

The 5ESS Switching System:

System Test, First-Office Application, and Early Field Experience

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Comprehensive system testing and verification of feature design at a "first-office"-application site are integral parts of the design and development methodology for the 5ESS™ system. The strict enforcement of this methodology has led to a product that has exhibited high quality and reliability in the field. This paper describes the activities associated with the integration and system testing of 5ESS system generics, as well as the procedures used at the first-office-application site to verify operational compatibility prior to release for service. The operational experience with in-service 5ESS systems is also described.

I. INTRODUCTION

Since the introduction of the first multimodule office in Sugar Grove, Illinois, in 1983, the number of 5ESS systems in service has increased dramatically (see Fig. 1). In anticipation of this rapid buildup, and the rapid introduction of new designs and features, the system was designed to include steps to ensure reliability during manufacture and installation. These have made it possible to bring systems to the market rapidly.

During the first two years of 5ESS system service, three major system program releases (generics) plus several minor "point" generics were designed and released by AT&T (see Table I). Each of these generics went through extensive system testing and comprehensive

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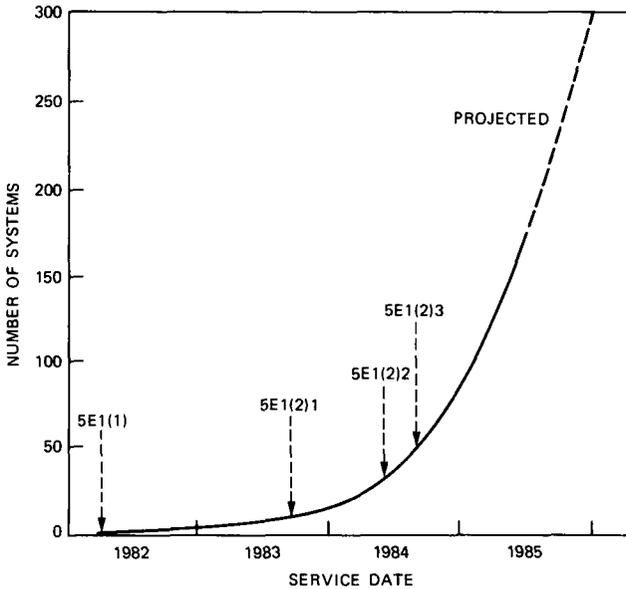


Fig. 1—5ESS switching systems in service.

verification of operational performance and customer acceptance at a First-Office-Application (FOA)* site.

This paper describes the activities of system integration, system test, and FOA-site verification. The methodology for 5ESS system development is briefly described in Section II. System integration activities are described in Section III. Section IV describes the functions of system test, while Section V describes the activities at the FOA site. The field experience with the early 5ESS switch is described in Section VI.

II. DEVELOPMENT METHODOLOGY

Generics for the 5ESS system are created following a strict methodology for both hardware and software development. Using this methodology, specific milestones for each of the development and test phases are established for completion within a specified time frame. A representation of the methodology is shown in Fig. 2. The design organizations are responsible for the capability design, design-unit design, coding, unit test, and capability test. System test, regression test, and FOA verification are the responsibility of separate test organizations.

* Acronyms and abbreviations used in the text are defined at the back of the *Journal*.

Table I—Generic development

Service Date	Generic Issue	Principal Features
3/82	5E1(1)	Basic single module
3/83	5E1(1A)	Improved module processor
8/83	5E1(2)1.0	Multimodule system
10/83	5E1(2)1.1	Local/toll
2/84	5E1(2)1.2	Improved network fabric
4/84	5E1(2)2.0	Remote switching, integrated <i>SLC</i> [®] carrier system
6/84	5E1(2)2.1	Module growth, optically integrated Remote Switching Module (RSM)
9/84	5E1(2)3	Frequency-selective ringing, RSM trunking
4/85	5E2(1)	Carrier interconnect, basic Centrex

Early in the planning for a *5ESS* system generic, each feature approved for development is divided into “capabilities.” A *capability* is a specific software or hardware function. For example, capabilities needed to implement the feature “three-way calling” would include a conference bridge, a special digit-handling program, and a data-change program for three-way-calling parameters. A specific schedule for completion of the development and test phase for each capability is established. A project management group tracks and reports milestone completions (see Ref. 1).

III. SYSTEM INTEGRATION

System integration plays a central role in the overall development of *5ESS* system generics. System integration includes program change control, software-load building, system-load bringup, and field delivery. System integration teams are formed early in the generic development cycle and work closely with the project management, feature planning, and test groups to establish an integration plan for the generic. This plan includes the requirements for the system-lab test equipment and configuration, program-support environments, and specific schedules for the development, testing, and delivery of the features required for the generic. The integration team’s main responsibility is to ensure that a stable development and test environment is maintained as major software functions are added to the generic.

