THE BELL SYSTEM TECHNICAL JOURNAL
Vol. 58, No. 6, July-August 1979
Printed in U.S.A.

Traffic Service Position System No. 1:

System Verification and Evaluation Procedures

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(Manuscript received December 11, 1978)

This paper describes the verification and evaluation procedures followed in the development of new features for the Traffic Service Position System (TSPS). Beginning with the definition of new feature requirements, these procedures are adhered to throughout the TSPS development cycle. Hardware and software designs are reviewed to verify that all requirements are met and to ensure that Bell System standards for reliability are maintained. Finally, both system laboratory and site testing are performed to verify the proper implementation of each new feature and to evaluate the overall performance of the TSPS.

I. INTRODUCTION

A significant part of the effort required for any switching system development involves determining whether the system performs properly. The ultimate judge of system performance is the user. In making this judgment, the user considers both system reliability and maintainability. Since Bell System standards for service are very high, measures of acceptable performance are rigorous. Thorough plans are made to ensure that switching systems provide this required high level of performance. These plans begin with the initial concept of a switching system or new feature and continue throughout the development process. Every design decision is based on providing the best possible service at the lowest possible cost. Each decision is evaluated for its impact on the customer who uses the switching system and on the operating company that must administer and maintain it.

This paper discusses the methods used to verify and evaluate system performance of the Traffic Service Position System (TSPS). It also describes the facilities specifically designed to support the verification and evaluation process.

II. STAGES OF THE TSPS VERIFICATION AND EVALUATION PROCESS

The verification and evaluation process for new TSPS features involves all aspects of system development. This process begins with the determination of feature objectives and continues with the verification that the design requirements for each new feature are consistent with these objectives. Finally, the system is tested to ensure that the implementation reflects the design requirements. This process is divided into several stages. The stages of verification and evaluation discussed in this article are (*i*) requirements reviews, (*ii*) design reviews, (*iii*) circuit analysis or program reviews, (*iv*) unit testing, (*v*) integration testing, and (*vi*) system testing. Figure 1 shows these six

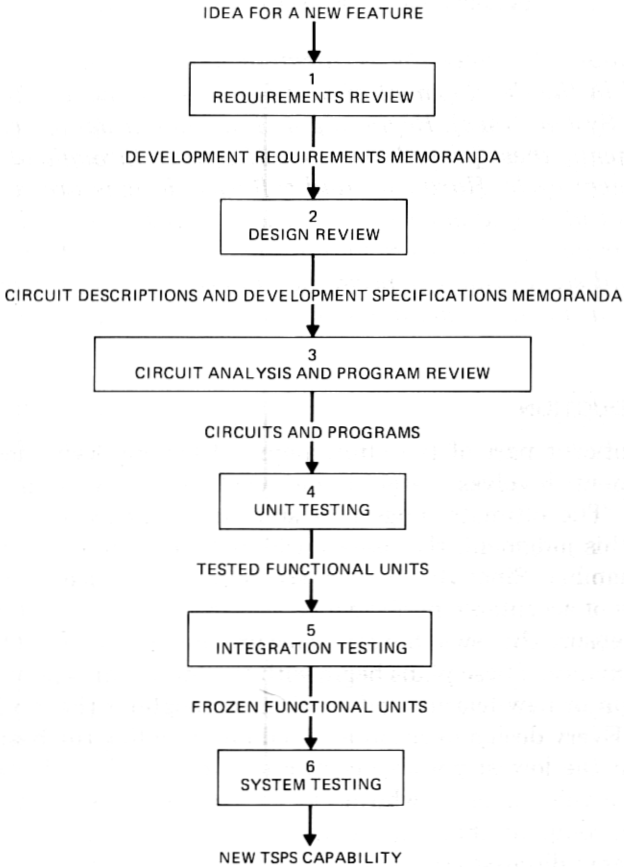

Fig. 1—Six stages in the TSPS verification and evaluation process.

stages and how the results of each stage are used in subsequent stages of the development.

The first stage of the verification and evaluation process begins when a new TSPS feature or system capability is proposed. Each new feature is analyzed to determine the service and maintenance requirements that must be satisfied. This analysis can be very extensive for some new features, such as the Automated Coin Toll Service (ACTS) feature. To perform this analysis for ACTS, an in-service TSPS was modified to simulate ACTS for a comprehensive human factors trial.[1] The results of this trial guided the formulation of the requirements for ACTS. These requirements are documented in development requirements memoranda and form the basis for detailed design and development.

