# QUALITY IN AT&T NETWORK SYSTEMS



**Eugene J. Eckel**

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AT&T Network Systems has in operation a formalized quality-improvement program. It is spearheaded by a Quality Council made up of all vice presidents from Network Systems and three from AT&T Bell Laboratories and is carried out by employees at all levels. Underlying principles of the program include commitment, communication, education and training, teamwork, and monitoring of results. Numerous techniques and tools, such as system simulations and software packages for analyzing processes, are applied to manufacturing operations at Network Systems plants to identify problems, prevent defects, increase product yields, and reduce costs. The purpose of the program is to increase customer satisfaction.

**Developing a Quality-Improvement Program**

AT&T has always enjoyed a reputation for quality. But in today's marketplace, quality alone is no longer enough; the cost of quality is equally important. This means it is necessary not only to maintain a high level of quality, but also to drastically cut its cost.

AT&T Network Systems estimates the cost of quality at 20 to 25 percent of sales. Manufacturing's share is about 14 percent of sales. By significantly reducing that burden, we can open up our profit margins to get the kind of flexibility in pricing needed to operate effectively in a highly competitive environment. Network Systems' goal is to cut the 20-to-25 percent cost of quality by 60 percent over the next four years, bringing it down to a more acceptable 8-to-10 percent of sales. At the same time, we intend to cut the manufacturing cost of quality to less than 5 percent of sales. These goals aren't options; they are imperatives.

Of course, our ultimate goal is total customer satisfaction. Realization of that goal requires the total commitment of every AT&T Network Systems employee. To be effective, such commitment has to be integrated into a formalized, across-the-board program. Such a program exists and is well under way. In 1984 Network Systems began an intensive look at all its operations and appointed a quality officer. The next year a formal program was started with the formation of a Quality Council consisting of all Network Systems vice presidents as well as three from AT&T Bell Laboratories development organizations that directly support Network Systems. By March of that year, the Council had initiated a process for achieving quality improvements in those areas considered most important to Network Systems. A task force was assigned to study and make recommendations on

- A planning "template" that can be used by all organizations to develop quality-improvement programs
- Employee training
- Interaction with suppliers, both internal and external
- Identification of primary quality-improvement opportunities in the total business process
- Quality as seen from the customer's perspective.

Some of the principles and practices of the program are described below.

*Commitment.* A successful quality program requires a total commitment by all employees. This does not mean simply personal commitment to the company's cause, but to well-defined, highly specific goals. As stated earlier, the ultimate goal is customer satisfaction. Every step toward that goal must be focused on enhancing the customer's perception of AT&T as a high-reliability supplier.

*Communications.* The only way to get everybody's commitment to a cause is to tell them everything about it in every way possible. That means using the entire line of employee media, from technical publications like this to simple posters; from face-to-face meetings to videotapes. Employees must be encouraged to see themselves as both suppliers of and customers for quality.

*Leadership.* Somebody has to point the way and push hard to get everyone moving. Leadership must come from the top of the organization. Managers have to get out with their people and see firsthand what's going on. They have to listen, and they have to help solve problems.

*Organization.* Network Systems' Quality Council spearheads and provides direction for quality-improvement programs. In addition, the Quality Engineering and Planning organization maintains a close working relationship with the Bell Laboratories Quality Assurance Center in developing and implementing quality methods and tools for use at the manufacturing locations. At the local level, each location has a quality manager who is responsible for quality programs and who is accountable to executive management. For marketing and sales, Network Systems has organized a Bell Communications Research (Bellcore) Interface Group to interact with Bellcore, our customers' agent for quality.

*Support.* At the corporate level, support for the program begins with AT&T President James Olson. Within Network Systems, support is provided by the groups named above under *Organization.* At the local level, the quality manager can obtain help not only from Bell Laboratories but also from other sources such as AT&T Engineering Research Center (ERC), Corporate Education Center (CEC), and Corporate Headquarters.

*Monitoring.* No program can be effective without continuous auditing of proposals and results. Quality improvement is monitored in much the same way as the company's cost-reduction program—on a case-by-case basis—and at two levels. At the executive management level, *cost of quality* is carefully watched at each Network Systems location. The goal is to reduce the overall cost and place more emphasis on preventing defects and less on inspection and rework, which are costly processes. At the manufacturing level, *product yields* at the "as manufactured" and "as shipped" points are closely monitored, as are design and manufacturing processes and quality of components received from outside suppliers.