3.1 Program change control

Integration of code added to the generic is overseen by the Program Change Committee (PCC). In this way, the PCC ensures that generic stability is maintained as new features are added. The PCC is chaired by the integration team and has representation from all the software development areas as well as system-test and site-test groups. The PCC approves the software changes introduced into the generic. During the early stages of a new generic development—when major software functions are being coded—the PCC reviews the integration and

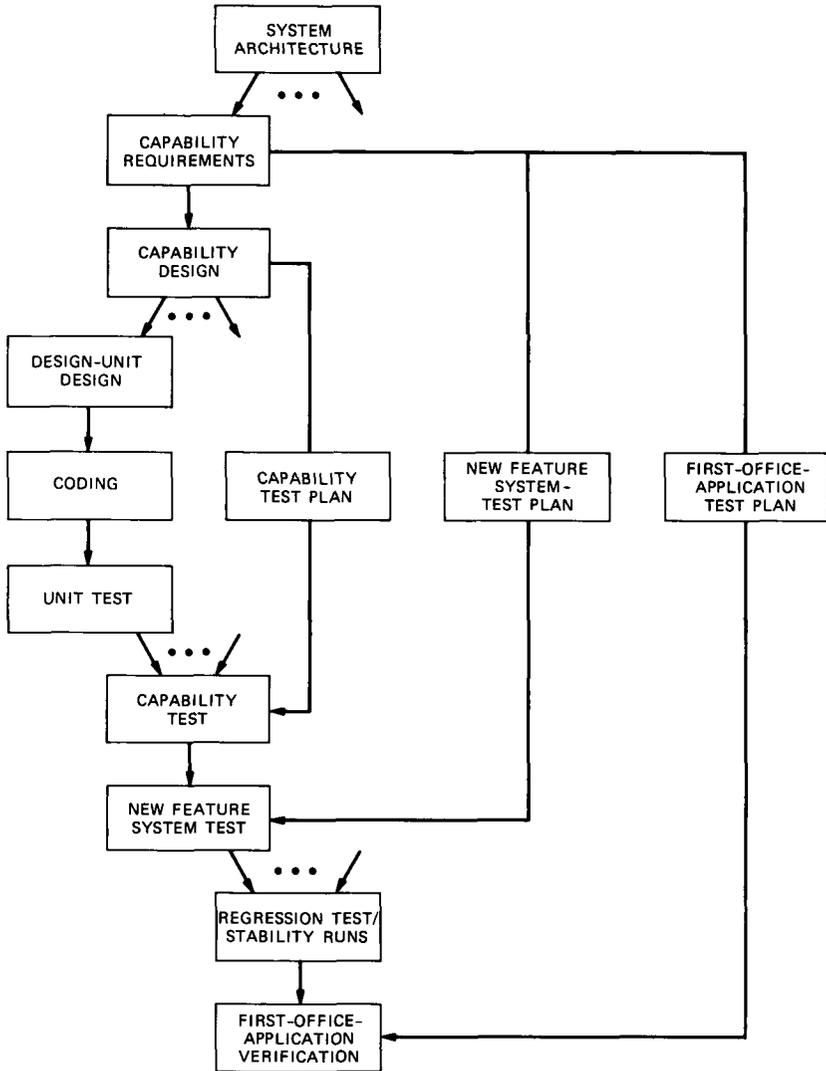


Fig. 2—Development methodology.

testing plans for the new code and any accompanying data changes. Near the end of the generic development cycle, most of the software changes are fixes for bugs uncovered during system and site testing. During this period, the PCC reviews all software changes introduced into the generic.

An automated problem-tracking system allows the PCC to review and manage software-change activity. All software problems or design deficiencies that are found or detected are documented by an Initial

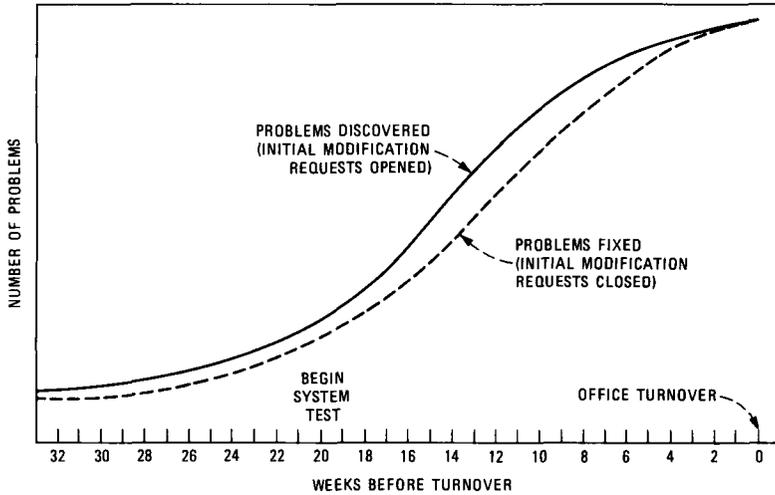


Fig. 3—Problem status history.

