GASP II SIMULATION OF PARTS INVENTORY FOR ELECTRONIC FUZE PRODUCTION

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Abstract

Inventory and shortage costs of more than one hundred types of piece parts used in the continuous production of the FMU-56/B proximity fuze were simulated using GASP II. Probabilities of lateness of received lots and of lot rejection were introduced on the basis of historical data on these specific parts. The program includes expedients for coping with parts' lateness and means of selecting lowest cost alternatives when lots are rejected. Order quantity and safety stock level are the input variables; annual inventory holding cost, inspection cost, and lateness/rejection work-around costs are the output criteria. Results include search runs on individual items and groups of parts, and evaluation of the effect of changing the random number seed.

1. BACKGROUND

Production of the FMU-56/B proximity fuze at Motorola's Government Electronics Division requires the purchase of many millions of dollars worth of parts and materials annually. To date this line has operated with emphasis on high quality and rapid response. Motorola's management requested this study of inventory cost in the interest of cost effectiveness and with the intention of applying the results to future, continuing production of this fuze. It was considered important to investigate the effect of altering parts inventory levels and to devise a means for exploring the cost impact of various inventory policies. Low levels minimize inventory holding costs but increase the risk of shortages and costly interruption of production. Discrete event simulation by digital computer appeared to be the most direct means of providing the desired answers.

2. OBJECTIVE

The goal of this computer simulation was to provide a means of evaluating two prime decisions related to the ordering of parts and materials needed to sustain the FMU-56/B Fuze production line. The decisions pertain to each part and material type and are:

(1) What safety stock level should be maintained?

(2) In what lot sizes should periodic shipments be specified?

The minimum-cost overall solution is sought.

3. GENERAL APPROACH

The daily production rate (5-day week) is fixed, and it is assumed that the rate will be maintained in the long run with under-production on some days being recovered soon thereafter. The safety stock level (DSL, for days of stock level) and the lot size (QD, for quantity, in days) are defined in units of days, based on daily parts requirements including shrinkage. Parts and materials purchases for an extended period of time are assumed to have been negotiated, and the suppliers require two pieces of information based on (1) and (2) above, namely:

(a) When should the first shipment be scheduled?

(b) What quantity is specified per shipment, given the plan that the annual quantity required is divided into a sequence of shipments of identical size, scheduled for arrival times that are equally spaced over the year.

Item (a) is related to item (1) in that if (1) is determined, a count of existing inventory will permit calculation of (a). For example, if the inventory today is sufficient for 25 days of fuze production and we wish to keep a minimum stock level of 10 days supply, and if the time required for inspection is 7 days, we would schedule the first shipment for arrival 8 days from now.

If there were no uncertainties in this inventory model, it could be solved analytically to determine optimal values for lot size and safety stock level. In this model, however, are included a probability distribution for lateness of delivery (with the scheduled delivery date as a reference), and a probability of the lot failing inspection after it reaches Motorola. Furthermore, several decisions regarding alternatives for disposition of failed lots and for coping with extreme lateness of lots without completely shutting down the production line have also been included. These complexities, which bring the model much closer to reality, suggest that computer simulation is the only feasible method of solving the problem.

This computer program provides a tool for evaluating the cost impact of any combination of lot size and safety stock level that it is desired to propose; it also permits a search to be conducted for near-optimal values; some such search has already been performed and is reported herein.

4. SIMULATION LANGUAGE

4.1 GASP II CHARACTERISTICS

GASP II was selected for use in this simulation because it is a flexible, Fortran-based language, and because it is well-documented* and presently is being taught at Arizona State University. This simulation language requires no separate compiling system and it is easily modified and extended to meet the needs of particular applications.

GASP II is not nearly as well known as SIMSCRIPT (which it resembles) and GPSS (from which it differs markedly). GASP II views the world as composed of <u>entities</u> that are described by <u>attributes</u> and related through <u>files</u>. A system state can be changed only if entities are created or destroyed, attribute values are changed, or file contents are altered. GASP II treats the creation and destruction of entities logically by keeping track of available columns in arrays. Arrays are used for storing attributes of entities as well as files of entities. The master filing array, NSET, is the heart of the GASP II system; it serves as the reservoir into which entities and attributes, including scheduled events, are filed and from which the scheduled information is used in chronological order to call upon event subroutines.

4.2 MAJOR GASP FUNCTIONS AND SUBROUTINES

A brief summary of the functions and major subroutines that accomplish these functions follows; these subroutines, written in Fortran, comprise GASP II, and form the skeletal framework into which the user fits his specific, event-handling subroutines.

*"Simulation with GASP II," A. A. B. Pritsker and P. J. Kiviat, Prentice-Hall, 1969

Function	Subroutine Names
Executive Control	GASP
Initialization	DATAN
Information Storage & Retrieval	SET, FILEM, RMOVE, FIND
Data Collection	COLCT, TMST, HISTO
Statistical Computation & Reporting	PRNTQ, SUMRY
Monitoring & Error Reporting	MONTR, ERROR
Random Variable Generators	DRAND, UNIFRM, RNORM, RLOGN, ERLNG, NPOSN

4.3 EVENT-HANDLING SUBROUTINES

Events, defined as state changes occurring at points in time, are represented by computer subroutines which the user writes for a particular application. These subroutines make the state changes, query the system about its past, present, and perhaps forecast future state, and schedule future state changes to take place through other events. Typical subroutines might be those that are called to handle each arrival or end-of-service in a queque, or the receipt of goods into inventory, the end of an accounting period, or the completion of a particular machine-operation.

5. BASIC DESCRIPTION OF MODEL

If shipments of the piece parts used in the fuze production line were always received exactly on their scheduled dates, and if none ever failed inspection, the cost consideration related to the parts inventory policy would be primarily the following: (1) the inventory carrying charge (set at 10% per annum for experiments described herein, but since revised upward); and (2) the cost of performing inspections. Obviously, as the lot size (QD) is increased there are fewer inspections per year, but a higher inventory level results. Under these assumptions of certainty, the average inventory would be the safety stock plus 1/2 the lot size. With certainty as to time of receipt of shipment, the safety stock could be set to 0. Within the range of QD where inspection costs are constant, the optimal QD may be derived by differentiation as $QD = \sqrt{2(260)(IC)/0.1(PCD)}$, where IC is the inspection cost per lot, PCD is the value of the parts used per day, and 260 is the number of days of production per year.

