

Traffic Service Position System No. 1B:

Integration and System Testing

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The integration testing and system testing strategies used in the development of the Traffic Service Position System No. 1B (TSPS No. 1B) are described in this article. It discusses novel methods developed for the integration and testing of the first embedded application of the 3B20D Processor and DMERT operating system. The new testing techniques and project management aides, which were vital to the achievement of system quality for the Bell System service, are described. The first TSPS No. 1B went into service on November 20, 1981, in Fresno, California.

I. INTRODUCTION

The first Traffic Service Position System No. 1B (TSPS No. 1B) was placed in service in Fresno, California, on November 20, 1981. This newly installed TSPS brought modern Stored Program Control (SPC) operator services capabilities to telephone customers in Fresno and other San Joaquin Valley communities, and permitted Pacific Telephone to close the largest remaining Bell System Cordboard installation in the United States. Modern operator services^{1,2} are bringing convenience to telephone customers and increased efficiency and savings to Pacific Telephone.

Placing the Fresno TSPS No. 1B in service marked the conclusion of a major testing program that was vital to the delivery of a high-quality system, capable of meeting all objectives.¹ This was especially critical because of the planned, rapid conversion of existing TSPS No. 1 sites to TSPS No. 1B. Furthermore, since TSPS No. 1B is the first electronic Stored Program Control system to utilize an embedded

3B20 Duplex (3B20D) Processor and its Duplex Multi-Environment Real-Time (DMERT) operating system,³ confirmation of its capabilities was essential to the success of the TSPS No. 1B program, as well as to other systems utilizing the 3B20D Processor.

Following the successful introduction of TSPS No. 1B in Fresno, a second new start TSPS No. 1B was placed in service in San Antonio (Southwestern Bell Telephone) on January 30, 1982. Both the San Antonio and Fresno sites were instrumental in the overall test program. The first conversion of an existing in-service TSPS No. 1 office to TSPS No. 1B occurred at Redwood City, California, on March 13, 1982.

The balance of this paper will focus on the overall test program for TSPS No. 1B, specifically on integration and system testing. These systemwide test activities are major components of the methodology used for development of TSPS No. 1B (see Fig. 1*). Integration testing specifically includes: the introduction of various system components (hardware and software) into the development laboratories; the integration of these components to form a stable operating environment; and testing to ensure that a sufficient set of capabilities exists to warrant full, comprehensive, and broad testing. System testing includes the later testing and is done to verify the system, as a complete functional product, before its release to the field.

The integration and system testing of TSPS No. 1B and its components—the 3B20D Processor, the TSPS Peripheral System Interface (PSI), the DMERT operating system, and TSPS application software—was a complex effort. Because TSPS was the first user of the 3B20D as an embedded processor, a substantial cooperative effort with the 3B20D development team was scheduled to identify and solve processor and operating system problems that were encountered during the design, integration, and testing of TSPS No. 1B. A tightly scheduled and controlled series of integration tests were performed by a team at the Bell Laboratories Indian Hill Laboratory in Naperville, Illinois, as new hardware and software capabilities were delivered to the system laboratories. After these new capability packages were integrated and certified as ready for system test, they were delivered to the system test teams at Indian Hill, Fresno, and San Antonio. The use of the two field sites provided settings similar to live TSPS offices for early identification of site-dependent problems and for verification of future in-service retrofit procedures with Western Electric engineers.

The system test plan consisted of over 16,000 unique tests of three general types:

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

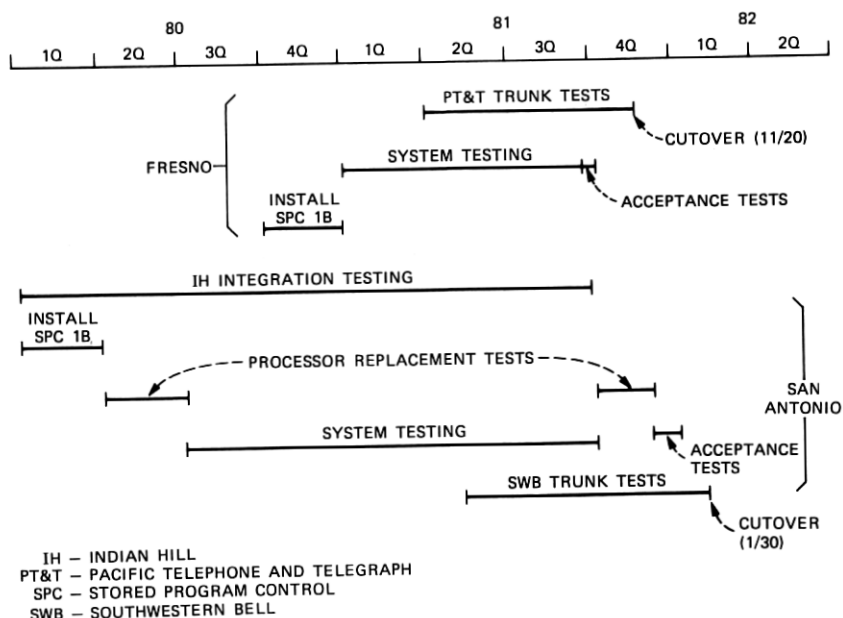


Fig. 1—Test schedule for system integration.

