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RESOURCES FORECASTING SYSTEM

Technological Spinoff Report

March 1974

Bendix Corporation
Kansas City, Missouri

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RESOURCES FORECASTING SYSTEM

Published March 1974

Prepared by:
J. J. Kolich
Department 742

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Prepared by J. J. Kolich, D/742

Management uses forecasting to determine the manpower, machines, material, tools, gages, test equipment, and floor space required to support current schedules and planned or contemplated production. An automated Resources Forecasting System (RFS) is now being used in a manufacturing operation involving 2400 products, representing 25,000 different parts and 175,000 production operations. The system is applied to product categories including electrical and electronic, plastics and rubber, mechanical, and electromechanical. All customer order requirements are consolidated into piece part or assembly schedules for production and procurement activities; completed piece parts and assemblies are then allocated back to customer orders on a shipment priority basis. The system is designed to accommodate multiple product definitions and changing schedule requirements. Use of RFS has reduced the time required to produce manpower and machine forecasts for budgeting exercises from 36 to 10 days, and for routine monthly forecasts from 23 to 5 days. The period which can be forecasted has been extended from 2-1/2 years to 10 years.

Atomic Energy Commission

Contract Number AT(29 1)-613 USAEC

CONTENTS

Section	Page
INTRODUCTION	5
SYSTEM FORECASTS	7
<u>Direct Manpower</u>	7
<u>Production Machines</u>	9
<u>Square Footage</u>	9
<u>Production Material</u>	14
<u>Production Tooling</u>	14
DATA BASE DEVELOPMENT.	14
<u>Schedules</u>	18
<u>Production Definition</u>	23
<u>Production Status</u>	26
FORECAST COMPUTATIONS.	28
<u>Direct Manpower, Machine Load, and Square Footage</u> . . .	28
<u>Headcount Pricing</u>	37
<u>Production Tooling</u>	37
<u>Production Material</u>	38
COMPUTERIZED SUPPORT	41
CONCLUSION	41
ACKNOWLEDGEMENT.	43

ILLUSTRATIONS

Figure		Page
1	Integrated Production Management Systems.	6
2	Standard Hour - Direct Labor Forecast	8
3	Area Direct Labor Forecast.	10
4	Department Machine Load Forecast	11
5	Engineering Machine Load Forecast	12
6	Square Footage Forecast	13
7	Incurred Material Forecast	15
8	Tooling Budget.	16
9	Resources Forecasting System	17
10	Interaction of Open Requirements, Emergency Explosion & Schedule Selection Systems	21
11	Package Rate File Status	27
12	Computation of Standard Hours	29
13	Department Labor Table.	31
14	Department Machine Code Table	36
15	Tooling Categories.	39
16	Production Material Expenditure Profile	40
17	Analysis of Computerized Support for RFS.	42

INTRODUCTION

Forecasting is an essential function performed by management to determine overall plant resources required to support authorized production schedules and planned or contemplated production. In a manufacturing operation involving a large number of products, representing many different parts and production operations for each product, manual manipulation of the data used for forecasting is complex and time consuming, and sometimes results in forecasts which are not timely or which have not considered all applicable data. Due to the continuing growth of complexity in product design and manufacturing technology it has become more and more difficult to properly evaluate the impact on plant operations and resources of changes in factors such as product schedules, product definition, manufacturing processes, operator performance, and attendance. As a result, computerized systems have played an increasingly dominant role in support of forecasting activities, and by evolutionary development have obtained a level of sophistication and use currently reflected by the Resources Forecasting System (RFS).

The level of automated systems integration currently embodied in the RFS represents an overall effort spanning the past ten years characterized by continued systems upgrading, new capability development and the integration of independent functional data bases to serve both specific and overall plant operating needs. Although the computer has been widely used throughout the plant, it has now become an intrinsic part of production requirement activities due to continued management guidance in the identification of system development priorities and in the overall allocation of ADP resources.

Figure 1 portrays an overview of the computerized Production Management function; the illustration generally excludes automation in areas such as Personnel, Engineering, Quality, Facilities Management, and Accounting. Essential production data related to product definition and processing, orders, and other factors are processed by integrated computer systems which automatically develop production and procurement schedules, schedule load center operations, and maintain production status and material inventory data. RFS manipulates this basic production data, along with additional, specific forecast data to create a forecast data base which is then used for forecast computations.

The RFS concept is embodied by an integrated network of computerized systems and manual functions which, ultimately, selects the best production definition available, correlates this definition against a variety of requirements and schedules, and provides the information in both detail and summary form. Because

Figure 1. Integrated Production Management Systems

RFS design philosophy and guidance provided by management stress the maximum use of automation and detail data to ensure the highest degree of timeliness and accuracy in computing forecasts, operating departments are required to provide the system with planning data related to the definition and processing of anticipated product. This data was not previously available in computer files and therefore limited computerized forecasting to authorized production for defined products only. The availability of this data allows for detailed, fully automatic computations of resource requirements for both authorized and anticipated production for periods of up to ten years.

System components providing specific new capabilities were implemented in phases as part of a specific RFS effort spanning 2-1/2 years. Concurrently, existing systems were upgraded and interfaced as required to satisfy overall RFS design requirements. Among other capabilities, RFS automatically computes forecasts of direct manpower, machine loads, square footage, material costs, and tooling costs associated with overall plant operations. The remainder of this article describes these forecasts and the methods used to develop them.

SYSTEM FORECASTS

Direct Manpower

Figure 2 illustrates the forecast of direct manpower required to support production schedules by department, production program, and part number. The forecast identifies standard hours required for firm order, planning, and budget assumption schedules by month and year up to a maximum of ten years. Production program and department summaries are provided for forecasted standard hours and direct labor.

The information within Section 1 of Figure 2 represents standard hours by schedule type within part number within production program. It includes both defined (1.A) and undefined (1.B) parts. Section 2 includes standard hours by schedule type, summarized for all part numbers within the program. The example bracketed by (2.A) identifies the total standard hours forecasted for a defined and an undefined part based on their Budget Assumption (B/A) schedules for October, Fiscal Year 1973.

Section 3 illustrates standard hours converted to men (using a 0.25 factor; see *Forecast Computations*) by schedule type within production program. Sections 4 and 5 represent a summary of all standard hours and men, respectively, for all programs within the department by schedule type.

STANDARD HOUR - DIRECT LABOR FORECAST														SCHEDULE CUTOFF DATE 9-14-71	
DEPT 026	FY	PD	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	
PGM 777															
123456-101 (1A)															
REL-HRS	71	694			1000	1000	500								
FO-HRS	71	694			1000	1000	1000	1200	1200	1400	1400	1400	1400	1200	
	72		1200	1200	1200	1200	1200	1000	1000						
PL-HRS	72						500	500	500	500	500	500	500	500	
	73		500	1000	1000										
BA-HRS	73					1000	1000	1000	1000	1000	1000	1000	1000	1000	
	74		1000	1000	1000	1000									
234567-102 (1B) PKG SUMMARY															
BA-HRS	73			200	200	200	200	200	200	200	200	200	200	200	
	74		200	200	200										
PGM 777 STD-HRS (2A)															
REL-HRS	71	694			1000	1000	500								
FO-HRS	71	694			1000	1000	1000	1200	1200	1400	1400	1400	1400	1400	
	72		200	1200	1200	1200	1200	1000	1000						
PL-HRS	72						500	500	500	500	500	500	500	500	
	73		500	1000	1000										
BA-HRS	73			200	200	1200	1200	1200	1200	1200	1200	1200	1200	1200	
	74		200	1200	1200	1000									
PGM 777 DIRECT LABOR															
REL-MEN	71	17.35			25.00	25.00	12.50								
FO-MEN	71	17.35			25.00	25.00	25.00	30.00	30.00	35.00	35.00	35.00	35.00	35.00	
	72		30.00	30.00	30.00	25.00	25.00								
PL-MEN	72						12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50	
	73		12.50	25.00	25.00										
BA-MEN	73			5.00	5.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	
	74		30.00	30.00	30.00	25.00									
DEPT 026 STD-HRS (4)															
REL-HRS	71	1244			2600	2400	2200	550							
FO-HRS	71	1244			2600	2600	2600	2800	2800	2500	2500	2500	2500	2300	
	72		2300	2300	2300	2200	2200	2000	2000	1000	1000	1000	1000	1000	
	73		500	500	500										
PL-HRS	72						500	500	500	1000	1000	1000	1000	500	
	73		1000	1500	1500	500	500	500	500	500	500	500	500	500	
BA-HRS	73			200	200	1200	1200	1200	1000	1500	1500	1500	1500	1500	
	74		1500	1500	1500	1500									
D/26 DIRECT LABOR (5)															
REL-MEN	71	31.10			65.00	60.00	55.00	13.75							
FO-MEN	71	31.10			65.00	65.00	65.00	70.00	70.00	62.50	62.50	62.50	62.50	57.50	
	72		57.50	57.50	57.50	55.00	55.00	50.00	50.00	25.00	25.00	25.00	25.00	25.00	
	73		12.50	12.50	12.50										
PL-MEN	72						12.50	12.50	12.50	25.00	25.00	25.00	25.00	12.50	
	73		37.50	37.50	37.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50	
BA-MEN	73			5.00	5.00	30.00	30.00	30.00	25.00	37.50	37.50	37.50	37.50	37.50	
	74		37.50	37.50	37.50	37.50									

