frequency of use, relative size, number of items, interlinkage, and importance.)		

Figure C-6
PRIMARY LINE OF SIGHT DATA CARD

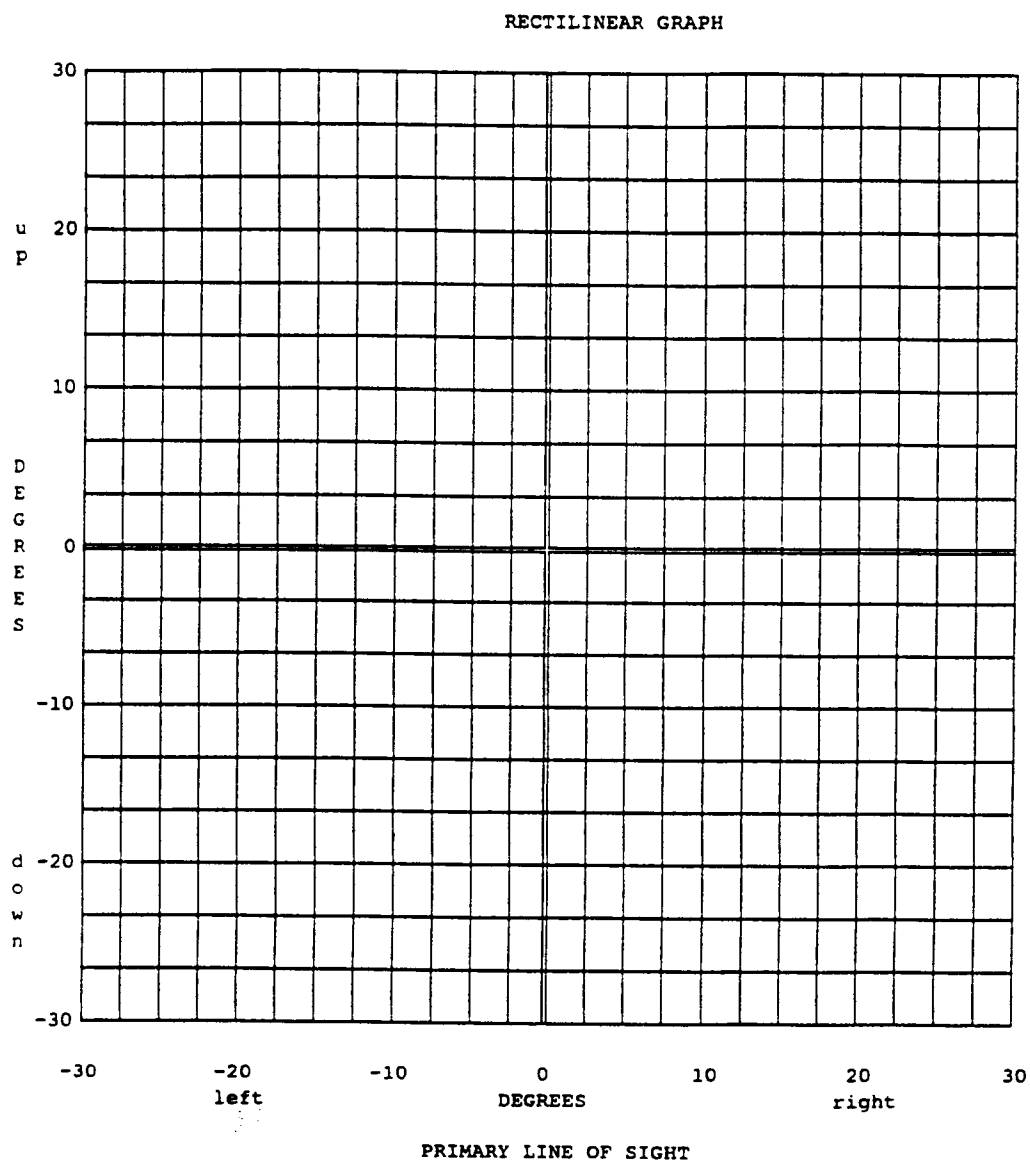


Figure C-7
PRIMARY LINE OF SIGHT RECTILINEAR GRAPH

CARD NO ____-1
DATE _____

CONTROL NAME: _____

CONTROL DESIGN GUIDELINE CONFORMANCE

		OQR
(Sub)System Associated With		
Location of Control		
Describe control's physical characteristics		
What is the control's function with respect to the operation of the aircraft or system?		
What is the control's function with respect to the mission?		
CONTROL REDUNDANCY		
Will the control being inoperative have an adverse effect on the operation of the aircraft or system?	YES no	
Will the control being inoperative have an adverse effect on the mission?	YES no	
Time required to operate	SEC	
Is time required to operate control sufficient?	NO yes	
QUALITATIVE COMMENTS:		

Figure C-8
CONTROL DESIGN GUIDELINE CONFORMANCE DATA CARD NO 1

CARD NO ____-2
DATE _____

CONTROL NAME: _____

CONTROL DESIGN GUIDELINE CONFORMANCE

		OQR
FUNCTIONAL CRITERIA		
Does control's operation conform to population stereotypes?	NO yes	
Does control's operation provide logical response to system operation?	NO yes	
Does control provide for required immediacy of operation throughout its entire range?	NO yes	
Does control provide for degree of precision required for system operation?	NO yes	
Does control range provide for sufficient scope of action or extent of motion demanded?	NO yes	
Force required for operation		
Is the force required to manipulate control satisfactory?	NO yes	
Describe control category (Activation, Discrete Setting, Quantitative, Continuous, Data Entry)		
QUALITATIVE COMMENTS:		

Figure C-9
CONTROL DESIGN GUIDELINE CONFORMANCE DATA CARD NO 2

CARD NO ____-3
DATE _____

CONTROL NAME: _____

CONTROL DESIGN GUIDELINE CONFORMANCE

		OQR
CONTROL LOCATION		
Ascertain frequency of use for control.		
Does frequency of use justify control's location?	NO yes	
Trace operating steps through panel layout. Are there too many crossing or reversing pathways?	YES no	
Does control size correspond with location?	NO yes	
Does the control category complement its placement?	NO yes	
Do the number of controls required for operation correspond with location?	NO yes	
Does control location foster interlinkage with location of other interfacing systems?	NO yes	
Is the aircrew required to visually acquire control prior to operation?	YES no	
QUALITATIVE COMMENTS:		