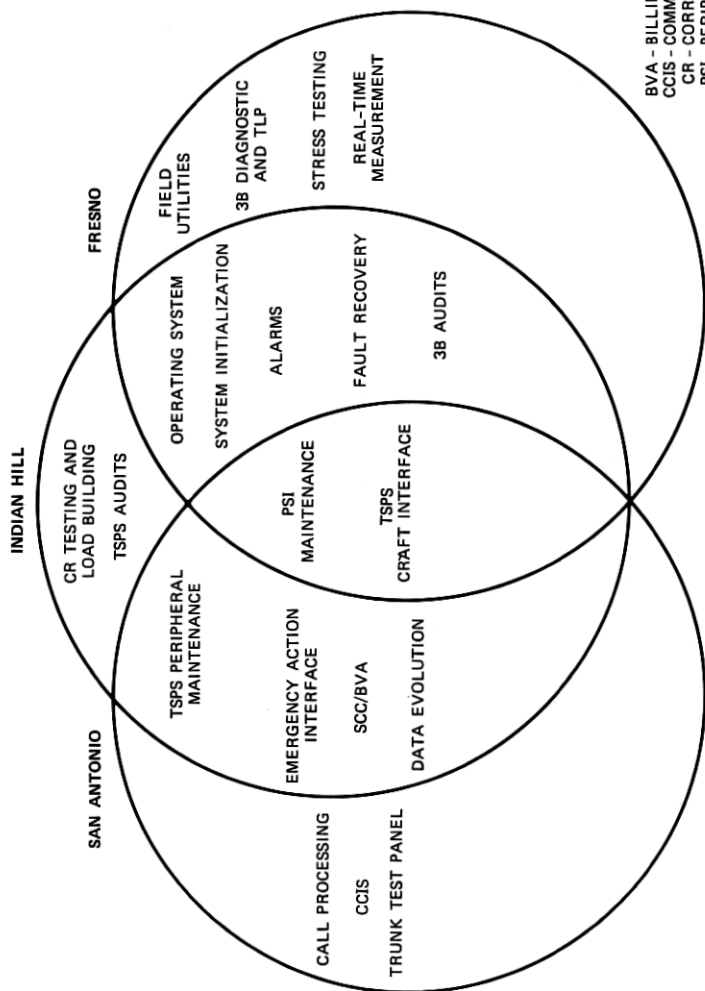
(i) Functional tests—to verify that design requirements were met by new features.

(ii) Regression tests—to verify continued proper operation of previously delivered features.

(iii) Stress tests—to parametrically determine and evaluate system limits, response characteristics, and overall performance under traffic overload conditions and fault conditions.

As depicted in Fig. 2, system test responsibilities were allocated to teams at the three locations with some intended overlap. For example, most of the DMERT feature system testing was scheduled for Fresno, to take advantage of the higher simulated-traffic-load capability at that site. Of these tests, some had been previously run at Indian Hill and at San Antonio, where exposure to different hardware and system configurations was critical. San Antonio was selected as the site to perform exhaustive tests of the existing TSPS periphery and to test external interfaces, such as to the Switching Control Center System (SCCS). In addition, a core of tests was periodically selected for all three system test sites to evaluate key software releases and to regularly assess the performance of a broad spectrum of features. In general, these "Run-for-Record" tests were a subset of the tests included in the system test plan.

Both integration and system testing were pursued for a period of over one year to completely verify the operation of the TSPS No. 1B.



BVA - BILLING VALIDATION APPLICATION
 CCIS - COMMON CHANNEL INTEROFFICE SIGNALING
 CR - CORRECTION REPORT
 PSI - PERIPHERAL SYSTEM INTERFACE
 SCC - SWITCHING CONTROL CENTER
 TLP - TROUBLE-LOCATING PROCEDURES
 TSPS - TRAFFIC SERVICE POSITION SYSTEM

Fig. 2—Test plan overview.

Deliverables were phased to provide a smooth work flow. For this rigorous and demanding test program, tests were conducted ranging from microscopic tests, aimed at verifying operational status of specific elements of system capabilities, to global capacity and performance measurements and evaluations. During the test period, all problems found were tracked and pursued to their resolution. Performance criteria were set, performance was measured to ensure convergence to these criteria, and strong project management techniques were employed to ensure a timely introduction of a high-quality TSPS No. 1B.

The following sections of this article describe how the laboratory integration and site system testing were conducted. The excellent performance of the TSPS No. 1B system at cutover resulted not only from good planning and design but from timely integration and comprehensive testing supported by appropriate documentation, development tools, and change control procedures.

II. INTEGRATION TESTING

2.1 Overview

A crucial stage of the verification and evaluation process for new 3B20D/DMERT and TSPS capabilities is integration testing. During the early stages of the process, the development environment was considered to be "non-frozen," and designers could freely make large-scale changes to the existing capabilities or introduce new ones. The design and development of various features were accomplished by partitioning them into a series of functional units, which were then tested by the designers to make sure that each unit met the design requirements. Upon the completion of unit testing by the designers, a set of integration tests were performed by an independent team to ensure that each functional unit performed reliably in the total system environment. Upon successful integration of functional units, they were considered "frozen," and changes were made only through formal procedures. The frozen functional units were then ready for system testing and evaluation, the last stage of the verification process.⁴

Certain unique characteristics of the TSPS No. 1B development environment required special attention during the integration process. These characteristics can be summarized as follows:

(i) TSPS No. 1B was developed in a multilanguage environment. DMERT software was primarily developed in the high-level C language, while TSPS software was developed in both assembly language (TSPS emulated software) and the high-level C language (TSPS native software).

(ii) DMERT software changes were concurrently developed by the common system organization and had to be integrated with the TSPS

software changes developed by the application organization. In some cases a DMERT change required a coordinated change from TSPS or vice versa.

(iii) 3B20D firmware/hardware changes had to be similarly integrated with the TSPS firmware, hardware, and software changes, such as those associated with the PSI.