With risk of lateness and of failing inspection, the actual expedients for coping with these events must be included in the model. Alternatives available for circumventing lateness (work-around) are:

(1) Wait, at no cost, if the safety stock is sufficient to permit this.
(2) Use alternate procurement through distributors, and pay higher price for parts.
(3) Schedule around the shortage by stopping a portion of the line, and suffer costs due to inefficiencies.
(4) Expedite inspection to save time.

The time that can be gained from each of these alternatives is limited. If all reach their limit, the line will be completely shut down with a severe penalty. Alternatives for disposing of failed lots are:

(1) Return to vendor for rework, and buy time (see above) as needed.
(2) Perform 100% screening, incurring added labor costs.
(3) Accept on risk, incurring costs due to higher expected reject rate of assembled modules.

Figure 1 shows the overall block diagram of the logic with much of the detail suppressed. The logic is repeated for each of the types of parts and materials, each type having its own specific parameters such as probabilities, costs, distributor availability, screening costs, and so forth. The parameters are based on prior fuze-line experience, as more fully discussed below.

6. FIXED INPUT DATA FOR PARTS

6.1 GENERAL DESCRIPTION AND SOURCES

Nineteen specific items of fixed input data were required for each part type, to be stored in the data array NDATA (144 x 27). A data form (see Appendix A) was prepared and various operating departments within Motorola's Government Electronics Division cooperated in providing the required information.

Line Items	Departmental Sources
1,12,13,14,15	Purchasing
2,19	Outgoing QA
3,4	Industrial Engineering
5,6,7,9,10,16,17,18	Incoming Inspection
8	Design Engineering
11	Purchasing & Production Control

A most cooperative spirit was evident in all participants. Interest in seeing what the results would be ran high. No real difficulties were encountered in attaining the data, although the time and effort required exceeded initial estimates. Conservatively, the data collection effort comprised at least 60% of the effort.

In general, one data sheet was prepared for each part type, and was considered representative of the part type regardless of the vendor from whom it was procured. An exception to this is a tantalum capacitor for which the two vendors were handled separately; the inspection and screening cost for one vendor's product is higher because additional monitoring of quality is considered necessary. In several instances similar parts from the same sources were grouped together on one data sheet, a prime example being the numerous resistor-values procured from Allen-Bradley.

6.2 DISCUSSION

6.2.1 Probability Data on Lateness

Historical data were available on the past schedule-meeting performance of the parts suppliers. However, because of changes in design and other factors, the historical data were considered not entirely representative of the conditions pertaining to the next year or two. Therefore, the data were modified by purchasing personnel to reflect what the future schedule performance would most likely be. It was found that the most practical way of compiling the data was to use histograms. The data, lumping all suppliers for a given part, and tempered by each buyer's judgment, were submitted as forty-six different histograms, with all cell widths being one week. Computationally, there are advantages in using a continuous distribution rather than a discrete one, so an equivalent truncated normal distribution was approximately determined, by geometric analysis, for each histogram. The RNORM function of GASP II was rewritten to reject deviates outside the specified limits to obtain the truncation. Thus, a random deviate drawn from the truncated distribution will be an integral number of days (not weeks) and will approximately conform to the original histogram.

6.2.2 Lot Acceptance

The probability that a lot of a given part type will pass incoming inspection was based on inspection records for 1968. Very few of the parts had less than 5 shipments, most had 10 to 25 shipments, and some had as many as 48. In general, the ratio of the number of acceptable lots to the total number of lots was modified to the 50% confidence level of the binomial distribution to reflect the fact that a percentage based on a large number of lots is more accurate than one based on a few lots.

6.2.3 AQL of Rejected Lots

For all electrical parts except printed wiring boards it was estimated that approximately one-half of the rejected lots would have AQL's of 4% or less and one-half greater than 4%. For other parts experience tends to indicate that all rejected lots have AQL's exceeding 4%. This information is used in risk evaluation (see 6.2.5), and comprises line item 7 of the NDATA array.

6.2.4 Forced Return to Vendor

Inspection experience has shown that when certain types of parts fail inspection they tend to be 100%

non-conforming. Hardware, mechanical (except the fuze housing), and packaging items are in this category and most of these items were considered, upon failing inspection, to be wholly unacceptable. (An example is the receipt of a shipment of screws of the wrong size.) Thus, screening to cull the discrepant material, and acceptance on a risk basis, were not allowed as alternatives for lot disposition. Return to vendor was considered "forced" in the simulation model. Such parts were flagged by using the number 500 as line item 2 in the NDATA array.

6.2.5 Cost of Accepting Discrepant Lots on a Risk Basis

For discrepant parts not having forced return to vendor, the cost of accepting on risk without screening was based upon the additional troubleshooting, rework, reinspection, and retest that could be anticipated. All parts used in the FMU-56 fuze were divided into the following classes related to the assembly sequence in order to determine the consequences of failures.

Class I	Insertion line electrical parts.
Class II	Duplexer subassembly and interconnect parts. (Module test occurs here.)
Class III	Stack hardware. (Stack test occurs here.)
Class IV	One-shot components.
Class V	Electrical and mechanical parts added prior to final test. (System test occurs here.)
Class VI	Packaging parts.

The average cost per discrepant part was obtained for each class from operating history.

These costs were multiplied by 3% of the quantity used per day to determine the daily cost of accepting on risk if $1\% < AQL \leq 4\%$ and entered as line item 19 in the NDATA array. The cost of accepting on risk if $4\% < AQL$ was considered to be twice as much and was entered as line item 2.

6.2.6 Production Line Work-around

The cost of production line work-around (line item 4) was calculated as the cost of reduced productivity of production personnel who are shifted to new assignments when their normal activity is stopped due to part shortages. Productivity increases as the personnel continue to perform the new activity. Also, as the shortage drags on more people are affected. The total permissible work-around time (line item 3) was determined for each of the parts classes listed above as the maximum period before the entire line is disrupted. An average inefficiency cost per day was calculated for this period.