*Education and Training.* Following the task force's recommendation, a professional was recruited to administer the quality curricula and coordinate all training with Network Systems business plans. By the end of 1985, over half of Network Systems employees had completed an average of four hours of training in quality basics. Top-management training began early in 1986; it provides a global view of quality as a strategic asset, reinforces management's role in making quality programs work, and supplies practical "how-to" information on setting goals and implementing programs.

*Systematism.* Every process—particularly every manufacturing process—has to be statistically studied, characterized, and understood before it can be systematically improved. In short, it should be information driven. Managers who don't approach quality improvement on a systematic basis will forever find themselves in a fire-fighting mode.

*Teamwork.* To solve problems, everyone who can help should be involved. This includes not only the support groups and individuals specifically responsible for quality improvement, but also unions, suppliers, vendors, and customers.



**Tools and Techniques for Quality Analysis**

Many tools and techniques are available to make a quality program work. They range from truly basic items, such as process control charts, to complex statistical software for analyzing multivariable processes. Some of these are described below. Sources are listed in the panel on page 36.

*Process Characterization Analysis Package (PCAP).*[1] This software package is an integrated collection of statistical techniques for characterizing complex products and processes. Using data gathered during the normal course of production and testing, and performing many statistical judgments, PCAP helps engineers to systematically identify significant process variables, the interactions among them, and the operating regions offering maximum yields (see Figure 1).

PCAP also enables users to model processes and set screening limits that will minimize product costs. It is an effective tool for answering many of the "what-if" questions that engineers must constantly ask as they fine-tune manufacturing processes. Although primarily intended for use with multifacility processes, PCAP is equally effective with single-facility processes. In addition to being used to characterize assembled electronic products at the Oklahoma City and the Merrimack Valley Works, it has been used to solve manufacturing problems associated with silicon devices, cable, and printed wiring boards at component manufacturing locations.

*Quality and Cost Analysis Plan (QCAP).* This tool provides an optimum strategy for testing assembled products, beginning with incoming components and going through to final system testing. Using QCAP to develop a statistical model of an assembly process, engineers can analyze the cumulative effects of component and workmanship quality on product costs and yields. QCAP also performs a sensitivity analysis, and determines test equipment requirements and costs of testing and repairs. QCAP has been used to evaluate the design and manufacturability of circuit packs for the 5ESS™ switch.

*System Simulation.* By constructing a realistic mathematical model of the manufacturing process, the engineer can manipulate the simulated system and observe the effects of product flow, process capability, machine and operator allocations on throughput time, product queue, and manufacturing efficiency. Many "what-if" questions can be evaluated and their economic benefits shown. Simulation studies often reveal surprising results that may run contrary to intuition. For example, it has been shown that it is sometimes preferable to temporarily halt a line and hold people idle rather than carry excess inventory.

*Statistical Design of Experiments.* This is a procedure for gaining insight into the simultaneous effects of many process variables on a selected set of response variables. Interpretation of results is easier and usually more valid than is possible with traditional, one-variable-at-a-time experiments. Statistical design also significantly reduces the number of variable combinations that must be studied by selecting only those subsets that are necessary.

*S Statistical Analysis System.*[2] This is a graphics-oriented, comprehensive package of interactive data analysis software. Using appropriate macros, functions, and

