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HUMAN FACTORS CONSIDERATIONS IN THE DESIGN OF THE ASCS INTERACTIVE COMPUTER SYSTEM

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TABLE OF CONTENTS

P R E F A C E

This document is the final report under contract 123351034. It describes activities, issues and concerns supplementary to the Dialog Specification Procedures presented in BBN Report 3092 and will make occasional reference to that report.

The development of a large scale system of the sort envisioned by ASCS is a multidisciplinary problem involving cooperation of a number of sources. The dialog design will have an impact on the efforts of many people, both users and designers. This report will address a number of human factors issues related to the design.

Section 1 documents the method used for creating the Dialog Specification Procedure. This background section will provide a perspective on what was done and serve to set a precedent should further specifications be required. Section 2 discusses the implications for terminal and concentrator software that result from the dialog characteristics we have proposed. In Section 3 we present some specific human factors recommendations for the design of the terminal display and keyboard console that should help to optimize user performance and acceptance of the terminal. Section 4 raises user-based issues in the control of privacy and security while Section 5 introduces a concept for interactive training of county office personnel. In the Final Section we present a number of other areas in which human factors activity is likely to benefit overall ASCS interactive systems effectiveness.

Section 1

DEVELOPMENT OF THE DIALOG SPECIFICATION PROCEDURE

To our knowledge BBN's effort at the request of ASCS Data Systems Division represents the first time that the development of such a dialog specification procedure has been attempted for a large-scale information system. Although the success of the undertaking remains to be proven in practice, we feel that it has been possible to accomplish the main goals that were defined for us and therefore the first section of this final report is devoted to reflection on the way in which the project was undertaken and the conditions that made it possible.

1.1 Initial Conditions

At the time BBN began its work, the system concept document was complete and the system requirements for many of the subsystems had been written. Some major philosophical decisions had been made, or at least were presented firmly, concerning the level of interaction that could be expected of the system. The major steps that had not been taken were the definition of the hardware and software for both the communications concentrator and the terminal itself.

The timeliness of these circumstances needs to be elaborated further. On the one hand, it is essential that these features be known or assumed reliably in order to have a clear picture of the potential for interactive dialog. On the other hand, if these characteristics had been given to us as doctrine, the development of effective dialog would have been severely hampered. The development of dialog procedures and terminal hardware and software together with concentrator characteristics must progress together if one is not to severely limit the other.

1.2 Defining Dialog Requirements and Constraints

The way in which our development proceeded was first to examine the concept documents, a sampling of the requirements specifications, and to talk intensively with individuals fully knowledgeable concerning the way in which the particular subsystems operate today or were envisioned to operate under the automated system. These discussions focused on dialog needs and requirements, not on the way in which the dialog requirements should be implemented. In fact, the loan-application subsystem was the focus of our in-depth examination, and even though much dialog had actually been written for this subsystem, we explicitly requested that it not be shown to us until after we had completed our own assessment of how the dialog should look.

After this general indoctrination and several discussions with individuals charged with responsibility for system implementation, we explored feasible and practical alternative hardware and software specifications, and prepared a set of proposed characteristics of the system. This "assumptions list" was submitted to the project monitor who distributed it to other interested parties and it was returned to us with a critique that largely approved it, but set out alternative assumptions where ours were found unacceptable. It must be emphasized that the resulting dialog specifications depend heavily on the veracity of these assumptions. It is very important for the ultimate success of the interactive characteristics of the system that they be met or exceeded. In some cases to be described in the next section, system constraints already will limit dialog effectiveness.

In retrospect the development and approval of this assumptions list was perhaps the single most critical detail of the entire development process. It needs to be worked out in concert between the individuals responsible for user-oriented dialog specification and the systems designers who must implement the system within the current state of technology and within realistic budget constraints.

After having outlined to our own satisfaction the range of system requirements, the characteristics of the user population and the dialog constraints that could be assumed, we began detailed development of two or three specific dialogs. Following the procedures outlined in Section 5 of the resulting document, we used our interview data from subsystem-knowledgeable individuals to construct a task flow chart as seen from the user's perspective, and then we expanded that flow chart into a detailed dialog flow chart of the sort illustrated in Section 7.3 of the Dialog Specification Procedures. These and the subsequent steps were time-consuming and tedious because at each point we were considering not only the particular dialog under development but the question of whether the solution to this particular issue would provide a principle that could be generalized to the dialog specification procedure. There were, of course, many iterations, because internal consistency was essential in the final product.

The same procedures were used to develop the specific dialog frame layout and format specifications, beginning first with the specific dialogs that served as test cases and then generalizing to the recommendations that appear in the final specification. Undoubtedly designers will find circumstances for which our specifications are incomplete. However, within the practical time and effort constraints, we found this procedure to be a very effective way to derive general specifications. Hopefully the structure we have imposed provides a designer with the ability to extrapolate new dialog requirements in a manner consistent with the framework we have supplied.

Section 2

IMPACT OF DIALOG STRUCTURE ON ASCS DESIGN EFFORT

2.1 Introduction

Since terminal memory storage will be restricted to approximately 4000 words, we have tacitly assumed on the basis of the best information available that dialog control software will be operated from the concentrator. Our dialog structures have been specifically designed so that access to the central facility will be minimized but without more terminal memory capacity the communication load between terminal and concentrator will be substantial.

2.2 Projected Software Procedures

Without knowledge of the details of the concentrator capabilities, and since the terminal has not been selected, we can only speculate about the actual software implementation. However, we envision the operation in the following way.

The concentrator retains a set of menus that may be used to set up, through terminal interaction with the user, a code that designates any desired subsystem dialog control program that is to be requested from the central computer. Once it has been called, the dialog frame specifications and control algorithms are transferred from the central computer to the concentrator and the first frame is, in turn, transmitted to the terminal. Thereafter all interaction is between concentrator and terminal until such time as an inquiry or transaction request has been prepared that requires access to the data base.

When a frame is sent to the terminal, the transmission includes the background text to be displayed, the characteristics of each input data field that may be used for terminal error detection and the default values and help message associated with each data field, if defined. Terminal software will provide the capability to invoke these latent specifications should they be called upon.

We believe that application-based errors may be handled in a corresponding way. When an input frame has been prepared, the user presses the enter key and the data are packed and transmitted to the corresponding application program in the central computer by way of the concentrator. The application program conducts its error validations and, if it rejects one or more entries, the error messages assigned to each variable found to be in error are returned to the concentrator. The concentrator then transmits this frame or page back to the terminal with the appropriate variables highlighted and with the error messages associated with that page to be displayed according to the prescribed error message control logic. The user is then free to make any changes he wishes in the page and reenter it.

Although it would be preferable to evaluate each correction to a variable as it is entered by the user, the communications load and delays associated with this procedure make it impractical to do so.

The small set of terminal-based error messages should be stored as an element of the terminal software so that they can be accessed directly when signaled by the terminal-based error validation routines.

2.3 Implications for User Interaction

It appears that if all of these requirements for storage of information associated with each page or frame are to be met, it will be necessary to limit the temporary storage at the terminal to a single page together with the information and software necessary to support processing of that page by the user. Such an allocation will provide a clean specification of terminal- and concentrator-based processing. All actions that the user undertakes with respect to each page of the dialog will be self-contained within the terminal system and every action that invokes the dialog control program or requires introducing a new page will require a transfer of information between concentrator and terminal.

