SYSTEM DESIGN FOR THE HUMAN FACTOR

R. F. HAAKE
American Telephone and Telegraph Company

The performance of total business oriented electronic data processing systems is not simply a function of good computer programming because the computer is still only one component in the middle of the system as many scarred veterans of data processing wars will testify. The other component, people, has been largely ignored until recently. After four years of research and development it is this component that the Bell System now handles through a Systems and Training Application Requirements Program termed STAR. Success with the STAR Program in the Bell System prompts our desire to share it with the CPRG membership.

STAR introduces a new discipline to the system design process. It is a discipline which accounts for the human factor in systems operations during system design rather than after conversion as was conventionally the case.

Project STAR was a two-year research and development effort undertaken in September, 1964 through a contract with the American Institutes for Research.

In the beginning of Project STAR, the question was simply, how could clerks best be taught their jobs in data processing? Training was expensive and in most cases it was inefficient, ineffective and uncontrolled. This was especially true when converting to new systems. Not long after research began, however, it became clear that training problems were only symptomatic of more serious problems. The more serious problems were consequences of the limited approach being taken to system design.

Simply speaking the fact was that in order to establish a viable training program we first of all had to know, and have described in some useful way, what there would be to teach. When the work to be taught does not exist, as is the case when new systems are being designed, then the new work must be designed as an integral part of the system. In this way, and, frankly speaking, only in this way did we find it possible to design meaningful training.

During the design of new systems in the past, however, preoccupation with the computer to capitalize on its capacity had resulted in virtual disregard for the human element in these systems. And yet, the fact remained that the human element accounted for at least two-thirds of the cost of operating the systems. Furthermore, and equally distressing was the impact of the indiscriminate treatment given employees who found themselves without support in a strange new operating environment. STAR research confirmed that development of major parts of the system had been ignored – the parts that people must play in its operation. STAR also demonstrated that machines and people are interdependent components of these systems; that if either component should falter, both do and the whole system suffers. Out of Project STAR grew a new set of procedures to use in the design of systems and a new set of products to

support those who operate them. The new procedures parallel and complement those already in use for design of the computer or the machine sub-system. With STAR'S concentration on the human side of systems – the personnel sub-system – it can now be stated that system design and development is a total effort aimed at the creation of total systems.

The balance of this paper will not deal with the details of research that led to the STAR findings. They are available in a final report of the project which you are free to examine upon request. Rather, the paper will deal with the manner in which the findings are being used in order to design and support new EDP systems.

My objectives are to demonstrate how, with STAR, we find it possible, and I must add practical, to do the following:

- to plan, organize and control development of the personnel sub-system.
- to balance the capability and constraints of machines and people during design of the system.
- to complete the data base necessary to simulate the total system for feasibility.
- to objectively configure new employee assignments ahead of conversion.
- to design training which produces rapid, effective learning.
- to provide worker-oriented job instructions for reference by employees when training is done.

In order to describe the STAR process to you in the brief time available it will be important to set the stage through two minor diversions. One deals with the composition of systems which involve a computer. The second deals with the process by which such systems are created.

Figure 1 illustrates characteristics of today's computer oriented business information systems.

Two points should be emphasized about this diagram. First, it is apparent that computer process represents only one of several process functions required to sustain a system, that is, to make it run. The other processes fall into the realm of STAR, the personnel sub-system. Second, systems transcend the data processing center. In fact the data center is invariably only one of many participants in systems. For instance, source information seldom originates in the center nor is the center generally the final user of system products. STAR considerations concern all processes not undertaken by the computer. They extend beyond the data processing center. And STAR, while originally designed to serve data center needs, also, we find, serves the needs of others who must play their part in the operation of these total systems.

This factor is extremely important to the telephone company. The salaries and wages of those affected by data processing systems now in operation and under design in the Bell System exceed and from all evidence will continue to exceed the expense of associated computer rental by at least a factor of two and in some cases by as much as a factor of five. Under these circumstances we consider it simply good business to heed the human element of the system–just as deliberately and as systematically as we heed the computer element.