6.2.7 Cost of Inspection

The cost of performing incoming part inspection was supplied for a typical lot size of each part type. A fixed dollar charge per lot was added to cover receiving costs. For a minority of the parts (primarily hardware) a fixed sample size of 20 is inspected, so the inspection cost will be constant regardless of the size of the lot received. However, for the majority of the parts Sampling Table III of MIL-STD-105 is followed. The cost data provided was altered proportionately to apply to various lot sizes. Appropriate variable inspection data was calculated to apply between reasonable limits of lot size embracing the theoretical optimum, assuming zero lateness and no lot rejections. At present, these limits comprise a constraint on the range of lot size with which we may experiment, but, as will be demonstrated, experimental results show that the lot size is not as important as the safety stock level. While the present limits on lot size are considered adequate, a pending improvement will use step-function inspection costs and not limit selection of lot size.

6.2.8 Expedited Inspection

The normal inspection time was estimated to be 7 working days. It was determined that expedited inspection, on occasion, could be performed in 2 days but at twice normal cost. The computer program consequently effects the appropriate reduction in inspection time and doubles the normal cost when expedited inspection is indicated.

7. VARIABLE INPUT DATA

The variable input data for each part comprise three numbers:

(a) Lot size (QD), in number of days' requirements the lot will provide.

(b) Safety stock level (DSL), in number of days' requirements the stock will provide.

(c) Starting inventory (SINV), in number of days' requirements that are on hand.

These data are fed to the program in punched data card format. The simulation program may be exercised on one, a few, or all parts, to determine the cost impact of changing values of (a) and (b) above.

The lot size (QD) should be maintained within predetermined limits. Variation of QD has considerably less effect on total cost than does variation of the safety stock level.

The safety stock level (DSL) is restricted only for the 25 part types in the ALAS* program. For these parts, DSL is presently required to be 35 days.

The starting inventory is used solely to fix the time of the first delivery; it must be in excess of the sum of the safety stock level and the time required for normal inspection ($\mathrm{SINV} > \mathrm{DSL} + 7$). The effect of a large value of SINV has a very small effect on the integrated inventory level since it is quickly dissipated and the inventory settles down to a range determined by QD, DSL, inspection time, and the lateness and lot reject probabilities.

8. OUTPUT DATA

In addition to an echo check of the input values of QD, DSL, and SINV, the printout for each simulation run includes the following annual costs:

Cost of accepting reject lots	XX
Cost of screening	XX
Cost of days line was completely stopped	XX
Cost of return to vendor	XX
Cost of performing inspection	XX
Cost of buying time for late lots	XX
Inventory holding cost	XX
Total cost per year	$ XXXX

Also, a statistical summary provides: (1) counts of late and failed lots and of all the events implied by the above list; (2) mean, standard deviation, minimum, and maximum values of lateness, of the daily inventory level, and of the costs listed above; (3) a histogram of the number of lots received per day.

9. EXPERIMENTAL RESULTS

The simulation program and all fixed input data were put on magnetic tape to expedite and simplify use of the program. Running time on the SDS 930 computer was about 2 minutes for simulating the receipt and processing of 1000 shipments.

Total annual cost is defined for purpose of this simulation program as the sum of inspection cost, inventory holding cost, and the cost of lateness and lot rejections. For pseudo random number generation the number 251 was used as the seed. Considerable work was performed in exploring the adequacy of the pseudo random number generator used on the SDS 930. The HISTO subroutine of GASP II was used to form histograms of the sequence of random numbers. It was concluded that the generated numbers formed satisfactorily uniform distributions. Additional modifications were incorporated to permit recalling the original seed when multiple runs are made with one compilation.

The following results are not intended to be complete, but merely to demonstrate exercising of

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*Advanced lot acceptance sampling, wherein 15 days' supply of these parts is held in bond until fuzes made with a randomly selected sample are completed and successfully pass final test.

the program. At the time of application of this program to the scheduling of parts deliveries, which is planned for production of a slightly modified version of this fuze, the fixed part input data will be reviewed and more thorough experimentation will be performed on individual (particularly the most expensive) parts, to determine optimal ordering schedules.

9.1 WITH FULL PARTS COMPLEMENT

The full parts complement comprises over one hundred types of parts and materials. Three types of experiments were performed with a full parts complement to determine the effect on total cost of (1) duration, (2) size of order quantity (QD), (3) safety stock level (DSL). Only one of these three variables was changed at a time. Initial values of the order quantity were calculated theoretically. Starting values of safety stock were arbitrarily based on parts cost, ranging from 5 days for parts used at a rate of > $1500 per day, up to 30 days for parts used at a rate of < $20 per day. The safety stock for all ALAS parts remained fixed at 35 days throughout all experiments on the full parts complement.

9.1.1 Duration

The use of 1, 2, and 3 years as the simulation period gave the following results:

Duration, Years	Total Annual Cost, Dollars	Number of Line Stops per Year	Days of Line Stoppage per Year
1	$283,700	2	6
2	$286,100	3	5.5
3	$284,800	4	11.6

The penalty cost of the line stoppages has not been included in the total annual cost column. The simulation program printout identifies the specific parts that cause the line stoppage; if it were considered vital to eliminate all line stoppages, the safety stock of the responsible parts could simply be increased. In this experimentation, however, it was considered informative to keep the safety stock marginal on some parts and observe the change in criticality; judged by number of line stops, as the experiments proceeded. The large increase in days of line stoppage occurring in the third year is caused primarily by a spacer sleeve which requires forced return to vendor if it fails to pass incoming inspection. A value of 20 days safety stock was used but was not sufficient to cope with the combination of lateness and lot rejection that occurred. (An obvious conclusion is that the safety stock should be increased.) The return to vendor, requiring 15 days, caused a line stoppage of 11 days. The order quantity used was 50 days supply, which means that only about 5 shipments were received per year. The probability of lot rejection is 11% for this part, so it is possible that no failures occurred in the first or second year of the simulation. It can be concluded from this that, when looking at any one part, the sample statistics obtained in a one-year run are far from sufficient.