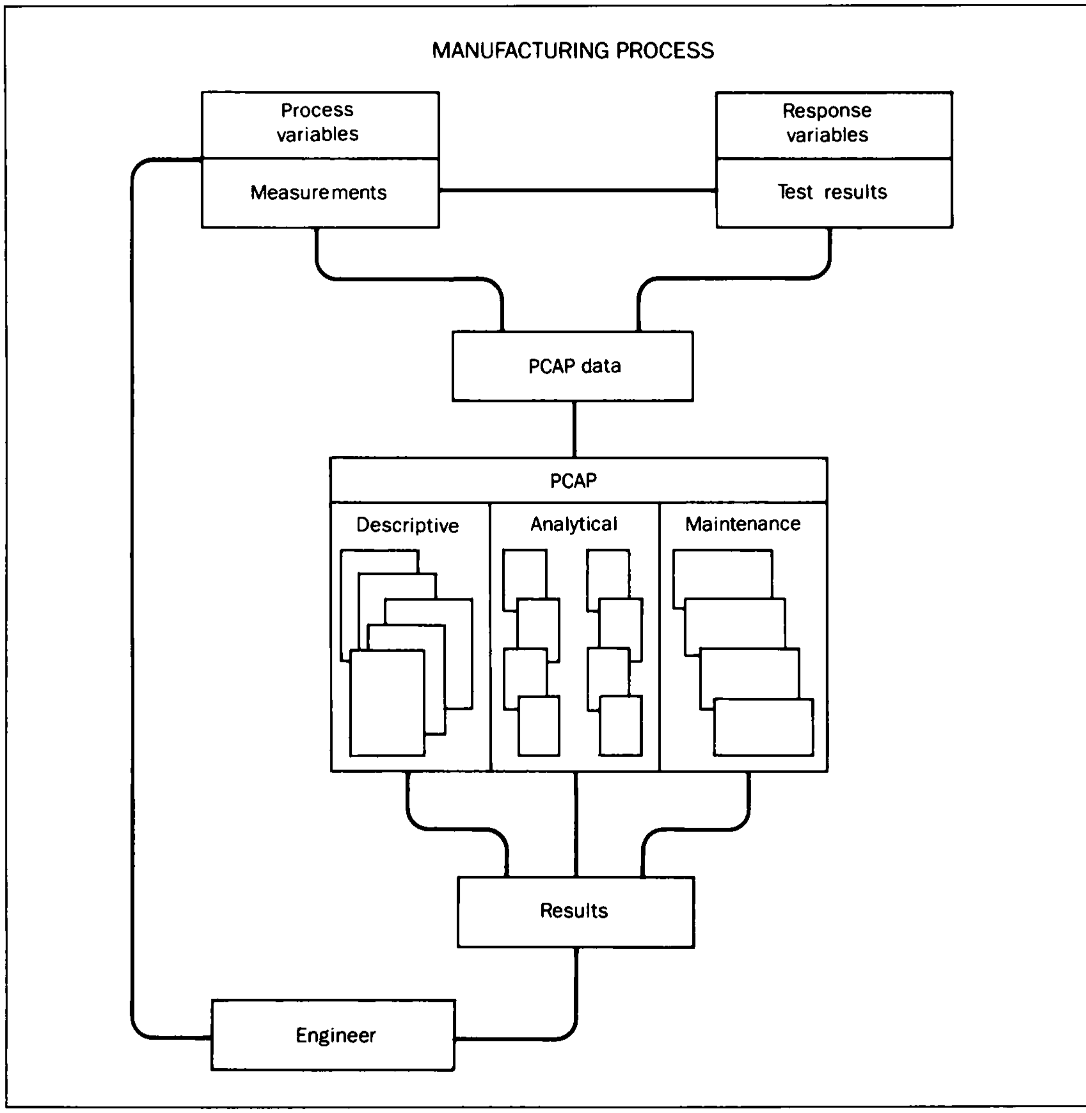


**Figure 1. One quality-improvement tool is the Process Characterization Analysis Package (PCAP), by which data are collected from a manufacturing process, transmitted to the computer, and systematically analyzed. Results are used by the engineers to alter the inputs to the process.**



algorithms, engineers can apply S to manufacturing and other types of data and see the results in a variety of graphic formats. For example, it has been used at the Merrimack Valley, North Carolina, and Columbus Works to produce Pareto diagrams and control charts of circuit pack manufacturing data.

*Cause-and-Effect Study and Force Field Analysis.* This combination is one of the few systematic problem-solving approaches for analyzing quality-improvement opportunities in nonmanufacturing situations. Combining cause-and-effect studies developed by the Japanese quality expert Kaoru Ishikawa,[3] and force field analysis, developed by the American behaviorist Kurt Lewin,[4] it is a procedure to identify quality-related problems and to analyze the forces working for or against the quality of work. In carefully controlled brainstorming sessions, those closest to the issues identify problems, their causes, and the forces that can effect improvement. This procedure has already been used successfully in installation, secretarial, production control, and legal applications. New applications are emerging in market planning and account management.

