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Job Performance Aids: Concept, Implementation and Implications

Ronald Edward Anderson

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ABSTRACT

Job Performance Aids:
Concept, Implementation and Implications

Ronald Edward Anderson

Research into job aid technology has been conducted for more than twenty five years by the United States Department of Defence with good evidence that the technology supports on-the-job worker performance. In spite of the findings, the U.S. military has not embraced the technology as a means of improving the worth of worker performance. Worth in this context is the result of the value of the worker accomplishments in relation to the cost of acquiring the behaviour repertories. The results of findings reported in the literature concerning job aid technology are compared to a conceptual analysis using Stafford Beer's Viable System Model as a deductive reasonning methodology. The analysis at the system level indicates where there may be difficulties for implementation of job aid technology. It is hypothesised that these difficulties explain the reason for the failure in introducing job aids to the military. A general model for the introduction of the technology into a large organization is proposed using the Canadian Forces as an example.

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Last, I thank my family for putting up with long hours of separation physically and mentally while I progressed this thesis. Liz I owe you a great deal, thank you.

DISCLAIMER

The opinions expressed in this paper are those of the author and do not necessarily reflect the views of the Canadian Armed Forces.

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CHAPTER ONE

THE PROBLEM AND ITS SETTING

Introduction

The results of a study into the research that has been conducted on job performance aid technology are presented here. A substantial amount of effort has been expended on research of the job aid concept (Folley & Munger, 1961; Elliot, 1966; Elliot, 1966; Foley & Cramm, 1972; Booher, 1978a; Smillie, 1985). Some issues appear to have been resolved, while others remain targets for further study. These research topics are identified and subjected to a novel systems analytic procedure which attempts to extract information useful at the micro (worker) and macro (system) levels.

There were three phases to the study. The first phase was the identification and description of the research problem for this study, this chapter. Next was the selection of research method and analytic devices; this is the subject of chapter two. The final phase was the compilation of the analysis which is presented in chapters three through five. Chapter five also summarizes possible research topics.

The first phase is discussed below in two parts: the definition of the problem; and the setting.

The Problem Defined

The problem definition is discussed in three phases. The concept job aid is first defined to provide focus. The context of job aid research is then presented, and followed by a refinement of the research principles to provide a clear definition of the research problem for this study.

Job aid definition. A job aid is an information aid which guides an individual's performance on the job so as to enable him to do something which he was not previously able to do, without requiring him to undergo complete training for the task (Wulff & Berry, 1962). The following is a list of equivalent terms:

- job performance aid (JPA)
- performance aid
- job guide (manual)
- procedural guide
- how-to-book
- task performance map

This definition is further refined in chapter three where the concept is expanded, but the definition will suffice as a starting point. The key elements of the concept are that it is used on the job while performing a task, and it is used as an alternate, but complement, to training.

An example of a job aid is the piece of paper that comes with a new unassembled bicycle or garden shed telling the purchaser how to assemble the parts. These tasks may be ones the purchaser has never encountered before. However, with the aid of the piece of paper together with previously acquired general skills (reading instructions, using a screwdriver, etc.) a new performance can be accomplished without special training. The amount of difficulty (and cursing) exhibited in performing the task is an inverse measure of the effectiveness of the job aid. It is apparent that there are good and bad job aids. This suggests potential research problems.

The research problems in context. Wulff & Berry (1962) proposed some research questions with regard to job aid technology. They presumed that the psychological problem posed by the requirement to design job aids is one of stimulus control of human performance on the job. How can stimulus situations be arranged in a job aid so as to produce optimal performance by controlling behaviour? In refining this question, they rejected any research problems attempting to categorize the bewildering variety of human performances in systems.

Wulff & Berry suggested that it might be possible to classify the varieties of change in performance that could be brought about by introducing job aids. The research problem proposed was how to define such classes of change and how then to relate them to the characteristics of the performance aid. Change of performance or behaviour is related to learning. In the learning environment, however, the student is given opportunity to make errors, refining his performance toward the model performance through successive attempts; this procedure is referred to as shaping the behaviour. In the job environment the task performer is expected to perform correctly on the first and every attempt. The problem in changing on-the-job performance by using job aids is that one job aid which may be appropriate for one individual may be inappropriate for another. The problem proposed by Wulff & Berry is related to the categories of learned behaviour in relation to the characteristics of job aids.

Since 1962, when the Wulff & Berry article was published, the United States Armed Forces have sponsored a substantial number of studies in job performance aids. The culmination of this work is the introduction of an entire military trade which is based on, among certain other principles, job performance aids. This project is the Enlisted Personnel Individual Career System (EPICS) (Blanchard &

Smillie, 1979, 1983; Blanchard, Smillie & Conner, 1984; and Blanchard, Clelland and Megrditchian, 1984). The research information base that has been developed in the investigation of job aids is generally unavailable to the public. This is not due to security classification of the studies, but due to their "fugitive" nature.

A search for information on job aids using various information sources such as card catalogues, dictionaries (e.g., Educational Technology: Definition and Glossary of Terms), encyclopedias (e.g., Encyclopedia of Education), indexes or abstracts (e.g., ERIC) will produce very little in the way of results. Searching through textbooks will produce results if the searcher already knows which authors to look for. Much of the information will not be found except through an exhaustive search of "fugitive" literature. The fugitive literature information base is large, being primarily studies conducted for the United States Department of Defence.

In these twenty five years since Wulff & Berry proposed research problems in job aid technology it can be presumed that much has been learned. However, reading of the studies done to date will not reveal a general model which answers the all aspects of the problem proposed by Wulff & Berry. A goal proposed by these researchers was to develop a method to classify job tasks so that job aid developers could learn to classify any given task and then enter a table by type of task to determine appropriate rules for generating optimum job aid material.

Undoubtedly other research problems have been encountered as a result of individual studies, and additional problems may have been discussed. The problem for the present study is what has been learned about job aid technology? Is there sufficient information for a generalized systems model for job aid utilization in the context of life cycle support of major capital equipment procurement? These questions are posed within context of a goal to transfer job aid technology from the United States, in particular the military, to the Canadian Industrial Complex. It is the author's desire that Canadian Armed Forces will also benefit from the research.

The research to date has been extensive as will be demonstrated, but how are researchers to know whether the job aid concept has been fully explored? Much is known and is being employed, but, what are the guiding principles to organize further knowledge about job aid technology? A two level model is proposed for the analysis of job aids and these levels provide a useful division for the research problems investigated in this study.

The problem refined. The research problem for this study was dealt with on two levels: the micro level - that is the interaction between the task performer and the job aid; and the macro level - that is the role of job aids within the larger systems context. The problems for this study are basic ones:

Micro Level -

- What are job aids and what do they do in task performance?
- Why use job aids to help individuals perform tasks?
- Where and when should they be used?
- How should job aids be used on the job?

Macro Level -

- What are job aids in the systems context and what do they do for overall system performance?
- Should job aids be developed as an integral part of a whole system?
- At what stage should they be developed in the system

development process? And, where in the system should they be used?

- How, in context of the whole system, should they be used?

The investigation of these problems created further needs. A conceptual framework for systems development was needed. A systems engineering point of view was selected. Also an analytical method was required to cope with the large number of variables and the research data. A cybernetic model was used to process the research information and the model provides a method for proposing a system design framework for job aid implementation. The handling of these needs is discussed in chapter two.

From this definition of the research problem the discussion leads to the setting of the problem.

The Setting of the Research Problem

The setting of this current effort is within the academic and military milieu with potential industrial benefits. The sponsor of the study is identified below with a statement of the intended scope of the study and finally the importance to the three communities.

The sponsor. The Canadian Forces have provided some sponsorship for this study as part of a general program which has a goal of increasing resident knowledge within the Forces of various topics. In particular, for the author's involvement, the need for a strategy for application of job aid technology has been identified. The findings of this study should aid the development of a job aid strategy.

Scope of the study. This study was conducted within a context of Applied Research in that the results have a practical application that can be applied in various settings. It is not intended that the findings be only applicable to the sponsor of the study. It is expected that, while the Canadian Forces is used as the organizational example, other large organizations which have a heavy training load could benefit from this study's findings.

This study does not propose detailed methods for job aid development as they are dealt with elsewhere (Harless, 1979; Horabin, 1980), but does deal with factors influencing their design. The study does propose a task guidance strategy using a general model for job aid technology. It is suggested that this strategy is suitable for the Canadian Forces.

Importance of the study. This study is important to three communities: the military, in particular the Canadian Forces; industrial complex, including defence contractors; and, the research and development community.

The Canadian Forces are currently engaged in several major capital acquisition programs to upgrade operational capabilities.

- Aurora Long Range Patrol Aircraft (LRPA). The delivery of these aircraft is complete; training has been implemented; and, some job aids were provided, however a system was not introduced for the updating and maintenance of the job aids.
- New Fighter Aircraft (NFA). This contract is well into implementation; the NFA Training Development Team was briefed on a systems approach to performance aid technology in January 1981 (Morse, unpublished).
- Canadian Patrol Frigate. The contract for this project was let in July 1983; this project is the largest capital project ever undertaken by the Canadian Government; it is

costing over three billion dollars.

In each of these projects, it is anticipated that major changes to the skill repertory of Canadian Forces personnel will occur. These projects will result in a shift from "tube technology" to "solid-state digital technology". Significant retraining is required and savings may be possible with increased utilization of job performance aids. These projects are also having an effect on the Canadian Industrial Complex. This is especially true in the Patrol Frigate Project which has an important Canadian Industrial Benefits package which emphasizes "transfer of technology" from U.S. to Canadian Industry. There have been indications that successful contractors with the Canadian Government will have a proven capability in integrated life cycle support.

It was recognized several years ago that future technologies would present problems in the provision of skilled personnel to maintain complex computerized systems. The Canadian Forces Maritime Command conducted a study which has resulted in a major restructuring of Naval Trades (Maritime Command, 1978). The study has been known as the MORPS Report. MORPS is an acronym for Maritime Other Ranks Production Study.

The MORPS Report describes several problems which may be universal to volunteer military organizations:

- attrition of trained personnel
- high front end costs of training, especially maintenance training

In addition the Canadian Naval Forces have had a general attrition problem which has resulted in trade structure imbalance at the middle rank levels. The MORPS Report anticipated the technological advances and predicted quite accurately the discrepancy between skill levels of the late 70's and the skill requirements of the early 90's as is evident in the NFA and CPF Projects.

It is unfortunate that the MORPS trade restructuring is being done without cognizance of research being done by the United States Armed Forces into means of reducing the effects of attrition of trained personnel and the impact of technological leaps. The answer to these problems coming from the U.S. research and development efforts involves deferred training, but immediate employment in maintenance areas with task guidance by the use of various forms of job performance aids. The MORPS answer, on the other hand, involves deferred training and deferred employment in maintenance areas.

Until recently, little emphasis has been given in the Canadian Forces to the potential of job performance aids in solving performance problems on the job. The specifications that govern technical manual production do not make reference to job performance aids, nor do they require the kind of "user friendly," procedural document that is implied in the job performance aid concept.

The job aid concept is now included in the curriculum for the Canadian Forces Training Development Officer Classification training. One could expect some job aid development in some instances as a function training development.

The Canadian Forces have recognized the need for a strategy for wider scale application of the Job Performance Aid Technology (ROIT, 1982). It is intended that this paper will provide groundwork for developing such a strategy. This present study explores the job aid concept from the worker point of view, supervisory point of view and the system point of view. By handling the topic in this way, specific working procedures can be developed for implementation of job aids in appropriate ways using the concepts presented and the skeleton system model presented.

While the government sector has been engaged in study into the job aid concept in an attempt to justify the technology so that funding can be allocated, the industrial complex has been the benefactor of much of the research. Improved presentation of information to workers by means of job aids in appropriate instances results in improved worker performance and therefore an improved profit picture. It is suggested that many of the personnel involved in the research are from time to time consultants to industry and a transfer of the technology has occurred. Further research into job aids could have additional benefits. Some of the same benefits proposed for the Canadian Forces could apply to industry.

For the research and development community, this study collates information available in disparate "fugitive" sources. The findings and concepts are presented in a rational and novel way using Stafford Beer's cybernetic model (Beer, 1972; 1979; 1985) for analysis and presentation. It is also proposed that the analytic method used in this study could be used before conducting research and development work to make the research more focused while avoiding the problems of implementing the findings.

By handling this complex subject in the way that has been described, it is expected that this paper will further knowledge about job aids and promote their use.

This chapter has presented the first phase of the present research, the statement of the problem in terms of the questions to be addressed as well as setting of the study into the problem. The next chapter is a presentation of second phase of the study, the selection of the research method and analytical devices.

CHAPTER TWO

DESIGN, CONCEPTUAL FRAMEWORK AND RESEARCH METHOD.

<u>Introduction</u>

The second phase of the research reported here was the selection of a design, a framework, and analytical method and instrumentation for the study. The selected analytical method also provided the means to propose an idealized organizational model which includes job aid technology. First the design.

<u>Design</u>

This section describes the design approach for the study and discusses the nature of the information sources.

<u>Historical Design</u>

A Historical Design was selected for the present study. There is a large information base in job aid technology. Comprehensive reviews of the literature have been conducted about every five or six years since 1961 (Folley & Munger, 1961; Elliot, 1966; Foley & Cramm, 1972; Booher, 1978a). Morse (Note 1) conducted a review of the literature in 1980 but did not complete the study; however, an excellent Bibliography with Abstracts was prepared covering the period 1954 to 1980. Other than the Morse notes, no study or review of the literature on job aid technology has been conducted in Canada or within a Canadian context.

Substantial information on job aids is buried away in a "fugitive" data base. These studies were accessed through the

Canadian Department of National Defence (DND), Defence Science Information Service (DSIS) a section within Chief of Research and Development (CRAD). DSIS is not normally available to the public, however institutions and companies which have contracts with DND may subscribe to the service. DSIS accesses research reports from Canadian and foreign institutions conducting defence research.

The Nature of Job Aid Literature

Prior to 1960 research reports relating to job aid technology were, for the most part, informal studies using a scientific approach and the findings are not generalizable. The early reports were studies of particular systems or parts of systems. By 1958 guides to the design and use of job aid types of materials were published (Hoehn & Lumsdaine, 1958; Miller, 1956), but no studies were found in which any attempt was made to identify the relevant variables in the performance aids problem (Elliott, 1966).

1960 to 1972. By 1972 job aid research had determined that certain variables were important in the technology:

- job aids vs no aids vs training (Horabin, 1967)
- job aids vs traditional technical manuals vs training length vs subject technical aptitude (Elliot & Joyce, 1968)
- job aids vs traditional technical manuals vs length of training (Gebhard, 1970)
- job aid formats - flow diagrams vs simple lists of instructions vs subject technical aptitude (Elliott, 1965)
- job aid media - visual vs audio media (Elliott, 1966)
- subject technical aptitude vs job aid vs control (Elliott, 1967)

These studies were primarily Research and Development type of studies, however, inferences were made in some cases to a more generalized population. These studies were not true Experimental designs, but Quasi-Experimental (Causal-Comparative or Correlational). The subjects were generally in preformed groups and occasionally subjects were randomly assigned to treatment.

1972 to 1978. For this period fewer of the studies emphasize the utility of job aids and a greater emphasis was placed on the structure of the job aids and their acceptability. New job aid variables were studied:

- level of job aid detail vs traditional manuals vs technician experience vs spares usage (Potter & Thomas, 1976)
- user and supervisor acceptance of job aid vs traditional technical manuals (Joyce & Chenzoff, 1974; Johnson et al, 1977; Richardson & Syster, 1977; Bialek & Kulas, 1978; Thomas, 1978)
- job aids with imbedded training vs on job training (Pulliam & Goett, 1977; Theisen, Elliot & Fishborn, 1978)

The studies in this period were more rigorous in attention to design and reduction of confounding variables. The potential for integrating training and knowledge or skill advancement within the job aids was conceptualized. During this period and extending to date have been some studies on the use of algorithms in instruction (Brecke & Gerlach, 1973; Gerlach, 1974; Gerlach, et al, 1975). The emphasis in these studies is on the effectiveness of flow chart type formats for communication as well as analysis of procedures and content; some useful design information can be drawn from the algorithm research.

1978 to Date. The most recent studies in job aid technology were concerned with job aid structure and large-scale implementation:

- flow chart vs equipment state tables vs traditional manuals (Smillie, 1981)
- use of callouts (Curran, 1980)
- integrated training, job aids and individualized personnel system (Blanchard & Smillie, 1979, 1983; Blanchard, Clelland & Megrditchian, 1984; Blanchard, Smillie & Conner, 1984)

The research during this period attempted to deal with the failure of job aid advocates to achieve wholesale acceptance of job aid technology. In the previous periods, job aid research was out of the main stream. It was R&D and not necessarily oriented to implementation. Examples of job aids had been developed for comparison and effectiveness studies. In some cases job aids were delivered for implementation, but supervisors pegged the job aid users as "dummies" because they don't talk like real technicians, even though they may perform every bit as well (Joyce, 1977). The EPICS Project is an implementation study which, when complete, could close the book on job aid research (Blanchard et al, 1979, 1983, 1984a, 1984b). However, a telephone conversation between the author and Dr. Smillie at NPRDC (1987) suggests that in spite of every evidence of the value of highly procedural job aids, job aid users are not wanted in the military; highly trained technical people are preferred. Has the research to date been a waste of government money? One would hope not. Much information has been learned about the design, development and implementation of improved job instructions and task guidance on-the-job.

The present study will reexamine the job aid concept to determine what should be done in order to successfully introduce job aid technology into large organizations. The literature seems to point to the valuable contributions that job aids can provide, but there seem to be system level problems. Workers can use the aids on the job; supervisors say that workers perform adequately (Smillie & Clelland, 1986); but, job aids are not being introduced into the military. Private industry, however, has embraced them because they effect the "bottom line".

The method selected to conduct this study requires some explanation. It follows from what has been discussed so far. Since the problem of job aid implementation is at the system level, a method is needed to examine it in some meaningful analytic way. An approach was found which is novel and could have wider scale applications as will be discussed in chapter five. The analytic method is within a conceptual framework of engineering.

Conceptual Framework

Gilbert (1978) compares science and engineering. His ideas are summarized here.

> Science attempts to discover from first principles the nature of things. Its purpose is to find out what the world is like. It uses a well-developed methodology, and will go where it leads. Science makes no value judgments; things are what they are. Science sees knowledge as an end for its own sake.
>
> Engineering on the other hand, is intent on remaking the world; it is not content with just finding out what the world is like. It knows precisely where to go and will use whatever methodology to get there. Engineering makes value

judgments about the nature of things and seeks to make changes that will be valued. Knowledge is not the end; knowledge should be applied efficiently so as not to detract from the valuable ends. However, new knowledge of the nature of things may be a spin-off of the application of engineering approaches.

The scientist who sets understanding of phenomena as his immediate goal is mainly concerned with conceptual systems; by contrast, the engineering scientist whose immediate interest is in controlling "nature" deals with systems of an empirical type (Finan, in Gagne, 1962).

The engineering point of view was selected for this study because, in the opinion of the author, while there is much that is not known about the human element in systems development, there is a great deal that we do know about human performance and performance systems. There is a problem, however, in the access and application of that knowledge in control of performance. A discussion of systems engineering is in order to establish where job aids fit in the engineering context.

Systems Engineering

The complexity of the job aid concept required a design consideration not normally found in historical research. Experimental psychology by its nature tends to be diachronic, meaning it cuts across time and place (Gilbert, 1978). The laws and generalizations are meant to be universal, but strict experimental control, while reducing confounding, uncontrolled variables, usually results in less generalizability but greater internal validity. Less experimental control tends to lead to greater generalizability but greater potential for confounding variables.

Engineering, on the other hand, must deal with universal principles and apply them in real time to achieve specific results. Control is in real time, not in contrived episodes, and the control is subject to normal external variables (i.e. the system environment). While history and maturation are threats to internal validity of experimental psychology, these synchronic factors need to be accounted for in an engineering vantage point to ensure fidelity of the forecast of results (Finan, 1962). Gilbert (1978) refers to the engineering vantage point as metachronic, meaning "change in time." The diachronic vantage point focuses on process and interaction (e.g. what is the nature of the process); the synchronic vantage point focuses on results and effects of time (e.g. the historical view); and the metachronic vantage point focuses on process and results (e.g. what can be done to produce results).

The study of job aid technology requires a metachronic vantage point. The problems with the introduction of job aids is that the studies that have been conducted were episodic and under an umbrella of R&D. Large-scale introduction of job aid technology requires high level conviction in the organization and an integrated systems approach. The organizational system must be engineered for results; indiscriminate introduction of these kinds of changes are doomed to be anomalies in the organization.

Job aid technology is an aspect of a personnel subsystem of a larger organizational system. Organizations which depend heavily on large equipment components require careful engineering of the relationships between the personnel and equipment subsystems (the man/machine interface). The engineering of equipment systems has become extremely complex with more integrated control devices being incorporated. The human functions in systems is not as discrete as it was in an earlier epoch. The boundary among the functions of man, machine and computer is fuzzy. For optimum performance, man/machine systems must be engineered as a whole - all the parts including the man must be built to fit together as an organized entity.

The nature of systems. Ackoff (1971) defines a system as a set of interrelated elements. It is an entity composed of at least two elements and a relation or organizing principle that holds each of the elements to at least one other element in the set. Beer (1979) provides a complementary definition:

> A System consists of a group of elements
> dynamically related in time
> according to some coherent pattern.
> (p. 7)

The second definition suggests the notion of purpose. The purpose of a system is subjective. It is based on the observer. Purpose, and the facts which provide evidence of purpose, are in the eye of the beholder. When an observer comments on a system, the nature and purpose of the System being observed are entailed. The concept of system also implies interaction and communication between components or parts. In the case of the man/machine systems the components are individual humans and the machines they control and by which they are controlled. A man/machine system is an organization whose components are men and machines, working together to achieve a common goal and tied together by a communication network (Kennedy, 1962, from Gagne)

System development. Compared to natural organisms, synthetic or man-made systems may seem contrived and *ad hoc*. However, they do go through cycles which are like natural systems. There is the birth of a concept which is followed by development and growth, and after the system matures a productive (in-service) phase is next. Finally, there is death or disposal when the system is no longer viable.

The development phase of the life cycle of a man/machine system is shown in Figure 2-1. The bias of the Figure is on the human element. The figure shows that, after system purpose, advance design and assignment of functions to man and machines, there is a temporal relationship between the development of machinery and the design, development and testing of the human element. The engineering of the human element has its own techniques and procedures. It also takes time, therefore the planning must be integrated with the machine development to insure an appropriate man/machine system. The human element of the system should be engineered to take advantage of the equipment features.

Engineering human performance. In the engineering of human performance systems there is one basic purpose: to see that the goals of the system, as they have evolved, are met. The development of the human performance component of a system should consider various tradeoffs: selection criteria; training development; and environmental support to performance on the job, job aids being one form of environmental support. Low selection criteria may result in increased training requirements; increased environmental support to personnel performing their jobs may result in reduced training requirements. These tradeoffs made during system development have attendant front end costs and down stream costs and/or savings. Put in another way: "You pay for the performance of personnel now (i.e.

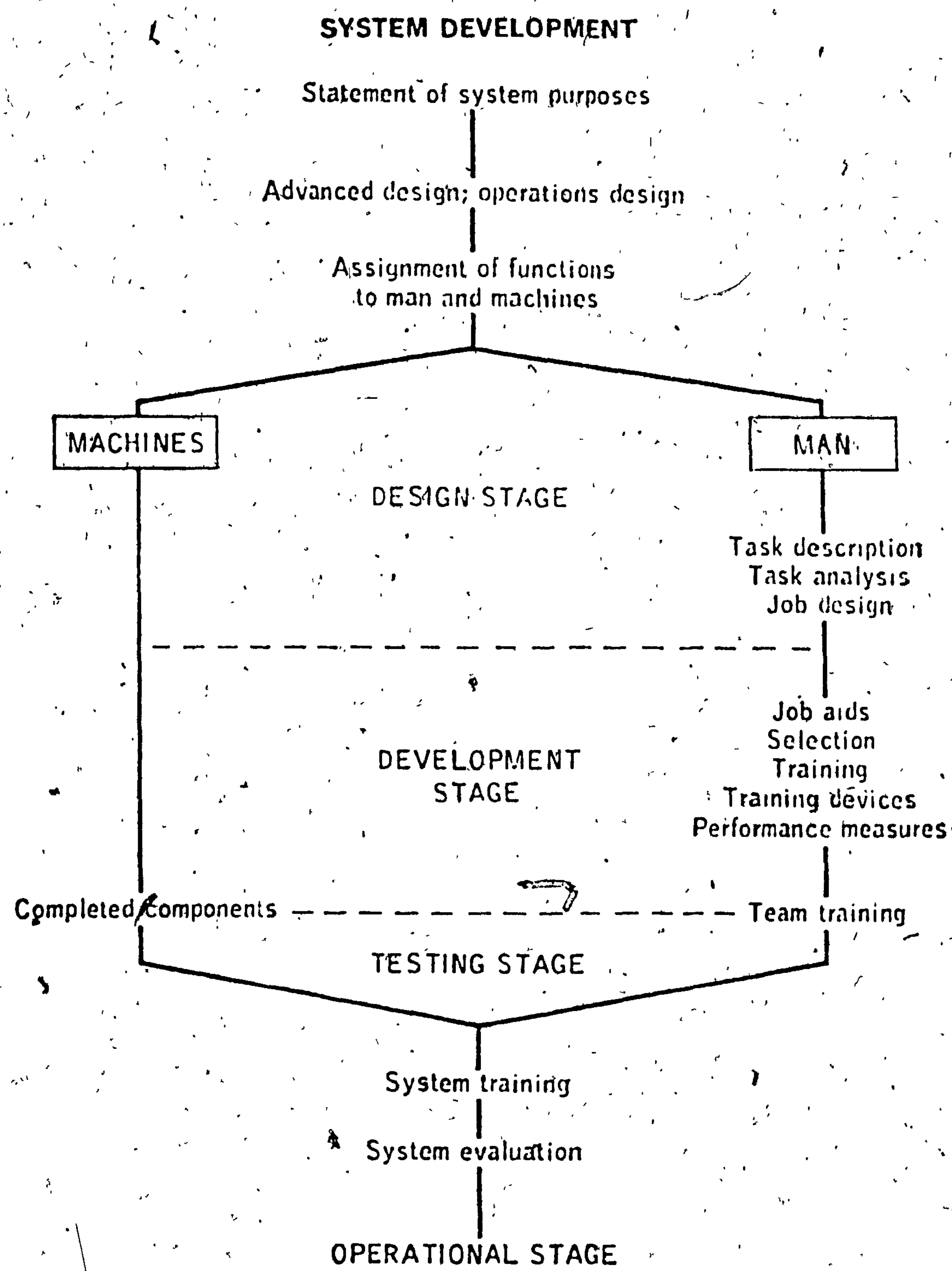


FIGURE 2-1

SYSTEM DEVELOPMENT

during development) or later (i.e. when in service)." Figure 2-2 is an illustration of the relationship among these personnel subsystem components and the hardware system.

An assumption that must be made in the design of human performance systems is that the human element is one of the major components in a total system. Complex modern systems require a good interaction between the human component and the other system components. Means must be found in systems and their development to ensure successful integration of the various system components in order to optimize the system.

Performance engineering is a relatively new concept. The definitive work on it is Human Competence Engineering Worthy Performance (Gilbert, 1978); Psychological Principles in System Development (Gagne, 1962) is another useful reference. A brief description of the concept will set the tone for this paper.

Gilbert coined the term teleonomics from the Greek "laws" (nomos) of "ends" (teleos). Teleonomics is a system for studying, measuring, and engineering human competence. Variations of this system have been employed by some performance technologists in their work. The National Society for Performance and Instruction (NSPI), an international organization which is dedicated to the advancement and application of performance and instructional science and technology, has frequent articles in its journal, Performance and Instruction, which advance the teleonomics concept and describe applications.