If one part, or a subset of parts, is to be explored in detail the duration should be extended, as discussed below for 5-part experimentations, where 8- and 12-year durations were accomplished in 3 minutes of computer execution time. For all remaining experiments on the full parts complement a 1-year duration was used, recognizing that sizeable variability might be expected in line-stop data. The computer execution time for the full program with 260 days (1 year) is approximately 3 minutes.

9.1.2 Size of Order Quantity

Figure 2 shows the effect of changing the order quantity. Reducing the order quantities approximately doubled the cost and frequency of inspection, as expected. Increase of order quantity was constrained by considerations discussed above under "Cost of Inspection." Specific values of order quantity (QD) used for the reduced and increased levels are estimated to be 50% and 125% overall.

The cost results of Figure 2 indicate that the order quantities chosen for initial values are a good choice. One effect not graphed, that of line stoppage, further indicates that no great change should be made in QD. The line stoppages obtained are:

Order Quantity, Approximate % of Initial Values	Number of Line Stops	Days of Line Stoppage
50	5	5
100	2	6
125	5	18

The obvious way to reduce the line stoppage is to increase the safety stock level of the specific parts causing it.

9.1.3 Safety Stock Level

Figure 3 shows the effect of changing the safety stock level (except for ALAS parts which are held constant at 35 days supply). The stock levels were approximately halved for non-ALAS parts to obtain the low levels, and were increased to approximately 120% and 125% of initial level to obtain medium high and high levels.

The cost of lateness and rejections decreases rapidly as safety stock levels increase. The lowest total annual cost for the levels simulated occurred at the medium high level.

The line stoppages that occurred are:

Safety Stock Level Approximate % of Initial Values	Number of Line Stops	Days of Line Stoppage
50	20	71
100	4	8
120	0	0
125	0	0

If line stop penalties are added, it is clear that the low stock level is untenable and that the cost decreases as the stock levels are increased about 20% from initial values. Further increase of stock levels are undesirable costwise.

The reason that inspection costs are slightly lower at the low stock level is that the simulation model skips inspection on part lots that are so late that they have stopped the line. The reasoning is that so much pressure would exist to restart the line that we would prefer to accept on a risk basis without inspection. The cost of this risk is lumped into the line stop penalty.

9.2 WITH ALAS PARTS ONLY

The 25 part types within the ALAS program are integrated circuits and other semiconductor devices. They comprise 32-1/2 per cent of the dollar value of the parts expended daily on the FMU-56/B fuze line and presently require holding a 35-day supply so that bonded lots may be sampled and proven satisfactory by manufacture of completed fuzes.

An experiment was performed in which the safety stock level was varied. The intent was to see how low the safety stock should be for minimum holding cost and cost of lateness and rejection if it were feasible to accomplish ALAS with less safety stock. The results are shown in Figure 4.

No line stoppages were obtained at any level used in the simulation. The duration of simulation was 1040 days (4 years).

9.3 WITH FIVE MOST EXPENSIVE, NON-ALAS PARTS

The following five parts are the most expensive non-ALAS parts in terms of dollars consumed per day, representing 31% of the total.

	Part Description				
	Btry	Safe & Arm Device	Btry Firing Device	Tant. Capacitor	Fuze Housing
Identity No.	65	68	24	11	9
Initial DSL	10	10	5	5	19
Rescheduling Slack, Days	3	2	10	8	2
Maximum Lateness, Days	17	17	17	7	27

An experiment was performed to determine the effect of increasing the safety stock level (DSL) by 5, 10, and 15 days. Cost results are shown in Figure 5.

No line stops were obtained at any level. This is explainable as follows: For all of these parts, return to vendor is not forced upon failing inspection. Assume that a lot fails inspection. The total stock in house is 7 days stock for the normal inspection period plus unused DSL. Five days can be gained by expediting inspection, which is sufficient to permit screening (or to cover delay in procuring from a distributor, but this option is not applicable to these particular parts). Assume that a part is going to be late (see table above for maximum). The sum of time that can be bought by expediting inspection (5 days) and rescheduling the production personnel, when added to DSL, is practically sufficient to cope with even the maximum lateness.

The lowest level that avoids line stoppage (initial DSL values) is the most economical level. The duration of simulation was 2080 days (8 years).

9.4 WITH INDIVIDUAL PARTS

Experiments were performed on the following three parts individually to determine specific optimal order quantity and safety stock level.

		Part Description		
		Film Resistor	Diode	Flag Assy
Identity No.		8	41	70
Rescheduling Slack, Days		8	8	10
Lateness, Days	Avg	-2.5	3.3	1.25
	Max	7	17	12
Probability of Accepting Lot		.93	.62	.94
Time to Return to Vendor, Days		7	15	15*
Distributor Availability		None	None	None

*Forced return to vendor if lot fails inspection.

Figures 6, 7, and 8 show the results, using a random number seed of 251. Of the three parts, only the flag assembly (70) caused line stoppage. The other two parts have sufficient slack for coping with lateness and lot rejections so that smooth curves are obtained as safety stock levels and order quantities are varied. The optimal values of lot size and safety stock are fairly evident from the plots.

9.5 EFFECT OF CHANGING RANDOM NUMBER SEED

While a pseudo-random number series used in generating probabilities is reproducible when started with a given seed, one might well ask whether identical simulation results would be obtained if a different starting number were used. The three individual parts, discussed above, were re-run with two different seeds for random number generation. The duration of each run was set at a period sufficient to receive 600 lots. The following results give an indication of the reproducibility of the experiments, and show that precision of better than ± 5% should not be expected in Total Annual Cost.

