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HUMAN INTERFACE DESIGN METHODOLOGY FOR INTEGRATED DISPLAY SYMBOLOGY

1. SCOPE:

The recommended design approach is described in Figure 0. The approach emphasizes the fundamental relationship between symbols, the information they encode, the context within which the symbols are displayed, and the tasks being supported. While this document is aimed at aircraft displays involving dynamic control or monitoring tasks, the methodology is applicable to a wide range of symbology development situations.

2. PURPOSE:

This document outlines a recommended approach for the design of integrated display symbology in support of flight tasks.

3. REFERENCES:

3.1 Applicable Documents:

ARP1068 - Flight Deck Instrumentation, Display Criteria and Associated Controls for Transport Aircraft

ARP1093 - Numeral, Letter and Symbol Dimensions for Aircraft Instrument Displays

ARP4032 - Human Engineering Considerations in the Application of Color to Electronic Aircraft Displays

ARP4102 - Flight Deck Panels, Controls, and Displays

ARP4107 - Aerospace Glossary for Human Factors Engineers

4. DEFINITIONS:

This section contains definitions of terms used in this document:

CULTURAL STEREOTYPES: Information interpretations or expectations that are characteristic of a particular culture, discipline, or user community.

DISPLAY MEDIA: The various basic technologies through which information can be communicated visually: printed paper, cathode ray tube (CRT) display, liquid crystal display (LCD), etc.

DISPLAY TECHNOLOGY: The technical means by which symbology is presented to an operator.

DYNAMIC INFORMATION: Information which changes during the time of relevant task performance.

HUMAN FACTORS: The study of the physical, mental, and social variables which affect human performance and behavior.

INDIVIDUAL DIFFERENCES: Behavioral or performance characteristics which vary between people even though they have equal qualifications or have received identical training.

INTEGRATION: The combination of two or more functions into a coherent operating entity.

NOTE: Integrated symbology is frequently characterized as having more specific information content than the total number of symbols used. Integrated symbology may also refer to displays containing multiple symbols having a common context.

PERFORMANCE OBJECTIVES: Criteria setting forth the maximum allowable deviations from the relevant dimensions of perfect performance.

REDUNDANT CODING: The use of more than one symbol or symbol characteristic to convey the same information.

STATIC INFORMATION: Information which remains constant during the time of relevant task performance.

SYMBOL: An identifiable display element characterized by shape, size, structure, location, brightness, and color. Any of these characteristics may be static or dynamic. One or more of these characteristics is used to encode information.

SYMBOLOGY: The use of one or more symbols which make up a format to portray or define information.

SYMBOL-TASK PAIRING: The relationship between symbol attributes, information content, and the task to be accomplished by the end-user.

4. (Continued)

TRANSFER OF TRAINING: The degree to which learning one skill is facilitated by the prior learning of another task.

Note: Negative transfer of training can occur when a previously learned skill interferes with learning of a new skill.

TASK: A physical or mental operation, or a sequence of such operations, performed by a human operator to achieve a specific goal.

TASK ANALYSIS: The process of breaking a task into its component parts, such as skills, actions and decisions.

5. BACKGROUND:

The designer must ensure that display symbols:

a. Are able to convey, without bias, the specific information they encode.

b. Are effective, in combination with related symbols, in enabling the user to achieve criterion task performance.

c. Do not interfere with the interpretation of other flight deck symbols and the performance of other flight deck tasks.

As flight decks become more information intensive and display devices become more flexible, the possibility diminishes of satisfying all three of these requirements at the same time without compromise. Achievement of an effective display is greatly enhanced if the designer uses a structured design approach early in the development cycle.

Consistent use of symbol-task pairings is known to improve transfer-of-training as pilots operate different subsystems in one aircraft or as they make the transition from one aircraft type to another. The increasing sophistication of aircraft flight decks negates much of the one-symbol-one-function simplicity characteristic of earlier aircraft. Highly integrated aircraft and aircraft systems require integrated display symbols. These trends make it more difficult to maintain consistency. The user's finite capacity for recognition, identification, and memory dictates that proliferation of symbols must be carefully managed.