Figure C-10
CONTROL DESIGN GUIDELINE CONFORMANCE DATA CARD NO 3

CARD NO ____-4
DATE _____

CONTROL NAME: _____

CONTROL DESIGN GUIDELINE CONFORMANCE

		OQR
CODING		
Describe control's coding features:		
Shape, Texture, Size	NO yes	
Location	NO yes	
Operational Use (Control that moves only in certain plane)	NO yes	
Labeling On control or immediately adjacent?	NO yes Control Adjacent	
Is label obstructed by control throughout its operational range?	YES no	
Color	NO yes	
Is coding adequate?	NO yes	
CONTROL TYPE		
(Pushbutton, Toggle, Rotary Selector Knob, Control Knob, Thumbwheel		
Is control type correct match for required functional criteria and category?	NO yes	
QUALITATIVE COMMENTS:		

Figure C-11
CONTROL DESIGN GUIDELINE CONFORMANCE DATA CARD NO 4

CARD NO ____-5
DATE _____

CONTROL NAME: _____

CONTROL DESIGN GUIDELINE CONFORMANCE

		OQR
SIZE		
Is control size appropriate for force required for operation?	NO yes	
Is control size sufficient for finger, thumb, or foot operation?	NO yes	
Is control size suitable for precision required for system operation?	NO yes	
Are controls long enough to allow for easy access and movement when grouped together	NO yes	
Can aircrew reach the control with harness locked?	NO yes	
Can control be reached under all operational and emergency conditions that require its use?	NO yes	
Is control equally accessible with either hand or foot?	NO yes	
Does control allow for use of preferred hand or foot?	NO yes	
QUALITATIVE COMMENTS:		

Figure C-12
CONTROL DESIGN GUIDELINE CONFORMANCE DATA CARD NO 5

CARD NO ____-6
DATE _____

CONTROL NAME: _____

CONTROL DESIGN GUIDELINE CONFORMANCE

		OQR
DESIGN INDUCED ERROR		
Does control design induce errant operation?	YES no	
Can this control be easily confused for another? If so, why? (Improper arrangement or coding.)	YES no	
If the mistaken control is inadvertently operated, what affect will it have on the operation of the aircraft or system?		
If the mistaken control is inadvertently operated, what affect will it have on the mission?		
Is control manipulated in wrong direction?	YES no	
Is control use forgotten. If so, why?	YES no	
Are there any safety problems associated with the control? If so, what?	YES no	
Is control equipped with a guard?	NO yes	
QUALITATIVE COMMENTS:		

Figure C-13
CONTROL DESIGN GUIDELINE CONFORMANCE DATA CARD NO 6

CARD NO ____-7
DATE _____

CONTROL NAME: _____

CONTROL DESIGN GUIDELINE CONFORMANCE

		OQR
MULTIPLE CONTROL IMPLEMENTATION TECHNIQUES		
Number of systems affected by this control?		
Is this control operated by time sharing or combining the control?		
Does limited work space require this implementation?		
Does this implementation impede operation of any specific (sub)system?	YES no	
Determine implementation technique. (Integrated, Stacked, or Multi Function)		
QUALITATIVE COMMENTS:		

Figure C-14
CONTROL DESIGN GUIDELINE CONFORMANCE DATA CARD NO 7

CARD NO __-1
DATE _____

CONTROL NAME: _____

CONTROL LEVERS

		OQR
Is there sufficient distance from adjacent controls to allow for deflection throughout entire range of motion? (If not, what is distance from adjacent controls?)	NO yes	
Is lever coded to promote discrimination from adjacent controls?	NO yes	
Is lever labeled regarding function and direction of motion?	NO yes	
If fine or continuous adjustments are required, is there adequate support for the arm (elbow, forearm, wrist) to assuage fatigue?	NO yes	
Time required for operation.	SEC	
Is time required to operate control sufficient?	NO yes	
Does lever shape promote easy grasping?	NO yes	
Diameter of handle (Recommended diameter 3/4 to 3 IN for finger grasped and 1 1/2 to 3 IN for hand grasped spherical handles.)		
QUALITATIVE COMMENTS:		

Figure C-15
CONTROL LEVERS DATA CARD NO 1

CARD NO ____-2
DATE _____

CONTROL NAME: _____

CONTROL LEVERS

		OQR
Maximum displacement (Recommended maximum movement forward-aft 14 IN and lateral 38 IN.)		
Maximum force required for deflection. (Recommended resistances)		
Joystick - 5 LBS minimum.		
One handed operation (fore- ward-aft axis - 30 LBS maximum 10 IN forward of NSRP, 40 LBS maximum 16 to 24 IN forward of NSRP).		
One handed operation, lateral axis - 20 LBS maximum 10 to 19 IN forward of NSRP.		
Two handed operation, lateral axis - 30 LBS maximum 10 to 19 IN forward of NSRP.		
Is force gradient uniform throughout deflection range?	NO yes	
QUALITATIVE COMMENTS:		

Figure C-16
CONTROL LEVERS DATA CARD NO 2

CARD NO ____-3
DATE _____

CONTROL NAME: _____

CONTROL LEVERS

		OQR
Is lever self centering or does it remain where last positioned?		
Does lever operation conform with expected population stereotypes?	NO yes	
Does lever operation provide logical response to system operation?	NO yes	
Does lever displacement regulate system performance in distance, velocity, or acceleration?		
Is lever sensitivity adequate for control operation?	NO yes	
Center Post Stick		
Does it allow for lateral clearance between legs?	NO yes	
Does stick height interfere with view of displays?	YES no	
Does stick height allow for comfortable posture when gripped?	NO yes	
QUALITATIVE COMMENTS:		

Figure C-17
CONTROL LEVERS DATA CARD NO 3

CARD NO ____-4
DATE _____

CONTROL NAME: _____

CONTROL LEVERS

		OQR
Side Stick Controller		
Determine forward-aft plane displacement in DEG from center. (Recommended is + or - 30 DEG.)		
Determine lateral plane displacement in degrees from center. (Recommended is + or - 45 DEG.)		
Wheel Type Controller		
Are handles comfortably spaced to allow for maximum application of pull and rotation force?	NO yes	
Is controller mounted to allow sufficient clearance for elbows when stick is at full aft deflection?	NO yes	
Determine rotation movement from center. (Recommended is + or - 40 DEG and not to interfere with the knees.)		
Is forward-aft displacement in a straight line or arc? (Straight line is recommended for easier force application than arc pattern.)		
QUALITATIVE COMMENTS:		

Figure C-18
CONTROL LEVERS DATA CARD NO 4

CARD NO -1
DATE

CONTROL NAME:

ROTARY SELECTOR SWITCHES

		OQR
Number of discrete settings (Recommended minimum 3, maximum 24.)		
Is knob shaped to easily facilitate grasping by fingers?	NO yes	
Does shape or size coding inhibit grasping of control?	YES no	
Is coding applied where a group of rotary selector switches is used?	NO yes	
Is knob equipped with distinct pointer?	NO yes	
Does position of the pointer knob relative to the scale or label promote minimum parallax?	NO yes	
Does control use fixed scale with moving pointer? If not, what is justification for moving scale with fixed pointer?		
QUALITATIVE COMMENTS:		

