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THE BELL SYSTEM TECHNICAL JOURNAL
Vol. 61, No. 6, July–August 1982
Printed in U.S.A.

Automated Repair Service Bureau:

Human Performance Design Techniques

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(Manuscript received July 6, 1981

Successful implementation of the Automated Repair Service Bureau (ARSB) Systems in the Bell Operating Companies is the result of the early integration of a variety of disciplines in the development process. This paper provides an overview of one of the basic human performance design techniques and an example of its application in the design of the Mechanized Loop Testing System. The expanding role of human performance design in the ARSB systems is also reviewed.

I. INTRODUCTION

In this issue, individuals from the disciplines of software, hardware, and systems engineering relate the design and development of ARSB systems from their perspectives. In this article, we discuss one of the functions that psychologists perform in the design and development of ARSB systems. This particular function is labeled personnel subsystem development (PSD), which means the integrated design of those factors that affect human behavior in the system, including the design of manual procedures, human-machine interfaces, training, performance aids, and documentation as part of the total system.[1] The PSD process also includes the systematic testing of the personnel subsystem prior to the initial field installation. As an illustration of PSD, we will first give a synopsis of the process and then relate the process as it was applied to the Mechanized Loop Testing System (MLT).[2] Our intentions are not to relate a "how-to-do-it" guide but to illustrate the approach and emphasize that system development is not just software development but the integrated design of hardware, software, and human information processing components.

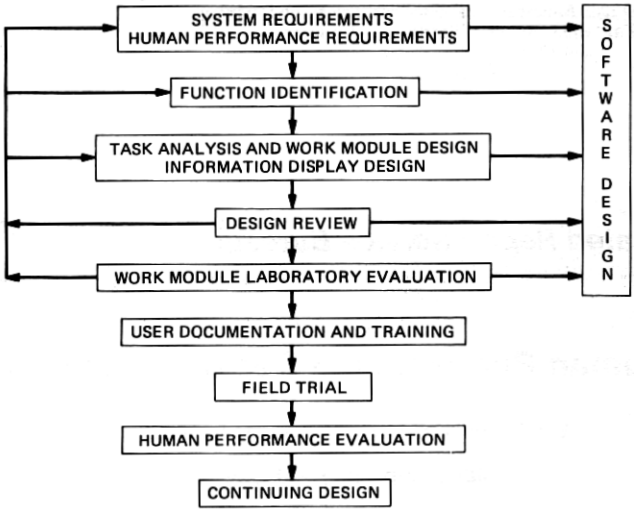

Fig. 1—Automated repair service bureau human performance design process.

II. OVERVIEW

Consideration of human performance in the MLT system began with the functional requirements for MLT and continued through system design, development, installation, and enhancements. An overview of this process is shown in Fig. 1. As system requirements were defined, the functions to be performed by people were defined, and aspects of the system which would affect human performance requirements were identified. In the MLT system, these manual functions included such activities as trouble analysis and system maintenance. Specific tasks were then identified to describe all the manual activities within each function. Related tasks were combined into work modules with specified inputs, outputs, and performance objectives. These work modules could later be combined to form complete jobs in the telephone company environment. At this point, we also provided initial specifications for the design of the information displays (CRT displays, printouts, forms, etc.). With preliminary versions of system operational features and human/machine interfaces, we conducted a formal design review with systems engineers and hardware and software designers. This design review provided the first opportunity for everyone involved in the design process to review the proposed system operation from the user's perspective.

When the initial design was complete, we conducted laboratory evaluations of work module design and preliminary documentation and training under conditions simulating actual system operation. For these evaluations, telephone company personnel who met the specified minimum skill and knowledge requirements received training on the new activities. During the simulation, the participants processed typical inputs as they would on the job. Performance data were collected during the simulation, and the participants were interviewed to determine their subjective reactions to the system design, training, and documentation. If data from the evaluations indicated that redesign was required, the procedures and human/machine interfaces were redesigned prior to the development of final user documentation.

This design process was highly iterative, with changes at each phase affecting design decisions made earlier, as shown in Fig. 1. But the most significant effect of this approach was the impact on the design of the software. At each phase, as various design decisions were reviewed or tested, many recommendations for software changes were made and implemented to improve the total system. This process illustrates a view of the system as an integrated unit of people and machines processing information to achieve stated objectives. This view of the system requires that human performance considerations be integrated with software design from the earliest phases of system development.