Performance engineering begins by focusing on the results, products and accomplishments that are desired. The inputs and conditions are analysed to determine the optimal mix of input variables and then a system is engineered to increase the probability

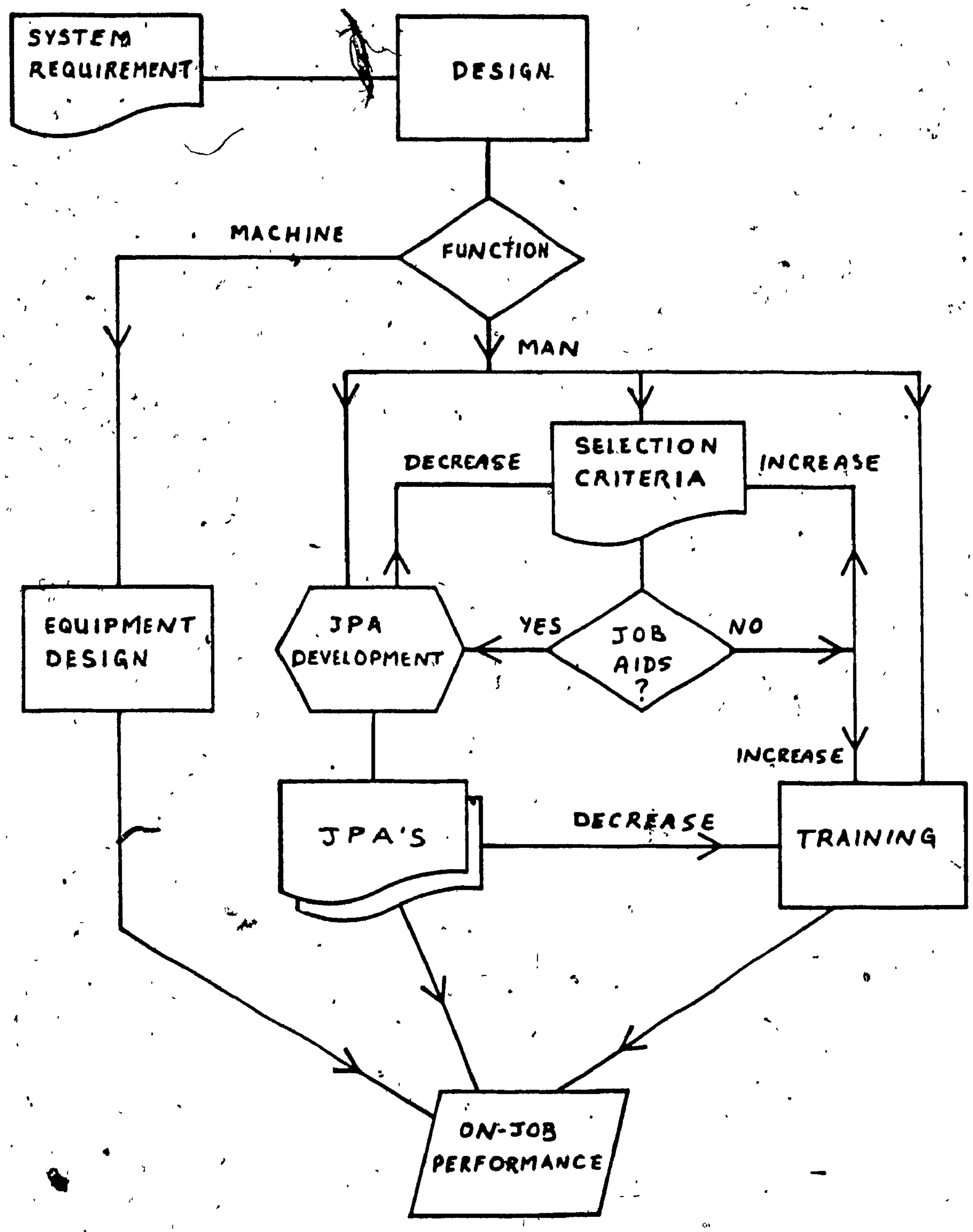


FIGURE 2-2
PERSONNEL SUBSYSTEM

that the optimal inputs and conditions will occur so that the outcome will be worthwhile and the one that is desired. The behaviour of the human in the system is but one of the inputs. Human behaviour is not the only input that can be manipulated; in fact, it is the most expensive variable to be manipulated according to Gilbert (1978).

The Teleonomic model is a problem solving engineering approach which includes strategies for analysing problems, methods for measuring cost and worth of problem and solutions. Integral to the system is a "Behavior Engineering Model." This model is pertinent to the job performance aid discussion.

Table 2-1 illustrates the Behavior Engineering Model. The six-celled matrix presents two categories of locus of condition, environmental locus and internal locus of individual, and three categories in a Stimulus (S) or Information condition, Response (R) or Instrumentation condition, reinforcing Stimulus (Sr) or Motivation condition. The Table provides examples of characteristic conditions that should be present to avoid performance deficiencies in a system. It will be noticed that "guidance job aids" are located in the environment locus under stimulus/information condition. The matching person locus is the skill/knowledge condition of the worker. While job aids are in the information condition, the relationships between work design (instrumentation) and work quality/autonomy (motivation) have a strong impact on job aids. This will be discussed in more detail in chapter three.

To summarise this discussion, the purpose of an Engineering Approach to human performance is to invent (create) a system which produces worthy performance. It should be possible to describe the goals of any performance system; the direction to proceed can be made

	INFORMATION	INSTRUMENTATION	MOTIVATION
ENVIRONMENT	Do people have the data needed to perform well?	Do they have the needed resources/ work design/tools?	Are there meaningful incentives/ rewards?

	☐ Desired accomplishments
	☐ Recommended/required behaviors
	☐ Performance appraisal measures, standards
	☐ Job or task theory
	☐ Guidance job aids
	☐ Reference sources
	☐ Feedback
	  ☐ Ongoing
	  ☐ Constructive
	  ☐ Frequent
	  ☐ Timely
		☐ Resources
		  ☐ Satisfactory work environment/ facility, work stations
		  ☐ People/things resources readily accessible
		  ☐ Optimum space of control – upward/downward
		  ☐ Adequate problem solving authority
		☐ Work Design
		  ☐ Acceptable inputs
		  ☐ Significant inputs
		  ☐ Supervisory support
		☐ Tools adequate, readily accessible (including job aids, references)
			☐ Accomplishments recognized
			  ☐ Performance-based
			  ☐ Compensation
			  ☐ Advancement
			  ☐ Special assignments, "threats," time off
			  ☐ Other
			☐ Career pathing and planning in place
			☐ Work quality adequate
			  ☐ Autonomy
			  ☐ Completeness
			  ☐ Other
			(Note Work quality deficiencies may require an organizational development intervention.)

PERSON	Do people have the needed skills/ knowledge?	Do people have the needed capacities?	Do they have appropriate motives/ expectancies?

	☐ S/K for using the data above
	☐ Other S/K
	  ☐ Managerial
	  ☐ Supervisory
	  ☐ Technical
	  ☐ Socio-political
	  ☐ Interpersonal
	  ☐ Intrapersonal
	Deficiencies indicate the need for training.
		☐ Capacities appropriate to
		  ☐ Data inputs
		  ☐ S/K inputs
		  ☐ Resources/work design/tools
		  ☐ Incentives/rewards
		  ☐ Motives/expectancies
			☐ Desire recognition via
			  ☐ Performance
			  ☐ Compensation
			  ☐ Advancement
			  ☐ Special assignments, "threats," time off
			  ☐ Other
			☐ Expectations of career development
			☐ Concern for quality of work
			☐ Motives/expectancies
			  ☐ Data inputs
			  ☐ Resources/work design/tools
			  ☐ S/K, training

*Gilbert, Thomas F. *Human Competence*. New York: McGraw-Hill, 1978

TABLE 2-1
THE BEHAVIOUR ENGINEERING MODEL

quite clear. The methodology of how to get there must be determined. The remainder of this chapter is a discussion of a method which is derived from the engineering approach described above. The analytic method of this study not only serves as the analysis instrument, but also the engineering tool to present system design.

Analytic Method and Instruments

The previous section of this chapter suggested that a methodology was required which would assist in the analysis of human performance systems. What follows is a discussion of the analytic requirements, an organizational model which is derived from management science, and the analytic method used in this study which was derived from the organizational model.

Analytic Requirements

The discussion of analytic requirements for this study will cover three elements: the need to make inferences about the nature of things; the availability of inferential methods; and, how these methods do not adequately help make system level inferences.

Making inferences. There are two reasoning standpoints that are used in research efforts - deductive and inductive reasoning. In inductive reasoning inferences are made by collecting data about specific cases of events and drawing conclusions about a general model. For example, if the specific behaviour is observed, then the theory or general model is supported; when the specific behaviour is not observed, the theory is not supported. In deductive reasoning, on the other hand, inferences about specific events are made by logical deduction from a general model or theory. For example, if the theory is correct then certain specific behaviour ought to be observed.

Inductive reasoning moves from the specific to the general, while deductive reasoning moves from the general to the specific.

Whether the reasoning is deductive or inductive, methods are required to generate objective information from some form of data. In the broader context inferential methods are required to obtain objective information.

Inferential methods. With statistical approaches to research, scientists endeavour to describe phenomena, establish correlations and in certain cases determine cause and effect relationships among variables. Generally speaking, this approach is inductive in nature as specific cases are observed for data collection in order to confirm or deny a more general theory. When the data of the specific case supports the theory the researcher infers that the theory is correct if the confounding variables are controlled. While statistical methods are suitable for an inductive approach, they are not as helpful in deductive analysis. When a large number of related studies using inductive approaches support one another and a general theory, a certain accuracy is probable in making deductions about specific instances covered by the theory. This suggests that deductive analysis is valid only when comprehensive inductive analysis is performed. It is the author's suggestion that this is clearly not the case since much of the time reasonably accurate predictions about specifics are made. For the present study analytical procedures are required for system level analysis using a deductive approach. An alternate to statistical procedures is required.

System level inferences. The principle that is being developed here is that for system level analysis a deductive approach is appropriate in this study of job aid technology. It has been suggested earlier in this chapter that a metachronic or engineering approach is required when developing the human element of systems. Earlier in this chapter it was suggested that experimental psychology is diachronic; therefore inductive reasoning is diachronic, it cuts accross time and place. Problems of control and validity make it difficult to generalize. System level analysis, on the other hand, must leave control of the synchronic factors to normal external variables. For this study a method is required to analyse the metachronic nature of systems and their components. What deductive approach can generate data about processes as well as the results and what analytical technique is available?

The requirements of this study for a technique for generating and collecting data in order that inferences can be made about the design, development and implementation of job aids within a total systems context leads to the next phase of the discussion. Beer (1979, 1981, 1985) provides a systems model which is useful for organizational analysis and data generation.

The Beer Cybernetic Model

The discussion of Beer's cybernetic model of the viable system is by necessity only briefly covered in the main body of this chapter. A somewhat more comprehensive presentation of the important parts of the model are contained in Appendix A. Readers are encouraged to seek out the references for a complete discussion. The most useful references in understanding the method are The Heart of Enterprise (1979) where the scientific laws are presented in reference to the viable system model, and Diagnosing the System for Organizations (1985) where the analytical tools that were explained in "Heart" are presented in a procedural manner.

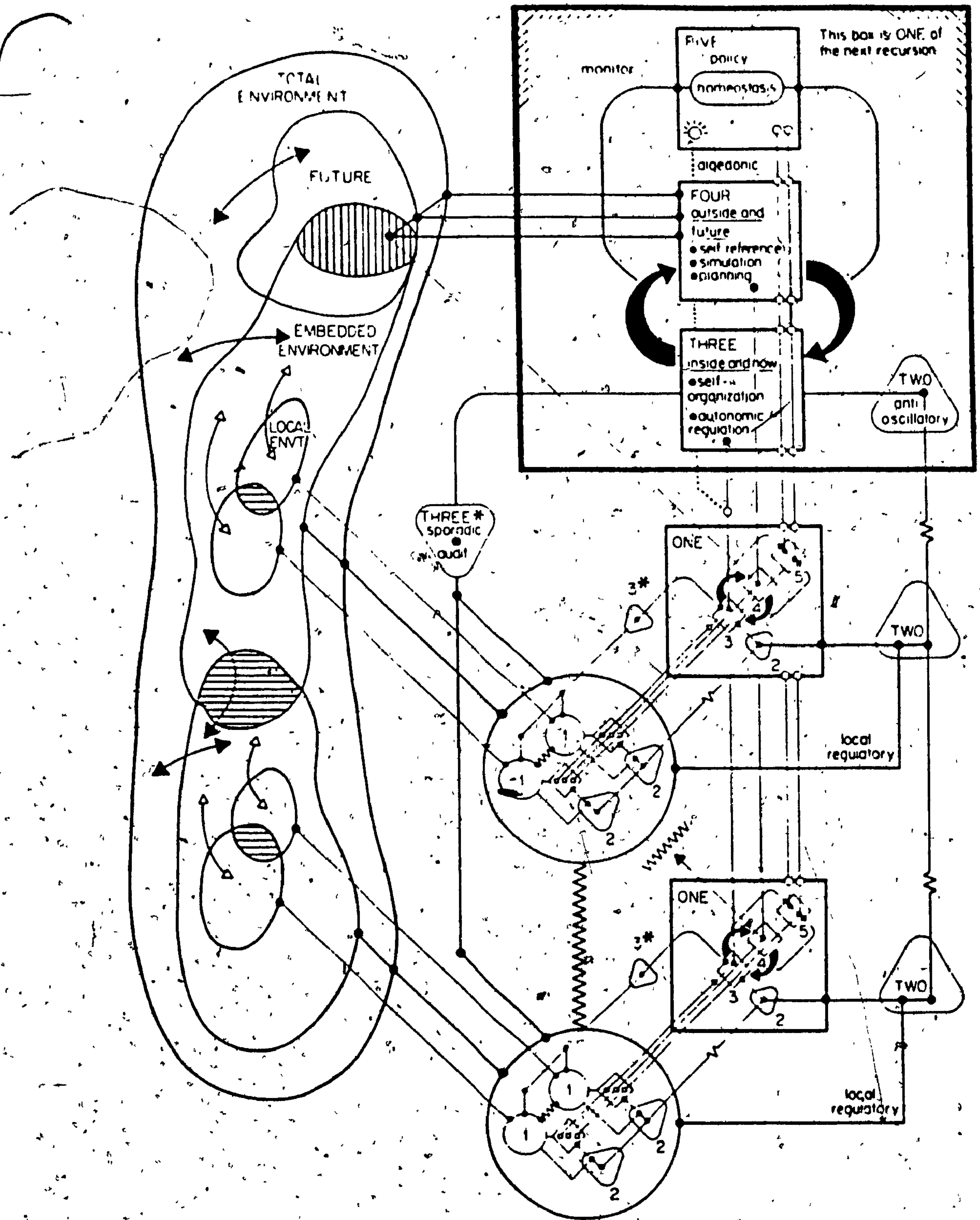
There are three facets of the Viable System Model (VSM) that are of interest to the discussion at hand: first is the nature of organizational structure; next is the neurological analogy; and, finally the use of the analytical model in system design.

Organizational structure. The Beer model was developed in order to better analyse organizations of human endeavour or the enterprise. Conceptual tools were created within the context of management cybernetics and the tools are useful in modeling organizations and their components. Management cybernetics is the science of effective organization (Beer, 1979 & 1985). Cybernetic analysis of actual or conceptual systems provides data about what makes the organization viable and what structures are weak or missing that makes the organization unviable. The Viable System Model permits the analysis of the "adaptive connectivity" of the parts of an organizational structure. According to Beer the organizational structure of any system of human endeavour is analogous to the organization of the human neurological system. In fact, the human component within a system is a recursion of that system.

Neurological analogue. The Viable System Model was derived from a scientific study of the human neurological system (Beer, 1981). The subsystem relationships that make the human system viable were described using a graphic convention. The connections between the brain and the affectors and effectors of the body create a vertical axis of system control down the spinal column. An horizontal axis of control is observed in the nervous connections between the spinal column and the various motor centres. Figure 2-3 is the Viable System Model (see Appendix A for explanation). This diagram represents any viable organization. The vertical axis connects viable units to the command and control system, the brain of the enterprise. The horizontal axis of control consists of, for the most part, the links between the parts of the enterprise and the environment. The connections between functional entities of the system are homeostatic links which pass information. When homeostasis exists, they are also the adaptive mechanisms.

Since the study of job aids concerns information, the Viable System Model was selected as the analytical model. The model provides the systems perspective that is necessary as well as a means of generating data for scrutiny. The model also provides a system design tool for the presentation of an adaptive organization which incorporates job aid concepts. This last facet of the Viable System Model will be discussed next.

The Viable System Model as a design tool. The Beer model provides analytic conventions which are graphically presented. The conventions are expository in nature. As analytical instruments, the VSM conventions identify functions that are necessary for viable systems. The lack of certain functions or weaknesses in them that are exposed by analysis can be rectified using "black box" approaches. If something is missing or weak the statement "some form of mechanism which has the following inputs and outputs" is adequate as an initial description of the black box. The Black Box in this context is defined by its purpose and what it does in response to its inputs. Further analysis of the machinery requirements to make the appropriate transformations can be done by taking a recursive step down in the viable system. The information network and adaptive structure of the black box can be described in the same conventions of the analytical procedure. The organization can therefore be designed much in the



THE VIABLE SYSTEM
- Stafford Beer

FIGURE 2-3

same way that modern electronics are designed with appropriate components being used to create the functions that are required. This is Beer's First Principle of Organization (1979, 1981 & 1985). Knowledge of the workings of the components is not necessary as long as the input and output conditions are within the tolerances of the "black box" and they contain requisite variety. Since the analysis in this paper is conceptual, that is, not an analysis of a specific organization, the resulting organizational description will be prescriptive of a structure which could be designed for successful job aid implementation. It is a design skeleton which focuses on the task guidance requirements of the organization.

<u>Analytic Method and Devices</u>

The organizational model that Beer has called the Viable System Model is used in this study for analysis of the job aid concept. The descriptive nature of the model also permits certain inferences to be made about appropriate system design features. There are three aspects of the model which were used for analysis: recursive analysis, system functional analysis; and, homeostatic analysis. It will be noted that these aspects are themselves recursive.

<u>Recursive analysis</u>. Recursive analysis is descriptive and explains the relationship of the viable system in focus with the viable system it is a constituent part of as well as the viable system it contains. Viable systems contain and are contained in other viable systems. By referring back to Figure 2-3 it will be noted that the system-in-focus described contains two functionally identical systems. The system management is metasystemic to these two operations as well as being the system one box of the next recursion up in the system of nested systems. It will be noted that in chapter one that a two level

analysis was conducted: micro level, the level of the worker and the job aid; and, macro level, the level of the job aid and the management system. It will be seen that one recusion down was analysed, the presumed inner workings of the worker, as well as one level up, the relationship of the local management (supervisor) with the larger management structure. In addition to recursive analysis, detailed system analysis was also conducted.

System analysis. System analysis, as well as being descriptive, permits inferences to be made about the system and how it works. For a system to be viable it must contain the various subsystems: System One; System Two; System Three and Three Star; System Four; and of course, System Five. The subsystems must be in relation to one another such that the variety of the vertical axis of control is adequate to absorb the variety of the horizontal axis (The First Axiom of Management and The Second Principle of Organization - see Beer, 1979). Apropriate attenuators and amplifiers of variety must be present as well as sufficient homeostatic links. Most of the analytic requirements of this study were met by system analysis using the Viable System Model; however, some analysis was required of homeostats.

Homeostatic analysis. Homeostatic analysis is descriptive and permits inferences to be made regarding cause and effect. Homeostatic analysis examines the transduction process for inputs and outputs, the amplifiers and attenuators, and the channel capacity of the information links. For the relation to be stable on the homeostat, the transducers must be effective in converting to the metalanguage requirements of each of the variety blocks as well as having adequate variety (The Third Principle of Organization - see Beer, 1979).

The specific graphic conventions (instruments) used in this study to conduct the analysis of the job aid concept are used with permission of Stafford Beer (Beer, 1985, p. 137). For readers who are unfamiliar with the VSM, most of the conventions are presented in Appendix A.

Chapter Summary

In this second chapter the historical design, the engineering conceptual approach, and the analytic method using the Viable System Model were presented. The selection of a suitable conceptual framework and research method for the study lead to a useful way to draw inferences about the job aid concept using deductive reasoning. The results of the analysis as well as the infered relationships are presented in the following chapters.

CHAPTER THREE

AN ANALYSIS OF TASK PERFORMANCE CONSIDERATIONS OF JOB PERFORMANCE AIDS

Introduction

Chapters Three and Four present the study's analytical findings of the job aid concept. Chapter Five presents a model of job aid technology as well as a summary of recommended research topics. Comments are also made regarding the suitability of the Viable System Model as an analytical tool.

This chapter concerns the study findings at the micro level of job aid technology. The discussion has three facets. The first aspect concerns the job aid concept in general. Next the cybernetics of task performance is discussed. The last facet is job aid design.

The Job Aid Concept

On the basis of the discussion that the author had with Dr. Smillie (see Chapter Two) one might conclude that the U.S. government has wasted a great deal of money in job aid research. It would appear that the military complex would rather have highly trained personnel than implement the findings of the research. Before the allegation can be refuted, it must be determined whether any benefits have accrued as a result of the studies.

Before discussing the study results it is appropriate to discuss the job aid concept itself. This discussion is in two parts followed by a reiteration of the micro level research questions from Chapter

One.

Cult of Behaviour

One of the negative forces working against the successful introduction of job aid technology is the "cult of behaviour". Gilbert (1978) suggests that there is something disreputable about job aids. "The cult of behaviour tells us that 'really worthy people' don't need such crutches" (p. 198). People who can perform without directions are somehow superior: The Renaissance Man. The cost of behaviour is often ignored. People who can accomplish tasks using task guides without hours, days or years of training produce more valuable results. That is, the benefit of the accomplishment is achieved at lower behavioural cost.

The selection criteria one uses to hire personnel is influenced by whether the new hires are expected to posses the requisite behaviour repertory. One could expect to pay a higher salary to personnel who arrive at the job trained. So whether the individual is trained on the job, or prior to the job, his behaviour costs more than if little or no training is provided but effective performance is obtained by providing task guides on the job.

This line of reasonning suggests that job aids are a good idea. What then, are the features of job aids? What follows is a discussion that elaborates the definition of the job aid concept presented in Chapter One.

Job Performance Aids

In the most broad definition, a job aid is any tool, device or document which "aids performance". This definition is not particularly useful as it is too all-encompassing; it could include almost any tool. The definition of job aid that I wish to present here is more restricted, and I suggest more useful.

Job aid definition. A job aid is a device, usually a document, which stores guidance information for the conduct of a task. A job aid is used on-the-job during task performance. A job aid is a procedure as defined by Gerlach, Reiser, and Breck (1975):

> A procedure is an ordered list of instructions or rules. ... The invariants of the rules include the following: they are (1) directed to someone and (2) specify with varying degrees of precision how a certain process is to be carried out. (Gerlach et al, 1975)

A subset of a procedure is an algorithm. An algorithm has all the characteristics of a procedure as well as the following:

> Attributes of an Algorithm -
>
> - Must possess generality - it must be applicable to a class of problems. That is, any problem which leads from various initial data in a class of problem can be dealt with.
> - Must possess replicability - it must specify an unambiguous procedure. It must indicate precisely the nature and conditions of each action, excluding any chance components.
> - Must possess resultivity - it must always lead to a correct result. While there is a probability that an individual may make an error (such as using the wrong algorithm for the class of problems) the errors must be attributable to the user and not the algorithm. Any errors made in the use of an algorithm would be non-systematic, i.e. not generally repeatable.
>
> (Gerlach et al, 1975)

A job aid is intended for use on the job as opposed to prior to the job. This points out the difference in function between job aids and training aids. Training aids are used in training and provide informational support to learning activity. The job aid provides informational support but is used on the job. The line between job aid and tool can be fuzzy and, with advances in computers, is getting fuzzier. Tools provide a physical, mechanical, advantage on the job. However, some forms of job aids by their design physically change the job or tasks. A transformation table or a maintenance dependency chart (MDC) simplifies the technician's task and has the task strategy built in. Computers confuse the distinction further; they are tools, in that they allow for rapid physical manipulation of facts and figures, but they can provide an informational advantage. Computer Based Job Performance Aids (CBJPA's) guide task performers through tasks; Automatic Test Equipment (ATE) are tools that physically test the hardware, but with "friendly software" that guides the user through the ATE procedure. Is it a CBJPA or ATE? It is both. Figure 3-1 illustrates the differences between training aids, job aids and tools. The figure itself is a transformation type of job aid.

The definitions of procedure and algorithm point out a continuum of the concept job aid. At one end of the continuum are procedural descriptions which are so detailed and step-by-step that errors are virtually impossible (algorithms); and at the other end are procedural descriptions which, although they tell the user what to do and how to do it, they do not guarantee that the task will be completed successfully. Algorithmic job aids remove much of the burden of task performance from the user; procedural guides (sometimes referred to as heuristic recipes) remove less of the burden of task performance from the user - s/he must use his head more.

Differences Among
Job Aid, Training Aid and Tool

if	and...	then it is a
it provides informational advantage	it is used in trg	trg aid
	it is used on the job	job aid
it provides a physical advantage	it is used on the job	mechanical tool

Figure 3-1
(adapted from Main, 1974)

Head/Book Tradeoff. Joyce (1975) coined the phrase Head/Book Tradeoff in reference to job aids. A maintenance technician obtains information to do his job from two sources:

- Information which s/he has obtained from formal training and job experience which s/he has stored in his head; and,
- Information that has been stored in documents or other devices rather than his memory. The traditional source of this external memory has been the book.

The Head/Book Tradeoff, therefore, refers to the decision of whether task guidance information should be stored in the head, via training and job experience, or in the book or other task guidance media.

The most dramatic example of the Head/Book Tradeoff is in the comparison of job aids and traditional technical manuals (TM). The traditional technical manual provides the technician with theoretical descriptions of how the equipment s/he is to repair works. It provides the technician with diagrams and charts and occasionally procedural descriptions. The traditional technical manual is often written by an engineering staff at the level of engineers, or at least at the level of experienced technicians. The technician using the manual is expected to draw from his memory the technical theory that the manual makes reference to in order to construct a strategy for doing the various maintenance tasks. A job aid version of the maintenance manual, especially a Fully Proceduralized Job Performance Aid (FPJPA) - an algorithm - is aimed at the novice technician with little technical knowledge or experience. The decision not to use job aids is a decision to emphasize well trained, experienced personnel for task performance. This decision increases the cost of the behaviour with uncertain increase in benefit.

The foregoing discussion has been about what job aids are and their purpose. This answers in part one of the questions posed for this study. The remainder of the chapter addresses this and other micro level questions questions.

Research Questions

This chapter concerns the findings in the literature regarding the micro level of job aid technology; that is, the level of the interaction between the task performer and the job aid on the job. The questions for this chapter are:

- What are job aids and what do they do in task performance? The concept has been discussed in terms of definition and relationship to training aids and tools.
- Why use job aids to help individuals perform tasks? The cybernetics of task performance are discussed and research

findings regarding the benefits of job aid technology in reducing the cost of task behaviour are compared to the analysis.

- Where and when should they be used? The role of task guidance on the job and the evidence of their utility in controlling performance are presented. A tabular presentation is included which shows the interactions among task complexity, experience, and level of detail in fault finding tasks.
- How should they be used on the job? In particular, what are the specific design features that are pertinent? These questions are discussed in terms of the design of job aids from a cybernetic analysis point of view supported by research findings.

To clarify further just what job aids do in assisting task performance, it will be useful to examine how an individual performs any task. The following is a cybernetic analysis of task performance.

The Cybernetics of Task Performance

Un-Aided Task Performance

The principal means that tasks are performed by humans is by motor activity of the individual in his environment. Through his senses the individual determines that action is required and voluntarily or involuntarily s/he makes a motor response. The reaction of a child to a burn from hot water is automatic - s/he withdraws from the water. He eventually learns to make voluntary actions to avoid being burned.

Definition of task. Miller (1971) provides a definition of task:

> A task consists of a series of goal-directed transactions controlled by one or more "programs" that guide the operations by a human operator of a prescribed set of tools through a set of completely or partially predicted environmental states. (p. 11)

This definition illustrates the notion of a transaction between the task performer and the environment. It also illustrates the need to be able to adapt to the variability of the environment.

Consider an example (refer to Figure 3-2): an individual is performing a task - the repair of a radio set. The individual is operating in an environment which has provided an occasion to repair the radio. His contact with the environment is through his sensors (eyes, ears, tactile sensors) and effectors (probably his hands in this case); these are his transducers which transform the metalanguage of his internal control system to or from the informational language of the environment: changes in states of mechanical aspects of the environment, including sound and light energy.

The task performer amplifies his own capabilities through the use of various tools and equipments. Tools such as soldering irons, screwdrivers, and so on, provide him the mechanical advantage s/he requires to complete the task.

The individual uses the various data sources to extract information as to problems in the environment and possible actions to take. He then utilizes tools and instruments to modify the environment. The changes in the environment are evaluated through

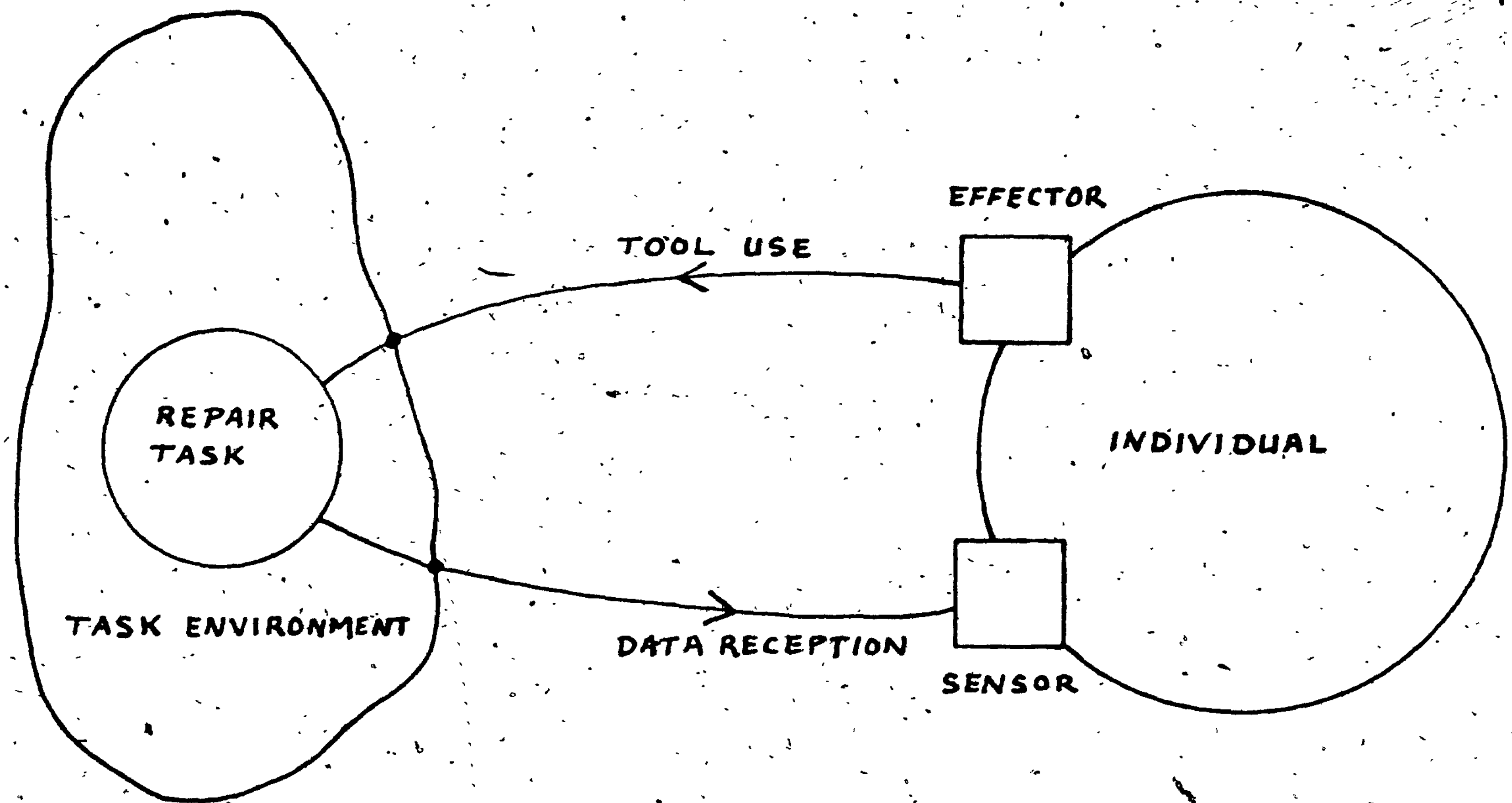


FIGURE 3-2

INDIVIDUAL AND ENVIRONMENT

further data collection; instruments are utilized again, and so on until the task is completed.