Figure C-19
ROTARY SELECTOR SWITCHES DATA CARD NO 1

CONTROL NAME:

QQR

Is pointer width sufficient?	NO yes	
Displacement between adjacent settings (Recommended minimum 15 DEG for visual positioning and 30 DEG for non visual positioning.)		DEG
Force requirements for adjustments (Recommended 12 to 48 OZ.)		OZ
Does minimum force required for adjustment prevent inadvertent movement?	NO yes	
Does switch deflection provide operator with tactile click as feedback that new switch setting has been achieved?	NO yes	
Time required for operation		SEC
Is time required to operate control sufficient?	NO yes	
QUALITATIVE COMMENTS:		

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CARD NO ____-1
DATE _____

CONTROL NAME: _____

CONTROL SWITCHES

		OQR
Number of discrete settings (Recommended minimum 2, maximum 3.)		
Is switch hand or foot operated?		
Distance from adjacent controls. Is it sufficient to impede errant control?	NO IN yes	
Is switch shaped to easily facilitate grasping by fingers if designed for hand operation?	NO yes	
Does shape or size coding impede operation?	YES no	
Is coding applied where a group of switches are used?	NO yes	
Is switch equipped with a distinct pointer or indicator?	NO yes	
Are switch positions labeled?	NO yes	
Are switch settings relative to the labels positioned to promote minimum parallax?	NO yes	
Time required for operation		SEC
Is time required to operate control sufficient?	NO yes	

Figure C-21
CONTROL SWITCHES DATA CARD NO 1

CARD NO __-2
DATE _____

CONTROL NAME: _____

CONTROL SWITCHES

		OQR
If the switch is a push-button, is surface concaved to provide a high degree of frictional resistance to prevent slipping?	NO yes	
Force requirements for adjustments (Recommended between 10 to 40 OZ for hand operation and 10 to 20 LBS for foot operation.)		
Does minimum force required for adjustment prevent inadvertent movement?	NO yes	
Does switch deflection provide operator with tactile click as feedback that new switch setting has been achieved?	NO yes	
Switch or Pushbutton displacement (recommended 1/2 to 3/4 IN for hand, 2 1/2 IN maximum for ankle flexion operation, 4 IN maximum for leg movement.)		IN
Are toggle switches oriented in vertical position with the up positioning representing ON and the down position representing OFF.	NO yes	
QUALITATIVE COMMENTS:		

Figure C-22
CONTROL SWITCHES DATA CARD NO 2

CARD NO ____-1
DATE _____

CONTROL NAME: _____

DATA ENTRY KEYBOARD CONTROLS

		OQR
Type of data entry (numeric, alphabetic, both, or other)?		
Number of individual keys.		
Are keys distributed in a line-abreast or in a matrix?		
Are keys arranged in a logical sequence?	NO yes	
Does keyboard arrangement conform with expected population stereotypes?	NO yes	
Does keyboard arrangement facilitate low control error rate?	NO yes	
Does keyboard distribution allow for one or two hand operation?		
If keyboard allows for one handed operation, is keyboard equally accessible by either hand?	NO yes	
Are all the keys within reach of hand without significant movement of the entire arm?	NO yes	
QUALITATIVE COMMENTS:		

Figure C-23
DATA ENTRY KEYBOARD CONTROL DATA CARD NO 1

CARD NO ____-2
DATE _____

CONTROL NAME: _____

DATA ENTRY KEYBOARD CONTROLS

		OQR
Does keyboard possess backspace capability?	NO yes	
Does keyboard possess capability to clear entire data sequences prior to entry?	NO yes	
Are all keys same size, color, and shape?		
If all the keys are not similar, is the coding method effective in distinguishing individual keys?	NO yes	
Is texture coding used to allow fingers to find reference keys?	NO yes	
Are keys labeled? If so, are labels obscured by fingers during operation?	NO yes YES no	
Time required for nominal data entry?		SEC
Is time required to operate keyboard sufficient?	NO yes	
QUALITATIVE COMMENTS:		

Figure C-24
DATA ENTRY KEYBOARD CONTROL DATA CARD NO 2

CARD NO ____-1
DATE _____

DISPLAY NAME: _____

DISPLAY DESIGN GUIDELINE CONFORMANCE

		OQR
(Sub)system Associated With		
Display Location		
Describe Display's Physical Characteristics.		
Describe nature of variable or function to be displayed. (Value, time rate of change, or frequency rate of change.)		
Is display's feedback to aircrew unambiguous?	YES no	
What is the display's function with respect to the operation of the aircraft or system?		
What is the display's function with respect to the mission?		
What is the effect to the aircraft or system if the display is inoperative?		
What is the effect to the mission if the display is inoperative?		
QUALITATIVE COMMENTS: 		

Figure C-25
DISPLAY DESIGN GUIDELINE CONFORMANCE DATA CARD NO 1

CARD NO __-2
DATE _____

DISPLAY NAME: _____

DISPLAY DESIGN GUIDELINE CONFORMANCE

		OQR
Is the aircrew provided with an indication that the display is inoperative?	NO yes	
Does the display conform to population stereotypes?	NO yes	
Time required to read or acknowledge display?	SEC	
Is time required to read or acknowledge displayed information sufficient?	NO yes	
Define display precision classification. (Examples: representational, qualitative, psuedoquantitative, or quantitative.)		
Define Display Information Classification. (Examples: real, artificial, static, or dynamic.)		
Do classifications support system feedback requirements?	NO yes	
Define sense display targets? (Visual, auditory, or tactile)		
QUALITATIVE COMMENTS:		

Figure C-26
DISPLAY DESIGN GUIDELINE CONFORMANCE DATA CARD NO 2

CARD NO ____-3
DATE _____

DISPLAY NAME: _____

DISPLAY DESIGN GUIDELINE CONFORMANCE

		OQR
FUNCTIONAL CRITERIA		
Define frequency of use for display.		
Does display reflect relevant changes in system activity?	NO yes	
Is minimum accuracy presentation displayed sufficient?	NO yes	
Is minimum system change required to initiate a display change sufficient?	NO yes	
Define total range of variables or functions.		
Determine maximum speed of information transfer.		
Is maximum equipment error rate acceptable?	NO yes	
Does display design induce errant operation?	YES no	
Can another display be mistaken for test display?	YES no	
QUALITATIVE COMMENTS:		

Figure C-27
DISPLAY DESIGN GUIDELINE CONFORMANCE DATA CARD NO 3

CARD NO ____-4
DATE _____

DISPLAY NAME: _____

DISPLAY DESIGN GUIDELINE CONFORMANCE

		OQR
Does mistaken display have same physical characteristics as the test display?	YES no	
If mistaken display is used, what effect will it have on the aircraft or system?		
If mistaken display is used, what effect will it have on the mission?		
Is display use forgotten? If so, why?	YES no	
Are there any safety problems associated with the display? If so, what?	YES no	
CONTROL ASSOCIATION		
Is the display located as close as practicable to the associated control?	NO yes	
Does display obscure the use of the associated control(s)?	YES no	
Do any associated controls obscure use of the display?	YES no	
QUALITATIVE COMMENTS:		

