A QUALITY ASSURANCE SYSTEM FOR MANUFACTURING USING BASE SAS SOFTWARE ON A MINI-COMPUTER

Sandra Heard, M/A-COM Telecommunications
Judith Mopsik, ORI, Inc.

Quality Assurance - making sure that a product meets a certain standard of reliability - is of great importance to everyone. From the dependability of the office products we buy to the safety of the cars we drive, dependability depends on the integrity of the quality controls that are built into the manufacturing process. Traditionally, the measurements of reliability and quality have been performed manually, and a lot of paper (i.e., forms) was generated to keep track of the assembly line production or the manufacturing process. The integration of microprocessors and minicomputers on the manufacturing floor is making it possible for paper forms to be eliminated. Putting production status on an on-line data base is making it possible for Management to determine more quickly where production problems occur and what corrective actions need to be taken. The result of this is realized as cost savings.

The conversion from manual procedures to automated processing involves data entry using a computer terminal or key-punch machine, data base management, computerized data editing, statistical analysis and report generation. The conversion to automation is taking place all over the world. Both large and small businesses are learning that the cost of automating their manual processes and integrating them into a unified system can pay for itself in the first year of operation. The by-products of integrating the computerized processes include faster turn-around from the time data is collected until it is analyzed and reported, as well as a greater degree of accuracy and reliability.

This paper will discuss the automation of a quality assurance reporting system for electronic assemblies. It is operational today at M/A-COM Telecommunications in Germantown, Maryland. The system was programmed using SAS software, on the Digital Equipment Corporation VAX 11/780 mini-computer. The system was designed, coded and implemented in 6 weeks. The results of this project demonstrated to M/A-COM Management that the conversion to automation in the area of quality assurance could be completed in a short period of time to meet the needs of both current and future work. Furthermore, the cost of a custom-designed system was significantly less than a "canned" package, which the in-house MIS staff had been unable to implement during the six previous months. As more procedures on the plant floor are automated (e.g., data entry using bar code readers) at M/A-COM, the original system is being expanded. The following topics will be covered in the sections that follow:

- A manual system for Quality Assurance
- Goals of an automated system
- The SAS system on a mini-computer
- Using the SAS system in manufacturing applications
- Expansion of the system beyond its initial implementation
- Future plans for automation

A MANUAL SYSTEM FOR QUALITY ASSURANCE

In the Summer of 1983, the manager of Quality Engineering at M/A-COM Telecommunications sent ORI, Inc. a series of hand-drawn bar charts and reports that tracked electronic assemblies through all manufacturing inspection and test points, as well as throughout their warranty periods as they are returned for updates and repair. The data was collected from Failure Trouble Report (FTR) forms and Customer Returned Goods (CRG) forms that are manually recorded at each test point. The information on the forms included the assembly number, pertinent dates and codes for defect descriptions, status, repairs, and project name. The coded information was transcribed into descriptive information for the tracking reports. The reports that were produced enabled the Quality Engineer to assess which assemblies were driving the overall program performance.

M/A-COM wanted all of the tracking reports produced by computer. Large volumes of data was becoming increasingly difficult to summarize by hand. The firm had a VAX/780 and was considering the purchase of the new SAS software (Base product and Graph) that had just been announced for the mini-computer. He had only two questions:
1) Can ORI develop a software system in two months on the VAX/780 to produce the tracking reports?

2) Can the software system be designed so that the Quality Engineering staff could easily use the system and update it as needed?

GOALS OF AN AUTOMATED SYSTEM

The Quality Engineering manager wanted an automated system that would be flexible enough to accommodate changes (e.g. database expansion). The data was to be keyed into the system on a daily basis, and an historical file needed to be maintained so that time series (i.e. trend) analysis could be run periodically. The tracking assembly reports and graphs, labeled appropriately, were to be stratified by several of the analysis variables that were being collected (repair and defect codes, status, and assembly number). The software was to aggregate the data weekly, monthly, and sometimes at five-week intervals.