(iv) A new generation of TSPS No. 1B support tools was developed, resulting in new load generation, installation, and integration procedures.

The above characteristics were taken into consideration to establish an efficient integration and test strategy, which ensured the quality of the functional units integrated into the system.

2.2 Integration testing methodology

The integration testing philosophy adopted for TSPS No. 1B established a rigorous methodology with systematic checks to independently evaluate all functional units supplied by designers in a single environment. To meet this objective, it was decided that the integration group should be independent of the development groups. Independence provided an unbiased and fresh viewpoint in assessing the functional units and interpreting the test results.

The integration test plan started early in the development cycle, subsequent to the availability of feature requirements. The plan took into consideration the availability sequence of various features and functional units within each feature. A strategy was established that guaranteed efficient handling of all units ready for integration testing without interrupting the other development activities. Special efforts were required to coordinate and synchronize the integration testing of TSPS functional units with 3B20D/DMERT features and capabilities. This was especially crucial in interface areas where direct interaction between the two environments existed. Another major consideration in the plan was that the software, firmware, and hardware environments evolve in a manner compatible with the system test plan, thus allowing the system testing activities to proceed without any interruption.

The TSPS No. 1B integration tests were generated independently, following a thorough analysis and review process, which is summarized as follows:

(i) Feature requirement and design specification documents were reviewed to identify functional units within each feature.

(ii) Functions performed by each unit, along with its input/output characteristics, were identified.

(iii) Software interfaces with firmware and hardware were examined and reviewed.

(iv) 3B20D/DMERT interfaces with the TSPS application were thoroughly analyzed, and expected input/output responses of the interface units were identified.

(v) The control flow among various units and their time sequence description was carefully inspected.

(vi) A general layout and description of data used by each unit were identified.

Based on these examinations, a set of integration tests were developed to exercise each functional unit within the total system environment and to stress 3B20D/TSPS interfaces. These tests were later augmented by the information supplied by the designer(s), upon completion of unit testing, to start the integration testing process. During this process it was first verified that each unit correctly performed all intended functions, including its interaction with other units in a single environment. The second, more subtle, objective was to ensure that the unit did not perform any function that, either singly or in combination with others, would degrade the performance of the system. Third, each unit was examined to make certain that it met the standards set for design structure, documentation, and coding.

Problems identified during the process of integration testing were classified according to their impact on the overall system. Problems were prioritized and fed back to the designer(s) for corrective actions. Problems related to the TSPS software were primarily tracked by Trouble Reports (TRs), while Modification Requests (MRs) were used to track 3B20D/DMERT problems. Specific corrective action by a designer was required to close a TR or an MR.⁵ The list of all open TRs and MRs was carefully monitored to evaluate the total impact and to establish a plan for closing each individual TR or MR. The primary objective of this plan was to ensure that the evolution of the TSPS No. 1B software, firmware, and hardware could proceed on schedule without any interruption.

2.2.1 DMERT integration testing

The development of DMERT software was done in parallel with the development of TSPS software. At well-defined points of the development, a full DMERT release was generated by the common system organization and delivered to the various applications after being tested on a stand-alone basis.⁶

Upon delivery, each DMERT release was first installed in the Program Support System (PSS). Subsequently, steps were taken to incorporate the new DMERT release into the TSPS No. 1B environment (see Fig. 3). These steps can be summarized as follows:

(i) The Equipment Configuration Database and System Generation Database (ECD/SG) were updated to reflect the latest DMERT

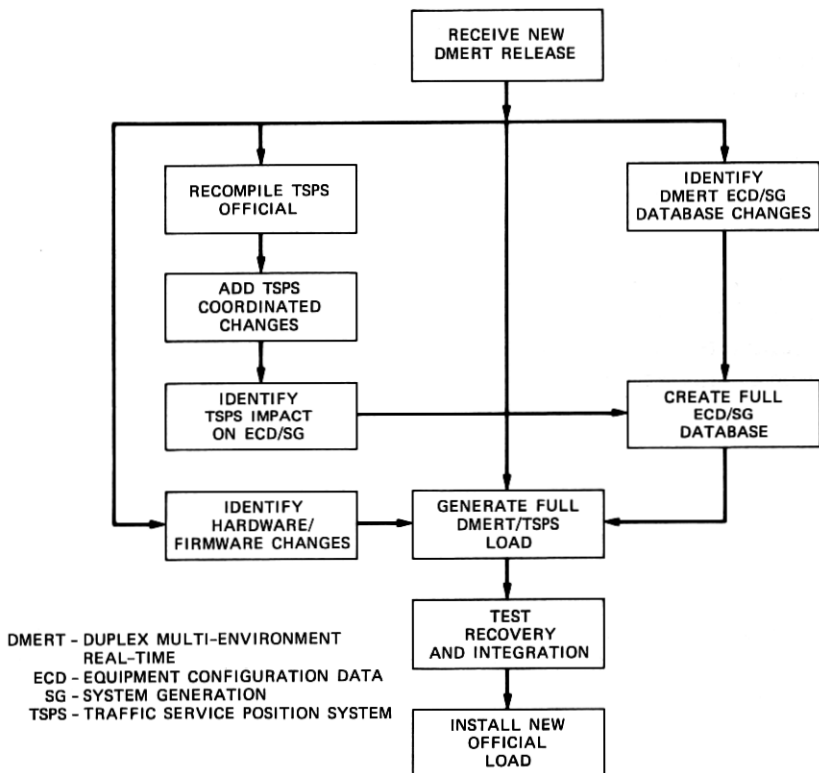


Fig. 3—DMERT integration testing.

changes. These databases contain data structures necessary to generate and run the TSPS No. 1B software system.