Modification Request (IMR) that describes the specifics of the problem or affected software. The PCC assigns priorities and responsibility to IMRs.

A Modification Request (MR) is used to document the actual software submitted for the generic. When the code represented by an MR is added to the generic, the associated IMR is closed. The PCC regularly publishes reports that summarize the open and closed IMRs. The number and seriousness of open IMRs are used to evaluate the software quality. The history of open and closed IMRs for a typical 5ESS system generic is shown in Fig. 3.

3.2 Program administration

Part of the integration plan for a generic is a set of regularly scheduled software loads that allow incremental introduction of new software and subsequent software fixes. Each software load contains all the old software plus any new code or corrections approved by the PCC. The generation of these software loads is the responsibility of the Program Administration Group (PAG). PAG incorporates the MRs that are approved by the PCC into the official generic database and recompiles the software source code.

The output of the PAG software-load-building process is a set of software files and associated reference documents such as program listings and address cross-reference maps. The files contain the executable software for both the Administrative Module (AM) and Switching Modules (SMs), plus the Office-Dependent Data (ODD) needed for the system-laboratory configuration.

3.3 Load bringup

Hardware and software integration and testing is carried out in several system laboratories that, as much as possible, replicate a field environment. The process by which a new software load is introduced into the system labs is known as *load bringup*. The integration team is responsible for load bringup. After the system lab is initialized with the new software load, problems with generic operation are documented with IMRs, and, where appropriate, fixes are made to maintain a stable environment. A set of comprehensive baseline test scripts are executed to verify the integrity of major functions, such as system recovery, diagnostics, and basic call processing. At the end of a load bringup, major problems and deficiencies with the generic are documented in a user's guide, and the system is released to software developers and testers.

Several system laboratories, each with a slightly different equipment configuration and test environment, are available for *5ESS* system development and testing. After a load is brought up and is sufficiently stable for testing new code, it is copied into each lab and initialized with the lab-specific ODD. Development and test activity then proceeds in parallel in several labs until the next load is introduced.

3.4 Load distribution

The software loads created early in the development cycle are distributed and maintained specifically for the system laboratories to support new software design, testing, and evaluation. About three months before a system is released to the customer (the turnover date), a generic load is needed at the FOA site so that hardware and software verification tests can be started. This generic load is designated as a prerelease version and undergoes a stringent set of tests to ensure its usability in the field environment. Any design deficiencies or operating exceptions with this load are thoroughly documented for the site personnel.

At the site, the generic program and ODD are loaded in the system and initialized. The prerelease load is officially supported by the integration team, which provides the fixes designated by the PCC that are needed to continue site testing. If necessary, other prerelease versions of the generic are sent to the site prior to the official turnover load. The official load, along with necessary software documentation, becomes the standard release of the *5ESS* system by AT&T Technologies, Inc.

IV. SYSTEM-TEST DESCRIPTION

The *5ESS* system is a universal switching system with a distributed-hardware architecture and a comprehensive set of features. It is

difficult to verify by laboratory testing that the system performs correctly under all possible combinations of circumstances. The goal of system testing is to rigorously stress each new generic release in the system laboratory so that as many errors as possible can be found and corrected. The system-test phase includes three types of testing: new feature testing to exercise new features, regression testing to exercise existing features, and system testing to exercise the system as an entity.

Most system testing takes place in 5ESS system laboratories that are configured specifically for system-test use. The system laboratories contain a complete, representative set of production hardware so that the proper operation of various combinations of hardware can be verified. By carefully planning and engineering the installation of equipment, an environment can be created that can simulate many typical field configurations with a minimum amount of actual hardware. In particular, maximum-size equipment configurations are engineered whenever possible.

4.1 Feature testing

Each new feature or capability of a generic is assigned to a system tester, who tracks the development of the feature and reviews feature requirements and design. The tester seeks to identify areas where the implementation of the feature adversely affects earlier capabilities, or where the implementation does not work as it was defined to work. To verify a feature, testers use several sources of information, including internal requirements (as defined in feature-specification documents and capability-requirements memoranda), external requirements (as defined in the Local Switching System General Requirements and the 5ESS System Technical Specification), and user documentation (such as AT&T Practices and Telephone Operating Procedures).

Testers attend appropriate requirements and design reviews and provide feedback on all levels of development. This not only allows the tester to gain an early working knowledge of the feature, but also lets the tester bring a system-level, cross-feature perspective to the development process. While the developers are designing and coding their capabilities, the testers plan and write the tests to be used for each new capability or set of capabilities. The tester also defines and writes specific tests to stress system aspects of the capability. System aspects include real-time performance, human interfaces, interactions with other features, and operation under various abnormal conditions. Developers and testers jointly agree on the testing approach and review each other's test plans.

