Simulation of Resources in Gantry Machining Center

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Abstract

This paper addresses utilization of manpower and equipment resources in the three spindle, five axis gantry machine tool center at McDonnell Aircraft Company in St. Louis, Missouri. A GPSS (General Purpose System Simulation) model is developed to help analyze the impact of system changes so that cost effective decisions may be made about gantry fabrication operations. Besides resource utilization, the model provides a basis for making changes in the load mix on the machine tools and the number of set up men servicing this area. Emphasis of the paper is placed on model development and validation.

INTRODUCTION

Fabrication operations involving the flow of materials and documentation through people, processes, and machines to yield marketable products, constitute systems that are subjected to much study and planning activity. There are four basic types of models used to study the behavior of manufacturing systems: descriptive, physical, mathematical, or procedural.(1)

A descriptive model uses words to describe the system and its attributes. A comparison of the descriptions is made, and the system which best describes what is desired can be found. As an example, when buying a large piece of machinery, companies normally compare more than the price of the different machines available. Exceptions to the specification, additional features, warranties, and repair service record are other factors that are considered before the purchase is made.

The physical model is perhaps the most familiar of the four. It serves as a physical representation of the system and its operation is studied under various conditions. The model can be small, such as wind-tunnel models used in aerospace research, or they can be quite large, like a pilot plant. The models can be static representations, like models used for plant layout, or they can be operational models, like an experimental test car.

A less familiar model and at times the most difficult to understand is the mathematical model. Mathematical expressions or equations are used to describe the various relationships within the model, and some sort of mathematical technique is used to solve the set of expressions or equations. While these techniques can be quite simple, more often than not they are highly involved in mathematics and are difficult to understand.

A number of mathematical optimization models directed at fabrication operations have been developed by both the academic and industrial communities. However, the innate limitations of the methodologies utilized, along with the constraints and assumptions of real-world behavior imposed by the researchers, tend to diminish their usefulness as a managerial tool. Also, the nature of mathematical models make them incapable of handling the "undefinable multiple trade-off response" dilemma. This is the problem of being aware that certain relationships exist among the controllable variables, but not being cognizant of the manner in which they are related (2).

Finally, there is the procedural method which uses functional statements to describe the flow of activity in the system. Basically, this amounts to building a working model on paper, and then following its operation as the activity goes from point to point in the model. The computer has proven to be a valuable tool for simulating this type of model because of the numerous occurrences of events and large data scans required. From an engineering point of view, it has provided inexpensive means of analyzing the impact of system changes, e.g., new equipment, training parts or forms required, etc. (3).

Current equipment/manpower utilization models are usually based on historical activity and sets of equations that place limitations on the flexibility of the application and the predictability of the model. When applied to real-world situations, Methods Engineers are sometimes forced to factor analysis obtained from these models to establish standard targets and forecast shop loads accurately. At McDonnell Aircraft Company,

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Equipment Engineers are constantly faced with purchasing and/or replacing equipment in fabrication areas due to fluctuations in production rates, equipment utilization schedules, raw materials, etc. Problems are amplified in the 3 spindle, 5 axis gantry machine tool center because of the varied situations in which a job may run and the number of resources required.
Costing over $1 million each, these machines represent McDonnell's most significant capital investment in Computer Aided Technology (Reference Figure 1). Three positioned part loads varies from $10,000 to $60,000 per load before roughing or finishing cuts (Reference Figure 2).

Simulation is one method which attempts to provide the necessary facts so that cost effective decisions may be made. While simulation has been used quite successfully for years in many diverse fields of engineering and science, the advent of the computer has increased its utilization as a managerial decision making tool (5). Coupled with a special purpose simulation language such as GPSS (4), a model study of equipment acquisitions and resource allocations is now feasible.

NATURE AND SCALE OF PROBLEM

At McDonnell Aircraft Company, work orders for major fittings of several aircraft models are received at the 3 spindle, 5 axis gantry work area with varying priorities, run-times, and specialized running conditions. As shown in Figure 2, each 5 axis gantry has 3 available loading positions allowing the head of the machine to move from load to load without stopping for adding new parts. There are 4 absolute gantries which are scheduled to run aluminum jobs only. There are 12 incremental gantries which are designed to run titanium jobs for close tolerance requirements. Because of the size and weight of the parts overhead cranes must be used to load and unload these jobs. Crane #1 (10,000 lb. load capacity) must be used for titanium jobs, but Crane #1 or #2 (5,000 lb. load capacity) may be used for aluminum jobs. The bulk area where most of the jobs are received will hold up to 100 jobs. Six (6) set up men are used in this area to prepare, load, and unload the parts and clean off the machine beds for new jobs. Two forktrucks are available to move parts in and out of the area. The following sections are peculiar to the various types of aircraft parts fabricated on 5 Axis Gantry Machine Tools. Because of security regulations the names of aircraft models are not mentioned.