Symbology selection is made more difficult by the fact that modern aircraft flight decks seldom remain in exactly the same configuration throughout their operating life. Changing regulatory, airline, and ATC requirements dictate certain modifications. Improvements in technology and the continuing search for operating advantage and increased efficiency also contribute to the inevitability of flight deck change. For most aircraft many people will be involved in the selection of symbology for use on the flight deck.

This document is offered as a first step in expanding the understanding of all who design, integrate, regulate or specify symbology for flight decks and by those who use the symbology. The quality and utility of future versions of this document will benefit from feedback of your comments, insights and criticisms to the SAE G-10 Committee.

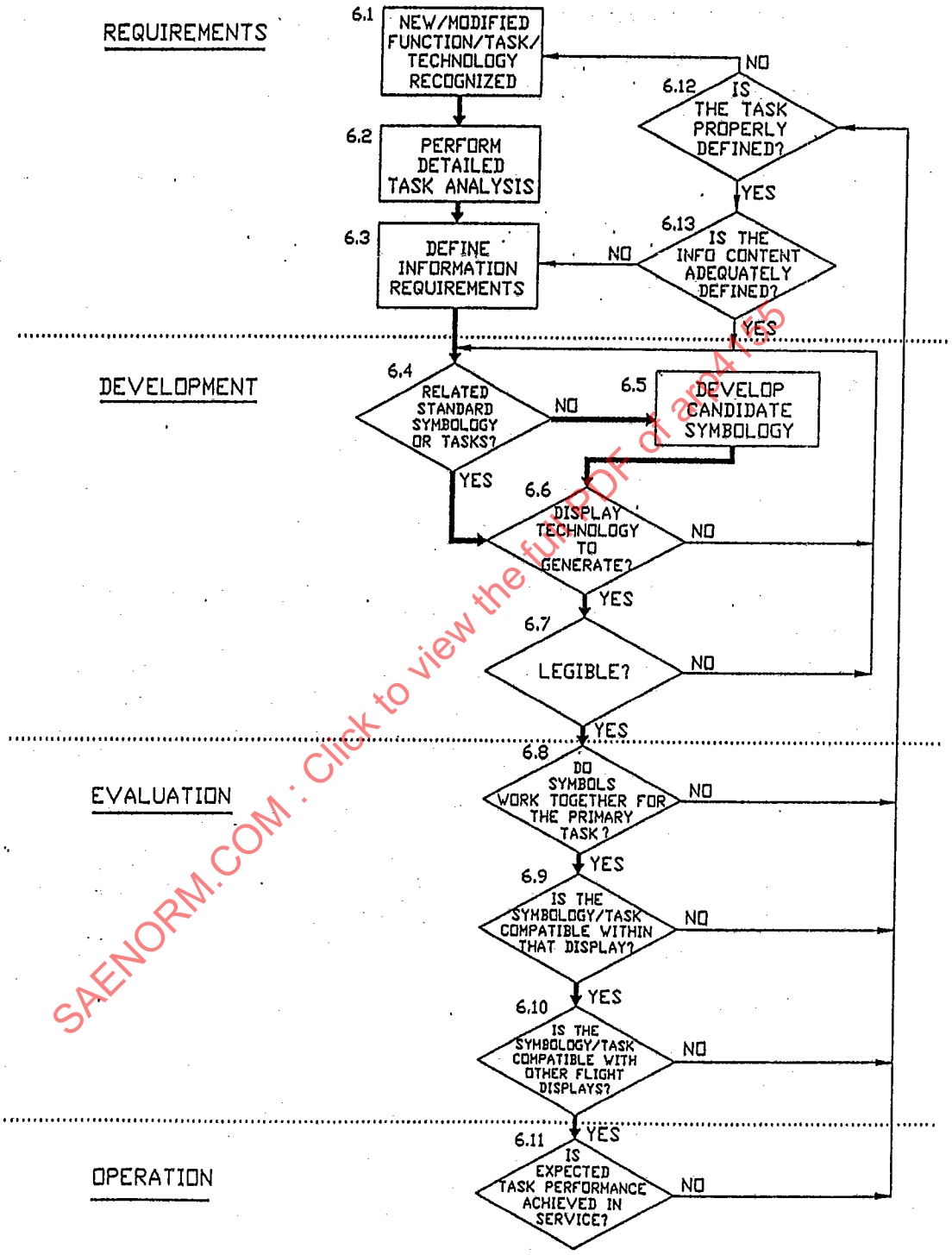

Figure 1. - **DISPLAY SYMBOLOGY DESIGN FLOWCHART**

6. DESIGN METHODOLOGY:

The methodological steps shown in Figure 1 are explained in the sections which follow. The recommended approach for achieving the action or decision covered by each step in the process is identified along with one or more reasons why the step is necessary. This is followed by a brief explanation of the key elements involved in completing the step. Any significant cautions or limitations associated with the step are highlighted within a box.

6.1 Recognize a New or Modified Task (*Action*)

6.1.1 Approach:

The designer should clearly identify the task and related performance objectives the desired symbology is meant to support.

6.1.2 Reason:

a. Identification of quantifiable performance objectives associated with an identifiable task increases the likelihood that the proper task has been recognized.

b. These performance objectives will be the criteria against which the selected symbology will be evaluated.

6.1.3 The task recognized in this step can result from:

a. a new user requirement,
b. the use of technology new to the application,
c. the transfer of information from one display medium to another,
d. a change in the means of response available to the user,
e. the integration of several subordinate or related tasks,
f. the physical or conceptual integration of two or more existing displays,
g. a change in the user population, or
h. the failure of existing symbology to achieve expected performance.

Appropriate task definitions are best developed by beginning from a clearly stated top level system goal, proceeding through identification of applicable constraints on the goal and its achievement, and finally establishing appropriate monitoring requirements for functions assigned to machines or other operators.