Within the individual is a complicated control system which handles the coordination of motor activity, see Figure 3-3. The autonomic nervous system, System Three and System Two, controls actual motor activity in response to the forcasting and planning activity conducted by System Four. System Five, volition or conscious control, provides general direction/control to System Four while monitoring the activity between System Four and System Three (the Three/Four Interface). Some tasks are performed more or less automatically, such as walking, or an expert knitter who can knit while talking. Other tasks require more directed control such as a ballet dancer performing intricate steps.

The operation of the system is well illustrated by the example of a pianist who is playing some complicated piece of music from sheet music. His control of his/her fingers is automatic; his/her conscious control is in directing his/her vision to pick out the trend of the music. A good musician, like a speaker who reads from a script, reads ahead of the actual section being performed. If the pianist consciously attends to exactly what his/her hands and fingers are doing, s/he no longer can play the music; s/he can only play notes.

The individual's System Four activity consists of evaluation of the environment, forming knowledge maps or models of the environment and projecting them on to its model of itself which System Four understands in terms of System Three, or autonomous activity; System Four learns about the environment and how the individual can respond to the environment. These knowledge maps form the basis for autonomous activity.

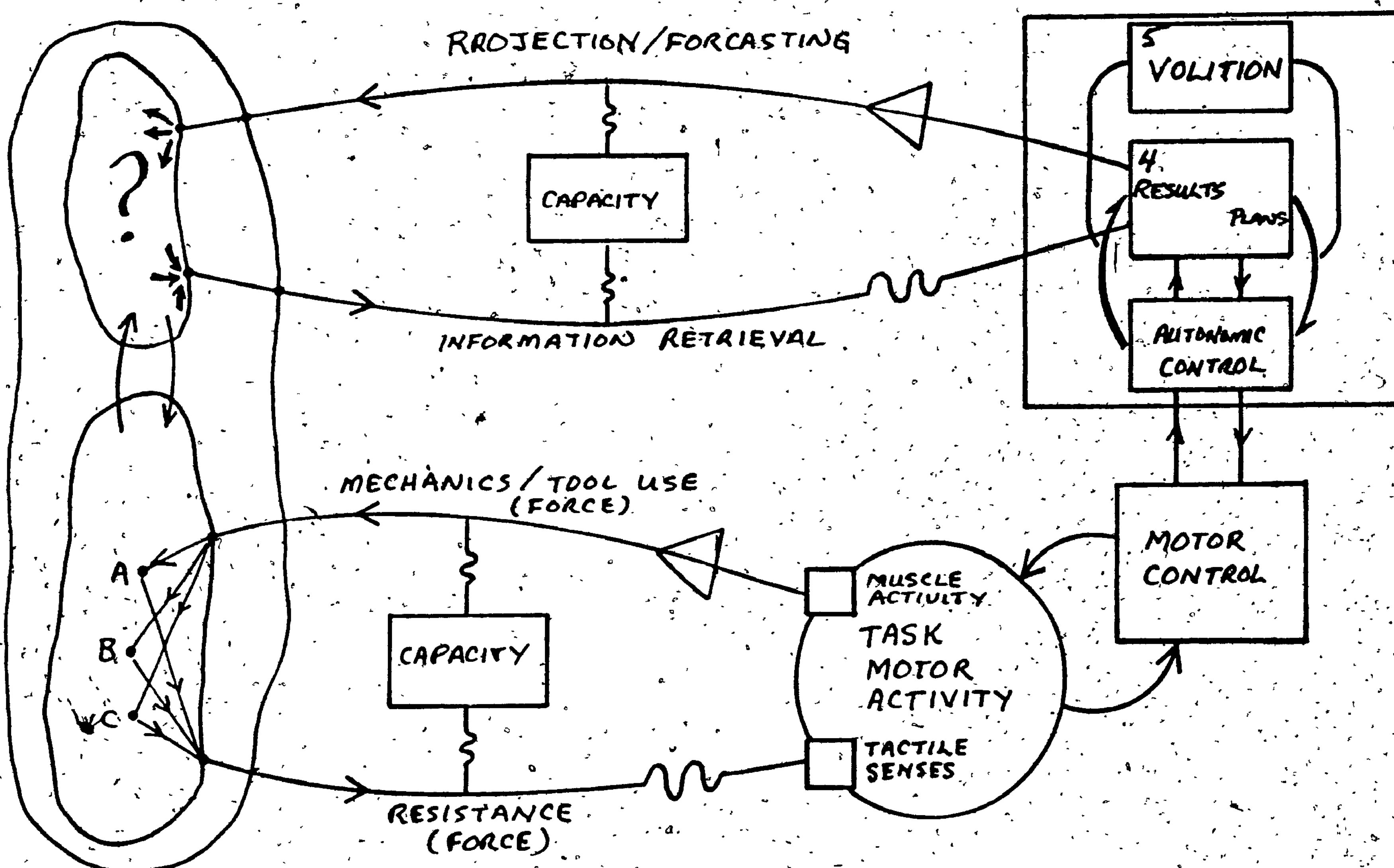


FIGURE 3-3 TASK CONTROL

The autonomic nervous system is in a constant information search/retrieval with the memory portion of System Four, the stored understanding of internal and external system states. Repeated motor activity becomes an ingrained part of the knowledge map (e.g. walking). Different instances of performing the same motor activity produce generalized components of the knowledge map, and specialized components (e.g. walking upstairs versus walking on level ground).

The conscious part of the brain also utilizes the knowledge maps in active memory search. The consciousness can decide to attempt to reorganize the knowledge map based on its understanding of the System Three/Four Interface. The word attempt is used deliberately since old memory patterns and habits may be difficult to extinguish.

The performance of any task has certain physiological limits. Each homeostat in the control system has physiological limits for operation of the homeostat. The homeostat between the worker and his/her environment has physiological limits in the physical capacity of the worker to use various instruments for task performance. For example, s/he can not use a hand tool which will not fit his/her hand; s/he cannot see if it is too dark or the markings are too small.

Similarly there are physiological and psychological limits to the internal control system of the individual which may affect his/her ability to perform a task. The nervous system has a response capability including inherent lags and delays which, in most circumstances, are not a hinderence to task performance. But, if the individual has an inadequate model or concept of the environment s/he will not be able to handle all the environmental variety. For example, one may say that a friend has changed because s/he has witnessed the friend in a drunken stupor for the first time. It may be that the model one has of the other is incomplete - the friend hasn't changed, s/he has just taken on one of his/her possible states which is at higher variety than the model would allow.

Information aids, job aids, amplify the task performer's ability to handle the environmental variety when his/her internal models are inadequate. The next section discusses the cybernetics of aided task performance.

Aiding Task Performance

Environmental support. A worker in a system is usually provided with various tools and aids, environmental supports, to assist in the performance of the various tasks that make up his/her job. As has been discussed, tools and instruments act as amplifiers of motor activity. The utility of the instruments is a function of the user's capacity to manipulate them. Test equipment amplifies the worker's ability to collect and interpret data which helps him/her to decide what to do next. The worker's capacity to use the test equipment is a function of his/her knowledge and the test equipment design. Workers may exhibit difficulties in task performance as a result of physical incapacities. An obvious example of correction of problems of this nature is in the provision of a prosthetic device to a handicapped person. This represents a change in the capacity of the user, rather than a change in the environment; the prosthetic device has become part of the user's performance system. (Compare to Table 2-1.)

Less obvious examples may not be corrected. Keyboard design of a computer terminal which does not take into account the physiological aspects of the user is an example. It is generally believed that the QWERTY typewriter keyboard was specifically designed to attenuate the user's speed to that which could be handled by the earlier typewriter mechanisms. The user's behaviour was then shaped to match the QWERTY keyboard. Attempts today to modify the high speed keyboard to facilitate ease of learning and use are resisted because typing is still taught in "QWERTY" metalanguage.

Job performance aids. Job performance aids are a category of environmental supports that can be provided to the worker. Data for task performance is usually available in the environment. The problem for the worker is detecting the _information_ contained in the data. A definition of information is appropriate.

Information is that which changes us (Beer, 1979, p. 283).

For management, job aids attenuate inappropriate procedures which result in damage (inefficiencies, eventually higher costs of performance.)

Performance guides and job aids are supports that assist the finding of information from the environment. An expert task performer may have an adequate model of the environment in his/her repertory of behaviour. This allows him/her to detect information in environmental data unaided. Job aids provide the inexpert task performer with strategies and tactics for information retrieval. The effectiveness of the worker in translating the job aid information into action is a function of the job aid design.

The inexpert task performer who must perform the task unaided may go into uncontrolled oscillation, depending on the adequacy of his/her knowledge of the system being worked on. He/she _hunts_ for information without really knowing where to look or what the data and/or information looks like. A job aid dampens the oscillation. It assists the memory by providing an external (preferably optimal) model of the task.

When an individual is being guided by another individual through a task as a function of on-job-training (OJT) or formal training with job-like conditions, he attempts to emulate the trainer, the model task performer. The trainee monitors his/her own performance in the task based on the results he perceives in the environment (external feedback) and his/her understanding of his/her internal System Three/Four Interface (internal feedback). The adequacy of the model task performer's (the teacher) performance (i.e. his/her ability to use his/her model of the task and the adequacy of his/her model to handle variety) will affect the learning that is achieved by the trainee. Practice of the various tasks being taught also affects how permanent and consistent the trainee's knowledge map will be.

The trainee undergoing deliberate on job training, consciously tries to model the expert performer. On the other hand, the task performer who is using a job aid to assist his/her performance is not required to learn the model being presented by the job aid. However, he may learn the job aid model of the task through conscious effort or by more or less accidental (incidental) assimilation. A job aid by design may foster conscious or incidental learning of the task model.

An analysis of the relationship between the worker and the supervisory level of management reveals the need of both the worker and the supervisor for task guidance strategies. What follows is a cybernetic analysis of the task management concept.

Management of Task Performance

The cybernetic analysis of the task management concept presented below is recursive. First the system-in-focus is the supervisory level of task performance. This analysis points to the need to look down a level of recursion to examine the internal workings of the task performer. Between the supervisory level and the worker is the job guidance requirement; this is presented last.

<u>The management view of workers</u>. Management views task performers as potential sources of variety proliferation. If a task performer does not know how to perform the task well, he may introduce new variety into a lesser variety situation. Returning to the example of the radio repair task, if the technician cannot interpret the data available, that is his/her model has insufficient variety to extract information from the data sources (e.g. meter readings), he may do things which make the task performance, fault diagnostics and repair, more difficult. The technician may replace parts which have no faults or he may use procedures which cause further faults in the system: he increases the number of possible states of the task performance activity - he increases variety.

Figure 3-4 is the result of a cybernetic analysis of the worker and his/her management metasystem. The metasystem is the supervisory level of management. Only one worker is depicted.

The worker is shown in interaction with the environment, machine operations and repair. The supervisor has various vertical controls to ensure accomplishments by the worker(s) (System Two, Systems Three and Three Star). Both the supervisor and the worker have a perception of the possible future states of the environment. Now, the First Axiom of Management (Beer, 1979) states that the sum of the horizontal variety disposed by the workers must equal the sum of the vertical variety disposed by the supervisor. Generally speaking, when workers are accomplished, alert and reliable, the supervisor's task is easy, and Ashby's Law is preserved (Beer, 1979). However, what happens if

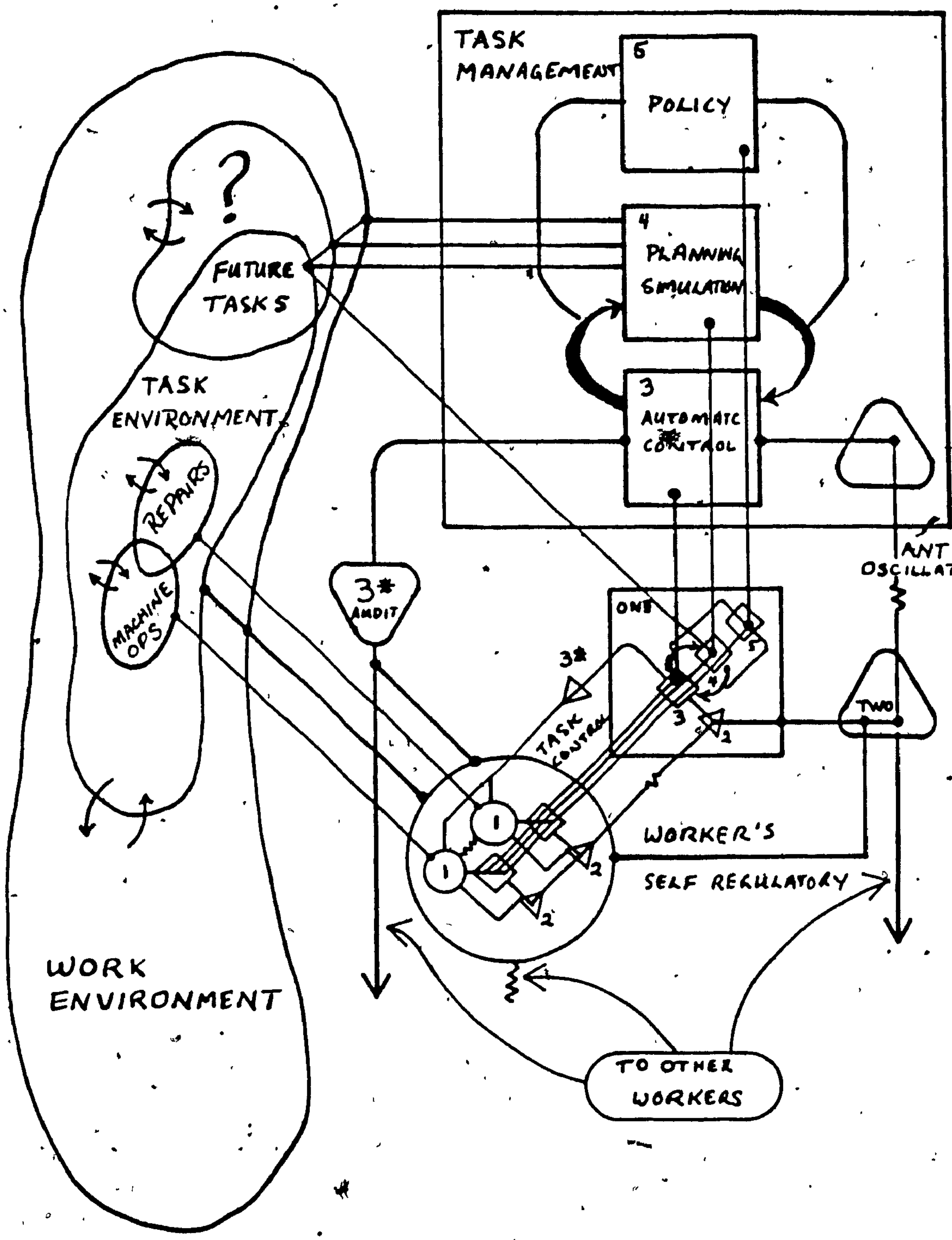


FIGURE 3-4

WORKER AND MANAGEMENT METASYSTEM

the workers are unreliable?

Imagine a section of an organization which has people in it who are clinically insane; the manifestation their insanity includes making random, as opposed to reasoned, decisions about all aspects of work. The variety of this workplace activity is fantastically large: that is, machinery would be broken due to improper and inappropriate use, personnel would be injured, perhaps killed. Very little of the purposeful work of the organization would be done, and these accomplishments would be at great cost in time, capital and human resources. It is obvious that this mythical section is unviable, and that unless the variety of the workers is destroyed by massive variety attenuation (lock them up), the Law of Requisite Variety cannot be preserved.

Most of the time the potential variety proliferation is managed by the societal and organizational norms of conduct, the relative sanity and reasonableness of the workers, and the ability of the workers to do their job "well enough." Much of the remaining variety is managed by various management tools which rest on the vertical axis of control. The discussion here considers the job aid as a management tool for control of variety while at the same time providing the worker with the amplifiers of his/her own variety to handle his/her tasks at hand.

Worker self management. Figure 3-5 illustrates the cybernetics of the worker performing his/her task. The emphasis is on the System Four activity of the worker.

Some conventions are used in the figure which require explanation:

- Comparitor. A comparator (⊗) takes an input and outputs an

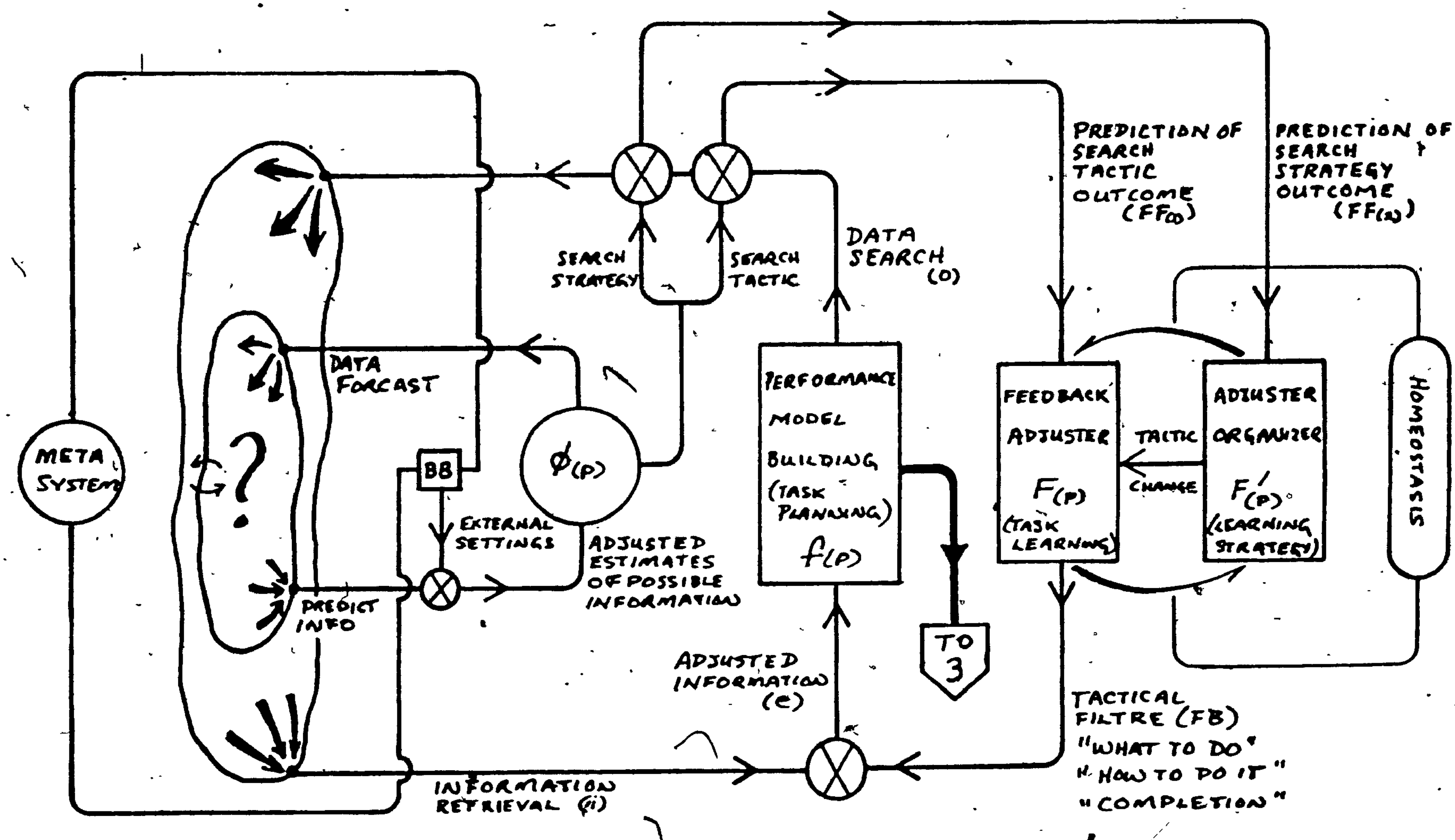


FIGURE 3-5 TASK PLANNING CYBER

error signal to modify the input based on externally set criteria. Any transfer function (q.v.) changes its states to adjust its output based on the error signal. Comparitors can amplify or attenuate based on the type of comparator and how it is externally set. Amplifiers in Figure 3-5 output a feedforward signal (FF); attenuators output a feedback signal (FB) to modify an input.

- Transfer functions. There are four types of transfer functions shown in the Figure -
  - Φ(p) is the intellectual fabric of the individual, the value system or the purpose, the overall performance of the individual
  - f(p) is the transfer function of the system-in-focus (the worker), in this case the System Four task planning activity which is passed to System Three for action -
  - F(p) is the feedback adjuster which takes some feedforward information (FF1) from f(p) based on the setting at Φ(p) and changes the feedback (FB) being sent to the information retrieval comparator
  - the feedback sets the comparator which results in a change of the input (i) to its output (e) which is adjusted information, i.e. it is interpreted
  - F′(p) is the adjuster organizer which takes other feedforward information (FF2) and changes F(p) by reorganizing it

  F(p) and F′(p) continually adjust to one another and the feedforward information that is set by Φ(p).
- Homeostasis. Homeostasis is the System Five activity of the.

task performer. Homeostasis and $\Phi(p)$ make up the stabalized intellectual fabric of the individual.

- Black Box. The black box (BB) is the summation of all external mechanisms for management of the task performer by his/her metasystem, the supervisor and all other management devices.

Operation of model. The purpose of the task performer is to plan and execute the task at hand, which for discussion, is the repair of a radio. The purpose of the system, the goal seeking of $\Phi(p)$, is the query of the known environment and possible futures in order to gather observable data and information as well as indicators of possible future states of the task. The worker selects search strategies and tactics which help organize and interpret information perceived from the environment. Task relevant information is used by the planning activity, f(p), to form actions which are carried out under motor control (Figure 3-3 illustrates). The task performer continuously adjusts the planning activity, F(p) and F′(p), until the goal is accomplished; the radio is repaired or replaced. The metasystem assists (via BB) the task performer by helping to set goals as well as provide adjustments to ways of achieving them, including the provision of on-the-job supervision or information aids.

Management tries to control variety proliferation by ensuring that the task performer's plans, models, knowledge, are adequate by training him/her or by providing him/her assistance. A common method of providing the assistance is close supervision of the task by an expert task performer. This method causes massive variety reduction of the inexpert technician and can degrade to the expert performing the task while the inexpert watches or assists. This situation obviously does not have requisite variety - what problems are the other workers under the supervisor having? An alternate method to control ambiguity of performance and proliferation of variety is being proposed here: the use of job performance aids. This is a System Two function.

The purpose of job aids is to reduce the ambiguity of the task for the task performer; to control otherwise uncontrolled oscillation. Viability of the performance system depends on the management of the operational elements (i.e., Systems One); successful management produces synergistic performance in the performance system.

System Two. A job aid is located between the operational element, the task performer, and the task management metasystem. Specifically, job performance aids reside in the homeostat between the anti-oscillatory System Two and the operational elements. This is also part of the worker's self regulatory system (refer back to Figure 3-4).

A cybernetic analysis of the worker's self regulatory system with the introduction of task guidance is presented in Figure 3-6. The internal workings of the worker have been simplified (compare Figure 3-5). The figure illustrates that the worker's self regulatory activity is the worker's ability to "get out side of himself" to externally monitor his/her own performance. The introduction of job aids provides comparators additional to the worker's internal ones which modify in an iterative way how the task is performed. The worker seeks environmental data which, by adjustment of the job aid, feeds forward certain expectations of task performance outcomes. This results in adjustments provided by the guide about how to perform the next task element. In addition to providing adjustment feedback, the

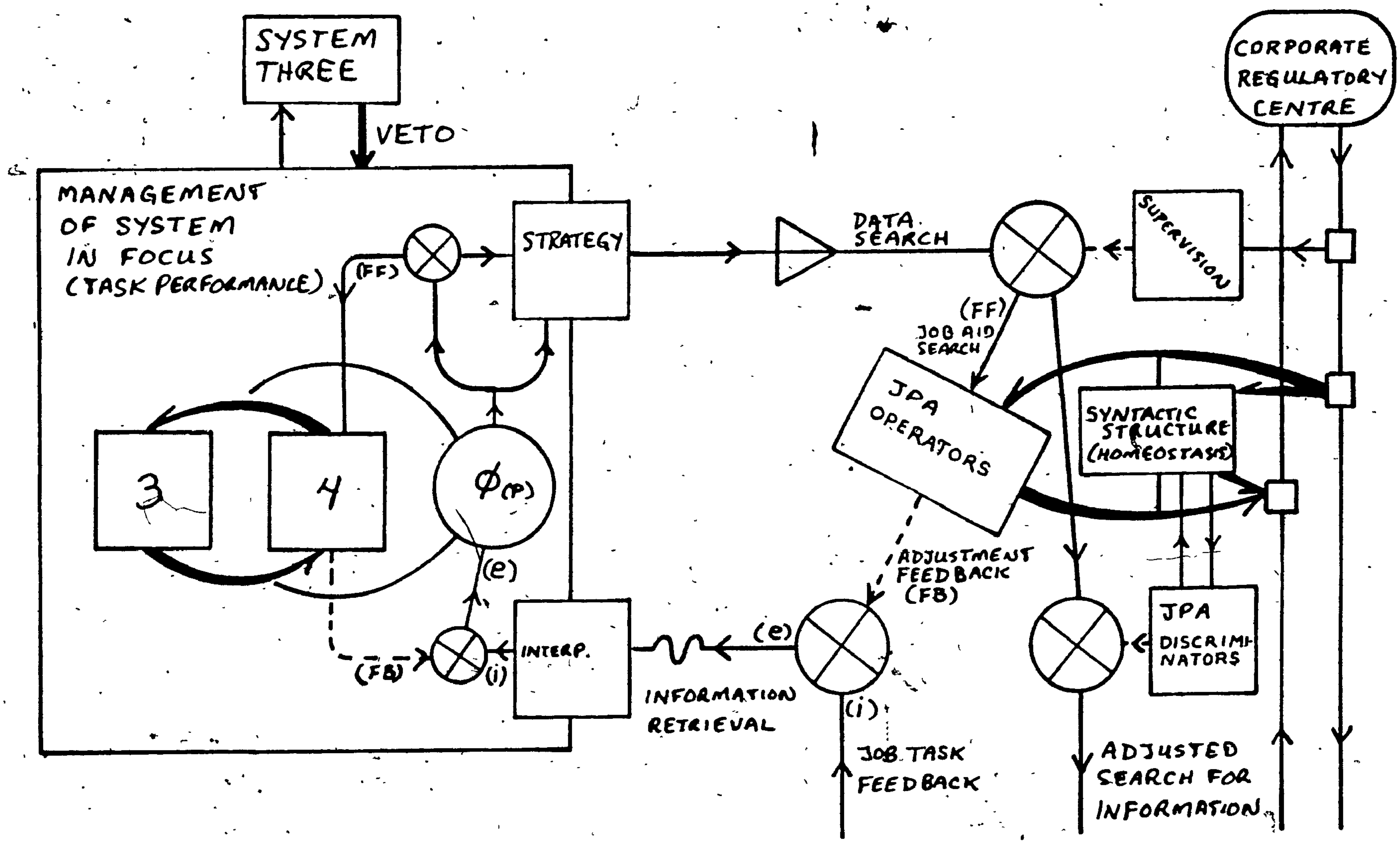


FIGURE 3-6 WORKER-JPA CYBER

job aid adjusts task monitoring search behaviour. The relation between the operators and the discriminators has the same stability criteria which is the syntactic structure of the job aid and, as will be seen in the next chapter, is regulated by the management metasystem. (Compare the function of this box with the adjuster organizer in Figure 3-5.) This management regulation is high gain but low frequency (for an appropriate job aid).

Job aids when appropriatly used provide a fulcrum of task regulatory control. Figure 3-7 illustrates the homeostasis of the worker, job aid and supervisory guidance. The figure is self-explanatory. The movement of any of the elements in the illustration changes the balance of control among the job aid user, the job aid and the supervisor. This figure summarizes the forgoing section on aiding task performance. As the JPA approaches the user (needs), the less supervisory intervention is required (supervisory element can be smaller and still maintain balance). The more the supervisory element approaches the worker without corresponding approach by the worker to the supervisor, the more likely it is that the worker will avoid the task.

Job performance aids have been analysed in terms of purpose and where cybernetically they reside. But, what evidence is there of the utility of these devices? What does the literature say about how well job aids help individuals perform tasks?

Effectiveness of Job Aids in Controlling Performance

The cybernetic analysis of job aids in relationship to the worker and the supervisor points to control benefits for both management and the task performer. The following discussion focuses on the evidence of the value of job aids in improving the worth of accomplishments.