As part of the testing approach, a set of acceptance tests is defined for each capability. The acceptance tests are typically a subset of the

system tests. When the developers are satisfied that a capability is ready for system testing, they formally deliver it to the system-test organization by demonstrating that the capability can pass the majority of the acceptance tests. The delivery package includes documentation of any failing tests and a plan for resolving them. After the capability is delivered, the system tester executes the complete set of system tests and records all problem indications. Possible problems are analyzed to determine what sequence of events caused abnormal responses and whether the problem appears to be an environmental (system-laboratory hardware or data) or generic problem. Possible generic problems are formally documented with an IMR and referred back (through the PCC) to the responsible development organization for resolution.

4.2 Regression testing

In addition to testing new features, system testers must also test existing features to verify that they work as they did in the previous generic. Tests that exercise existing features are collected into a package of regression tests. As additional features are developed, new tests are selected and incorporated into the regression test package. Because regression tests are repeatedly executed, they are automated whenever possible and are usually executed by specially trained batch operators.

Full regression testing is done after all new capabilities have been added to the generic. Regression testing must be done late enough in the development interval to catch most problems, but early enough so that there is time for the problems to be corrected.

4.3 Metrics

System testers keep a detailed account of executed tests and uncovered problems. Status is reported periodically. Testers report on the number of tests planned, the number of tests executed, the number of tests that passed on the first attempt, and the total number of tests passed. All problems are identified and tracked, and the corrections are retested as they are turned in.

Results from the testing of two generics are summarized in Table II. Generic A was virtually a completely new software program; hence, the relatively low number of regression tests. Testing productivity increased significantly for Generic B; about 20 percent for new feature testing and about 50 percent for regression testing. This increase is mainly attributable to a more stable system at the beginning of the system-test phase, additional test automation, more experienced testers, and better test tools.

Table II—System-test metrics

Metric	Generic A	Generic B
Number of new tests executed	10,600	7,500
Number of tests executed per hour of test-model time	2.2	2.7
Noncommentary source lines of code tested per test	23	23
Noncommentary source lines of code tested per hour of test-model time	50	61
Number of regression tests executed	950	2000
Number of regression tests executed per hour	2	3

4.4 System testing

In addition to examining individual features, the system-test organization looks at the overall system. To provide a benchmark for system quality, regular stress tests, or stability runs, are performed. During the development phase, a stability run is performed on every new load. These runs measure the performance of the system and provide data to analyze the change in performance over time.

Stability runs are usually 24-hour sessions in a system laboratory. During the session, the system is operated as if it were a live-traffic telephone office. Routine user and maintenance activities are performed and a heavy call load is generated. Since many activities such as traffic reports and routine maintenance are automatically run on a daily basis, a 24-hour period allows all such regularly scheduled activities to take place. The effect of these regular activities on the system performance is observed and analyzed. Towards the end of the development period, extended (up to a week long) stability runs are used to check for subtle problems whose symptoms may take a longer time to surface. Longer stability runs also incorporate typical telephone-office-acceptance tests (see Section 5.5) such as the half-office test and the integrated-volume test.

During all stability runs, the system is carefully monitored for any abnormal behavior. All potential problems are logged and investigated. The performance of the system is quantified by several metrics, including calls successfully processed per hour, hardware interrupts, software-detected audits and asserts, initializations, and printer output. An overall index is defined by using a weighted average of the individual metrics. For each metric, acceptable thresholds are defined. As thresholds are attained, the criteria are tightened to force continued effort to a higher level of quality. For example, once a phone call completion rate of 99.99 percent is attained, the threshold rate may

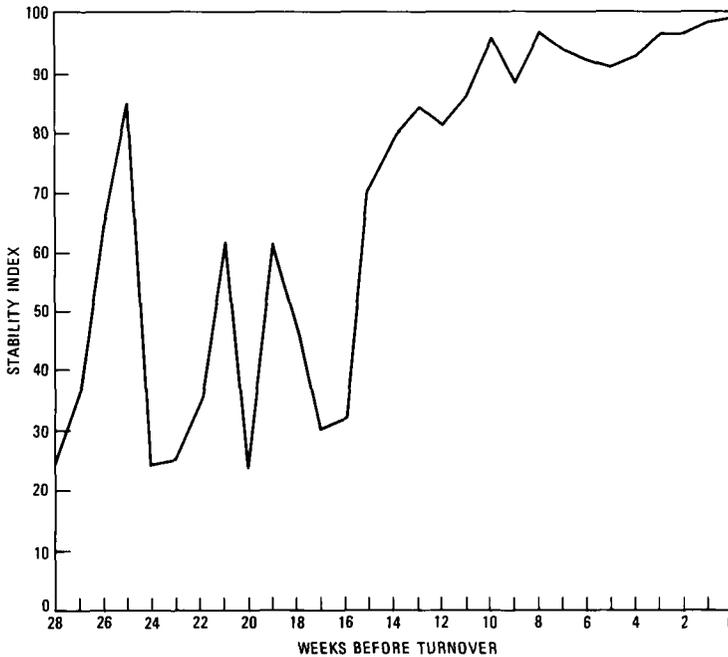


Fig. 4—Stability run index.

be increased to 99.999 percent. The system must meet an acceptable level of quality before it is released for general use.