GROUP A AIRCRAFT

Group A Aircraft work orders arrive on an average of 15 per day within time increments of 96 ± 30 minutes. Due to current assembly jig dates, these jobs have priority over other aircraft models. Approximately 40% of these orders are aluminum and the remainder are titanium. When received all Group A jobs are sent to the bulk area where set up men and expeditors prepare required cutters, tools, and part programs to run the parts. This takes 120 ± 60 minutes for aluminum jobs, and titanium jobs are already set up when received. It takes approximately 60 minutes to clean up, 45 ± 15 minutes to load, 30 ± 15 minutes to unload and 120 ± 30 minutes to run an aluminum job. Similarly, it takes 20 ± 10 minutes to clean up, 60 ± 15 minutes to load, 60 minutes to unload and 240 ± 30 minutes to run a titanium job.

GROUP B AIRCRAFT

Group B aircraft work orders arrive on an average of 30 per day within time increments of 48 ± 16 minutes, requiring 30 ± 10 minutes to prepare them for running. The Aft section of these parts is sent to a 3 spindle 30" machine (Profiler) for slot cuts by fork truck (one load at a time) taking 30 ± 15 minutes. Because of logistics, this machine uses Crane #1 only, taking 120 ± 40 minutes to load the machine, 360 ± 60 minutes to run each load and requiring no crane to unload them. The truck driver unloads the parts and brings them back to the 3 spindle, 5 axis area where they are merged with the Forward section (fabricated on the 3 spindle, 5 axis machine tools). All Group B parts are aluminum. The Forward section run-time is about 180 ± 60 minutes with loading taking 120 ± 30 minutes, and unloading taking 60 ± 30 minutes.

GROUP C AIRCRAFT

Group C aircraft work orders are received every 60 ± 30 minutes. These jobs are all titanium and must be run on incremental machine tools. It takes 90 ± 45 minutes to load, 30 ± 15 minutes to clean machine bed before loading, 45 ± 15 minutes to unload and 360 ± 60 minutes to run. Each crane breaks down or is used by maintenance personnel approximately 2 hours per day lasting about 20 minutes exponentially distributed. Servicing usually occurs during off hours or at low peaks to prevent interference with production runs.

MODEL DEVELOPMENT

Implementing a new production line, considering a major facilities change, and isolating cost problems in the manufacturing process, require analytical efforts that support some of the most critical decisions made by Production Management. Yet in the mass of data that is gathered, sorted, charted, and summarized to enable the decision process to begin, the net effect of all specified variables is often obscure.

