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# A COMPUTERIZED PRODUCTION SCHEDULING SYSTEM

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ABSTRACT

A computerized production scheduling system is described that was developed to replace a manual system for scheduling production in a production subsystem consisting of one hundred seventy people and a considerable amount of expensive production equipment. This computerized system uses a deterministic simulator for scheduling production and requires large data bases.

## 1. INTRODUCTION

This paper describes a computerized production scheduling system developed to replace a manual system for scheduling a portion of the production in the Photogrammetric Data Division of the Defense Mapping Agency Hydrographic/Topographic Center. The computerized system was developed because production schedules were becoming obsolete soon after their completions due to changes in the production requirements; production schedules were time-consuming, burdensome, and costly to produce manually; and additional capabilities were desired that were not possible to achieve using the manual system such as rapidly determining the effect of changes in the production requirements or production resources (e.g., manpower).

The computerized production scheduling system developed was designed to run in the batch mode on a large-scale digital computer with the inputs being inputted either from a terminal or by a set of computer cards and the output reports being produced on the computer output printer. This computerized system contains a deterministic simulation model (Emshoff 1970, Shannon 1975) which performs static scheduling (Baker 1974, Conway 1976) and data bases which contain the large amount of data needed in the system.

The team concept was used in developing this computerized system. The team consisted of a specialist in developing such systems, operations research analysts, a computer programmer, the production scheduler, and management. As one would expect, most of the development effort was by the operations research analysts and the computer programmer.

## 2. PRODUCTION SUBSYSTEM DESCRIPTION

The production subsystem of interest produces map sheets which are map drawings used in the production of maps. The sets of information and materials required to develop the map sheets are received from other production subsystems by blocks which are geographical regions, e.g., cities, military bases, or regions of countries. During production, each block is divided into subregions and map sheets are produced for each subregion. The boundaries of each map sheet in a block must be compatible with their neighbors and this is accomplished during production by a process called panelling. Fig. 1 contains the production flows of this production subsystem which consists of eight UNAMACE systems, nine AS-11A instruments, one RPIE system, and approximately 170 people.

This production subsystem is a flowshop (Baker 1974, Conway 1967) consisting of two different types of production flows as shown in Fig. 1 and Fig. 2. The differences between the two types of production flows are that different types of production equipment and processes are used. As seen in Fig. 2, one type of production flow has eight (8) parallel production lines which are labelled as routes one

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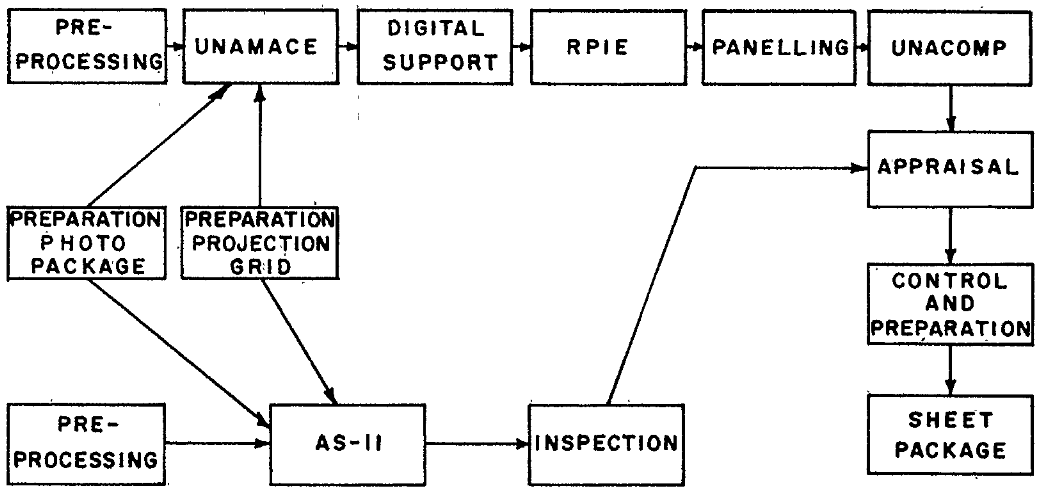