Figure 2. Standard Hour - Direct Labor Forecast

Labor forecasts by standard hours and man are also provided for designated manufacturing areas such as Machining, Rubber and Plastics, Printed Circuits, and Mechanical and Electrical Assembly. Figure 3 illustrates a forecast for the Rubber and Plastics area which shows direct men required for normal production activities (1), plus additional requirements to support special activities such as Engineering Projects and Process Development (2). Total men required for each manufacturing area are then summarized (3).

Production Machines

Normal machine load forecasts used for budgeting and general planning are created for each machine within a department and contain standard hours for Firm Order, Planning, and Budget Assumption schedules by month for a maximum of 10 years by part number within production programs. Total requirements are accumulated for each type of machine in the department and displayed along with the number of each type available and their net capacities. Overload conditions are reported on an exception report and identified by type of machine and department. A normal department machine load forecast is shown in Figure 4.

A special Machine Load Forecast is created for engineering and is illustrated in Figure 5. This report combines schedule types (Firm Order, Planning, and Budget Assumption) and forecasts requirements by quarters and fiscal years for a maximum of 10 years. It highlights overload conditions by machine and schedule period within each department, and supports evaluation of possible alternative processing to meet specific part schedules. The forecast shows that machine A111 (1) has requirements (2) which exceed its net capacity (3) until the third quarter of 1972. (Computation of net capacity is explained under *Forecast Computations*.)

Square Footage

Figure 6 illustrates square footage requirements forecasted by part number within production program within department for all schedule quantities for a time period up to a maximum of 10 years.

The requirements are not for machine space but for "leg and elbow" room for the operator, and for additional benches, tables, and other furniture required to perform the operation. (Factors and computation are explained later.) Additional space requirements for machines currently installed within or projected for a department are manually developed and added to computed square feet to provide a forecast of total square footage requirements.

Text continued on page 14.

AREA DIRECT LABOR FORECAST												SCHEDULE CUTOFF DATE 9-14-71			
	FY	PD	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	
RUBBER AND PLASTICS															
①	FO-MEN	71	23.95			61.30	61.30	61.30	66.30	66.30	61.30	61.30	61.30	61.30	
		72		66.30	66.30	66.30	63.30	63.00	58.00	58.00	33.00	33.00	33.00	33.00	
	73	16.50		16.50	16.50										
	PL-MEN	72					21.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50	
		73		29.00	41.50	41.50	16.50	16.50	16.50	16.50	16.50	12.50	12.50	12.50	
	BA-MEN	73			5.00	5.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00
		74		46.50	46.50	46.50	41.50								
OFF SCHEDULE 300	71				9	9	9	9	9	9	9	9	9	9	
	72		9	9	9	9	9	9	9	9	9	9	9	9	
	73		9	9	9	9	9	9	9	9	9	9	9	9	
	74		9	9	9	9	9	9	9	9	9	9	9	9	
②	ENGR PROJECT	71			39	39	39	39	39	39	39	39	39	39	
		72	39	39	39	39	39	39	39	39	39	39	39	39	
		73	39	39	39	39	39	39	39	39	39	39	39	39	
		74	39	39	39	39	39	39	39	39	39	39	39	39	
	PROCESS DEVELOPMENT	71			19	19	19	19	19	19	19	19	19	19	
		72	19	19	19	19	19	19	19	19	19	19	19	19	
		73	19	19	19	19	19	19	19	19	19	19	19	19	
		74	19	19	19	19	19	19	19	19	19	19	19	19	
	NON-STANDARD DEPT	71			5	5	5	5	5	5	5	5	5	5	
		72	5	5	5	5	5	5	5	5	5	5	5	5	
		73	5	5	5	5	5	5	5	5	5	5	5	5	
		74	5	5	5	5	5	5	5	5	5	5	5	5	
RUBBER AND PLASTICS TOTAL DIRECT LABOR															
③		71	23.95			133.30	133.30	133.30	138.30	138.30	133.30	133.30	133.30	133.30	
		72		138.30	138.30	138.30	135.00	147.50	142.50	142.50	117.50	117.50	117.50	117.50	
		73		117.50	135.00	135.00	118.50	118.50	118.50	118.50	102.00	102.00	102.00	102.00	
		74		118.50	118.50	118.50	113.50	72.00	72.00	72.00	72.00	72.00	72.00	72.00	

Figure 3. Area Direct Labor Forecast

DEPARTMENT MACHINE LOAD FORECAST										SCHEDULE CUTOFF DATE 9-14-71					
DEPT 026	FY	FD	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	
MACH-CD A111 PGM 777															
123456-101	FO 72	2.263			1.560	1.560	1.560	1.560	1.560	1.560	1.560	1.560	1.560	1.560	
	73		1.560	1.560	1.560	1.560	1.560	1.560	1.560						
	74		1.560	1.560	1.560	1.560	1.560	1.560	1.560						
	PL 73						1.560	1.560	1.560	1.560	1.560	1.560	1.560	1.560	
	74		1.560	1.560	1.560		1.560	1.560	1.560	1.560	1.560	1.560	1.560	1.560	
	BA 74					1.560	1.560	1.560	1.560	1.560	1.560	1.560	1.560	1.560	
	75		1.560	1.560	1.560	1.560									
234567-101	FO 72	1.977			1.120	1.120	.353	.353	.152	.152					
	PL 73										.152	.152	.152	.152	
654321-101	BA 75				.005	.005	.005	.002	.002	.002					
PGM 777 TOTAL															
	FO 72	4.240			2.680	2.680	1.913	1.913	1.913	1.913	1.560	1.560	1.560	1.560	
	PL 73						1.560	1.560	1.560	1.560	1.712	1.712	1.712	1.712	
	74		1.560	1.560	1.560										
	BA 74					1.560	1.560	1.560	1.560	1.560	1.560	1.560	1.560	1.560	
	75		1.560	1.560	1.565	1.565	.005	.002	.002	.002					
MACH-CD A111 PGM 999															
123456-101	FO 72	.333			.333	.333	.030	.030	.030	.004	.004	.004	.004	.004	
	73		.004												
	PL 73			.004	.004	.200	.200								
234567-102	PL 74		.152	.152	.152	.152	.152								
567890-103	FO 72	.850			1.000	1.000	1.000	1.000	1.000						
654321-101	BA 75							.005	.005	.005	.005	.005			
799012-111	FO 72	.250			.500	.500	.500	.450	.450	.450	.450				
PGM 999 TOTAL															
	FO 72	1.433			1.833	1.833	1.530	1.480	1.454	1.454	.454	.004	.004	.004	
	73		.004												
	PL 73			.004	.004	.200	.200								
	74		.152	.152	.152	.152	.152								
	BA 75							.005	.005	.005	.005	.005			
MACH CD A111 NO-MACH 4 NET-CAPACITY-300-PROD 3.400 K-FACTOR .0050 DAY 5 SHIFT 2 300-PCT 70 OTHER-PCT 15 SU-MAINT-FCT 15 EFF-PCT 60															
	72	5.673			4.513	4.513	3.443	3.393	3.393	3.367	2.014	1.564	1.564	1.564	
	73		1.564	1.564	1.564	1.760	3.320	3.120	3.120	1.560	1.712	1.712	1.712	1.712	
	74		1.712	1.712	1.712	1.712	1.712	1.560	1.560	1.560	1.560	1.560	1.560	1.560	
	75		1.560	1.560	1.565	1.565	.005	.007	.007	.007	.005	.005			