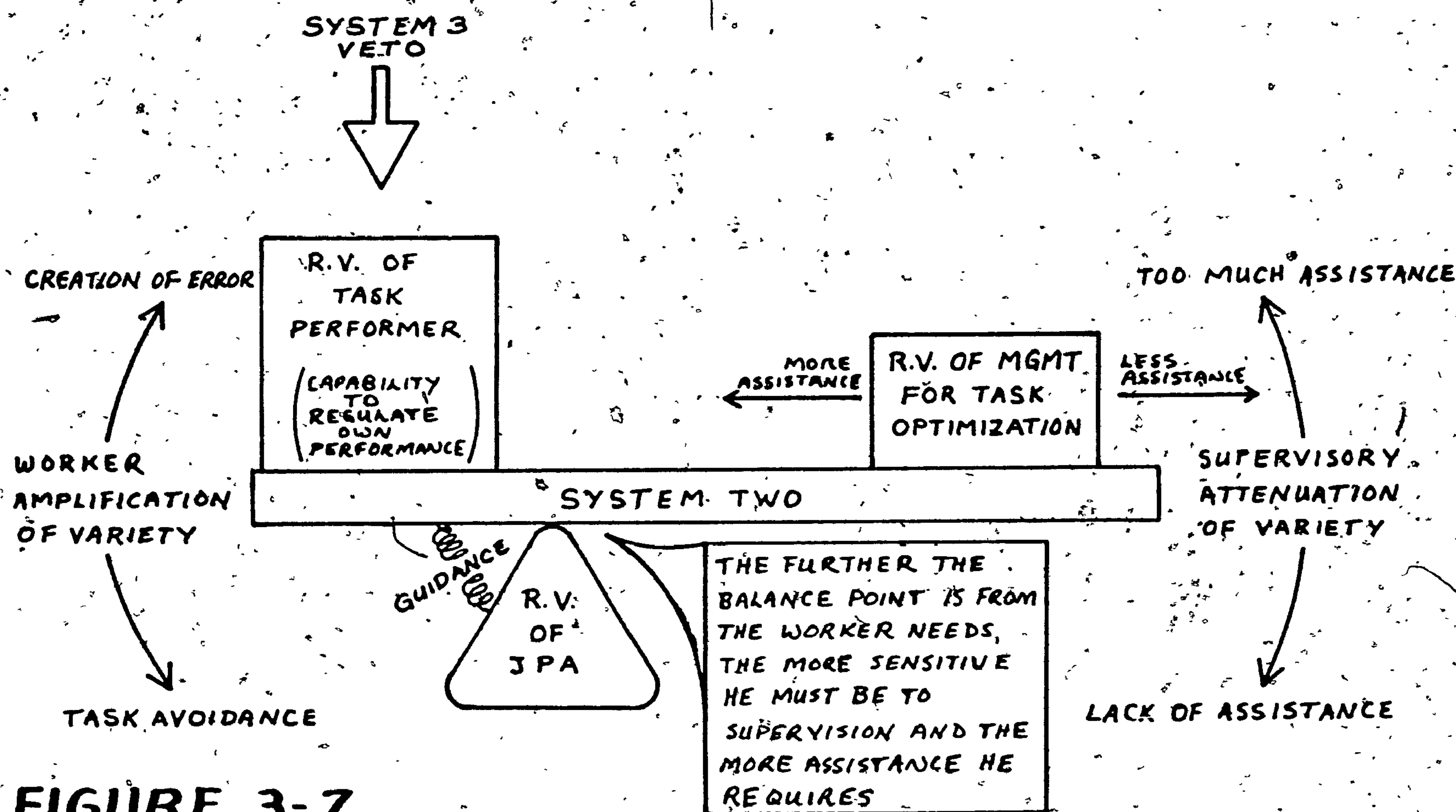


FIGURE 3-7

SUMMARY: WORKER/JPA/SUPERVISOR HOMEOSTASIS

Before presenting the research findings reported in the literature, a discussion of performance measurement will establish some principles. Next the context of the literature findings will be explained in terms of costs and benefits at the job aid user level. And last the literature support of the analysis in this section will be discussed.

Performance measurement. The aspects of performance measurement relevant to this study are the variables pertinant to value and worth of accomplishments. Gilbert (1978) provides a useful exposition of the variables and a summary is provided here. The first group of variables related to accomplishment of tasks are the benefits that are valued (for whatever reason) of task behaviour:

- Quality - the quality measures of task completion are the accuracy of the output, the class/affect of the outcome, and novelty/creative variance in procedure or product.
- Quantity - the quantity measures are the completion rate, the meeting of deadlines, and volume of production.

The second group of variables are the costs of task performance in achieving the valuable ends:

- Labour - the labour measures are manhours, wages, and direct overhead costs including amortized training expenses.
- Material - the material measures are supplies including storage costs, tools, space, and energy.
- Management - the management measures are supervisory labour, administrative costs, and management structural overhead.

The combination of all these variables in the achievement of valuable ends can be expressed in terms of the worth of the achievement. This is traditionally referred to as Cost/Benefit. Economics provides us with a formula for costs and benefits:

- Worth is a function of the ratio of valuable accomplishments (A) to costly behaviour (B). This is the payoff ratio which should always be equal to one or greater; otherwise more effort is being expended than value achieved. The formula is simple - W = A / B.

The unit of measure is usually monetary, however, any unit that is practical can be used provided all variables are reduced to the same units.

Cost/benefit of JPA's. The variables just presented relate to the worth of job aids. The discussion earlier in this chapter makes reference to the achievement of tasks without attendant high training or wage costs (due to pay requirements of persons who have requisite skills) by the worker's use of job aids. The benefits of the task performer behaviour in accomplishing a task are the values that management places on the successful task outcome. The costs of the task outcome are the costs of producing the behaviour. If the behaviour can be achieved with less expensive labour (including amortized training costs), or less supervision, or less material expense, then the worth of the outcome would be greater. The cult of behaviour would declare that this denies the "quality of performance". The quality of the outcome in terms of management values is what counts, if the behaviour required to provide what management values is elegant, i.e. inexpensive but effective, that is quality performance.

Job aids, by cybernetic analysis, ought to improve the worth of worker accomplishments. What does the literature say about the worth of job aids in terms of the variables presented here?

Research Findings in JPA Effectiveness

The principles of measurement of interest to this study have been presented. The measurement of performance is simplified to cost and benefit and a ratio of these indicates worth. Job aids ought to enhance the worth of task accomplishment by their very nature. This section examines the literature findings about JPA effectiveness in the following way. First, a discussion is presented of the variables related to worth. Second, the literature related to cost measures are reviewed. Last, the research into benefits is examined.

Research variables. The evidence indicating that job aids are a suitable means for controlling performance is primarily from studies commissioned by the United States Armed Forces. The measures of effectiveness of performance are numerous but they can be categorized under two headings: costs of performance; and benefits of performance. Table 3-1 summarizes some of the variables.

TABLE 3-1 - Benefit and Cost Measures of Performance

Benefit Measures	Cost Measures
- accomplishment of task: - accuracy - speed - tasks completed	- cost of behaviour: - spare parts use - cost of training - recruitment of high aptitude personnel - cost of developing performance system

Some variables are more important to some organizations than others. And, some data is difficult to collect for some variables. Government organizations, for example, do not have a measure of "profit" in the same way as profit making corporations so the measures of accomplishments must rely on indirect measures of achievement. The accuracy and speed of performance as well as number of tasks performed in a time span are difficult to convert to monetary units. The worth, then, for these organizations has to be in terms of some benefitial values related to societal goals. The true "worth" is accomplished by cost cutting. Job aid research has demonstrated cost savings, therefore their worth to organizations.

Findings concerning cost measures. Foley (1978) in a summary of the impact of maintenance data and training technologies stated that one of the high costs of maintenance in the United States Armed Forces was due, in part, to the unnecessary usage of spare parts. Potter and Thomas (1976) in a study of electronic technicians found that experienced technicians using job aids used fewer spare parts than experienced technicians using traditional technical manuals. They also found that inexperienced technicians using more detailed Fully Proceduralized Job Performance Aids (FPJPA's) used fewer spare parts than inexperienced technicians using less detailed Logic Tree Troubleshooting Aids (LTTA's). The same study demonstrated that for difficult tasks, spares usage by inexperienced technicians using FPJPA'S was less than by experienced technicians using traditional technical manuals.

There are several studies indicating the effectiveness of job aids in reducing training costs. Elliot and Joyce (1968) found that they were able to take low aptitude technician candidates (they were below the cut off for admission to advancement training) and give them a twelve hour course in maintenance procedures using a job aid. No difference was found in percentage of faults found between this group and experienced technicians using traditional technical manuals. Gebhard (1970) found that a course designed around the use of job aids was half as long as the conventional course; no significant difference was found in troubleshooting performance between technicians taking the new course and those having taken the old course. Theisen (1978) had similar results as Gebhard (i.e. no difference) using medium aptitude trainees (below cut off for advancement training), shortened courses (reduction for basic level course was 45%; reduction for intermediate level course was 55%) and job aids, compared with high aptitude technicians who had completed traditional training and used technical manuals. The emphasis in the Theisen study was reduction of course length to a minimum by using programmed instruction and job aids.

The costs of developing job aids, and other technical manuals, is proportional to the level of detail, and the amount of graphics and illustrations: the more detail the greater the development cost. Potter and Thomas (1976) report that the development costs of FPJPA's were from 48% to 90% higher than LTTA's which were at a lower level of detail and did not include pictorial locators. While no data were found to illustrate the cost differences between job aids and traditional technical manuals, estimates run in the region of five to one greater costs for job aids than TM's. The Canadian Forces estimates that the cost of camera ready originals of traditional technical manuals cost about $450 per page to produce. Due to the accounting procedures used, it is uncertain whether the cost includes the cost of job and task analysis (Note 3 - Desorcey, 1983). One might estimate that FPJPA's would cost, for camera ready masters, in the neighbourhood of $2000 to $2500 per page (1982 Canadian dollars - using the five-times estimate). Theisen (1978) reported that the job aids and associated training (total of 29 weeks for two courses) cost

$300,000, or about $350 per hour of instruction. In 1983 dollars, one might expect the figure to be about $700 (Canadian) for each hour of programmed instruction and the associated job aids. This cost should be compared with the costs of developing traditional technical manuals and traditional training conduct (which is about 50% longer) and development.

Findings concerning benefit measures. The conclusion one must come to in examining various studies that have evaluated the effectiveness of job aids is that job aids are effective in guiding task performance. Job aids are at least as effective as traditional technical manuals (Elliot & Joyce, 1968; Gebhard, 1970; Potter & Thomas, 1976; Theisen, 1978), and are more effective than in situations where no other task guidance methods are available (Horabin, 1967; Pilette, 1978; Walch, 1978); therefore, task guidance is better than no guidance. Potter and Thomas (1976) found that high aptitude technicians using FPJPA's found more faults than technicians using TM's regardless of experience level (i.e. inexperienced, up to 6 months experience, over six months); they also found that technicians with up to six months experience using LTTA's found as many faults as more experienced technicians (more than six months) using TM's. The more experienced technicians using LTTA's were more successful in finding faults than the technicians using TM's.

A summary of the interaction among experience, level of procedural detail and task complexity vs faults found is in Table 3-2. For the system engineer, Table 3-2 summarizes the interactions in terms of predicted fault finding performance. That is, for high complexity tasks, low experienced personnel using FPJPA's are predicted to be as reliable as high experience technicians using traditional technical manuals and medium experience personnel using PPJPA's. For high complexity tasks, performance better than that which can be accomplished by low experience performers using FPJPA's, requires a more experienced technician using FPJPA's; a more experienced technician using PPJPA's are predicted to be only as good as low experienced personnel and highly detailed job aids.

Table 3-2 Predicted Fault Finding

	Task Complexity low	Task Complexity high
Low experience (<6 mo.)	FPJPA > 85% PPJPA > 75% TM don't use	FPJPA > 85% PPJPA > 60% TM don't use
medium experience (6></12 mo.)	FPJPA = 100% PPJPA = 100% TM = 100%	FPJPA > 95% PPJPA > 85% TM > 60%
high experience (>12 mo.)	FPJPA > 95% PPJPA > 95% TM = 100%	FPJPA > 95% PPJPA > 85% TM > 85%

The greatest measure of the worth of job aids in guiding task performance is in the interaction effects of the variables. So far, the variables of interest have been specifically related to task accomplishment. However, research has provided some information regarding job aid design. The design issues are the subject of the next part of this chapter.

Job Aid Design

The Design of the Transducers

Returning now to the cybernetics of job performance aids, recall that the job aid is task guidance information that exists on the homeostat between the task performer and the management metasystem, in System Two. Specifically the job aid is an amplifier of management variety and an attenuator of task performer variety, from the management view. From the worker viewpoint, the job aid is an amplifier of his/her own variety in regulating task accomplishment. The job aid is at a lower level of variety than the worker; it therefore requires its own variety amplifiers and attenuators. Traditional technical manuals are seldom designed to interrogate users to help them identify problems and solutions (Kern, in Duffy, 1985); they lack requisite variety. What are the features that give job information aids requisite variety? Looking deeper into the relationship, an analysis of the homeostat between the task performer and the job aid reveals much about how the job aid amplifiers and transducers should be designed.

Figure 3-8 illustrates the job aid/task performer homeostat. Once again let us use the example of a technician repairing a radio, but let us examine the homeostat between the technician and the job aid. The technician has his own transducers: his data search behaviour is the output transducer; the input transducer is his ability to translate or interpret information presentations.

For the job aid to be effective, it must attenuate the variety increasing search behaviour; that is the novice technician, left to

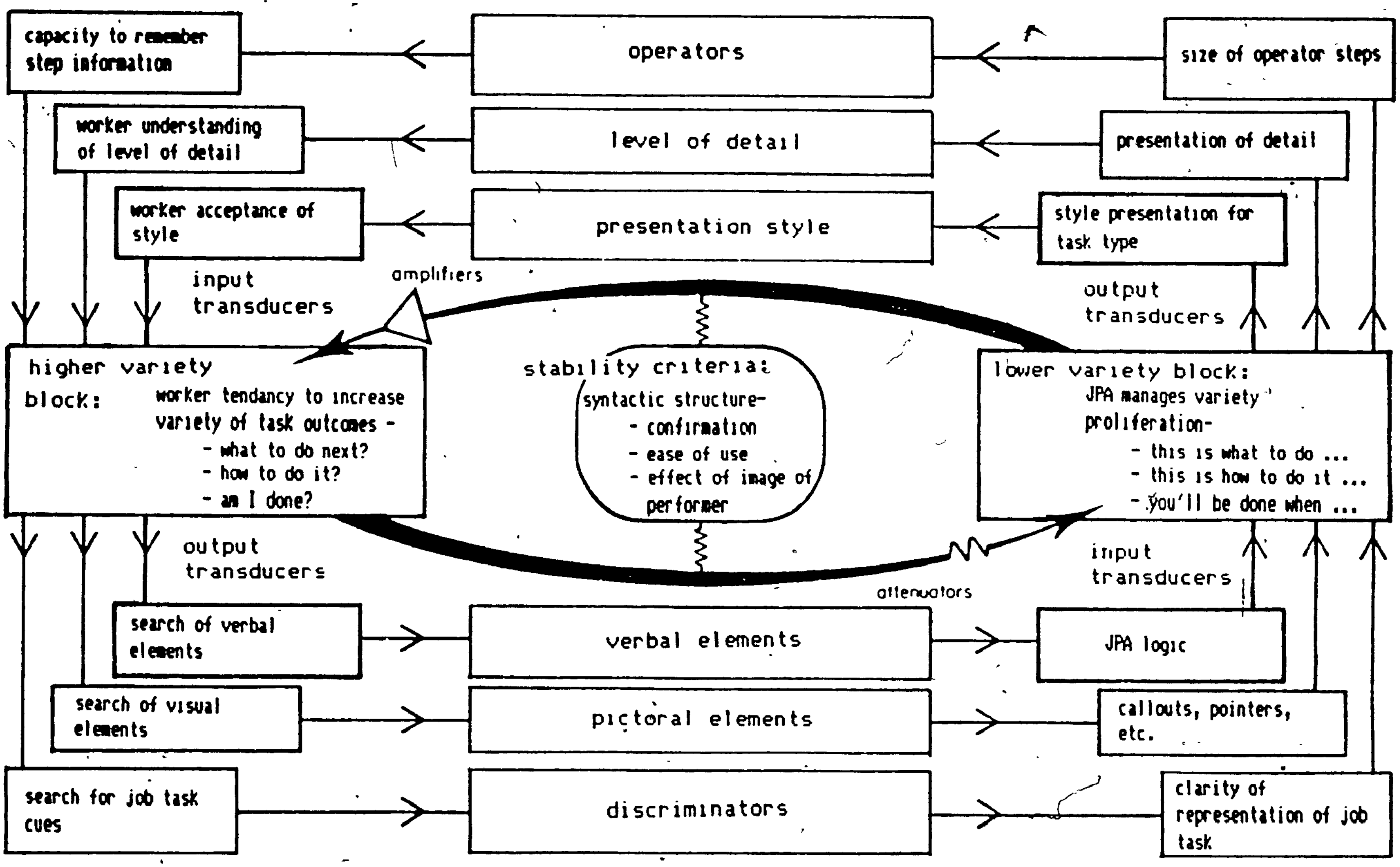


FIGURE 3-8 WORKER/JPA HOMEOSTAT

his own devices, might randomly search the job aid for information, increasing variety. The transducers of this attenuator are the means the job aid controls the user's search patterns. These transducers are the discriminators; diagram callouts; and the logic of the algorithm in directing task activity based on results of environmental conditions.

The job aid must also amplify its own variety, it being at lower variety than the user. The job aid must present information in a way which takes into account the ability of the user to interpret it. Since information is "what changes us", the transducer must change the behaviour of the user. The operators that are chosen for the job aid will affect whether a change occurs or not. For example the transducers of the amplifier are: medium of presentation; style of presentation - prose, flow diagrams, use of information maps, etc; amount of detail in presentation (drawings, prose); use of tables; etc. The ability of the job aid to present information has an affect not only on the success of task completion, but also on the quality of the task performance. Speed and accuracy of performance are a couple of quality measures often affected.

There must be good interaction of the output and input transducers of the job aid; the syntactic structure must effectively relate the operators (output transducers) and the discriminators (input transducers). Information which confirms the correctness of the user's actions provides him with the necessary feedback to permit him to adjust his use of the job aid. According to Gilbert (1978) task performers often do not know when they are performing well, so the job aid design must have sufficient variety to ensure performance is confirmed. The designed strength of the job aid amplifiers and attenuators is a function of the potential variety proliferation by the user. Well trained, or experienced personnel are less likely to proliferate variety than novice task performers with little or no training. This and other target audience characteristics must be taken into account in the design of a job aid.

Research into JPA Design Variables

Presentation techniques. The research into job aid presentation techniques is of three types: format of procedure presentation; effect of detail; and effect of communication channel (i.e. visual/audio). Elliot (1965) found that flow chart type diagrams were better than list forms when speed was the evaluation criteria. Flow charts were also found to be better for accuracy for medium aptitude individuals versus no difference for high aptitude individuals. Schmid and Gerlach (1977) found that there was no difference in performance of pilot trainees between prose and flow chart forms of algorithms. Levine (1978) found that individuals using a decision aid flow chart had consistently reliable performance.

Elliott (1965) found that the amount of detail included in a job aid affects speed: too much detail depresses performance scores. He suggests that the amount of detail to be included should be only that amount which is necessary and sufficient for the performance of the task. However, Joyce and Chenzoff (1974) found that dual level job aids would be acceptable in the opinion of potential job aid users. Dual level job aids have two levels of detail: one level which can best be described as a procedural guide for experienced technicians; and a second level which is an algorithm to be used by nonexperts. In current forms, this presentation technique uses bold type for the procedural guide; the algorithm includes both bold and regular type.

If speed is not critical, this technique of presentation now referred to as Hybrid Job Performance Aid (HJPA) may be a suitable form.

Research seems to indicate that the use of dual channel presentations has no significant effect on user performance (speed of performance, number of errors, etc.). Elliott (1966) and Serendipity (1969) found that there was no difference between visual and audio-visual presentations. Frey and Eichert (1977) found no difference in the use of holograms, line drawings or photos in job aids. However there has been an effect noted in detail of pictorial components of written communications. Biege, Borge & Schuller (1977) found that the amount of detail in drawings and photos significantly influenced performance: less detail (i.e. only that detail which is necessary and sufficient) is better for understanding.

Control of search behaviour. On the input side of the job aid, the transduction process which controls user search behaviour, a few studies have provided results which are note-worthy, in particular the use of callouts on technical diagrams. (Callouts are the means whereby parts are identified; usually a circled number with an arrow.) Curran (1980) found that a technician's search of a diagram for a part from a list is facilitated by use of numbered callouts where the numbers begin at a consistent place on the diagrams, typically upper left, and the numbers continue clockwise around the diagram. The use of random numbering strategies, that might be typical of numbering based on item function or by alphabetical order by part name, seriously interfered with part location when the number of parts was over 20. The research also suggested that there is no difference in part finding success and speed for ten to 62 callouts provided that sequence was used. The research suggests that for part location when the user knows the name of the part and when callouts exceed 20, the optimal procedure is to put nomenclature in an alphabetic table which is crossreferred to the numbered callouts.

No studies were found which evaluate the effect of algorithmic approaches on search procedure. One would expect that algorithms, by definition, control search behaviour as a function of the replicability and resultivity requirements (Gerlach et al, 1975).

Language itself is significant, however, in technical manual design. A consistant recommendation in the literaure is the use of simplified language (Curran, 1977, 1980; Kniffin, 1980; Kieras, 1982). By simplified language what is meant is short words and short sentences using the active voice. The reading grade level (RGL) should be appropriate for the target audience. Technical manuals often have an RGL of 14 or so (technical school/university graduation), while typical new entries in the U.S. Forces have a measured reading ability of only grade six (Theisen, 1978; Curran, 1980). Twenty five percent of recruits in the U.S. Forces are five RGL's below the technical training materials.

The amount of detail in drawings would be expected to influence search success. This is a function of the need of the user to discriminate items in the drawings. Each item or element in a drawing would serve as a distractor for every other element in the drawing. Research suggests that simpler drawings result in better composite task performance (i.e. total performance not just search behaviour) (Biege, Borg & Schuller, 1977).

Chapter Summary

This Chapter was a presentation of an analysis of the job aid concept primarily at the "micro" level. The attributes and effectiveness of job aids within the context of the cybernetics of task performance was assessed against the research. Various design features are alluded to on the basis of studies.

The effectiveness of job aids cannot be disputed. However, implementation of job aids into large corporate structures has had problems. Corporations that operate on the profit motive have utilized job aids on the basis of influencing the "bottom line" (e.g. Bell Systems, Ford, Westinghouse, IBM). Government organizations like the military have no bottom line incentives and are less able to measure total system performance. This may in part explain the allegation stated at the outset of the chapter - that the U.S. government has wasted money on the research because it has not implemented job aid technology. The government does not seem to have a way of collecting all the costs of behaviour and may not have a relatable benefit. The next Chapter will deal with these and other system considerations influencing job aid implementation.

CHAPTER FOUR

SYSTEMIC CONSIDERATIONS OF JPA's

Introduction

The previous chapter concluded that, while job aids improve the worth of worker accomplishments, the military which has sponsored the research has not embraced the concept. It would seem then, that the military has wasted money in conducting the research because users are saying: "We'd rather have well trained personnel". But placing this allegation in context, since benefits and values have been demonstrated, and therefore the worth potential, industry is using the concept to affect the bottom line - thanks, in part, to the government research.

Is the situation without hope for the government sector? Can job aid technology be implemented as a general policy of task guidance? These and other system concerns are the subject of this chapter.

This study's findings at the macro level will be presented in two parts. The first part is an examination of the cybernetic concerns at the system level; this includes the reactive and adaptive mechanisms of organizations. The second part presents the research findings reported in the literature regarding the macro level of job aid technology.

The questions for this chapter are:

- What are job aids in the systems context and what do they do for overall system performance?
- Why should job aids be developed as an integral part of

the whole system?

- When should they be developed in the system development process? And, where in the system should they be used?
- How, in context of the whole sytem, should they be used?

System Level Cybernetic Concerns

The introduction of job aid technology in an organization such as the military seems to be difficult. Research has been conducted for more than twenty five years in the concept, but technical manuals are still not "user friendly". And, as a friend of mine who is a Naval Technician working on the Canadian Patrol Frigate Project said: "the technical manuals we are getting today are down right hostile." The manuals being provided to the CPF Project are being developed by U.S. (and other) industry which originally developed the equipment systems for the government.

It seems that if the user attitude is that highly trained personnel are wanted, the command organization of the military cannot just say "use job aids". I suggest that the command structure does not even know the benefit of job aids. This points out a major shortcomming of the structure of organizations and the location of the research and development activity in the planning and system development process.

The theme for this section of chapter four is that there is inherent waste when planning is autocratic (from above) or when it is passive (bottom up). What is needed is top-down adaptive planning with constant attention to the purpose of organization. I suggest that any organization which uses this latter approach to system development will probably already have job aid technology as well as other adaptive measures.

The discussion of this theme is in two parts. The need for responsiveness by the metasystem of system one requirements will be analysed first. The adaptive mechanisms will be analysed next.

Reaction to System One Needs

The first part of the cybernetic analysis of the macro level of job aid technology concerns how Systems One and the metasystem, System Three, respond to one another in achieving the larger system goals. This analysis is in aid of examining how the high level decisions regarding resource allocation, including personnel resources and their job information support system, are translated into productivity.

In an earlier discussion it was suggested that in government organizations, it is difficult to collect all the costs associated with achieving on the job performance. Assuming the behaviour that workers exhibit affect in a positive way the desired outcomes of the organization, there is a benefit to the activity. For the net worth of the activity to be profitable, the costs of the activity must be less than the value of the benefit (the worth formula). For government the best way to improve the worth of its activities, it seems, is to cut costs.

For the metasystem to state that it will cut costs is likely to arouse the cry from Systems One: "they don't know what we need or what I'm doing". The following presentation of the study analysis concerns the metasystem reaction to user needs. The focus is, of course, on the personnel requirements. Three topics were identified for discussion: system one resources; the Resource Bargain; and, decision making by System Three.

System One resource requirements. The need that was identified earlier was trained personnel to ensure that management accomplishes its goals. When System One focusses on such a need it seems to make sense. The rules for viable systems state that System One must be accountable for its work and resource utilization. It is natural for any System One to desire the best of everything. This, of course cannot be achieved by any System One without resulting in "unfair" resource allocation to other Systems One. Resources are distributed as equitibly as can be achieved in order to create synergy.

In the broader context, the needs of System One are directly related to the system purpose. Cybernetically the purpose of a system is what it does, that is, its value creation activity. What a viable system does is done by System One (Beer, 1979). When a supervisor claims that well trained personnel are wanted, the hidden agenda is that he cannot create value with anything less.

The principle that is working in this context is: "I have to get the job done, but look what you gave me to work with'." When the accountability for value creation is lost, as in much (most) of government activity (my suggestion), then objectives stop being completely relatable to the stated purpose of the system. When what System One does is the purpose of the system, objectives and purpose can be created anywhere in the system without regard to the main event objectives of the metasystem as long as the resources available are not exceeded. The purpose can shift: "the purpose is to have the best personnel under my control regardless of cost because I'll look good." But, System One should not be able to change its purpose without regard to the metasystem "main event". A Resource Bargain is struck between Systems One and the metasystem, System Three being the metasystem focus for System One.

<u>Resource Bargain</u>. For System One to declare that it needs better trained personnel is a category mistake. It is cybernetically illogical. A Resource Bargain is struck between Systems One and Senior Management. The main characteristic of the bargain is the autonomy granted to the junior counterparts by senior management. The bargain declares that out of all of the activities that might be undertaken, only these are authorized and, as negotiated, this is the resource allocation (Beer, 1985). It is logical for System One to declare that the resources (i.e., the total mix) are or will be no longer adequate due to some unforseen perturbations in the operational environment.

It is the metasystem's perogative to declare the purpose of the system through the Resource Bargain. Appropriate capital and human resources accompany the bargain. In return, the viable system requires accountability from System One in return for the resources and autonomy necessary to create the value which is its purpose. Part of the Resource Bargain is the combination of human resources and support system for the effective utilization of those resources. Of interest to the present study is the decision making that occurs regarding this element.

<u>System Three decision making</u>. Senior management allocates resources to the various Systems One in accordance with certain policies and guidelines, and operational plans. The constraints affecting the Resource Bargain include the staffing policies: personnel selection; training; and, provision of environmental support. Earlier in this study it was suggested that these elements are traded off one against the other in providing personnel who are capable of accomplishing valuable work. (See Figure 2-2 for an

illustration of the concept.)

System Three, the part of Senior Management that looks after the autonomous operation of Systems One, allocates human resources to the operations, Systems One. The decision to use moderate aptitude personnel, with minimal training and job aid informational support can have the requisite variety for System One if the three elements are complimentary. The selection of personnel who cannot read, or the use of printed information that is at a reading level much higher than the user, is likely to result in a poor Resource Bargain and an inappropriate investment in human capital. The appropriate Resource Bargain will have the following personnel element characteristics:

- <u>Selection</u> - Only personnel who have the skills, knowledge and aptitudes that are seen to be necessary for job performance are selected. This assumes that the environment, the job market, has the facility to provide qualified personnel. Recruitment efforts are directed to obtaining personnel who would be motivated, capable and posses the correct behaviour repertories.
- <u>Training</u> - Personnel are provided training experiences, formal and on-the-job, to develop requisite behaviour repertories. Discrepancies between actual skill and knowledge, and the skill and knowledge seen to be required for the job performance are corrected.
- <u>Environmental supports</u> - Environmental support systems are provided to correct the discrepancies between the actual skill/knowledge, capacities and motivation of personnel, and the requirements for worthy performance on the job. Environmental supports include job aids, equipment, tools

and instruments, and incentive schemes (refer back to Table 2-1).