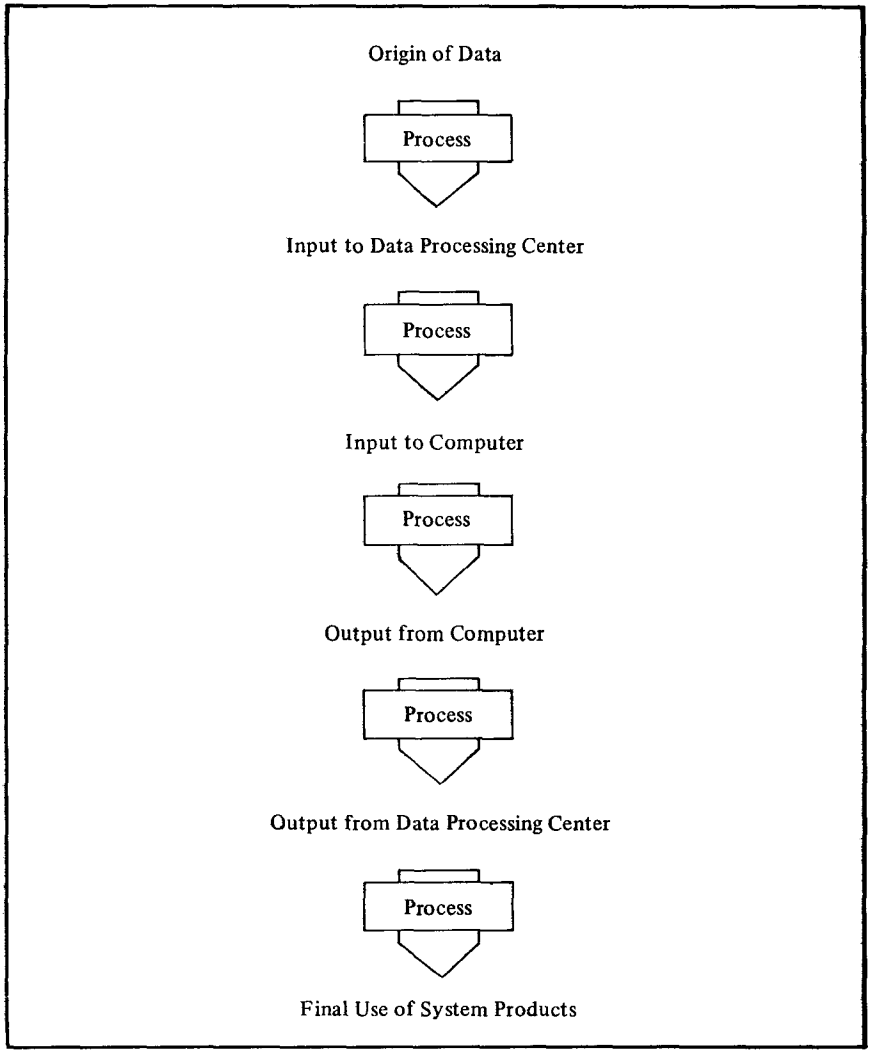

FIGURE 1
Span of a System

The major point of this diversion has been to demonstrate the interrelationship of machines and people in system operations. The real issue, however, is to determine, during system design, which of the process activities should be performed by people, which activities by the computer and how each should perform them. These questions, among others, are faced and answered during system design.

So, let's next examine the process of system design.

Roughly speaking there are four stages generally agreed to exist in the process of creating or designing a new system:

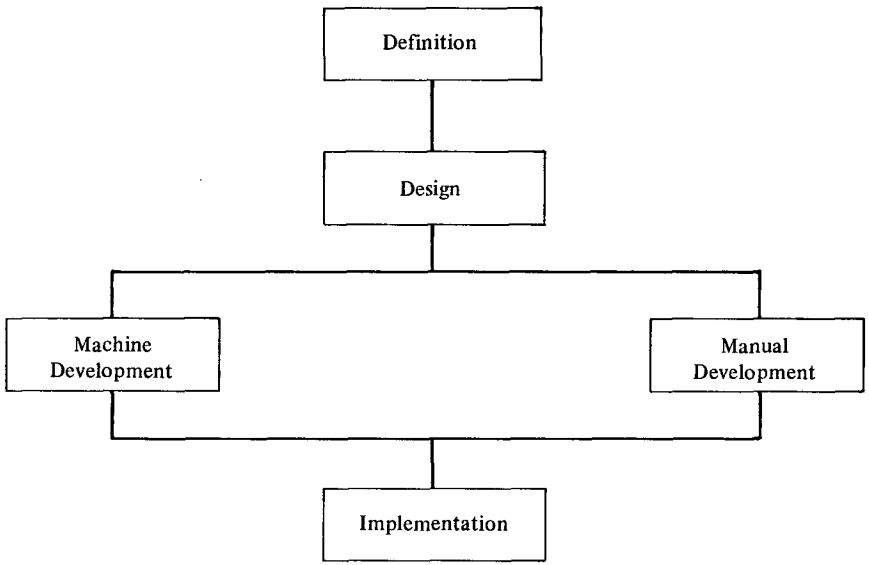

FIGURE 2
Stages in Creating a System

It is unfortunate that two dimensions limit the display of these stages, because, in the first place, they are not at all this clear. In practice there is a definite overlap of activity between them. In the second place they are really iterative and not purely sequential as the diagram implies. And, in the third place, design really never ceases except momentarily at the point in time when conversion takes place. Thereafter repair and refinement repeat the cycle over and over again.

However, be that as it may, this chart will serve our needs.

For purposes of further discussion, and because not everyone agrees upon what takes place in these four stages, consider that at least the following activities take place and in roughly the following order.

Define – Assemble data which: (1) specify minimum acceptable system performance objectives; (2) include system product and process requirements; and (3) identify corporate restrictions which must override system development.

Given the goals and constraints for the system thus defined, i.e., a stipulation of what to build and how to know when it is finished, then . . .

Design – Allocate system functions between machines and people considering the capabilities and constraints of each.

Designers deduce from the defined product goals of the system and from known raw input to it, all of the processes that will be required to get from one end to the other. Then they allocate the processes. In this allocation, along with deliberations about computer capability and constraints, here are a few of the human capabilities and constraints that designers consider:

Is the work possible to do?
Is it practical?
Can it be taught?
What about productivity?
What about quality?
Will it be satisfying?
Does the physical environment change?

The product of the design stage is a blueprint – a graphic display of all the process functions required to produce and to utilize system products. The blueprint reflects, symbolically, all system process activity. It shows the computer activity as programs or machine process modules and people activity as work process modules. It also reflects their interrelationship. We call the collective display a "Function Flow Diagram." Separately, the machine diagram is called a "General Flow Chart." The manual diagram is called a "System Work Flow Chart."

Given these blueprints of the system . . .

Develop – Concurrently develop, document and test programs, practices and training considered necessary to implement and sustain the system.

The key word in this definition is *concurrently*. At the same time as the logic of computer programs is determined and charted, the logic of tasks within work modules is also determined and charted. While programs are encoded into a computer language, tasks are described in command prose or with decision trees or decision tables as appropriate. While programs are tested, practices are dissected to derive and design training.

Another way to view the development stage is through a display of the types of people engaged in it and the products that they create.

There are some points to make clear about this group of Developers and their products.

1. Control Technicians develop the computer control system including parameters for common records and internal files.
2. Machine Technicians develop application programs for the computer.
3. Job Technicians design the work that people will have to do. The product of their design, the Position Practice, describes this work in a level of detail suitable for reference by employees when training is done.

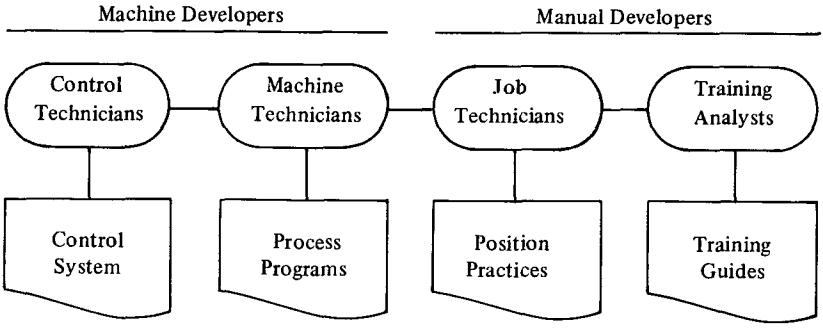

FIGURE 3

4. Training Analysts design the best way to teach what the workers will do. Instructors will be job-knowledgeable supervisors or clerks – those who know how to do the work but who are not necessarily thereby qualified to teach it effectively.
5. All developers, no matter what their responsibility, are equal in management level and in status. To be most effective they sit side by side ("eyeball to eyeball" as the expression goes) while at work. Each can veto the other's contribution to the system.