(ii) Those areas of TSPS software that were directly affected by the new DMERT release were identified. The corresponding TSPS software changes were then developed on the PSS under the control of the Change Management System (CMS). More information about the software generation process may be found in Ref. 5.

(iii) The TSPS official native-mode software was recompiled using the new DMERT release to update the TSPS programs that were affected by the DMERT release (such as a library that is shared by both DMERT and TSPS software and is changed by the new DMERT release). All TSPS programs that were changed by the recompilation process were audited for potential impact on the overall system. If necessary, appropriate TSPS software changes were generated [see Step (ii)] to compensate for the impact.

(iv) Those areas of DMERT that required changes unique to the

TSPS application were identified. These changes were also reflected in the PSS.

Subsequent to these steps, a full TSPS No. 1B load was generated on the PSS and was installed in the system laboratory for load recovery and integration testing. This load contained the latest DMERT release, along with changes unique to the TSPS application; a recompiled version of the TSPS official load; ECD/SG database changes; and the TSPS software changes required by the new DMERT release.

Any problems in the new load were quickly identified using the debugging tools associated with the TSPS No. 1B,⁵ and immediate steps were taken to obtain the necessary changes from the appropriate designers (DMERT or TSPS). Once the load was cycling, a set of integration tests were conducted to ensure that each functional unit performed as expected in the total system environment. These tests were based upon the ones independently generated by the TSPS application organization, augmented by those supplied by the 3B20D common system organization. Special emphasis was given to DMERT/TSPS interface modules, TSPS areas directly impacted by the new DMERT release, DMERT changes unique to the TSPS application, and ECD/SG database changes. Problems identified during the process of integration testing were tracked using the strategy described in Section 2.2.

2.2.2 TSPS integration testing

Modifications to the TSPS software were introduced into the TSPS No. 1B environment via base loads.⁵ Introduction of a new base load began with identification of all source file changes that had occurred since the prior base load. Then a new test load was created, containing additional software changes and associated ECD/SG database changes. New software changes were usually grouped in one or more test packages. The packaging strategy for the TSPS changes took into consideration many factors including:

(i) Keeping a high degree of resolution in testing of various changes that have an impact on the same programs.

(ii) Optimizing the amount of time used in the system laboratory.

(iii) Keeping the PSS effort for compiling various changes to a reasonable amount.

(iv) Optimizing the system capacity for processing software changes.

Keeping these objectives in mind, all software changes were first mapped into a series of test packages. Program dependencies played a key role in determining the number and content of these test packages. The load of the test packages, along with coordinated hardware and firmware changes, were then installed in the system

laboratory separate from the TSPS official load before the integration testing could proceed.

Upon installation of the load, a predefined set of integration tests were used to examine each test package. These tests were aimed at quickly identifying problems and attributing them to individual changes. Problems encountered during the testing were classified by their impact on the normal operation of the system and tracked as described in Section 2.2. This process was then repeated for all test packages until the necessary resolution was obtained, and it was ensured that all changes could coexist and perform as expected in a single environment. All changes that successfully passed the integration testing were then installed in the system laboratory as the new official base load (see Fig. 4).

Upon completion of the integration testing, functional units were considered "frozen" and ready for system testing. In the frozen environment a set of stringent change control procedures were used so that the TSPS software evolved in a rigorously controlled manner, leading to a high-quality production release. All problems were documented and tracked by appropriate trouble reports, which were carefully monitored. To close a trouble report, a designer was required to submit a Correction Report (CR), which contained the functional description of the change, all necessary information relevant to the software change, and a description of the unit tests used by the designer. Each change was considered an independent entity and was individually tested in the total system environment before its approval. All changes had to be approved by the Change Review Committee (CRC) before they were incorporated in the official load. The CRC comprised representatives from each hardware/software design and test organization on the project.

2.3 Testing of 3B20D and TSPS firmware and hardware changes

Firmware and hardware changes associated with the 3B20D were also tested in the system laboratory environment by the TSPS integration group to uncover problems unique to the TSPS application. These changes, along with coordinated software modifications, were first installed in the system laboratory environment. A series of integration tests were then performed to stress and exercise the firmware-hardware-software interfaces. Problems encountered during this stage of testing were tracked in a fashion similar to that described in Section 2.2.

In cases where 3B20D microcode changes had an impact on the writable portion of the microstore,⁷ no firmware change was necessary, and the microcode change was released in a fashion similar to a software change described in earlier sections.

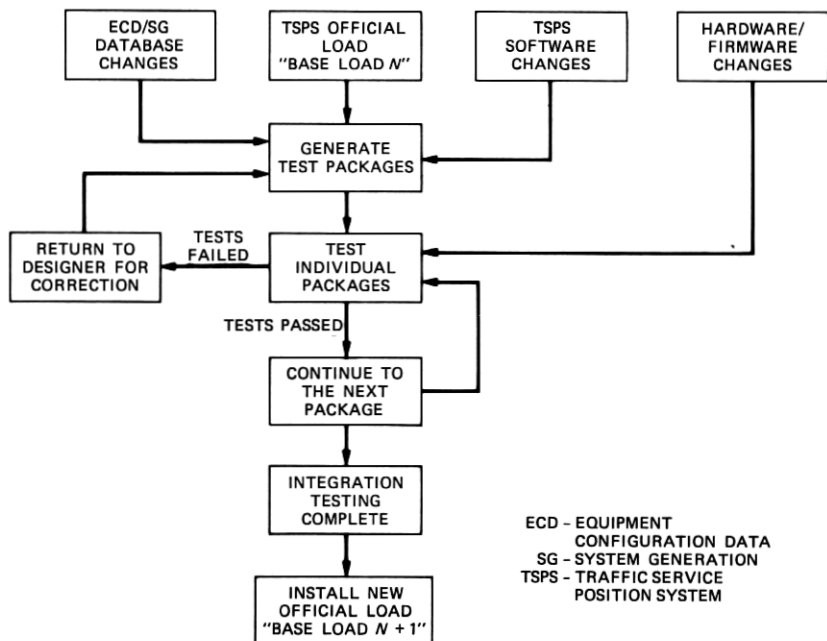


Fig. 4—TSPS integration testing.