These strategies are seldom used in isolation. Varying degrees of each strategy are used to achieve system performance. Selection and training (including career planning) are the most common methods of providing personnel who can produce valued accomplishments. Tools and instruments are usually taken for granted and incentives often take the form of Christmas Bonuses and periodic pay raises in which the incentive is hard for the worker to relate to specific behaviour which lead to improved outcomes. (Cybernetics, however, suggests that accountability requirements should automatically result in incentives being built in.) Job aids and other task guidance strategies or other information aids are of specific interest to this study.

Figure 2-2 illustrated the balance among personnel selection criteria, training specifications and job aid specifications. Decisions concerning selection criteria influence training specifications. The selection criteria establish the base level of the Target Audience for training. The specifications for training are developed so that training will be designed to correct the skill/knowledge shortfall. If job aids will be used, the training specifications can be trimmed, resulting in less training development. The decision to increase the job aid component of the performance system results in reduced training and makes the decisions concerning selection criteria easier. Ultimately, the selection criteria must take into account the actual job market. The ability of the organization to attract personnel who have the appropriate behaviour repertories must be accounted for. Shortages in the job market of personnel with target behaviour repertories increases the need for training, job aids or increased wages. (You pay for training whether you have it or not!)

System Three uses the policy, whatever it is, to provide the human resources to Systems One. It is part of the Resource Bargain. The decisions made by Three are guided by the policy. Problems in the Resource Bargain are understood by System Three in terms passed to it from Systems One. Since System Three is concerned with the "here and now" operations of the system, the only way System Three can understand the future with respect to System One, is through System One activity in the environment. There is no capacity in System Three to know about the future except through Systems One or System Four. If this is the case, how is planning for the future accomplished? Where do the policies come from that determine what the mix will be among selection, training and job aids? The answer is found in System Four - the adaptive mechanism of senior management.

This part of the analysis investigated the allegation that senior management does not know what System One needs or what it is doing. In a viable system, this does not make sense. The Resource Bargain ensures that what System One does is its purpose and that appropriate resources are available to accomplish the goals for which it is accountable. Part of the Resource Bargain is the human capital as well as the equipment capital. The policies and plans which make the system responsive to future change are developed in the interaction between System Three, which understands current activity, and System Four, which deals with future environmental states. The next part of the study results concerns the mechanisms for adapting the structure of the organization for future states. The structure of System Four is important to the understanding of policy development and, for this study, the development of job aids.

Adaptive Mechanisms - Inventing the Future

Attempts by System One to change without adjustments to the Resource Bargain, could result in misdirected expenditure of resources, waste. But, successful adaptations could result and the Resource Bargain could be renegotiated (intrapreneurism could/should be part of the Resource Bargain - System One is/ought to be a viable system and therefore has System Four activity of its own). System One activity cannot change its own purpose, without reference to the metasystem, without causing perturbations among the other Systems One at the same level in the recursion. The metasystem contains the adaptive mechanism which understands the future in terms of its own level in the recursive structure of the organization. System Four understands System One requirements in terms of System Three.

This section of the presentation of the study results is a discussion of the adaptive structure required in the viable system. The introduction of job aid technology is an adaptive measure to some pertibation(s) in the environment: changes in the job market; introduction of new equipment technology to the system; problems of on-job performance identified within the organization; cost cutting measures; etc. The adaptive structure discussed here is of a general nature since it deals with system change, and applies not only to job aid implementation, but also other personnel sub-system innovations or any change in the value creation capital mix of the organization.

System Four and System Three continuously interrogate and adjust to one another in order to match the variety generated on the vertical axis. Planning and adaptation should be continuous without lag or hiatus for the variety to match. If a meter reading could be taken at the Three/Four interface, the meter would observe this message: "The future is now - here is the new set of Resource Bargains which will keep the organization alive".

The discussion will cover three facets of the business of "inventing the future". The first discussion concerns the cybernetics of planning and development. Next is the System Four response to System Three. The final facet in this section concerns various aspects of implementing change.

Planning and development: System One operates at its own level of recursion in response to the environmental lobe which is its operating environment. System One, as a viable system, knows this environmental lobe and has plans within that compass. System One does not have the wherewithall to "see" the larger environment that contains its environmental lobe. Senior Management looks into the larger environment and considers things which are beyond the imagination of System One; the metasystem operates in a different language (cybernetically speaking) from System One. System Three is responsible for translating the operating language of Systems One to and from the operating language of the metasystem.

System Four is responsible for interogating the putative environment at its own level of recursion, i.e., not the recursion above. The problematic element at System Four's recusion includes the environment of Systems One. (Refer back to Figure 3-4.)

Research and development activity conducted within the System Four planning activity attempts to discover what the nature of the future is within the environmental context. Beer (1979) maintains that in most organizations research and development is often outside the planning activity; it is a staff function, not a line function.

R&D is a service in this case which can be used or not. Cybernetically this is unsound and does not efficiently contribute to system viability - it does not have the requisite variety necessary on the vertical axis. This is where, I suggest, the problem lies in the attempts of the R&D activity in the U.S. military to introduce job aid technology; the research has been discovering adaptive organizational structures, job aid technology, but the research activity is not in the continuous planning loop - it is an appendage.

System Four must not only discover adaptive structures for future requirements, it must also invent the future for the organization and help introduce it. To do this System Four must understand the organization at its own level of recursion as well as the environment, and be provided the wherewithall to cause the organization to change its states. There must be requisite variety between System Four and System Three as well as System Four and the putative future.

Response to System Three. For requisite variety to exist between Systems Four and Three, there must be a continuous flow of information up and down the homeostat between these system elements. Since "information is what changes us", Systems Four and Three must continuously change states. The here and now inputs of System Three result in adjustments in System Four with respect to its understanding of the operations, and System Three adjusts its operational planning and structures in response to System Four's understanding of the future.

Figure 4-1 illustrates the informational links between System Four and, System Three and the environment. The description (adapted from Beer, 1979) that follows is somewhat lengthy, but essential to the main points that will follow with respect to the implementation of

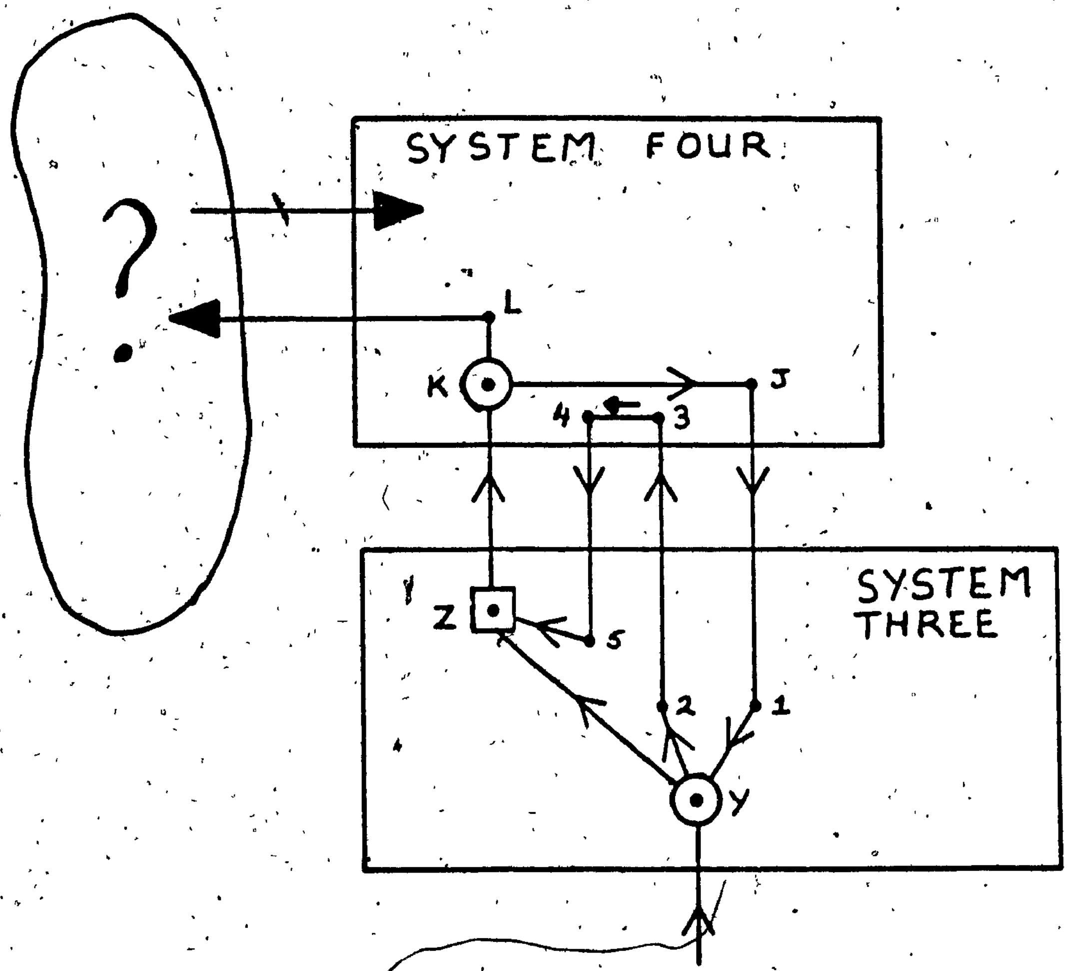


FIGURE 4-1

THREE/FOUR INTERFACE

CONTINUOUS PLANNING

job aid technology. For ease of understanding an example is used, the Canadian Forces Defence Program Management System (DPMS).

The development of Defence Innovations is, cybernetically, a System Four activity. As has been discussed, the relationship between System Three and System Four is critical to the viability of the system. The Three/Four Interface requires some functions to be present to ensure the varieties match. In the Figure, the interaction of System Four with the problematic environment of the putative future is indicated by the arrows to and from the System Four box and the environment bubble. Point "L" in System Four represents a point of access to the development activity of System Four. It is, in particular, the point in System Four which has collated System Four's understanding of the whole system's posture concerning external environments and the possible futures of the system. Point "Y" is a similar point in System Three; it represents System Three's understanding of System One's posture concerning the external and future environments (at its own recursion).

Information from "L" passes through point "K" to point "J" for transduction to System Three. When the information reaches "Y" through point "1" it causes a change of state at point "Y" which is represented as the change from "1" to "2" (recall the definition of "information" - that which changes us).

The information accessible at point "Y" is passed to System Four and is registered at "3" which changes state to point "4". This adjusted information returns to System Three at "5" which changes state, and becomes part of the collation activity of System Three at point "Z". Point "Z" represents the synthesis of System Three's understanding of System's One understanding of external and future environments.

Points "J", "3" and "4" are the transduction mechanisms in System Four of System Three's understanding of System One's posture with respect to happenings in the system. Points "1" and "2" are corresponding transducers in System Three.

Because there is more than one Systems One, there are more points "Y" than shown; at least one for each System One. Point "Z" synthesizes the information available at points "Y" for transmission to System Four. In System Four, likewise, there are several points "J", one for each System One. This is half of the variety equation between System Three and System Four. System Four must be able to handle System Three variety with respect to its functions concerning Systems One. System Four must be able to generate information concerning the future which pertains to each System One.

The information which passes between points "Z" and "K" is of a different type. It is information concerning the synthesis of Systems' One postures with respect to current environmental conditions and the putative future as seen by System Four; this synthesis is tempered by System Three's understanding of the actual and potential synergy of Systems One.

This other half of the variety equation results in the stable operation of the homeostats between the system development activity of System Four and the autonomous control activity of System Three. The channel from "Z" to "K" must be able to handle all the variety that is generated in the operation of the various "J-Y" channels including their double loops (transducers 1 to 5), plus the variety of the synthesis of point "Z" and the synthesis at point "K" of System Four's understanding of actual and future environments (which is registered at point "L"). Several points "K" probably exist in System Four, one for each environmental lobe (significant sub-environment).

Putting this Three/Four Interface into practical terms requires an example. Figure 4-2 is an illustration of my understanding of the operation of DPMS in the cybernetic terms just discussed.

Several other System Four functions have been included in the diagram and will be discussed presently. The box marked LCMS (Life Cycle Management System) represents all the System Three functions of the previous Figure. In the center of the Figure is a box marked "Collator of System Posture," this is point "L". In DPMS it is probably not explicitly stated, but resides inside the heads of the collection of persons involved in development activiy. The equipment change generator is the mechanism which considers the possible future in light of what is known about the possibilities as understood by organizations outside of the Canadian Forces (the homeostat between Equipment System Change Generator and the circles - outside organizations). This is information of the possible future as filtred by other organizations (equipment suppliers, researchers, other government agencies, etc.). The box marked Equipment System Query Generator is the function in the development process which generates innovative variety in the putative environment. It is the concept of <u>inventing</u> the future.

Unfiltred reception of possible futures occurs at the Equipment Change Generator function. Initially the Equipment Query Generator, in DPMS, is the informal investigation by anyone in the system into the future. The submission of a Statement of Requirement (SOR) formalizes the change proposal and is registered at the Equipment Change Generator. In the Canadian Forces, the Query Generator function is handled formally by funding of R&D projects by NDHQ, Chief

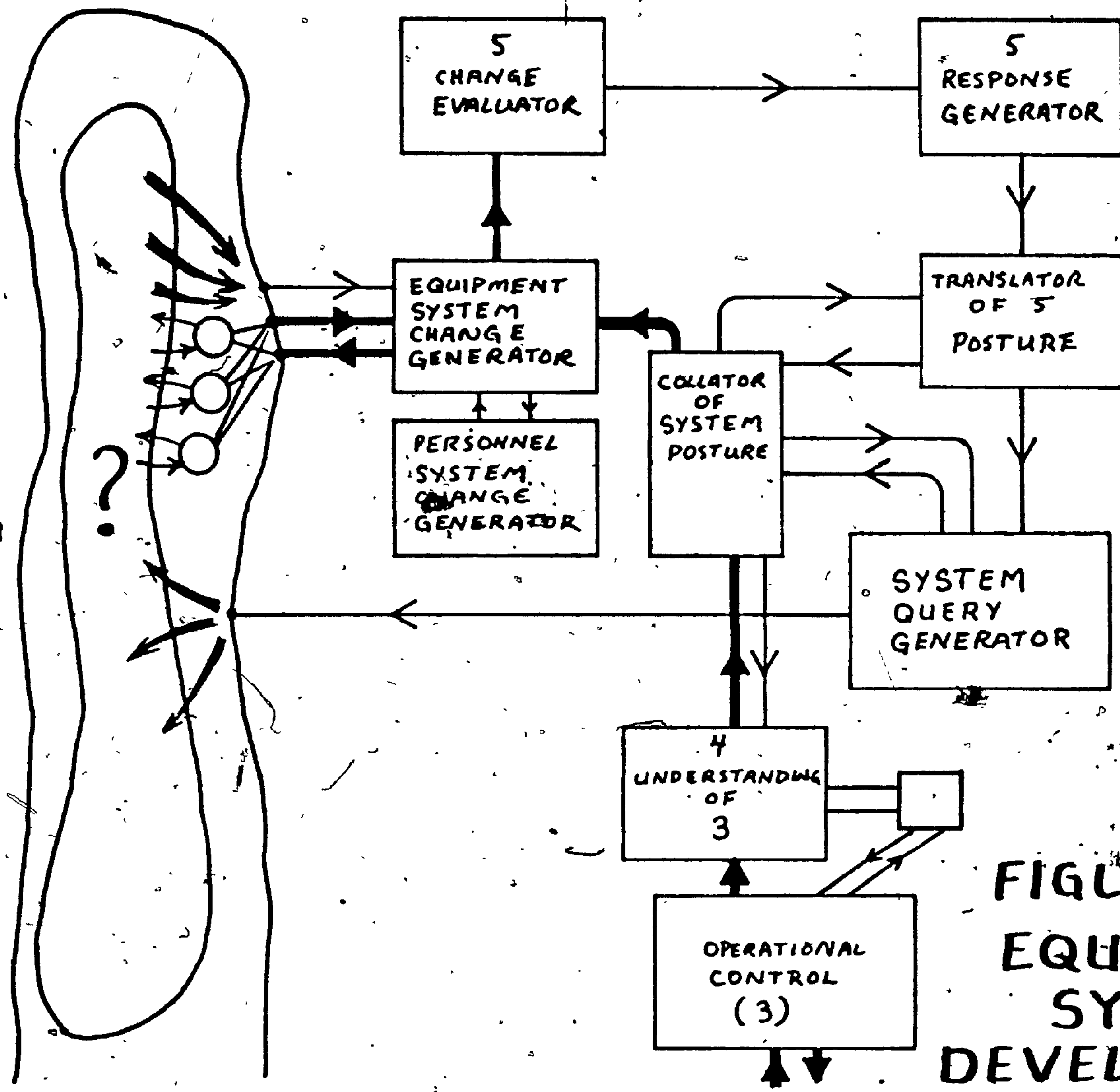


FIGURE 4-2
EQUIPMENT
SYSTEM
DEVELOPMENT

of Research and Development (CRAD). There are other organizations that have research functions (Director General Operational Research - DGOR, Director General Personnel Research and Development/Personnel Applied Research Unit - DGPRD/PARU). Some changes to the personnel system have occured as a result of their efforts.

Informal queries are generated by anyone in the organization who has contact with possible futures. Formal replies to queries concerning possible futures usually come, solicited or unsolicited, from non-DND organizations. Interpretations of the possible future within the Canadian Forces is represented by the arrows from the Problematic to the channel from the environment to the Equipment Change Generator. This is the "inventing of the future" as seen within the organization.

The Change Evaluator and the Response Generator are the System Five functions which assess the suggested changes. This function is handled in part by the Research and Development Program Review Committee (RDPRC). The Change Evaluator must damp change suggestions to keep the organization from constantly fluxing. Potentially major changes could be initiated which are incompatible with one another or with metasystemic considerations. The response from System Five is registered at the transducer which Translates System Five Posture with respect to changes. In the formal sense within DPMS this is the understanding by change initiators of System Five's response to the change. Disapproval of an SOR(P) is not necessarily interpreted as a "no-go" for a change idea.

The box marked System Four Understanding of System Three Synergy is point "K" in Figure 4-1. It is part of the crutial balancer in the program development process; it interprets the needs and concerns of the operational components of the system (Systems One). In DPMS this function is probably handled by the make-up of a project development team. The interpretation by the team members of the system's posture with respect to the current state of the system and the future that is being invented will affect the operation of the Three/Four Interface. If the team has insufficient channel capacity to cope with all the implications of the system changes, then the implementation may be faulty. This kind of channel capacity problem may result in parts of the system not being addressed, such as impact on the training system of the change, or installation of a system without sufficient availability of spare parts.

The DPMS scenario just presented seems to be quite typical of Major Capital Projects. ROIT (1982) suggested that DPMS projects frequently did not include parts of the system in developing the innovations. The author is aware of a situation concerning the purchase of some large electrical equipments. At the time the cut off for Major Capital Projects was $250,000. The value of purchasing the electrical equipment was about $200,000, within the limits for Minor Projects. The purchase of the electrical equipment was made and it was delivered. However, removal of the old equipment, installation of the new ones and rewiring was to cost in excess of $50,000. The local funding authorities could not spare the cost of the installation on an ad hoc basis because of planned commitments. The electrical equipment was not installed until more money could be obtained from the original funding authorities (about a year later). There were some difficulties in getting the additional funds since the total project was now over the limit for Minor Projects. If the original submission had followed the correct procedure (i.e. submission of an SOR(P)), the installation would have been included as part of the normal development of the project definition.

It should be noted that the operation of DPMS is primarily equipment driven. System changes are usually perceived as equipment changes. Similar changes could be proposed in the Personnel System.

The forgoing analysis demonstrates the need for a substantial information transfer between the operations activity and the planning and development activity; System Five is also active. (See again Figure 4-1.) Within System Four must be a model of the environment that the system in focus is operating in, as well as a model of the system itself (including Systems Three and Four). Figure 4-3 illustrates the concept. This is how the system understands itself and can know how to change in response to environmental pertibations. I suggest that the Model ought to be located in the Collator of System Posture (Figure 4-2).

The adaptive mechanism descibed above needs to be on the vertical axis of the variety equation. The variety absorption requirements are extensive - The Second Axiom of Management (Beer, 1979). It is the author's suggestion that, the reason the U.S. Government R&D efforts in job aid and related technologies has not had the extensive implementation that might be warranted, is due to the tendancy of organizations to treat R&D as a staff function, not part of the continuous planning process. This points to the need of a Planning Directorate which embodies the cybernetic principles described in this study. This leads to the next facet of the current analysis - implementing changes.

<u>Implementing change</u>. When an organiztion exhibits the adaptive mechanisms described here, the introduction of change is on the basis

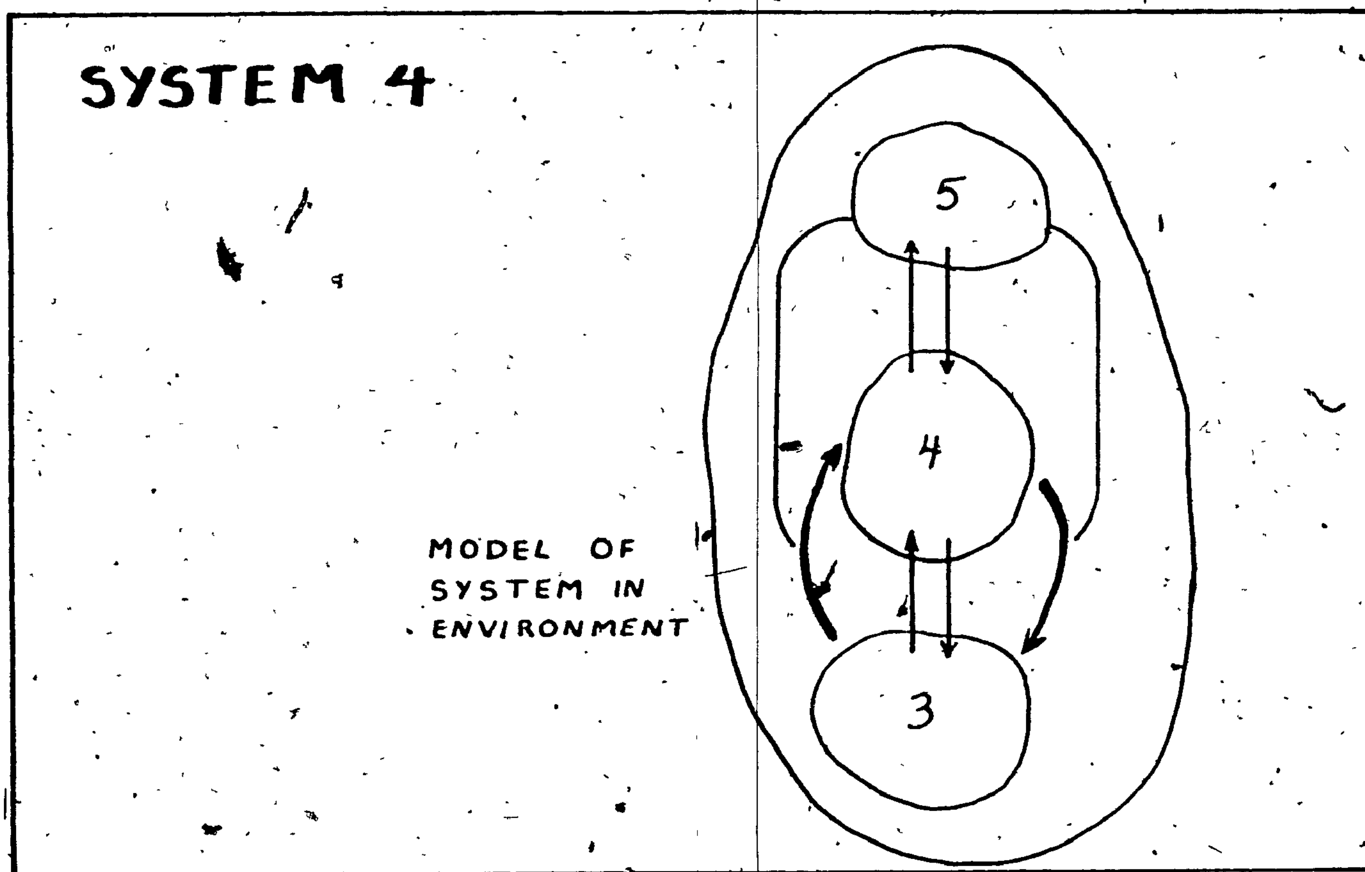


FIGURE 4-3
SYSTEM FOUR MODEL

of the system learning about itself. Change is evolutionary, not revolutionary. Evolution implies gradual adaptation to the environment. Revolution implies sudden large changes. Revolutionary hiatus goes against the principle of continous planning and development. Large changes are more intrusive and destroy some of the organizational cohesion: "Look what the 'grownups' are trying to push at us!" Organizational change should be more like learning than a frontal lobotomy.

The introduction of changes could be aided by change agents or change advocates. Abrams, et al (1974) suggests that implementation of change can be improved if both change agents and advocates are employed:

- Change agent - is defined as an individual or agency sponsoring the change. The agent must push the change process toward a problem solving format involving the increased understanding of issues, concepts and possibilities, and away from the emotional affect-laden interpersonal confrontations.
- Change advocate - is an individual who functions formally or informally, in the role of initial communicator concerning the advantages and capabilities of the device or change to the potential users.

The use of change agents and advocates are reasonable from a cybernetic standpoint. But the notion of a requirement for this concept indicates that an hiatus is present. Changes should be known by the players before they happen as a function of the continuous operation of the Three/Four Interface. System One ought to be anticipatory - "some good things are about to come just like we expected".

This final suggestion is not to say that change should not be followed through and followed up. System Four may even be asked to participate in ensuring that the changes are managable by Systems One. Ultimately System Five is interested that the Three/Four Interface is continuing to keep the system adaptive. There was a suggestion previously that if a meter were placed at the Three/Four Interface it would register the message: "The future is now - here is the new set of Resource Bargains which will keep the organization alive". This meter is part of System Five.

To conclude this section, planning and development for the health of the organization must be adaptive to System Three (System One controller) and the outside future as well as the purpose of the organization as stated at System 5 (which is the system in focus understanding of the metasystem as well as the 3/4 Interface).

With respect to job aid research the allegation made earlier seems inevitable because of the cybernetics of the R&D process in the government sector - Government has wasted money on research. But looking at the broader context, Industry has benefited. Job aid technology may be to the Defence Department what teflon is to the Space Agency.

The cybernetic analysis presented in this chapter points to some fairly extensive system considerations for an adaptive planning process. The allegation that the government research effort has wasted money is cybernetically understandable. If the allegation is true in terms of utility of job aid and related technology research findings, it is because the R&D effort does not meet the cybernetic principles - The Second Axiom of Management has been violated. This appears to be the case in spite of macro level studies (as defined in this study) in job aid technology.

The concluding part of this chapter is a presentation of findings reported in the literature on the macro level questions. Some analysis is presented of how the study findings should result in system change.

System Level Research Findings

The findings reported in the literature regarding the efficacy of job aid technology were discussed in Chapter Three. In this chapter the findings regarding system level issues are being presented. The cybernetic analysis concluded that system level introduction of job aid technology is difficult without certain system features present. The most significant feature is the requirement that the research and development activity must be on the vertical axis of system control for the variety equation to balance. The R&D activity must be part of the continuous planning and development activity.

The R&D efforts in job aid technology have discovered adaptive mechanisms which ought to affect the worth of worker performance. The value of the behaviour could be enhanced by better performance (speed, timeliness, completeness) or the costs of behaviour could be reduced (fewer spares used, labour and supervision reduced, lower level of behaviour repertories). Research has also found some useful information regarding how to implement job aid technology. The future of job aid technology is here and now - what is needed is the Resource Bargain.

The literature findings regarding system and implementation issues will be presented in three parts. The first discussion concerns some system issues; the next part examines the JPA development findings. The last presentation deals with integration of job aid technology into the personnel system. Conclusions about system requirements will also be discussed.

<u>System Issues</u>

In striking the Resource Bargain, senior management considers various system issues related to the personnel subsystem. The literature related to this concern will be presented in the following way: first the issues relating to system tradeoff; then job aid types; and finally, decisions regarding the selection of job aids.

<u>Head/Book tradeoff</u>. Senior management makes the decision regarding the human resource element by trading off behaviour repertories (selection and training) and on job support (job aids). This has been referred to as the head/book tradeoff (Joyce, 1975). Chapter Three presented research findings regarding the demonstrated value of job aids supporting worker performance. Job aids influence the benefit of worker behaviour (speed, timeliness, completeness) and reduce the costs of behaviour (spares use, behaviour repertories, worker and supervisor labour). This demonstrated efficacy contributes to the variety of management choices in establishing the human resource mix.

The decision to use job aids is influenced, in part, by the characteristics of the job for which the job aids are being considered. Two job categories are of interest:

<u>Operations</u> - Operations are the conduct and control of the primary system functions which, in combination, lead to the achievement of system goals.

<u>Maintenance</u> - Maintenance functions are the means whereby

system components faults are predicted/avoided, and repaired if they occur. There are two types of maintenance functions-

- routine maintenance, and
- corrective maintenance.

Routine maintenance tasks include fault prediction, adjustments, alignments, calibration, inspection, lubrication, installation and removal, etc. Corrective maintenance tasks might include some of the tasks involved in routine maintenance as well as troubleshooting or fault finding/isolation and problem solving.

The jobs that the U.S. Armed Forces are emphasizing for job guidance strategies are primarily maintenance jobs. This is true as well with some corporations. In the middle 1970's Armco, in Pennsylvania, began an apprentice program which uses FPJPA's and programmed instruction in electro-mechanical maintenance of its rolling mills. Both routine and corrective maintenance tasks were included (Foley, 1976). Foley (1976) states that most of the U.S. Armed Forces job aid effort is directed at improving performance of troubleshooting tasks. Bell Systems in the U.S. (and Canada) are using job aids for operator jobs as well as maintenance jobs (Foley, 1976).