	Part Description		
	Film Resistor	Diode	Flag Assy
Identity No.	8	41	70
Order Quantity, Days	21	25	25
Safety Stock Level, Days	3	25	18
Seed = 251:			
Total Annual Cost	$1577	$816	$928
Annual Inv. Holding Cost	879	552	553
Annual Cost of Rejection Alternatives	176	107	21
Annual Cost of Buying Time for Lateness	33	---	---
Seed = 567:			
Total Annual Cost	$1508	$892	$928
Annual Inv. Holding Cost	833	523	556
Annual Cost of Rejection Alternatives	107	181	18
Annual Cost of Buying Time for Lateness	29	---	---
Seed = 777:			
Total Annual Cost	$1530	$864	$937
Annual Inv. Holding Cost	878	524	562
Annual Cost of Rejection Alternatives	131	152	21
Annual Cost of Buying Time for Lateness	32	---	---

10. CONCLUSIONS

This simulation program, now in convenient form on magnetic tape, provides a tool for quickly analyzing the effect of change of order quantities and safety stock levels of the parts purchased for the FMU-56/B fuze production line. The study led to a better understanding of the actual mechanism of the parts supply problem on the part of all participants, which should lead to more efficient actions and decisions.

The program requires a computer with a memory of 16K words, but could be run on an 8K unit with runs restricted to one part at a time. The basic program can easily be modified to accept new fixed input data as changes occur in engineering design or procurement conditions.

The study was performed in a 4-month period (part-time) by personnel without any previous experience in simulation except for a course in GASP at Arizona State University. Most of the time one person was engaged, but for a short time, during data gathering, approximately 12 people participated.

The results have been presented to numerous groups at Motorola, including top management. A flip chart method of presentation seemed to be quite effective in describing the probabilistic simulation techniques and potential cost savings.

Future improvements are planned, including storage cost and capacity considerations, provision for variable production rate, and inclusion of step function inspection costs. It is expected that the improved simulation program will be applied in formulating the production plan for a slightly modified version of this fuze, soon scheduled to enter production.