Figure 4. Department Machine Load Forecast

ENGINEERING MACHINE LOAD FORECAST DEPT 26										SCHEDULE CUTOFF DATE 9-14-71									
MACH-CD	NO-MACH	NET-CAPACITY-300-PRCD			K-FACTOR	DAY	SHIFT	300-PCT	OTHER-PCT	SU-MAINT-PCT	EFF-PCT								
A111	4	3.400 ③			.0050	5	2	70	15	15	60								
PGM 77		PD	1-72	2-72	3-72	4-72	1-73	2-73	3-73	4-73	1-74	2-74	74	75	76	77	78	79	
123456-101		2.263	1.560	1.560	1.560	1.560	1.560	2.600	2.080	1.560	1.560	1.560	1.56	.52					
234567-102		1.977	1.120	.608	.068				.050	.152									
654321-101																			
PGM 777 TOTAL		4.240	2.680	2.168	1.628	1.560	1.560	2.600	2.130	1.712	1.560	1.560	1.56	.52					
PGM 999		PD	1-72	2-72	3-72	4-72	1-73	2-73	3-73	4-73	1-74	2-74	74	75	76	77	78	79	
123456-101		.333	.333	.131	.012	.004	.004	.133											
234567-102											.152	.101							
567890-103		.850	1.000	1.000	.666														
654321-101																			
789012-111		.250	.500	.483	.450														
PGM 999 TOTAL		1.433	1.833	1.614	1.128	.004	.004	.133			.152	.101							
CODE A111 ①		PD	1-72	2-72	3-72	4-72	1-73	2-73	3-73	4-73	1-74	2-74	74	75	76	77	78	79	
GRAND TOTAL		② 5.673 4.513 3.782			2.756	1.564	1.564	2.733	2.130	1.712	1.712	1.661	1.56	.52					
REMAINDER		1.113- .382-			.644	1.836	1.836	.667	1.270	1.688	1.698	1.739	1.84	2.88					

Figure 5. Engineering Machine Load Forecast

DEPT 55		SQ-FT-FACTOR			SHIFT-RATIO			DEPT-EFFIC											
		125			60			50											
PGM	777	PD	2Q72	3Q72	4Q72	1Q73	2Q73	3Q73	4Q73	1Q74	2Q74	3Q74	4Q74	1Q75	3AL75	FY75	FY76	FY77	FY78
	123456-101	19752	19700	19700	10000	10000	10000	5000	5000										
	234567-101	363	350	350	300	300	300	300	300	300	300								
	456789-101							10000	10000	5000	5000	3000	3000	3000	4000	4000	4000	4000	4000
PGM	777 TOTAL	20120	20050	20050	10300	10300	10300	15300	15300	5300	5300	3000	3000	3000	4000	4000	4000	4000	4000
PGM	999																		
	123456-101	3000	2000	2000	2000	3000	3000												
	678901-111			200	200	200	200	200	200										
	789012-103										5000	5000	5000	5000	6000	6000	6000	6000	6000
PGM	999 TOTAL	3000	2000	2200	2200	3200	3200	200	200		5000	5000	5000	5000	6000	6000	6000	6000	6000
OS	300	50	50	50	50	50	50	50	50	50	50	50	50	50	200	200	200	200	200
DEPT 55																			
GRAND TOTAL		23170	22100	22300	12550	13550	13550	15550	15550	5350	10350	8050	8050	5050	6200	6200	6200	6200	6200

Figure 6. Square Footage Forecast

Production Material

Figure 7 illustrates a forecast of incurred production material dollars identified by schedule type (SCD) and production category (CAT) within production program (PGM). The estimates, which are phased by month and fiscal year, are summarized at the bottom of the report to reflect total dollar requirements for each production category within a program, and for each program. The codes under CAT are used to identify production categories such as pilot production, new production, material returned by customer for repair or modification, and others. Computation and phasing of dollar estimates are described later.

Production Tooling

Estimates of tooling costs are provided by major component within production program and then summarized to reflect overall plant totals. Figure 8 illustrates the last page of a report containing an approved tooling budget for a specific production program (1) and the plant totals for all programs (2). Totals are provided by quarters for 2 years and by yearly totals for an additional 5 years. Budget figures are further broken down by designated tooling categories (3) such as Production Tools, Gages, Test Equipment, and Vendor-Supplied Tools.

DATA BASE DEVELOPMENT

The basic operational structure of RFS consists of a network (Figure 9) of manual functions integrated with automated component systems and files, each of which serves a specific functional organization. Information flow through the network is achieved by the interchange of data across functional organizational boundaries and the hierarchical buildup of computer systems, some of which collect and maintain specific operation data while others subsequently retrieve, analyze, and report desired information.

Because certain events may occur daily, weekly, monthly, or aperiodically, depending upon the specific function being performed, the network does not represent a dependent series of activities which occur non-stop from start to finish in a discrete time frame. The forecast cycle may vary from overnight to 10 days or more, due mainly to the manual effort that may be required prior to the start of automated computations to load and adjust a forecast data base.

Each exercise has a unique cut-off date which identifies the beginning of the forecast period. Production status as of that date is automatically captured from production control files onto

Text continued on page 18.

INCURRED MATERIAL FORECAST BY PROGRAM BY MONTH
IN THOUSANDS
FOR RECORD TYPE DEH

Nov. 15, 1973

CATEGORY WITHIN PROGRAM SEQ FOR FY 1974

PGM	CAT	SCD	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	TOTAL
P26	A	FO PL	2	*	2	1	3	2	2	1	13 1
	U	FO PL	32	29	30	34	31	36	29 1	42	262 1
	X	FO	189	187	169	163	159	143	126	87	1222
	4	FO PL	3	*	8	6 *	8	6	12 *	29 *	72 *
	5	FO	10	11	11	22	17	20	21	37	149
P26 TOTAL		FO	236	227	219	227	217	207	190	196	1718
P26 TOTAL		PL				*			2	*	2
P26	A		2	*	2	1	3	2	3	1	14
P26	U		32	29	30	34	31	36	29	42	263
P26	X		189	187	169	163	159	143	126	87	1222
P26	4		3	*	8	6	8	6	12	29	72
P26	5		10	11	11	22	17	20	21	37	149
TOTAL PGM P26			236	227	219	227	217	207	191	196	1720

Figure 7. Incurred Material Forecast

SEP. 12, 1973																	
TOOLING BUDGET - SUMMARY ALL PROGRAMS																	
PROGRAM...	TL	FY-74	FY-74	FY-74	FY-74	FY-74	FY-75	FY-75	FY-75	FY-75	FY-75	FY-76	FY-77	FY-78	FY-79	FY-80	TOTAL
CAT	QTR-1	QTR-2	QTR-3	QTR-4	TOTAL	QTR-1	QTR-2	QTR-3	QTR-4	TOTAL	TOTAL	TOTAL	TOTAL	TOTAL	TOTAL	TOTAL	ALL-FY
1	0	0	0	0	0	0	924200	0	0	0	924200	1353900	116600	0	0	0	2394700
2	0	0	0	0	0	0	20500	0	0	0	20500	132000	27000	0	0	0	179500
3	0	20000	80000	255000	355000	2274000	0	0	0	2274000	1902300	721500	0	0	0	0	5252800
4	0	0	0	0	0	256900	0	0	0	256900	236000	55000	0	0	0	0	547900
TL	0	20000	80000	255000	355000	3475600	0	0	0	3475600	3624200	920100	0	0	0	0	8374900
TOTAL ALL PROGRAMS																	
TL	FY-74	FY-74	FY-74	FY-74	FY-74	FY-75	FY-75	FY-75	FY-75	FY-75	FY-76	FY-77	FY-78	FY-79	FY-80	TOTAL	
CAT	QTR-1	QTR-2	QTR-3	QTR-4	TOTAL	QTR-1	QTR-2	QTR-3	QTR-4	TOTAL	TOTAL	TOTAL	TOTAL	TOTAL	TOTAL	ALL-FY	
1	412118	88125	228350	301990	1030583	1853380	315260	336440	662590	3167670	2599340	2759800	1307400	59200	48000	10971993	
2	143722	36625	68350	73790	322487	337480	72460	58940	320740	789620	795640	1089300	389800	39000	0	3425847	
3	1197799	485300	523300	631300	2837699	3347200	95000	54000	260300	3756500	3890100	3311100	768100	3000	0	14566499	
4	215028	29200	77100	61100	382428	927300	10500	12800	36100	986700	1742200	691100	92100	0	0	3894528	
TL	1968667	639250	897100	1068180	4573197	6465360	493220	462180	1279730	8700490	9027280	7851300	2557400	101200	48000	32858867	

Figure 8. Tooling Budget

Figure 9. Resources Forecasting System

provisional forecasting files. This allows the production files to continue in their support of daily operations while the provisional files are being synchronized in preparation for data base development. The data base essentially contains forecast schedules, resource estimates developed from product definitions, and the status of work in process. These elements and their development are described, in order, in the remainder of this section.