STEREO COMPILATION
FIGURE I

(1) through eight (8) and the other production flow has two (2) parallel production lines which are labelled as routes fifteen (15) and sixteen (16). Each block and its resulting sheets must be processed completely on one production line (route) where they move from task to task. Each route has only one UNAMACE $(u_i)$ or AS-11A Group (1 or 2) which are required in more than one task as indicated in Fig. 2. Conflicts are resolved by decision rules based upon the job requirements.

Jobs are scheduled and produced in this subsystem by job categories (priorities) and first-come first-served within each job category where jobs are initially blocks and then map sheets. Basically, there are regular jobs and "crises" jobs, with crises jobs having priority over regular jobs. Jobs are scheduled to start production at a date after which all of the required block information and materials are scheduled to arrive from other production subsystems. Jobs are classified into four job categories.

Category I: Crisis jobs in production.

Category II: Crisis jobs which can begin production when production resources become available or at a future date when all of the required information and materials become available.

Category III: Regular jobs in production.

Category IV: Regular jobs which can begin production when production resources become available or at a future date when all of the required information and materials are available.

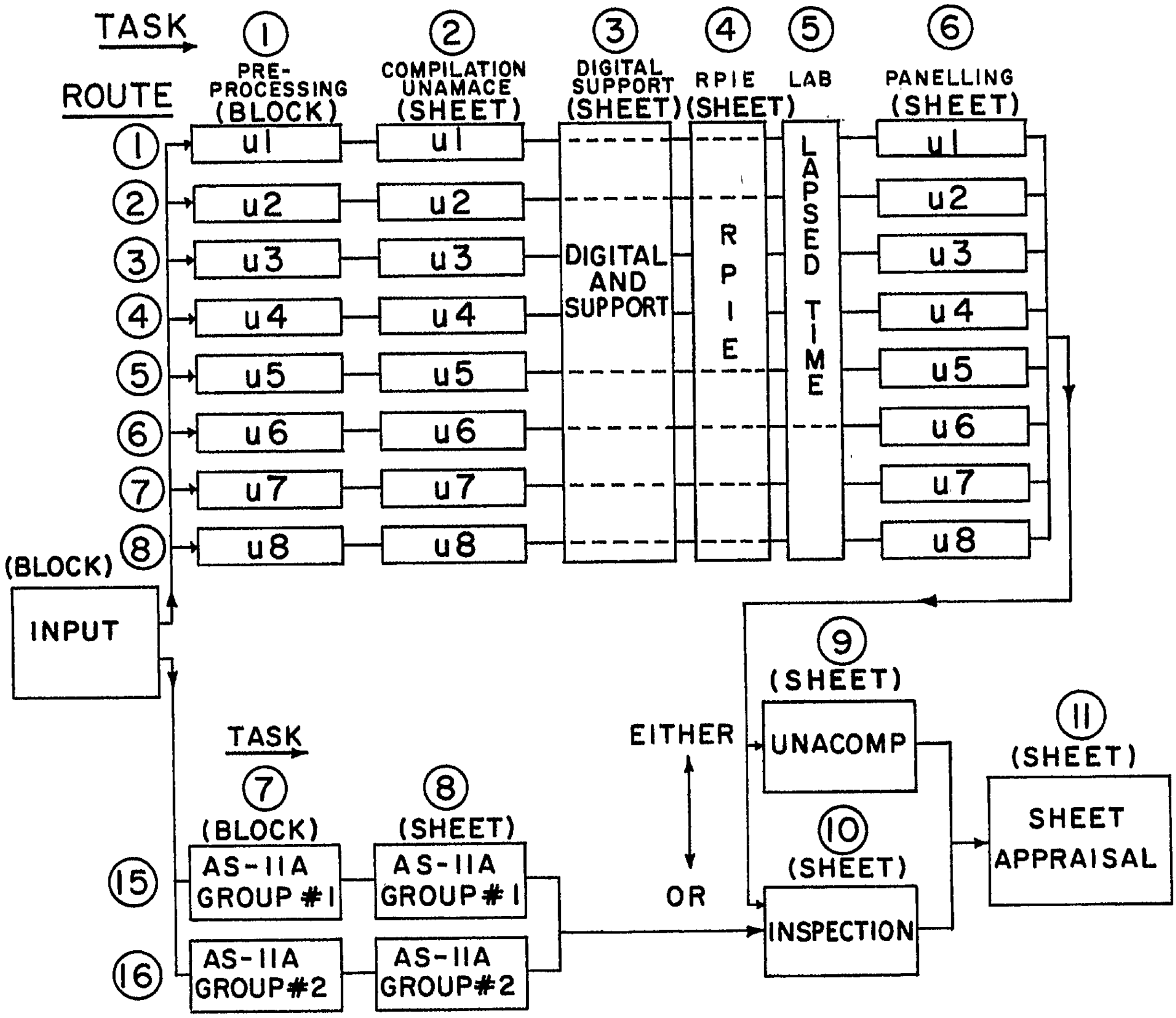
Higher priority jobs preempt lower priority jobs if the task time remaining is large; otherwise there is no preemption. Conflicts for equipment (UNAMACE or AS-11) are resolved first by job category and then by highest task number.