The implication of these distinctions is that every menu selection, including menu bypass actions, every transition from page to page within a frame, every user choice of next page (frame) last page (frame) will involve a concentrator access and will introduce a system delay of up to five seconds from initiation to completion. The design goal of a five-second delay for access to the concentrator thus becomes a very important and possibly limiting factor in the overall effectiveness of the user-computer system. It is important that this duration be exceeded only in the exceptional case and, if possible, it should be reduced if the user is to feel he or she is working with a genuinely interactive system. It has implications for the capacity requirements of the concentrator and for the number of terminals or multi-terminal processors that may be associated with each concentrator. It also emphasizes the importance of investing considerable effort to create efficient concentrator and communications software to minimize the processing overhead associated with these data transfers.

Fortunately, the intrinsic processing load at the terminal and concentrator involves mostly packing and unpacking of data, and logical bookkeeping. Thus one might expect, on an unloaded system, that each user might average at most one minute of concentrator CPU activity per hour of user terminal activity. The magnitude of this ratio obviously depends on the specifics of implementation, but a one-to-sixty ratio is not atypical for some fairly sophisticated interactive systems.

Section 3

HUMAN FACTORS RECOMMENDATIONS FOR TERMINAL DESIGN CHARACTERISTICS

3.1 Display Characteristics

There are two main requirements for an effective CRT alphanumeric display. First, the alphanumerics should be highly legible, and other required coding, such as shifts in brightness that segregate one character field from another, should be clearly distinguishable. Second, the display should otherwise be designed so that the operator can perform his visual tasks efficiently and comfortably for reasonably extended periods of time. Included in this second requirement is minimization of display flicker, matching of display and ambient background brightness, and preclusion of specular reflection from the display face.

We first provide some bench marks for the designer to utilize in setting performance specifications for the CRT display. These bench marks have to be rather loosely specified, because each characteristic can vary over a considerable range from system to system, and they all interact in a complex fashion. Thus, the specification for any one performance characteristic has to be expressed as a generally achievable and acceptable range within which it can vary, as the particular settings of other characteristics are chosen or adjusted.

We then discuss manufacturers' specifications of currently available CRT displays that determine these critical performance characteristics. The aim is to provide a basis for making good choices among the alternative systems currently available. We acknowledge at the start, however, that these issues may not be completely resolved from a purely logical analysis of manufacturers' specifications. In the end field studies should be conducted to see which of a narrowed set of alternative display systems is best for the particular requirements of the ASCS system.

3.1.1 Legibility of Alphanumeric Characters and Distinguishability of other Codes

ASCS operators will be keying in and verifying data at the terminal and transcribing data from the CRT. The designer must acknowledge from the outset that these activities will never be conducted error-free. The goal of CRT specification is to minimize the contribution of reading errors and character confusions as a source of invalid data at every point in the operation. Most available systems will provide satisfactory results in this respect, however, these specifications will serve to eliminate unacceptable designs and to provide the extra increment in performance that can make the difference between a satisfactory design and a truly superior one, both in terms of performance and user acceptance.

The most critical problem to be dealt with here is legibility of the alphanumeric characters. The particular tasks that the operator performs have to be taken into account in defining criteria for legibility. In the ASCS system, the operator will often be required to identify individual letters and numbers in isolation as well as read text. The former requirement is the more critical in that the operator cannot rely on word and textual redundancy to abstract information from the display. Each character has to be clearly identified by itself.

Legibility of CRT characters is a joint function of several interacting variables, mainly: subtended visual angle, contrast ratio, sharpness, and design of the characters.

3.1.1.1 Size of the Characters

The minimum acceptable size of character depends mainly on its contrast and sharpness, but also to a degree on its particular design. Even for sharply printed hard copy, standard characters are not clearly legible unless they subtend at least 5' of arc (22 mils*). The limit here is the visual acuity of the operator. For CRT displays, characters have to be larger because of limits on achievable contrast, sharpness and design of the characters. The minimum acceptable size will vary depending on the particular values of these controlling variables, but as a general rule, characters on currently available CRT displays have to subtend at least 15' to 20' of arc (70-93 mils) to be clearly legible.

3.1.1.2 Contrast Ratio

Contrast ratio (C_r) is defined as the maximum brightness of the display relative to the minimum brightness. Conventionally, both maximum and minimum brightness include reflected ambient light under conditions of normal use.

For sharply-printed-hard copy material, well-designed characters subtending at least 10' of arc (46 mils) are clearly legible at values of C_r as low as 7. For CRT displays, C_r has to be higher because of limitations on character sharpness and character design. Here again, the minimum will depend on characteristics of the particular display system; but as a general rule C_r has to be at least 13-17 and may have to be much higher if characters are unusually blurred.

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* Size, expressed in minutes of arc, describes the angle that the image subtends at the retina. It is computed by the formula, $\tan \frac{\theta}{2} = \frac{S}{2R}$ where R is the viewing distance, and S is the size of the image on the display. To show S in more familiar terms it will also be given in terms of its size (1 mil = .001 inch) on a display, where R is assumed to be 16".

3.1.1.3 Image Sharpness

By sharpness we mean the steepness of the brightness gradient between a character and its background. If the characters are not sufficiently sharp, two problems emerge. First, they become less legible. Second, they may look blurred, and that may be a source of annoyance to the operator, perhaps even a cause of visual fatigue.

For sharply printed hard copy, sharpness of the image is limited by smearing of the image on the retina. This smearing is due to a variety of optical and fine motion characteristics of the eye. Due to this smearing, the distribution of light from a point source is roughly characterizable as Gaussian or bell-shaped, with a half width for a normal observer (20-20 vision) of about 1' of arc (4.5 mils). The half width is the diameter of the central area of the spot within which the luminance is one half the peak amplitude.

Points of light displayed on a CRT are similarly smeared, due to characteristics of the electron beam, characteristics of the phosphor and other optical characteristics of the tube face. Typical available CRTs have 15 mil spots (half widths of 15 mils). At a 16" viewing distance, this translates into about 3.3'of arc. Taking into account the additive effect of the visual spread function and the CRT spread function, a 15 mil spot at the retina would have a half width in the range of 4'-5' of arc (18-23 mils). Thus, if one wanted to have the bars of an E clearly resolvable on a CRT (15 mil spot; C_r=15), it would have to be drawn at least 4-5 times larger than the minimum 5' (23 mils) at which it can be distinguished on the standard Snellen chart. If the display can produce a spot smaller than 15 mils or contrast higher than C_r=15, and such displays are available, then legible characters can be drawn to smaller visual angles. Just what can be accomplished, however, depends greatly on how the display "draws" the characters.

3.1.1.4 Design of the Alphanumeric Characters and Approaches to Character Generation.

There are two main questions to consider in choosing among alternative designs of fonts for alphanumeric characters. The first has to do with making the distinguishing features of the characters robust to deresolution, whether caused by reduction in size, contrast, or sharpness. Here, if one is dealing with a hard-copy system, the main variable is stroke width, the width of the strokes or lines that comprise each character. For sharply-printed characters in standard fonts, the general rule is that the stroke should be 1/8 of the character height for black letters on white background, and about 1/10 the character height for white letters on black.

When it comes to CRT display systems, questions of optimum character design become much more complex. The general problem is that character shape and stroke width cannot be continuously and arbitrarily adjusted. The restraints vary depending on which of four basic available systems are employed.