This application represented a small component of Quality Engineering's total problem. If Management could be convinced of the feasibility of automating one aspect of the Quality Engineering work, the company would provide SAS training for its staff so that the rest of the system could be completed with in-house support.

THE SAS SYSTEM ON A MINI-COMPUTER

A review of the tracking assembly reports (EXHIBIT 1) and the goals of the Quality Engineering staff indicated that this was a programming job tailor made for the SAS system. PROC CHART would produce all of the bar charts that were currently being drawn by hand. Some of the labeling, however, would pose a challenge without the use of MACRO variables. (The MACRO language was not part of the SAS system in the early releases on the mini-computer). A five-week trend analysis report of defects was a natural application for PROC RANK. All of the stratification could easily be handled with appropriate sorting and BY-group processing.

The ORI staff was concerned about how many features of the SAS Base product were available on the VAX/VMS system.

\[\text{o Could we write a system using PROC FORMAT and the PUT function for converting codes to descriptive labels (i.e. table look up)?} \]

\[\text{o Were the DATE functions available?} \]

\[\text{o Were DATE formats available as format modifiers on the INPUT statement?} \]

\[\text{o Was the printed output from the procedures comparable to the mainframe SAS procedure output?} \]

M/A-COM was in the process of installing the SAS system by the time that ORI was presented with this assignment. Before making a commitment that we could not back 100%, we presented the following plan to our client. Our lead analyst would write prototype SAS code for each type of report, over a two week period. At the conclusion of this work, ORI would be able to assess the state of the early release of the software SAS software on the VAX/780. We would also be able to present the client with sample reports demonstrating how closely the original, hand-drawn reports could be duplicated using the SAS system.

The development of the prototype was an immediate success. All labeling and report writing features necessary to developing the Quality Assurance reports could be tested in an "unpressured" environment. Using the VAX/VMS system in the SAS interactive mode, all of our early questions were resolved. If any unforeseen problems arose later on, we were confident that we could use other programming strategies to resolve them. The results of our two-week prototype development were:

\[\text{o The SAS procedures worked as we expected them to -SORT, FREQ, CHART, MEANS, RANK - but the labeling was not identical to the mainframe SAS product. We were able however, to enable to "mimick" the original labels on the reports by creating constants as "BY-group" variables. The values needed in the labels came out in the BY line.} \]

\[\text{o The SAS formatting features (including DATE formats) that we rely on so heavily were all in place. However, the use of the PUT function to simulate table look-up produced an error message. This problem was resolved by only using the formatted values in printing the final reports. The "table look-up" technique was simulated by merging the formatted values (as a SAS data set) with the original data. While this required additional sorting, the code could be replaced once the PUT function was fully implemented to accept user written formats.} \]
We would be able to write an interactive menu style "front end" to the software SAS programs that would imitate the macro features we had come to depend on. The input parameters were set up as the single observation in a SAS data set, and merged onto the working data files.

There were some reports we could not exactly reproduce. We presented the client with the data he needed in a format closely resembling the original reports. Our substitute reports were accepted.

The automated data entry system would be new to the clerical staff. The FTR and CRG forms would have to be transcribed using a computer terminal keyboard. The demonstration of prototype illustrated that we could maximize the "friendliness" of the system using LIST input mode with INFORMAT and FORMAT modifiers.

**SPECIAL FEATURES OF THE QUALITY ASSURANCE SAS SYSTEM**

**DATA ENTRY**

Tracking data had never been keyed into a computer at M/A-COM for this purpose. In order to make the process simple, we designed a record format that enabled the data entry staff to enter data in a modified "free format". Each variable on the tracking form was keyed in the order it was entered on the original form. Each value was separated by at least one blank space. The SAS INPUT statement looked like it utilized the straight LIST input mode. However, all character variables and date values were defined by INFORMAT or FORMAT modifiers. A "comment" field that enabled engineers at each test point to add additional information to the form was incorporated into the record layout - only the blanks were replaced by "hyphens".