Schedules

Order Files

Production schedules and forecast schedules are contained in separate files maintained by the Customer Order (CO) system and the Production Budget Master (PBM) system respectively; for purposes of this article, references to *Order Files* may include either or both of these files.

Reviewing, loading, and adjusting schedules are initial activities in the forecast cycle and require a major portion of the overall amount of time and manual effort to be expended. Forecast requirements are normally provided to the system by the Atomic Energy Commission (AEC) and General Management in the form of product ship schedules rather than projected sales based on a market survey. Separate schedules are identified for each product type and maintained in the Order Files. These schedules include dated quantities for up to 10 years and are identified by schedule types as shown below.

- Firm Order (FO)--Authorized to build and procure material, normally 18 to 24 months.
- Planning (PL)--Short range planning, reasonably firm for up to 30 months.
- Budget Assumption (B/A)--Long Range planning only up to 10 years maximum.
- Impact and Capability Studies (I & C)--Used only for assessing impact of potential future production on existing resources and facilities.

The file may contain and store multiple sets of schedules which may consist of any combination of the above schedule types. Upon receipt of schedule options and the cut-off date from management, the Schedule Selection system and the Emergency Explosion system (EE) correlate the designated base schedules with the consolidated net production/procurement schedules provided by the Open Requirements system and automatically generate the necessary forecast base.

In order to understand the respective functions and interactions of these three systems, it is first necessary to understand certain factors which govern current plant operations.

Orders are received for different product types which use some common parts. This generates production/procurement requirements for items designated as multiple-use parts. For greater efficiency in manufacturing and storage operations, firm order requirements for multiple-use parts are consolidated and developed by the Open Requirements system into production/procurement schedules. This consolidation destroys all direct linkages associating individual part requirements with their originating orders. As a result, material is released for production in the form of job lot quantities. Completed parts are then maintained on inventory records and stored in bins identified simply by part number rather than being physically separated and allocated to specific orders. Therefore, in order to satisfy forecasting requirements, the Schedule Selection system and Emergency Explosion interact to provide the capability to apportion individual, firm order part requirements back to their originating sources.

Open Requirements System

Open Requirements is primarily a Production Management system which functions on a weekly basis independently of planning and forecasting systems. Its capability to develop netted schedules to reflect requirements for the scheduling of production/procurement activities is essential to the development of the firm order portion of the forecast base. The computerized, logical development of this portion is outlined on the left side in Figure 10. Ship level requirements are initially provided to the system in two ways: automatically through the Order File, and manually by production schedulers in the form of miscellaneous orders. By subsequent automated analysis of the Bill of Material (BOM), Next Assembly Requirements, and the Part Specifications (SPEC) files, additional data related to component parts, next assembly usages, and production flow times is retrieved and used to redevelop (Explode) and consolidate piece part requirements resulting in gross requirement schedules by individual part numbers. (At this point, linkage to originating sources has been destroyed.)

In order to provide an accurate reference base for any calculations, these schedules contain a complete production history spanning the life cycle of the part. In addition to cumulative, total firm order requirements, the history includes cumulative lump sum quantities for product shipped, contained in next assemblies, and used miscellaneous *prior* to the cut-off date, and for remaining firm order schedules by quantities and dates subsequent to the cut-off date. Thus, the essential first step

in developing net build schedules is to reduce the gross requirements schedules by the lump sum quantities referenced above to properly reflect previously satisfied requirements. The result is a gross open schedule (A) which is further developed by the Open Requirements system during its weekly run to support routine Production Management operations. (During forecasting exercises, a similar gross open schedule is redeveloped by the Emergency Explosion process but contains only the designated schedules, identified by product type, required for the specific forecast. See *Emergency Explosion*.)

Any additional schedule adjustments, manually input to reflect management's staffing and production intentions, are then processed. The adjusted schedule is correlated against inventory records and reduced appropriately, resulting in a net *to stores* schedule. This schedule is then factored automatically by a pre-planned attrition percentage developed from production experience, and then is reduced by scrap quantities resulting in a net *attrition* schedule. This schedule is added to the net *to stores* schedule resulting in the ultimate net *build* schedules (B) which are to be used primarily for production and procurement activities. During forecast exercises, this same schedule is used directly by EE in developing the forecast base. The net result of the above adjustments has been to reduce gross requirements by satisfied requirements (completions) for which all labor and material has been expended, thereby minimizing duplicate requirements. Relief for partially completed product occurs later in the system cycle and is discussed under *Job System*.

Schedule Selection System

The basic function of the Schedule Selection System is to pre-process forecast schedule data for subsequent use by the Emergency Explosion system (Figure 10). Upon receipt of ship level schedule options and adjustments, the system retrieves the required schedules from the Order Files, scopes them to correspond to the forecast time frame, and redistributes certain quantities within the time frame, as directed by adjustments, to minimize peak and valley conditions. These schedules are then correlated against the Package Rate system (see *Package Rate*) to determine the availability of product definition. Schedule types (FO, PL, and B/A) are interpreted for both defined and undefined product schedules to determine which subsequent processing capabilities will be required.

At this point, the Schedule Selection system passes to the Emergency Explosion system ship level schedules for defined product, identified by product type and schedule type, scoped and adjusted for the forecast period. Because these schedules contain complete production histories for any active parts

Figure 10. Interaction of Open Requirements, Emergency Explosion & Schedule Selection Systems

involved, the Emergency Explosion system will adjust them for previously satisfied requirements to establish a calculation base and will then process remaining schedules. Schedules for undefined product are passed directly to output files for subsequent merging into the forecast base.

Emergency Explosion System*

The Emergency Explosion System supports various information needs of many functional organizations such as Production Management, Purchasing, Accounting, and Planning and Budgets. Although it is similar to the Open Requirements weekly explosion in that it can develop requirement schedules from the order level or any given level in the Bill of Material (BOM) chain, it does not consolidate the developed part schedules for production economies and therefore maintains order, product type, and other identifiers which provide linkage to originating sources. This specific capability is required to determine the impact of certain actions to a part and its components, such as a cancellation order or an engineering change. During forecast exercises, and specifically for multiple-use parts, this capability is used in conjunction with a ratio to apply exact portions of requirements, relief, and attrition to their originating source. The system will perform optional variations of this capability based on the specific data passed to it from the Schedule Selection system.

Only FO schedules require relief and allocation processing because they represent product which may have had production activity. PL and B/A ship schedules for defined product will be exploded to develop part number schedules which are then factored by part number attrition percentage and time phased to reflect production lead times.

Firm Order schedules for defined product will be fully exploded to develop part number requirements resulting in a gross open FO schedule (C) Figure 10. This schedule is similar to schedule (A) developed by Open Requirements, but it must be redeveloped by Emergency Explosion because of the following characteristics of schedule (C).

- It contains only designated forecast schedules.
- It includes product type identity.
- It provides a starting position for allocation and relief.

*"Emergency Explosion" does not imply a physical emergency. It is a system which develops requirements for selected parts and their components.

- It relieves the Open Requirements system from storing and handling large volumes of records and data not required for its routine weekly processing, thus making it more economical in terms of storage space and processing time required.

To obtain the Net FO schedule base (X), Emergency Explosion relieves and allocates schedule (C) by using the following ratio:

$$\frac{(B) \text{ Net (Part Number) Prod/Procure}}{(A) \text{ Gross (Part Number) Open}} = \frac{(X) \text{ Net (Product Type) Prod/Procure}}{(C) \text{ Gross (Product Type) Open}}$$

Emergency Explosion develops schedules (A) and (C) and receives schedule (B) from the Open Requirements system. During actual processing, the Emergency Explosion system selects from schedule (B) only those schedules which match the designated forecast schedules. In the following example, for ease of illustration, the forecast schedules include all production schedules.

$$\begin{array}{rcl} & \text{Schedule A} & = 60 \\ \text{Inventory and Adjustments} & & -32 \\ & \text{Attrition} & +2 \\ & \text{Schedule B} & = \underline{30} \end{array}$$

Product Type	Schedule C (Open)	(C X B)/A	= X
1	30	(30 X 30)/60	= 15
2	20	(20 X 30)/60	= 10
3	10	(10 X 30)/60	= 5

The resultant piece-part schedules developed for defined product by the Emergency Explosion and the ship level schedules for undefined product obtained from the Schedule Selection process are then combined by the use of special programs and standard sort/merge routines to produce the forecast base.