While the task likely will be application specific, identification of similarities between this task and other tasks associated with the same user population will aid the effort to achieve consistent symbology usage.

The task performance requirements must be as objective as possible since they will be used as performance evaluation criteria in step 6.8.

6.2 Perform a Detailed Task Analysis (*Action*)

6.2.1 Approach:

The designer should perform a detailed task analysis to break the top level task definition into smaller, manageable decision or action steps.

6.2.2 Reason:

a. Recognition of all elementary steps in the task is a prerequisite to identification of all relevant information requirements.

b. Knowledge of the elementary steps in the task increases the probability of finding similarities with other tasks.

This step is accomplished by iterative decomposition of the high level task into progressively lower level subtasks. Generally this process is continued until single actions or decisions have been identified. The availability of reliable on-board computational capability makes it feasible to consider halting the decomposition at an intermediate task level, if the resulting man-machine interface would be simpler to train or less susceptible to error.

Through this analysis all significant decision or action characteristics, risks, relevant human performance capabilities and limitations are identified. This step is critical to the success of the design process since information requirements follow directly from the detailed tasks.

This step also serves to clarify human interface issues early in the design process when they can be addressed most easily.

Because of the intimate relationship between tasks and supporting information, the task analysis is often done in conjunction with step 6.3, the definition of information requirements.

6.3 Define the Information Requirements (*Action*)

6.3.1 Approach:

Using the detailed breakdown provided by the task analysis, the designer should determine what information is necessary to support each decision or action step in the task.

6.3.2 Reason:

a. Clearly established task-information links enable the designer to develop specific performance requirements and to establish the relative importance for each information element.

b. Sources must be found for each information element.

Recognition of the wide variety of information sources available to the human operator can help to identify that portion of the total information requirement, which needs to be explicitly coded into the symbology.

Quantitative information requirements must be specified fully in terms of range, accuracy and resolution. If the information is dynamic; latency, bandwidth and refresh rate would be of concern as well.

