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SARTS—An Overview of Remote Special-Service Testing in the Bell System

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As the telephone system has grown, it has become increasingly complex. Dedicated facilities and equipment began to be offered to customers on a full-time basis. Growth of these types of services, called "special" services, presently exceed message-service growth. Because access to these types of circuits is difficult to achieve without personnel interaction or high capital investment for access relays, automation for remote testing in these services has lagged the switched message network. This paper traces testing evolution in this area and suggests the economic and service pressures that led to the concept of Switched Access Remote Testing (SARTS). We describe SARTS generally, to prepare the reader for the following and future papers that describe hardware and software in detail. The total Special Service Center (SSC) concept provides testing support for installation and maintenance within a structured organization and records and administrative system. The aim is to provide one person with control and testing of a large variety of circuits, on an end-to-end basis.

I. INTRODUCTION

The high quality of special services provided to Bell System customers depends in part on adequate testing and maintenance of the circuits. Typical examples of special-service circuits are toll-free lines to a business office or data links between a company's central computer and remote locations. Over one-third of the Bell System's revenue comes from these services—and the proportion is increasing. Many special-service circuits bypass conventional switching systems, and in densely populated regions they present a considerable problem in accessing them. Another feature of these circuits is the large variety of specialized signaling and transmission equipment which the craftspeople must deal with.

Testing is a complex issue and usually one involving craftspeople at many different locations along the circuit path. The Special Service Center (SSC) has evolved to centralize administration and testing of these circuits. The Switched Access Remote Test System known as SARTS provides the technical core of an SSC and the means for reaching out to various remote locations with highly automated test equipment. This paper presents an overview of the subject of remote testing leading up to SARTS and an introductory description of SARTS.

II. BACKGROUND

Early telephone plants contained mechanical systems which required a trained force to keep them running smoothly. Few switching entities were without craftspeople on site, many on a 24-hour basis. The cost of maintaining Plain Old Telephone Services (POTS) was reasonable because the test equipment to support the craftspeople was inexpensive and unsophisticated. The labor turnover in the operating companies was small, principally because the job was interesting and personnel could work in their own community. Both craftspeople and the Bell System prospered under this arrangement, which continued throughout most of the mechanical dial-switching era.

With the advent of the electronic age, however—which began in earnest when carrier transmission facilities were introduced, long before the age penetrated switching systems—craftspeople and equipment sophistication grew. The early electronic systems had the same philosophy of maintenance and installation testing used in central offices themselves. This philosophy was based on a craft team who would be dispatched or rove throughout a troubled area, seeking problems and solving them. As the circuits increased and their critical nature developed, the dependency of the network on quick restoral of trunks between wire circuits led to the development of many new techniques. For example, protection switching methods were used to provide almost hitless restoral, and long-haul carrier systems were improved by outfitting them with tracing tones and telemetry surveillance techniques which helped isolate faults.* Craftspeople were therefore dispatched with greater accuracy, and the efficiency of the testing operations increased. Although some of these new techniques were costly, the highly multiplexed carrier facilities carrying large numbers of conversations could afford them and absorb the expenses. New carrier systems, including digital ones, were designed having these new techniques built into their programs. The difficult problem of isolating faults after sectionalization led to the development of a highly skilled work force, in many ways the elite of the system.

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* For example, PEARL for L3 coaxial radio-carrier systems having built-in pilot signals.

Another phenomenon was taking place, however, that would have serious effects on the quality and quantity of craftspeople required for maintenance and installation. This was the almost insidious growth and tremendous diversity of private line and switched special service circuits. The transmission of data on these circuits placed stingent demands on what were previously "voice channels," and both designers and craft maintaining the equipment and circuits were highly taxed to meet them.

The initial impulse was to embark on an extensive training program to enable craftspeople to install and maintain these circuits as well as electronic switching machines having stored program and other computerized features. These training programs provided the craftspeople with new skills. These skills had a high marketability, and therefore the turnover rate increased, especially in metropolitan areas. Soon the system was beset with the problem of requiring a large installation and maintenance force with a knowledge and training in very sophisticated communication and computerized equipment, plus all the specialized tools to keep it going. The mobility of the trained craft, and the large expanding electronics industry, placed a serious burden on the Bell System training system, and on the few experienced personnel who were actually doing the work.