Production Definition

Defined Product

Forecast data for defined product is obtained from three basic computer files used primarily to support production operations. The Bill of Material (BOM) contains next assembly and component part numbers and usages. The Part Specification (SPEC) file contains part descriptions, units of measure, manufacturing flow times, and other general part number data. The Manufacturing

Operations Master Record (MOMR) contains the sequence of steps required to produce a part or an assembly from its direct (first level) components. These steps are identified by operation number and include production department, machine code, and standard hours. As described previously, the BOM and SPEC files are used to develop part schedules. In addition, the SPEC and the MOMR files are used to extend part schedules into part operation schedules. This establishes a gross part number requirements base, by production operation, which is then relieved of labor and material already expended on partially completed product.

Undefined/Partially-Defined Product

The Advance Data File (ADF) and the Package Rate system (PKG-RT) provide the basic capability to handle defined or undefined product. The ADF system is used primarily during the early, conceptual stages of new product and has minimum automated interfaces with other RFS component systems, whereas the PKG-RT system is essentially a highly integrated computerized link encompassing the definition spectrum from fully defined parts in production to new product definitions contained within ADF. The specific capabilities and functions of each system are treated below.

The Advance Data File (ADF) is a system designed to collect, store, correlate, summarize, and distribute *preliminary* technical definitions and cost estimates for new products. This data is treated as advance planning information only and is not maintained at a level of detail or accuracy suitable for production files. Therefore, ADF is used chiefly by Engineering to file and retrieve previous budget estimates. Methods Engineering interprets information supplied by ADF and manually loads the PKG-RT system with data available for product included in specific forecasts.

Data maintained in the system's single file is provided by many functional organizations (Figure 9) and is similar to data found in many production files. Essentially, it includes component parts and their specifications; manufacturing operations and processing, including standard hours, machine codes, and cycle times; inspection operations; tooling, material, and acceptance equipment cost estimates; facilities estimates (square footage); production and procurement lead times; engineering assignments; and a schedule of departmental events depicting selected milestones leading to production.

Tooling cost estimates contained in ADF are identified by tool, piece part, and required date. Preliminary tooling budgets are prepared by summarizing the detail estimates and by reporting tool cost estimates by ship item (cost control entity), tooling category, part number, and tool. These estimates are automatically time phased by fiscal year quarters for 2 years and

yearly totals for an additional 5 years. (Tooling categories and phasing are discussed later.)

These estimates are then reviewed and adjusted as necessary and submitted to the Tool Cost Monitor (TCM) system for subsequent monitoring and reporting of actual costs versus estimates.

The Package Rate (PKG-RT) system develops and maintains resource estimates for products which have only conceptual or partially completed technical definition. In contrast to resource data for defined product, which is available from multiple production files and maintained at the component, piece-part level, the estimates developed by the PKG-RT system are summarized at the ship item level and maintained, along with other general data, in a single Package Rate File. This expands the computerized resource base and establishes a capability to automatically compute forecasts for all product, regardless of level of definition.

The Package Rate File used in computing forecasts contains, in addition to ship item resource summaries, the status of definition for all ship items in the forecast. This status information is used to determine specific processing required by the Schedule Selection and EE systems. The file is developed by iterative loading and adjusting activities described below.

The ship item schedules retrieved from the Order Files are correlated with production files by the PKG-RT system to determine the amount of definition available. Definition for a ship item is considered complete only if all its component parts are established and their respective flow times, material costs, and standard hours by operation are available. After all ship items have been reviewed, Methods Engineering is notified of product with both complete and incomplete definition. For product with incomplete definition, Methods Engineering may pursue the following alternatives.

- After evaluating the amount of definition available, they may declare it suitable for the specific forecast exercise and submit an override indicator to the system. During computation, the system will treat it as defined product.
- Available definition may be supplemented with manually fed resource estimates or a Lookalike (L/A) concept may be used which enables description of anticipated product in terms of current or past products. The L/A concept allows new product to be described by one or more L/A part numbers for which production data exists. If desired, each L/A part number's respective data may be adjusted by complexity factors for both labor and material. The PKG-RT system then automatically retrieves L/A part number data from production files, factors it if required, and summarizes it into ship item estimates.

Figure 11 illustrates resource estimates contained in the final Package Rate File for an anticipated ship item identified by 17600001-00 (1). The total estimates for material price (2) and standard hours (3) were summarized from detail information provided by each of the six L/A part numbers (4) which were determined to collectively provide the most representative amount of resources required to produce one unit. The complexity factors for labor (5) indicate that the standard hours to produce 357542-107 and 1440103-005 should be multiplied by 1.5 and 2.0 respectively. Item (6) indicates, in work days, the longest expected production flow time and the expected procurement time for purchased items. The production flow time figure is required in formulas used during subsequent computations to time-phase standard hours. The items contained in (7) indicate that machine A429 is located in Department 020 and will require a total of 3.51 standard man-hours to complete the required operations. The sequence is repeated horizontally across the page, indicating that Department 020 will perform production operations which require seven different machines. The total standard hours required for those machines is summarized by department and indicated at the bottom of the report (8).

Production Status

Material flows through manufacturing operations in the form of discrete job lots. Production schedulers, after reviewing the consolidated net production/procurement schedules developed by OR (Schedule B, Figure 10), release, through a computerized Job System, material required to produce a specific quantity of parts (Job Lot). The Job Lot quantity is determined by factors such as economical runs, convenience of manufacturing, and the movement of material through reporting operations. The Job Lot is monitored and controlled through its manufacturing cycle by the Job System, which automatically generates and assigns a unique job number to the lot.

Released material is automatically allocated by the Job System to the highest priority Job Lots. When the material is delivered to the production floor, it is recorded as being in Next Assembly and the Next Assembly Requirements file (Figure 10), used during OR processing, is automatically updated to reflect the change.

Computerized files for released Job Lots contain the part number's first level components and the required manufacturing operations. At designated report points, records in the Job System are updated via IBM 1031 Data Collection Terminals and IBM 2260 Cathode Ray Tubes (CRT's) to reflect completed manufacturing operations and the quantities involved for each Job Lot.