One approach is to form the characters by extruding the electron beam into the required shape. A mesh, containing holes the shape of each character is inserted in the path of the beam. When the beam is deflected through the hole for a particular character, it is extruded into that shape. The beam is then deflected to the required position on the scope. In the second and third main approaches, the characters are generated by deflecting the beam over a small matrix of addressable points, typically a 5 x 7 matrix. In one system, characters are formed by plotting points at the addressable locations in the matrix. In the other system, characters are formed by drawing lines which have to begin and end at those addressable locations. In the fourth approach, characters are formed as the beam continuously scans the CRT. The character is built up as a stack of parallel line segments. In principle, the continuous scan technique can generate any character that can be produced by plotting dots on a matrix, and the same evaluative criteria apply.

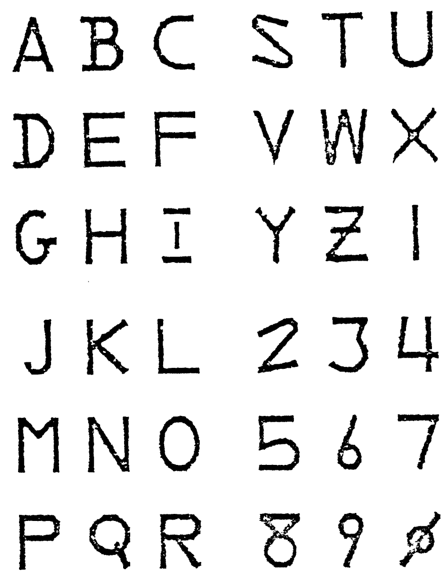
The main limitation on the design of characters using the beam extrusion approach is in constructing the character mask. It has to be constructed like any stencil, which means that islands of opacity such as in the middle of the O, or the top of the P, have to be held in place by slim bridges to the outside rim of the character. Though such bridges can be etched very finely, for reasons purely of structural integrity they cannot be made so fine as to have negligible effects on the appearance of the characters.

In those approaches employing point and vector plotting, the general limitation is in the number of addressable locations on the tube face. To generate an unambiguous character set composed of numbers, letters, and a minimum set of symbols for punctuation requires use of a 5 x 7 matrix. Some systems employ a 7 x 9 matrix and it is of interest to know whether there are performance or preference advantages to the larger and therefore more refined matrix. A 7 x 9 matrix is practically essential if all 96 ASCII characters are to be displayed, although it has been shown that for the best implementation possible of a particular font with 5 x 7 and 7 x 9 sizes that there are only small and statistically insignificant differences in terms of speed or accuracy of recognition under otherwise comparable display conditions. The larger matrix produces aesthetically nicer characters since there are more degrees of freedom available to shape them. Finally, there is some evidence that the larger 7 x 9 matrix retains its legibility under degraded viewing conditions better than a 5 x 7 matrix. Given that the full ASCII character set is not required for this application we believe a 5 x 7 dot matrix is sufficient for the ASCS system unless the larger matrix can be obtained without sacrificing cost or other desirable characteristics.

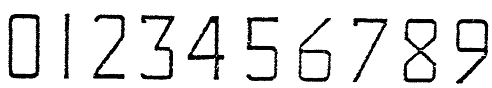
The second question has to do with the general configuration of the characters and how they can be shaped for each to retain the appearance of familiar letters and numbers but look as different as possible from the others. There are specific problems, for example, in confusability between the number 5 and the capital letter S. The number 8 is potentially confusable with the capital letter B. Research over the years has led to the development of some very effective fonts to minimize these problems. Early efforts were concerned with optimizing the design of numbers for hard copy systems, see e.g. the Berger font in Fig. 3.1.1.4. More recent efforts have been specifically concerned with optimizing fonts for CRT displays. The MITRE font shown in Fig. 3.1.1.4 has been designed specifically to avoid these confusions, but it has not yet been widely adopted, perhaps because of the non-standard character shapes involved.

3.1.1.5 Brightness Levels for the Split Field Option

When two brightness levels are to be used, the dim field has to have sufficient contrast to ensure legibility and the bright field has to be clearly brighter than the dim. To meet that requirement, it may be necessary to use $C_r < 15$ for the dim option. C_r as low as 7 or 8 may be permissible as long as the dim option is used for fixed form material and familiar text.



Lincoln/MITRE Font



Berger Font

Fig. 3.1.1.4

3.1.2 Other Display Requirements to Maximize Operator Efficiency and Minimize Discomfort and Fatigue.

There are several aspects of the appearance and positioning of the display and the illumination of the work area that can significantly affect an operator's performance. The following main factors are considered here: display flicker, apparent blurring, matching of work area luminance and display luminance, specular reflection off the tube face, and position of the display.

3.1.2.1 Flicker

The characters on a CRT will appear to flicker if the phosphorescence of the tube decays to a detectable level before being refreshed. The solution is to use a phosphor with greater persistence, or to employ a higher refresh rate. The rate required to preclude noticeable flicker depends mainly on the phosphor and on the spot brightness at normal ambient illumination levels. The P12 phosphor, for example, requires a refresh rate of only about 30 cps for fusion at 32 ft lamberts; whereas a fast phosphor like the P31 requires about 50 cps. Required regeneration rates for several commonly used phosphors are given in Table 3.1.2.1

The problem with using fast phosphors and consequently higher refresh rates is that it limits the number of characters, or the amount of character detail, that can be held flicker free on the display. The prime advantage of a fast phosphors is that they permit rapid updating of the display, and also the display of dynamic imagery, without leaving noticeable ghosts and streaks of prior presentations. In this setting, however, where there is no requirement for dynamic displays, or even for ultra fast up-dating, a rather slow phosphor could be used if only a limited refresh rate is available.

TABLE 3.1.2.1

Persistence Characteristics and Empirically Determined
CFF of Phosphors Commonly Used on Displays

Phosphor	Residual Light after 1/30 sec	Residual Light after 1/60 sec	Persistence to 10% (sec)	Empirically Determined CFF (small fields)(cps) Turnage(1966) 10 ft-L	32 ft-L	100 ft-L
P-28	85	90	550×10^{-3}	34	40	46
P-19	80	90	220×10^{-3}			
P-12	70	85	210×10^{-3}	25	29	32
P-7(Y)	45	80	400×10^{-3}	32	38	43
P-1	4	23	24.5×10^{-3}	33	38	43
P-4(Y)	1.3	7	60×10^{-6}	35	41	47
P-31	<1	<1	38×10^{-6}	37	44	51
P-20	<1	<1	50×10^{-6} to 18×10^{-3}	40	47	54

after Gould (1968)

3.1.2.2 Apparent Blurring

When the spread of the character image on the retina is large relative to the visual spread function, the character will look blurred. When that is the case, the operator may consciously spend an unusual amount of effort vainly trying to focus the image. This situation can be a source of non-specific annoyance to the operator and a cause of visual fatigue.

The general direction for improvement is to make the system component of the overall spread function smaller relative to the component contributed by the human visual system, thus, either the spot size has to be smaller, or the observer has to sit at a further distance from the display. In the latter case, there may have to be a compensatory increase in the size of characters.

3.1.2.3 Matching of Work Area Luminance and Display Luminance

There are two problems to consider here. One is the deleterious effect of glare from very bright sources in the field of view surrounding the display. The other is the deleterious effect of mismatching of the luminance of the display and of other surfaces in the work area on which the operator's eye may settle from time to time as he works at the display console.

Glare may be uncomfortable and can significantly reduce C_r. The general solution is to ensure that bright sources cannot invade the visual field of the operator as he sits facing the display.