The detailed design and development of a new feature is generally accomplished by partitioning the feature into functional units which are then assigned to development teams for implementation. Continued division of responsibility within a team for the development of a functional unit is dependent on the complexity of that unit. This partitioning applies to both hardware and software portions of the system.

The second stage of the TSPS verification and evaluation process begins when design reviews are held to determine if the conceptual aspects of each functional unit are consistent with the overall system requirements. Once the architectural design of the functional unit has been evaluated in this manner, the development team begins the detailed design of the functional unit. The design of each element in the functional unit is reviewed. Depending on the number and complexity of functional unit interfaces, members of other TSPS development teams may participate at this point in the process. After this review, development specifications memoranda and circuit descriptions are usually written documenting the detailed design.

The hardware development proceeds with the generation of circuit schematic diagrams and the specification of the circuit components used in constructing the circuit. The layout of the circuit components and their interconnections are specified, and prototype circuits are built. The prototype circuits are tested off-line from the system to ensure that they perform as required. Manufacturing tests are also generated for digital circuits using a logic simulation program.[2] After these tests and prototypes of the digital circuits are verified with a circuit pack tester, testing begins in the system laboratory. Once the circuit is verified to operate in accordance with the design intent, manufacturing and factory test information is transmitted to Western Electric. This activity is scheduled so that standard Western Electric-supplied hardware will be available when site testing begins.

The software development is done in parallel with the hardware development. After each program is written, a program review is conducted (*i*) to ensure that all development requirements are met; (*ii*) to verify that the interfaces between programs are correct; and (*iii*) to check that each program instruction is correct. Problems identified and corrected during this program review require much less effort than if they were left to be resolved during later stages of the verification and evaluation process.

The fourth stage in this process is the formulation of functional tests which utilize special test facilities (see Section III) and which ensure that each functional unit meets the design requirements. Upon the completion of unit testing, the fifth stage of the verification and evaluation process occurs when integration testing is performed. Integration tests ensure that each functional unit performs in a total system environment. Specifically, interactions between functional units and hardware-software interfaces are emphasized. Once the integration tests have been successfully run, the functional unit designs are considered frozen, in that changes to a functional unit can only be made on a more formal and controlled basis. The frozen functional units are now ready for system testing, the sixth and last stage in the verification and evaluation process.

During system testing, additional functional tests are written, and the total set of functional tests are performed by an independent group to ensure that any biases held by the design engineers are not reflected in the interpretation of test results. Beginning with this phase of TSPS testing, every change introduced into the system—hardware or software—must be initiated by a trouble report which specifies the seriousness of the problem so that corrections can be generated on a priority basis. Changes must be submitted in a formal manner and approved by a special committee called the change review committee.

Beginning with the system testing phase of the verification and evaluation process, each change is tested incrementally. That is, the correction to each problem, when possible, is considered an independent entity. Each correction can be rejected if not deemed appropriate by either the change review committee or the system testers. This procedure is used (*i*) to provide a high degree of visibility to all changes being introduced into the system, (*ii*) to provide a procedure whereby each change is individually and thoroughly tested, and (*iii*) to provide a procedure whereby design engineers can make changes without repeatedly going through the integration process.

To this end, each change submitted by the design engineer must be accompanied by a very specific test procedure which has been verified before the change is submitted. System testers then take great care to ensure that the test procedure is appropriate and that the change does not invalidate a previously verified functional capability. In some cases, this can only be done by repeating a long series of previously completed functional tests. This verification and evaluation process is greatly enhanced by a comprehensive set of test facilities discussed in the following section. These test facilities are available to both designers and system testers.