Given these products, the system is ready to be implemented . . .

Implement – Prepare all concerned for an orderly transition from the old to the new system.

So much for the organization into which STAR practitioners have been implanted.

Now let's get to the heart of STAR – to this notion of a work module which we call a position. As you can see, we are constructing systems in a truly modular fashion: not only, as always, with process programs, program segments and macros on the machine side; but also with their equivalent, positions, tasks and steps on the man side. Positions in combination with programs represent the sum of all processing required to produce and utilize system products.

Each position work module is functionally oriented. It is never larger than the span of tasks which comprise one employee's full time job assignment. Most often it is smaller than a job and thus the job will encompass several positions. The task logic within each module is designed and diagrammed and each task elaborated in command steps or with decision tables as appropriate.

Perhaps the following diagram will help clarify the relationship of Steps, Tasks, Positions and Assignments. These labels represent successive levels of abstraction in configuring a hierarchy of work.

Job Technicians and Training Analysts design the system at the Position Level. Line Managers allocate or distribute the positions among their

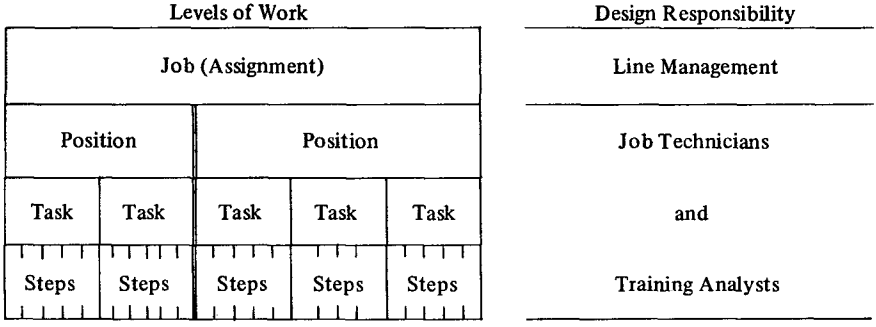

FIGURE 4

operating force based upon such factors as work volume, worker qualification, physical arrangements of the data center, supervisory span of responsibility and so forth.

Identifying and charting positions during the design of systems involves successive approximations about the work to be done in operating the system.

When considering the operation of an EDP based system certain classes of positions almost certainly will evolve. To demonstrate this let's examine such a system in the light of its potential positions. (See Figure 5.)

First of all there will be the computer to operate, i.e., the console at the central processing unit. This represents one piece of work, potentially a position.

Secondly, there will invariably be an input device through which data enters the computer and correspondingly an output device from which data leaves the computer. The operation of such gear as card readers, cathode ray tubes, tape drives and printers falls into these categories. The tasks involved in operating them are quite different from those involved in operating the computer console. Possibly different people will perform them. Potentially, therefore, they represent positions.

Next, there is customarily a point at which data is received within a computer center and similarly a point from which it is distributed from the center. Again, separate sets of tasks are involved – possibly to be performed by separate individuals. Hence, two more potential positions are indicated.

Errors are identified, sometimes in advance of computer processing and sometimes as a result of it. At any rate they must be analyzed and corrected. Once more we have a potential position, this time involving Error Correction.

Finally, while we have examined worker activities within the computer center we must acknowledge that other activities take place outside the center in support of the system. On the one end are those who receive and process data at its source, and at the other end are those who make final use of system products. Two differing sets of activities but, to repeat, activities which necessarily involve and affect performance of the total system. Thus, positions will also exist at

these two extremities of the system. In summary, one might display the basic positions this way . . .