The degree of specification for qualitative information is less well standardized and often changes from one application to another.

With the information requirements established, the designer should determine if the information is available in a suitable form or can be derived from available sources. The lack of properly matched information is reason enough to refine the detailed task analysis of step 6.2. Several iterations may be necessary before a suitable combination of action-decision steps and supporting information can be found.

6.4 Does Related Standard Symbology or Task Exist? (*Decision*)

6.4.1 Approach:

The designer should compare the newly-established specific information requirement with the information encoded in existing standard symbols.

6.4.2 Reason:

a. Standard symbology can simplify training requirements.

b. Standard symbology can minimize the risk of misinterpretation in use.

The search for suitable standard symbology should start with symbols used in closely related tasks, then proceed through other aviation-related tasks, and finally to consideration of symbols used for generically related information in other applications. The search should encompass all media to which the operator will be exposed (e.g., CRTs, paper, placards, electromechanical indicators).

Standard symbols portraying static information are easiest to find, since the information encoding is usually simple and direct with minimal limitations imposed by the overall display context. If the primary task is dynamic, it will be necessary to match symbol dynamics, within the context of the display format, with the desired task dynamics. Similarly, if the detailed action or decision step involves a comparison, the designer must ensure compatibility between relevant attributes and dynamics of all symbols to be used in the comparison.

Wherever possible use existing standard or recommended common-usage symbology. This will reinforce the standard and facilitate training. The use of slightly different symbols for identical tasks should be avoided, since the potential confusion created by the difference cannot be corrected easily.

Symbols cannot be associated solely with the information they encode, the symbol-response relationship is vitally important as well. The linkage between symbology and the various types of behavior (knowledge-, rule- or skill-based) is a key element in assessing the usability of any standard symbology.

In skill-based behavior tasks (such as most manual flying), the operator reacts to the situation with a minimum of investment of conscious effort. (The pilot doesn't have to think about which direction to turn his wheel to initiate a turn; he just reacts.) A skill-based behavior is established by linking particular symbology with a unique response to such a point that the response becomes automatic, resulting in the achievement of very high performance levels.

Once established, the symbol-response links can affect training to a new task. If a new response to a set of symbology is required, the old link must be completely broken and substituted with the new desired link. Even after significant training on

6.4.2 (Continued)

the new task, the operator may still revert to the previously linked response, particularly when under high workload or stressful circumstances. These "capture errors" may be avoided by changing the symbology or reconfiguring the task.

Common symbology used for tasks which require different responses should be avoided. The likelihood of operator error in this situation increases dramatically, especially if the task elicits a skill-based behavior. Even when appropriate training has been provided, high stress situations are often characterized by operator reversion to previously learned, and now incorrect, behavior.

Even though an automatic response does not occur in rule- or knowledge-based behaviors, care must still be taken that previously learned symbol and information content relationships do not interfere with interpretation of the situation. If symbology common to more than one task is used, it should be used in a context where establishment of the proper link to the desired task is assured.

Various documents listing standard or common symbol usage have been published. (See 3.1 for references applicable to aircraft.) These documents are an excellent place to start in the search for appropriate existing symbols. In such documents symbol usage is normally expressed in terms of the information it encodes. Identification of the specific tasks the symbol supports is far less frequent.

The explanation necessary to understand the information encoding associated with standard symbols is rarely available in a complete and concise form. Often, established usage of a symbol has evolved in a somewhat different manner than originally intended. It is essential that the designer be aware of the actual usage and evolution of a standard symbol before selecting it.

The designer must establish clearly that the information encoding of any "standard" symbology is both necessary and sufficient to support the intended task step(s). Otherwise, it will be necessary to develop a new symbol.

6.5 Develop New Candidate Symbology (*Action*)

6.5.1 Approach:

If a detailed analysis clearly indicates that a suitable standard symbol does not exist, the designer should create and test new symbol candidates.

6.5.2 Reason:

a. Using standard symbology out of its normal related task context is likely to degrade task performance.

b. The number of symbols must be controlled to ensure that the user's recognition and identification capacity is not exceeded.