This formed the impetus to develop increasingly automated testing systems that would reduce the requirements for craftspeople—both in their numbers and in their need for technical knowhow. Centralization was the obvious answer, where critical indicators from several wire centers were brought together at one point. The ultimate goal of this philosophy was to remove the maintenance craftspeople entirely from the wire centers by deploying test equipment and indicators which could be activated remotely and interpreted by the remote and centralized craft. Only installation and repair work would require dispersed on-site personnel. A series of specialized tools evolved for the maintenance of the common networks.

III. REMOTE-TESTING EVOLUTION

3.1 Test desks and test cabinets

In the early days of telephones, rudimentary remote tests were performed by operators at their cordboards to determine the stability of the connections they made. By listening to the person placing the call and to the person to whom the call was placed, an operator could detect excessive loss or noise and establish an alternate connection if necessary. But direct distance dialing (DDD) eliminated this simple, remote, human checking system. Instead a manuel effort was required at both ends of a line. This meant that considerable time had to be spent coordinating people and making many different kinds of tests.

Small offices began to use the No. 3 local test cabinet for making tests on their subscriber lines. A centralized repair service center evolved, which used No. 14 local test desks to make tests in several central offices.[1] Test desks and cabinets required dedicated 3- or 4-wire dc trunks between them and the circuits or offices being tested. The range was limited to about 20 miles, and resistance and capacitance tests over long test trunks were hard to interpret with any accuracy.

3.2 Automatic transmission test and control circuit

Probably the earliest concept of a remote transmission testing system was a system developed at Bell Laboratories in the 1950s, known as the Automatic Transmission Test and Control Circuit (ATTC)[2] This was a tone comparison system that adjusted an attenuator at the far end to equal the near-to-far loss, sending a tone back with and without the loss. The near-end equipment measured the far-to-near loss under both conditions and computed the loss of the trunk in the near-to-far direction as the difference of the two received tones.

3.3 Remote test circuit

But the controlling and measuring of individual circuits from a remote location and the transferring of the information back to a centralized area via voice frequencies were not introduced until 1965.[3] This subscriber-line testing system increased the centralization of local test desk functions and provided great savings in dedicated plant. Access was made on the subscriber line to a remote office, using a standard switch train, or it was made via "no test" access, which is a method of gaining access to lines even during busy conditions. Access now became possible to all subscriber circuits on the line side of the switch. This system, called simply a "remote testing circuit," used dedicated or dial-up trunks for controlling equipment at the far end. A stored number was provided at the far end to dial back to the near-end test circuit assigned to its office. When the connection was made, the initial dial-up connection was dropped, insuring security and preventing any unauthorized test access. The near-end tester had interface keys, lamps, and meters, and as far as the craftspeople were concerned, the testing operation was the same as being located at the far end. The control signals were by means of standard multifrequency (MF) signals, sent to a special remote testing circuit at the far end. Each control signal activated by a certain key would affect a relay in the remote test circuit to activate the test. A large variety of tests was available in this system, as shown in Table I.

The operation of this system depended on the fact that local subscriber services terminated on a switch. The switch was capable of selecting a particular local circuit and connecting into it automatically.

Table I—Multifrequency signaling codes

Key or Relay	Code When Operated	Far End Relay	Code When Released	Far End Relay
DIAL	A0–B0–C0	DL, DP	-	–
TD	A0–B1–C0	TD	A0–B1–C1	TDR
DISC	A0–B2–C0	DIS	-	
TTS	A0–B3–C0	TS	A0–B3–C1	TSR
PC (Relay)	A0–B4–C0	ST, ANS	-	
RG	A1–B1–C0	RG	A1–B1–C1	RGR
H	A1–B2–C0	H	A1–B2–C1	HR
FEMF	A1–B3–C0	F	A1–B3–C1	FR
24MA	A1–B4–C0	MA	A1–B4–C1	MAR
60V	A2–B0–C0	60V	A2–B0–C1	60VR
MDF	A2–B1–C0	MDF	A2–B1–C1	MDFR
IN	A2–B2–C0	IN	A2–B2–C1	INR
VM REV	A2–B4–C0	VR	A2–B4–C1	VRR
–T	A3–B0–C0	–T	A3–B0–C1	–TR
–R	A3–B1–C0	–R	A3–B1–C1	–RR
G	A3–B3–C0	G	A3–B3–C1	GR
M	A4–B0–C0	M	A4–B0–C1	MR
REV	A4–B1–C0	RV	A4–B1–C1	RVR
3WO	A4–B2–C0	3WO	A4–B2–C1	3WOR
KPP	A4–B3–C0	KP	A4–B3–C1	KPR
T	A4–B4–C0	TK	A4–B4–C1	TKR
NT	A0–B0–C2	NT	A0–B0–C3	NTR
TT	A0–B1–C2	TT	A0–B1–C3	TTR
SSRT	A0–B2–C2	SRT	A0–B2–C3	SRTR
+T	A0–B3–C2	+T	A0–B3–C3	+TR
+R	A0–B4–C2	+R	A0–B4–C3	+RR
CC	A1–B1–C2	CC	A1–B1–C3	CCR
CR	A1–B2–C2	CR	A1–B2–C3	CRR
+STA	A1–B3–C2	+STA	A1–B3–C3	+STAR
–STA	A1–B4–C2	–STA	A1–B4–C3	–STAR
RCCI	A4–B0–C2	RCCI	A4–B0–C3	RCCIR
PS RLS	A4–B1–C2	PR	A4–B1–C3	PRR
LRP	A4–B2–C2	LRP	A4–B2–C3	LRPR