Changes to the TSPS microcode were administered under control of CMS in a similar fashion to the TSPS software changes. A change was first developed on the PSS and was then submitted for integration testing. The change was transferred to the system laboratory in one or more files and was installed in the writable microstore unique to the system labs. A series of integration tests were then performed to verify its integrity in the total system environment. Similarly, all hardware changes associated with TSPS were tested in the system laboratory environment using prototype circuits prior to their official availability. Once it was verified that the hardware/firmware changes operated as expected, they were transmitted to Western Electric along with manufacturing and factory test information, and were subsequently installed at the field sites.

2.4 Distribution of individual software changes

Once a stable TSPS No. 1B release was installed in a field site, the subsequent individual software changes were supplied as individual packages and were installed using the field update commands.⁵ A package typically consisted of the software change, additional files containing field update commands, and information files required for

installation, testing, soaking, and distribution of the change to the field.

For a change in the 3B20D/DMERT software, the 3B20D common system organization generated a software package that was distributed to each application organization. Before the release of the package to the various applications, it was first tested and certified in the common system environment by the common system organization. Once the change was received by TSPS, it was examined for compatibility with the TSPS environment. In some cases a coordinated TSPS software change was required before actual installation and testing could proceed. A series of tests were then conducted to ensure that the change performed as expected within the total system environment. These tests included those supplied by the common system organization, as well as an independent set generated by TSPS personnel.

Once a software package was successfully tested and soaked in the TSPS system laboratory environment, necessary changes were made to its information files prior to field delivery. These changes were made to delete the test information unique to the system laboratory environment. This information was used by application organizations to verify the modification and was not applicable to the field environment.

The TSPS application software changes required for distribution to the field sites were individually tested and approved using the "frozen environment" methodology described in Section 2.2.2. These changes were then packaged using the standard format described earlier in this section. Necessary considerations were given in the packaging strategy to balancing and optimizing various factors such as the field installation time and the number of system initializations required to install the changes. Also, if necessary, these changes were retested to ensure that no problems were introduced in the final packaging.

III. SYSTEM TESTING AND EVALUATION

3.1 Overview

System testing also represented a crucial and essential part of the overall verification process. During this stage a complete set of functional tests were written and executed to independently evaluate all TSPS and DMERT operational and maintenance capabilities from a system viewpoint. These tests were systematically performed with the objective of ensuring that the requirements for each feature were met. Special emphasis was given to evaluating the interaction between the new features and the existing features that were emulated from the TSPS No. 1 environment. Furthermore, regression tests were performed to ensure that previous tested capabilities were not being adversely affected by the introduction of new ones. All problems

identified during the system testing interval were documented by appropriate trouble reports.

The system testing effort was divided into several areas with different objectives. They are listed below with the primary objective for each area and are further discussed in Sections 3.2 to 3.5.

(i) Call-processing objective—Verification of all emulated call-processing features.

(ii) TSPS maintenance software objective—Verification of fault recognition, routine exercises, and diagnostics.

(iii) External interfaces objective—Verification of external interfaces such as the Service Evaluation System (SES), Switching Control Center System (SCCS), and Billing Validation Application (BVA), etc. (see Refs. 1, 8, 9, and 10).

(iv) DMERT and 3B20D system testing objective—Verification of DMERT and 3B20D features, DMERT and 3B20D/TSPS interfaces, and sample faulting of 3B20D and its periphery in the TSPS environment.

(v) Regression testing objective—Determination of impact of new TSPS and DMERT/3B20D releases on previously tested capabilities.

(vi) System evaluation runs objective—Analysis of overall system stability and quality at various loads.

System tests were performed both in the system laboratory and the field sites. The field test plan consisted of functional tests, environmental tests, and an overall acceptance test, and was used as a final check that the system met its functional objectives at specified environmental limits. Over 16,000 individual functional system tests were written and executed during the system test interval at the San Antonio and Fresno test sites. The first execution of all system tests was scheduled and accomplished by early in the third quarter of 1981 (see Fig. 5). This timely execution enabled identification of problems, management, resolution, and closure by turnover (see Fig. 6). All significant system tests passed prior to the turnover of the Fresno site to the operating telephone company. The environmental tests verified system performance at the limits of high temperature and low voltage. The functional-site testing effort validated system performance in a fully equipped TSPS office that has been engineered by an operating telephone company with hardware supplied and installed by Western Electric.