After entering a day's worth of data onto a VMS file (analogous to an OS raw data file), the data was ready to be edited. The data technician invoked a special SAS program that reported all erroneous data, outliers, and invalid values (e.g. character data keyed for numeric fields, invalid date values, part and repair codes not in the FORMAT list). PROC MEANS and PROC FREQ were used to present some descriptive statistics and frequency counts on the "raw" data.

Once the data was edited, the corrections were made and at the end of the week the tracking reports could be run. Usually these reports were run weekly, but the time frame was at the user's option. On a weekly basis, the data technician would run an archival program to backup the files. This was also part of the SAS software that was delivered with the Quality Assurance system.

**INTERACTIVE REPORT REQUESTING**

Two separate data bases were created for the tracking reports. One was maintained for FTR's and the other was CRG's. When the report program was called up, the Quality Engineer selected either the FTR.REPORT program or the CRG.REPORT program. These were SAS modules stored as text in the VAX/VMS directory. The two programs were constructed in a similar style.

The first few data steps prompted the user for the parameters that controlled the reports to be generated:

- Time period
- Detail level (for individual projects, or for all projects)
- Stratification variables
- Subset selection

All of the input parameters were screened for correctness. If any were invalid, appropriate error messages were written to the users terminals and new prompts were issued. The input data was then sorted and merged with the data base to be analyzed. The result of the MERGE was an output data set that was a subset of the data base. The reports were generated using this working SAS data set.

**EXHIBIT 1**

![Image of a line graph titled "OBF: Renews failure descriptions"](image-url)
M/A-COM Telecommunications, produces communication and electronic products. Some are produced for repeat customers and may be high volume, while some are customized for specific customers' needs in a one-time contract. Due to the differences in product line and application of data, reports must fit many different needs. Both the SAS base product and SAS graph are easily adaptable to our system.

In most manufacturing facilities it is necessary to record activities as they occur for the purpose of evaluating the effectiveness of the processes, machines, work instructions, and work environments. For improved evaluation, it is important to obtain analysis from data on a real-time basis. Currently, at M/A-COM, SAS software is being used to process data for the end purpose of trend analysis, tracking, and initiation of corrective action. The Quality Assurance group is responsible for the collection and analysis of data and providing information on the results. Many activities are recorded on documents which are collected and entered into a computer file for manipulation. The end use of the data is to provide information to many levels of management to make management decisions.

EXPANSION OF THE SYSTEM BEYOND INITIAL IMPLEMENTATION

A few weeks after the new SAS system was in production, management was convinced that the SAS system should be used for all Quality Engineering's reports. Large amounts of Quality data could be reduced to simple reports for faster and easier decision making. The major areas where data collection was needed was Receiving Inspection, Manufacturing In-process and Quality Control Inspection, Automated Test Equipment (GenRad) results, and Rental Equipment costs.

RECEIVING/INSPECTION

The beginning of M/A-COM Quality system is at Receiving Inspection. The management requirements for this system were to include lots received history, and vendor performance. The new program was patterned after the initial failure history programs with modification adjusting to new variables to be entered and the desired output. The purpose of this data was to serve as a history of commercial and military parts received and inspected and an indicator of problems experienced with certain parts or vendors. This history would provide the factors needed for vendor rating and corrective action to vendor and M/A-COM part problems. Select vendors with a yield of 50% or lower would be identified and notified of results. Using PROC MEANS descriptive statistics were produced. Using PROC FREQ, a 2-way table was created containing disposition of the rejected parts and the affected vendors. The required reports were easily configured using the SAS system. Exhibit 2 presents a sample of the 2-way table created using PROC FREQ.