The cost of line circuits and the common switching was borne by the service itself, and remote systems only had to connect to the switches in a secure way to have complete access to that circuit. Likewise, the number to be accessed was identical to the regular number of that service, and therefore no additional records or administration was necessary. The local test desk function remained essentially the same, but now it covered a much broader area.

This testing ability applied essentially to POTS, with the exception of coin alone. Private-line services and switched special services, being dedicated or falling outside normal switching systems, could not be tested by these remote dialing techniques. In fact, the only access to many of these services was via a "shoe" at the distributing frame. A shoe is inserted by a frame craftsperson at the request of a tester and jacked back via a distributing frame test line to the person requesting it in a test area. The most common shoe provides the tester with control over the direction. When a private line traverses several wire centers which are sometimes located in different companies, locating a trouble entails the cooperation and coordination of many people—sometimes up to six, which is uneconomical and often difficult.

3.4 Nonstandard special-service jack boards

An additional technical problem arose for special service circuits. Because they frequently involve long distances and have many stringent requirements—such as special gain characteristics, equalization problems, and many special signaling treatments—they require both sophisticated equipment and craftspeople with unusual skills. The resultant cost of these services produces customers who are rightfully impatient when their services have troubles.

Operating companies tried to solve this problem initially by building jack boards which could be cross-connected into critical points in the circuits. As time passed, these boards became transformed into test boards, locally engineered with communication facilities and test equipment. Standard deployment strategies were generated for these "nonstandard" arrangements. The toll interfaces (and later, more generally, other special-service interfaces) were known as Serving Test Centers (STC). Private-line test boards, with appropriate test equipment, provided fast access to the craft. They suffered from serious maladies, however. They were complex and expensive. They required many jacks, with their associated problems of interconnection and rearrangement. They consumed floor space, typically providing only 150 to 400 jacks on a board, and they required expensive, sophisticated test equipment for the craftspeople at each test board.

Special-service circuits tend to be volatile, with an average lifetime in the order of two years. Test boards are often specially engineered and administered to maintain a specific customer testing community (that is, having all a particular customer's circuits brought to one test board). Circuit rearrangements are necessary when new circuits appear to preserve the test-board order. Even with considerable tailoring of these test boards, a test craftsperson might have to move from one board to another to cover the circuits of a particular customer, especially at times of minimum coverage. Additional test trunks could be added between boards to allow testing from one position, but this was less than convenient.

3.5 Automatic transmission measuring system

During the middle 60s, remote testing of telephone trunks reached a high level of sophistication in the switched-trunk environment. The Automatic Transmission Measuring System (ATMS)[4] for telephone trunks consisted of a control unit (called a Director) in one office and one or more remote units (called Responders) at distant locations.

Measuring sequences were under the command of the Director, which received its information from a teletypewriter tape or punched cards.

3.6 Remote office test line

As ATMS progressed, the number and range of its tests increased. Some offices, however, were too small to justify the full ATMS Director and its associated test frame. The Remote Office Test Line (ROTL)[5] permitted a director at Office A to measure trunks between a ROTL-equipped Office B, and an Office C which was equipped with code 100-, 102-, or 105-type test lines, a series of units developed for specialized transponding testing. It should be noted that ATMS evolved into the computer-controlled Centralized Automatic Reporting on Trunks (CAROT) system.[4]