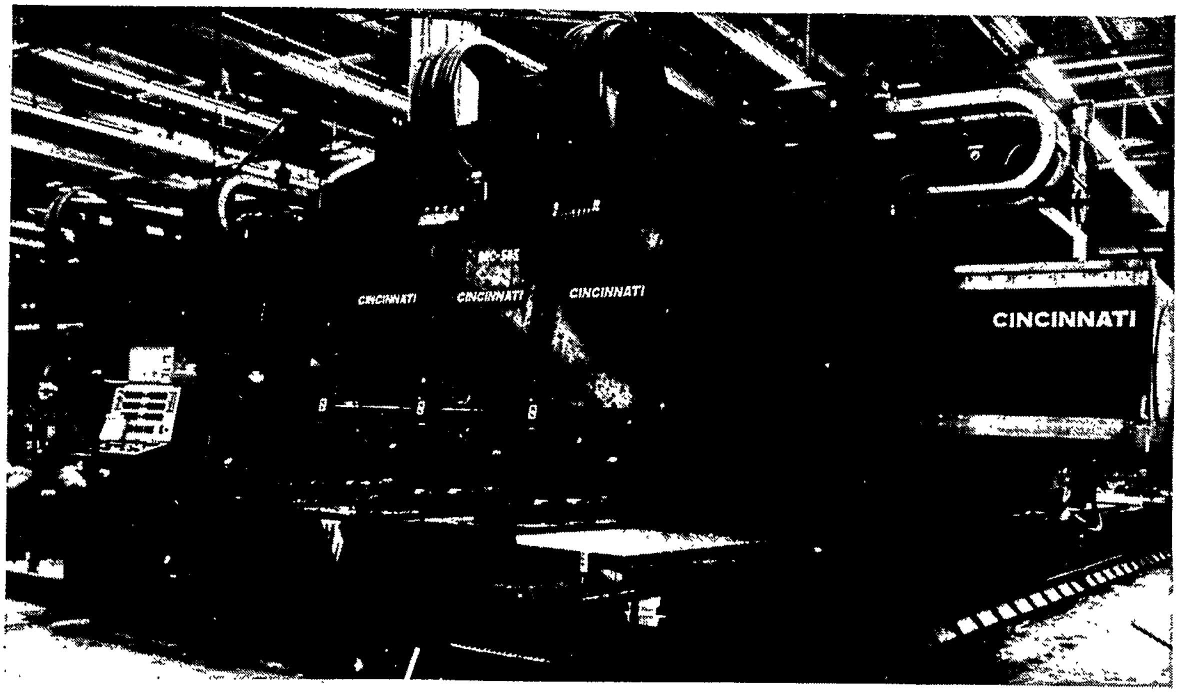

Figure 1

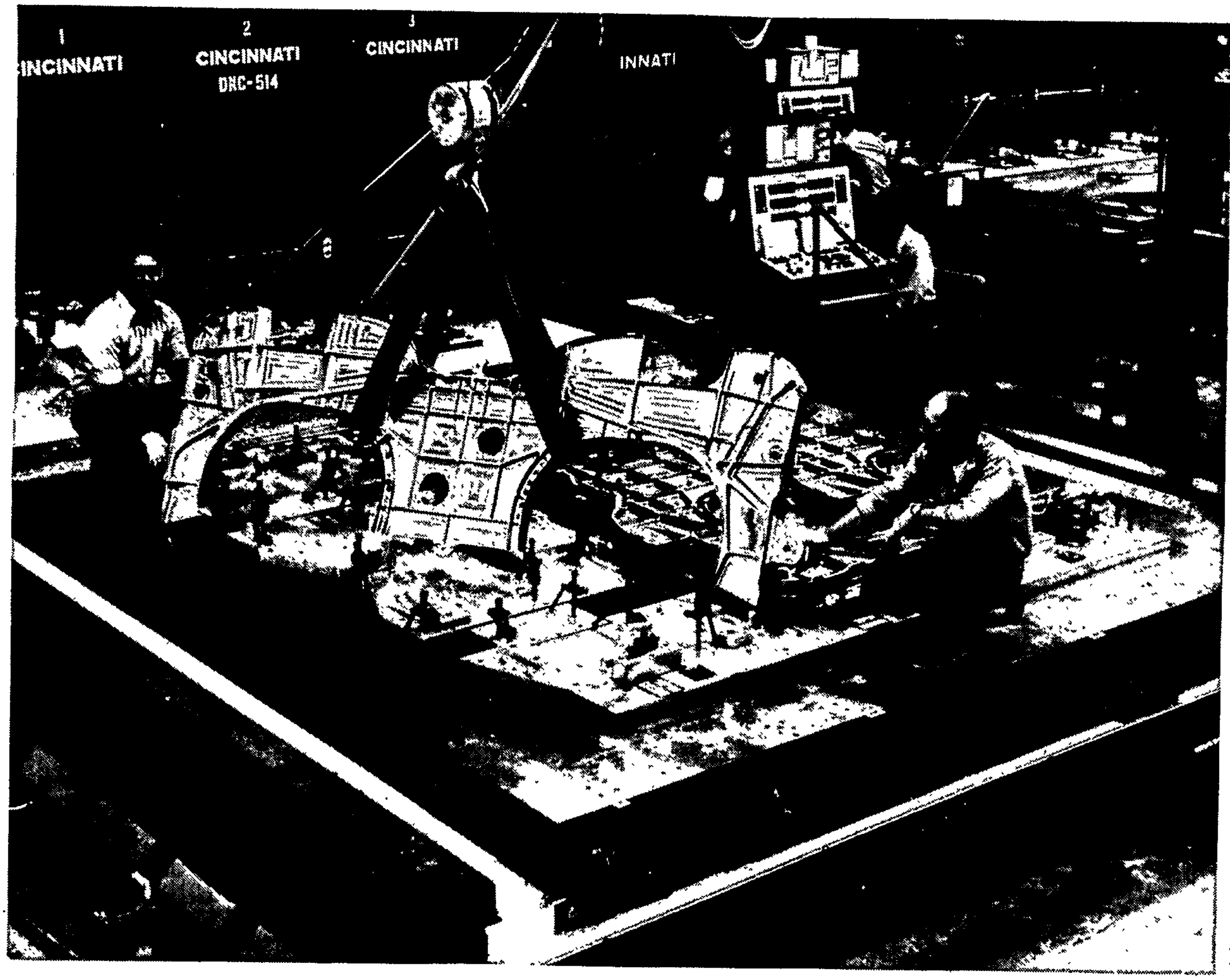

Figure 2

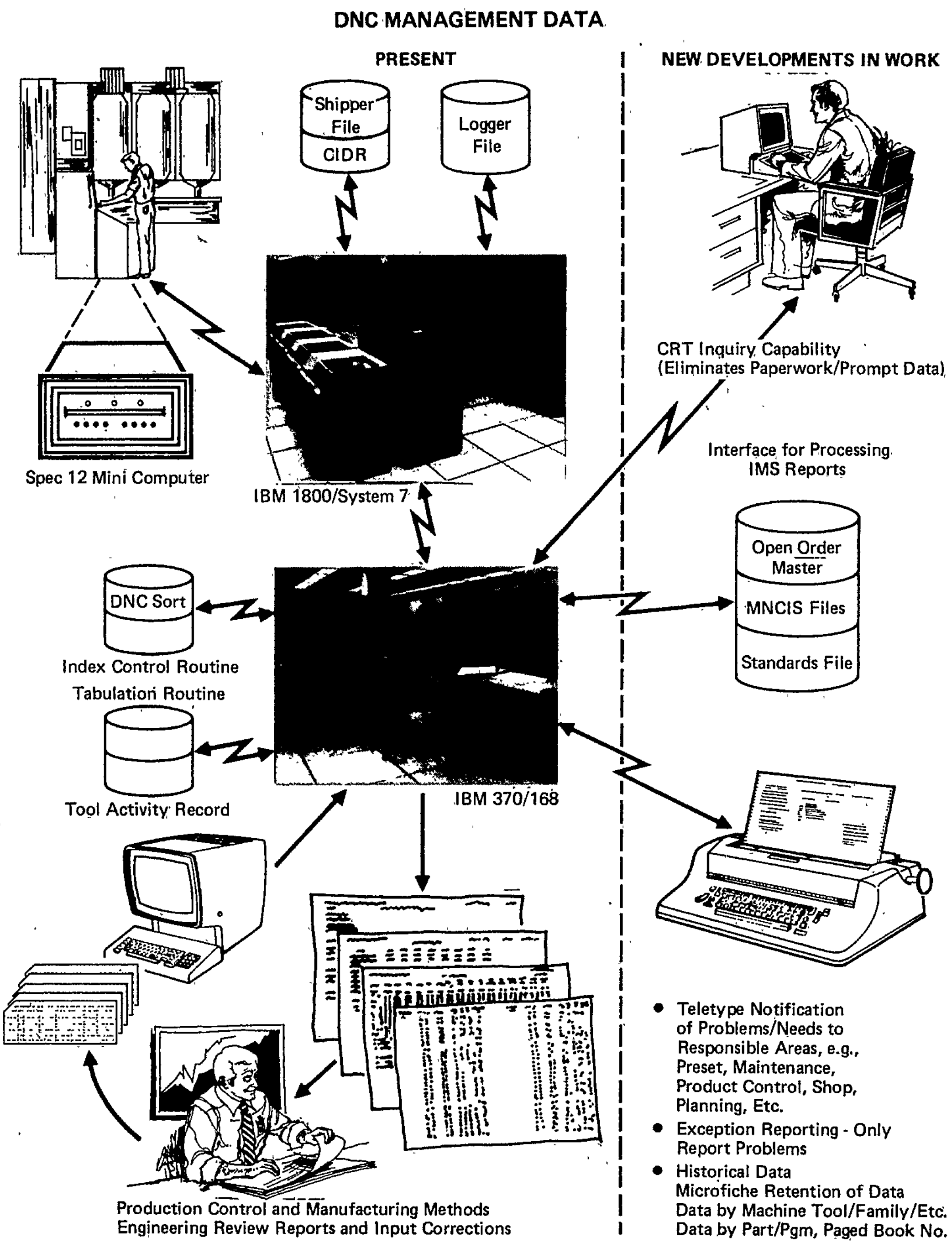

Figure 3

To avoid similar problems, a GPSS model of the 3 spindle, 5 axis machining center was developed that allows production management to ask what if questions about many relationships of time, materials, equipment and human resources.