The general problem of mismatches of display brightness and that of other surfaces is that the operator may not be properly light-adapted each time he returns his gaze to the display. This can impair his brightness contrast sensitivity and his visual acuity. As a general rule, the average luminance of a display should be only slightly less than the average luminance of ambient surfaces. For CRT displays such a luminance cannot be practically achieved, while still permitting the operator to work in normal lighting, without special lighting effects and very high luminance spots. The more helpful rule is to choose from a set of displays equivalent in all other critical respects, the one that provides sufficient contrast with the highest average display luminance.

One way to ease brightness mismatch problems is to avoid unnecessarily bright ambient lighting, as well as direct illumination. One particularly perverse situation to avoid is direct sunlight.

3.1.2.4 Specular Reflection

The surfaces of many CRT displays are polished glass, conseqquently much of the ambient light is specularly reflected. Mirror images of features such as lighting fixtures and windows may be superimposed on the display unless care is taken to preclude them. One solution is to avoid displays with polished surfaces. Another is to ensure that the display is so arranged that bright features are not reflected into the operator's visual field. Since it is not possible to anticipate the geometry of the work space, a general solution is to require that the display be tiltable and moveable over at least a small range. Often a slight shift in the angle of the display surface will put bothersome reflections out of the field of view.

3.1.2.5 Display Position

The display should be so positioned that the operator can inspect it in a comfortable position while operating the keyboard. For a seated operator, because of slumping of the head and a slight downward cast of the eyes, the resting line of sight is about 15° below the horizontal. The display should be so arranged that its center is on that natural line of sight. The surface of the display should be perpendicular to the line of sight and should be no closer than 13 1/2 inches.

3.1.3 Identifying an Effective System on the Basis of Manufacturers Specifications, Visual Inspection and Field Test Data

The process of choosing a particular display system to meet the performance requirements outlined above will not be entirely a matter of logical analysis of manufacturers' specifications. It will also require knowledgeable visual judgment of the appearance of the display. Field testing of the ultimate choice will also be necessary before procurement.

3.1.3.1. Narrowing the Candidates on the Basis of Manufacturers' Specifications

The Computer Display Review (GML 1975) now lists 126 different CRT alphanumeric displays that can be purchased off the shelf. Promising candidates can be chosen from among those displays on the basis of manufacturers' specifications. To judge the performance of the display along the main dimensions outlined above, the following specifications are needed.

a. spot size
b. spot luminance
c. reflectance of the display face
d. regeneration rate
e. character generation technique
f. number of addressable locations in X and Y
g. size of the scope.

Most of these specifications are supplied by manufacturers in brochures, and most of those available specifications are currently summarized in the Computer Display Review.

It is important to have in mind, however, that some of these specifications may not be precisely comparable from manufacturer to manufacturer because of differences in conventional definition or in measurement technique. Spot size, for example, is usually defined as the half width of the brightened area, but other conventions are sometimes applied. Measures of luminance and specifications of contrast can also vary depending on how the measures are taken. If contrast ratio is specified, implicit in that measure is a standard ambient illumination.

If C_r is not given directly, then it has to be computed by the following formula:

$$C_r = \frac{L_i + L_e}{D_i + L_e}$$

where L_i = internally produced symbol luminance

D_i = internally produced background luminance

L_e = reflected ambient illumination

In general, D_i can be considered inconsequential, but L_i, which is a function of ambient illumination and reflectance of the screen, is a significant factor in this equation.

3.1.3.2 Selecting a System on the Basis of Visual Inspection and Field Tests

It would be unwise to depend entirely on manufacturers' specifications in choosing a particular display. Even if all of the critical specifications were available, it is conceivable that other characteristics of the display, if known, would affect the choice. Also, it is quite likely that compromises will have to be made when an off-the-shelf display has to be chosen, and it may be difficult to predict performance of the compromised version.

For the size procurement envisioned here, a field study is recommended. That study should include checks on the operator's preference and performance concerning various aspects of the appearance and operation of the display.

It has already been mentioned that the critical question for this situation is whether the characters are individually recognizable. One effective approach to testing would be to program, at representative locations on the display, a random sequence of individual characters. The operator's task would simply be to indicate, by pressing appropriate buttons on the keyboard, which character was presented. The object of this test would be to produce a confusion matrix. The rows of the matrix would be the characters presented, and the columns would represent the characters reported. From such a matrix, the probability of error in general, and of particular kinds; e.g., "B" called "8" can be determined.

In conducting the field study, an effort should be made to have either a representative sample of the population of operators who will be using the system, and particularly to ensure representation of older operators who would require a higher degree of performance from the display. It is important to have in mind that most of the available data on which display performance standards have been based came from studies of young adults. Throughout this discussion, we have attempted to make allowance for that fact by suggesting relatively conservative performance standards.

3.2 Keyboard Characteristics

3.2.1 Sources of Keyboard Design Guidance

Because of the increasing importance and use of typewriter and other keyboard devices as computer input media, a significant amount of research has been conducted for the purpose of generating human factors design criteria. The results of these studies, though occasionally incomplete and contradictory, highlight certain critical considerations in the design of such equipment and should receive the close attention of the design engineer. A recent article by Alden, Daniels & Kanarick (1972) provides an adequate sketch of many of these considerations and an extensive set of references for more detailed study.

In addition to guidelines available as a result of research activities, the engineer is aided in the design of alphanumeric keyboards by the specifications laid down in USASI Document X4/35, X4-A9/54, X4-A9.1/160, 1967 for keyboards implementing the USA Standard Code for Information Interchange (ASCII). Use of the conventions defined in that document help insure a commonality with devices currently in use, thus minimizing the confusion and retraining of operators already accustomed to the operation of other keyboards.

Where the Standard does not provide direct aid in making choices among such factors as key position, coding, spacing, etc., and the designer is required to make an engineering judgment based on research literature and "common sense," it is recommended that he give consideration to criteria employed in the formulation of the Standard. Of possible relevance in this connection are the following (Reprinted from Communications of the ACM, V. 11, No. 2, Feb. 1968):

"A2.4.1 Facilitate simplicity of design.
A2.4.2 Provide ease of operation.
A2.4.3 Minimize operator training.
A2.4.4 Be acceptable for international standardization.
A2.4.5 Have maximum resemblance to present office electric typewriter keyboard arrangements.
A2.4.6 Minimize the total number of graphic keys.
A2.4.7 Minimize the total number of function keys."

The recommendations made below draw on both the Standards and empirical results cited in the human factors literature. Where appropriate, additional discussion is included in order to provide a basis for the subject recommendation. Recommendations concerning spatial aspects of console and keyboard layout and key coding are portrayed graphically in Fig. 3.2.1.