III. SYSTEM LABORATORY TESTING

TSPS verification and evaluation is done at Indian Hill using two system test facilities. Each test facility contains a TSPS and its associated peripheral subsystems (i.e., a Position Subsystem No. 1,[3] Position Subsystem No. 2,[4] Remote Trunk Arrangement,[4] Station Signaling and Announcement Subsystem[5]—see Fig. 2). Minicomputers and var-

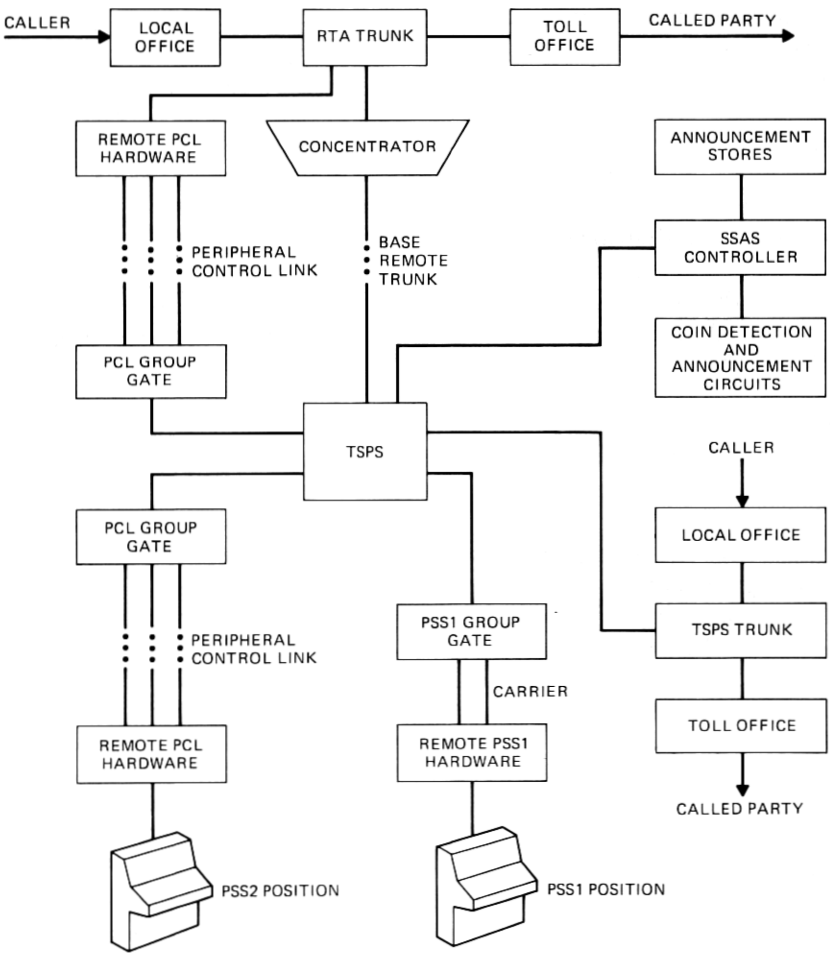

Fig. 2—Traffic Service Position System No. 1.

ious microprocessor-controlled circuits are utilized to produce the desired hardware and software environment.[6] In this environment, the system laboratory user can control and monitor the operation of the TSPS. Figure 3 shows one of the TSPS system laboratories at Indian Hill.

One aspect of controlling the TSPS operation is to establish the desired hardware and software configuration. The minicomputer provides three major capabilities for reconfiguring or modifying the system. First, the minicomputer provides the capability to load the TSPS with a new program, with the system's program stores being automatically reconfigured to match the memory requirements of the new program. Second, portions of the TSPS program can be modified with changes assembled by the minicomputer. This capability is used extensively in the incremental testing of modifications to frozen programs. Third, automatic fault insertion by the minicomputer is used to exercise system diagnostics in the preparation of trouble locating manuals. These manuals are used in conjunction with diagnostic outputs to identify hardware faults. The automatic process by which these faults are inserted helps to increase trouble locating manual resolution by allowing efficient generation of a large number of sample diagnostic results.

Once the desired hardware and software configuration has been established, the minicomputer can then be used to monitor the operation of the TSPS. Data associated with a specific event or combination of events can be recorded and later retrieved by the minicomputer. When correlated with the normal system responses such as teletypewriter messages, those data can be used to resolve problems or to confirm the proper operation of the TSPS.

An important part of testing TSPS features is ensuring that system interactions involving customers and operators are correct. Many inputs processed by a TSPS result from these interactions. To provide similar inputs in the system laboratory, stimuli comparable to those generated by customers and operators are produced using system utilities. A microprocessor-controlled facility is provided to simultaneously generate calls from many trunks. Both the traffic-handling characteristics of each trunk and call types can be changed under program control. Facilities are also provided to simulate the local and toll offices associated with a single TSPS trunk, thus allowing a laboratory user to completely control all stages of an individual call. Microprocessor-controlled operator simulators are provided to automatically handle calls at TSPS operator positions. In addition, calls can be handled manually at an operator position, thereby allowing the system laboratory user to test unexpected operator sequences.