There are some newer efforts by the U.S. Armed Forces in job aids. They are developing computer based job aids (CBJPA) to assist tactical decision makers. Operational Decision Aids (ODA's) are being tested for use by ship's command personnel (Peterson, Phillips, Randall & Shawcross, 1977). There is also an effort in using artificial intelligence programs in computers to augment the decision capacity of decision takers.

JPA types. Booher (1978) suggests that there are over 100 job aid systems. He has proposed five categories for dealing with them: Format/Content Systems; Display/Media Systems; Applied Training Systems; Peripheral Test/Diagnostic Systems; and Delivery Systems. He further suggests that there are three types of job aids from the Format/Content category which are sufficiently developed to warrant large scale implementation: FPJPA's; Hybrid JPA's (and Enriched JPA's); and Deductive JPA'S.

- Fully Proceduralized Job Performance Aids (FPJPA) - This type of job aid is the most detailed and step-by-step algorithmic type of aid. This type of aid has been well received and several different versions of production specifications have been published. The specification by Joyce et al (1973a,b,c) has formed the basis of several other specifications: U.S.N. Draft Specification (nd); CP-140 (Aurora) Program JPA Specifications (1977); USN P-3 (Orion) JPA Specification (1980).
- Hybrid Job Performance Aid (HJPA) - An evaluation of this type of aid was conducted by Post & Smith (1979) for the USN to determine what strategies could be employed to increase learning opportunities for career relevant knowledge. The principle characteristic of the Hybrid Aid is the use of two levels of task guidance: directive and deductive. The directive element is algorithmic; the deductive element is not algorithmic but procedural. The strategy underlying the Hybrid JPA use is that, over a series of performances, the technician will become more and

more familiar with the directive element until he feels ready to troubleshoot using only the deductive element. Should the technician encounter difficulty the directive element is available. This type of aid fosters incidental learning. Shiver & Hart (1975) describe a similar concept which separates out the detailed repeated tasks from the job aid and places them in a Job Performance Guide - it is expected that the user would learn the content of the JPG.

- Enriched (Hybrid) JPA - The EJPA takes the characteristics of the HJPA to the logical conclusion by providing, in addition to two levels of task detail, enrichment information concerning the task being performed. The enrichment relates to the content of the deductive and directive components of the job aid. Three types of enrichment were identified by Post & Smith (1979): 1. transition - any information designed to help the hybrid user transition from the directive to the deductive aid form; 2. system understanding - information about the operation of the hardware represented in the deductive aid of the hybrid; 3. theory - information about the operation of or principles underlying the class of equipment to which the present hardware belongs.

- Deductive Job Aid - This type of job aid includes only the deductive component as described in the Hybrid JPA. A deductive job aid could at best be described as a procedure (i.e. not an algorithm). Heuristic Recipes described by Harless (1980) and Ensamplers described by Gilbert (1978) are similar to deductive job aids. These aids are suitable for medium and aptitude personnel with moderate training.

The job aids described so far are suitable when the actual steps in performing a task are known. The guided query may be suitable when an "endless" number of factors must be considered; when task performance is better known by the performer than the guide developer, but a strategy for performance is required or lacking. The guided query takes the decision taker through a rational sequence to arrive at a decision. Some Artificial Intelligence studies are attempting to develop a computer program that forms an analogous strategy to the one used by the decision taker(s); the computer develops its own guided query strategy and may, in fact make the decision and operate on it (Note 2 - Pask & Mitchell, 1983).

There are more advanced types of job aids being developed using computers and various delivery systems. Automated or Computer Based (CB) JPA's are primarily Media/Display type job aids. The algorithmic component must be as complete and detailed as FPJPA's, but the transducer's controlling the display of information and the search behaviour of the user are computer driven. Scanland & Scanland (1981) suggest that the development of CBJPA's has been because of the logistical problems associated with paper based job aids. They cite the example of the job aids for the EPICS program which are in printed booklets. The paper life of booklets is short and the volume of the books present a significant problem in locations where space is at a premium, such as aboard ship where the EPICS program is being tried.

With the miniaturization of microprocessors and reduction in costs of chip technology, small-size computer based job aids are feasible. A prototype CBJPA has been developed by the Naval Training Equipment Center, Orlando. The Canadian Forces will be trying VIMADS

(Voice Interactive Maintenance Aiding Device System) which was developed by Honeywell for the U.S. Department of Defence. VIMADS combines video disc, microcomputer, voice recognition system and a headset/helmet. This device frees the hands of the user who can verbally ask VIMADS for guidance using 25 commands. The characteristics of the system include full motion visuals, repeat on request, silent and audio guidance. VIMADS has a training mode which permits repair of machinery using the video disc supplied information as a surrogate for the real equipment.

CBJPA's are still at the conceptual stage and require more study. Problems of reliability in military settings must be addressed. It is suggested that with the increased use of small format computers throughout modern machine systems, CBJPA's will become an important format for task guidance and may become resident in operational and maintenance software.

Job aid decisions. The trade off among the various factors are complex. Booher (1978b) presents an algorithm for the development and application of job aids which considers careers, formal classroom training, on-job-training (OJT), degree of job aid proceduralization, and hybrid job aids. The following factors were considered important decision criteria:

- Personnel aptitude.
- Task type being aided.
- Equipment complexity.
- Degree of proceduralization.
- Technical experience.
- Task complexity.
- Equipment type.

The decision algorithm uses hard data, most of which has been discussed in this report, and some hypothesis based on interpolation. Booher's algorithm is not summarized here as the report is detailed and lengthy, and would lose much in summarization. Interested readers are strongly urged to read the report in conjunction with its companion, Booher (1978a), which presents a classification scheme and a discussion of cost-performance trade off among other topics. The algorithm is not specific to the system design stage of system development, and may be useful in performance problem solving when jobs are being considered for performance aiding.

Booher (1978b) makes a questionable assertion in the discussion of his algorithm: "Low-experience technicians <u>cannot</u> troubleshoot with FPJPA if the equipment complexity is relatively high and the task complexity is high" (p. 7). Booher claims this assertion is supported by hard data (which study?). This assertion goes against the recommendations of some of the recognized experts (Gilbert, 1978; Harless, 1980; Bullock, 1983).

In my own research findings I could not find any support for this assertion concerning the interaction between experience and task complexity. The research evidence suggests that low experience personnel using FPJPA's can solve an average of 88% of electronic faults regardless of task complexity (Potter & Thomas, 1976). Excessive spares usage by low experience personnel in low complexity tasks is about 50% more than experienced technicians using TM's; about five times higher than experienced technicians using FPJPA's; and about three times higher than experienced technicians using Partially Proceduralized JPA's (PPJPA's). Excessive spares usage for high complexity tasks by low experience technicians is 23% lower than experienced technicians using TM's; and 40% to 50% higher than experienced technicians using FPJPA's or PPJPA's.

The inference that I am making from the data is that low experienced electronic technicians cannot reliably utilize job aids (i.e. with greater than 95% reliability -- that level should be expected with experienced personnel using FPJPA's or PPJPA's); however they are more reliable in performing complex troubleshooting tasks than experienced technicians using traditional technical manuals (88% reliability versus 78%). Less experienced technicians are less reliable in less complex tasks than experienced technicians regardless of form of task guidance. It is suggested that this apparent paradox is a demonstration of the amplifier effect of job aids in task guidance. The decision criteria seems to be the requirement for reliability of performance by low-experience personnel - for example, criticality of equipment in the system, or consequences of failing to find a fault may be the independant decision factors; spares usage is another factor. Less experienced technicians must be employed for less complex tasks, regardless of their lower reliability, in order to gain job experience (and have a meaningful function in the system.) Booher's treatment of the data must be reviewed to determine the correctness and suitability of his algorithm.

JPA Development

The literature concerning job aid development is closely related to training development. There are two entry points in system development for job aid consideration. The one that has been discussed extensively in this study, during system design, will be discussed presently. Another way is performance problem solving.

Performance problem solving. Performance problem solving in existing systems is often (usually?) handled by training solutions as first choice. This assertion is made on the basis of personal experience and the experiences of various training/performance consultants (Gilbert, 1978; Harless, 1975 - Ounce -; Mager, 1972).

Training and job aids in many instances are equivalent in providing solutions to performance discrepancies. As has been discussed job aids operate as external memory for the performance of a task; training, on the other hand, stores task performance information in the head of the task performer. The principle difference in choosing job aids over training, when either solution may be appropriate, is cost. According to Gilbert (1978), most organizations do not consider the cost of trainee wages in the costing formula for training. Approximately 90% of the cost of training is accounted for in wages (p. 221). Delivery costs about nine percent and development costs about one percent.

By this reckoning, a week-long course, using traditional instructor lead, group-paced instruction (as opposed to self-paced programmed instruction), with 20 students whose wages are $400 per week each, would cost about $9000 (only about $1000 of which would be attributable to delivery and development costs). Over a five-year portion of the lifespan of such a course, assuming 225 offerings of the course, $1.8 Million would be spent on trainee wages. The elimination of such a course by the provision of job aids would permit the workers to be on the job and productive to the organizational purpose, not in the classroom; the wages spent would be productive not overhead costs. But, an increase in development costs would result. I suggest that net savings are likely. It would be unlikely that development of the job aid would cost much more than two or three hundred thousand dollars (the job aid would be in the 100 to 150 page range using $2000 per page estimate of development costs).

Gilbert (1978) claims that almost any course offered by an organization can be reduced to one third of its former length by improved course development strategies and techniques. Harless (Note 3 - 1981) claims that, when job aids are developed and programmed instruction is used, a course can be reduced to one quarter of its former length. The experience of the U.S. Armed Forces in converting training to job aids and associated task oriented training is a reduction to half of a course's former length (Theisen et al, 1978; Gebhard, 1970). Let us say that for courses which were previously fairly well designed the reduction is half; other courses of questionable design strategy, the reduction would be to one third of the former course length. This represents for a 20-day course a reduction to between seven and ten days; a ninety-day course would be reduced to between 30 and 45 days.

The costs of the former 20-day course, using previous figures, is about $36,000, $4000 of which is attributable to delivery and development. The total trainee cost per year, assuming eleven offerings of the course, would be about $400,000. If the course were reduced to half of the former length, and still only offered eleven times the trainee costs would be $200,000, a savings of $200,000. Over five years the savings would be one million dollars. However, the course could be offered with increased frequency (i.e. 22 times per year); twice as many trainees could undergo the training or the student-instructor ratio could be doubled providing much greater individual attention. Again, for cost improvements, the development costs would have to be less than one million dollars if no increase in annual course load resulted, or less than two million dollars if the annual course load were doubled.

The decision to employ job aids could be simply an economic one. Job aids could be prescribed also in instances where there have been changes or unforeseen states in the organization environment. A good example of this is the change of reading ability of the average North American student leaving high school. It is estimated that the average high school leaver has no more than a grade eight reading ability (reported on Canada AM television show, March, 1983). According to Gilbert (1978, p. 232) only 80% of the adults in the United States can reach the minimum standard for literacy (i.e. understand and interpret simple want ads and grocery advertising); 33% of Americans are functionally inadequate (i.e. cannot determine the unit price of various sized boxes of breakfast cereal).

The problem of declining reading levels is aggravated by the tendency of technical manual producers to write equipment documentation at the level of engineering graduates. In a study conducted by Curran (1980) is was determined that 25% of the non-officer status recruits to the U.S. Armed Forces were five grade levels below the readability of training materials (grade 8 or 9 reading ability versus grade 14 [i.e. 2 years post secondary school] readability level of the documentation). The performance problems that must result when more than 25% of the trainees cannot satisfactorily read training materials could be solved by allowing them to fail; a solution that recognizes the potential that personnel who have poor reading skills may have, would be to rewrite the documentation.

Duffy & Waller (1985) provide substantial guidance regarding readability and comprehension of text material. Job aid specifications (Joyce et al, 1972; 1972b; 1972c; Shriver & Hart, 1975) are very specific with respect to readability; job aids must use standard vocabulary, and have a reading level of which is compatible with the literacy profile of the target audience.

<u>System design</u>. The research, design, and development component (System Four) of an organization should be prepared to address all aspects of job and task performance as a routine part of its operation. The methods, models and policies that are created can have enormous impact on system performance. The failure of system designers to take into account the human factors of the system and only the equipment and mechanical factors, could have far reaching results.

Designers who are conscious of the "front end" costs of a system could reduce the emphasis, deliberately or unintentially, of the personnel costs of the system. Failure to include training development and job aid costs in the front end costing does not eliminate them. Mager is quoted as saying "you pay for training whether you have it or not." Failure to provide for the human performance system in initial development may result in more damage than just deferring the costs or placing them in a different budget director's lap. The systemic nature of the system can be placed in jeopardy.

System design and modification usually commences with consideration of the system's goals. Discrepancies between actual achievement of the system and the goals are addressed with recommendations for system modification. The goals themselves may change. Recommendations for system change may include major equipment acquisition. The specifications for the provision of the equipment could include Intergrated Logistical Support (ILS): all the support requirements of the system including spares, warranties, training programs, technical documentation, and so on.

The system developer, whether in-house or contractor, must make an accurate assignment of system functions to both the machine components of the system and the man components. The capabilities and limitations of man must be placed in balance with judicious decisions concerning the need for machine amplification to correct his limitations, and for job satisfaction, the fostering of his capabilities. The overall performance strategy for achievement of the system goals must be designed with realistic estimation of future environments.

Job and task design should take advantage of the potentials for performance that are available. Selection, training, and performance aiding need to be traded off to optimize goal achievement.

The Research, Design and Development component of the system must develop satisfactory performance measures to determine whether system goals are being achieved once a system modification has been made. Researchers have identified problems in measuring human performance. Foley (1977) describes the problem of paper and pencil theory tests which show little demonstrated relationship to on-the-job performance. He cites the need for a shift of testing emphasis away from theory testing, to testing "off-line" in a job-like environment, when it is not possible "on-line". Symbolic substitutes for task performances need to be developed. There is a criterion problem in the difference between the real world and the simulation of the real world in testing and training situations.

Once performance measurement systems which encompass all aspects of the system which may be influenced by improved task performance have been put in place, feedback adjustments can be made on the information contained in the measurement data.

Ultimately the system developers must communicate the various modifications of the system to the various levels of management. One of the goals of this communication should be the image of the system that is wanted. A system which utilizes the Change Agent/Advocate concept might be projecting an image of itself as "willing to let all members of the system have a say in system changes." System modifiers and developers should be aware that their decisions do project an image; that image should be planned, not accidental. Total system closure and self awareness is a goal of a viable system to help maintain its viability.

The last issue considered in this section is the development scenario which employs outside contractors for system modifications. It is a common method used by governments to utilize the private sector in system updating and modification. The problem is, as I see it, how to control the activities of the contractor so that the system performs to specifications, while leaving to the contractor the variety that is necessary for the synergistic performance of its own system.

Once a contractor gains a contract, it has a certain amount of control over the contract letting organization. This has been dubbed the "buying-in syndrome" (Zaleski & Grice, 1980 - Proceedings: Interservice/Industry Training Equipment Conference and Exhibition of the National Security Industrial Association). The "buying-in syndrome" is the tendency of an organization, the government in this case, to set a trap for itself. Governments tend to award contracts to the lowest bidder who appears to provide services to meet the specifications of the system. This puts pressure on bidders to bid low. Once the contract has been let, the government is commited to the contractor provision of services.

Experience of U.S. Armed Forces suggests that shortfalls by the contractor in meeting contract requirements result in contract overruns: late delivery; system standards get reduced; system components get neglected; etc. But, the contract lettor becomes powerless, it seems - Governments can always get more funds. Failures will be picked up along the line. A concern in this paper is in the failure of contractors to provide technical documentation which meets the need of the contract letting organization. Technical documentation is easily hidden in contracts as a "one-liner": the contractor shall provie technical documentation. This author has seen such contracts let.

Integration into Personnel System

The failure of job aid implementation in the past has been due to the development of job aids in isolation from other system considerations. Job aid implementation is doomed if it is implemented half-heartedly and watered down (Foley, 1978). The EPICS Program is a large-scale implementation study whith addresses these concerns (Blanchard, 1979).

Gordon (1975) identified several reasons for implementation failure of task guidance strategies:

- resistance to change by personnel
- job satisfaction

- career advancement

Resistance to change. Fitting job aids, or any other change, into a system on a retroactive basis could result in resistance by the personnel directly affected. Gordon has expressed his concern on the basis of psychological research into the tendency of individuals to resist change. The studies which have been conducted into acceptability of job aids indicate no problem of acceptance by users of the various forms of job aids (Joyce & Chenzoff, 1974; Bialek & Kulas, 1978; Post & Smith 1979; Note 1 - Desorcey, 1983; Smillie & Clelland, 1986.)

Successful implementation of job aids can result if personnel at various levels are brought "on side" early in the planning stage of the program. Richardson & Syster (1977) found that if the end user was not involved in the development of the job aid he would find it less acceptable, but not less usable, than users who were involved in the development; acceptance by personnel involved in development and those not involved in the development was quite high in spite of the differences.

Abrams, Sheposh & Licht (1974) found that successful implementation of a change can be improved if both Change Agents and Change Advocates are employed. As discussed earlier, the Change Advocate should be a representative of the user group who becomes a representative for the Change Agent. He should have the following characteristics, as seen by the user population: credible; member of the population; influential with the population; perceived as an expert; and, physically attractive.

Job satisfaction. Concerns over the job satisfaction of the job aid user has been commented on by Post and Smith (1979). They found that among inexperienced technicians using Directive Job Aids (FPJPA's) that there was a high level of job satisfaction since the technicians were able to do work that would otherwise be beyond their capabilities. Poor results were obtained when the same level of personnel used Deductive Job Aids (Procedural Guides) since the technician is reduced to observing and menial support chores during the apprenticeship (learning how to use Deductive Aid); substantial challenge is present to learn the system and large investment of time by the learner and his mentor is required. For experienced users continued use of Directive Aid is reduced to rote performance with no development of system understanding and no challenge. Use of Deductive Aids by experienced technicians presents the challenge of producing or recalling work strategies which eventually results in reduced reliance on the job aid.

Blanchard, Clelland et al (1984) found that peer pressure from personnel serving in the same unit who were not using FPJPA's resulted in rapid transition from the JPA to more traditional Maintenance Dependency Chart. The supervisors felt that the FPJPA's were too detailed and "procedural".

It would appear that judicious utilization of FPJPA's, Enriched and Hybrid JPA's as well as Deductive Aids should provide job satisfaction at all levels, provided that they are the only form of task guidance for the peer group.

Career advancement. The decision for the large-scale implementation of task guidance strategies will have profound impact on career advancement methods. Advancement strategies which are oriented to advancement on the basis of course completion and certificate holding, must give way to accomplishment based career progression. The large scale system changes required in the career structure is, in my view, the most likely reason for resistance to implementation of task guidance strategies. The U.S. Navy is attempting to address this problem in its EPICS Program.

The skills and capabilities of personnel in a system which incorporates a career strategy must encompass graduated levels of experience and skill requirements. EPICS has adopted three (and perhaps four) skill levels:

- equipment technician (novice) - Personnel at this level would receive minimum formal training and maximum job aid support (FPJPA's); tasks assigned would be primarily nontroubleshooting in the maintenance function. It would be expected that only a portion of this level of personnel would remain in the system (take career status).
- subsystem technician (intermediate) - Personnel at this level would receive some formal training and utilize PPJPA's; tasks assigned would be both nontroubleshooting and troubleshooting.
- system technician (advanced) - Personnel at this level would receive extensive formal training in job specific as well as theoretical topics, and would utilize the full range of technical documentation including traditional technical manuals; tasks assigned would be system specific.
- "Master Technician" - The Master Technician is not described by Blanchard but it is a possible level that may be incorporated. Presumably the Master Technician would have varied experience and training enabling him to work on many different systems within the requirements of the trade.

Within each level there are grades which permit advancement opportunities in recognition of responsibility and proficiency.

The career structure suggested in EPICS, as just described, does not take into account the development of Hybrid and Enriched Hybrid JPA's which could be incorporated in the training component, reducing some of the burden of formal classroom training and traditional on-job-training approaches.

The decision to use job aids implies a shift of emphasis from "what a person knows," as measured by the number of courses and certificates he has, to "what he has done," as measured by the value of his accomplishments. Traditional military career decisions, such as promotion, have often been based, in part, on training level. This type of policy makes the inference that training level equals performance on-the-job level. For example, the Canadian Forces names its occupation (and pay) levels based on qualification courses (OQ3, OQ4 etc. - "OQ" refers to Occupation Qualification); progression is typically from OQ3 course to OQ4 OJT program to OQ5 course etc. The change from OQ3 to OQ4 accompanies a promotion (to corporal) as does the change from OQ5 to OQ6B (to sergeant); the promotion is necessary for advancement training continuation.

Opponents of an "accomplishments" based career system which employs performance aiding (that is those proponents of a "knowledge" based system) usually express the desire to have quality performance which cannot be achieved unless the task performer has a good theoretical knowledge of the task he is performing, and the associated systems (Gilbert, 1978). This bias in favour of ability to demonstrate behaviour and not necessarily valuable accomplishments, can be viewed as a preference for the "Renaissance Man", one who seeks knowledge as an end for its own sake; one who desires to delve into subtle nuances of knowledge systems. It is not my intention to suggest that the seeking of knowledge for its own sake is not valuable or desirable in some instances, rather I am suggesting that in some instances it is counter productive.

Complete rejection of the philosophical implications of the "Renaissance Man" in a system which employs task guidance strategies would be a rejection of the highly desirable "master performer" or the master technician in a maintenance system. The master performer in a system is on occasion a happy accident that results from a process of "natural selection". This form of master performer would do well in almost any capacity. The master performer could also develop as a product of a career planning strategy: excellent training opportunities; broad scope of employment; and reinforcement for good and excellent performance.

In a scenario which includes only a task guidance strategy for novice personnel at one end of the scale, and the master performer at the other with no one in between, an absurd situation results when one considers career progression: how does the novice become master? Transition from the job-aided novice to the master performer must occur in any system which employs career strategies. Training in any of various forms is implied. Enriched JPA's could be part of that strategy.

Backup support for JPA users. The job aid user on-the-job cannot be left in isolation. Research suggests that job-aided novice task performers may be less than 90% reliable in task performance (Potter & Thomas, 1976). Job aids, by design, including Fully Proceduralized JPA's, are not designed to handle all possible task performance scenarios; there will always be some aspect in the system which is not covered. Master performers at the highest level are necessary to help even experienced personnel. Provision of backup support to all levels of task performance competence should be made available.

For example, one could expect that between 90% and 95% of all system faults in a system being maintained could be handled by personnel with relatively little experience using FPJPA's. Personnel with efficient fault isolation skills and equipment design knowledge should be able to locate the "elusive" five to ten percent of the remaining problems in a system. However, it must be recognized that flaws in system design will, in all likelihood, be elusive to the master performer technician.

System Support

There are serious implications to a system which is introducing task guidance strategies with respect to the system support component. How the organization handles publication of documents, who makes policy decisions, who has control, and how performance improvement information is fed back: these are matters which could be overlooked in implementation.

A concept of costing of training has been proposed which identifies most of the cost of training as trainee costs, such as wages. The implementation procedure for task guidance strategies must provide a mechanism for reconciling reduction of trainee costs with the increased costs of producing job aids. In association with the introduction of task guidance strategies, the inclusion of task oriented (accomplishment rather than behaviour oriented) training may result in increased training development costs. The reconciliation mechanism must be able to accommodate this as well.

Reinforcing strategies for the technical manual production component of an organization must be based on more than cost of production. Rewards for inexpensive technical documentation that emphasize cost reduction only, cannot recognize performance benefits on-the-job that can result with the use of more expensive FPJPA's. A mechanism for reinforcing the utilization of performance improvement documentation must be fed back to the technical manual development authorities.

Claims have been made for reduced spares utilization (Potter & Thomas, 1976; Theisen, 1978). Mechanisms must be put in place which permit the reconciliation of the reduction of spares usage and the increased costs elsewhere in the system when task guidance strategies are implemented.

Successful implementation of job aids may necessitate the establishment of a management element within the research and development component (System Four) that is responsible for the various reconciliation mechanisms. Performance-based measurements of the various costs and benefits of implementation must be developed or recognized, if they already exist, for the system to generate performance feedback information to the relevant system components.

Chapter Summary

The system level research findings indicate that some problems are evident for the introduction of job aid technology. The cybernetic analysis indicated what the system features ought to be for research and development findings to be included in the Resource Bargain. It is my suggestion that these findings are complimentary.

An appropriate planning and development activity would be in a better position to address the implementation aspects of job aid technology.

To summarize the analysis so far, Chapters Three and Four took apart the job aid concept into the micro level and macro level components. These components were further distilled. Various positive findings were described which seem to confirm that the future of job aid technology is now. Chapter Five will put back the pieces using some "corporate glue" and present a model which addresses the Resource Bargain aspects that would ensure successful job aid technology implementation.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

Introduction

In this concluding chapter the results of the analysis of the previous chapters are synthesized into a model which could form the skeleton of a structure which would aid the introduction of job aid technology. The research into JPA's has been extensive, but problems of implementation into the government sector which sponsored the research are due to the unviable organization of the planning and development activity - the R&D is not part of the continuous planning process.

The conclusions and recommendations of this study are covered in three topics. A cybernetic model is described; the model uses some "corporate glue" to assemble the parts of job aid technology that are causing problems for implementation, into a whole. The second topic is the recommended research questions that fall out of this study. Finally some comments are made about the Viable System Model as an analytic tool.

A Corporate Model

This study examined the job aid concept from two vantage points: the micro level, the level of the worker in relation to task guidance strategies; and, the macro level, the level of the systemic concerns of task guidance concepts. This part of the study steps outside the two levels and examines them in relation to one another; the result is the synthesis of a corporate model.

The model is presented first from the broad perspective of job aids in relation to the worker and the management system all contained within their environments. The discussion narrows in on the Planning Directorate with an emphasis on the personnel subsystem in relation to equipment development. The last segment focuses in on the development of JPA's in a major capital project which introduces significant technological change.

The Job Aid Environment

The Viable System Model provides a means of looking at stand-alone systems. Systems do not truly "stand alone" since every system has a relation to its environment and, systems contain other systems which stand alone. This is the concept of recursion presented in Beer' VSM. A system is stand alone if it has some form of closure. The VSM refers to this closure as System Five. The ability of a viable system to be aware of itself is contained in the System Three/Four Interface; and, the ability to be aware of itself being aware of itself is contained in System Five.

This section of Chapter Five addresses, from a broad perspective, the recursiveness of systems. The focus within this perspective is the job aid concept. Figure 5-1 illustrates the concept being discussed.

By looking first at the organization bubble, it will be noticed that it contains the management system and the user (of the job aid). The management bubble contains the supervisor and the job aid(s). Outside of the user is the job environment which includes aspects of the organization and aspects of the environment outside the organization. The Problematic (future) is shown as connecting with

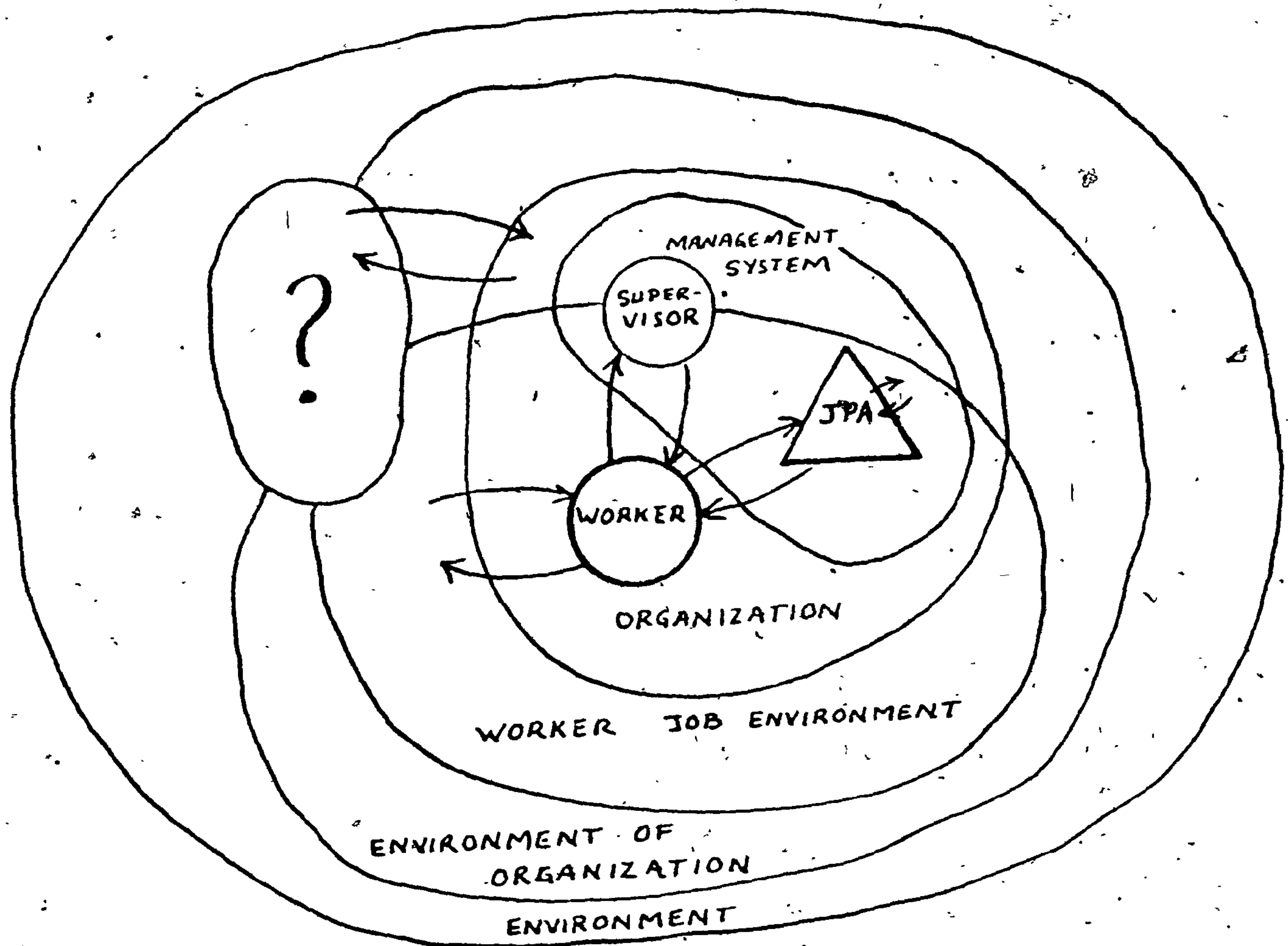


FIGURE 5-1 SYSTEM RECURSIONS

the environments of the organization and the job environment of the user. The whole of these systems is contained in the larger environment.