The final stages of the human performance design process for MLT involved the preparation of user documentation and training for the field trial. We then trained the Repair Service Bureau personnel at the trial site and monitored their on-the-job performance during the field trial. Follow-up activities included field evaluations of human performance within the system and recommendations for design changes to improve overall system operation.

III. EXAMPLE FROM MLT SYSTEM DESIGN

To illustrate the impact of this design process on the MLT system, we will describe the initial design and subsequent redesign of a specific manual function. As a result of the initial examination of system functions, the trouble analysis function was defined to include all the manual activities that must be performed when a trouble report is first printed in the work center. These activities consisted of the examination and integration of the trouble description, line record information, and automated test results to determine what the next stage of processing should be.[3] As a result of the initial task analysis, one work module was designed to accomplish all the activities in the trouble analysis function.

The primary input to this work module was the Basic Output Report (BOR) containing line record information, the trouble description, and detailed test results. The output of this module was a decision to route the report for either manual testing, additional automated testing, dispatch, or close out. Some design work had previously been done on

```
RSA/BOR SERIES MLT RESULTS
B(69)NO SERVICE AFFECTING DC FAULT             B(212)    = 8.217400    %
B(201)AC SIGNAT INDICATES                      B(285)XBAR, NO LINE CKT TEST
B(205)    OPEN TIP
B(207)OPEN OUT
B(208)    DISTANCE TO OPEN
B(209)       = 24.03210        KFT
B(211)    CAP IMBAL
```

Fig. 2—Original test results format.

both the content and the format of the test results displayed on the BOR (Fig. 2), and this was accepted as the initial human/machine interface design.

This initial design of the test results output and trouble analysis procedures was based on two major assumptions. First, we assumed that in-depth interpretation of *all* the detailed test results would be required for all trouble reports. Therefore, very little interpretation of the raw test results was provided by the software. All results were displayed, along with software codes, in the order in which they were obtained during the mechanized testing process. We also assumed that a person's prior trouble analysis experience in the manual Repair Service Bureau, plus some limited training in the new test results, would enable him or her to accurately analyze and process trouble reports containing MLT results. Therefore, the original training focused on providing "translations" of the new test results into familiar terms, with little procedural instruction in the integration of the test results with other information on the BOR to make trouble report routing decisions.

To gather performance data to validate these assumptions, we conducted a laboratory evaluation of this work module. Four operating telephone company craft employees who met the specified minimum requirements were given the work module training. Then they processed trouble reports (BORs) selected to provide a valid sample of the trouble descriptions, line records, and test results found in typical Repair Service Bureau operations. Analysis of the performance data revealed that the participants incorrectly routed 16 percent of the trouble reports, and most of these errors involved routing troubles for manual testing when the MLT test results provided sufficient information to directly dispatch the trouble report. Since a major goal of MLT was to reduce the number of troubles that required manual testing, this error rate would have a significant adverse effect on overall system operations and economics.

Based on the performance data and comments from the evaluation participants, we reexamined the initial assumptions and redesigned

```
MLT RESULTS:     VER 42   OPEN OUT, TIP, DISTANCE = 24,032 FT.

OPEN OUT
   OPEN TIP
CAPACITIVE BALANCE
   =  92.77 PERCENT
DISTANCE TO OPEN
   = 24,032 FT
VALID DC RESISTANCE AND VOLT
3 TERMINAL DC RESISTANCE
  >    3500.00 K OHMS T-R
  >    3500.00 K OHMS T-G
  >    3500.00 K OHMS R-G

3 TERMINAL DC VOLTAGE
   =          0.00 VOLTS   T-G
   =          0.00 VOLTS   R-G
3 TERMINAL AC RESISTANCE
   =      1012.23 K OHMS T-R
   =        845.34 K OHMS T-G
   =        710.76 K OHMS R-G
CROSSBAR, NO LINE CKT TEST
```

Fig. 3—Test results format—field trial.

both the human/machine interface and the analysis procedures. It was evident that some interpretation of the detailed test results could be accomplished by a software algorithm and that a brief summary statement could be provided at the beginning of the full test results (Fig. 3). Therefore, many routing decisions could be based solely on the summary without detailed examination of all the test results. In addition, extraneous information not needed for trouble analysis (e.g., software codes, nonsignificant digits) was eliminated. The detailed test results describing the fault condition were presented at the beginning of the results to facilitate trouble diagnosis. Training and documentation of the analysis procedures were expanded to include decision guidelines in a performance aid for work center personnel.