*Failure Mode Analysis.* Every product failure must be carefully analyzed and the failure mechanisms identified and catalogued. Through an information feedback loop, the design and manufacturing process can be developed, refined, corrected, and controlled so that failure mechanisms are eliminated. Failure mode analysis should be applied at every manufacturing phase of a product, from the component level to the system level.

*Success Mode Analysis.* This approach, the opposite of failure mode analysis, is equally important. Its purpose is to identify the factors that contribute to high quality in any product or manufacturing process and then capitalize on their use elsewhere.

**Applying the Tools**

Many of the techniques and tools described above are being applied throughout AT&T Network Systems. The Oklahoma City Works is an example of how all elements fit together in a single, well-focused effort.

The Oklahoma City Works produces two of the most advanced product lines in the world—the 5ESS™ electronic switch and the family of 3B computers. In 1984 and 1985 the employees made major breakthroughs in productivity and quality. In 1984 they raised production of the 5ESS switch to 2.4 million lines shipped—a tenfold increase—while realizing $210 million in cost savings. In 1985 they raised production further, to over 6 million lines, still without any increase in the number of employees. Manufacturing intervals were significantly reduced, and schedules were met 99 percent of the time, up from 30 percent. These successes were attributed in large measure to Oklahoma City's quality-improvement program.



The quest for quality began at the top with the plant's general manager, who emphasized that quality is everyone's responsibility, not just that of the Quality Assurance organization. Quality messages were disseminated by various media: videotapes, banners, posters, the plant's newspaper, and "live" from supervision. A special feature was a "Quality Olympics" that rewarded organizations showing the greatest quality improvement. To enliven the campaign, some "real" Olympic athletes attended a plant get-together. Management also encouraged teamwork, internally as well as with external organizations such as Bell Laboratories and suppliers and vendors.

Paralleling the communications activities were the Engineering organization's efforts to determine what degree of quality the plant's processes were capable of delivering. Every process in the plant was analyzed, using many of the aforementioned tools, and hundreds of opportunities for quality improvement were revealed. Once the engineers knew what they had, they were able to redesign many processes to make them capable of attaining the quality desired.

Work on circuit packs for the 5ESS switch is a good example of those efforts. In 1983 the Oklahoma City Works was having a major problem with defective circuit packs. The engineers teamed up with Bell Laboratories digital switching engineers to conduct a thorough analysis of circuit pack processes, from design to shipment. Statistical analysis of the circuit pack line showed that the process was incapable of producing at an acceptable level of quality. Quality was being *inspected* into the product—an activity that should be reduced because it results in excessive costs.

Another team used PCAP to analyze the interactions among dozens of wave-soldering variables on 450 different codes of circuit packs. Their efforts identified optimum process settings for parameters such as flux density, conveyor speed, solder temperature, and wave height. They also examined the relationships of a number of non-process-related variables, such as component lead solderability. The analysis results tied in with computerized process control, making it possible to preprogram wave-soldering machines with optimum settings for different codes of circuit packs. The result: a 100 percent improvement in soldering process yield across all circuit pack product lines.

Using system simulation techniques, a team of Bell Laboratories manufacturing systems analysts and Oklahoma City Works engineers analyzed factory capacity, manufacturing intervals, and operator and equipment allocations to determine the most efficient factory layout. The result was the development of Continuous In-line Manufac-