MANUFACTURING IN-PROCESS AND QUALITY CONTROL INSPECTION

This system represents the next step in the Quality Assurance process. The following are management requirements for the Manufacturing In-process and Quality Control Inspection:

- Weekly reports on all activity and on selected projects.
- A summary of quantitative values for inspection points and the resultant yields. The same statistics were produced for each project. Exhibit 3 presents the desired output. The project data was not originally part of the data base. The project data was easily obtained by creating an auxiliary file to convert assembly number to project name using MERGE. This eliminated the manual assignment of project names on the many forms which are initiated daily.
- Bar charts of defects for each inspection point and each assembly. The "PROC CHART" options used with HBAR were SUBGROUP, NOZEROS AND DISCRETE DESCENDING to produce charts. The results were items charted in descending order, omitting the zero items within each subgroup.
- An accounting of all serial numbers of boards passing through each inspection point. A form was initiated for data collection on lots having various size ranges from 1 to 100. Two raw data files were created to contain lot quantities and defect detail. Both files contain the form number which serves as a common element when the two files are match merged. The program consists of a series of PROC MEANS statements, to obtain the summaries for each Inspection point and project. PROC CHART statements were included for each Inspection point and assembly with horizontal bars representing defects. Again, the programs were easily implemented using SAS software. Exhibit 4 presents the system flow for Manufacturing In-process inspection data processing.
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EXHIBIT 3

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AUTOMATED TEST EQUIPMENT SYSTEM (ATE)

Data from the automated test machine was available on tape. It was refined by the operator to include only the indicated failures that were verified. When a verified failure occurs at first test, a number of retests are made until no failure occurs. The total of all nonverified failures were also provided for each board tested. This data would indicate the reliability of the machine to detect failures correctly. The management requirements for this system are as follows:

- A report that segregates the first test from the retest activity.
- The first test data would be used to determine the process yields from quantity passed and quantity tested.
- The retest data would indicate the number of times retested and the defects found.
- Totals were needed for comparison of quantity of defects vs quantity of unverified failures.
- Bar charts of components involved in the failure, and the defects found in each assembly were needed.

A series of PROC CHARTS and PROC FREQ executions in the program produced most of the needed output. The resulting output is a report which informs management of the amount of failures occurring at the assembled board level and the capability of the machine in detecting failures correctly and consistently.

FAILURE TROUBLE REPORT (FTR)
CUSTOMER RETURN GOODS (CRG)

The existence of additional systems initiated a need for revisions to our initial systems. Changes included modifications to programs to utilize raw data files for entry. Both files contain the FTR or CRG number as a common element for matching. The assembly number to project file had been incorporated into both FTR and CRG programs. The output format remained basically the same. The processing of the reports were made on the raw data files instead of archived file. Changes like these were easily made to the initial programs by using the SAS system.

OUTSTANDING RENTAL EQUIPMENT COST SYSTEM

The initiation of the Rental Equipment cost system created the biggest challenge due to the calculations, which were required, and the kind of information to be provided. This report had been done manually, in the past, with great difficulty and was very time consuming. The purpose of the report was to provide each department head with a listing of all rental equipment assigned to them and the cost to rent the equipment. It was determined that these aspects required improvement, or were missing from current data.

- Data required update to reflect current department numbers.
- Provide purchase cost of equipment so that management decisions could be made to purchase equipment, as the total rental cost approaches purchase cost.

The data base was created from the existing manual data and some additional data items. The program selected first the outstanding rental equipment items from those containing no return date. The date equipment was received and current report date were converted to julian dates so that length and cost of rental could be determined. Then a new field was created to represent the difference between total rental and equipment purchase cost. The primary output of the system is a listing by department of all outstanding equipment, the monthly charges for each item, the total rental charges, purchase price, and location of equipment. Items whose rental cost exceeds fifty percent of the purchase price are selected and listed separately for each manager. This information allows management to determine when to purchase equipment instead of continuing the rental of the equipment. When the initial report was run there were several items in which the total rental cost exceeded the purchase cost. The decision was made then to return these items and purchase new equipment. This kind of a decision not only saves M/A-COM money, but when new equipment is rented, maintenance and repair frequency is reduced. Then a chart containing the departments incurring a high cost of rental was created by use of the PROC CHART procedure.