3.2 Call-processing testing

The call-processing software in TSPS consists of a set of programs that provide the logic and control for processing telephone calls. These programs supervise the state of the call, transmit and receive signals

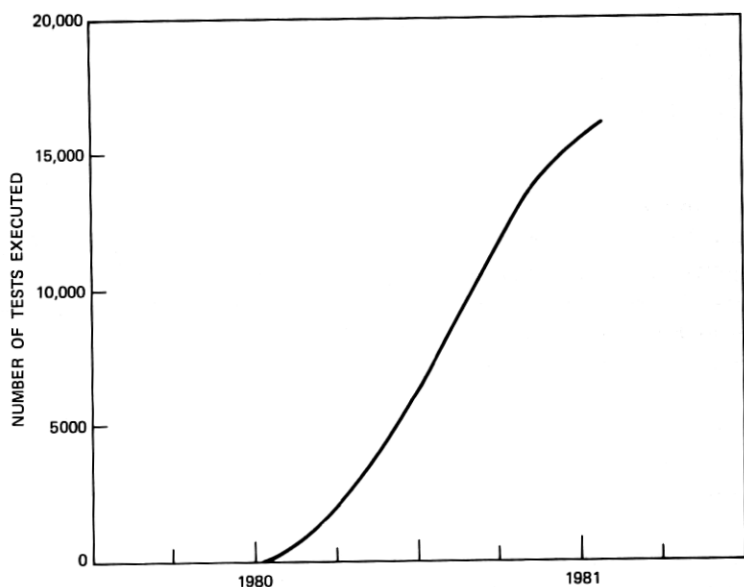


Fig. 5—TSPS No. 1B test schedule.

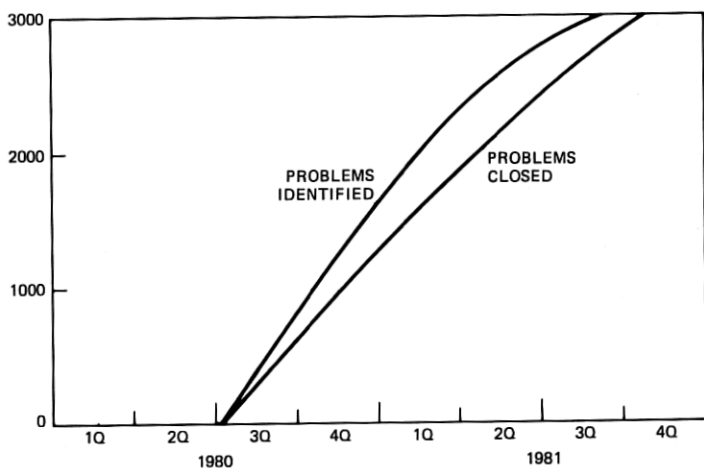


Fig. 6—TSPS No. 1B problem closure.

to and from other switching systems, send information to and receive signals from operators, and record billing details on the calls.

In most cases the call-processing programs were directly emulated from the TSPS No. 1 environment without any structural or code changes. Because the call-processing software was preserved in the TSPS No. 1B, the strategy for testing was mainly to verify the proper

emulation of the existing capabilities. This objective was accomplished by using system test facilities to generate simulated call inputs to exercise various call-processing capabilities, including those involving customers and operators. These capabilities were tested both on a single-call basis and under call loads simulating the normal traffic environment of the system.

3.3 TSPS peripheral fault recognition, diagnostics, and exercise

TSPS No. 1 peripheral maintenance programs such as fault recovery, diagnostic, and exercises were also preserved in the TSPS No. 1B environment. These maintenance programs were emulated from the TSPS No. 1 environment, after necessary code and structural changes were made to provide interfacing compatibility with 3B20D hardware, firmware, and maintenance software capabilities. The function of fault recognition is to analyze failure conditions and quickly reconfigure the system to a working state with a minimum interruption to operational call processing. Testing in this area verified that faults were successfully detected and appropriate actions were taken.

Diagnostics are used in TSPS to test the various equipment units in response to fault-recognition requests or manual requests. These capabilities resolve hardware malfunctions by providing trouble-locating messages for use by maintenance craft to repair the faulty hardware. Testing in this area verified that the diagnostics properly detected the presence or absence of troubles and produced messages consistent with expected results without adversely affecting system operation.

Specific routine exercises are used to periodically examine the correct operation of the hardware and to detect various failures that may not show up in normal system operation. In general, exercises utilize the diagnostic capabilities described above to verify the condition of the equipment units on a periodic basis. Testing in this area demonstrated that the exercise routines operate in the expected manner.

3.3.1 Test strategies

Sample physical fault insertion, power faulting, and data faulting, combined with manual actions initiated at the Local Maintenance Position, were the major means of verifying the proper operation of system maintenance functions. These techniques were used to develop specific tailored test strategies for each peripheral unit. Initially, tests were conducted in the absence of call load to verify the proper response. Subsequently, maintenance capabilities were tested in the presence of varying call loads to ensure proper interaction of call handling and maintenance functions.

Physical fault insertion was one of the primary methods of testing the operation of maintenance software and hardware. Physical fault

insertion verified proper cooperation of fault recognition, system re-configuration, and diagnostics. It further provided a test of the Trouble Locating Manual (TLM) used by the craft to identify faulty circuit packs. It was impractical to do exhaustive fault insertion, such as that utilized in TLM generation. However, it was necessary to develop sample faults to verify that the maintenance software performed within the existing requirements.

Power faulting was the second major means of introducing hardware faults. Power faults were introduced selectively by blowing fuses or intentionally removing power to verify the ability of the system to detect the fault, take the appropriate equipment out of service, and produce the proper alarm and output messages to enable craft personnel to restore the system.

Data faulting was the third faulting technique used in testing maintenance actions. Data faulting is the application of erroneous data to the system. It measures the sensitivity of the system, the adequacy of defensive program checks, and the efficiency of data consistency audits. This type of faulting was useful, for example, in testing response to transmission irregularities between the base and remote subsystems, such as the Remote Trunk Arrangement and Position Subsystem No. 2.¹¹

Various manual actions at the Local Maintenance Position were also used to verify the proper response of the system in areas such as reconfiguration, diagnostics, measurements, control and display capabilities, and exercises. These types of actions are usually taken by the craftspeople both on a routine basis and in emergency-action conditions.