The amount of time to perform each task depends upon the map scale, type of map (details required), type of region or block (e.g., city or desert), etc. Almost all production jobs are standard jobs, i.e., standard with respect to map scale, map type, etc.; but special jobs can and do occur.

## 3. COMPUTERIZED PRODUCTION SCHEDULING SYSTEM DESCRIPTION

A computerized production scheduling system was designed and developed to schedule production for the production subsystem described above having the following capabilities:

(1) To produce a production schedule for a specified future time horizon given a set of available production resources and production requirements.




WORKFLOW DIAGRAM

FIGURE 2

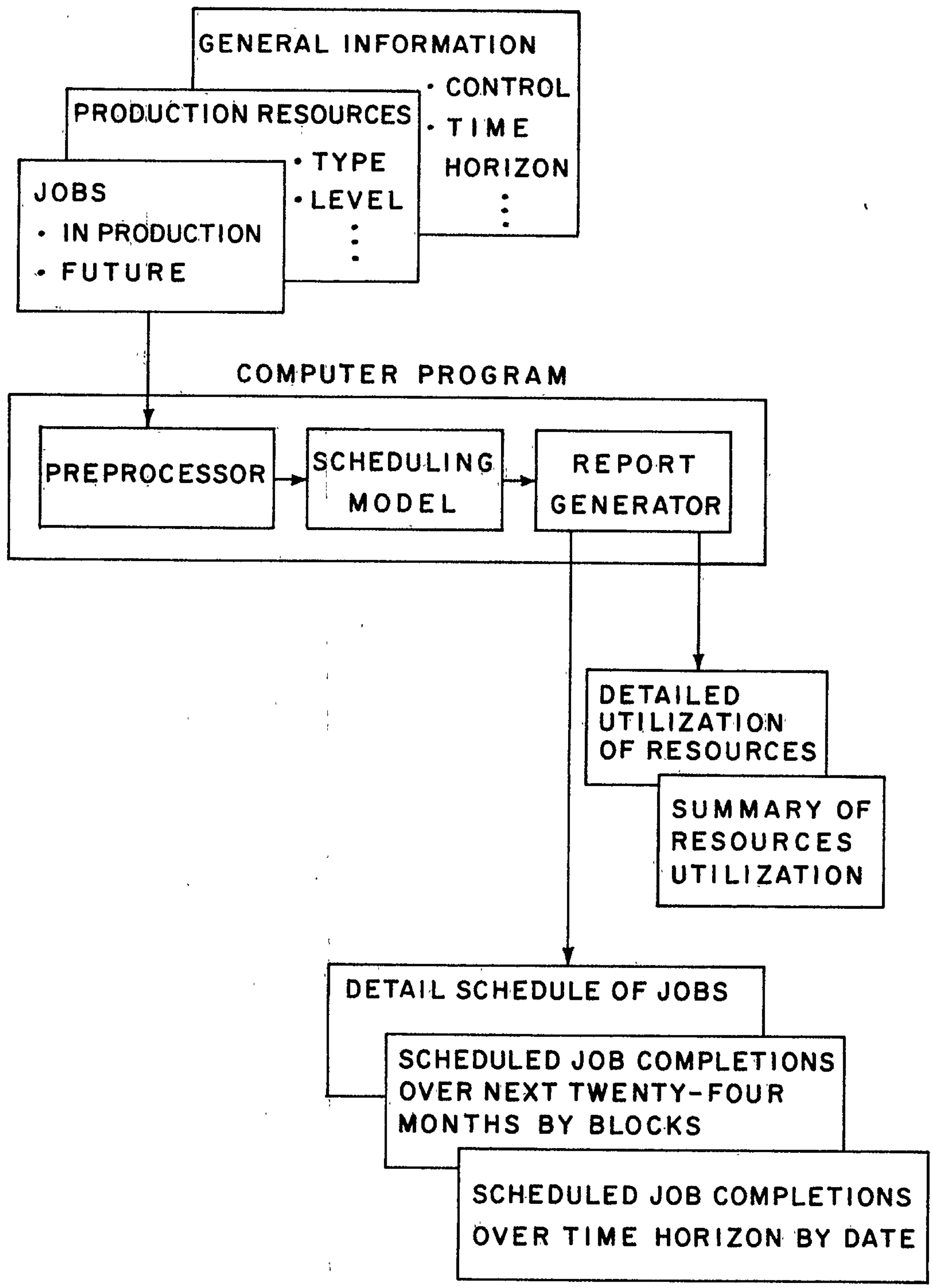
(2) To determine the impact on a production schedule for changed available production resources.

(3) To determine the impact of changes in the production requirements on the scheduled completion dates of a current schedule and on the utilization of available resources.

(4) To enable the production supervisor to evaluate and select the "best" production schedule and assignment of resources by running the computerized production scheduling system for various levels of available production requirements, including the use of overtime.

This computerized production scheduling system consists of three modules (computer programs) that are designed to execute in series as one batch computer program. The modules are a preprocessor, a scheduling model, and a report generator. For each computer run the input required consists of general information, production resources information, and job (production requirements) information, and the system's output consists of two resource utilization and three production scheduling reports. A diagram of this system is given in Fig. 3.

The production schedule obtained from each computer run of this system depends upon the three sets of information inputted into the system. The general information input includes the time horizon of the desired production schedule and the time intervals the time horizon is divided into for specifying the available production resources. The production resources information input consists of the amounts




COMPUTERIZED PRODUCTION SCHEDULING SYSTEM
FIGURE 3

of available production resources for each time interval in the time horizon. The job information input consists of information on the status of jobs in production (Job Categories I and III) and on future jobs (Job Categories II and IV), i.e., jobs that have not yet started production. Specifically, the information inputted on each future job (block) consists of its earliest possible starting date, production route or production routes allowed, job category, type of job, whether its task times are small, medium, or large (if it is a standard job, otherwise the estimated times to perform each task), and the number of map sheets in each block and for each job (block or map sheet) in production its status in addition to the appropriate information required of future jobs.