The initiation of this system has resulted in more efficient equipment rental, minimization of rental cost, and more accurate accounting of rental cost.
SYSTEM FLOWCHART FOR INPROCESS INSPECTION

1. EDIT: INSPECT.RAM and enter new data
2. EDIT LOGS.COM and assign .RAM files needed for processing
3. Execute BATCH.COM and run INSPECT.RAM
   - If errors indicated in .LOG
     - Make appropriate corrections to .COM or .RAM files
     - Go back to 3
   - Print corrections INSPECT.LOG and INSPECT.LIS
4. SITE INSPECT.BAS to change dates
5. Execute BATCH.COM to run INSPECT.BAS; produce INSPECT.LOG
   - If errors indicated in .LOG
     - Make appropriate corrections to .COM or .RAM files
     - Go back to 3
   - Print corrected INSPECT.LOG and INSPECT.LIS; distribute report as necessary.

FLOW OF FUTURE SYSTEM

1. Barcode and automated entry
2. Edit, review and correct data
3. Data load to IBM PC or VAX
4. Build data base in VAX
5. Output
   - PDF BROWSE
   - DB UPDATE
   - NEW SELECT REPORTS
   - ROUTINE REPORTS

EXHIBIT 4

EXHIBIT 5
PLANS FOR THE FUTURE

AUTOMATED SYSTEM DOCUMENTATION

The expansion of our SAS system also includes innovations related to automated documentation. The manufacturing systems described above require extensive detailed documentation especially when change in the system is a result of company growth. To minimize the time required to update documentation, programs have been created which will interpret the existing SAS programs and files, and generate system specification documentation. The program which produces a record layout does so by scanning the SAS programs for the LENGTH, INFILE and the INPUT statement. The INPUT statement contains all the data variables and their attributes. The length of each character variable is eight characters by default unless the length was previously specified. SAS programs are currently being developed to produce program flow charts and samples of the reports that are generated.

AUTOMATED DATA COLLECTION

The creation of many automated systems at M/A-COM has been successful but large amounts of paper work continue to be necessary. The company is now studying the feasibility of moving toward a paperless factory. An extensive study was conducted on a proposed automated data collection system using barcode readers and portable data entry units that would replace the forms currently used. Data will be read from the barcode labels by a hand-held laser or wand reader. Additional data is entered by the operators as each activity occurs. The data will be available on line on a micro-computer until the end of the day then down loaded to the VAX. SAS software will be developed to collect the data into a common data base. The advantages to automated data collection using SAS software for retrieval, review, and analysis of data is it's immediate availability via menu/screen prompts. The intangible benefits resulting from automated data collection and the integrated SAS data base are noted below.

- More accurate data collection possible than when written on forms which may be unreadable.
- The cost to purchase, review and handle forms will be eliminated.
- Common data base will allow overall quality system analysis.
- Immediate data analysis will shorten the time between data collection and corrective actions.

EXHIBIT 5 shows the Flow Chart of the future automated data collection system.

CONCLUSION

Utilizing the SAS base product in all of Quality Assurance reporting and analysis has yielded improvement in the efficiency, accuracy and availability of information to make management decisions. The SAS system was easily adapted to the current manufacturing applications. A cost saving has been realized since the initial implementation of the automated data processing, review and analysis. A report is now generated in a day as opposed to weeks that it took prior. The major factors that make the SAS base product ideal for use in our applications are:

- EASE OF ENHANCEMENTS
- ABILITY TO ACCOMMODATE MULTI-USERS
- DATA BASE EXPANSION AND MODIFICATIONS
- ON LINE COLLECTION AND RETRIEVAL OF DATA
- GRAPHIC CAPABILITY
- MENU DRIVEN DATA REVIEW AND RETRIEVAL
- USER FRIENDLY FOR NON-PROGRAMMERS
- STATISTICAL FUNCTIONS IN LANGUAGE
- CODE CREATION AND TRANSLATION
- CAPABILITY TO MERGE SEVERAL DATABASES

The authors can be contacted at:

M/A-COM Telecommunications
11717 Exploration Land
Germantown, Md. 20874
(301) 428-5636

ORI, Inc.
122 C Street, N.W.
Suite 250
Washington, D.C. 20001
(202) 737-2666