Figure C-28
DISPLAY DESIGN GUIDELINE CONFORMANCE DATA CARD NO 4

CARD NO ____-5
DATE _____

DISPLAY NAME:

DISPLAY DESIGN GUIDELINE CONFORMANCE

		OQR
CODING		
Does the display use coding to assist distinguishing it from other displays? If so, what?	NO yes	
Does the coding target the same sense as the display or another sense?		
Does the display presentation use coding to assist distinguishing the data transferred? If so, what?	NO yes	
ENVIRONMENTAL EFFECTS		
Is display use impaired by aircraft motion?	YES no	
Is display use impaired by high g flight?	YES no	
Is display use impaired by aircraft vibration?	YES no	
QUALITATIVE COMMENTS:		

Figure C-29
DISPLAY DESIGN GUIDELINE CONFORMANCE DATA CARD NO 5

CARD NO ____-6
DATE _____

DISPLAY NAME:

DISPLAY DESIGN GUIDELINE CONFORMANCE

		OQR
MULTIPLE USE DISPLAY IMPLEMENTATION TECHNIQUES		
Number of systems affected by this display.		
Is this display operated by time sharing or combining the display?		
Does limited work space require this implementation?	NO yes	
Does this implementation impede operation of any specific (sub)systems?	YES no	
QUALITATIVE COMMENTS:		

Figure C-30
DISPLAY DESIGN GUIDELINE CONFORMANCE DATA CARD NO 6

CARD NO ____-1
DATE _____

DISPLAY NAME: _____

TACTILE OR AUDITORY
DISPLAY DESIGN GUIDELINE CONFORMANCE

		OQR
Does this display attract aircrew's attention when operated?	NO yes	
Is information passed simple in format?	NO yes	
Is information passed short in format?	NO yes	
Is information passed referred to later?	NO yes	
Does information deal with events in time?	NO yes	
Does information call for immediate action?	NO yes	
Does use of this display assist in not over-burdening aircrew's visual demands?	NO yes	
Is the aircrew station too bright or is dark adaptation necessary?	NO yes	
Does display provide sufficient information for immediate action?	NO yes	
Does displayed information require aircrew to acquire additional feedback prior to initiating the desired response?	YES no	

Figure C-31
TACTILE OR AUDITORY DISPLAY DATA CARD NO 1

CARD NO ____-2
DATE _____

DISPLAY NAME: _____

TACTILE OR AUDITORY
DISPLAY DESIGN GUIDELINE CONFORMANCE

		OQR
AUDITORY		
Is information passed as tone or speech?		
Is volume controllable?	NO yes	
Is display information masked by aircraft noise? (Engines, airstream, or ordnance delivery.)	YES no	
Does display information override radio or ICS calls?		
TACTILE		
Is display kinesthetic motion masked by normal aircraft vibration?	YES no	
Is amplitude of kinesthetic motion controllable?	NO yes	
QUALITATIVE COMMENTS:		

Figure C-32
TACTILE OR AUDITORY DISPLAY DATA CARD NO 2

CARD NO -3
DATE

DISPLAY NAME:

TACTILE OR AUDITORY DISPLAY DESIGN GUIDELINE CONFORMANCE

		OQR
MULTIPLE INTEGRATION TECHNIQUES		
Does this display transmit single or multiple types of information?		
If multiple, are each type of data specific, discrim- inable, and unambiguous?	NO yes	
QUALITATIVE COMMENTS:		

Figure C-33
TACTILE OR AUDITORY DISPLAY DATA CARD NO 3

CARD NO __-1
DATE _____

DISPLAY NAME:

VISUAL DISPLAY DESIGN GUIDELINE CONFORMANCE

		OQR
Determine distance between display and DEP.	IN	
Does display location match its priority?	NO yes	
Is display size sufficiently large to quickly ascertain information presented?	NO yes	
Is display mounted perpendicular to aircrew's line of sight?	NO yes	
Does display location produce excessive parallax?	YES no	
Are display markings legible?	NO yes	
Does this display attract aircrew's attention when operated?	NO yes	
Is information passed referred to later?	NO yes	
Does information deal with location in space?	NO yes	
QUALITATIVE COMMENTS:		

Figure C-34
VISUAL DISPLAY DATA CARD NO 1

CARD NO ____-2
DATE _____

DISPLAY NAME: _____

VISUAL DISPLAY DESIGN GUIDELINE CONFORMANCE

		QQR
Does use of this display assist in not over-burdening aircrew's auditory or tactile demands?	NO yes	
Is visual display used since crew station is too noisy or subject to too much vibration?	NO yes	
Does display content provide sufficient information for immediate action?	NO yes	
Does displayed information require aircrew to acquire additional feedback prior to initiating the required or desired response?	YES no	
Is displayed precision optimized to reduce aircrew fatigue and mental stress?	NO yes	
Does displayed format interfere with established habit patterns?	YES no	
Are redundancy transmission methods to ensure feedback is obtained?	NO yes	
QUALITATIVE COMMENTS: 		

Figure C-35
VISUAL DISPLAY DATA CARD NO 2

CARD NO ____-3
DATE _____

DISPLAY NAME: _____

VISUAL DISPLAY DESIGN GUIDELINE CONFORMANCE

		OQR
CODING		
Define display coding schemes? (color, shape, location, or size.)		
Does coding scheme act as non-redundant, partial redundant, or total redundant means to distinguish displayed feedback items?	NON REDUNDANT partial redundant total redundant	
MULTIPLE DISPLAYS		
Are multiple displays grouped functionally?	NO yes	
Are multiple displays located in a logical order?	NO yes	
Does the use of multiple displays aid system feedback?	NO yes	
QUALITATIVE COMMENTS:		

Figure C-36
VISUAL DISPLAY DATA CARD NO 3

DISPLAY NAME:

QQR

Is color coding used?	NO yes	
Does color coding scheme provide for redundancy?	Total, Partial Non-redundant	
Is application of color coding located within the aircrew's primary LOS?	NO yes	
Are the expected population of users screened for color vision deficiencies?	NO yes	
Does use of color coding aid to draw aircrew attention from other visual tasks?	NO yes	
Does use of color coding aid aircrew in search for relevant information?	NO yes	
Does use of color coding aid aid when high density information is displayed in random format?	NO yes	
Does use of color aid in qualitative coding?	NO yes	
QUALITATIVE COMMENTS: 		

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CARD NO __-2
DATE _____

DISPLAY NAME:

COLOR CODING DESIGN GUIDELINE CONFORMANCE

		OQR
Does color appear to be used in random fashion simply to brighten the display?	YES no	
Does use of color have distracting effects?	YES no	
Is excessive color used?	YES no	
Is use of color logically related to aircrew task?	NO yes	
Do the meanings of the colors conform to expected population stereotypes?	NO yes	
Determine number of colors used in the display?		
Is number of colors used sufficient (recommended maximum 4 for operational and 7 when absolute color judgement is required.)	NO yes	
Does use of color have sufficient symbol to back-ground contrast?	NO yes	
Is color displayed pure?	NO yes	
QUALITATIVE COMMENTS: 		

Figure C-38
COLOR CODING DISPLAY DATA CARD NO 2

CARD NO ____-1
DATE _____

DISPLAY NAME:

DISPLAY ILLUMINATION DESIGN GUIDELINE CONFORMANCE

		OQR
GENERAL		
Is crew station exposed to outside ambient light or artificial lighting?		
Is display augmented with illumination capabilities?	NO yes	
Is illumination adequate for the task?	NO yes	
Is display illumination adjustable?	NO yes	
Is range of display illumination sufficient for all ambient lighting conditions?	NO yes	
Does display illumination attempt to outshine the sun?	YES no	
Does illumination of attention gathering light distract aircrew to point of impairing visual tasks?	YES no	
QUALITATIVE COMMENTS:		

Figure C-39
DISPLAY ILLUMINATION TECHNIQUES DATA CARD NO 1

CARD NO _____-2
DATE _____

DISPLAY NAME:

DISPLAY ILLUMINATION DESIGN GUIDELINE CONFORMANCE

		OQR
Is illumination equally distributed and balanced?	NO yes	
Are similarly grouped displays lighted at the same intensity?	NO yes	
Are display functional groups regulated by a single control?	NO yes	
Does illumination provide adequate color contrast and quality?	NO yes	
Does illumination provide the aircrew with sufficient flexibility for all required tasks?	NO yes	
Are the aircrew's eyes exposed to the light source?	YES no	
Are thunderstorm lights provided	NO yes	
QUALITATIVE COMMENTS:		

Figure C-40
DISPLAY ILLUMINATION TECHNIQUES DATA CARD NO 2

CARD NO ____-3
DATE _____

DISPLAY NAME: _____

DISPLAY ILLUMINATION DESIGN GUIDELINE CONFORMANCE

		OQR
NIGHT LIGHTING		
Is the display legible as illuminated?	NO yes	
Does display illumination allow for easy transition from display to outside?	NO yes	
Is illumination confined to display and associated controls? (Not to adjacent panels.)	NO yes	
Does display use light or dark display background?		
Is aircrew required to make color discrimination in low light conditions?	YES no	
QUALITATIVE COMMENTS:		

Figure C-41
DISPLAY ILLUMINATION TECHNIQUES DATA CARD NO 3

CARD NO -4

DISPLAY ILLUMINATION DESIGN GUIDELINE CONFORMANCE

		OQR
Is display surface color discernible under different ambient light conditions?	NO yes	
Is lighting uniform across display?	NO yes	
Does display illumination impair dark adaptation?	YES no	
Does display induce eye strain?	YES no	
Does use of back lit displays result in aircrew loss of frame of reference for the panel? (Does it float?)	YES no	
Does lighting impair aircrew from performing monitor tasks?	YES no	
What color light is used for night illumination?		
Is aircrew provided with capability to select light color used for illumination?	NO yes	
QUALITATIVE COMMENTS:		

Figure C-42
DISPLAY ILLUMINATION TECHNIQUES DATA CARD NO 4

CARD NO ____-5
DATE _____

DISPLAY NAME: _____

DISPLAY ILLUMINATION DESIGN GUIDELINE CONFORMANCE

		OQR
RED LIGHTING		
Is aircrew required to continuously view outside the cockpit?	NO yes	
WHITE LIGHTING		
Are aircrew visual tasks confined to within the cockpit?	NO yes	
GLARE		
Is there glare reflected from the display glass or adjacent panels?	YES no	
Is the display adequately shielded from ambient light?	NO yes	
Does canopy or windshield reflect display illumination light to aircrew?	YES no	
Is flat glass on display used to minimize reflectance?	NO yes	
QUALITATIVE COMMENTS:		

Figure C-43
DISPLAY ILLUMINATION TECHNIQUES DATA CARD NO 5

CARD NO -6
DATE

DISPLAY NAME:

DISPLAY ILLUMINATION DESIGN GUIDELINE CONFORMANCE

		OQR
Is glare shield used to block reflected light?	NO yes	
Do dark or matt surfaces surround displays to minimize glare?	NO yes	
Are artificial lights or lighted surfaces positioned such that reflection is not directed back to the aircrew?	NO yes	
Is the minimum illumination level achieved while maintaining adequate visibility of the display	NO yes	
QUALITATIVE COMMENTS:		

Figure C-44
DISPLAY ILLUMINATION TECHNIQUES DATA CARD NO 6

CARD NO -1
DATE

DISPLAY NAME:

LABEL DISPLAY DESIGN GUIDELINE CONFORMANCE

		OQR
Are size and print legible?	NO yes	
Is the label easily read under all expected lighting conditions?	NO yes	
Are trade names or other irrelevant information displayed?	YES no	
Is label obscured by adjacent controls or displays?	YES no	
Does label obscure other needed information?	YES no	
If letter characters are used, does use of upper or lower case characters aid pilot in reading labels?	NO yes	
Is each control labeled as to function?	NO yes	
If label is abbreviated, is it consistent?	NO yes	
QUALITATIVE COMMENTS:		

Figure C-45
LABEL DISPLAY DATA CARD NO 1

CARD NO ____-2
DATE _____

DISPLAY NAME: _____

LABEL DISPLAY DESIGN GUIDELINE CONFORMANCE

		OQR
Is the label placed immediately adjacent to (preferably above) the identified control or display?	NO yes	
Is the label placed to preclude errant association of the label with a different control or display?	NO yes	
Is the label placement within functional groups consistent?	NO yes	
Is the label name brief?	NO yes	
Does the label clearly indicate function of the control or display?	NO yes	
Does the label avoid highly similar names?	NO yes	
Are abbreviations used for the label clearly understood?	NO yes	
Is the label easily distinguishable from the background?	NO yes	
QUALITATIVE COMMENTS:		