FINAL PACKAGE RATE FILE STATUS												NOV. 9, 1973					
****PART NUMBER		CL	HLD-CD	LBP	MATI	--STATUS-- MATL-PRICE		A/B-MATL	SPCL-MATL	---MAX-FLT--- MAKE PCH		TOTAL-STD HRS****					
17600001-000 ①		SA	P	H	H	② 5861.18		0.00	0 00	⑥ 255 255		③ 208.5607					
L/A PART NUMBER		-COMP-FACT- LBR MATL		L/A PART NUMBER		-COMP-FACT- LBR MATL		L/A PART NUMBER		-COMP-FACT- LBR MATL							
④ 357542-107 1440103-005		⑤ 1.50 2.00		1.50		④ 1440083-013 1440108-003		1.00 1.00 1.00 1.00		④ 1440102-004 1442043-002		1.00 1.00 1.00 1.00					
DEPT	MACH	EXT-HRS	DEPT	MACH	EXT-HRS	DEPT	MACH	EXT-HRS	DEPT	MACH	EXT-HRS	DEPT	MACH	EXT-HRS	DEPT	MACH	EXT-HRS
020	A429	3.5100 ⑦	020	A813	6.5370	020	A826	6.1650	020	B236	1.4430	020	B816	1.4490	020	C332	2.7300
020	Z951	5.7300	026	B226	0.2453	026	B236	0.1400	026	E330	0.2623	026	E337	0.5290	026	E341	2.9470
026	E343	1.5840	026	Z951	2.4734	044	Z951	0.7890	045	C216	0.0484	045	E112	0.9931	045	F313	0.9340
045	F314	0.1924	045	F325	0.8232	045	G131	0.1174	045	G442	0.0321	045	Z951	0.6932	055	F941	0.2560
055	G571	0.0235	055	Z951	8.3614	059	G522	0.1224	059	Z951	1.3095	061	B422	0.5235	061	B820	0.5620
061	C212	0.3904	061	C812	0.1885	061	C834	0.5295	061	C841	0.2338	061	C845	0.2187	061	C921	0.0222
061	D731	0.3715	061	E123	0.3772	061	E151	0.0943	061	F951	0.1733	061	G131	0.1020	061	G415	0.1339
061	G588	0.0986	061	G651	0.2907	061	Z951	7.5326	063	G553	0.0005	063	G571	0.0020	063	Z951	0.4517
064	F441	0.0232	064	Z951	0.0297	065	E342	1.4040	065	G525	0.0255	065	G551	0.5395	065	G553	0.4194
065	Z951	15.1692	066	F421	0.5060	066	Z951	45.5059	068	G211	0.0352	068	G557	0.1329	068	G558	2.2048
068	G559	0.9218	068	G560	0.5228	068	Z951	14.2919	069	Z951	5.7934	091	C211	0.0137	091	F941	0.1278
091	F961	0.9090	091	Z951	0.5166	092	Z951	0.0094	093	A141	0.0538	093	A671	0.0313	093	G421	0.0300
093	Z951	0.2503	095	A111	0.0462	095	A131	0.3024	095	A141	1.7258	095	A151	3.2021	095	A213	0.5148
095	A215	1.3503	095	A217	0.2160	095	A224	0.1355	095	A415	1.8788	095	A425	0.1000	095	A511	0.0465
095	A516	0.5484	095	A612	0.0955	095	A614	0.5184	095	A616	0.1860	095	A622	0.1348	095	A624	0.2900
095	A626	1.1307	095	A822	0.6678	095	A914	0.0813	095	B122	0.0858	095	B212	1.3494	095	B222	0.4202
095	B232	0.3874	095	B312	0.4874	095	B322	0.0840	095	B332	0.2020	095	B334	0.6418	095	B336	0.3298
095	B412	0.1450	095	B422	0.1575	095	B812	5.1203	095	B814	2.1230	095	B822	1.9547	095	C111	0.2492
095	C131	0.0139	095	C214	4.9159	095	C216	2.1782	095	C812	1.1138	095	D112	0.4977	095	D311	0.0287
095	G221	0.0796	095	G311	1.8944	095	G411	0.3840	095	G442	0.1939	095	Z951	10.4825	097	Z951	2.6624
098	G411	2.6207	098	G421	0.4587	098	Z951	0.6234	099	Z951	1.2995						
DEPT	TOT-HRS	DEPT	TOT-HRS	DEPT	TOT-HRS	DEPT	TOT-HRS	DEPT	TOT-HRS	DEPT	TOT-HRS	DEPT	TOT-HRS	DEPT	TOT-HRS	DEPT	TOT-HRS
⑧ 020	27.5640	026	8.1810	044	0.7890	045	3.8338	055	8.6409	059	1.4319	061	11.8427	063	0.4542		
064	0.0529	065	17.5576	066	46.0119	068	18.1094	069	5.7934	091	1.5671	092	0.0094	093	0.3654		
095	48.6914	097	2.6624	098	3.7028	099	1.2995										

Figure 11. Package Rate File Status

During forecast computations, these Job System records are used to calculate total completed standard hours by operation and part number as a basis for relieving the gross part number operations schedule of already satisfied requirements.

FORECAST COMPUTATIONS

Direct Manpower, Machine Load, and Square Footage

The computation of direct manpower, machine load, and square footage forecasts involves the common element of standard hours and therefore is performed by a single Manpower/Machine Load Forecast (MMF) system. The following basic steps are used.

- Step 1--Convert all scheduled quantities to standard hours.
- Step 2--Time phase standard hours to calendar months.
- Step 3--Convert phased standard hours to men, machine loads, and square footage.

These steps are modified by MMF, depending on the schedule type and the level of definition available. For defined products with FO schedules, standard hours in Steps 1 and 2 are extended to component part numbers and manufacturing operations, the hours in Step 2 are phased by component part flow times and an additional step is added prior to Step 3 which applies relief for completed standard hours and allocates the relief to product type. For defined products with PL and/or B/A schedules, Steps 1 and 2 are extended as above for FO, but the additional step is omitted because there is no relief to apply. For undefined products with PL and/or B/A schedules, hours in Step 2 are phased at the ship item level by departmental phasing factors and factored for attrition by departmental attrition factors.

The method used in converting schedules for defined products to standard hours is outlined in Figure 12. MMF retrieves all schedule types from the forecast schedule base, selects those for defined products as indicated by the PKG-RT file, stacks them in core (maintaining product type identity) by aligning quantities and required dates, and then develops summarized, dated quantities. The quantities are multiplied by the total standard hours required to produce one unit (provided by the MOMR file) to obtain a dated, total-standard-hour figure for a specific part number. (This completes Step 1.)

The total hours are divided by the production flow time for the part (Part A = 4 months) to develop a phased, monthly increment of required standard hours by product type. (All quantities are

due at the end of the scheduled month. Thus, 25 percent of the hours for Part A's April quantity is allocated to April.) For ease of illustration, only the month of April is phased. In actual processing, the succeeding monthly quantities would overlap due to phasing and produce a different total. The hours are further subdivided by the part's manufacturing operations and their respective standard hours to produce the gross P/N operation schedule, by schedule and product type. (This completes Step 2.) At this point, PL and B/A schedules are held for subsequent merging with FO schedules which must first be relieved of completed hours.

The Job System records provide the completed P/N operations and quantities which are now converted to hours and subtracted from the gross FO operation schedule. To allocate relief to product types, the earliest dated quantities are relieved first. In the example, because Product Types 1 and 2 have identical schedules, the completed operation hours are divided and applied equally to the respective product type scheduled hours. The resultant allocated, relieved, FO standard hours are merged with the PL and B/A hours to provide the net required standard hours for defined product. (Conversion of hours to various forecasts, Step 3, is discussed later.)

The Department Labor Table (Figure 13) contains factors used to convert ship item schedules for undefined products to standard hours and subsequently to convert all standard hours to direct manpower and square footage (Step 3). Format 1 in Figure 13 illustrates a table which contains the elements used in computing available net work hours per month for any department in the plant. Methods Engineering supplies the number of work days and percentage factors for forecasted absenteeism and vacation for each month. The work days are multiplied by eight to obtain available hours per month. Net hours/month are computed as follows:

Let

W = Available Hours/Month,

A = Absence Percentage, and

V = Vacation Percentage.

Then

$W - (W * A) = B$, and

$B - (B * V) = \text{Net Hours/Month}.$

DEPARTMENT LABOR TABLE

DATE	WORK DAYS	FORECAST ABSENCE								FORECAST VACATION				
PD	20.58	.05								.00				
JAN	20.58	.05								.00				
FEB	20.58	.05								.00				
MAR	20.58	.05								.00				
APR	20.58	.05								.00				
MAY	20.58	.05								.00				
JUN	20.58	.05								.10				
JUL	20.58	.05								.10				

FORMAT 1

DEPT 123	AREA	EFFIC		PRCNT-PROD		ATTR		SQR-FT-MAN		SHIFT-RATIO				
	3	.70		.60		.05		100.0		.50				
		PD	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MO-LBR-PRCNT		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DETAIL-FCTR		0152	0152	0152	0152	0152	0152	0169	0169	0169	0160	0160	0160	0160
SUMMARY FCTR		0152	0152	0152	0152	0152	0152	0169	0169	0169	0160	0160	0160	0160

FORMAT 2

-----PHASING FACTORS-----										-----OFF SCHEDULE 300 MEN-----												
1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	11	12	13
00	06	12	24	36	12	06	04	00	00	00	00	01	01	01	01	03	03	03	05	05	05	05

---PROCESS DEVL P MEN---				----ENGR PROJ MEN----				---NON STD DEPT MEN---			
PRESENT EFF-DT FUTURE				PRESENT EFF-DT FUTURE				PRESENT EFF-DT FUTURE			
02	7-75	04		03		00		02		00	

Figure 13. Department Labor Table

Format 2 in Figure 13 illustrates a table of factors developed for each department in the plant. Department 123 is illustrated and the elements are described below.