Recognizing the flux of dynamic interactions in the machine shop, this model was constructed in modular units depicting the flow of production parts by aircraft type. Once tested individually for validity and adaptation to real-world conditions, these modules were combined to test the overall impact and relationship of the resources employed throughout the model.

After designing the system to be analyzed, a flow chart of the operational system was prepared defining its functions. Historical DNC Management Data Reports (Reference Figure 3) and Methods Engineering standard procedure data were used to produce reliable flow times for the functions defined in the flow chart. Using the flow chart and event cycle data, a GPSS program was written and run on IBM 370/168 CPU via remote Data 100 Input/Output terminal. This job took .029 CPU minutes to run utilizing .312 minutes of DISC Input/Output and 300K of core. Approximately, 120 programming hours went into developing this model over a cycle span of 20 days, giving a one time total implementation cost of $1,250.00.

VALIDATION

Output sheets from the initial computer simulation were checked against known system actuals via comparison with several Advanced Methods Studies (AMS) (Reference 4). Upon recommendations from functional personnel in the 5 axis gantry area, a few minor adjustments were made to the model to better represent the real-world.

PRELIMINARY RESULTS

The 3 spindle, 5 axis gantry model was run for 1 day to reach a steady state. Initial runs for 15 and 30 days showed about 56% utilization of Crane #1 for maintenance, loading and unloading. Normal crane utilization policy according to Methods Engineering is about 80%. The work load forecast in this area is anticipated to increase by 95% when the production rate for Group A aircraft is increased to 15 per month (anticipated March 1979). Projected sale of a new fighter model to the Marines will add to the work load in this area also.

According to Plant Engineering, the cost for upgrading Crane #2 to 10,000 lb. capacity is about $15,500 parts plus labor. This cost is very small in comparison to costs that may be encountered by not servicing the Gantry area effectively.

In addition to Crane utilization, this model also shows the utilization of other resources in the area and the Queues that formed for service. As a further development of this model cost associations to entries attempting to be serviced and time spans in which they spend at various storages and facilities are being considered to derive a cost for fabricating major fittings for various aircraft in this area.

Observations made by this simulation include the following:

- o With the high utilization for the 3 spindle 30" machine (Profiler) on the split Group B orders (99%) additional new equipment or subcontract work from this area if slot cuts are required for new aircraft models. On the other hand, Group B production is on a downswing and subcontract work may have to be recalled to maintain the current high utilization.
- o More Incremental 5 axis work should be added to current loads as is evident by the low utilization percentage 5.3%. Work designed to run on absolute machine tools could be run on the incremental machines.
- o The bulk area could be shared with 4 spindle 40" machine tools since only half of its space is loaded.
- o The setup men are doing a good job of keeping the Machine Bed loaded, but they are only working about 20% of the time. Four of these men could be located in another area or trained for other jobs. This savings alone, 4 setup men x $14,000/year = $56,000, is enough to justify upgrading Crane #2.

The savings that may be accrued from the use of this simulation model are intangible. Certainly no costs will be saved if simpler analytical techniques could have been used to produce the same conclusions. On the other hand, the cost of poor judgment because alternations were not adequately tested can be detrimental beyond measure.

CONCLUSIONS

Several basic conclusions may be drawn from this simulation model to assist in making decisions about fabrication operations and equipment acquisitions for the 5 Axis Gantry area. Besides the current utilization level of equipment and manpower resources, the queue statistics and flow diagram enable functional personnel to evaluate the relationship of dependent events over a specified time frame with a built in randomness feature that approximates real-world occurrences. GPSS output statistics are also helpful in preparing targets and workload forecast for similar production jobs. The crane utilization statistics will serve as a determinant for installing additional cranes or modifying the current ones to support more varied load combinations. Even though this simualtion is geared toward crane utilization it also provides a basis for making changes in the load mix on the machine tools and also the quality and type of resources servicing this area.