Figure C-46
LABEL DISPLAY DATA CARD NO 2

CARD NO ____-1
DATE _____

DISPLAY NAME: _____

ALERT LIGHT DISPLAY DESIGN GUIDELINE CONFORMANCE

		OQR
Does illumination of this light indicate a condition which will adversely impact the safety of flight or aircrew? (This may require simulation.)	NO yes	
How long does it take for the aircrew to notice the alert light once illuminated?	SEC	
Is the time required to draw the aircrew's attention to the illuminated alert light acceptable?	NO yes	
DETECTABILITY		
Is alert light size sufficient to draw aircrew's attention?	NO yes	
Is amount of light emitted and duration of exposure sufficient to draw aircrew's attention?	NO yes	
Is the alert light augmented with a Master Caution Alert?	NO yes	
Is the alert light system augmented by targeting other senses as a means to draw aircrew's attention? (aural tone or tactile feedback)	NO yes	
QUALITATIVE COMMENTS:		

Figure C-47
ALERT LIGHT DISPLAY DATA CARD NO 1

DISPLAY NAME:

ALERT LIGHT DISPLAY DESIGN GUIDELINE CONFORMANCE

		OQR
DISPLAYED INFORMATION		
Does the light indicate a warning, caution, or advisory condition to the aircrew?	NO yes	
Are the different categories of alert lights coded to provide easy distinction between a warning, caution, or advisory condition?	NO yes	
Are the different categories of alert lights functionally grouped based upon the condition of the severity?	NO yes	
Are the most important alert lights prominently located within the aircrew's primary line of sight?	NO yes	
Is the alert light illuminated by a steady light?		
QUALITATIVE COMMENTS:		

Figure C-48
ALERT LIGHT DISPLAY DATA CARD NO 2

CARD NO ____-3
DATE _____

DISPLAY NAME: _____

ALERT LIGHT DISPLAY DESIGN GUIDELINE CONFORMANCE

		OQR
Do alert light colors conform to expected population stereotypes? (Red for emergency, warning, caution alerts and amber or green light for advisory alerts.)	NO yes	
Is spacing between adjacent lights sufficient so as not to induce confusion in reading display?	NO yes	
Are alert lights equipped with the means to check operation? (e.g., press-to-test or master lights test)	NO yes	
MASTER CAUTION		
Is the Master Caution light located within the aircrew's primary line of sight?	NO yes	
Is the Master Caution light located separately from other system status and alert lights?	NO yes	
Is the Master Caution light's size prominent compared to other alert lights?	NO yes	
QUALITATIVE COMMENTS:		

Figure C-49
ALERT LIGHT DISPLAY DATA CARD NO 3

CARD NO ____-4
DATE _____

DISPLAY NAME: _____

ALERT LIGHT DISPLAY DESIGN GUIDELINE CONFORMANCE

		QQR
Does the Master Caution light use a flasher to aid in gaining the immediate attention of the aircrew?	NO yes	
What is the number of flashes per second? (recommended 3 to 10, 4 optimum.)	/SEC	
Is flash rate adequate?	NO yes	
Is the Master Caution light augmented with another means to gain aircrew's attention?	NO yes	
Is Master Caution light illuminated to indicate that one or more specific warning or caution lights has been actuated?	NO yes	
Is the Master Caution light illuminated to indicate that one or more specific advisory lights has been actuated?	NO yes	
Can Master Caution light be extinguished by aircrew?	NO yes	
If Master Caution light is extinguished by aircrew, does it illuminate again if a separate alert signal is subsequently illuminated?	NO yes	
QUALITATIVE COMMENTS:		

Figure C-50
ALERT LIGHT DISPLAY DATA CARD NO 4

DISPLAY NAME:

OQR

PURSUIT DISPLAY		
Does display provide two separate indices, one for desired performance, and the other for actual performance?	NO yes	
Are the displayed indices distinguishable as to their purpose?	NO yes	
Does the displayed information provide the aircrew with unambiguous feedback to manipulate system performance to required standards?	NO yes	
Is actual performance index sensitivity adequate to maintain system performance within required limits?	NO yes	
Is desired performance index setting adjustable? If not, does this inhibit system operation?	NO yes YES no	
QUALITATIVE COMMENTS:		

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DISPLAY NAME:

REFERENCE DISPLAY DESIGN GUIDELINE CONFORMANCE

		OQR
COMPENSATORY DISPLAY	NO yes	
Does display provide a performance index and a fixed reference point?		
Does the displayed information provide the aircrew with unambiguous feedback as to the difference between desired and actual performance, allowing the aircrew to manipulate system performance to required standards limits?	NO yes	
Is actual performance index sensitivity adequate to maintain system performance within required limits?	NO yes	
QUALITATIVE COMMENTS:		

Figure C-52
REFERENCE DISPLAY DATA CARD NO 2

CARD NO ____-3
DATE _____

DISPLAY NAME:

REFERENCE DISPLAY DESIGN GUIDELINE CONFORMANCE

		OQR
DISPLAY ORIENTATION		
Inside-Out		
Does the display fix the aircraft as the reference point and adjust the display to represent the aircrew's perspective?	NO yes	
Does the display support a visual scan in which the aircrew may switch from sighting the instrument to an outside view?	NO yes	
Outside-In		
Does the display use an external reference and adjust the display to represent the airplane orientation with respect to the given perspective?	NO yes	
Does the display support system feedback where the FOV from the aircrew station prohibits sight outside the aircraft?	NO yes	
QUALITATIVE COMMENTS:		

Figure C-53
REFERENCE DISPLAY DATA CARD NO 3

CARD NO ____-1
DATE _____

DISPLAY NAME: _____

GAUGE OR DIAL DESIGN GUIDELINE CONFORMANCE

		OQR
Diameter of Instrument	IN	
Is dial face deeply inset in panel such that bezel tends to limit viewing angle?	YES no	
SCALE		
Range of values		
Does range of values on scale support feedback requirements?	NO yes	
Does scale start at zero?	NO yes	
Determine number of graduation marks.		
Does instrument size support number of scale graduation marks?	NO yes	
Determine interval of graduation marks. (Recommended is 1, 5, or 10.)		
QUALITATIVE COMMENTS:		

Figure C-54
GAUGE OR DIAL DISPLAY DATA CARD NO 1

CARD NO ____-2
DATE _____

DISPLAY NAME:

GAUGE OR DIAL DESIGN GUIDELINE CONFORMANCE

		OQR
Does scale graduation support required level of accuracy?	NO yes	
Determine scale markings. (Dots, thick marks, and marks joined by heavy base line are not recommended.)		
Is scale marking uniform?	NO yes	
Is scale spacing sufficient to allow aircrew to discriminate between one scale mark and another?	NO yes	
Are scale numbers placed so as to minimize confusion in reading the instrument?	NO yes	
Is scale supplemented with color coding to aid in feedback transfer?	NO yes	
Does the scale markings use two different sizes for major and minor divisions to aid in feedback transfer?	NO yes	
QUALITATIVE COMMENTS: 		

Figure C-55
GAUGE OR DISPLAY DATA CARD NO 2

CARD NO -3
DATE

DISPLAY NAME:

GAUGE OR DIAL DESIGN GUIDELINE CONFORMANCE

		OQR
Are the number of minor or intermediate scale markings nine or less?	NO yes	
Are marking sizes large enough to be distinguished?	NO yes	
(FOR ROUND DIALS) Are scale markings symmetrically placed around dial?	NO yes	
When both positive and negative values are displayed, is the zero value placed at the 12 or 9 o'clock position?	NO yes	
Is scale break width sufficient to preclude errant interpretation of non multi-revolutionary displays?	NO yes	
QUALITATIVE COMMENTS:		

Figure C-56
GAUGE OR DIAL DISPLAY DATA CARD NO 3

CARD NO ____-4
DATE _____

DISPLAY NAME: _____

GAUGE OR DIAL DESIGN GUIDELINE CONFORMANCE

		OQR
Are scale numbers oriented upright rather than slanted or turned on their side?	NO yes	
Are scale numerals large enough to be easily read?	NO yes	
(FOR LINEAR SCALES) Are numerals placed on the side of the graduation marks away from the pointer to avoid having the numbers covered by the pointer?	NO yes	
POINTER		
Is the relationship between the pointer and scale easily distinguishable by the aircrew?	NO yes	
Does pointer movement conform with expected population stereotypes? (Increases shown as deflection upward, to the right, or counterclockwise.)	NO yes	
QUALITATIVE COMMENTS: 		

Figure C-57
GAUGE OR DIAL DISPLAY DATA CARD NO 4

CARD NO ____-5
DATE _____

DISPLAY NAME:

GAUGE OR DIAL DESIGN GUIDELINE CONFORMANCE

		OQR
Is there more than one pointer per instrument? If so, does it induce errant reading?	YES no	
	YES no	
Does pointer's length reach scale markings without obscuring them?	NO	
	yes	
Does pointer's width obscure scale numerals?	YES	
	no	
Is pointer shape simple or artistic?	ARTISTIC	
	simple	
Is width of pointer same as smallest scale graduation mark?	NO	
	yes	
Is pointer color easily distinguishable from instrument face?	NO	
	yes	
Is pointer color easily distinguishable from scale markings and numerals?	NO	
	yes	
Is pointer equipped with a tail to aid in distinguishing pointer movement?	NO	
	yes	
QUALITATIVE COMMENTS: 		

Figure C-58
GAUGE OR DIAL DISPLAY DATA CARD NO 5

CARD NO ____-6
DATE _____

DISPLAY NAME: _____

GAUGE OR DIAL DESIGN GUIDELINE CONFORMANCE

		OQR
Is tail's length less than 1/3 length of pointer?	NO yes	
Is tail's color easily distinguishable from pointer, instrument face, scale markings, and scale numerals?	NO yes	
For linear scales, is the located at the 12 o'clock position for left-to-right directional information and at the 9 o'clock position for the up-down directional information?	NO yes	
MULTIPLE POINTERS ON THE SAME INSTRUMENT		
Is this convention necessary?	NO yes	
Is there a pointer visibility or discrimination problem?	YES no	
Are pointers (and tails) the same color, size, or shape?	NO yes	
Does each pointer have it's separate scale for reference?	NO yes	
Is there any difficulty determining which scale the pointer is using as a reference?	YES no	
QUALITATIVE COMMENTS:		

Figure C-59
GAUGE OR DIAL DISPLAY DATA CARD NO 6

CARD NO -7
DATE

DISPLAY NAME:

GAUGE OR DIAL DESIGN GUIDELINE CONFORMANCE

		OQR
MULTIPLE INSTRUMENTS		
Do display indications reside generally in same relative place on the instruments to aid check-reading task?	NO yes	
Are displays arranged to be read in proper sequence? (left-to-right or top-to-bottom)	NO yes	
Are multiple controls placed in similar or relative manner as the instruments?	NO yes	
QUALITATIVE COMMENTS:		

Figure C-60
GAUGE OR DIAL DISPLAY DATA CARD NO 7

CARD NO -1
DATE

DISPLAY NAME:

QUANTITATIVE READOUT
DISPLAY DESIGN GUIDELINE CONFORMANCE

		OQR
Is display used for presenting large ranges of quantitative data where continuous trend indications are not necessary?	NO yes	
Does displayed information require quick and precise reading?	NO yes	
Is displayed data in analog or digital format?	Analog Digital	
If analog instrument, does displayed accuracy meet precision requirements?	NO yes	
If digital is used, is displayed format easily assimilated?	NO yes	
Are numerical characters legible? (Consideration should be given to character style, height-to-width ratio, stroke width, and figure contrast.)	NO yes	
QUANTITATIVE READOUTS:		

Figure C-61
QUANTITATIVE READOUT DISPLAY DATA CARD NO 1

CARD NO ____-2
DATE _____

DISPLAY NAME:

QUANTITATIVE READOUT
DISPLAY DESIGN GUIDELINE CONFORMANCE

		OQR
Does display allow for numbers to be read left-to-right?	NO yes	
Do numbers change by snap action rather than continuous movement?	NO yes	
Does display use mechanical drum or electronic pulsed counter (LED or LCD)?	NO yes	
MECHANICAL DRUM		
Is movement of mechanical drum upward to show increase in value?	NO yes	
Are mechanical drums digits widely separated (except for use of comma or decimal point)?	YES no	
QUALITATIVE COMMENTS:		

Figure C-62
QUANTITATIVE READOUT DISPLAY DATA CARD NO 2

CARD NO ____-3
DATE _____

DISPLAY NAME: _____

QUANTITATIVE READOUT
DISPLAY DESIGN GUIDELINE CONFORMANCE

		OQR
ELECTRONIC PULSED COUNTERS		
Are displays free of brightness variations?	NO yes	
Are displays free of jitter and flicker?	NO yes	
Does display provide sufficient contrast between numeral display and background?	NO yes	
Are counters mounted close to panel surface to maximize viewing angle and minimize parallax errors and shadows?	NO yes	
Does update rate allow aircrew to read numbers consecutively? (Recommended rate not faster than two updates per second.)	NO yes	
Does display automatically reset after use?	NO yes	
QUANTITATIVE COMMENTS:		

Figure C-63
QUANTITATIVE READOUT DISPLAY DATA CARD NO 3

CARD NO ____-1
DATE _____

DISPLAY NAME: _____

ELECTRONIC DIGITAL DISPLAY
DESIGN GUIDELINE CONFORMANCE

		OQR
Does use of an EDD support task requirements?	NO yes	
Is aircrew required to transpose, compute, interpolate, or mentally translate displayed data into other units, numbers, bases, or languages?	YES no	
Determine display refresh rate? (Recommended maximum 5/SEC for alphanumeric strings and 2/SEC for real time displays)	 /SEC	
Is refresh rate sufficient for task demands?	NO yes	
DISPLAY DENSITY		
What percentage of display area is used for data presentation (Recommended maximum 60 %.)		
Is aircrew provided with the capability to control display density (i.e., clutter reject)	NO yes	
QUALITATIVE COMMENTS: 		