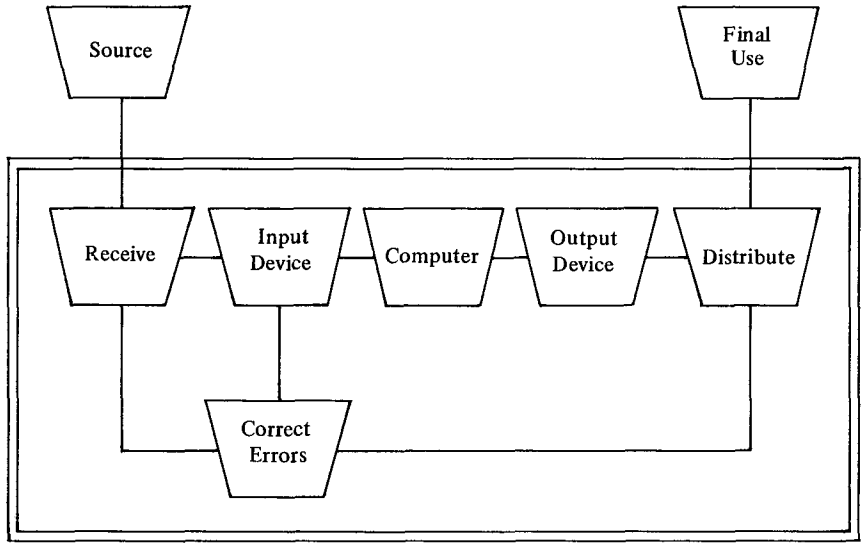

FIGURE 5
Potential Positions in an EDP System

This diagram represents the probability that any given computer-based system consists of at least eight positions.

But this particular system configuration does not achieve anything. It has no purpose. In order to demonstrate how design of positions takes place in practice it is necessary to ascribe some character to the system – to make it do something. For that reason I'd like you to join me in building a piece of a hypothetical system.

We will construct a system oriented to telephone company work. It is a system (grossly simplified) that is initiated when you call our business office to request new telephone service or to discontinue service or to change it in some way. The Service Representative who handles your request prepares a service order. The order is mailed to our installation department so that they can perform the work you want done. Upon completion of the work, the order is mailed again, this time to the computer center so that the record keeping activities can begin.

One day a proposition is set forth that instead of using mail to send this service order from place to place we should use teletypewriters and teletype circuits – after all that is our business. Furthermore, using teletypewriters we could transmit perforated paper tape for direct computer input at the same time as we transmit printed copy. And another system design job is inaugurated.

Now let's consider how this might affect the system model of positions which we just completed. For purposes of limiting complexity we will only examine the implications involving the data processing center up to the point of computer input.

Look at what this means in terms of positions.

Hypothetical Service Order – Teletypewriter System
System Work Flow Chart

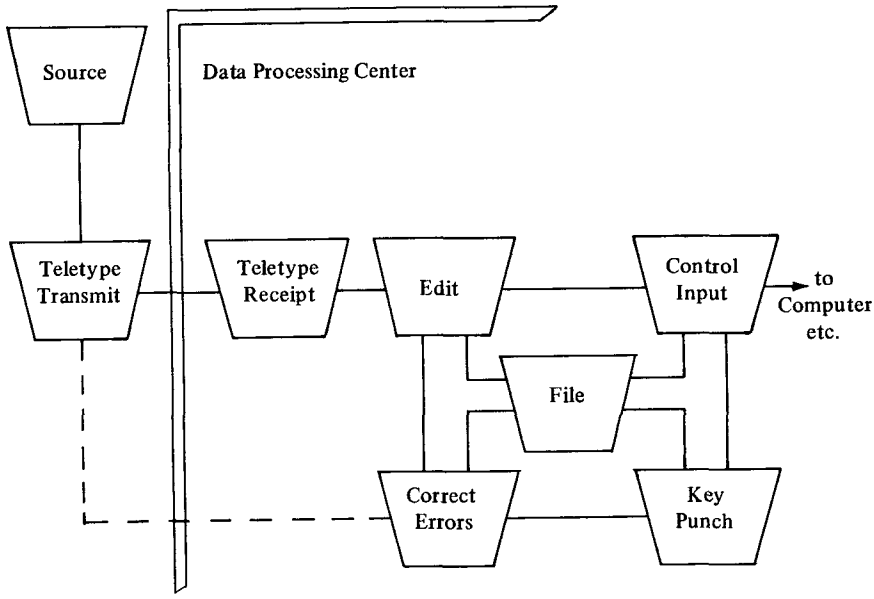

FIGURE 6

Since we introduced the use of teletypewriters, someone must obviously transmit service orders on them and, correspondingly, another must receive the orders in the data center. Two positions are thus immediately indicated, Teletype Transmission and Teletype Receipt.