New symbols should be both simple and distinct. The designer should adhere to established practice for encoding related information through specific symbol attributes.

The specific symbol attributes available for information encoding will depend on the display medium and associated technology. As a consequence, selection of symbol candidates involves iterative consideration of the issues involved in step 6.6.

Where the importance of the information warrants, the information should be encoded using two or more symbol attributes (e.g., color, size, shape.) The objective of such encoding redundancy is to accommodate individual differences between users, to provide a means for the user to detect an interpretation error, and to ensure recognition in case of equipment degradation.

Care must be taken to ensure that symbol attributes which have strong attention getting value (e.g. flashing or color) are used sparingly and only when justified by the relative priority of the top level task in relation to all of the user's other tasks and possible cultural stereotypes. This is necessary to avoid degradation of overall flight deck attention getting capability.

6.6 Can the Display Technology Generate the Symbol? (*Decision*)

6.6.1 Approach:

The designer should determine whether the available display technology can reproduce the symbol and all its relevant attributes with the necessary degree of fidelity.

6.6.2 Reason:

Attributes of a particular display technology may interfere with desired symbol characteristics.

Attributes such as color, pixel size, resolution and contrast ratio, along with artifacts such as aliasing, may restrict the range of symbols a particular technology can support. The perceptual consequences of the operating characteristics inherent in the desired display technology must be evaluated in relation to the essential symbol attributes. Similarly, the failure characteristics of the display technology must be evaluated to determine what effects these characteristics may have on perception or display interpretation during and after a failure event.

A negative finding for this decision may cause reconsideration of the display technology in use. If this option is not available or is not warranted by the importance of the information encoded in the offending symbol, it will be necessary to seek another symbol candidate by returning to step 6.4.

6.7 Is the Symbol Legible? (*Decision*)

6.7.1 Approach:

The designer should test the entire symbol set against existing human factors legibility guidelines under all relevant environmental and operational conditions.

6.7.2 Reason:

a. *Accommodate human visual system differences and limitations.*

b. *Accommodate variations in the viewing environment.*

If the symbol is dynamic or part of a dynamic display, the legibility tests must include appropriate dynamic situations.

If the display medium has unique failure modes or degraded operational characteristics, legibility must be checked under these conditions as well. The pass-fail criteria for legibility will depend on the importance of the information encoded by the symbology, the consequences of misinterpretation of specific symbol attributes, and the likelihood of operating under the specific conditions where legibility begins to degrade.

Any failure to satisfy legibility criteria will be accompanied by enough information to establish what characteristic(s) of the symbol must be changed to achieve satisfactory performance. If the display technology cannot support such changes, then a new symbol may be the only acceptable alternative.

6.8 Does the Symbology Support Achievement of the Primary Task? (*Decision*)

6.8.1 Approach:

The designer should obtain objective performance data comparing task performance achieved with established task performance requirements.

6.8.2 Reason:

Ensure that the task in question can be performed satisfactorily.

The tests called for by this step ensure that the selected symbology enables the pilot to meet the task performance criteria established in steps 6.1 and 6.3. The type of tests conducted should correspond with the task characteristics as previously determined and encompass a broad range of normal, abnormal, and off-nominal usage situations. Particular attention should be paid to the consequences of: user error, partial information loss, display degradation, and display failure.

To ensure compatibility with a wide range of end-user individual differences, multiple test subjects should be used to evaluate the symbology.

Depending on the specific task it may be desirable to involve members of the end-user population as test subjects.

6.9 Are All Symbols Within the Display Compatible? (*Decision*)

6.9.1 Approach:

The designer should confirm through objective testing that the new or revised symbol set allows operators to maintain acceptable performance for all tasks supported by the display.

6.9.2 Reason:

Ensure that unplanned interactions or interpretations associated with display symbols do not interfere with satisfactory task performance .

These tests should encompass not only the primary task of design concern, but multiple tasks representative of the real-world use of the entire display.