The high level of quality is attained through continual, close cooperation between developers and testers. Problems uncovered during stability runs are investigated and resolved by developers who staff stability run teams. Each team has a speciality area, such as achieving high call-completion rates or decreasing the number of software auditor-error reports. The teams directly support the stability runs during the last several months of the development cycle when generic quality is rapidly improving. Figure 4 shows the trend for a typical index.

4.5 Test tools

Many tools have been developed to increase testing efficiency and productivity. Tools used during system testing include

1. Symbolic debuggers that provide ways to do traces, dumps, conditional matches, and other utilities on C language programs.
2. A call generator that generates Plain Old Telephone Service (POTS) calls at specified traffic levels over standard line connections.
3. An automatic call simulator that can be programmed to generate traffic loads with specified combinations of POTS and more complex call types on both lines and trunks.

4. Load-generation tools that simulate high call loads on the *5ESS* switch to stress the system beyond limits available through other load-generation tools.

5. The switching system automated test set, which performs switching, signaling, and transmission tests under traffic conditions.

6. The automated craft-message interface, which provides automated message input and detailed output analysis for automating user commands and analyzing system response.

V. FIRST-OFFICE APPLICATIONS

As a standard practice, major new releases of *5ESS* system software and major new hardware units are introduced after a FOA verification. FOA verification is under AT&T Bell Laboratories control, and its primary purpose is to test the new hardware and software by operating the *5ESS* system in a field environment. Consequently, most FOA tests use standard input messages and avoid the use of special utilities or other methods of intervention.

The FOA-verification stage follows system testing, but the two overlap. As new software loads are generated, their performance, as measured in the FOA, helps confirm the observations made by system testers.

FOA verification also gives the customer a chance to get hands-on training in the new features. In addition, the customer is assured by direct involvement that the office is ready for service. One of the main benefits to the supplier is an early opportunity to verify product performance in an actual operating environment and in a system configuration that is generally larger and more complex than a system laboratory.

5.1 FOA selection

FOA sites are selected to meet the service needs of certain offices while matching generic program availability dates. New offices that appear to be candidates are analyzed with respect to new features, schedule flexibility, and customer preference for FOA treatment. In some cases, a strong desire by some customers to obtain the use of new capabilities as soon as possible influences FOA schedules. In other cases, feature availability is the determining factor.

5.2 Preparation and planning

FOAs are chosen so all the major new features developed for each generic are verified. In many cases, several FOAs are needed to verify all features. For each selected FOA, an office verification schedule is

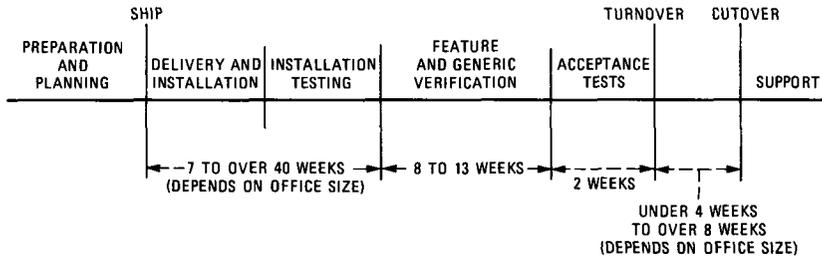


Fig. 5—Typical FOA schedule.

generated. This schedule includes dates for the normal AT&T Network Systems installation activities, FOA verification, and introduction of new software loads. A sample schedule is shown in Fig. 5. Before the 5ESS system arrives, early planning addresses several topics. The variables considered during early planning include the schedule, the features needed by the customer, office size, and the network interconnection plan. Before system delivery, space is allocated and provisions are made for installing power plant, cable racks, and making other building-support-structure changes. Cutover and transition committees are established, and they coordinate all of the activities associated with placing the new system into service.

5.3 Installation interval

The first parts of the 5ESS system delivered to the telephone office are the AM, Communications Module (CM), and at least two SMs. Nearly all intramodule cabling is done at the factory and all units are tested before they are shipped. This helps reduce installation time. After the modules are in place, power cabling and intermodule cabling are connected. Nearly all interframe cables for the 5ESS system are pretested and connectorized. This saves installation time and greatly reduces interframe wiring at site.

The general philosophy of the installation is to concentrate on powering up the core of the switch (AM and CM) as soon as possible. Because the AM and CM can be operated independently from the SMs, the core can be tested while the SMs are still being installed. The installation force is split so that some testers are devoted to the testing of the AM and CM while the others continue doing the cabling and powering up the SMs. Testing the AM and CM takes about three days. These core units are then used to test the SMs. As the SMs are powered up, they may be connected to the core units one at a time, or all at once. In large offices, where SMs may arrive in several shipments, the former is generally done.

