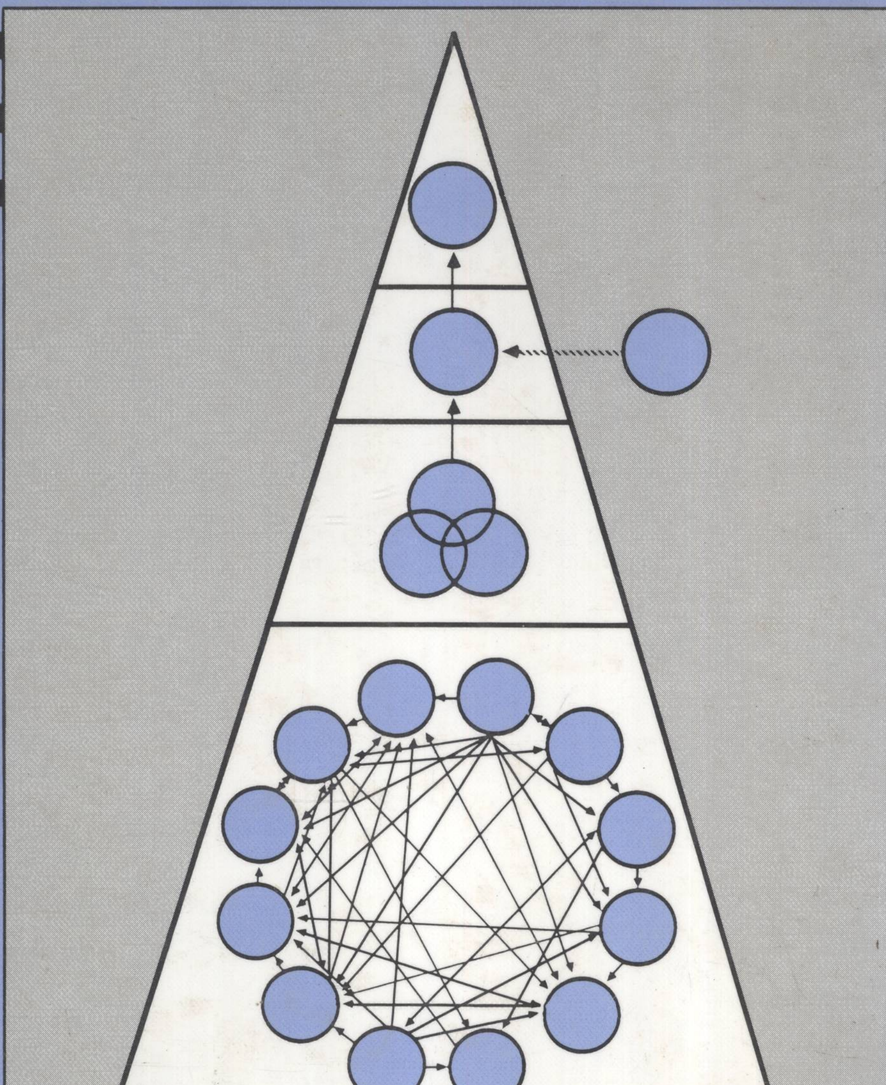
INTEGRATING THE AUTOMATED FACTORY



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Laying the CIM Foundation: A Structured Strategy Based Methodology
By Ken Branco

PREFACE

Much has been written about the benefits of factory automation in recent years. Programmable machine tools, industrial robots, computer-aided design, the computer, and computer-integrated manufacturing have made benefits such as improved productivity, better product quality, and greater manufacturing flexibility achievable for industry. Although automation offers the only prospect of continued profitability for many American industries, many in the industrial sector have yet to realize these benefits. Failure to reap the benefits of advanced automation are due, in a large way, to taking the wrong approach to implementing manufacturing improvements in the factory.

Automation can only be successful if it is first attempted, and once initiated, receives the total commitment of company technical personnel and management. Successful automation is no easy matter. It requires careful planning. It requires defining a company's strategic objectives and identifying where production must be changed to satisfy those objectives. It involves broad justification concerns, considerations in cash management, capital spending, and product marketing. It involves getting employees support early to ease the transition to a new manufacturing scheme. And it may require an organizational restructuring. Indeed, there are numerous critical issues which impact successful automation.