The use of a model for analyzing alternative operational policies is an extremely useful method for producing inputs to the management-decision process. Although several types of models are available, a procedural simulation model can be developed in situations where it is virtually impossible to formulate other types due to the complexity of the system to be studied. The existence of special-purpose computer programming languages, such as GPSS, SIMSCRIPT (Simulation Script), GASP (General All Purpose Simulation Package), CSMP (Continuous System Model Program), and DYNAMO, provide helpful frameworks for developing procedural models.

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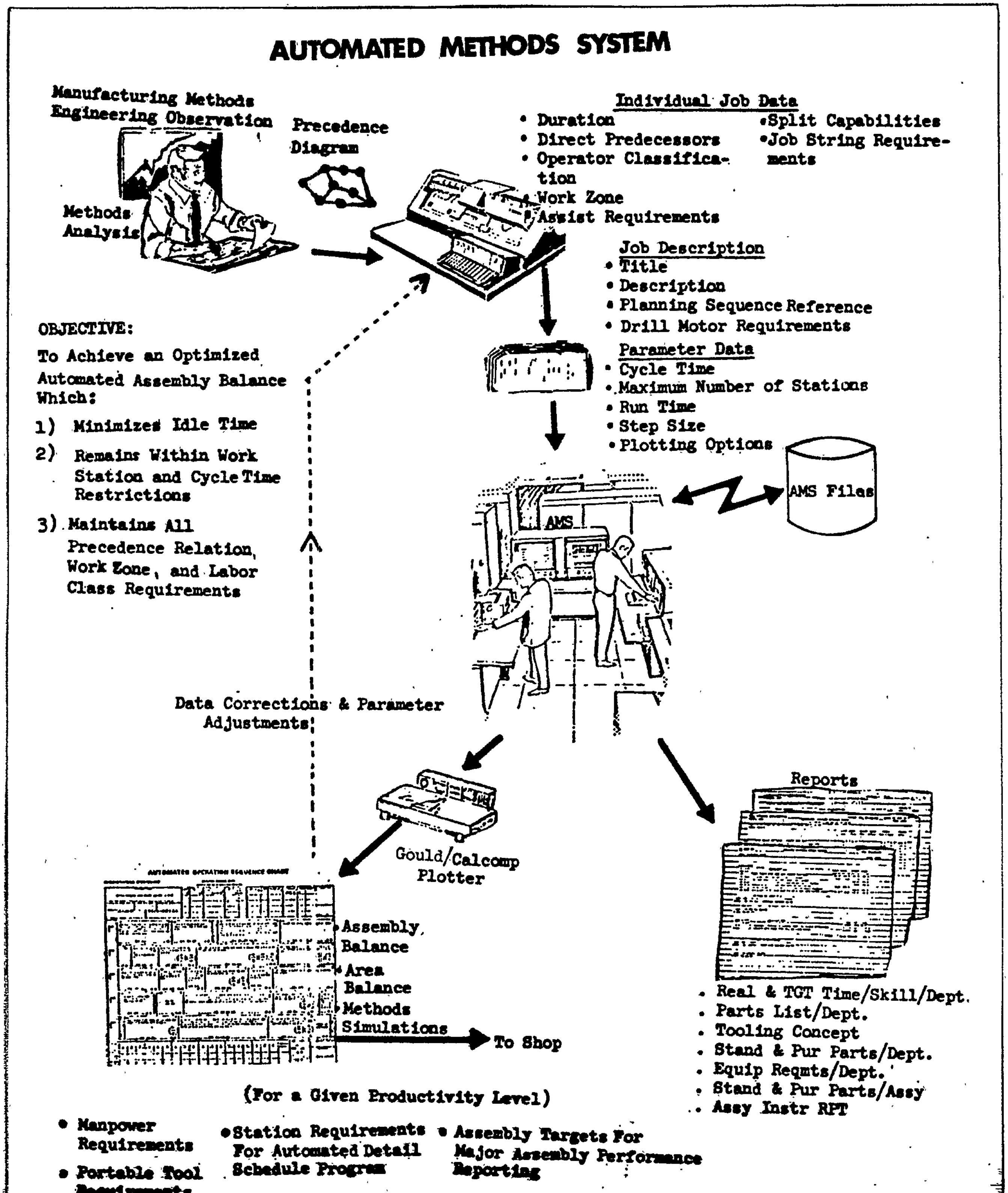

Figure 4

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