3.7 Switched maintenance access systems

3.7.1 SMAS 1A

The first switched maintenance system conceived especially for private lines was called the Switched Maintenance Access System (SMAS),[6] filed for a patent in January of 1968.[7] This system, operational as SMAS 1A, was a private-line access system recognizing the toll interface needs at that time. It had a 6-wire toll interface and a 5-wire drop interface that provided for signaling as well as transmission testing. SMAS was a solid-state, common-controlled, electromechanical 3-stage crossbar switch, with 1200 circuit accesses (11 pair, per access). It was capable of being brought to any one of four specially-designed 22A test boards, on up to 10 test trunks per position. The system was supplied with a manual patching capability that would allow spare equipment to be switched into a circuit to replace defective equipment in the SMAS 1A equipped office. It was also supplied with manual jacks beyond the normal trunks, connected to test boards where long-term testing could be accomplished without increasing test-trunk blockage.

3.7.2 22A test board

The 22A test board (see Fig. 1) was equipped with gas-filled numerical indicator tubes which displayed the 4-digit *Touch-Tone*® number used to access the circuit, and the class code associated with the circuit accessed. Up to 64 "classes" of circuits could be indicated by information stored in a magnetic memory. This information preconditioned the test position for level, impedance, and configuration (2- or 4-wire). Since special-service variations for 22 accessed wires (6-wire split and 5-wire split) can be far greater than that provided for in 64 conditions, an override, or "no class" condition, allowed the tester to set parameters to any desired point within the position. The information to

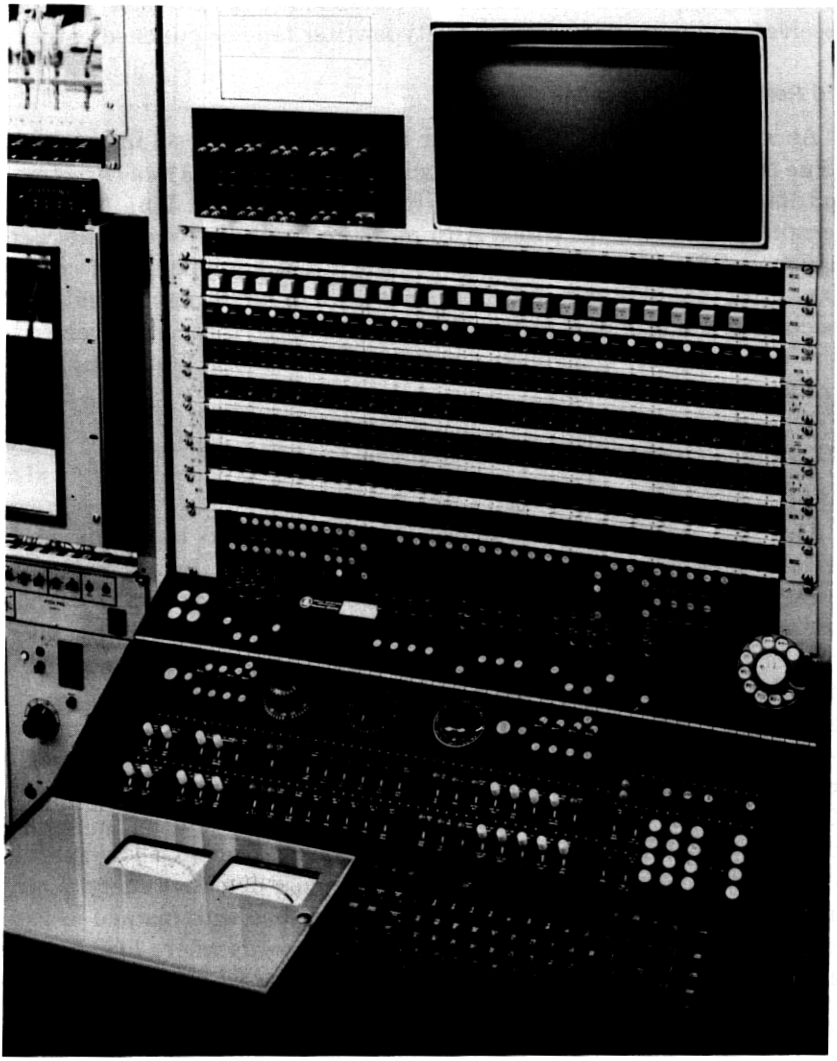

Fig. 1 22A test board.

access trunks was supplied locally as a list of 4-digit numbers that were associated with the circuit designation.