System testing is divided into functional testing and system evalu-

Fig. 3—The TSPS System Laboratory.

ation. Ideally, it would be desirable to write and perform functional tests in the system laboratory for each call processing and maintenance situation the TSPS will encounter. In practice, however, this is impossible. Consequently, during system testing, additional effort is required above and beyond the analysis of functional test results. This effort is referred to as system evaluation. In terms of cause and effect, functional testing involves setting up a prescribed set of initial conditions and then determining whether or not the proper response occurs. However, system evaluation involves observing every improper system response and then determining the cause of that response. This can be a difficult task, which at times is more of an art than a science. Reproducibility is a primary requirement for identifying the cause of a problem. Problems discovered during functional testing are generally reproducible, since a set of initial conditions have been specified for running each functional test. However, problems encountered during system evaluation frequently do not meet this reproducibility criterion. As a result, much more analysis of these types of problems is required.

During system evaluation, several indicators are used to determine that a problem exists. These indicators are:

(*i*) Unexpected teletypewriter output messages.
(*ii*) Loss of service of a hardware unit to the system for no apparently valid reason.
(*iii*) Unexplainable maintenance or call processing activity.

The audit messages[7] printed on the teletypewriter are a primary indication of system problems. Each audit message generally signifies the presence of some program error resulting in an inconsistency in unprotected memory. This memory is continuously updated by different programs to reflect the current state of the system. A detailed analysis of the audit messages will sometimes indicate what caused the error condition. The debugging capabilities of the minicomputer described above are particularly helpful in resolving this type of problem. With these capabilities, system activity which occurred before the audit program detected the error can be analyzed, and the cause of the problem can be identified.

The system laboratory provides a controlled environment where interfaces external to the TSPS have been simulated with system utilities. Although it is possible to test most aspects of the TSPS operation in this environment, increased confidence is built when new features are tested at a newly installed TSPS which interfaces with actual local and toll offices. For these and other reasons, the verification and evaluation process is continued at a test site.

IV. THE SITE TESTING INTERVAL

Each new generic is tested at a TSPS that has not been cut into service. This TSPS has been fully engineered by operating company personnel, and the hardware has been installed by Western Electric during a normal installation interval. Bell Laboratories testing of a generic at this pre-cutover TSPS evaluates the new features in a fully equipped TSPS. It also verifies the accuracy of the information provided to Western Electric and the operating companies on these new features. Testing is done with both local and toll offices to ensure that no interface problems exist. The length of the site test interval varies depending on the number of features being tested, amount and complexity of the new hardware, and size of the program change. Table I summarizes the test site, major new features, and size of the program change for each of the recent TSPS generics.

Testing at the site involves reverifying specific operational and maintenance capabilities for all new features, with the objective of determining whether or not the requirements for each feature are met. In particular, testing focuses on verifying interfaces with local and toll offices. Regression testing is also performed to ensure that previous TSPS capabilities are not adversely affected by the new features. Since site testing is performed after new feature development has been completed, problems identified at the test site are generally more subtle than those previously uncovered during system laboratory testing at Indian Hill. Furthermore, by the beginning of the site test interval, the hardware design has already been proven in the system laboratory. As a result, during this interval the majority of problems identified are in the software. Most are not due to any significant design problems and are easily corrected.

Both functional testing and regression testing at the site are done in a systematic manner; a specific set of tests are performed for each

Table I—Recent TSPS generics

Generic	Test Site	Major New Feature(s)	Size of Program Change (40-bit Words)
Generic 7, Issue 1	Syracuse, New York	Remote Trunk Arrangement, Position Subsystem No. 2	60,000
Generic 7, Issue 2	Saginaw, Michigan	Selective Call Screening, more than twenty stores on a bus	5,000
Generic 8, Issue 1	Phoenix, Arizona	Automated Coin Toll Service	40,000
Generic 8, Issue 2	Montgomery, Alabama	Automated Coin Toll Service with Remote Trunk Arrangement	7,000

feature, the results are observed, and these results are analyzed. The amount of detail with which functional test results are analyzed at the test site is minimal. Instead, any functional tests which fail are documented in trouble reports which are then sent back to the developers at Indian Hill. Extensive analysis at the test site is restricted to problems uncovered during system evaluation. In general, the exact conditions required to bring out these types of problems must be determined at the test site.