3.3.2 TSPS peripheral test sequence

Communication between the SPC 1A and peripheral equipment is accomplished by the Central Pulse Distributor (CPD), Communications Bus Translator (CBT), Master Scanner (MS), Universal Trunk Scanner (UTSC), and Universal Trunk Signal Distributor (UTSD). Maintenance testing verified that the emulated maintenance programs detect malfunctions in the above units and take appropriate recovery and diagnostic actions.

The TSPS periphery consists of a number of functional entities or subsystems (see Table I) that are administered by duplicated controllers that interface with the SPC bus system. Extensive tests were performed to verify the operation and maintenance of these functional units under control of the TSPS No. 1B software.

In TSPS, trunks and service circuits provide the interface between the TSPS and external systems. For maintenance purposes, access to these circuits is required to evaluate performance and localize or

Table I—TSPS peripheral subsystems

Position and Trunk Link Network
Position Subsystem No. 1
Peripheral Control Link
—Position Subsystem No. 2
—Remote Trunk Arrangement
Station Signaling and Announcement Subsystem
Common Channel Interoffice Signaling Links

isolate a trouble to a particular faulty unit. Comprehensive tests were required to ensure proper operation of these trunk and service circuit routines. Table II lists the TSPS trunks and service circuits for which maintenance routines were tested.

3.4 TSPS external interface tests

A number of systems external to TSPS provide operator administrative functions, or interact with TSPS for services and maintenance. In general, these are self-contained systems, but rely on communications with TSPS over data links and/or channels, thus requiring coordinated testing between the two systems. The communications generally rely on specific protocols or message types. Testing of external interfaces verified that the necessary protocols, message handling, and maintenance states were operational in the TSPS No. 1B environment. Some of the external interfaces include:

- (i) External administrative centers
- (ii) The Hotel Billing Information System (HOBIS)⁸
- (iii) The Service Evaluation System (SES)⁹
- (iv) The Billing Validation Application (BVA)¹
- (v) The Switching Control Center System (SCCS).¹⁰

The interfaces in items (i) through (iv) above required only verification that TSPS No. 1B had not introduced operational or maintenance problems. The SCCS interface [item (v) above] required substantive testing because of new interface hardware and software (see Ref. 12). This interface was functionally tested between the system laboratories of the SCCS and TSPS development organizations. Field-site testing verified these functional capabilities and stressed load-related features that could not be tested earlier.

3.5 3B20D/DMERT system testing

3B20D/DMERT testing evaluated 3B20D/DMERT hardware and software in the application environment. The 3B20D/DMERT tests concentrated on interfaces, resource utilization, and system response characteristics in the TSPS application environment. As such, overload response, resource audits, and software fault tolerance were extensively tested. The combined craft/machine interface and

Table II—Tests of TSPS trunk, service circuit, and maintenance circuits

Service Circuits
—Dial-Pulse receivers
—Multifrequency receivers
—Multifrequency outpulsers
—High-Impedance, Multifrequency receivers
—Coin Control and Ringback circuits
—Reorder Tone and Announcement circuits
—Audible Tone trunks
—Coin Detection and Announcement circuits—Type 1
—Coin Detection and Announcement circuits—Type 2
—Dual Tone Multifrequency Detection and Announcement circuits
—Multifrequency Announcement and Detection circuits
Trunk Test Panel
AMA maintenance
Recorded Announcement equipment
Tone and Interrupter circuit
Time of Day circuit

DMERT administrative functions (field utilities and field update, for example) were also extensively exercised.

3.5.1 Fault recovery, initialization, diagnostics, and overload

The TSPS No. 1B maintenance strategy is based on the 3B20D/DMERT maintenance design augmented by additional capabilities unique to the TSPS application. These additions are mainly in areas where TSPS software directly interacts with the DMERT software, or when specific hardware interfaces are required for the TSPS application.

Specific fault-recovery strategies were developed by TSPS for the PSI, the interface between the 3B20D and the TSPS periphery.¹² In addition, the TSPS Application Integrity Monitor (AIM) was developed to directly interact with the DMERT system integrity monitor (SIM) to ensure the system integrity of TSPS No. 1B. DMERT system initialization and overload features were augmented by TSPS to establish an overall system initialization and overload strategy for the TSPS No. 1B.¹³ These areas were tested extensively to determine the proper system response.

The 3B20D and PSI diagnostics, Trouble-Locating Procedures (TLP), and Routine Exerciser (REX) were tested by sample faulting techniques. Manual requests for removal/restoral were also used for verification of capabilities.

The TSPS No. 1 maintenance craft interface was replaced in TSPS No. 1B with a combined 3B20D Processor and TSPS maintenance craft interface. Testing in this area concentrated on combined craft response, software and hardware alarm interfaces, and an assessment of process priorities to provide sufficient terminal response time under load.

3.5.2 Administrative functions

Testing in this area concentrated in the areas of 3B20D recent change/verify (for equipment and system configuration database changes), system update (for installation of a "point" issue of a current generic or installation of a subsequent generic), and field update (for installation of one or more broadcast warning messages).

3.6 System evaluation runs

3.6.1 Purpose and definition

One goal of system testing was to monitor a set of quantified performance criteria to measure overall system quality and to ensure that system design goals were met. Of particular importance for TSPS No. 1B was the evaluation of system behavior at full-load call handling (maximum capacity). This was particularly important since a substantial number of TSPS No. 1 to TSPS No. 1B live in-service retrofits were scheduled for 1982 for offices at or approaching real-time overload of the SPC 1A. Since the Fresno site had a large amount of peripheral equipment, sufficient microprocessor-controlled call simulators and operator simulators were installed on a temporary basis to permit stressing the new TSPS No. 1B above the capacity design objective. This additional performance margin simulated variation among sites with respect to call mix and peakedness in the busy hour(s).