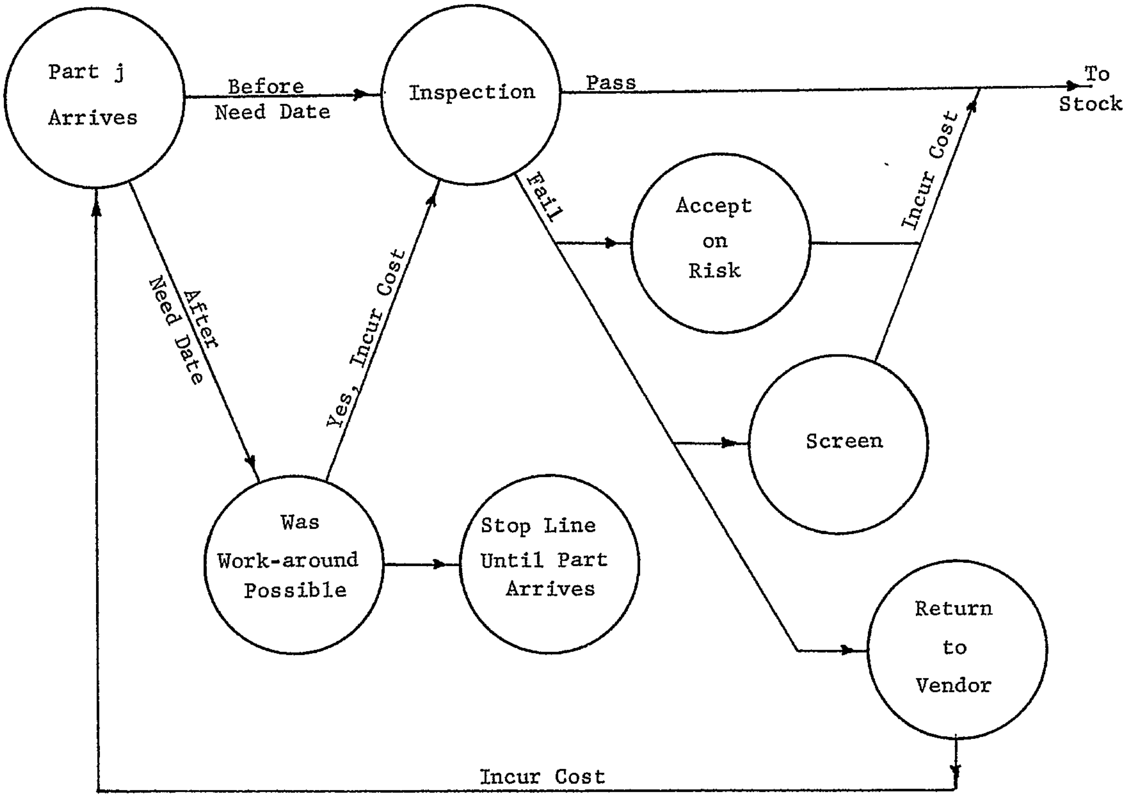

FIG. 1 BASIC FLOW CHART

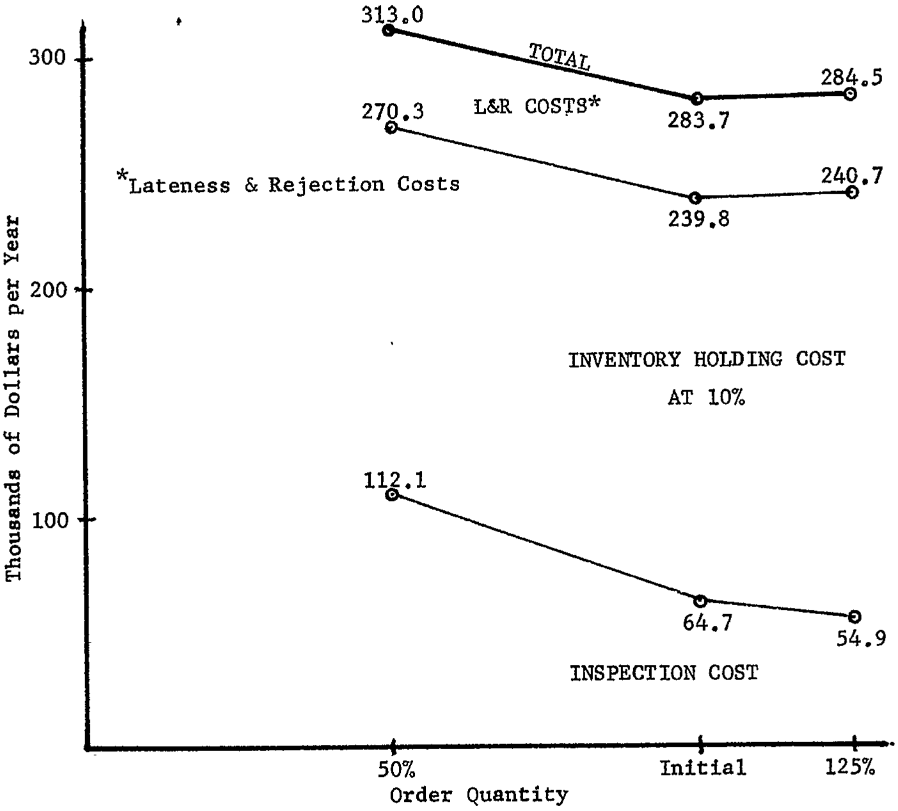

FIG. 2. CHANGE OF ORDER OUANTITY, FULL PARTS COMPLEMENT

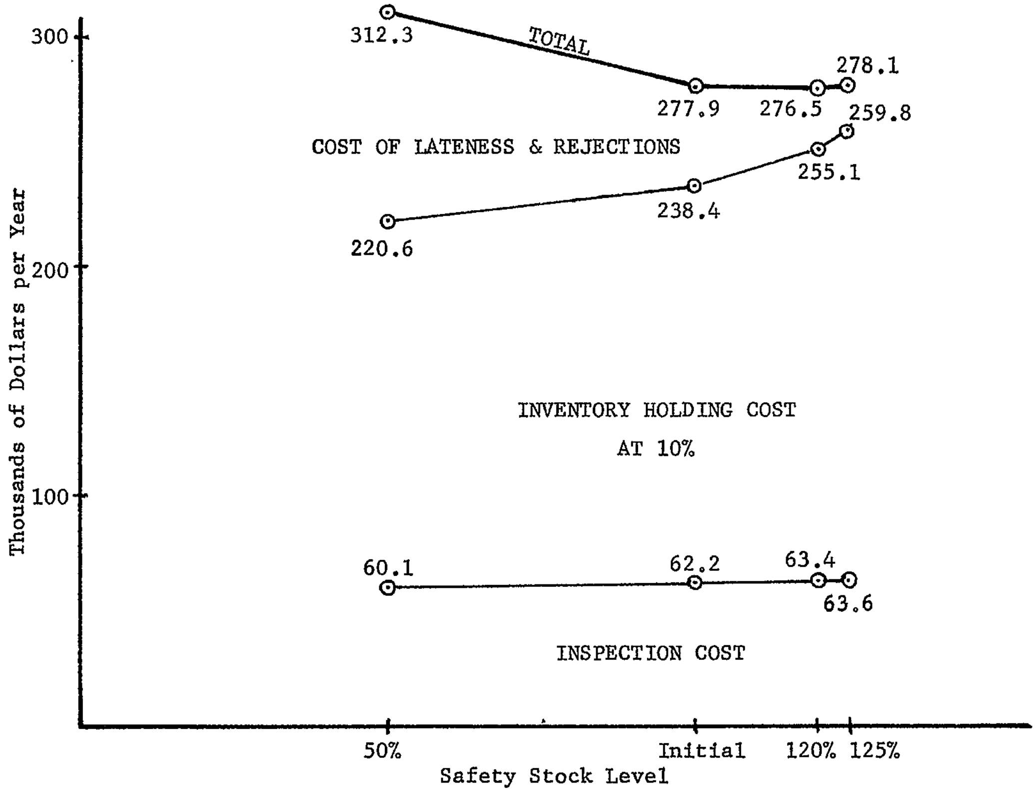

FIG. 3. CHANGE OF SAFETY STOCK LEVEL, FULL PARTS COMPLEMENT

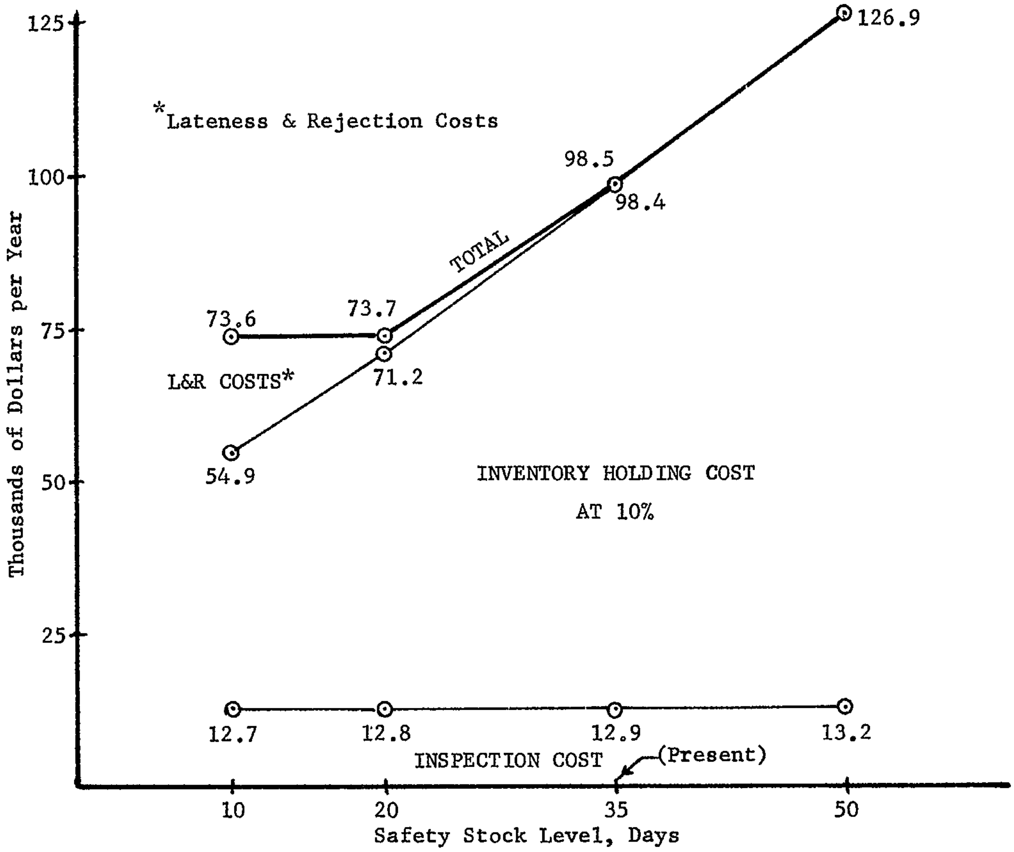

FIG. 4. CHANGE OF SAFETY STOCK, 25 ALAS PARTS ONLY

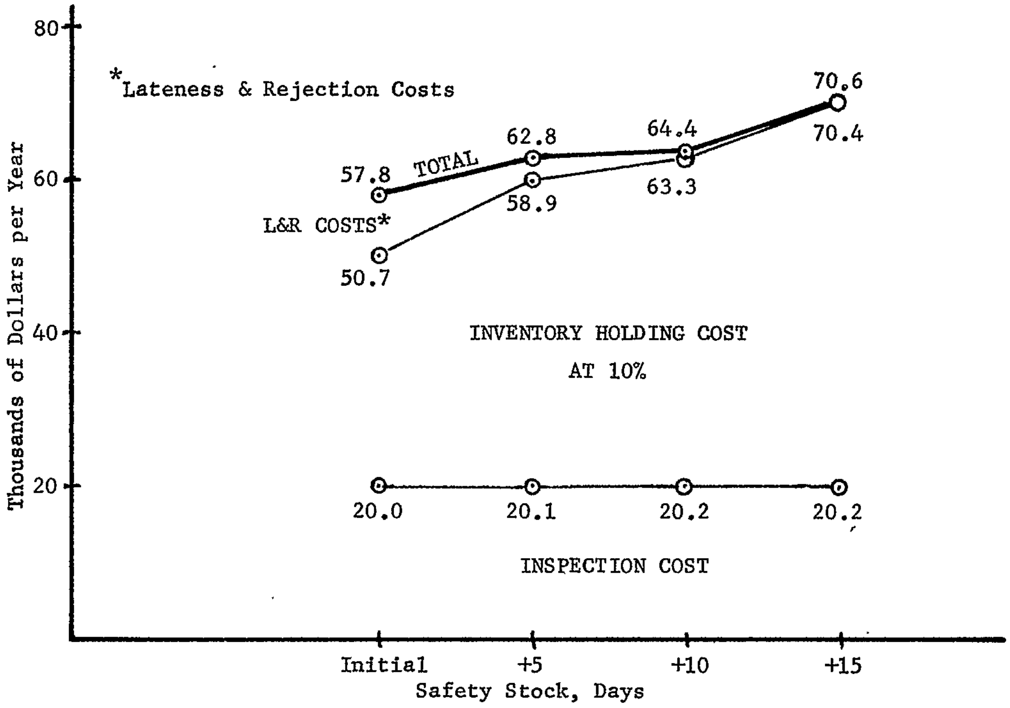

FIG. 5. CHANGE IN SAFETY STOCK, 5 MOST EXPENSIVE NON-ALAS PARTS ONLY

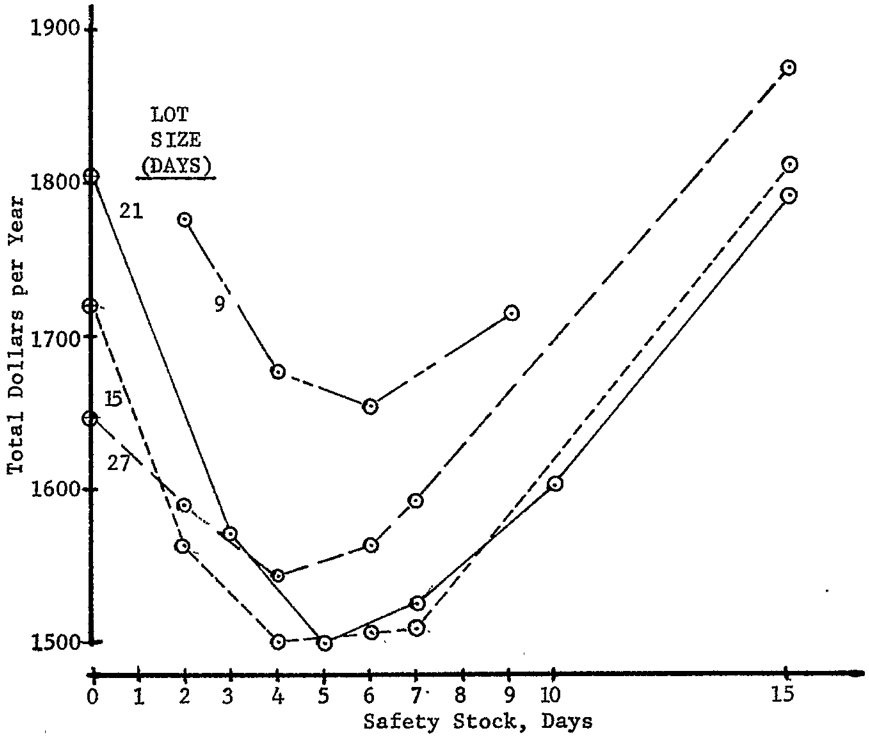

FIG. 6. PART NO. 8, FILM RESISTOR

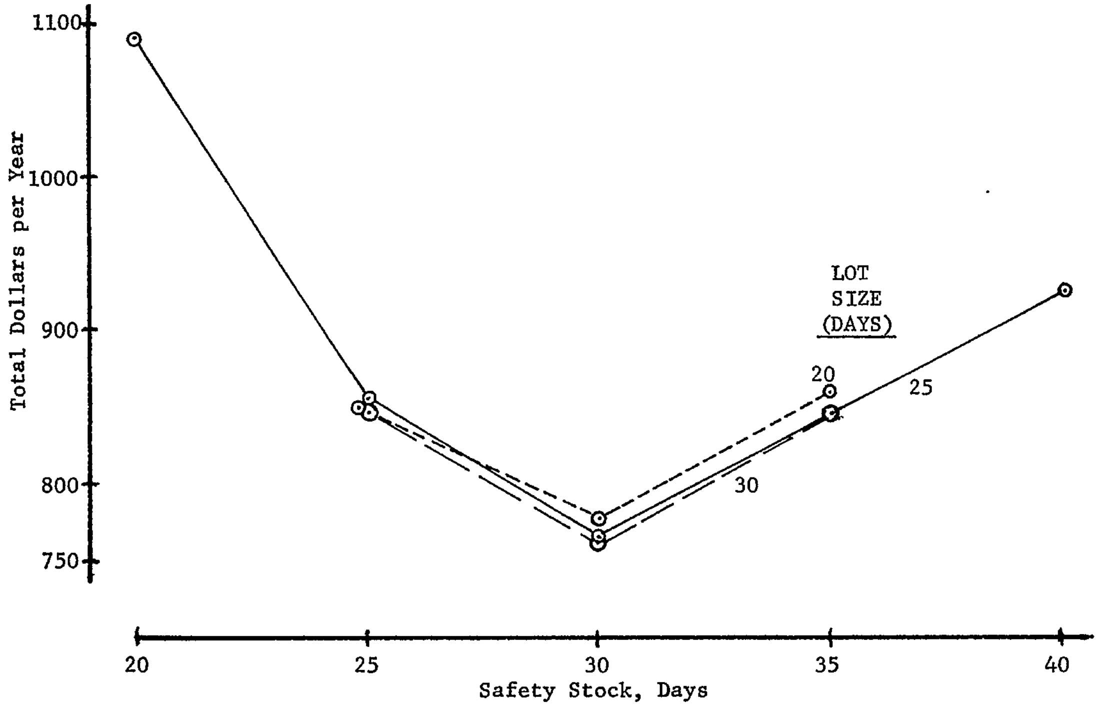

FIG. 7. PART NO. 41, DIODE

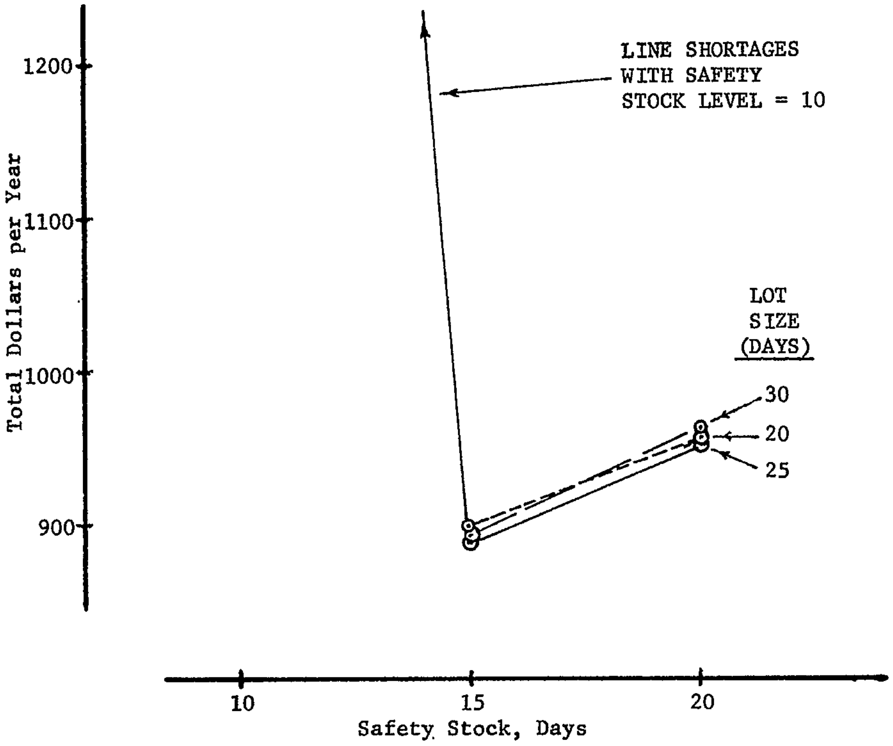

FIG. 8. PART NO. 10, FLAG ASSEMBLY

APPENDIX A

FMU-56B Simulation

PART DATA SHEET

Part Code: ______________ Identity: ________________________________

____

Info. Column	Value	Description
1		Distribution code for lateness.
2		Same as 19, except AQL ≈ 6% (500 is flag to force RTV)