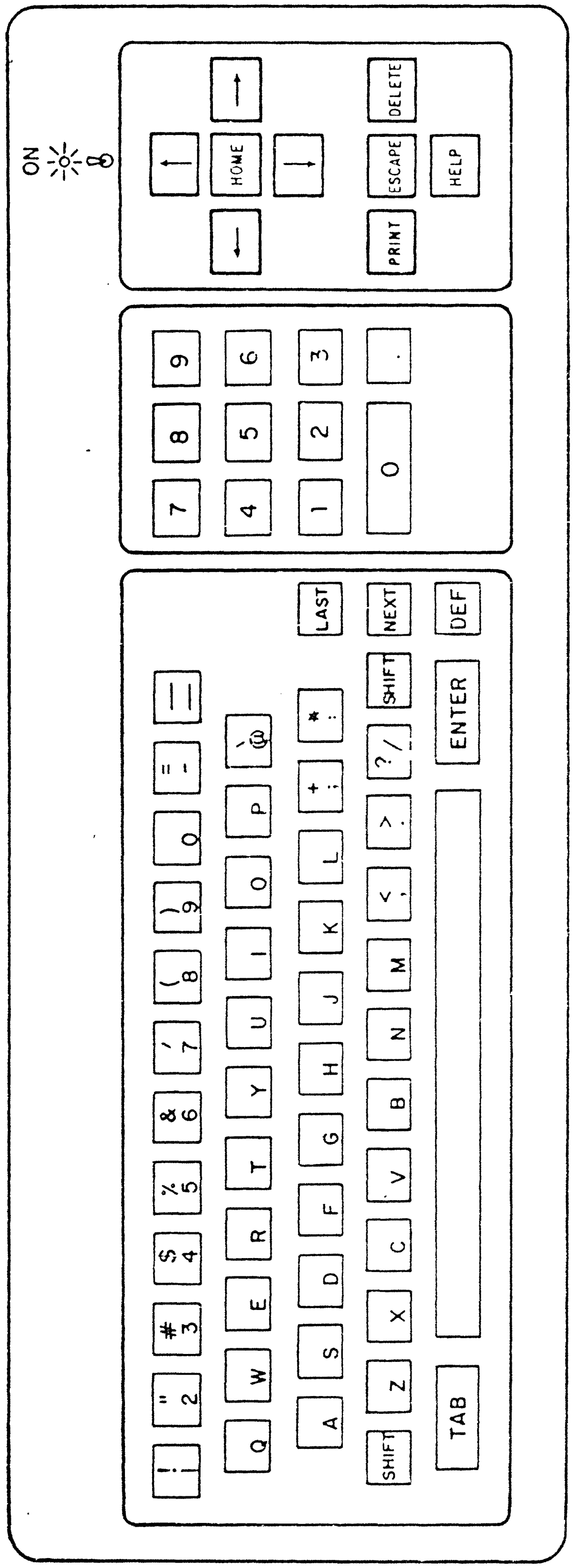


Fig. 3.2.1 Recommended Keyboard Layout and Key Coding

3.2.2 Console Configuration

The keyboard console supports three basic functions associated with operation of the system: (1) control over displayed information, (2) input of data, (3) editing. A design responsive to both the common and unique requirements of these basic functions requires close attention to the spatial arrangement of keyboard elements, labeling, and grouping of functionally related keys, coding of key tops, and touch and feel of keys and switches. A design goal should be to create a terminal in which individual tasks within and across functions are performed with equal ease by both skilled and semi-skilled operators.

It is recommended that the console be divided into three major sections, the first of which supports entry of alphanumeric data, a second supporting entry of numeric data, and a third supporting control functions. Guidelines for design and selection of elements comprising these regions are provided below.

3.2.2.1 Alphanumeric Section

This section of the keyboard should contain all keys associated with composition and entry of alphanumeric data. In addition, it should include special system keys relating to frame and page control and to display of default values. Because of its significance in all phases of terminal use, this keyboard should be located directly in front of the operator.

3.2.3.2 Numeric Keyboard Arrangement

We find a compelling similarity between the data input procedures defined with respect to the current system and those associated with input of accounting data via an adding machine or calculator. As a result, we recommend the use of the "adding-machine" format in this application, as shown in Fig. 3.2.1.

3.2.3.3 Keyboard Slope

Relatively few definitive data have been published on the question of optimal keyboard slope, though there is some evidence that a slope of approximately 21° is preferable from the standpoint of operator comfort. To accommodate a distribution of individual preferences with respect to slope, we recommend that keyboard console be designed such that its slope can be varied by the operator over a range of 10° to 35°.

3.2.3.4 Keyboard Size

Although it has been demonstrated that operators adapt successfully over a wide range of keyboard sizes, there seems no compelling reason why other than "standard" dimensions should be employed in the current application.

3.2.4 Key Parameters

3.2.4.1 Key Dimensions

Keys with a diameter of 0.5 in. (1.27 cm.) and a height-above-keyboard between 0.31 in. (0.18 cm.) and 0.45 in. (1.125 cm.) are typical in similar applications and are recommended here. A (typical) center-to-center spacing equalling 0.75 in. (1.81 cm.) is recommended.

3.2.4.2 Key Shape

Research on key parameters appears to suggest that keying speed and accuracy are much more significantly a function of key size than of shape. For purposes of maintaining commonality with other (particularly typewriter) keyboards, however, it is recommended that the designer select from a set of shapes with square cross-sections and concave top surfaces.

3.2.4.3 Force and Displacement

As with some other parameters of keyboard design, unequivocal recommendations with respect to optimal key force and displacement are difficult to formulate. Research appears to indicate little difference in keying performance of experienced operators over wide ranges of the two parameters, despite the fact that a "light" touch and short stroke are preferred. A force range from 0.9 oz. to 5.3 oz. (25.5 g. to 150.3 g.) and a displacement (extended position to switch closure) range from 0.05 in. to 0.25 in. (0.13 cm. to 0.64 cm.) are acceptable to most operators. Selection of average values in these ranges is recommended for all keys except those supporting the ESCAPE and ENTER functions.

Because of the potentially (data) destructive effect of inadvertent pressing of the latter keys, it is recommended that depression force be increased to 10 oz. (283.58 g.). For all keys, full bottom position should be reached at a distance of 0.06 in. (0.15 cm.) below switch closure.

3.2.4.4 Feedback

The depression of a key is normally accompanied by a variety of kinesthetic, visual, and auditory cues that inform the operator his stroke has been completed. Such feedback appears to be of benefit to the student and semi-skilled operator and should be retained in the current design.

In designing the keying mechanism, care must be taken to eliminate (or suppress) sources of delayed feedback, since such feedback may interfere significantly with typing speed and/or accuracy. We recommend that no auditory or kinesthetic cues persist beyond 0.10 sec. (100 msec.) after the full bottom position of the key is reached.

3.2.4.5 Coding of Function Control Keys

We recommend that arrows be used to code keys associated with cursor control, and the abbreviation DEF be used for "Default." Functions associated with all other non-alphanumeric keys should be completely spelled out, as shown in Fig. 3.2.1.

3.3 Design of Workstation

Effective design of the ASCS workstation requires attention to details both of terminal console configuration and of office operating environment. Concerns associated with the first of these factors are fixed and represent the focus of recommendations developed in this section. Those associated with the second may vary significantly from office to office and are, perhaps, best addressed on a site-specific basis. Examples in this second group are (1) need for client/operator privacy during data input and output, (2) need for secure storage of hard copy output, (3) location of terminal console within office given presence of glare sources and distracting noise.

Many details relating to workstation design are discussed at length in commonly available human engineering texts (see, for example, Morgan, et al, 1963; Van Cott and Kinkade, 1972; Woodson and Conover, 1964). The designer is encouraged to review these sources for information supplemental to explicit recommendations provided herein.

3.3.1 Console Configuration Keyboard/Display

The display should be located above and behind the keyboard such that an imaginary line drawn vertically through the display center intersects a second imaginary line through the middle of and parallel to the base of the keyboard approximately 2 inches (3.08 cm.) behind the top row of keys. The two components should be packaged in a single cabinet with easy near or side access to brightness controls and operating elements in need of periodic maintenance. Means should be provided by which the operator can vary the angle of the display in order to eliminate unwanted reflections. Maximum variation of this angle should be limited to 19° from true vertical.