As mentioned above, installation testing overlaps equipment installation. Some units are being tested while others are still being installed. The first test on all units is power and ground verification. Next, hardware circuitry is tested, much of it concurrently. Testing proceeds in the following sequence: AM, CM, SM control units, and finally, SM peripheral units.

Hardware is tested using diagnostic programs that are part of the system software. A graphic status display of each hardware unit can be requested on the Master Control Center (MCC) video terminal. The display includes a menu of commands, including diagnostics, that can be performed on the specified unit. Installation testing starts with diagnosis of individual units, and proceeds to subsystems and their interfaces with each other. Finally, subsystem operation with the generic program and ODD is tested.

Call-processing capabilities are tested next by applying a simulated call load to the system, with load boxes that simulate subscribers. A typical load box can simulate up to 64 telephone calls at one time and generates 15,000 calls per hour.

5.4 Verification and software introduction

In major FOAs, test and verification generally spans the next six weeks. Feature verification is planned to mesh with the same sequence established by system test. During the verification interval, the installation teams continue to do office maintenance, apply hardware changes, and complete installation testing. At the end of the verification interval, installation testing continues with acceptance tests.

During the verification interval, new software loads are introduced that contain corrections to problems discovered during system testing. New loads are usually introduced at the beginning of the verification interval and as often as weekly afterwards. Occasionally, new software loads that consolidate important corrections may be introduced after turnover so the corrections can be demonstrated to the customer before placing the system into service.

5.4.1 FOA and feature verification

The verification performed in the FOA includes verifying specific new feature operation; verifying the characteristics of the new software, hardware, and supporting installation; and overseeing customer-acceptance testing. For each FOA site, a list of required and desirable features is created by the customer. FOA-verification tests are designed for each feature. The features that will not be activated in a particular FOA may be temporarily activated or verified in another FOA.

Using previous experience to determine typical test-execution rates, the FOA-verification interval is scheduled for the new features. Feature

verification is generally scheduled for 16 hours a day, while office installation and maintenance activities are scheduled for the rest of the day.

Test scripts are generated for each set of features. These are applied in the FOA, and records are kept on which tests pass and which fail. If a failing test reveals a problem, an IMR is generated and referred to a development organization. When fixes are delivered in subsequent loads, the failing tests are rerun to assure the problem is corrected.

5.4.2 Generic verification

In addition to feature-specific verification, the new software release is checked for overall performance by executing a set of regression tests. Performance is verified through weekly stability runs that complement those done by system testers in the system laboratories. The FOA-stability runs help identify configuration and office-database-dependent problems. The results of the stability runs are analyzed with the help of special programs in support computers. While FOA testers continue with their verification tests, members of a special analysis group work with developers to resolve the problems detected by the stability run analysis.

A library of all FOA test scripts is maintained. A set of regression tests is selected from the library to assure that features provided in previous generics continue to function properly in the current generic. In selected FOAs, special performance tests are scheduled. For example, in one FOA, high traffic was generated by additional load boxes so that traffic-handling capacity could be verified. There are also special tests that verify compatibility with the trunk interfaces to connecting offices in the network and with line interfaces to station sets, coin telephones, PBXs, key, equipment, and range extenders.

5.5 Acceptance tests

At the end of the installation interval, tests are run on the switching system to demonstrate stability and performance to the telephone company. Throughout the tests, artificial traffic is applied to the system so that any changes in call-completion rates will indicate problems. Specific thresholds are designated for alarms, maintenance interrupts, and software errors during the tests. The specific tests performed are the half-office test, the heat test, and the integrated-volume test.

In the half-office test, the ability of the system to operate with only half of the duplicated equipment available is established. In this test, one side of all duplicated controllers is powered down for one hour, powered up, and diagnosed. The process then is repeated on the other

side. The test takes place with a call load running, and demonstrates that call processing is not affected.

The optional heat test demonstrates the system's ability to operate under high-temperature conditions, such as air conditioning failure. In the test, a plastic tent is constructed around the switching system and the temperature is raised to 118 degrees Fahrenheit. The switch operates for four hours under these conditions while being monitored for correct handling of the applied call load.

The integrated-volume test demonstrates the system stability and call-processing capabilities over a continuous 24-hour period under conditions that simulate a typical day. Again, call-completion statistics and other system measurements are used to help verify performance.

Once installation is completed and all acceptance tests are successfully executed, principal use of the system is turned over to telephone company personnel so they can conduct special tests to verify that each trunk and line operates properly and that office data are correct.

5.6 Metrics

The main FOA-verification metrics used fall into the following categories:

- Verification progress versus schedule
- Verification-test pass rate
- System quality and stability metrics.