The purpose of this book is to assist design and production engineers, as well as industrial management with the implementation of all the necessary steps in achieving automated manufacturing. The main focus is to make the gradual stepwise approach to automation work. This is done by presenting contributions from automation experts and experienced industrial representatives to offer many practical ideas for planning the automation program. The articles and technical papers in the pages ahead provide a comprehensive view of all the necessary steps for implementing successful factory automation.

The presentation of material in each chapter is arranged to address the varying levels of factory automation—robots, NC/DNC equipment, FMS, CAD/CAM, and the multifunctional automation atypical of CIM. I attempted to draw together the most exciting and explanatory works on implementing automation, and at the same time incorporate practical examples of how the automation process is carried out.

The contributions of Chapter One, "Management Strategies for the Automation Undertaking," will help the reader to develop a long-term plan for automation. Automation is a strategic issue which must touch the heart of the company's business picture. The articles and papers provide an understanding of the importance of a detailed strategy for planning factory automation.

For any attempt at automation to be successful, those company personnel charged with decision making and managerial responsibilities must take on the right attitude, and champion the automation effort. This is addressed in Chapter Two, "Management Responsibilities with Automation."

The articles and papers of Chapter Three "Designing and Specifying Automation Equipment," covers design approaches and considerations for robotic workcells and

FMSs. The emergence of factory automation assistance in the form of system integrators who can plan, design, remanufacture, integrate, and start-up custom automation arrangements also is explained.

The manufacturing automation migration should be carried out in the most efficient fashion with minimal disruption to operations and smooth transitions of new interfaces. This process of integrating the various elements of automation is discussed in Chapter Five, "Integrating the Elements of Automation."

Implementation of factory automation requires consideration for managing human resources. Chapter Six, "Managing the Human Aspects of Automation," addresses how elements such as labor relations, organizational communications, and employee retraining can influence the automation endeavor.

This reference is appropriately concluded with Chapter Seven, "Managing the Total Program-Success Stories," which allow the reader to learn from the experience of others through case studies of successful automation implementation.

I am grateful to the competent and capable authors, and their publishers, who allowed the reprinting of their works in this volume. Their contributions will help to usher in the successful automation of other factories. I also appreciate the foresight of the Publications Development Department staff of SME for recognizing the need for this reference, and for their assistance with the research of this topic. Finally, I would like to thank the management at the DuPont Engineering Development Laboratory, whose innovative exciting approaches to automation provided the motivation for developing this reference. Thanks also to DuPont management for enabling this engineer to participate in developing new manufacturing technologies, and in experiencing the total automation-implementation process.

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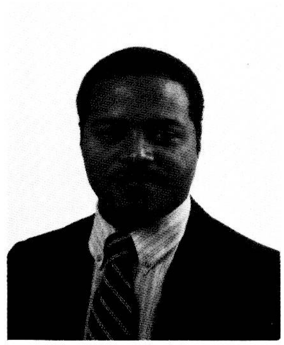
ABOUT THE EDITOR

Steven Cousins is a Mechanical Engineer at the Du Pont Engineering Development Laboratory, where hybrid automation equipment and new automated manufacturing processes are developed for Du Pont.

Mr. Cousins organized and chaired the RI/SME Robots 11 Robot Standards Forum. He has helped in an advisory capacity with the Department of Labor project to develop a high-tech in-plant training programs for robotic technicians. He has contributed sections and a chapter to the *Tool and Manufacturing Engineers Handbook*. Mr. Cousins is a Certified Safety Specialist, a Certified Manufacturing Engineer in Tool Engineering, and a Registered Professional Engineer.



He is a member of the Robotic Industries Association's R15 Robot Standards Executive Committee. He is the current Chair of the RIA R15.02 Human Interfaces Standards Subcommittee, and is a member of the ANSI/NMTBA B11.20 Standards Subcommittee on Flexible Manufacturing System Safety.