In the first quarter of 1981, a series of weekly System Evaluation Runs (SERs) were begun at both Fresno and San Antonio to measure system performance in an environment approximating post-cutover conditions. Typically, these SERs were executed on weekends and were 24 to 48 hours long. During these SERs the following conditions were met:

(i) Operating telephone company maintenance craft were assigned to monitor and maintain the office, performing all TSPS peripheral maintenance and trunk cutover testing simulating an in-service office.

(ii) Bell Laboratories and Western Electric site staff had instructed the maintenance craft in the use of normal 3B20D Processor and SPC 1B peripheral maintenance procedures. When craftspeople were troubleshooting equipment faults or potential design problems, normal field repair tools and techniques were used.

(iii) A simulated call load was applied to the system. At Fresno, the first quarter 1981 SER was conducted at a load equivalent to 25 percent of the system call capacity. This was gradually increased so that by mid-1981, SERs were conducted above the call-capacity design objective of the TSPS No. 1B.

3.6.2 Measurements and objectives

A team of designers, testers, and system analysts defined a set of eighteen measurements that were tracked as part of the SER each

Table III—Fresno Service Acceptance Test
Performance* (9/27/81–10/5/81)

	System Performance	First-Site Turnover Objective
Call Load (Percent of SPC 1A)	175%	160%
Mishandled Calls	0.04%	<0.05%
Plug-in Replacements	0	<1/10 days
System Initializations	0	0.02/wk

* Includes normal maintenance and PT + T trunk testing.

week to summarize system stability and maintainability. For each measurement, a turnover objective was specified. If several results deviated widely from the objective, a high priority was placed on resolution of these problems. When the measurements in those areas approached the turnover objective, resources were redirected to improving other areas of system performance. Statistics were kept on the frequency and cause of initializations, interrupts, audits, and overloads. The duplex performance of the processor and its disk subsystem was tracked and the degree of automatic fault recovery and identification was evaluated. Hardware failure rates were closely monitored and compared with reliability models. All initial service objectives were achieved prior to cutover. Table III shows Fresno Service acceptance test performance versus key first-site turnover objectives.

IV. SUMMARY

The strength of the integration and system test plan for the successful field introduction of the TSPS No. 1B involved the use of complementary techniques to set objectives and monitor progress. The comprehensive functional and regression testing, close tracking of correction and modification requests, and prompt integration and delivery of a diverse set of software changes were essential to the steady progress summarized by the periodically executed System Evaluation Runs.

An immediate benefit of this approach was the customer satisfaction expressed by Pacific Telephone and Southwestern Bell Telephone at turnover, cutover, and subsequent operation of their new TSPS No. 1B systems. Furthermore, the implementation of the comprehensive test program described herein is responsible for the excellent performance of the 37 offices now in service (35 of which were live in-service retrofits in high-traffic sites). Current Bell Laboratories and Western Electric efforts involve the continued coordination and support of the large number of TSPS No. 1B live in-service retrofits planned for the next few years.

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REFERENCES

1. R. E. Staehler and J. I. Cochrane, "Traffic Service Position System No. 1B: Overview and Objectives," B.S.T.J., this issue.
2. E. M. Prell, V. L. Ransom, and R. E. Staehler, "The Changing Role of the Operator," Int. Switching Symp., Paris, France, May 1979.
3. Special issue entitled "3B20 Processor & DMERT Operating System," B.S.T.J., 62, No. 1, Part 2 (January 1983).
4. J. P. Delatore, D. Van Haften, and L. A. Weber, "System Verification and Evaluation Procedures," B.S.T.J., 58, No. 6, Part 1 (July-August 1979), pp. 1335-46.
5. T. G. Hack, T. Huang, and L. C. Stecher, "Traffic Service Position System No. 1B: Software Development System," B.S.T.J., this issue.
6. W. F. Klinksiek and H. L. Mitchell, "3B20D Processor and DMERT Operating System: System Integration and Test," B.S.T.J., 62, No. 1, Part 2 (January 1983), pp. 399-410.
7. M. W. Rolund, J. T. Beckett, and D. A. Harms, "3B20D Processor & DMERT Operating System: 3B20D Central Processing Unit," B.S.T.J., 62, No. 1, Part 2 (January 1983), pp. 191-206.
8. S. Michael and J. Vizcarrondo, "HOBIS: New Designs on Hotel Billing," Bell Lab. Rec. (January 1980), pp. 11-18.
9. T. R. Lehnert, "A Better Way to Measure the Quality of Telephone Service," Bell Lab. Rec., 59, No. 6 (July-August 1981), pp. 186-9.
10. J. J. Bodnar, J. R. Daino, and K. A. Vandermeulen, "Traffic Service Position System No. 1B: Switching Control Center System Interface," B.S.T.J., this issue.
11. S. M. Bauman, R. S. DiPietro, and R. J. Jaeger, Jr., "Remote Trunk Arrangement: Overall Description and Operational Characteristics," B.S.T.J., 58, No. 6, Part 1 (July-August 1979), pp. 1109-18.
12. G. T. Clark, H. A. Hilsinger, J. H. Tendick, and R. A. Weber, "Traffic Service Position System No. 1B: Hardware Configuration," B.S.T.J., this issue.
13. R. J. Gill, G. J. Kujawinski, and E. H. Stredde, "Traffic Service Position System No. 1B: Real-Time Architecture Utilizing the DMERT Operating System," B.S.T.J., this issue.