We expected that the redesigned procedures and output format would enable a clerical level person to process many trouble reports. Also, fewer trouble reports would be routed incorrectly, thus reducing the need for manual testing. Data from a follow-up field evaluation confirmed these expectations concerning the effectiveness of the redesigned procedures and test results. In some work centers, clerical people were processing all of the trouble reports, with fewer instances of incorrect routing than were found in the laboratory evaluation.

Continuing engineering of the MLT system has resulted in refinements and improvements in the testing hardware and the software algorithms that control testing. Similarly, follow-up studies of field installations have provided more detailed information on the relationship between various line fault conditions and specific MLT test results. This information on the operational use of the system has been used to enhance the software interpretation of the detailed test results to provide over 50 additional test-result summaries. Based on the results of field evaluations of several MLT installations and a laboratory study comparing human performance on alternative test-results formats,[4] the display format has also been redesigned, as shown in Fig. 4. This

```
VER 42: OPEN OUT CABLE TIP- CAP BAL       92 %
        DISTANCE FROM STATION          1800 FT
        DISTANCE FROM C.O.            24000 FT

CRAFT:  DC SIGNATURE          MLT: DC SIGNATURE            AC SIGNATURE
        KOHMS    VOLTS             KOHMS    VOLTS          KOHMS
        3500            T-R        3500            T-R     1012          T-R
        3500        0   T-G        3500        0   T-G      845          T-G
        3500        0   R-G        3500        0   R-G      710          R-G

        CENTRAL OFFICE             BALANCE                 OPEN DISTANCE
      XBAR NO TEST                  CAP  92 %                FROM STA=  1800 FT
                                                             FROM CO  = 24000 FT
```

Fig. 4—Proposed test results format.

new format provides most of the test results information required for rapid trouble analysis in the summary. In addition, the summary will include the information to be relayed to outside repair technicians on dispatch.

IV. COMMENTS

The process of human performance design begins with and not after the development of system requirements. Human performance considerations begin not with a review of the requirements document but with an understanding of what the system is supposed to accomplish and the examination of alternative approaches.

The role of human performance designers in the design and development of the ARSB systems is continuing to grow along with the evolution of the systems. The initial systems were designed to mechanize the more routine, repetitive tasks performed by clerical or craft personnel (e.g., trouble report tracking, initial line testing). With the mechanization of many of these routine activities, more recent ARSB systems are addressing more complex craft and managerial activities. For example, the next generation of the MLT system will provide computer-assisted loop testing and analysis currently performed by experienced craft persons using old, but functional, work positions. The complexity of the information processing activities requires that the design of all system components be closely integrated.[5] Similarly, systems such as CRAS and Predictor are used by managers to support their decision making in such areas as plant analysis, force management, productivity, and budgeting.[6] In the design of these new decision support systems, the psychologist as designer and developer will play a major role, since these systems now address the issues of problem solving, direct managerial use of the system, design of the system for group problem solving, the incorporation of models and artificial intelligence to support decision making, the evaluation of systems in supporting decision making, and a host of other complex human-computer issues.

As the role of human performance designers increases, so does the variety of tools and techniques applied during the design process. The basic systematic design process illustrated here is employed in the design of ARSB systems. In addition, laboratory experiments and field studies have been conducted to address specific design issues.[6] Areas such as job quality are being examined, both in existing ARSB systems[5] and in current system design efforts.

For the development of ARSB systems, it has been effective to dedicate and organize psychologists on a group level to a particular system development effort. In their system design and development work, these people draw on numerous branches of Psychology and Engineering, including Experimental, Social, Cognitive, and Organizational Psychology, Industrial Engineering, and Human Factors. This dedication and continuity of effort ensures that systematic human performance design takes place as opposed to having the psychologist intermittently critique the development efforts with the result of a retrofitted system at best.

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