In addition, Mr. Cousins is a member of the American Society of Mechanical Engineers and has held numerous offices with his local section. As an SME member, he served with the 1986 International Advisory Committee, and is active with the Robotics International/SME Human Factors and Safety Division. Mr. Cousins is also a member of the Human Factors Society and the System Safety Society.

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- Information on Technology in Manufacturing Engineering database containing technical papers and publication articles in abstracted form. Other databases are also accessible through SME.

The SME Manufacturing Engineering Certification Institute formally recognizes manufacturing engineers and technologists for their technical expertise and knowledge acquired through experience and education.

The Manufacturing Engineering Education Foundation was created by SME to improve productivity through education. The foundation provides financial support for equipment development, laboratory instruction, fellowships, library expansion, and research.

SME is an international technical society dedicated to advancing scientific knowledge in the field of manufacturing. SME has more than 80,000 members in 70 countries and serves as a forum for engineers and managers to share ideas, information, and accomplishments.

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As a leader among professional societies, SME assesses industry trends, then interprets and disseminates the information. SME members have discovered that their membership broadens their knowledge and experience throughout their careers. The Society of Manufacturing Engineers is truly industry's partner in productivity.

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We sincerely hope that the information collected in this publication will be of value to you and your company. If you feel there is a shortage of technical information on a specific manufacturing area, please let us know. Send your thoughts to the Manager, Publications Development Department, Marketing Division at SME. Your request will be considered for possible publication by SME or its affiliated societies.

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CHAPTER 1

MANAGING STRATEGIES FOR THE AUTOMATION UNDERTAKING

EDITOR'S NOTE

Strategic goals and business priorities must be formulated before an automated process or factory is designed. Each step of the factory automation effort, from component selection to start-up scheduling, should be rooted in the business plan. The papers and article of this chapter address this relevent point—the automation implementation strategy from costs, to dealing with technological obsolescence, to employee training.

The paper by Boyd explores strategies to decide which functions to automate. Examples are included.

Soska and Thompson explain in their contribution that even the successful implementation of robotics can be accomplished through a systematic automation strategy involving managerial and technical personnel. Both parties must make the proper preparations, be responsible for design, and follow through with intelligent pre-installation activities.

Elavia provides several checklists in identifying a useful analysis and process for successful automation planning and implementation. Key ideas such as a written CIM plan and identifying Critical Success Factors are introduced.

Branco makes numerous recommendations to management in describing a methodology for successful CIM efforts. He focuses on the organizations business strategy as it relates to manufacturing and suggests a 5-10 year development roadmap.

Presented at the SME World Congress
on the Human Aspects of Automation, September 1985

Function Allocation: Strategies for Deciding What to Automate

by Stephen P. Boyd
United States Air Force Academy

INTRODUCTION

The automation of manufacturing processes has had and will continue to have major effects on industry and on society. While increased productivity and efficiency are the most obvious goals, one must also consider the shifts in skills required of the workforce. The manager who is tasked to evaluate the desirability of automating various processes may be barraged by conflicting views expressed by systems analysts, unions, comptrollers, and other people who have interests in the company. In the face of these conflicting demands, the planner is faced with such a complex set of trade-offs that it is difficult to put together a feasible, coherent design which meets organizational goals. What the planner needs is a systematic way of organizing the goals and constraints of the system combined with a strategy or strategies which will show how to logically select what functions to automate.

The problem of deciding what to automate is one of function allocation. That is, given that the system must perform certain basic functions, which ones should be performed by a machine and which should remain a job for the human operators? At one extreme is the fully automatic system, in which the entire system operates with little or no human intervention; the other extreme is the completely manual system in which all functions are allocated to the humans. Certainly, there is a continuum between these two extremes. The planner's problem is picking a point along that continuum.

Picking that point is more difficult than in the past because we now have the capability to automate more. The important thing to remember is that just because we <u>can</u> automate a given function, it is not necessarily true that we <u>should</u> automate it. In addition, even if we should automate it in one company, the situation might dictate a different solution in some other company. This means that there is no cookbook that can designate which functions should be automated; there can be no list of "things to automate" developed for planners to use. What those planners need is a method for making those decisions. That is what this paper will introduce: a systematic method for deciding what to automate.