The combined results of these metrics are used to help determine that the new generic programs are ready for service and to manage the priority items leading to the introduction of the new generic program.

VI. EARLY OFFICE INSTALLATION AND EXPERIENCE

Installation of *5ESS* systems has occurred according to the curve in Fig. 1. The first four systems were single-SM systems. Two additional single-SM systems have been added and one of the original systems has been converted to an RSM served by a multiple SM host. The rest of the installations have been multiple SM systems. As of November 1984, installed *5ESS* systems contain from 1 to 30 SMs. Plans exist for offices having over 60 SMs to be installed within the next year.

The first *5ESS* system RSM was placed in service in April 1984; others will be installed according to the curve in Fig. 6. RSMs are currently connected to their hosts, using conventional T1 facilities, and T1 over fiber-optic systems as umbilical links. An optically remoted switching module is also in service. This configuration uses a direct fiber-optic link from the *5ESS* system host CM to the RSM.

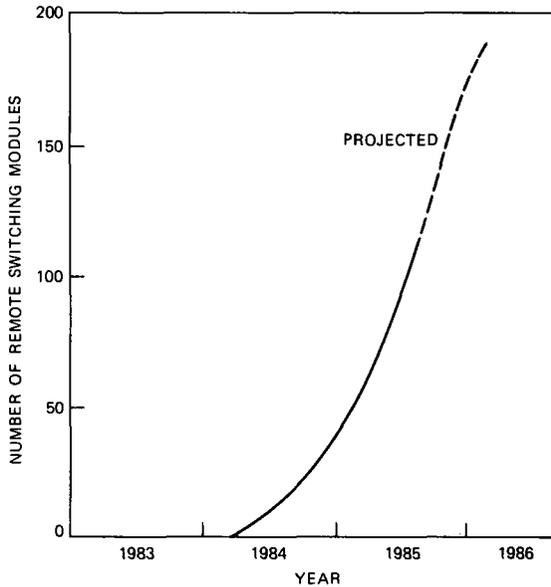


Fig. 6—Remote switching modules in service.

Additional facts about *5ESS* system capacity and installation are given in Table III.

6.1 Customer support

AT&T provides extensive support for the owners and operators of the *5ESS* systems. Problems and requests for assistance are sent first to a Regional Technical Assistance Center (RTAC), then to a centralized Product Evaluation Control Center (PECC), and finally to AT&T Bell Laboratories. Generally, AT&T Bell Laboratories receives only those problems and requests that require design changes or corrections.

Customer support facilities include specialized equipment that allows logging output from systems to help problem analysis, and portable, noninterfering field-test sets to help find any problems that cannot be reproduced in system laboratories. A large diagnostics center at the

Table III—System dimensions

	System Capacity (1985)	Maximum Observed in Service (11/84)
Number of SMs	192	30
Number of lines	100,000	27,000
Busy-hour calls*	300,000	80,000

* Assumes normal maintenance activities and feature use.

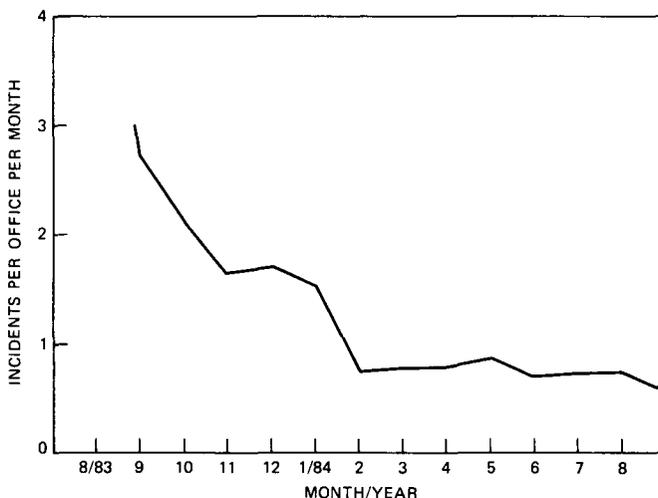


Fig. 7—Unplanned initializations (six-month rolling average).

AT&T Network Systems division in Lisle, Illinois, is available so offices requesting assistance can obtain advice from system experts, and can have their system output displayed for use by the experts.

6.2 Performance measurement

Many different performance measurements are used to evaluate 5ESS system performance. Measurements of system initializations traditionally have been widely followed. For the 5ESS system, initializations can occur with varying levels of impact. Most initializations are effectively confined by the system architecture to a single SM, and most do not affect stable calls. Higher-level initializations are available for recovering from more severe problems. Calls in the talking state are generally not affected even by these higher-level initializations. Figure 7 shows the number of unplanned initialization incidents per office per month. Figure 8 shows the trend for SM initialization incidents per module per month. Other system performance data that can be used to forecast potential trouble include measurements of audits, interrupts, software-check failures, and alarms.