- AREA--The number represents a designated manufacturing area (3 = Rubber and Plastics).
- EFFIC--Departmental efficiency percentage; a comparison of time used for a job to standard time allowed for that job.
- PRCNT-PROD--Percent of time used on standard, scheduled production. Allows for activities such as machine setup, rework, and stock handling.
- ATTR--Percentage allowance for in-house labor loss due to scrap.
- SQR-FT-MAN--Estimated square feet required, per man, for "leg and elbow" room in addition to tables, machines, and other fixtures.
- SHIFT-RATIO-- Percent of work to be performed on the first shift.
- MO-LBR-PRCNT--Percentage used to convert the SUMMARY FACTR to a DETAIL-FCTR. Allows for load leveling, if desired, due to five week months.
- DETAIL-FCTR--Factor used to convert standard hours for defined product into direct manpower ($\text{DETAIL-FCTR} = \text{SUMMARY-FCTR} \times \text{MO-LBR-PRCNT}$).
- SUMMARY-FCTR--Factor used to convert standard hours for undefined product into direct manpower.

$$\text{SUMMARY-FCTR} = 1/(\text{Net Hours/Month} \times \text{EFFIC} \times \text{PRCNT-PROD})$$

- OFF SCHEDULE 300 MEN--Represents a monthly estimate, beginning with the first month of the forecast period, of additional manpower required to perform unscheduled standard production activities. The monthly figures are added directly to manpower computed from standard hours. The figure in the 13th month is extended to all remaining months in the forecast period.
- PROCESS DEVL P MEN--Indicates that two additional men are required for process development activities through June, 1975, and that a total of four additional men will be required thereafter. The figures are added directly to computed manpower and used in square footage computations.

- ENGR PROJ MEN/NON STD DEPT MEN--Both figures represent additional men required for special Engineering Projects and nonstandard departmental work, respectively, and are added directly to computed manpower, effective for the entire forecast period.
- PHASING FACTORS--These factors represent a labor expenditure profile used to phase standard hours for undefined product into monthly time periods. It estimates percentages of labor expenditures and the months in which they would occur based on the type of work performed by the department. For example, heavy machining operations would occur early in the production cycle, whereas assembly and finishing operations would occur in the final months. The labor table contains a standard 10-month profile which is scaled to reflect individual flow times for each ship item. Its use is illustrated in the following section.

As discussed earlier, standard hours for undefined product are developed by the PKG-RT system and are summarized at the ship item level by department and machine code. The scheduled ship item quantities provided by the forecast schedule base are then multiplied by the PKG-RT hours, and the results are sorted and totaled to obtain an *unphased* total standard hour requirement by department and machine code. Departmental phasing factors are then used to allocate the hours into proper time periods as illustrated below.

Department 123 Phasing Factors from (Figure 13) are

Month	1	2	3	4	5	6	7	8	9	10
Percent	0	6	12	24	36	12	6	4	0	0

Then, given for ship item A,

Flow time from lowest part = 6 months,

Schedule date = 12/74, and

Number of standard hours for Dept. 123 in ship item A = 275,

the Department 123 factors are scaled to the 6-month flow time, giving 10/6 or 5/3 of the original table to give the ship item table:

Month	1	2	3	4	5	6
Percent	4	22	52	16	6	0

The time periods are converted to dated months based on the schedule date, and the total departmental standard hours are allocated to proper time periods:

Date	7/74	8/74	9/74	10/74	11/74	12/74
Hours	11	60.5	143	44	16/5	0

The illustration involves only one ship item, one flow time, and one schedule date. During actual processing, a matrix of ship item tables is developed in core to handle a variety of ship items, flow times, and schedule dates that affect a single department. The hours and dates are aligned to provide summarized departmental monthly quantities.

The monthly quantities are then factored by an attrition percentage contained in the Department Labor Table. The result is a phased, total-standard-hour requirement schedule for undefined product. This schedule is combined with the net standard hours requirement schedule for defined product (Figure 12) to provide the forecast standard hours base.

Converting Standard Hours to Forecasts

The forecast standard hours base is used in conjunction with factors in the Department Labor Table to produce direct manpower and square footage forecasts. Because standard hours are developed for both defined and undefined products, manpower forecasts require two computations.

Manpower (defined product) = Standard hours (defined product)
x (DETAIL-FCTR)

Manpower (undefined product) = Standard hours (undefined product)
x (SUMMARY-FCTR)

The results are totaled by monthly increments. The requirements for Off Schedule, Process Development, Engineering Project, and Non-Standard department men, as provided by the Department Labor Table, are added directly to the computed manpower figures to produce the final direct manpower forecasts which are submitted for management review.

Square footage forecasts involve the total standard hours base, but the computations are not broken down by defined and undefined hours. The forecasts are computed as follows using factors from the Department Labor Table.

Given

Hours per month = (Work-Days) x 8, and

$$K = \frac{1}{(\text{EFFIC}) \times (\text{PRCNT-PROD}) \times (\text{Hours Per Month})}$$

Then

Square Feet = (Standard Hours) x (K) x (SQR-FT-MAN) x (SHIFT-RATIO).

The result is computed square feet in monthly increments. As in manpower computations, requirements must be added for Off Schedule, Process Development, Engineering Project, and Non-Standard department men. These are computed by multiplying the requirements in the Department Labor Table for each category by SQR-FT-MAN. The results are added to the computed square feet to produce the final forecasts.

A Machine Code Table (Figure 14) contains factors used in converting standard hours to machine load forecasts. The factors, which are described below, are established by Methods Engineering for each unique departmental and machine code combination.

- MACH FACT--A factor used to convert standard hours or cycle time to machine requirements. (Cycle time is the hours used by the machine rather than the man in performing the operation.) The factor is computed as follows:

$$\text{MACH FACT} = 1/(\text{MACH-EFFIC} \times \text{PROD-RATIO} \times \text{Hours Per Month})$$

Where hours per month = 329 for 5 days, 2 shifts or 463 for 5 days, 3 shifts.

- MACH INV--An inventory figure representing the numbers of a specific type of machine located in the department.
- OTHR PROD--Represents the percentage of total time allocated to production other than scheduled standard production.
- SETP MAINT--Represents the percentage of time allocated to setup and maintenance.
- MACH EFFIC--A comparison of machine time used for a job to standard time allowed for that job.
- NUM OF SHIFTS--The number of shifts scheduled for the specific machine.

DEPARTMENT MACHINE CODE FACTORS-MACH CD SEC											OCT. 26, 1973	
MACH CODE	DESCRIPTION	DEPT	LOAD CNTR	MACH FACT	MACH IN	OTHER PROD	SETP MAINT	MACH EFFIC	NLM OF SHIFTS	NET CPCTY	PROD RATIO	300 PROD PERCENT
A111	JEWELERS LATHE	045	A111	.0053	1	.15	.15	.70	2	.850	.82	.70
		046		.0000	1							
		093	A111	.0053	2	.15	.15	.70	2	1.700	.82	.70
		095	A111	.0053	2	.15	.15	.70	2	1.700	.82	.70
A121	BENCH LATHE	026	A000	.0053	1	.15	.15	.70	2	.850	.82	.70
		095		1.0000	0							
A131	BENCH LATHE	045	A131	.0053	1	.15	.15	.70	2	.850	.82	.70
		093		1.0000	0							
		095	A131	.0053	1	.15	.15	.70	2	.850	.82	.70
A141	BENCH LATHE	093	A141	.0053	3	.15	.15	.70	2	2.550	.82	.70
		095	A141	.0053	4	.15	.15	.70	2	3.400	.82	.70
A151	CHUCKER LATHE	026	A151	.0053	1	.15	.15	.70	2	.850	.82	.70
		046		.0000	1							
		093	A151	.0053	8	.15	.15	.70	2	6.800	.82	.70
		095	A151	.0053	8	.15	.15	.70	2	6.800	.82	.70
A152	CHUCK LATHE TRACER	093	A152	.0053	1	.15	.15	.70	2	.850	.82	.70
A213	HTL RAM NO. 3	095	A213	.0053	3	.15	.15	.70	2	2.550	.82	.70
A215	HTL RAM NO. 5	095	A215	.0053	4	.15	.15	.70	2	3.400	.82	.70
A217	HTL RAM NO. 5AR	095	A217	.0053	1	.15	.15	.70	2	.850	.82	.70
A222	HTL 2A & 2L	095	A222	.0053	1	.15	.15	.70	2	.850	.82	.70
A224	HTL NO. 1L	095	A224	.0053	0	.15	.15	.70	2		.82	.70
A225	HTL NO. 3L	095	A225	.0053	1	.15	.15	.70	2	.850	.82	.70
A231	CENTER DRIVE 30	020	A231	.0053	1	.15	.15	.70	2	.850	.82	.70
A232	CENTER DRIVE 33	020	A232	.0053	2	.15	.15	.70	2	1.700	.82	.70
A322	VTL STD 42 & UNDER	020	A322	.0053	0	.15	.15	.70	2		.82	.70
A332	VTL DUP 42 & UNDER	048	A000	.0053	2	.15	.15	.70	2	1.700	.82	.70