OPERATIONAL REQUIREMENTS AND CONSTRAINTS

First the system purpose must be defined in general terms. It would be useful to discuss this process in terms of an example. Suppose that a given company is about to build a warehouse. Defining the purpose for this system in the broadest way, the warehouse is a holding point for products between manufacturing and shipment. This definition implies that there is a flow of items through the warehouse, with each item spending an indeterminate amount of time in storage. So, to keep the focus on the dynamic nature of the warehouse, I will give a generic, but more descriptive title of Materiel Storage and

Retrieval System (MSRS). While the title may sound like jargon, it is useful for two reasons. First, it points out that the warehouse is more than a place where things sit; rather, items move in and at some time later, move out. Second, it more clearly identifies the system boundaries: from the time items arrive to be stored to the time that they leave the warehouse.

The next step is to derive concrete specifications to which the system must conform. For example, given that the door to a house must provide security, the next question is, "How much security is enough?" In the case of the MSRS, the amount of storage space required (perhaps in terms of cubic feet) is only one of many requirements. We would also be concerned with the number and size of the items to be stored (many small items, fewer large items, or a combination of both). But, since storage is a process as much as a location, we must be equally concerned about how well the system gets items in and out of storage. How long should it take to place an item in its proper location, and then how long to find and retrieve that item?

These are operational requirements which describe what the system must do to accomplish the mission -- how fast, how high, how often, when, how reliably, how accurately, etc. It is important to realize that the derivation of operational requirements is not always easy and does not necessarily flow naturally from the stated purpose of the system. If you were designing a nuclear power plant, the system purpose might include the safe generation of electrical power using nuclear fuel. How safe is safe? Zero probability of an accident is impossible to achieve. What probability represents the minimum acceptable level of safety?

One might take the approach of specifying some operational requirement in terms of "as much as possible." For example, a door could be as secure as possible, a nuclear power plant could be as safe as possible, or the MSRS could retrieve items as fast as possible. There are two main problems with this approach. First, "as much as possible" may not be an actual requirement. Do you really need a titanium vault door for your house? In most cases, there is really an acceptable minimum amount of some requirement which can be specified.

What if an item is expected to be stored in our warehouse for an average of thirty days, with a minimum of 5 days? Obviously, if items arrive faster than they are being stored or if there is a significant delay time for storage, there will be a backlog of items awaiting storage. An operations research analysis could determine the maximum allowable storage time, based on the arrival rates of the items to be stored and the permissible backlog. This would then provide an operational requirement for the system. This requirement or specification serves as a criterion by which design options can be evaluated. Any proposed system must meet this and any other criteria which have been developed. Other operational requirements for the MSRS might include the sizes (minimum and maximum) and weights of the items, how many different stock numbers there are, retrieval speed and accuracy, inventory control (speed and accuracy of updating, resupply, etc.), invoicing, and control of damage of items. Some of these requirements are easier to quantify than others, but if they are not quantified, how can one determine whether or not a proposed design meets the specifications?

Notice that, so far, there has been no discussion of specific design options. The relative merits of manual, mechanized, or automated systems have not been mentioned. Often, decisions concerning automation made too early in the design process are somewhat arbitrary.

It is critical that such decisions be deferred until the system specifications and functions are fully described. In other words, we must know what the job is before we can tell if a certain design proposal will do the job. This analysis is intended to reduce the problems associated with someone deciding what kind of system to build, and then searching for justification for that decision.

Once the operational requirements have been specified, we have the criteria by which the performance of various design options can be evaluated. However, it is important to remember that as designers, we must live with real-world restrictions which place limitations on what we can or cannot build. Obviously, these operational constraints must be dealt with.