The existence of a printed service order copy enables us to review or to edit it for gross errors which obviously the computer cannot process and this, therefore, introduces the possibility of an Edit position.

We can anticipate that errors will be found. They must be corrected. This is a different order of work. Indeed, "Error Correction" is one of the more complex positions we will have in a data center. The possibility exists, of course, that the error cannot be corrected from the information available – or can only reasonably be accommodated by calling for a retransmission of the order, so that possible work flow path is indicated. On the other hand, if the error can be corrected locally, then it will be necessary to regenerate machine input. Since the erroneous paper tape is no longer of use we may determine, as a design decision, to key punch the corrected service order information. This gives rise to the need for a Key Punch position. Finally, from either one of two paths we arrive at the Input Control point and computer processing can begin.

In our business, records retention is a legal requirement as well as a practical expedient and so we must also acknowledge that another position, File, is ever present.

Now let's examine what a position is – this time by going inside of one, so to speak. Take Key Punch for example . . .

On the one hand in key punch we have the various media to be punched. Our service order system will require as many as ten different kinds of data to be punched into as many different cards. This will include such information as:

Name and Address
Type of Telephone Service and Equipment
Directory Advertising
Deposits
Etc.

On the other hand, in considering the "Key Punch" function we must also consider the "Key Verification" function. Furthermore, we must also consider the activity required to "Translate" random data on the service order form into specific groupings of data for the specialized cards to be punched. Another possible activity to consider is a "Sort" of the orders so as to arrange them into an optimum order for translation and punching. Possibly, too, we would want to consider preparing grid sheets for the key punch operator so that all she needs to do is punch what someone has transcribed to be punched into specific columns of specific cards. Possibly another activity, "Transcribe," will be needed.

Let's sum up. Here we have at least five possible functions or activities to be performed upon one document so as to create as many as ten new documents.

Functions	Media				
	N&A	S&E	DA	Dep.	Etc. to 10 Forms
Sort	X	X	X	X	(X)
Translate	X	X	X	X	(X)
Transcribe	X	X	X	X	(X)
Key Punch	X	X	X	X	(X)
Key Verify	X	X	X	X	(X)

FIGURE 7

The question, "What is a position?" can now be answered. Theoretically a position can be any one of the 50 (five functions times 10 media types) function-media coordinates, they all represent work to be done. Practically speaking, however, the position will first orient functionally, without regard to media, because it is considered to be more efficient to perform the work this way. Such an orientation could produce five positions in the above example, there being five functions. However, one must also seek to cluster related functions to produce a logical combination of the largest number possible. To do

so in this case would produce, again theoretically, only one position - meaning that one type of individual would be given all functions to perform and thereby would create all ten documents. (A position, it should be emphasized, represents a function or set of functions to be performed – irrespective of the number of people required to do them. The factor of the number of people to whom a given position may be assigned is governed by the volume of work to be done and the time required to complete it.)

It is also possible to design positions around media, that is to have specialists who perform all the indicated functions but only to produce one or two types of media. While this may appear, at first, a poor approach from the standpoint of efficiency, there are strong psychological arguments in its favor. For one thing, it enhances identity with the work which we have found is an important motivator. This option, therefore, should not be dismissed out of hand. Another option, of course, is to combine some of the initial functions such as "Sort," "Translate" and "Transcribe" with those included in the previous position, "Error Correction."

Many designers might hesitate to combine "Key Punch" and "Key Verification" within one position. The possibility here is that Line Managers will want to divide these functions among two people. Given this possibility, two positions are indicated. It is always possible for Managers to combine positions to make job assignments. It is never possible – by definition – for them to divide the tasks (or functions) contained within a position among two or more people. If this is anticipated, two or more positions must be designed.

So much for what might be done.

Suffice it to say that the combinations and permutations of these options are bewildering. But I submit that deliberations such as these are truly as involved and equally as important as are those undertaken by computer programmers. They are not decisions that ought to be abandoned during system design and left to the whim of clerks and supervisors, persons ill-equipped to make them under pressure on the day that the conversion switch is turned on.

What is a position? Well, a position is whatever you, the designer, determine what it ought to be – considering the needs of the system while at the same time considering the needs of employees – of people.