SMAS 1A provided a relief from the demands of a craftsperson to change positions in order to gain access to many circuits (up to 1200), and it eliminated the need for rearrangements caused by jack-ended test boards. It had several features, however, that made it expensive. These features were outgrowths of the (then) present method of

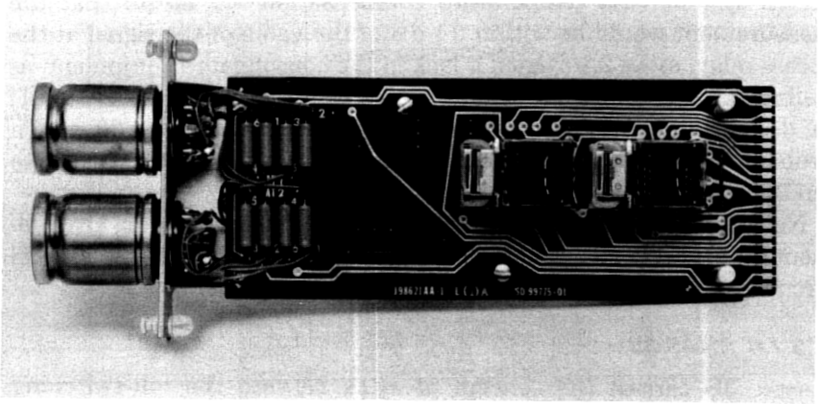

Fig. 2—Voice frequency maintenance connector unit (access relays with level adjust P pads).

operation. The patching feature and the manual access placed a large economic burden on the switch. The patchwork method of providing special services on an elemental* basis caused a larger number of accesses per circiut to become cross-connected on distributing frames.

3.7.3 SMAS 2A

During the same time period, another system for gaining access was being developed, first introduced in March 1968. Called SMAS 2A, it had several major differences from SMAS 1A. It was for limited application (in the No. 1 ESS, 4-wire government network called AUTOVON), and it had access at a specific interface, namely the VF patch jack. SMAS 2A is notable for several reasons. It was the first maintenance access system that built access into the circuit as part of an engineered bay. The concept of consolidating equipment into a manufactured unit, with the elemental pieces of the circuit wired together rather than being separate and wired at the distributing frame, was novel for this application.[8] The access relay for the 6-wire circuit (four transmission leads, plus E&M signaling leads), was incorporated on a plug-in unit with level adjustment resistors (P pads). See Fig. 2. These relays were in turn wired to E signaling units in the same frame. This eliminated four distributing frame appearances per circuit, and the associated administration and installation costs.

Another concept introduced with SMAS 2A was in constructing the

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* The word "elemental" used here means that each equipment unit performed a single function, such as amplification or equalization, and all were individually connected together at the distributing frames, providing the necessary circuit configuration.

access system with temperature compensation* to insure that the measurement would be within 0.1 dB of the value of the signal at the access relay. SMAS 2A carried a jack in the consolidated equipment, as well as the access relay. The access concentrator was therefore simple in design, and it had an ultimate blocking of 1 out of 30 and a probability of blocking of about 0.05. It could handle 4500 circuits to ten 21A test boards.

Neither SMAS 1A or SMAS 2A contemplated a remote testing arrangement, but merely struggled with the problem of test access at several circuit points from one local test position.

3.7.4 SMAS 3B

SMAS 3B carried the concept of SMAS 2A into the toll-switching environment of large offices. It consists of a relay-logic, common-controlled, four-stage concentrator. Up to 250 maintenance lines (to test boards) can be connected through a concentrator network to 6-wire access relays on a maximum of 120,000 circuits. This system is built out to provide temperature-compensated links less than ± 0.1 dB from the access relay to the test board. Access is distributed throughout the office in consolidated bays, or in the facility terminals where the channel bank of the facility is included in the manufactured circuit entity. SMAS 3B did not require a specific test board; instead, a maintenance panel was made which fit into several different, existing boards (such as the 17C VF test board or the Integrated Manual Test Frame). The first service of SMAS 3B in a consolidated terminal environment was in Sherman Oaks, California, in April 1970.

SMAS 3B was an important part of the installation and maintenance of the last 4A electromechanical toll offices, installed with Dial Up Integrated Testing (DUIT).[9] SMAS 3B was also used in several offices for accessing special-service circuits. Although it was not specifically developed to provide remote testing capabilities, the address mechanism of SMAS 3B via MF pulsing was provided because of the expectation by its designers that remote testing would one day follow.