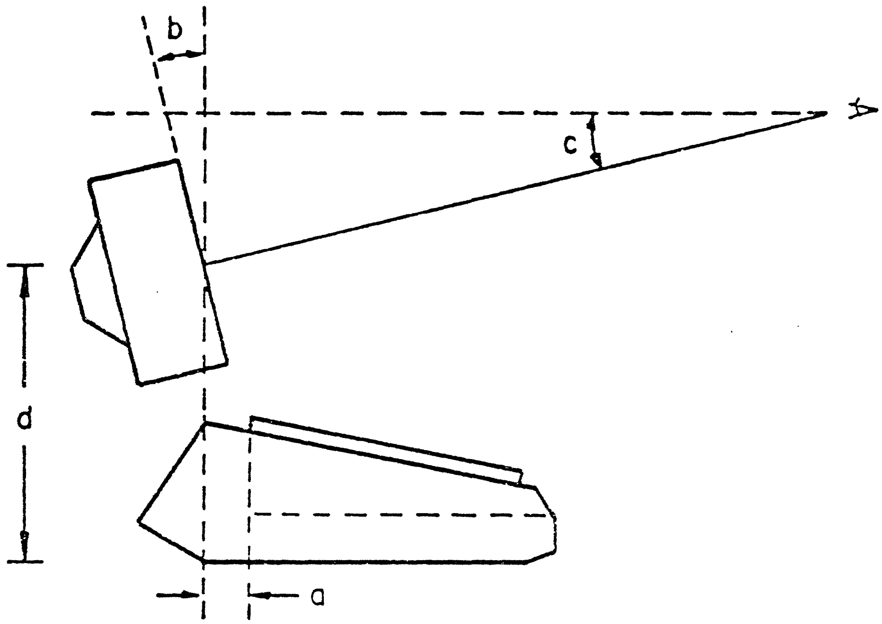
To accommodate the normal downlook angle (15° from horizontal discussed in connection with display viewing (see Section 3.1.2.5) the center of the displa·· should be located at a height of approximately 20 in. (50.8 cm.) above the surface of the table on which the console rests.

A diagram of the terminal console together with dimensional relationships recommended here is presented in Fig. 3.3.1.

3.3.2 Console Desk

A multi-purpose desk/table is recommended for the ASCS work-station. This desk/table should be designed such that it provides a stand for the keyboard/display console, a surface for writing and a surface for the temporary storage of hardcopy printout and other record materials employed in operation of the system. It should be useable by both right and left-handed operators.

It is recommended that the desk/table be of the split-level type, with the bottom of the console-supporting surface at a height of 26 in. (66.04 cm.) from the floor and the bottom writing/storage surfaces at a height of 29 in. (73.66 cm.). Surface thickness should be from 1.0 to 1.5 in. (2.54 to 3.81 cm). For convenience of the operator and to avoid the possibility of materials on the higher surfaces falling onto the lower surface, a barrier 0.25 in. (0.64 cm.) in height should extend above the former surfaces at their junction with the latter.



a	=	2 in. (5.08 cm)
b	=	0°-10°
c	=	15°
d	=	20" (50.8 cm)

Fig. 3.3.1 Recommended Console Configuration Keyboard/Display

A concept for the recommended desk/table configuration along with those dimensions that are, in our judgment, relevant to a successful design is presented in Fig. 3.3.2

3.3.3 Operator's Chair

The operator's chair should be of the swivel type. The chair should be able to be varied in height by a seated operator. The allowable range of variation (floor to top surface of seat-pan cushion) should be between 18 in. and 24 in. (45.72 to 60.96 cm). The seat pan and chair back should be contoured and covered with a material with good ventilating properties.

3.3.4 Portability

No special requirements for portability exist in this application. It is recommended, however, that both desk/table and chair be equipped with casters so that relocation can be easily achieved.

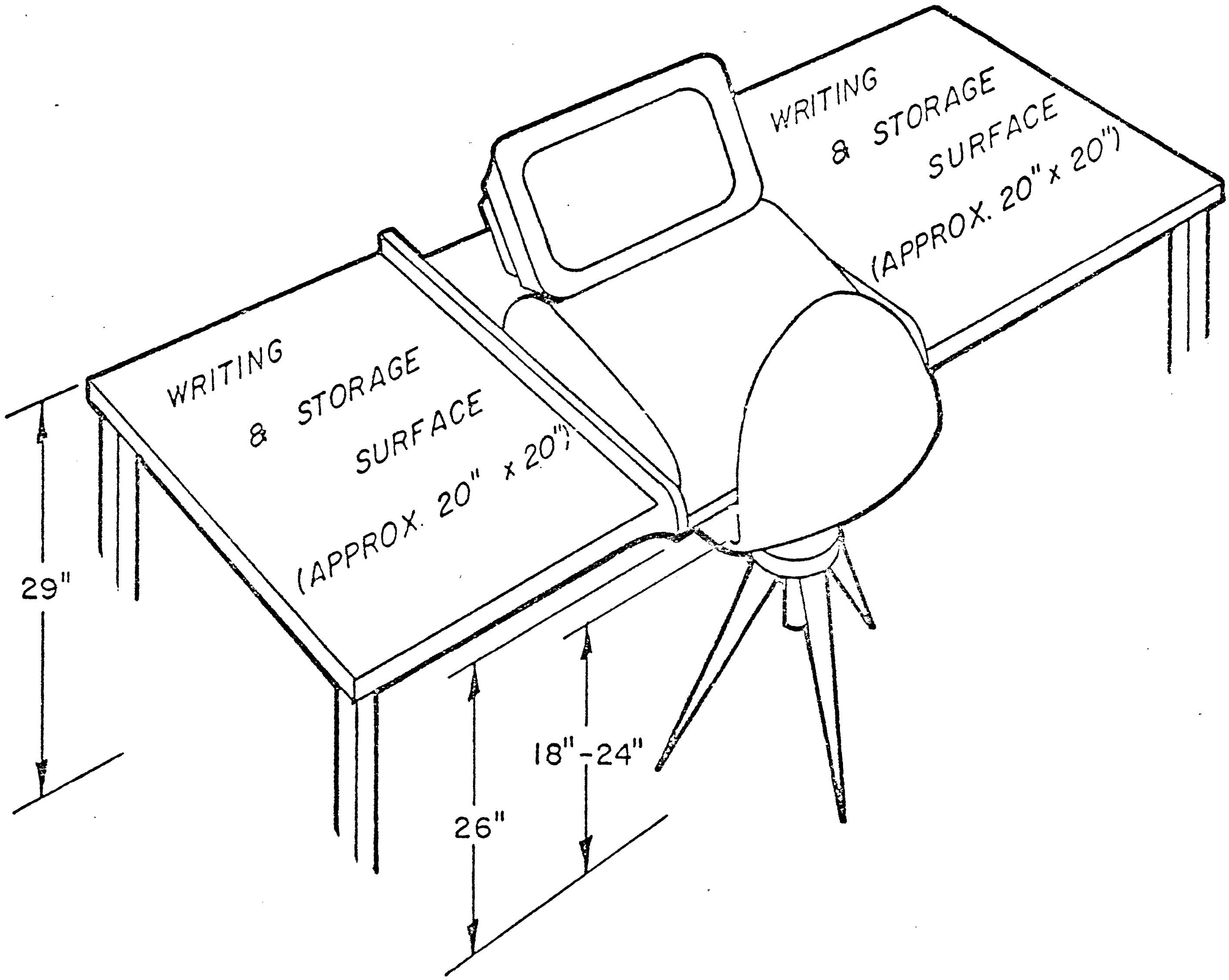


Fig. 3.3.2 Recommended Desk/Table Configuration

Section 4

SECURITY AND PRIVACY CONSIDERATIONS

4.1 Introduction

Whenever large amounts of computerized information concerning individuals exist, the issues of security and privacy become crucial. Dialogs that interact with the data must be designed to protect the integrity of the information and closely monitor access to it. When well designed, a good dialog is simple to use and facilitates easy storage and retrieval of information. On the other hand, provisions must be made to insure the privacy and security of that information. The two goals, to some extent, conflict with each other. The designer wants to avoid making the security procedures an obstacle course that would discourage users, but wants to insure a secure system protecting the privacy rights of every individual who is served by the system.