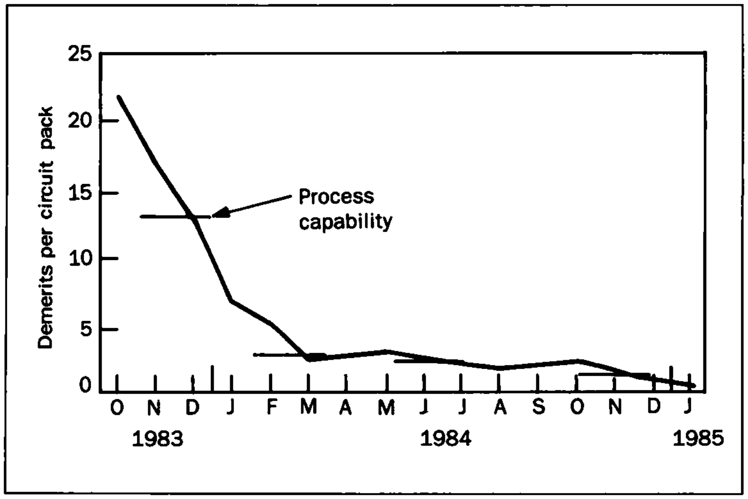


**Figure 2. By continuous analysis and process improvements, the Oklahoma City Works reduced the number of demerits per circuit pack to near zero.**

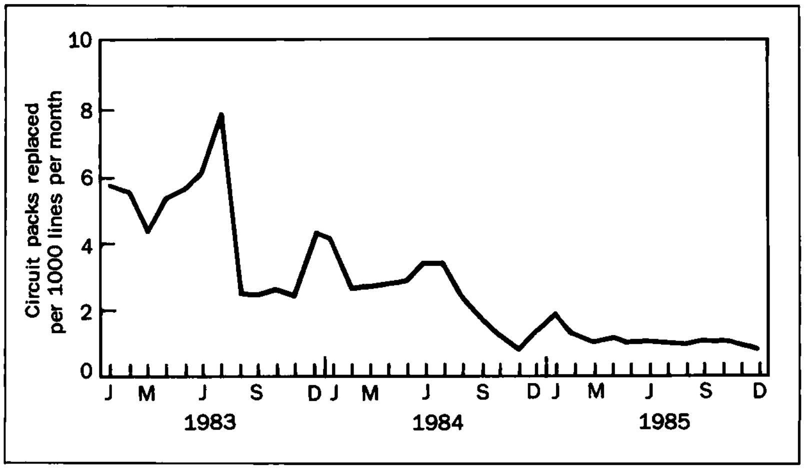


**Figure 3. Through an intensive quality-improvement program, the Oklahoma City Works significantly reduced the number of circuit pack replacements needed in 5ESS™ switches.**



turing (CIM) lines for circuit packs for the 5ESS switch and 3B computers.

Other manufacturing changes resulting from process analyses included the following:

- Kitting of components for shop operators was improved to reduce handling and subsequent damage from electrostatic discharge.
- Change orders were bundled into monthly packages so operators would not have to absorb daily changes.
- Bar-code labeling was instituted to help identify troublesome operations.

After every change, the circuit pack process was analyzed again to look for the next improvement opportunity. By January 1985 this continuous, incremental process had cut demerits* per pack by more than 95 percent (see Figure 2).

*A *demerit*, as distinguished from a *defect*, is a measure of the seriousness of defects in a process or product. A defect is a failure to meet a requirement.

Analyses also led to changes in circuit pack testing, including improved diagnostic software and increased thermal stress to cause early life failures during the test interval, before the product is turned over to the customer.

All of these changes led to the quality improvements graphically shown in Figure 3. By May 1985, the circuit pack return rate had been reduced by a factor of five. Since then it has been reduced by another 50 percent.

The Oklahoma City experience proves that a coordinated, systematic, and sustained approach to quality improvement does work. In this case the fact that employees were producing two much-publicized "flagship" products was a motivating factor. It was relatively easy to make them see that the future of these products and the future of the company were related. When there is no such immediate psychological payoff, then it is all the more necessary for managers to work hard at generating a sense of importance and urgency.