Figure C-64
ELECTRONIC DIGITAL DISPLAY DATA CARD NO 1

CARD NO ____-2
DATE _____

DISPLAY NAME: _____

ELECTRONIC DIGITAL DISPLAY
DESIGN GUIDELINE CONFORMANCE

		OQR
DISPLAY FORMAT		
Is presentation in a readable and usable format?	NO yes	
Does format conform to expected population stereotypes?	NO yes	
Is display field organization standardized for format?	NO yes	
Are identical data types from various subsystems displayed in a standardized and consistent format?	NO yes	
Does display require aircrew to identify individual data fields using past familiarity?	YES no	
Is display arranged by reserving certain areas for specific types of data?	NO yes	
Are individual data fields broken up or chopped into multiple sub-divisions?	NO yes	
QUALITATIVE COMMENTS:		

Figure C-65
ELECTRONIC DIGITAL DISPLAY DATA CARD NO 2

CARD NO ____-3
DATE _____

DISPLAY NAME: _____

ELECTRONIC DIGITAL DISPLAY
DESIGN GUIDELINE CONFORMANCE

		OQR
Are data fields presented in some recognizable order for ease of scanning and identification?	NO yes	
Determine maximum number of alphabetic characters in a given string? (Recommended maximum five.)		
Are numerical character data fields displayed vertically presented in a right justified format?	NO yes	
Are alphabetic character data fields displayed vertically presented in a left justified format?	NO yes	
FUNCTIONAL UTILITY		
Does display provide sufficient information to allow aircrew to take immediate action based on displayed information?	NO yes	
Is a list of display options presented with the most probable option at the top of the list?	NO yes	
QUALITATIVE COMMENTS:		

Figure C-66
ELECTRONIC DIGITAL DISPLAY DATA CARD NO 3

CARD NO ____-4
DATE _____

DISPLAY NAME: _____

ELECTRONIC DIGITAL DISPLAY
DESIGN GUIDELINE CONFORMANCE

		OQR
Do directions to aircrew concerning system operation precede list of choices?	NO yes	
DISPLAY CHARACTERISTICS		
Does display appear to flicker?	YES no	
Are characters or symbols displayed with sufficient contrast to stand out from the background?	NO yes	
Does display provide capability to provide both positive and negative contrast?	NO yes	
Does display provide sufficient resolution for presenting clear and sharp symbology?	NO yes	
Is character or symbol size satisfactory?	NO yes	
QUALITATIVE COMMENTS:		

Figure C-67
ELECTRONIC DIGITAL DISPLAY DATA CARD NO 4

DISPLAY NAME:

		OQR
Is character or symbol luminance satisfactory?	NO yes	
Is character or symbol luminance controllable?	NO yes	
If yes, is range sufficient?	NO yes	
Is display surround luminance satisfactory?	NO yes	
Is display surround luminance controllable? If yes, is range sufficient?	NO yes NO yes	
Does display surround luminance inhibit acquisition of displayed information?	YES no	
QUALITATIVE COMMENTS:		

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CARD NO ____-6
DATE _____

DISPLAY NAME: _____

ELECTRONIC DIGITAL DISPLAY
DESIGN GUIDELINE CONFORMANCE

		OQR
DISPLAY HIGHLIGHTING		
Does display possess capability to highlight specific character strings or symbols? (e.g. increase luminance, brighten color, flash on and off, underline, present in different size or font, or maximize contrast)		
Does highlighting scheme serve to focus aircrew's visual scan to desired data field?		
If different levels of brightness are used for highlighting, determine number of levels. (Recommended maximum 3.)		
QUALITATIVE COMMENTS:		

Figure C-69
ELECTRONIC DIGITAL DISPLAY DATA CARD NO 6

CARD NO ____-1
DATE _____

INTERFACE NAME: _____

INTERFACE DESIGN GUIDELINE CONFORMANCE

		OQR
CONTROL-DISPLAY ADJUSTMENTS		
What is ratio between control input and display movement? (Recommended 1:1 for general use and 1:2 or 2:1 for fine adjustments.)		
Does control-display ratio provide for adequate control sensitivity?	NO yes	
Determine cursor travel time across screen?	SEC	
Is cursor travel time sufficient?	NO yes	
Does the interface prevent control-display drift?	NO yes	
SOFTWARE		
Does software provide consistent operational procedures?	NO yes	
Does software provide for efficient use of full system capabilities?	NO yes	
QUALITATIVE COMMENTS:		

Figure C-70
INTEGRATED INTERFACE DATA CARD NO 1

CARD NO ____-2
DATE _____

INTERFACE NAME: _____

INTERFACE DESIGN GUIDELINE CONFORMANCE

		OQR
Is learning time required by aircrew to become proficient in software use acceptable?	NO yes	
Does use of software require excessive memory retention?	YES no	
Does software use provide for predictable operation?	NO yes	
Are data entry transactions consistent?	NO yes	
Does software promote minimal entry actions by the aircrew?	NO yes	
Does the software promote for the compatibility of the data entry with the data display?	NO yes	
Does the software promote for flexible data entry procedures?	NO yes	
Does software provide aircrew with prompts for expected input or action?	NO yes	
Are prompts consistent in meaning and context?	NO yes	
Does the software provide on line help to the aircrew concerning its use?	NO yes	
QUALITATIVE COMMENTS		

Figure C-71
INTEGRATED INTERFACE DATA CARD NO 2

VITA

Harry Michael Robinson was born in Philadelphia, Pennsylvania on August 9, 1960. After graduation from the Lower Merion High School in June 1978, he entered the Pennsylvania State University under the Naval Reserve Officer Training Corps Scholarship Program. He received a Bachelor of Science degree in Computer Science and earned his commission as an Ensign in the United States Navy in May 1982.

After completion of flight training, he was winged a Naval Flight Officer in March 1985. Harry Robinson then received orders to an operational Carrier Airborne Early Warning Squadron (VAW-126) where he flew the E-2C Hawkeye aircraft and embarked in the USS JOHN F. KENNEDY (CV-67). As a Test Project Officer at the Naval Air Test Center, Patuxent River, Maryland, he conducted a major Developmental Test and Evaluation Phase (DT-IIC) of the E-2C Update Development Program Group II aircraft. He has completed courses of instruction at the United States Naval Test Pilot School, Navy Fighter Weapons School, and Carrier Airborne Early Warning Weapons School.

Harry Robinson holds the rank of Lieutenant Commander, and is assigned to the staff of Commander, Carrier Air Wing ONE as the Anti-Air Warfare Operations Officer. He has logged in excess of 1,900 flight hours in over 30 different aircraft.