4.2 General Principles for a Secure System

4.2.1 Maintain Accuracy.

All attempts should be made in the design of a dialog to insure that the data collected are correct and complete. Updates should be made regularly, and old and obsolete information should be deleted or revised. Procedures for error corrections should be made easy and error checking done whenever possible. Systematic regular correction and updating of information will keep the data base timely, accurate, and complete.

While not a part of security principles directly, the maintenance of accuracy in the data base is an obligation of systems developers that goes to the heart of the issue of privacy and security. Given that security is required, the citizen to whom the data refer has a right to feel confident that his records are accurate.

4.2.2 Limit Access

Access to data should be restricted. The person at the terminal must be identified before he can see any of the stored information. Only employees with a need for the data in the performance of their duties should have access to it. The legal requirements for access have been set out in recent federal privacy legislation.

4.2.3 Limit Authorization

Once the user is identified, the system must check what he is authorized to do. Not all people may be authorized to see personal, individual data. Others may not be allowed to make changes in the data base. The limits to types of access are previously set by agreement between the user himself and those in charge of protecting the security of the system.

4.2.4 Provide Audit Trails

Records should be kept by the system of major changes in the data base. These should include the person making the change, the date and where the change originated. Also an accounting must be made whenever information is released to any person outside the county office. The computer should keep a record of the nature of the released material, it's destination, and the purpose of the disclosure.

4.2.5 Educate Employees

A strong potential force in protecting the privacy of the data rests with the employees who will come into contact with that data. Specific rules of conduct should be established governing the collection, use, maintenance, and dissemination of information. Any person who could have any access to the data should be informed of these rules. Legal restrictions on dissemination are required to be made public, and all employees should be fully aware of what they are.

4.2.6 Monitor Administrative and Physical Safeguards

To maintain high security in a county office, someone is needed to take responsibility for the protection of data. This person should oversee all phases of the security program for that office, evaluate their successes and report weaknesses or failures. He should be responsible for supervising physical, administrative, and technical designs. These include placement of the computer terminals to insure privacy, checking on computer password confidentiality, seeing that paper records are appropriately handled, etc. He should be responsible for seeing that security procedures are enacted, monitored, evaluated and enforced. Violations are certain to occur, most through negligence and normal errors. Deviations from normal occurrences should be brought to the attention of the security person.

4.3 Recommended Authorization Practices

There are many levels of possible authorization. The people attempting to access the data may be categorized by their position, by the type of use they will normally make of the data, by the type of access others believe they should have to the data. The data itself may be protected, rather than the users, and access restricted to certain people for only certain purposes. For example, the "county office authorization" described below is a quasi-regional protection of large bodies of data, rather than an attempt to classify each type of data.

4.3.1 County Office Authorization

It is recommended that each county office have a domain, partly determined by geography, which delineates the data available to anyone in the office. The domain for an office is envisioned as including information related to local producers but not producers outside the area serviced by the office. As producers and holdings may not follow county lines, or, for that matter, even state lines, the domain may not be completely geographical. It should be defined by the needs of the producers served by the office and should include information needed by that office to handle the business normally encountered. Unusual transactions, requiring information from other offices, should also require unusual procedures to obtain that information. These are the types of requests requiring formal documentation and formal release of information.

4.3.2 User Identification

There are several ways of identifying a user. For this type of application a user password appears to be the most feasible. Every user should have his own password which, plus his name, should be required to gain access to the computer. The password should never be printed by the computer.

A difficulty with passwords is that they may not remain secret. People with long passwords will type slowly, those with difficult ones will tend to recite them aloud, and those passwords which are cute and obvious will be particularly vulnerable to detection. For that reason passwords must be able to be changed whenever a user wishes, or suspects his password might be known.

4.3.3 User Authorization

Of the persons who legitimately should be able to access the data, there are a number of different ways of controlling that access. For the ASCS system, four categories of user are recommended. As the computer system develops, provisions for more categories will very likely become necessary, and designs should allow expansion of the possible legitimate user types. All of the categories described below are also restricted by the domain of the office. Unlimited ability to read and write on the data base, for example, will still only be true within the portion of the data base available to users in the county office.

The first category of users who are allowed to access the data are only able to read information in the data base. They are not able to change or modify or even correct items. They can document inaccuracies, answer inquiries, prepare legal forms and do other clerical duties which do not involve computer modification of information. This is a "read only" classification, allowing unlimited ability to see the data but no ability to change or modify it.

The second category of user will be able to change some things in the data base as well as being able to read it. However, only a limited number of subsystems will allow him to actually enter data. Clerks and other office personnel belonging to this group will be able to do regular bookkeeping updates, changing addresses and phone numbers, making minor corrections to erroneous information, and revising information that normally is expected to change in day-to-day transactions.

There are also a number of functions that could be performed by the same group of people preliminary to the execution of a transaction. Collecting and entering information, checking and correcting errors, preparing data for legal forms can all be done by the second category of users. They will be allowed to create suspense files and do everything up to, but not including, completing the transaction and changing the data base. Attempting to do an illegal entry will do two things. First the computer will generate all the error messages it would normally display if the entry were actually being made. Then it will notify the user that his authorization does not allow him to change the data base and that the "enter" instruction has not been executed.

The most privileged group of users are those who are allowed both read and write access to the data. This may be just one person in the office, the county executive director, or may be several depending on the office organization. All users in this group will have unlimited reading and writing privileges, restricted only by the domain of information available to the county office.

The fourth group of users is a special group. These are people who are only allowed to see statistical summaries of information in the data base. The computer will be acting in part as a management information system, supplying those in management positions with the kinds of summary data needed to make decisions. These people will have no access to any individual records and will not be permitted to change stored information. The computer will only allow the subsystems that compile statistics to be used by people in this group.

4.4 Implications of Dialog Design on Security

It is in the actual dialog, as opposed to the sign-on procedures, that the tradeoffs between ease of use and security become most evident. The ASCS dialog gains its greatest security from the specialized nature of the information transfer. It is very difficult to get through the dialog without a knowledge of the agriculture system and its terminology. Even with that, the branches leading to data access are not obvious except to someone familiar with the normal protocol.

Also, the dialog requires specific knowledge of the data being accessed. Suspense file numbers, producer ID's, loan numbers are the types of identification needed by the computer before it will return data to the terminal. If adequate control over paper records is maintained, these checks will be a further impediment to privacy violations. Errors can be monitored, if desired, to look for any unexplained increase in normal error rates. These should always be checked by the person with responsibility for security.