Figure 14. Department Machine Code Table

- NET CPCTY--Represents the machine units available for scheduled standard production including setup and maintenance but excluding other production. It is computed as follows:

$$\text{NET CAPACITY} = (\text{MACH-INV} - \text{MACH-INV} \times \text{OTHR-PROD}).$$

- PROD RATIO--Represents percentage of time available for scheduled; standard production out of time available for such production, including setup and maintenance. It is computed as follows:

$$\text{PROD-RATIO} = B/A$$

Where

$$A = 1 - (\text{SETP-MAINT}), \text{ and}$$

$$B = A - (\text{OTHR-PROD}).$$

- 300 PROD PERCENT--Represents percentage of time the machine is available for scheduled standard production. It is computed as follows:

$$300 \text{ PROD PERCENT} = 1 - (\text{SETP-MAINT}) - (\text{OTHR-PROD}).$$

Standard hours (cycle time) are multiplied by the machine factor to produce machine load forecasts which are then compared to net capacity to determine overload conditions.

Headcount Pricing

The direct manpower forecast computed by MMF provides a headcount level for hourly production personnel only. The figures are combined with indirect labor forecasts (salaried and indirect hourly personnel) manually developed by each operating department to produce a total headcount line for the plant which is then submitted for management review. The approved headcount level is automatically correlated against payroll and burden files, which respectively contain average departmental payroll rates and additional costs for vacations, holidays, shift premiums, and overtime, to develop gross payroll costs. Fringe costs for FICA, insurance, pensions, and various other payments to be made on behalf of employees are then manually added to the gross payroll to produce a forecast for total manpower costs.

Production Tooling

Automatic computation of tooling estimates is an optional capability recently added to RFS and is currently used primarily during early planning stages on major components of new product.

Engineering reviews planning configurations and prepares preliminary technical definitions which identify ship entities and their component parts and usages. After reviewing this data against forecast schedules, Engineering develops and stores in ADF estimates of tool quantities, dates required, and costs for each component.

The ADF/TCM interface system extracts the cost estimates and tool required dates and automatically phases the amounts into quarters for two years, and into yearly totals for five additional years, using formulas derived from historical data based on the production category of the tool and the amount of the tool estimate. The categories and sample *portions* of their respective formulas are illustrated in Figure 15.

The figures in the Month Allocated column indicate months within the spread period. For example, in Category I above, if the required date was June 30, 1974, thirty, fifty, and twenty percent of the cost would be allocated respectively to April, May, and June. The phased dollars are automatically accumulated by the ADF/TCM interface system and subsequently submitted for management review.

Approved estimates are entered into the TCM system which periodically prepares reports comparing estimated costs against actual tooling expenditures obtained from computerized accounting systems.

Production Material

Schedule type determines the method to be used in computing cost estimates for production material. FO schedules require computations involving production files and data at the part number level, whereas PL and B/A schedules utilize ship item data in the PKG-RT file.

When processing FO schedules, the Material Forecasting system retrieves from the Order Status system the undelivered balances on committed purchase orders and phases the quantities by their expected "to dock" receipt dates. Open requisition quantities for which purchase orders have not been written are obtained automatically from the Order Status system and manually from Purchasing and Production Control, and are added to the committed undelivered quantities. Prices are obtained from the SPEC file and used to compute a forecast of monthly material costs extending from the forecast cut-off date through the FO schedule period.

In addition to the PKG-RT file, material forecasting for PL and B/A schedules involves the use of a Production Material Expenditure Profile (Figure 16) which automatically phases lump sum material estimates for a ship item into anticipated monthly

Category	Estimated Dollar Value of Tool Order	Spread Period From Required Date	Month Allocated	Percent Cost Allocated
I. Production Tools	1,000 - 3,000	3 months	1	30
			2	50
			3	20
	3,000 - 20,000	4 months	1	20
			2	40
			3	20
			4	20
II. Gages (Use same formula as I above)				
III. Test Equipment	60,000 - 100,000	12 months	1 - 2	10
			3 - 4	20
			5 - 6	26
			7 - 8	24
			9 - 10	12
			11 - 12	8
IV. Vendor Tools	All Orders	Order Date + 5 months = 100 percent or 100 percent on Promised Date		

Figure 15. Tooling Categories

expenditures relative to ship dates. The EE system develops specific profiles for each defined program by first developing a dollars-per-month schedule based on the flow times and costs of all purchased parts within a specific program, and then summarizing the monthly figures and converting the totals into percentages of the program's total material cost. The Material Forecasting system then retrieves an appropriate profile, based on the program identifier contained in PL and B/A schedules, and allocates percentages of the ship item's material cost estimate into time periods which represent months prior to ship dates in which the expenditures will occur. For example, Figure 16 indicates that Program P20 will incur 34 percent of its material costs 14 months prior to ship date or 39 percent of its *total* material costs 14 months prior to ship date. The profile makes it possible to slide or accelerate the schedule dates and still obtain representative estimates per program month which are subsequently converted to calendar months on the final material forecast.

COMPUTERIZED SUPPORT

Automated support of RFS consists of computer systems grouped in Figure 17 as either Planning and Forecasting (A) or Independent supportive systems (B). Group A is used exclusively for forecasting purposes, whereas Group B primarily serves other functions and, although it has direct automated interfaces with forecasting systems, is technically independent of them.

Figure 17 identifies for each system the number of computer processes involved (discrete computer runs requiring unique Job Control Language, JCL) and the total number of programs involved. The number excludes SORT/MERGE, CPO, protective dump, and restore routines, and other miscellaneous utility software. In addition, the table identifies core size of the largest program, the number of permanent data files maintained by the process(es), and the estimated total bytes of permanent data. All systems run on IBM 360/65 hardware under OS/MVT and ASP, utilizing IBM/2314 disk packs and IBM/2420, 1600-bpi tape drives.

CONCLUSION

RFS has demonstrated its value to management in such activities as budgeting, periodic manpower and machine load studies, and assessing the impact of proposed new production upon available facilities and resources under a variety of design and schedule conditions (impact and capability studies). As a result, the time required to produce manpower and machine forecasts for budgeting exercises has been reduced from 36 to 10 days, and the time required for routine monthly forecasts has been reduced from

	Computer Processes	Number of Programs	Maximum Core	Data Files	Approximate Bytes of Data
A. Planning and Forecasting Systems					
1. Manpower Machine Forecasting (MMF)	8	21	250	0	0
2. Advanced Data File (ADF)	2	20	160	1	25,000,000
3. Productive Budget Master (PBM)	15	69	82	1	3,450,000
4. Package-Rate (PKG-RT)	2	11	172	1	18,000,000
5. Department Labor Table	1	1	100	1	8,000,000
6. Material Forecasting	1	9	104	0	0
7. Manpower Pricing	<u>2</u>	<u>7</u>	166	<u>2</u>	<u>600,000</u>
Sub-Totals	31	138		6	55,050,000
B. Supportive Independent Systems					
1. Customer Order (CO)	5	29	168	1	6,000,000
2. Bill of Material (BOM), Includes Maintenance of Part Specifications (SPEC)	2	9	174	2	21,984,000
3. Manufacturing Operations Master Routing (MOMR)	3	18	144	3	9,000,000
4. Open Requirements (OR)	2	10	250	1	10,275,000
5. Emergency Explosion (EE)	1	8	250	0	0
6. Tool Cost Monitor (TCM)	4	27	170	2	3,000,000
7. Job System (WIP only)	<u>3</u>	<u>21</u>	182	<u>3</u>	<u>36,010,000</u>
Sub-Totals	<u>20</u>	<u>122</u>		<u>12</u>	<u>86,269,000</u>
Totals for RFS (A + B)	51	260		18	141,319,000

Figure 17. Analysis of Computerized Support for RFS

23 to 5 days. Response time for impact and capability studies is now as low as overnight. The period which can be forecasted has been extended from 2-1/2 years to 10 years.

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