Since the basic interface of SMAS 3B for access was at the voice input to a carrier facility, the equipment containing the access relay to the circuit was constructed in digroup modules (i.e., one having 24 circuits). The Maintenance Connector, shown in Fig. 3, was designed to be wired into manufactured equipment frames, called Analog (AFT), Metallic (MFT), or Digital (DFT) Facility Terminals. These frames allowed for the provision of special service circuits terminating on these facility terminals, to be accomplished by selecting a plug-in unit, rather than

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* This feature became unnecessary with the universal application of temperature control in central offices.

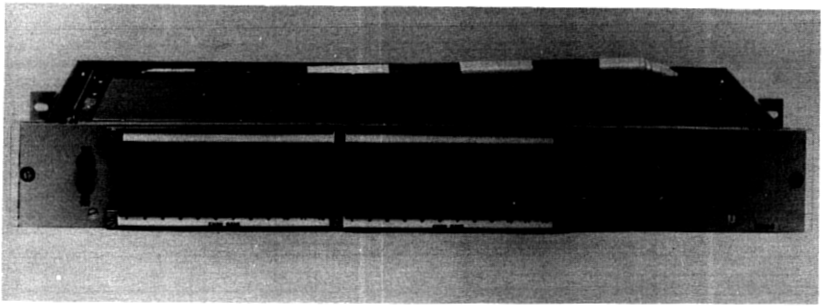

Fig. 3—Maintenance Connector for 24 6-wire circuits.

by interconnecting many units on a distributing frame. This concept, which included the access via the Maintenance Connector, decreased the engineering, administration, and installation costs of special-service circuits. The Maintenance Connector is the basic building block for the Switched Access Remote Test System (initially called SARTS 1A).

IV. CENTRALIZED REMOTE, SPECIAL-SERVICES MAINTENANCE

4.1 Circuit layout record

The problem of testing special-service circuits is one of obtaining access to the circuit at the correct point. Further, it is critical to bring these access points, at low loss, to a test location having the proper equipment and communication links. Even though remote testing was introduced in the loop plant as far back as 1965, since access was available through the central office switch, remote testing in the private line environment was dependent on a total commitment to an autonomous access network—a commitment which the economics of the design made difficult. In addition, this network had to be engineered and documented as part of the Circuit Layout Record (CLR) card, an institution which was not easily altered. Up to this time, access points were locally engineered, and all records or lists of them were kept within the office. Access point definitions are shown in Fig. 4, and it can be seen that they represent a formidable entry on the CLR.

4.2 Special-service centers

In addition to the problem of establishing the access network and recording the access points, a conceptual hierarchy had to be developed for the installation and maintenance of special-service circuits. The Serving Test Center (STC) was incapable of coping with the remote test environment, since it was wire-center oriented. A new entity had to be conceived as the near end of a remote testing system. It was

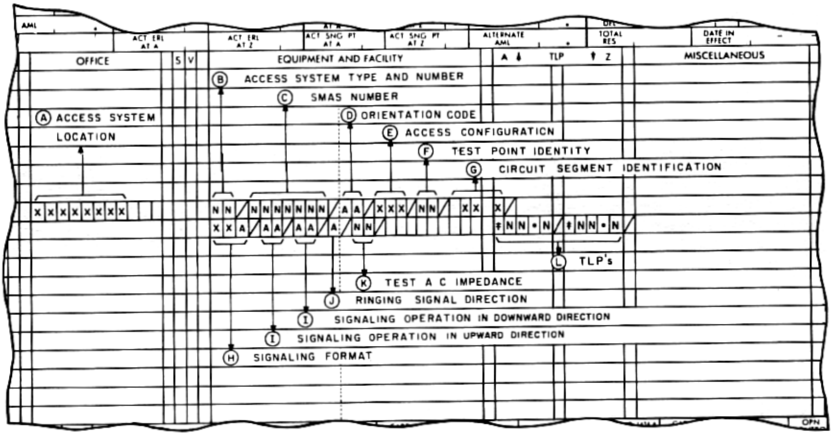

Fig. 4—Circuit layout record entry format.

called the Special Service Center (SSC).[10] SARTS became the operational testing tool for the SSC.

4.3 *Circuit maintenance system*

It was originally realized that an administrative system would have to be constructed beyond the manual methods available if the SSC was to control a large population of circuits over a wide area of special-service users. Thus an operating support system, called the Circuit Maintenance System (CMS),[11] came into development. The SSC would be connected to a Trunks Integrated Record Keeping System (TIRKS)[12] for provisioning purposes, and it would have interconnections with other centers, according to an overall Bell System operating plan. The hierarchical structure of this system is shown in Fig. 5, with administrative links shown for illustration.