If you were trying to convince a home builder to install titanium vault doors in the houses that they build, what kind of response would you expect? They would probably say that no one would be willing to pay the extra thousands of dollars necessary to have the doors installed. There is a limit to how much people are willing to pay for added security. By the same token, the MSRS will probably have some cost ceiling and schedule limitations. This and other limitations form the operational constraints on the system you are designing. Operational constraints place boundaries on your design -- how soon we need it, how much we can pay, what technology is available, who must be able to use it, etc.

Taken together, operational requirements and constraints yield the yardsticks by which our designs are measured. Any candidate designs for a system must meet these criteria. Function allocation becomes a critical issue when there are several possible ways to meet the criteria.

FUNCTION IDENTIFICATION

Our goal is to allocate system functions is a way which satisfies operational requirements and constraints. To do this, we must first identify what those functions are. There are a number of possible approaches for identifying the functions, one of which is flow charting. In the MSRS, the items arrive, are identified, are moved to some location, and the location is recorded. Then, the item to be removed is identified, its location is determined, the item is retrieved, and the inventory is updated. A flow chart could easily show these activities in sequence. However, this would probably provide insufficient detail. What is involved, for instance, in retrieving an item from storage?

One way to ferret out the individual functions which make up the tasks is to consider the system as a processor of information. The diagram below, which is actually a model of human information processing, can easily be extended to represent some of the tasks which must be accomplished by the MSRS. It shows some sort of sensing of the environment, processing that information, a flow of data to and from memory, and then making some response which affects the environment. The model above can then be used to identify the functions which are associated with the retrieval process. It is important to note that it does not represent an end-to-end flow chart, but rather serves as a means of isolating individual components of a task. First we must assume that the location of the item to be retrieved has been put into memory (That process would be a different part of the analysis). To retrieve the item, the system must either sense or remember its current location, compare it to the location of the item to be retrieved, and then determine a path to the storage location. Another possible function would be to recall from memory the size, shape, weight, and special handling requirements (if any) of the item to be retrieved, then determine if any configuration changes are necessary (lifting devices, manipulators, etc.) After configuration changes are made, the system must move to the location, while sensing or remembering fixed or moving obstacles and avoiding them by either changing paths or waiting until the obstacle has moved out of the way. Upon arriving at the location, the system must sense or remember the orientation of the item, properly place the manipulators, and then lift and remove the item from its position. It may be necessary to sense any other items which are in the way and then move them to get the desired item. Then the return path must be determined and followed to the destination (e.g. a loading dock).

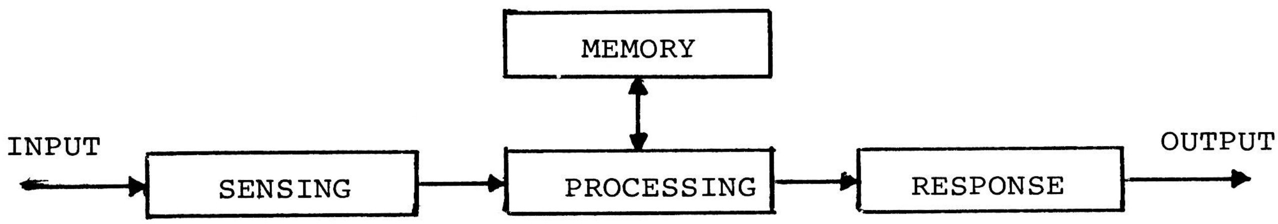

Figure 1: Information processing system (from VanCott and Kinkade, 1972)

This may at first seem to be an excessive amount of detail. That is because when people do jobs such as these, they do many of the functions somewhat automatically and continuously, especially when well-trained. However, if you watch a new trainee, you will see the individual functions much more distinctly. If you were considering automating the tasks (one possible outcome of our function allocation), this level of detail would be essential. You cannot simply tell a computerized system to go get an item off the shelf. It would have to be programmed to do all the things discussed above. If you do not identify the functions carefully, there is no way to know whether or not a given design could do the task.

FUNCTION ALLOCATION

Up to this point in the design process, we have

--determined the system mission objectives;
--specified operational requirements;
--determined operational constraints; and
--identified system functions.

Logically, the next step is to decide which functions will be accomplished by the machine and which will be accomplished by the human. There are a range of possible options - it's usually not just