**For more information ...**

More detailed information about the application and the availability of the quality-analysis tools described in the accompanying article may be obtained from the sources listed below.

| | |
|---|---|
| Cause-and-Effect Study and Force Field Analysis | Quality Planning<br>AT&T Network Systems<br>475 South Street<br>Morristown, NJ 07960 |
| Process Characterization Analysis Package (PCAP)<br>Quality and Cost Analysis Plan (QCAP) | Quality Engineering<br>AT&T Network Systems<br>475 South Street<br>Morristown, NJ 07960 |
| S Statistical Analysis System | Quality Assurance Center<br>AT&T Bell Laboratories<br>Crawfords Corner Road<br>Holmdel, NJ 07733-1988 |
| Software Quality Assurance Plan (SQAP) | Quality Systems Engineering<br>AT&T Network Software Center<br>2600 Warrenville Road<br>Lisle, IL 60532 |
| Statistical Design of Experiments | Statistical Theory and Methods Department<br>Quality Assurance Center<br>AT&T Bell Laboratories<br>Crawfords Corner Road<br>Holmdel, NJ 07733-1988 |
| System Simulation | Manufacturing Systems Analysis Department<br>AT&T-ERC<br>P.O. Box 900<br>Princeton, NJ 08540 |



In a very real sense, any location can be only as good as its suppliers and vendors. Fortunately, many suppliers and vendors repeatedly ask us how they can better satisfy our needs. The answer is teamwork.

For example, in early 1984 supply problems with film integrated circuits (FICs) and hybrid integrated circuits (HICs) were in turn creating problems for electronic switching systems and other products. A team of engineers from the Hawthorne Works, the Merrimack Valley Works, Bell Laboratories, and Network Systems worked together to characterize and improve FIC and HIC processes. Among the resulting improvements were these:

- For FICs, Hawthorne reduced contamination in its thick film driers, improved its laser operation by means of a new mask set, and developed new photo-resists for sharper lines and better resistors.
- For HICs, Hawthorne improved its lead-insertion operation and data collection system, and automated the sealant operation, while Merrimack Valley installed robotic test facilities to reduce contamination, improved its test programs for defect analysis, and installed encapsulation equipment.

The end result of this close cooperation was an increase of more than 40 percent in FIC yields and about 22 percent in HIC yields.

Another supplier problem for Network Systems was cleared up when the Dallas Works took prompt action to improve the quality of board-mounted power modules. Bell Laboratories and Network Systems engineers worked with Dallas engineers to double the yield by improving soldering and cleaning processes, tightening up on electrostatic-discharge protection procedures, improving quality control of incoming FICs, and training operators and checkers.

**Software Quality**

Over the years, software has become an increasingly larger part of manufactured products. In the past, testing was the only means of detecting software errors, and that could be done only during the late stages, when errors are costliest to fix. Now the Software Quality Assurance Plan (SQAP) is available for catching errors in the requirements and design stages of software development. This plan, through which quality can be built into software early, has proved itself in several products by eliminating nearly half the errors that used to plague later stages of product testing.

A comparison of average demerits over service life for 1AE6 generic software with later generics shows the dramatic improvements SQAP has made possible (Figure 4). It was primarily because of this program that the 1AE8 generic was able to enter service with less than half the defects the 1AE7 generic started with. What is more, the improvement interval was halved, while customer satisfaction increased proportionally.

**Nonmanufacturing Applications**

*Every* operation affects quality, and manufacturing processes are often substantially affected by the quality of paperwork. Network Systems is beginning to apply to billing, engineering records, and other nonmanufacturing areas the kinds of statistical techniques that once seemed useful only on shop floors. The payoffs are often as substantial as those achieved in factory operations.

A good example occurred when a team from Central Region Engineering and the Columbus Works attacked what had become a well-entrenched level of errors in engineering specifications. These errors had settled in at about 24 percent by October 1984 and in some areas were considered "unavoidable." The team identified the causes, and within eight months the error rate had been reduced to 3 percent.

Similar problems with the accuracy of bills of material were investigated and resolved during the same period. Inaccuracies in these bills impact directly on the cost of inventory and material handling, so causes and corrective measures were pursued aggressively. They were quickly found, and the accuracy of bills of material in Network Systems rose from 60 percent to 94 percent. Efforts are continuing to achieve 100 percent accuracy.

There are many other examples, but these two are sufficient to point out that quality in nonmanufacturing areas is as vital to business operations as it is to manufacturing, and that it can be improved by the same systematic approach.