Let's return again to our hypothetical system. And for the sake of continuing we'll freeze this work flow chart just as it is. Consider it done and all of the deliberation about the content of its positions completed.

What we now have is the blueprint mentioned earlier. It is a diagram which signifies all of the work activity required to be performed by people in order to operate the system. The question to be answered now is, "Must every position be documented?" The answer is "No." Not all of the positions are worthy of further development. Given this blueprint of the system, the design manager can finally make some intelligent decisions about the use of his own design resources – his staff manpower. Obviously he would only assign further manpower to develop and document positions of consequence to system operation. Staff resources are invariably limited. So is time. Neither should be dissipated on activities that will not pay off.

Error correction, for example, deserves high priority for further attention. It is both complex and critical to system performance. File, on the other hand, or even Key Punch (despite our careful analysis) would probably rank

much lower. What I'm saying is that here, for a change, is a tool with which and by which a design manager can wisely employ his limited resources in further development of the man side of systems.

The position work module has another important advantage – one, in fact, that overshadows most others. It provides the Line Manager with great flexibility in the distribution of work among his employees.

Using the hypothetical work flow chart we just designed we can demonstrate this facility by considering possible combinations of the positions indicated into a variety of different jobs. In one data center, for example, Teletype Receipt, Edit and Error Correction might be combined into one job while in another center the distribution of these positions might, with good reason, be quite different. In centers with more than one shift the distribution of positions varies between the shifts. Indeed, variations in position assignments occur among employees in the same shift doing the same work. Position assignments will vary depending upon such factors as employee capability, work volume, schedule requirements and so forth. Growth is a factor too. Certainly, as an employee masters one set of positions he can absorb additional positions. In this way it is possible to enlarge his span of responsibility and enrich the work itself.

Long ago we discarded as impractical the thought that we could design static employee jobs. Things just don't work out that way. Instead the position work module has become our building block for the personnel sub-system. It accommodates the multiple variations to be found in the nature of the work to be done, the environment within which the work is performed and the skill and ability of those who do it. It also accommodates the psychological need people have to find continuing challenge in their assignments.

For each selected position an instruction manual is prepared. We call it a Position Practice.

Each Position Practice contains, in order: (1) a copy of the "System Work Flow Chart" showing all processes contained in the system with its own position highlighted to show where it fits in the system, (2) a diagram of the task logic for this position called a "Position Diagram" to show the order in which the work is done, (3) the tasks with their elaborating steps detailed in the body of the practice, called the "Position Description" and (4) appended "Corrective Procedures" and "Exhibits." One of the regimens imposed by STAR is to account for exceptions to normal routines. Contingency analysis is built into the design process. Thus steps in the position practice not only describe what to do when things are right, they also describe, in the corrective procedures section, what to do when things are not right – a provision we seldom made in the past.

The next step of STAR involves the design of training and the preparation of Training Guides. Training requirements are extracted from the tasks and steps contained in the position description and translated into training objectives, rearranged into order for teaching and reflected in a (Training) Unit Flow Diagram. With this diagram as an outline, the Training Plan is created. It serves as a guide to job-knowledgeable but instructionally naive teachers, namely, job incumbents and their supervisors. The Training Guide covers the items to be taught and the order in which they should be taught plus the best means to employ in presenting them. The guide also includes validated performance measurements to assess student learning so that both the student

and the teacher will know when training is done. Training Guides are prepared for selected Position Practices depending upon such factors as complexity of the position, frequency of training need, and so forth.

Through the medium of Position Practices we learn of the new work to be done. Through training design we learn how long it will take to teach. We also learn how productive our newly trained employees will be. By applying predictable volume figures to this base of productivity we can finally determine how many people will be required to operate the new system. Not only that, we can finally predict the probable full cost of converting and operating the new system.

This, Ladies and Gentlemen, is the STAR Story. In closing I should like to paraphrase a statement which appears in the Final Report of STAR Research dated August, 1966. It neatly summarizes all the problems we had and the solutions we now employ . . .

> We believe that human activities in any changing business system should be designed, not permitted to evolve; should be formalized by documentation, not passed on by word of mouth; and, should be introduced through systematically derived training, not just exposure to working conditions.

By now I think you can see that the STAR Program unveils a whole new facet to system design. I trust that you can also see how we use this program to design systems which account for the human factor.