The combination of system laboratory testing and site testing during this interval complement each other in the verification and evaluation of a TSPS generic. In the system laboratory at Indian Hill, emphasis is placed on testing individual changes being made to correct specific problems. However, as indicated above, effort at the test site is oriented toward verifying and evaluating functional capabilities rather than testing changes or corrections.

The test facilities provided at the major test sites are comparable to those permanently installed in the system laboratories at Indian Hill. These facilities include the minicomputer, call generation capabilities, and operator simulators described in Section III. Additional capabilities are also provided to remotely control these test facilities so that testing can be done from one location.

The number of problems identified from the time the hardware and software were frozen until the completion of site testing is shown in Table II for each of the recent TSPS generics. These totals are broken down into: (*i*) problems identified at Indian Hill in the system laboratory and (*ii*) problems identified at the test site.

At the completion of the site testing interval, responsibility for monitoring system performance is given to TSPS field support personnel. In addition to continuing the evaluation of TSPS and new feature performance, field support personnel are responsible for updating the system with any necessary changes. To assist in these efforts, the TSPS's maintenance teletypewriter output can be transmitted to the TSPS Diagnostic Center at Indian Hill. Problems detected from this output or reported by the operating company are analyzed, and cor-

Table II—Trouble reports written through the completion of site testing

Generic	TRS Written at the Base Location	TRS Written at the Test Site	Total
Generic 7, Issue 1	600	615	1215
Generic 7, Issue 2	33	20	53
Generic 8, Issue 1	565	800	1365
Generic 8, Issue 2	108	58	166

rections are generated by designers working in conjunction with field support personnel.

V. SYSTEM CAPACITY

The addition of each new feature to TSPS has an impact on the real-time capacity of the TSPS. Overall system real-time capacity varies for each TSPS installation based upon the hardware configuration used and the particular call mix being processed. Each new feature is evaluated during the development cycle to determine its impact on system capacity. This evaluation is verified at the first in-service office or the first office close enough to capacity for a verification to be made. The real-time capacity estimation and verification process is extremely important due to its effect on the long-range planning of the operating companies. To assist the operating companies in their analysis of an individual office's real-time capacity, a program called TSPSCAP is available. This program runs on an off-line computer and is updated with each generic to reflect the addition of new features.

VI. SUMMARY

System verification and evaluation is a process that is interwoven with all aspects of the development of new TSPS features. From the inception of the idea for a new feature, development requirements are evaluated to ensure a proper understanding of the proposed capabilities and to verify that the proposed design will provide these capabilities. After formal reviews, these requirements are specified in development requirements memoranda, and the design is specified in development specifications memoranda and circuit descriptions. Next the design is implemented and each functional unit is verified in the system laboratory. Before the commencement of site testing, both hardware and software are placed in a frozen mode, after which all changes to the system are verified through a formal procedure. Site testing is done in a pre-cutover TSPS engineered by an operating company with hardware supplied and installed by Western Electric. During site testing, functional tests are run to verify the proper implementation of all new features and regression tests are run to ensure the proper operation of previous TSPS capabilities. In addition, system evaluation is done before the site is cut into service, thus resolving many of the more subtle problems. Finally, an analysis of the real-time effect of each new feature is made after cutover to confirm the theoretical analysis made prior to cutover.

This verification and evaluation approach is followed for each new TSPS feature. Adherence to this methodology allows new TSPS generics to be properly verified and evaluated, thereby insuring Bell System customers of the best possible service.

VII. ACKNOWLEDGMENTS

Verification and evaluation of new TSPS features are accomplished through the efforts of many people in the Operator Systems Laboratory. Due to the laboratory-wide scope of this process, a list of all contributors to its success would be very long. However, the authors would like to acknowledge the special contributions of the following people: J. W. Hopkins, R. C. Jackson, R. Kroning, D. J. Rak, B. D. Reh, M. J. Traube, and D. A. Yackley.

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