V. SARTS DESIGN

The temptation in designing a remote-test system is to apply the test-board or test-position philosophy that has long existed in the central office environment—a limiting philosophy. Keys, lamps, buttons, and levers are restricting because of plans for future growth. The local environment can also handle a large degree of error in test planning. With the old philosophy in the local environment, if a test or a circuit condition is not considered in the original design, either through oversight or lack of planning, it is possible to add portable equipment by means of plug-in test-board jacks which expand the facilities to provide auxiliary functions. With remote-test systems, this escape hatch is not available.

The design and development of SARTS, however, approached the remote environment from an entirely different point of view. A new concept of an interface between the craftspeople performing a test and the remote circuit under test was evolved.[13] This interface on the one hand, and the SMAS access system on the other, shaped the Remote Test System (RTS)[14] design, that piece of equipment which serves as the automaton at the remote site for performing the remote tests.

5.1 SARTS 1A

The centralized location of a remote testing system where the tester resides is called the "near end." The remote offices under craftspeople control from this site are designated "far ends." In SARTS 1A, near ends are SSCs. Each SSC is supported by a minicomputer, the PC 1A, which can control up to 50 far ends in that local area. The PC 1A can be configured in a backup mode to serve as an "alternate" to a failed PC 1A in another area. The PC 1A can also communicate with a "foreign" PC 1A to reach far ends outside its immediate vicinity.

5.2 52A test position

SARTS 1A near-end equipment consists of the 52A test position and the PC 1A computer. The 52A test position (Fig. 6) consists of a desk with a Teletype *Dataspeed*® 40/4 Keyboard Display (KD), and a communication console called a 126A6 Telephone Console. In essence, this 52A test position is SARTS to the tester. The design of the position

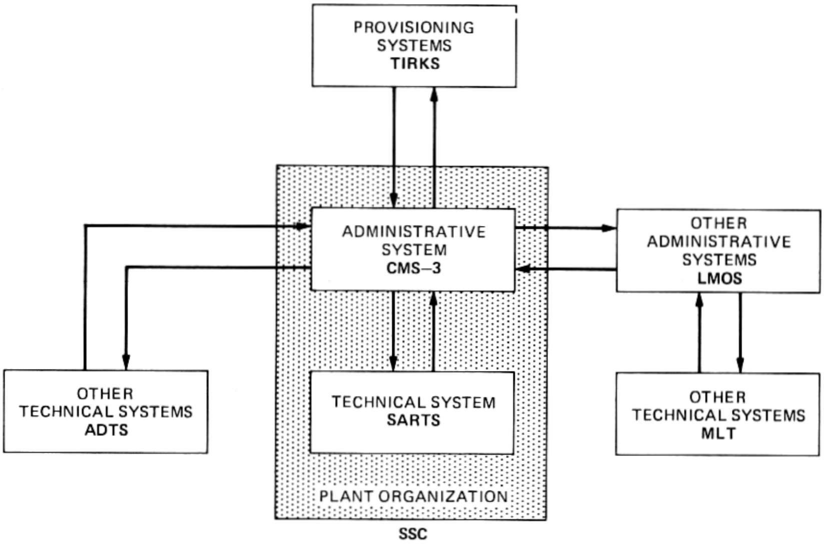

Fig. 5—Special Service Center hierarchy.