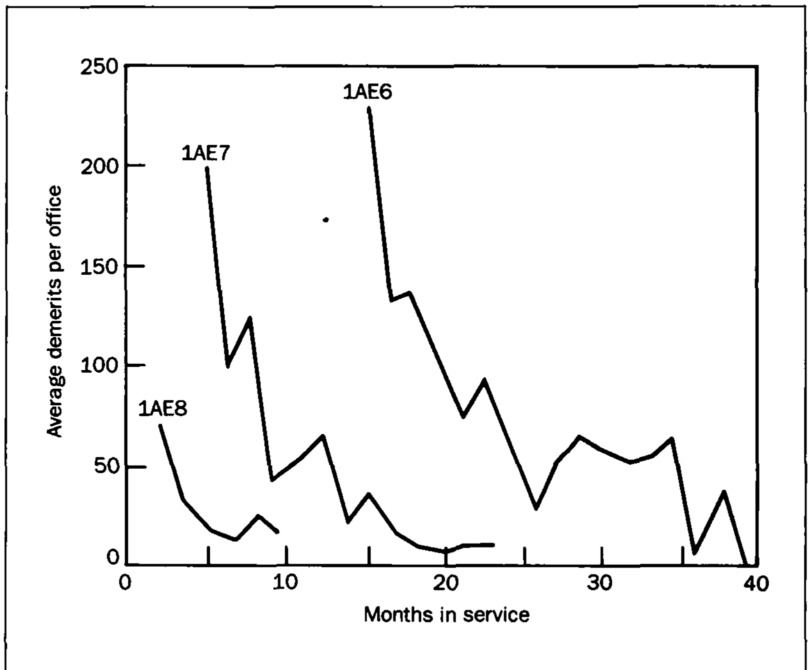


**Figure 4. In the development of software for the 1A ESS™ switch, the Software Quality Assurance Plan (SQAP) was used with the 1AE7 and 1AE8 generics. It enabled the developers to eliminate defects and attain an acceptable level of performance in substantially less time than was required for the earlier 1AE6 generic.**

**Customer Satisfaction**

All the tools, techniques, and concepts described in this article exist only for the purpose of satisfying our customers. Since customers are the ultimate judges of how well we are doing, we should consider the effect on them in all that we do.

We regard Bellcore, Network Systems' principal customers' agent, as a partner in our quality efforts and are involved with Bellcore in several joint activities. One of these is the Reliability Review Board, which consists of managers from Bellcore, the Regional Bell Operating Companies, and Network Systems. This board closely monitors the performance of Network Systems products in the field.

Another activity is the quality program analyses of Network Systems internal operations that Bellcore conducts on an ongoing basis. These analyses measure the effectiveness of 14 elements of our quality process (listed in the panel on page 38). In addition, Bellcore maintains about 70 people on site at

**Toward Customer Satisfaction**

As the customers' representative, Bellcore measures the effectiveness of Network Systems' quality program by regularly analyzing the following elements:

Management commitment and organization
Documentation of quality system
Control of design changes
Control of procured material
Manufacturing controls (in-process)
Completed item inspection
Equipment calibration and maintenance
Control of nonconforming material
Storage, handling, and packaging
Corrective action program
Product identification
Periodic product qualification
Quality information
Collection and analysis of field performance data



AT&T Network Systems plants to conduct lot-by-lot inspection of products. However, since Bellcore is as aware as we are that quality belongs in the process, it is moving away from inspection and toward auditing of processes. This front-end approach is gradually becoming standard for everyone, and Network Systems hopes to work this way eventually with all its customers.

**A Continuing Process**

Quality improvement is a continuing process throughout AT&T Network Systems. As tools and techniques are enhanced and new ones become available, their use will be expanded. The key ingredient to success of the quality program is continued executive leadership and involvement.

Quality is a strategic business asset for the entire AT&T enterprise, an important market differentiator, and a vital contributor to productivity and profitability.

**References**

1. *The Western Electric Engineer,* special issue on Process Characterization Analysis Package—PCAP, July 1978.
2. R. A. Becker and J. M. Chambers, *S—An Interactive Environment for Data Analysis and Graphics,* Wadsworth Press, Belmont, Calif., 1984.
3. Kaoru Ishikawa, *Guide to Quality Control,* Asian Productivity Organization, Tokyo, 1982.
4. Kurt Lewin, *Field Theory and Social Science,* edited by Dorwin Cartwright, Greenwood Press, Westport, Conn., 1975.

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