The main interactions of the systems, shown by homeostatic arrows, summarize the findings of Chapters Three and Four. The variety equations are assumed to be in balance. This simple illustration of the very complex relationship provides a point of embarkation for the discussion of the systemic development of job performance aids. The choice of "systemic" not "systematic" is deliberate; the cybernetic analysis explained the problems of implementation of job aid technology to be systemic. The systematic development of job aids on its own will not assure successful implementation. Systemic development requires the organization to have a continuous planning and development activity which includes personnel performance in the planning.

The Planning Directorate

Chapter Four presented an analysis of System Four in relation to System Three. An example from the Canadian Forces was used to make the discussion more concrete. This section elaborates that analysis to propose a skeleton organization of a Planning Directorate that is on the vertical axis of organizational control.

The difficulty with introducing the job aid concept into the U.S. Military has been due to the non-systemic nature of the research and development process. The R&D effort has been very thorough and systematic in the approach, but systemically the effort does not function, in the case of JPA development, within the variety management network. This assertion has not been confirmed in this study and requires validation. But, cybernetically treating the implementation effort as a "black box," the inputs and outputs of the JPA effort lend credence to the suggestion.

The model being presented in this study uses the Viable System Model as the basis. The model focuses on the need to integrate the development of the personnel requirements and the equipment requirements of the organization. The Canadian Forces is again used as an example to make the discussion more concrete.

Integration of equipment and personnel development. Figure 5-2 is an elaboration of Figures 4-1 and 4-2. It may be worthwhile for the reader to reread the related section in order to place the following description in context.

The organizational difficulties that have been identified as being a reason for the job aid technology implementation problems are likely present in the Canadian Forces situation. This is an assumption for the following discussion. Any failures and short comings of the Candian Forces' equipment and personnel development activities is amplified by the failure to provide a mechanism to integrate the Development efforts. Figure 5-2 illustrates a possible configuration of Canadian Forces System Four Operations.

The first principle change that is proposed is the integration of the change generation activities into the System Change Generator function and recognition of the function of System Four's interaction with outside organizations as separate from the change generation function. The second principle change is the formalizing of the Collator of System Posture. Beer (1979) suggests that this function should be made more explicit and be stated openly rather than remaining in the heads of the people involved in development activities. The third change is formalization of the Equipment Query

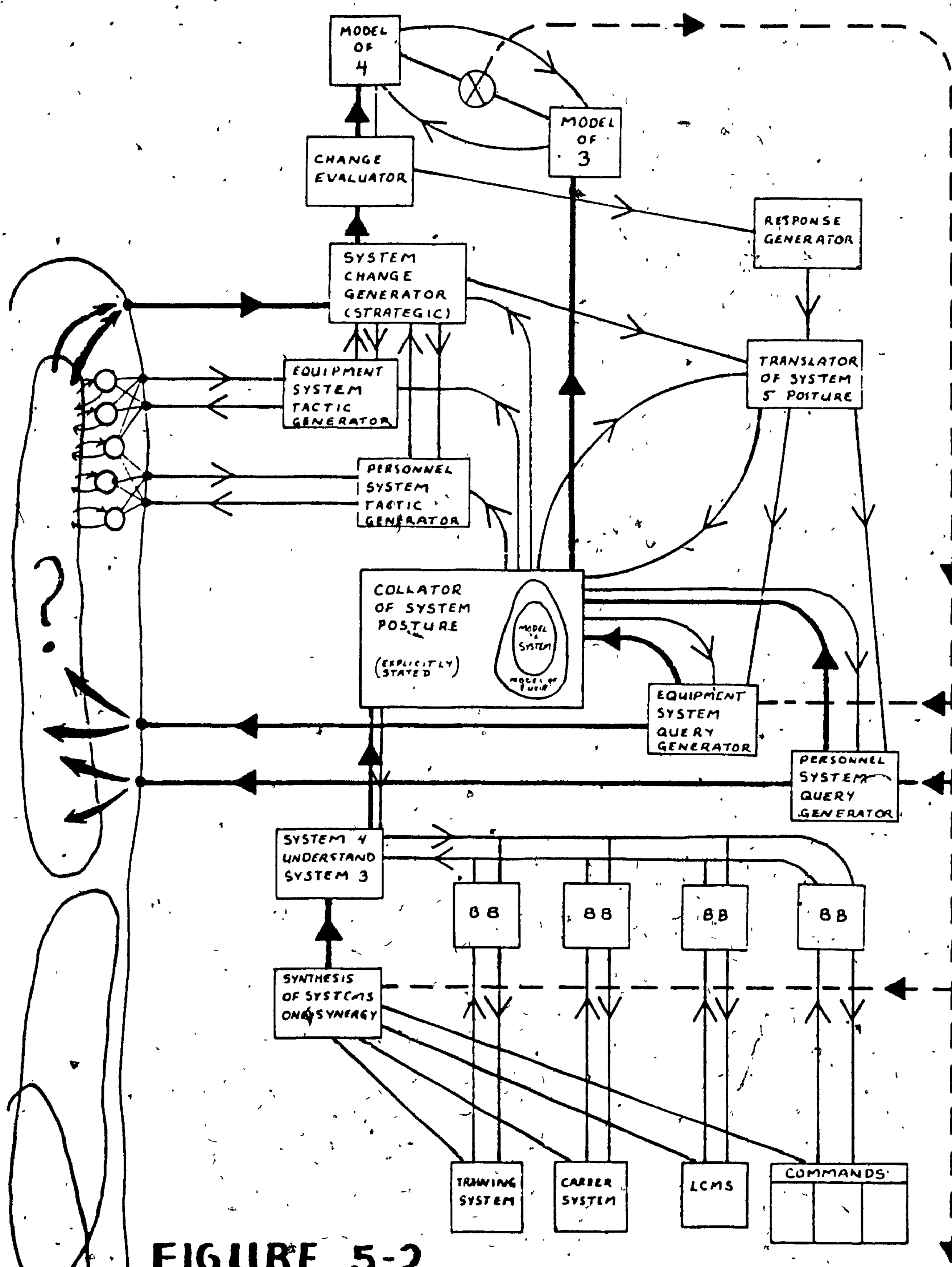


FIGURE 5-2

PLANNING DIRECTORATE

Generator and Personnel Query Generator function. This requires a commitment on the part of DND to initiate investigations of the Future on its own, not just to remain as a reflector of other organization's interpretations of the Future. These changes, while substantive, are not intended as a challenge to the established operations of DPMS, but, rather an enhancement of the system designed to help correct some of the deficiencies that have been identified.

Operation of development directorate. The discussion begins at the two boxes marked Equipment System and Personnel System Querry Generator. General variety increasing queries with respect to the Future would be generated as a routine function of the Development Directorate (Equipment/Personnel System Query Generators). Formal responses by organizations in the environment to general queries would be handled by the appropriate System Query Response Evaluator (environment input and output transducers to the Equipment System and Personnel System Tactic Generators). The Tactic Generators would feedback DND posture to the response and feedforward the information to the System Change Generator. The System Change Generator would interprete within DND the possible futures in light of the results of the information available at the System Response Evaluators and based on information available in the Collator of System Posture. Changes would be proposed as appropriate.

The current operation of System Five does not need to change substantially. The utilization of this system I am proposing would reduce the need for the Change Evaluator to assess the balance between the effects of equipment system changes and personnel system changes; this information would have been handled within System Four in its normal operations. Figure 5-2 illustrates the existance of models of

System Three and Four within System Five. The principle activity of System Five is the assessment of whether the System Three/Four Interface is operating in a stable state and feeding back overall system posture (heavy dotted line).

Major System planning and development information flow is indicated by the bold lines in the Figure. Emphasis is indicated in direct query of the Future by DND. Routine responses to other organizations' interpretations of the putative future could continue virtually unchanged. The introduction of a system such as indicated, is cybernetically sound and should correct some of the problems identified by ROIT (1982).

The use of contractors to develop systems for the Canadian Forces could take on two forms. The first would involve the exporting of the Personnel and/or Equipment System Response Evaluator function(s). The contractor could undertake these functions on behalf of the Canadian Forces. The operation of these activities would be very much like the current Canadian Patrol Frigate Program; the contractor is responsible for interpreting external research into factors which affect the Program. The second form of utilization of the model would keep the System Response Evaluator functions "in house." The contractor would be required to interprete DND understandings of external research. Regardless of which method would be used, the ultimate System Changes would be seen as a function of the Canadian Forces' own interrogation of the Future.

It is my suggestion that, if a system such as this one just proposed were already in existance, many of the problems in the Defence Program Management System would not exist. Personnel considerations such as the utilization of task guidance strategies would have already been addressed as a normal result of the development effort.

New Capital Projects

The development of job aids for existing systems should be, conceptually, easier than for completely new systems. Actual tasks can be analysed. Actual jobs can be performed using the job aids in real or experimental situations. The experience of researchers in the U.S. Forces has been in job aid applications within existing systems. Problems have been identified in implementation of job aids into existing systems. In new systems the developement of the job aids is more difficult, but, if the system provides for the kind of development being proposed here, implementation should be easier since there is no status quo to change. Evidence for this can be found by looking at the introduction of job aids in the CF-140 Aurora - the aids were well received (Note 1 - Desorcey, 1983).

The example being used here for implementation of job aids is the Canadian Forces. The large-scale new equipment procurement by the Canadian Forces is usually managed by contractors in the private sector. This presents challenges additional to the equipment design ones. The next discussion proposes a mechanism to address the problems.

Job aid development system. A close analysis of the functioning of the whole system development mechanisms (System Four for the Canadian Forces - see Figure 5-2) reveals that the principle activity conducted by the Defence Program Management System is in the writing of specifications for system modifications. For the most part, these system modifications are left to the contractor who must be able to interpret the substance and intent of the specifications as presented in the contract. Much of the operation of System Four is transferred to the contractor, especially the functions of Query Response Evaluator (for equipment and personnel systems). The contractor must also have a mechanism for Collating System Posture, which incorporates the contractor understanding of his own system as well as his understanding of the Canadian Forces' posture with respect to the Future and actual environments.

Figure 5-3 is a representation of the operation of the development activity of the contractor in addressing the Specifications of the Contract. Emphasis is taken in this presentation on the development of job aids; parallel structures should exist for other Performance System components as well as the Equipment and Maintenance Systems.

This Figure is not too much different from the previous Figure. One of the notable differences is the interaction between the Specifictions of the Contract (anti-oscillatory mechanism from contract letting organization) and the Collator of System Posture (divided here into personnel and equipment functions). The second difference is the introduction of the Surrogate of System Operations. I am assuming for the purposes of this discussion that the system that is being developed is brand new, completely innovative, such as the development of the Canadian Patrol Frigate (CPF).

In the normal operations of the Development Function (System Four), interaction is possible between the actual System Three and System Four. Recall in Figure 4-1 that the Three/Four Interface attempts to balance System Three understanding of System One Synergy and Systems' One posture with respect to the putative future, and System Four's understanding of its own posture as well as System

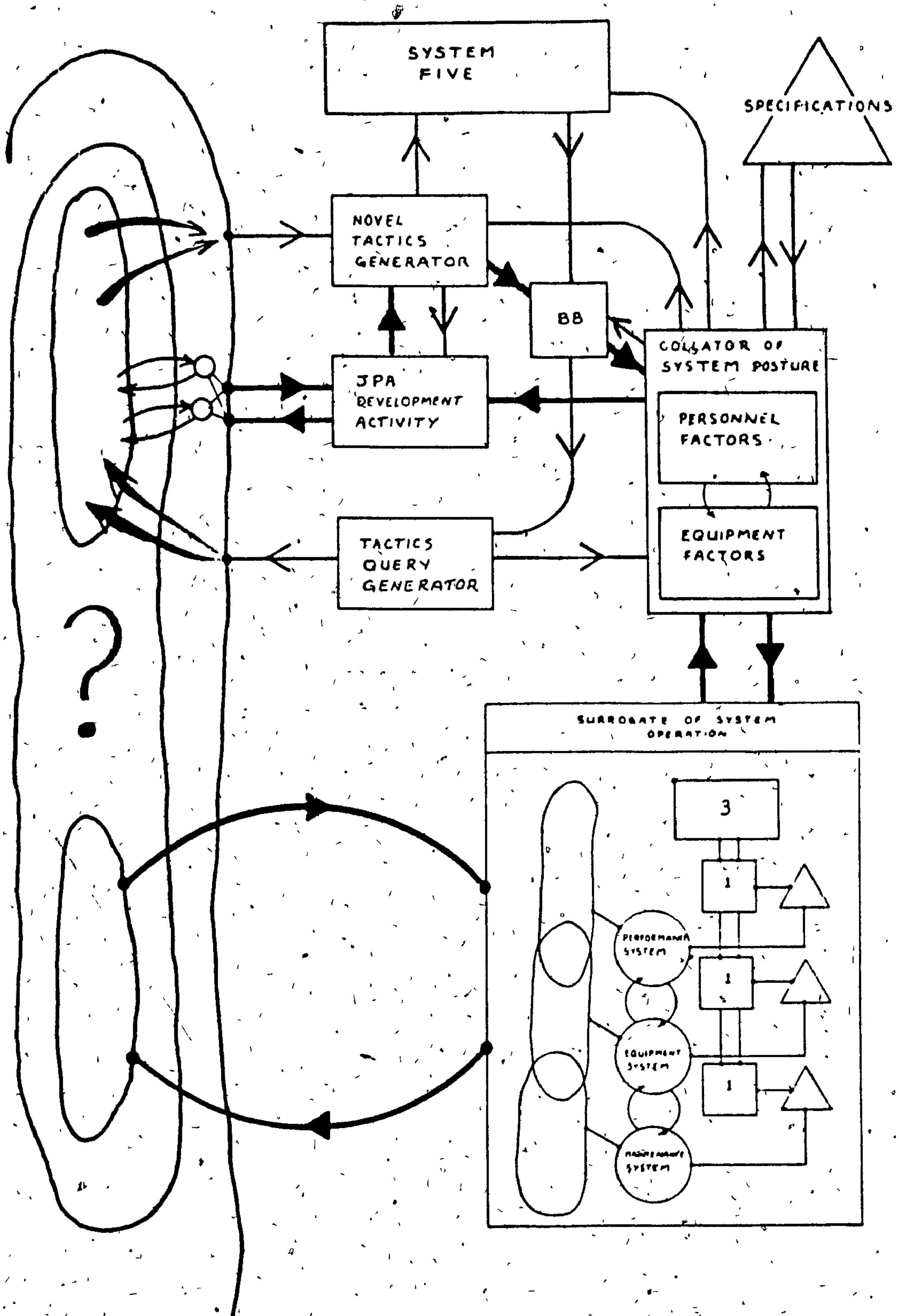


FIGURE 5-3

NEW SYSTEM JPA DEVELOPMENT

Three's posture with respect to possible futures. In the development of completely new systems, System One does not exist; in fact System Three does not exist but is part of the development effort. The Surrogate Function as presented in Figure 5-3 is an attempt to come to grips with this problem. Part of System Four's activity is in the development of the Management System as well as actual components which eventually will make up Systems One. In initial stages of development, models must be developed of what the proposed system will look like and how it will respond to the Future. The Surrogate of System Operations functions in this model building capacity; interactions with the Future are indicated.

The development of job aids and associated training in a very problematic, ever-changing environment of possible futures presents particular problems. The problems are amplified by the fact that similar problems are being encountered by other elements of the development activity. As actual equipment is produced in prototype, it is easier to discover the tasks that will be performed with respect to the equipment. Integration of the whole system must eventually take place. The Surrogate of System Operations must have the capacity to handle these demands. It must be shaped during the development of the system. It must be a machine for learning how to implement the future.

New Research Questions

The research that has been done to date in job aid technology has been fairly extensive. The thesis of this paper is that much is known about job aids; the problems are, for the most part, systemic ones of the target organization. The resolution of those problems should be the subject of system and performance engineering.

This study concludes that job aid technology is sufficiently developed that organizations should consider job aids when making the trade off among personnel selection, training and the provision of environmental support. In considering job aids as part of the environmental support, this paper proposes some system considerations. Further research topics follow from the conclusions presented.

Research Based on This Study

The most difficult research question to investigate concerns the model presented in this study. What specific adjustments are needed to the Canadian Forces to permit the Planning Directorate skeleton to be fleshed out and implemented? The development of the answer would be much simpler than its implementation. It is not just job aid technology that would be introduced but a whole new Headquarters structure.

An extensive cybernetic analysis of the Canadian Forces Headquarters, as it is currently configured would be required. The analysis should focus on the Planning Directorate functions. Adjustments to the structure of the organization could be made, but a substantial amount of political will would probably be required to effect the new structure indicated by a cybernetic analysis.

Other Research Topics

There are potentially a large number of research topics which are off shoots of the present study, however, a few lead from the trade off model presented in Chapter Two. This study concentrated on job aids, but there are interactions to be considered among personnel selection, training and job aids.

Personnel selection. There are a few questions that are of specific interest to the Canadian Forces. What is the reading level of recruits? - Currently the Canadian military does not test recruits for reading ability. Related to this is the question of what the Reading Grade Level of technical manuals should be. The author has tested some of the technical manuals being provided with the Canadian Patrol Frigate Project and the RGL's range between grade 14 to as high as grade 17 (university level); the target technicians are recruited with a minimum of Ontario grade ten. Sticht (1985) suggested that job related literacy tests ought to be developed to avoid some of the concerns about bias against low reading ability adults. Any of these questions could result in a substantial amount of research effort.

Training. What is the effect on learning gain when related JPA's have been used first? Is there a retention effect? Do the different types of JPA's (FPJPA, PPJPA, HJPA, EHJPA) have differing effects on formal learning gain? These questions are especially of interest to organizations which have a career management policy such as the military does. It may be that there are different savings potentials to the costs of acquiring skill repertories depending on the type of job aid used prior to training. An hypothesis is that task related learning would be faster and more complete for individuals who used job aids on-the-job prior to job related training.

Cybernetic Analysis as a Method

It is useful to step outside of the study that has been presented to look at the method - to apply closure to the study. The Viable System Model was used as the analytic tool for analysis of the various aspects of the job aid concept. The model also was used for the design of a Planning Directorate. The Viable System Model served the role that was intended.

The VSM is recommended for future work when a deductive reasoning approach is appropriate. System-wide inferences are possible and important relationships can be identified. Data can be generated relating to the relationships: the variety can be measured; cause and effect estimations can be made; and when cause and effect cannot be estimated accurately, a black box approach can be used for the analysis.

The main caution with the use of the VSM concerns the repeatability and validitiy of the model.

Repeatability. The nature of cybernetic analysis depends on the stated purpose of the system. As indicated in Beer (1979) the stated purpose of a system is very much dependant on the point of view of the observer. For independant researchers to analyse the same system using the VSM would possibly stem from different stated purposes. For example, the purpose of the educational system could be stated as: a machine for student learning; a children control system; or, a baby sitting service. I suggest that even when the same stated purpose is used, the analysis would likely be somewhat different based on the knowledge the researcher has of the system being investigated. Much of the difficulty of repeatability might be avoided if an iterative approach to the analysis were used; alternately the use of three or more team members might reduce variability of the analytic result. Beer (1981) provides guidance regarding the probability of error when three or four persons are engaged in a collaborative effort (the multinode); he suggests that the reliabilty could be in excess ninety five percent if the reliablity of the team members is quite high. This problem might prove to be an interesting subject for research.

<u>Validity</u>. The validity one would expect with the VSM is content validity. The researcher's access to and understanding of system content would influence study validity. Verification of the content of the analysis with members of the organization being analysed could ensure validity; however, more abstract systems may be difficult to validate.

To close, an important consideration for researchers is that with a thorough cybernetic analysis prior to beginning other scientific methods, research questions can be made more precise and more applicable. The cybernetic method could help target research questions.

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Note 1 - Interview with R. Desorcey (1983) National Defence Headquarters, Department of Drafting and Drawing Services.

Note 2 - Notes from work in progress by P.D. Mitchell and G. Pask (1983), Concordia University, Montreal P.Q.

Note 3 - Personal communication with J. Harless (1981) during Advanced Instructional Development Workshop, Atlanta, Georgia.

APPENDIX A

CYBERNETIC ANALYSIS

Introduction

The analytic method used in this study to analyse the systemic considerations of job performance aids is the Beer Viable System Model (Beer, 1979; 1981; 1985). Thorough discussion of the model is not practical in this report because of the model's complexity. A brief overview of the salient aspects of the model are presented here to provide the reader with an orientation to the use of the model in this study. Readers who are interested in a fuller explanation are directed to Stafford Beer's own presentations of the model.

The first part of this discussion concerns some important concepts to cybernetics in general. The second part is a discussion of the Beer model through the use of an example.

Cybernetics. Cybernetics (from Greek meaning "steersmanship") may be defined as "the science of effective organization" (Beer, 1979). Cybernetics is concerned with system control. System control theory has evolved over the past fifty years out of general systems theory. There are two branches of cybernetics: natural systems; and synthetic (man-made) systems. Cybernetic analysis of how biological systems control themselves and interact with their environments have provided models for analysis of synthetic systems. The Viable System Model (VSM) is a neuro-cybernetic model in that, while it is a model for effective organization of human endeavour, it is analogous to the biological neurosystem.

There are various related concepts that are key to the understanding of cybernetics. Some of the related concepts are: system, previously discussed; environment; system states; variety; viability; stability; homeostasis; metasystem; and, system recursion. Each is defined briefly below.

Environment. The nature of a system is determined in part by how the environment of the system is defined. All real systems have environments. Abstract systems can be conceptualized so that they have no interaction with any element not contained in it. The environment of a system is a set of elements and their relevant properties which are not part of the system but, a change in any one can produce a change in the state of the system (Ackoff, 1971). The definition of a system by an observer necessarily defines its boundaries. The boundaries are where the system and its environment interact.

System states. The state of a system at any moment in time is the set of relevant properties which that system has at that time (Ackoff, 1971). Typically in the definition of a particular system only some of the system states are relevant to the observer. The states of a system change in response to changes of state in the environment.

Variety. Variety is a cybernetic concept which has to do with system states. It is a measure of complexity. "Variety is defined as the number of possible states of whatever it is whose complexity we want to measure" (Beer, 1979, p.32). Variety is a numerical estimate of complexity of system elements. The complexity of the social systems of man and most of his synthetic systems are a result of the large variety of states that the systems may take in response to changes in their environments.

Viability. System viability is measured by the system's ability to exist on its own within its environment. Systems which are not viable, therefore, cannot survive the perturbations that occur in the environment. The viability of any system is dependent on its internal stability in response to the environment.

Stability. The stability of a system is its ability to resume equilibrium when displaced. An ultrastable system is one that can survive arbitrary and unforecast interference (Beer, 1981). By this it is meant that regardless of the perturbations of the environment, including unforseen ones, the system is able to resume equilibium. The stability of a system is based on the homeostatic connection between the system and its environment.

Homeostasis. Homeostasis is the basic cybernetic principle of stability of a system. It is the tendency of a system to maintain equilibrium between itself and its environment. In an ultrastable system, the homeostatic connection, homeostat, between the environment and the system is able to handle all the variety of possible states of the system and its environment. For the ultrastable system, when the environment takes on an unfavourable state, a mechanism must be available in the system to respond appropriately to restore the stability of the system.

System Recursion. A fundamental concept to the Beer Viable System Model is the concept of system recursion. Viable systems contain and are contained in viable systems. Systems are imbedded within one another; each level of system organization is a recursion of its metasystem.

Metasystem. The distinction between a system and a metasystem is a logical one. "Meta" means "over and beyond". A metasystem then, is logically over and beyond the system being examined. It is the next logical level of recursion above the system of concern.

The following example will illustrate, in context of the Beer Model, the cybernetic concepts presented thus far. The example is an analysis of a simple system with an emphasis on the homeostatic link between the system and its environment. Additional cybernetic concepts will become evident through use of this example.

A familiar example of an homeostat is the thermostatic control of a home heating system (see Figure A-1). The static nature (equilibrium) of the internal temperature of the home, in spite of heat loss and changes in outdoor (environmental) temperature, is maintained by the dynamics of the heating system which is turned on or off by the thermostat. The heating system is itself contained within the house — its environment. The heating system is the management principle which regulates the internal temperature of the house.

The thermostat has a temperature sensing component that turns the heating system on or off. The heating system also has a distribution network of some form to distribute heat to the house. The house has a large variety of possible states of temperature: it could be at the coldest temperature ever recorded for the area, at the hottest temperature, or at any temperature in between. The heating system has low variety, basically two states: on or off.

How does the low variety temperature controller regulate the higher variety environment, the house? The controller uses amplifiers of its own variety and attenuators of the environmental variety. The variety attenuation is handled two ways: first, the heating system is intended only to increase temperature (I am excluding for the moment

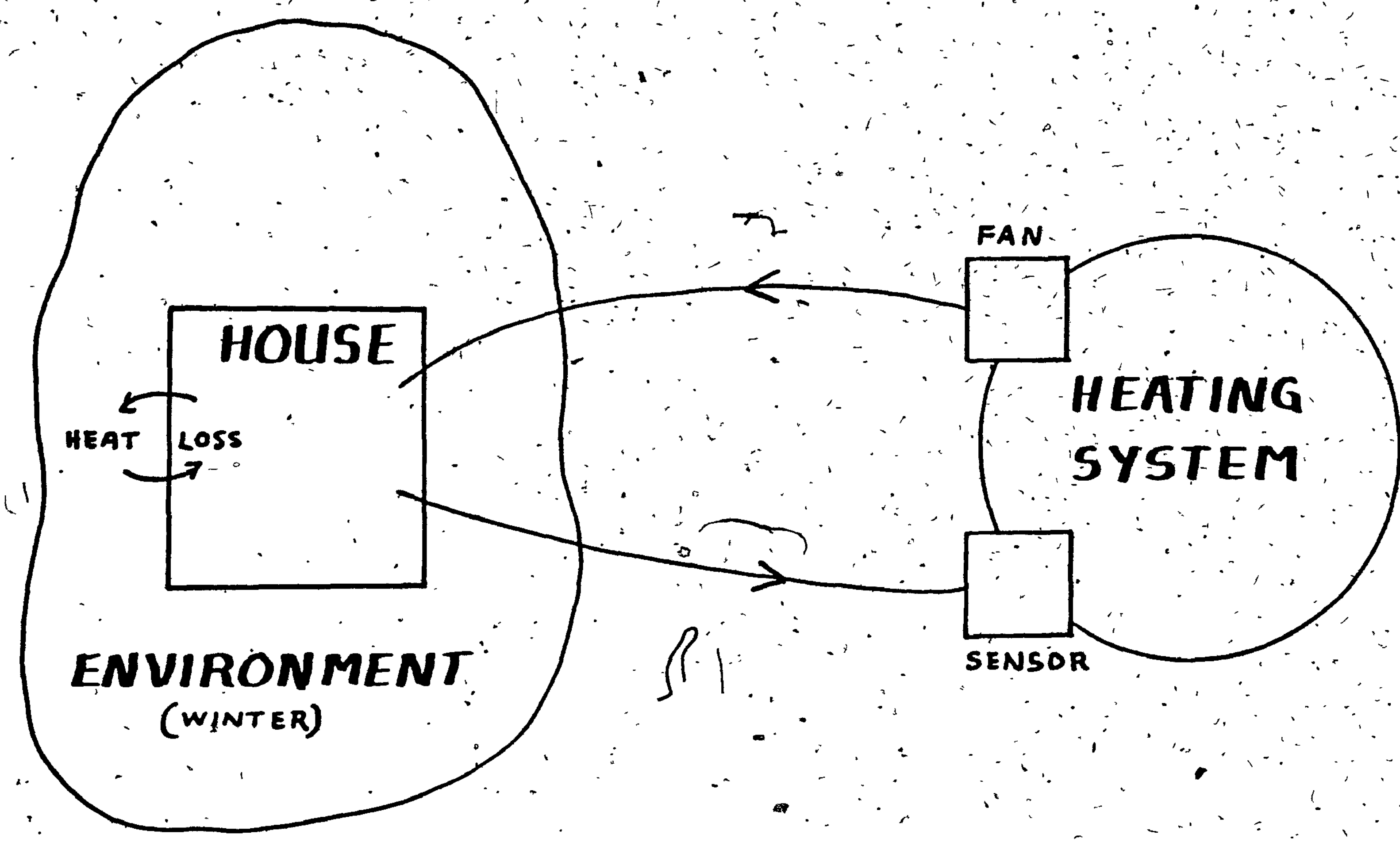


FIGURE A-1 HEATING SYSTEM CYBER

air conditioning), so those temperatures above the comfort range are attenuated; secondly, the thermostat has a sensing element that can determine if the temperature of the house is below the temperature which is set - if it is, the heating system is turned on, if it is not, the heating system is turned off. The large variety of the heating system's environment has been massively attenuated. Amplification of the variety of the two-state heating system is accomplished by the ducting network, which distributes warm air/water to the various parts of the house. Success of this temperature management system depends on the ability of the amplifiers to counteract the heat-loss of the house to its environment.