3		Maximum number of days without parts that can be rescheduled around without shutting down entire line, working days (SKFLX).
4		Cost of 3 (if 3 other than 0), $ cost per day (DCSK).
5		Inspection time required, including transit, waiting, and paperwork time, working days.
6		Probability of passing inspection (#lots passed/#lots inspected) %.
7		Probability of AQL exceeding 4% (#lots with AQL > 4%/#lots inspected) %.
8		Do we always require inspection, even if late? Yes (0) or no (1).
9		Fixed inspection cost, $ per lot (Y) (linear equation IC=Y+100 X *QD)
10		Variable inspection cost, ¢ per day's supply (X).
11		Cost of parts needed per day, $ (including shrinkage).
12		Delay in getting resupplied by vendor if lot is rejected, working days.
13		Max. no. of days supply available from distributor (DSLK).
14		Time to procure from distributor, working days.
15		Cost per day's supply from distributor, $
16		Is this a type of part we would screen in-house if lot failed inspection; yes (1) or no (0).
17		If yes in 16, delay time to perform per lot, working days.
18		If yes in 16, cost of screening per one-day's supply, $
19		Added cost of reject modules, etc., if accept a reject lot having AQL ≈ 3% on a risk basis, $/day's supply (500 is flag to force RTV).

Biography

Mr. Petersen is the Senior Technical Assistant to the Manager of Reliability and Components Engineering at Motorola's Government Electronics Division. Among his responsibilities is that of introducing operations research techniques where applicable. For the past fifteen years he has been closely associated with Motorola's reliability endeavors and was their representative to the Electronic Component Reliability Center at the Battelle Memorial Institute. Prior affiliations were with IIT Research Institute and Commonwealth Edison Company. His B.S. is in Electrical Engineering and M.S. in Industrial Engineering. He is presently writing his dissertation on integer programming techniques at Arizona State University.

APPENDIX B

PARTS PROCUREMENT SIMULATION MODEL (Condensed)