The ultimate responsibility for a secure and private system will always rest with the employees who use the system. When they are dedicated to protecting the privacy of information, they can influence data management to and from the computer, in the computer, and in virtually every aspect of normal office operation. Their knowledge of and respect for privacy concerns will make the difference between a clean, secure system and an open vulnerable one.

Section 5

A METHODOLOGY FOR TRAINING SYSTEM USERS

It has been assumed from the outset of this project that the population of users of the ASCS interactive system will be knowledgeable concerning agricultural office procedures but naive with respect to computer systems and the use of computer terminals. The training of users is thus separable into two parts; training in agriculture procedures and training in the use of the terminal and its associated software. While it can be expected that at the time the system first goes on-line there will be some changes in agricultural procedures to adapt them to the new system, the major training need at that time will be training in terminal use.

Unless employee turnover becomes a significant proportion of the user population per year, it probably will not be cost-effective to build special applications programs for the purpose of training new employees in agricultural office procedures. For this purpose we would recommend continuing or upgrading existing training activities. However, training in the use of the computer terminal is needed immediately by everyone who will use the system and it seems well worth the relatively small effort necessary to prepare software that makes it possible to learn to use the terminal through direct interaction with it. The feasibility of doing so is further enhanced by the underlying philosophy of the interactive dialog that will be implemented. It is designed to be largely self-explanatory and to minimize the need for such training.

The training procedure we would recommend is a self-teaching program. A single instruction sheet is used to carry the student through the log-in procedure the first time. From there a "boot-strapping" technique is used to present each new step that is required to expand the student's repertoire of available commands and to expand his access to new dialog procedures. At each step he would be presented with the next concept tutorially. Then he would be asked to demonstrate that he could use the concept. Then he would be given a few exercises to demonstrate the generality of the concept. The teaching program would have the capability to evaluate his response to each exercise and to branch back to further tutorial material or ahead to new concepts according to each student's needs. At any point in the simulated dialog the student may type a question mark to receive a hint or further explanation of the required response.

A critical feature of the program is the logical order in which concepts are presented. It should be built so that new response keys and new display materials are introduced in an order that permits continued expansion of user capability toward the ultimate goal of actually using menus to select simulated subsystems and demonstrating that the student is able to use the system to fill out a predefined sample of typical ASCS forms. In the process the student builds up larger and larger subroutines in his own behavior and begins using the component displays and keys more routinely. It seems likely that one to two hours of such interaction is all that will be required.

Although much further refinement will be needed, Table 5.1 shows a tentative outline of the developmental flow of concepts for a portion of the teaching program.

TABLE 5.1

Concept Outline for Training Terminal-System Users

- Display screen
- Standard typewriter keyboard
- Log on
    - name
    - password
    - terminal ID
- Use of character editing features
- Use of question mark
- Log out
    - procedure
    - meaning of sign-off message
- Menu selection
    - choice of single item
    - multiple menu sequences
    - menu bypass
- Use of sequence control keys
    - escape
    - last page
    - next page
- Simple input frame
    - single item input
    - entering tables of data
- Use of data entry keys
    - cursor control
    - default
    - tab
    - enter
    - help
- Suspense files
- Error correction
    - procedures
    - use of *
- Simple output frame
    - selecting multiple pages
- Use of print key

The teaching program should be self-contained and should probably reside in the concentrator. When it calls for actual ASCS forms, these forms would be simulated in the program with sufficient back-up to allow the program to react to alternative responses the student gives. In effect the program contains a model of the desired responses and can observe and react appropriately to deviations from the desired response. So long as it is only the interactive features of the dialog and not the substance of the ASCS procedures that is being trained, the representation of desired responses can be quite superficial and can focus on acceptable user actions at each branch of a dialog. Teaching programs similar to the one proposed here have been produced repeatedly both at BBN and elsewhere and represent little challenge to the current state-of-the-art.

Section 6

ADDITIONAL AREAS WITHIN ASCS SYSTEM DESIGN EFFORT IN WHICH HUMAN FACTORS ACTIVITIES MAY BE USEFUL

6.1 Terminal Selection

In Section 3 it was proposed that a human factors evaluation of interactive terminal display and keyboard be conducted as a part of the terminal procurement cycle. Such an evaluation of the three or four alternatives that seem the most promising candidates could be conducted rather easily and should include detailed review of system specifications with knowledge of the desireable characteristics outlined in Section 3. It should also include actual formal measurement of display legibility and keyboard effectiveness for each alternative being considered.

6.2 Evaluation of Designers use of the Dialog Specification Procedures

The usefulness and effectiveness of the dialog specification procedures from the perspective of the designers themselves should be studied systematically soon after they have been instructed as to their use and have begun to gain experience in actually writing dialogs that meet the specifications. It seems likely that helpful refinements in dialog documentation and gaps in the specifications will be revealed through this evaluation. It would involve systematic observation and interviews with a sample of system designers to assess the weak and strong points at each phase of application from dialog formulation to documentation.

6.3 System Conversion and Initialization

While system changeover occurs only once, planning for this activity involves all aspects of system design. Special temporary jobs are created, training for operators must be planned both for for the initial transition and for routine training throughout the period of system operation. Quality control in preparing the data base to ensure that it is as error-free as possible should involve attention to human factors issues in data conversion. Consideration of these issues at the time of system conversion is the first step toward effective system utilization.

6.4 Field Office Organization

Although the system plan calls for evolutionary development and implementation over a period of years, qualitative changes in the structure and organization of the county and state agricultural offices are likely to be desirable, if not essential. Qualified specialists in organizational development and job design should be asked to conduct a study of the impact of automated data processing on field office organization. Experience in the implementation of automated systems has shown that user acceptance of the new system can be considerably enhanced by giving users an opportunity to play a role in the development of the system. Organization specialists can provide suggestions for the appropriate steps during the process of organizational change to involve potential system users, soliciting their inputs and providing a communication exchange between users and designers.

6.5 System Test and Evaluation

System designers are likely to conduct careful studies of the effectiveness of operation from the point of view of the system hardware and software but an important component of T and E that they are likely to overlook is the quantitative evaluation of user performance. It is only at this stage that measurements of acceptable workload, dialog design, productivity and the effectiveness of job design can be evaluated. Systems are rarely used in exactly the way in which the designer envisions them. Evaluation of the design in light of these differences can lead to important adjustments that can improve the overall level of effectiveness.

ASCS has planned a phased program of implementation that include introduction of new subsystems during a pilot program that serves a single set of state and county offices. This is an ideal point at which to conduct these tests.

To study the effectiveness from the point of view of the field office will involve systematic study of real users interactions with a sample of subsystem dialogs. These studies should collect quantitative data concerning terminal use. Such measures as the distribution of log-on time, number of concentrator accesses per unit log-on time, number of data base accesses per unit log-on time, concentrator and central computer CPU time assignable to a particular user's interaction with a sample of transactions will provide descriptive data useful for further analysis of system load factors and system efficiency. An analysis of the nature and distribution of user errors will pin-point improvements that may be made in the dialog structure as well as in the applications software. Systematic direct observation of users, together with interviewer questionnaires sampling user's opinions of system acceptance will further aid in the development of a more effective overall system. These studies will require the cooperation and assistance of system designers and programmers but should be conducted by human factors specialists.

Section 7
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