The purpose of the preprocessor is to create in each computer run a production resource data base and a job data base. The production resource data base is created from the input data with its size determined by the number of time intervals in the time horizon. Approximately twenty percent of its data entries are entered when the data base is created and the remainder are entered as the production schedule is developed by the scheduling model. The job data base is created from the input data and the task time data base contained in the preprocessor. The task time data base contains three levels (small, medium, and large) of estimated times in manhours to perform each task of all standard jobs. The size of the job data base is usually large as each map sheet scheduled can have up to fifty-five data entries. A typical production schedule for the next two years will have 600 to 1000 map sheets resulting in the job data base having up to fifty-five thousand data entries. Approximately half of job data entries are entered when the data base is created and the remainder are entered as the production schedule is developed by the scheduling model.

The scheduling model is a deterministic simulator of the production subsystem in Fig. 2 and its decision rules. This simulator is run over the time horizon of interest using information stored in the job and production resource data bases. As the simulator moves through time, the information required to create the production schedule (e.g., starting and finishing times of each task for each job) are stored in the job data base and the information required to create the resource utilization reports (e.g., utilization of the production resources and number of jobs processed by each resource during each time interval) are stored in the production resource data base. After the scheduling model has run, the report generator generates the five output reports using the data stored in the job and production resources data bases.

The resource utilization output reports consist of a detail report and a summary report. The detail report contains the utilization of each resource for each time interval and information on jobs using each resource in each time interval such as the number of jobs processed, average job waiting time, and the number of jobs waiting at the end of the time interval. The summary report summarizes the detailed report.

The production scheduling reports consist of one detailed scheduling report and two scheduled job completion reports. The detail report contains the route scheduled and the scheduled starting and finishing times of each task for each job. The scheduled job completion reports are (1) a report of all scheduled job (map sheets) completions ordered by the scheduled completion dates and the status of the jobs still in production at the end of the time horizon, and (2) a report using a format currently in use containing the jobs (map sheets) scheduled to be completed over the next twenty four (24) months ordered by block.

The computer language chosen for this computerized production scheduling system was FORTRAN. The reasons this language was selected were (1) the computer center limited all day and evening users of the computer to a small amount of main (core) storage because they ran a high degree of multiprogramming, (2) the personnel knew FORTRAN, (3) three large data bases were required, (4) available simulation languages either could not handle this problem or could not handle it under the constraints imposed by the computer center, and (5) the desirability to have efficient program execution. The data bases were stored in secondary storage and the data to be used and stored during execution were moved in sets aperiodically between main and secondary storage using a special fast Input/Output system available on this computer system. The data sets had to be designed with respect to what was needed and being generated by the scheduling model during its execution.

This computerized production scheduling system was verified and validated (Sargent 1979, 1981, Shannon 1975), by the production scheduler and one of the operations researchers working together as a team. The methodology used was (i) to initially test portions of the computerized system using a small number of jobs, (ii) to gradually increase the number and variety of jobs and production resources available until the total system was being tested, and (iii) to compare the results of an actual Quarterly Scheduling Report (QSR) developed using the manual system with one produced from the computerized system. (A QSR is a production schedule for the next two years prepared quarterly, i.e., every three months, given a set of available production resources, a set of job requirements, and status of jobs in production.) Initially, the two QSR's did not agree but the differences were traced to a different set of inputs being used. When identical inputs were used, the QSR's agreed and the computerized system was considered verified and validated.

This new scheduling system was further evaluated during its first application. At the end of six weeks, seventy-five percent (75%) of the jobs were found to be on target. The causes for the twenty-five percent (25%) that were not on schedule were found to be unforseen production delays or the production rates used were incorrect. Overall, the users were satisfied with the results.

## 4. CONCLUSIONS

A computerized production scheduling system was developed containing a deterministic simulator and large data bases for scheduling production of a large production subsystem. The computer execution time was reasonable for producing a production schedule for the next twenty four months which typically consists of a thousand jobs. The most time consuming aspect of using this new production scheduling system is determining the status of jobs in production to input into the computerized system.

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