Whenever a homeostat transits the boundary between an environment and an operation or a control system, information transitting it must undergo a transduction process. A transducer transforms the information on the homeostat from the form of the output source to the form required by the input. There are four locations of transducers: at the input and output stages of the amplifier; and, at the input and output stages of the attenuator.

In the heating system example the transducers are:

<u>amplifier input</u> - the circulator transforms the static heat energy of the heat source into fluid energy of the amplifier, the distribution network;

<u>amplifier output</u> - the heat radiator transforms the fluid heat energy of the distribution network into the warmth of the air inside the house;

<u>attenuator input</u> - the bimetallic coil transforms the temperature information of the environment into mechanical force;

<u>attenuator output</u> - the electrical mercury switch transforms

the mechanical force into the electrical control (on/off) of the system.

The success of the homeostat in handling the variety of possible system states is determined by the adequacy of the amplification and attenuation channels. For stability to exist, the transducers must have the capacity to handle the same variety as the other elements of the homeostat.

Homeostasis is exhibited in this example between the house and its environment. The house continually adjusts itself to the environmental temperature in the form of heat loss or gain. The environment is also adjusting itself to the temperature of the house by gaining heat. The capacity for the environment to absorb the differences in temperature is much greater than the capacity of the house, so the net adjustment appears to favour the environment. Large built-up areas of many buildings, however, often are warmer than rural areas as a result of the environment adjusting to the temperature of the buildings and other man-made heat sources. The capacity of a building's insulation and weather stripping to resist the heat loss is a demonstration of the effectiveness or ineffectiveness of the amplifiers and attenuators in the house/environment system.

The adjustments that the house and the environment make to one another is an example of a self-organizing homeostat. Many of the homeostats between systems are self-organizing. This is especially true in natural systems such as ecosystems. It is the contention of Stafford Beer that, if a homeostat and and its attendant amplifiers, attenuators and transducers in a synthetic system are not designed specifically for the variety of system states, it will self-organize. The self-organized homeostat may not be as adequate in handling variety as a homeostat which has been specifically designed (Beer, 1981).

A cybernetic system, one designed for homeostasis with its environment and its control systems, can be described as a machine which handles information (Beer, 1959). Information transits the homeostat in two directions. The ability of the information channels and their transducers to handle the variety of information affects the system's viability.

This example illustrated some of the fundamental concepts in cybernetics. A system which is designed to be "cybernetic", designed for homeostasis, must have adequate means to handle the variety of system states. An ultrastable system, or one approaching ultrastability, must have controls and management principles which have the capacity to handle all the variety including unknown future states.

System control cybernetics. For system engineering, cybernetics offers tools for analysis and design of systems. Models of the system being analysed and its environment can be described with varying degrees of fidelity as appropriate. For the present study, cybernetics provides a modelling instrument for determining what the control requirements are and what the communication links are for the human element in man/machine systems. Job aid technology was analysed as part of a task guidance strategy in system control using the concepts described below.

In any viable system there are four identifiable parts:

- the operational element of the system;
- the environment;
- the management of the operation (the local management

principle); and

- the metasystem.

In the Beer model of cybernetic analysis and system design, the management principle consists of five sub-systems. System One is the basic local management principle of an operation and the operation itself. Systems Two, Three, Four and Five are part of the Metasystem.

As stated earlier, a metasystem is logically over and beyond the system being examined. To the system, the metasystem is a "black box" that operates in another language from the system. Returning to the example of the home heating system, the language of the heating system control (electrical on/off) is metasystemic to the language of the operation of the heating system (addition of heat to air). The transducers serve to translate from one logical language to the other. In the Beer model the control principle which manages several operations, Systems One, is metasystemic to the control principle of each individual operation.

System One. System One is a viable system at the level of recursion that is being observed. It consists of the group of operational elements that perform the various transfer functions which make up the operation of the system, and the imbedded operational control system. Figure A-2 illustrates a System One and its environment. The box is the control principle of the System One and has been removed from the circle for clarity of presentation.

A typical enterprise consists of several Systems One and a metasystemic organizing principle. Figure A-3 illustrates two operational elements and their relationship to the metasystem. Within the metasystem are system components which control the operations of the Systems One to ensure synergy. "This refers to the margin of

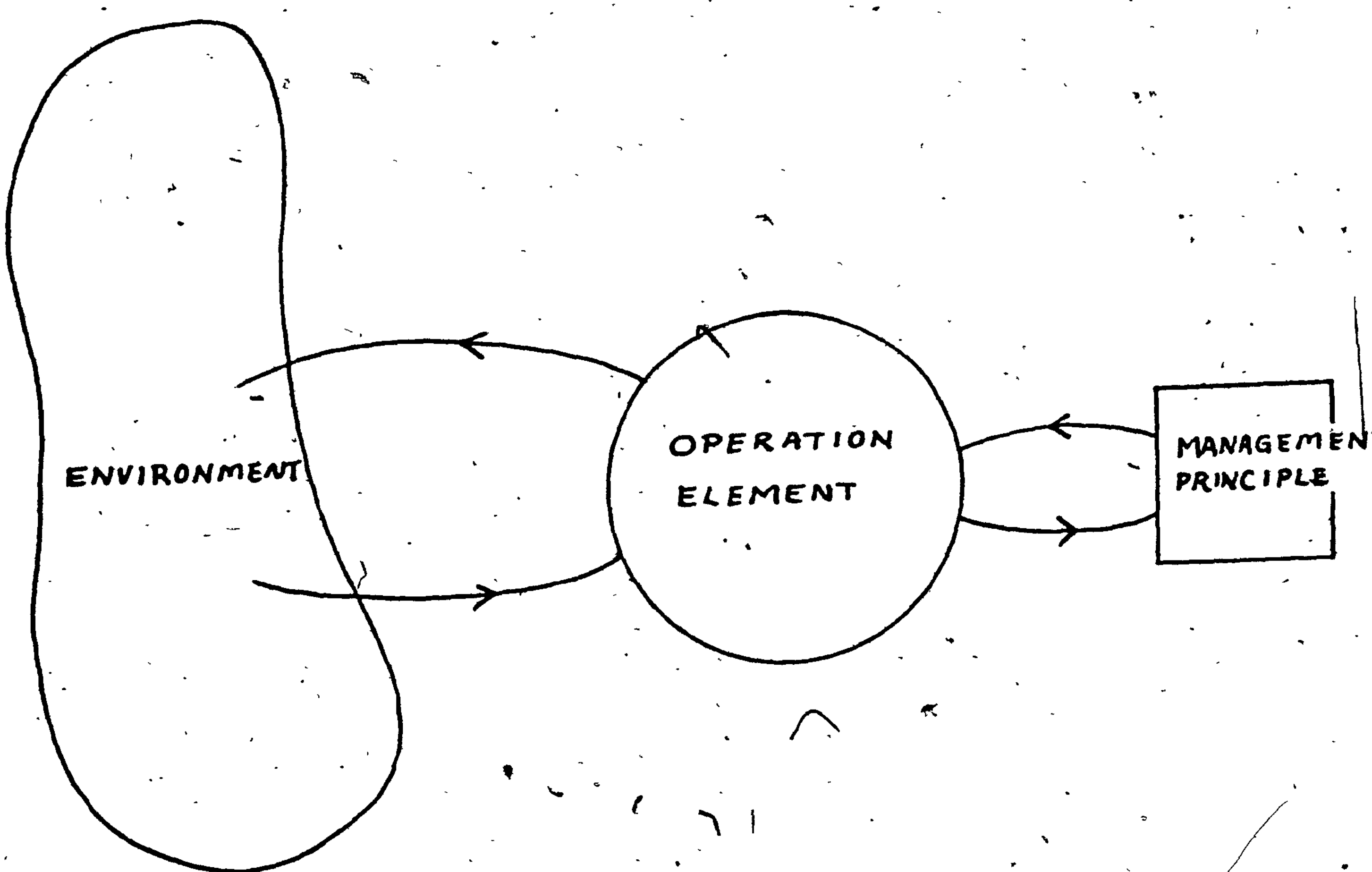


FIGURE A-2 SYSTEM ONE

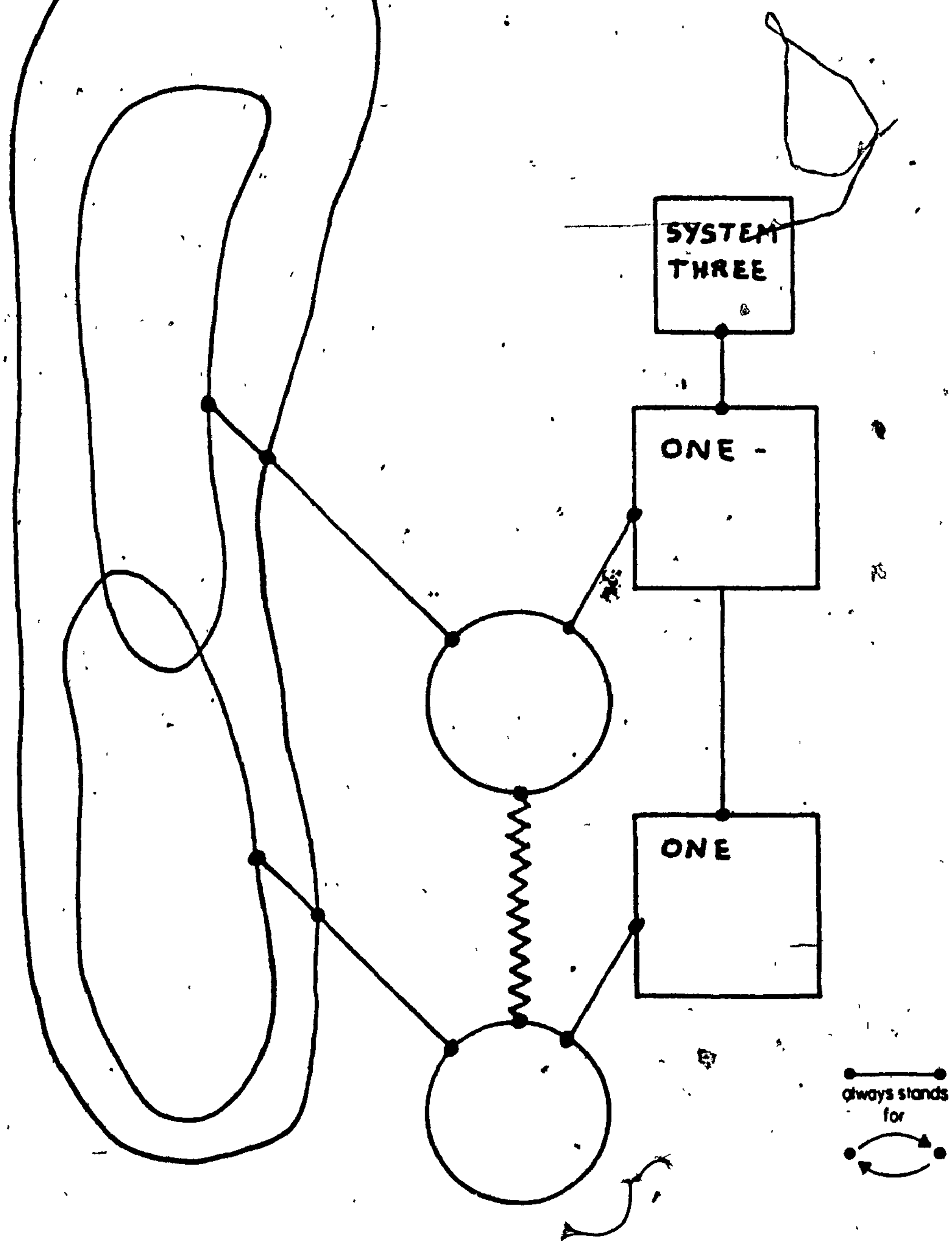


FIGURE A-3
TWO OPERATIONAL ELEMENTS

profitability that derives from having a viable system rather than a collection of parts" (Beer, 1979, p.203).

System Two. System Two is the management function which damps the oscillations that may result as a function of two or more Systems One being out of phase when they are each at a stable state with respect to their own environments. In electrical control systems oscillation is sometimes referred to as hunting. Delay and/or impedance is added to damp the hunting. Damping in this way is a System Two function. An example of System Two in an enterprise is the use of production control. Flexible work schedules (Flex Hours) have a System Two function of permitting workers to go to work at hours of their choice while damping uncontrolled oscillations that might occur by establishing core working hours.

System Three. System Three is the management principle which controls the autonomic operation of the Systems One. For example, this is the autonomic nervous system in animals. The control by System Three is to ensure that the operations of Systems One produce synergy. System Three controls the enterprise by use of System Two and by a direct route to individual operations, the command channel. Figure A-4 illustrates System Three and System Two and the control channel homeostats.

The System Three command channel cannot handle all the variety of the operations of Systems One. For System Three to attempt to do this would result in a collapse of System Three into Systems One. The command channel in a viable system should be used only to veto planning that may be stable in the language of System One, but unstable or not optimal with respect to the collection of Systems One operating in conjunction with one another. Most of the control exercised by System Three in a viable, synergistic system is through the operation of System Two and through an Audit Channel, System Three Star (*). System Three (*) is the management prerogative to audit the operations of Systems One. Adjustments to the control system would optimally be exercised through System Two.

Example of System Three Operations. A good example of the autonomic control by system three is the use by the Army of the Orders Group (O Group) concept. When a Company Commander is given an objective to accomplish, he prepares a plan which includes situational information, a mission statement, means of execution, administration and logistics, and radio control frequencies (SMEAC). His execution statement will include information about individual platoon (System One) objectives, but not details of how the objective is to be carried out; that is variety which can and should be handled by the individual platoon commanders. The radio control net is a good example of a System Two operation - provision of information up and down the chain of command well as between Platoons. The administration and logistical plan is also a System Two anti-oscillatory function which ensures that supplies will be in optimum position to meet the overall objective. Each platoon commander then exercises his own control of his operation by having an "O Group" with his platoon, giving them SMEAC.

Once the operations begin, the Company Commander will audit the progress of individual operations and provide revisions to SMEAC as required. Only occasional use of the veto channel will be used, Platoon Commanders have the responsibility to run their own operations; they must handle the variety at their own level of recursion.

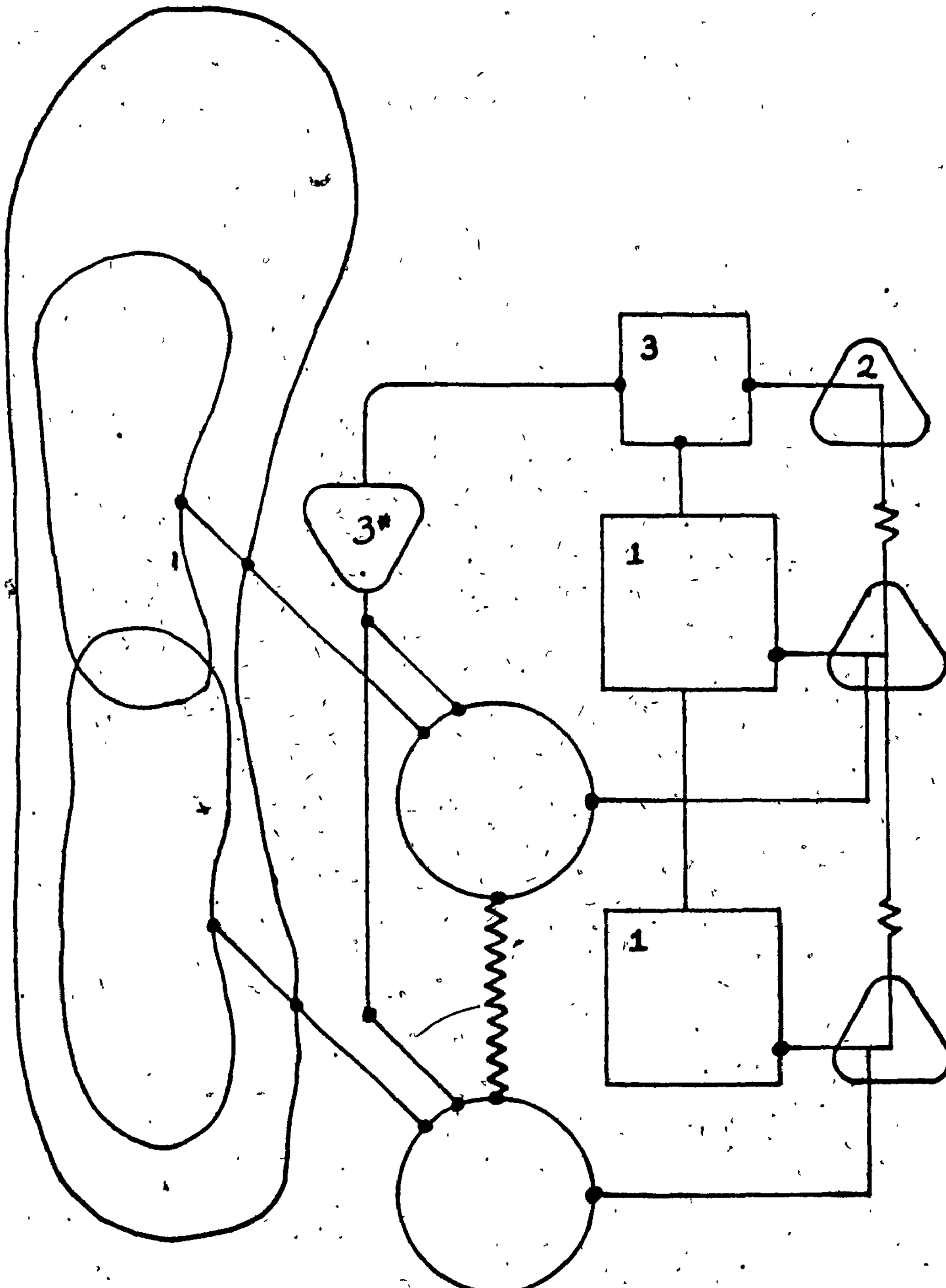


FIGURE A-4

SYSTEMS 3/2/1 COMMUNICATION

This example illustrates the recursive nature of viable systems as well: the Company is a viable system which contains Platoons; Platoons are viable systems.

<u>System Four</u>. The previous example illustrates the need for System Four. System Three is autonomic control of the viable system, but provision must be made for future contingencies that cannot be known or understood because of the metasystemic nature by System One. System Four is sometimes referred to as the Research and Development (R & D) function, and Operational Research. Autonomic systems cannot react to major changes in their operations until the changes actually occur. If System Three encounters a state for which it does not have sufficient variety in its control systems, it could send the system into uncontrolled oscillation and eventually death. System Four attempts to predict these changes by building models of future environments and proposing new models of the viable system and system components which will be able to respond to the future. In this way the viable system becomes adaptive. It learns about the environment and its own ability to respond to the environment. In natural systems, the evolutionary process and the learning process are examples of System Four in operation.

Failure to adapt spells death to a previously viable system. System Four and System Three must have sufficient capacity to absorb one another's variety. System Four, if it is operating properly, should be generating a large variety of possible states, models, of the viable system. It should be <u>inventing the future</u>. System Three should be able to absorb those model changes without lag or hiatus. System Four should be able to absorb and measure the affect of model changes on System Three. Figure A-5 illustrates the homeostatic

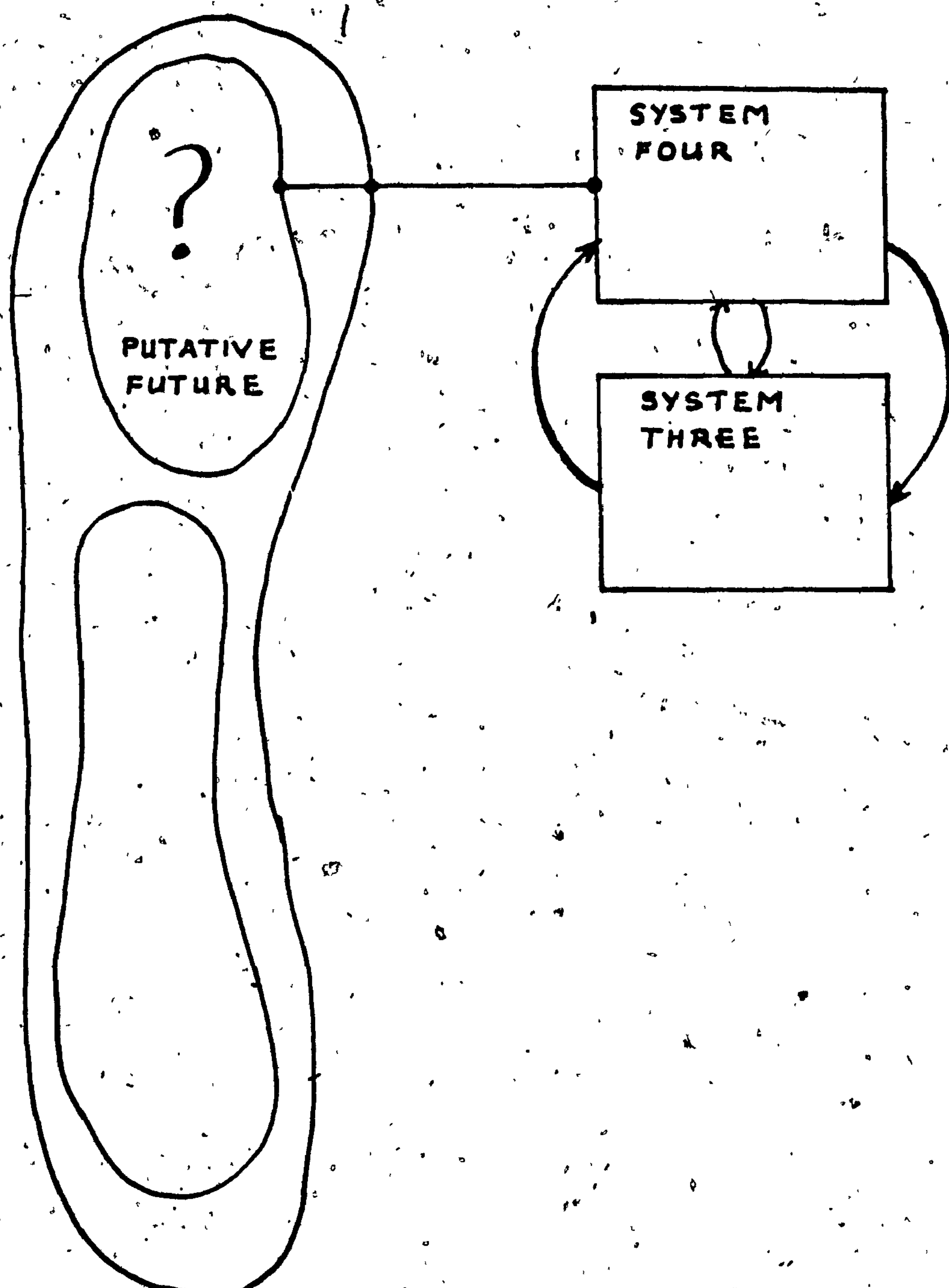


FIGURE A-5

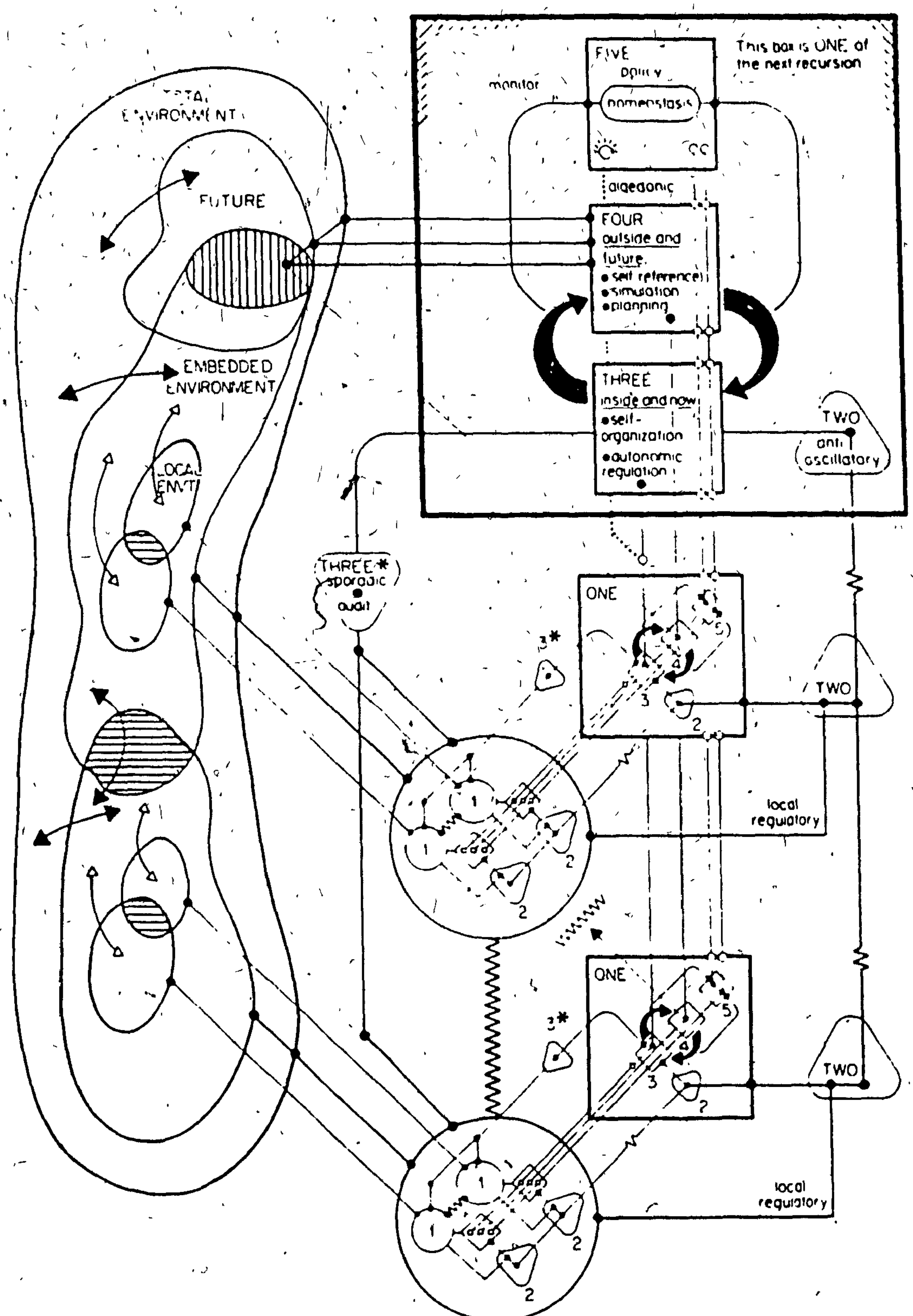
THREE/FOUR INTERFACE

connection between System Four and System Three.

Example of System Four Operations. Returning to the example of an Army operation in the field, intelligence gathering is an example of System Four operating. Intelligence is gathered to build and modify a model of the environment: enemy disposition; the terrain; etc. This model is projected against the model of its own forces to determine congruence and incongruence. System Three implements appropriate adaptations of its disposition.

System Five. The previous example points out the need for System Five. Not in all cases will the operation of the System Three/Four Interface handle all the variety of the situations. System Five provides the closure which is required for system viability, by measuring the affect of the System Three/Four Interface and the overall affect of the operations. System Five exercises veto control over unstable states of the system. System Five, in most practical cases, is the boss at the level of recursion being examined. System Five is metasystemic to Systems Three and Four, that is it is metasystemic within the metasystem. Beyond System Five of the recursion being examined, is the next level of recursion in the viable system. Figure A-6 illustrates the total management concept of the viable system.

Too often in the operation of an enterprise, System Five collapses into System Three by exercising direct control over operations. This results in a reduced affect of the variety handling capacity of the System Three/Four interface. In this situation, System Four is seen as a service appendage to the operations of the system rather than as an integral component in the variety equation; System Five loses its affect as well, there is no closure to be



THE VIABLE SYSTEM
- Stafford Beer

FIGURE A-6

applied and there is a danger of closure being applied by the recursion logically above the one being examined. While this situation may not threaten viability directly, it does reduce the synergistic nature of the viable system as presented; ultimately viability may be threatened if the recursion logically above is unable to handle the variety of environmental and internal changes with respect to the recursion being observed.

<u>Example of the Closure of System Five</u>. An example of closure being applied by the level of recursion above is in the management of severely retarded persons by a hospital staff. The severely retarded individual who has little voluntary control over his activities (operations) has no System Five functioning, no volition. The information gathering capacities of his senses are used only for autonomic control of his being, not for learning and adapting to environmental states. Adaptation to environmental states is handled by the recursion above, the hospital organization.

The cybernetic model, according to Beer (1979; 1981), is invariant. All viable systems exhibit the the characteristics described in this section. Some viable systems are, however, somnolent; they are technically asleep. The well oiled mechanisms for autonomic control operate efficiently, but the System Four activity is displaced or deactivated. System Five is out of the picture because of the attenuation of information flow that results from System Four displacement. The system reacts to changes, rather than foreseeing them. The future happens; it is not <u>invented</u>. Any extraordinary environmental change can place the operations of the system into disequilibrium. If there is insufficient time for the metasystem to react to the screams for action by Systems One, the system will die.

Summary

The discussion here of the Viable System Model has been necessarily brief. Beer's works on the subject are extensive and recommended to researchers as an analytical tool when the total system needs to be studied in a deductive manner. In my view the latest book, Diagnosing the System for Organizations (1985) is the most useful for analysis. The other books should be read for detailed understanding of the model.