The reliability of the 5ESS system hardware is also tracked by plotting the actual circuit pack replacement rate against the expected replacement rate. The expected replacement rate is calculated at one circuit pack per month per thousand lines. The number of packs returned to the factory for repair is then compared to this value. A plot of the overall replacement rate is shown in Fig. 9. Several Line Unit (LU) codes have had higher replacement rates than expected,

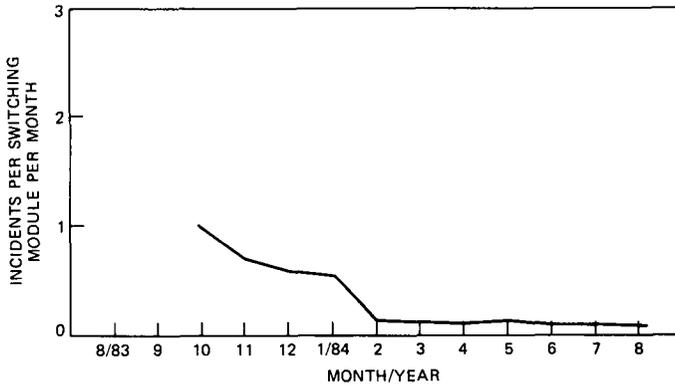


Fig. 8—Unplanned switching module initializations (six-month rolling average).

and a series of improvements in design, manufacturing, and testing have been made. The AM, CM, and the SM (minus the LU) are all showing reliability performance that tracks expectations very closely. The latest improvements in the LU packs are showing favorable early reliability in factory yield and test data.

6.3 Retrofit and growth

Retrofit is the general name for the introduction of new generic issues and their corresponding databases into an in-service 5ESS system telephone office. Early retrofit methods carefully controlled full-system initializations. The system-initialization time associated

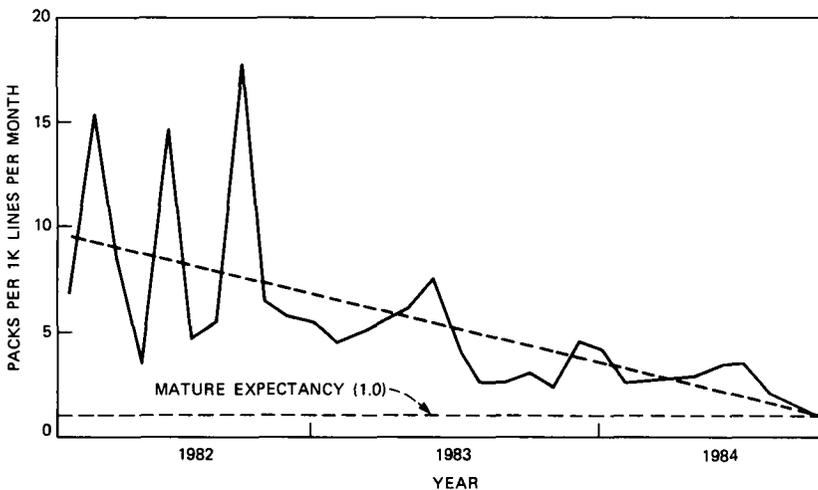


Fig. 9—Hardware replacement rate trend.

with these retrofits was roughly proportional to the number of SMs in the system. Failure of any SM to successfully initialize resulted in an incomplete retrofit.

Beginning with the 5E1(2)2 generic, significant improvements were made to the retrofit procedure. These improvements allow the new generic to be off-line loaded into the out-of-service half of each SM without affecting service. Under control of the active generic and without affecting service, each SM can be preinitialized with the new generic to detect any database or hardware problems. The resulting system-initialization time is independent of office size. In addition, calls in the talking state are saved over the retrofit.

Growth capability allows addition of SMs, RSMs, and units within them, without affecting service. Growth equipment is added and tested in a manner similar to new equipment; however, the growth process is controlled with special procedures to avoid affecting service. Early experience with growth procedures has been very good. A number of SMs and RSMs have been added to in-service 5ESS systems with growth procedures.

VII. ACKNOWLEDGMENTS

The successful and rapid introduction of the 5ESS system is the result of the dedicated effort of many people at AT&T Bell Laboratories and AT&T Network Systems. The cooperative team work and continuing high quality of individual contributions of all have made the 5ESS system a significant success. Performance of initial releases has been excellent. Customers find the 5ESS system reliable, easy to use, and flexible. The authors wish to acknowledge the efforts of all the many individuals who have participated in this project.

VIII. CONCLUSION

The high quality and reliability of the 5ESS system depends on a methodology that includes a series of integration, test, and validation phases. The integration, system testing, and FOA-verification procedures described in this paper have been used in the development of several major program releases. They have played a key part in the successful introduction of the 5ESS system and will continue to be important as the system evolves.

REFERENCE

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