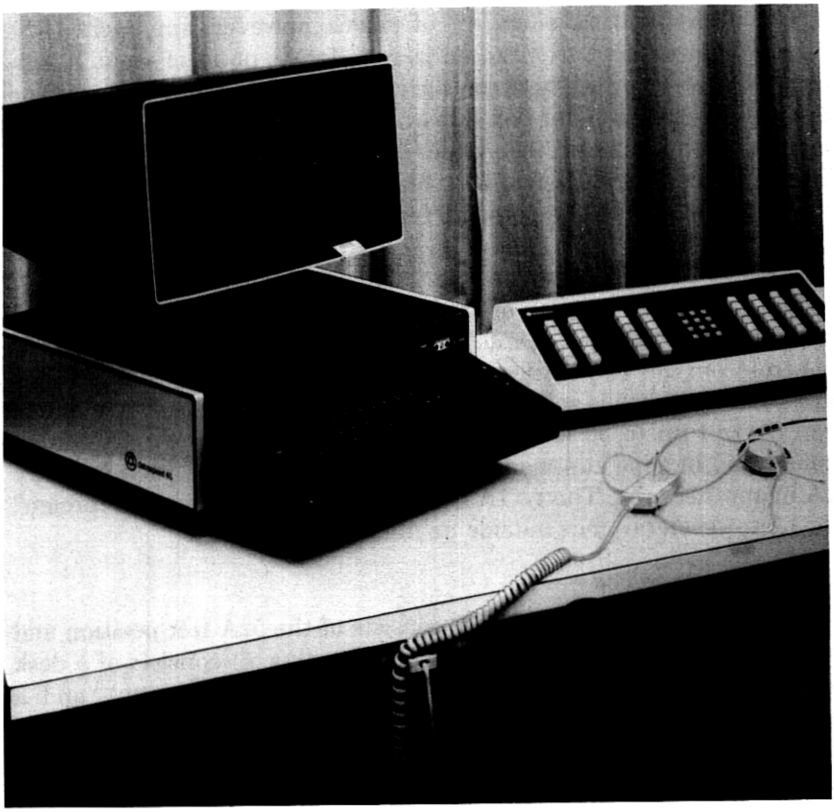

Fig. 6—SARTS 52A test position.

and the environment which contains it determine the productivity of the craft. The position represented an intricate human-machine design problem, reaching into the software itself. The problem of making tests seem real to the craft, even though they were remote and automated, was solved by making the display similar to the actual configuration of the test being performed. As described in Ref. 13, the instruction set for the tester is contained in menus readily called up and displayed and presented in a form easy to learn which lends itself to simplification as the craftspeople gain experience using it.

The control of the displays is contained in application programs and display modules contained in the Process Controller 1A (PC 1A). Additional test capabilities, system features, or differing services which demand different test sequences, are accommodated in PC 1A software, displays, and prompters, designed without requiring fundamental changes in the 52A test position.

The 52A test position provides for two simultaneous accesses by the tester. The nature of special-services installation and maintenance testing requires access at one location in coordination with an access at a second location. In the past, this has always required two people. SARTS, however, enables a craftsperson to access two locations on the circuit at the same time. For example, a person can introduce a tone at a California access point and measure it when it arrives at New York—all from a SARTS location in St. Louis. A less dramatic, but more usual, example is when a craftsperson measures loss across some suspected facility or equipment within the immediate area. Intercommunications over wide areas and the security problems associated with them are important considerations, and SARTS has provisions which assure confidentiality of testing (described in Section 5.7).

5.2 Communication

The next most important function (after the testing capability) which the 52A test position provides to the craftspeople is communication with the circuit under test, or with someone in the vicinity of that circuit. In today's environment of multiple and massive installations, it may be considered by some to be the most important. The 126A6 Telephone Console provides two 4-wire communication links so that the tester can verify the circuits. The craftspeople can listen or talk on the circuit being tested, and the command structure of the PC 1A insures that if contact is to be made to the customer via a ringing command, the tester is prompted on the screen to provide a talking path over this console. In addition, DDD telephone communication is provided, and up to 28 lines can be used for coordination and administration from the test position. The console can be equipped with *Touch-Tone*® or rotary dial.

5.4 Process controller PC 1A

SARTS is managed from the near end by the PC 1A. In addition to its interface to the 52A Test Position, the PC 1A provides for an asynchronous private line or DDD links to the far ends or to other PC 1As. It also provides all application codes for controlling and interpreting the RTSs, and it assigns and keeps track of the RTS ports and test equipment replications being implemented when communicating tests to a far end.

PC 1A is a Digital Equipment Corporation PDP 11/34 minicomputer. The program for SARTS is contained in 128K of core and in an RK05 disk cartridge. RK05 disks are also provided for storage of access-point assignments against circuit identification, if the feature is desired. It is expected that a Circuit Maintenance System 3A (CMS 3A) will provide this function in the future, and this storage would therefore only be temporary. The system program is characterized as to its individual area by terminal and printer assignments and communication directory assignments. Various means are used to enter this information into the system, including altering it from the SARTS Maintenance Position (SMP), if necessary.

5.5 Sizing SARTS installations

SARTS was sized to provide installation and maintenance testing in an area having about 50,000 circuits, and with a maximum of about 50 local RTS locations. With the degree of automation in the system, this projects to approximately 2000 to 3000 circuits per tester, established with 24 near-end 52A test positions. The Teletype C400/4 clustering arrangement allows for 24 terminals to be arranged from a Station Cluster Controller (SCC) through six Device Cluster Controllers (DCC). Each DCC can be provided with up to two printers, if permanent test records are required. The recommended deployment of terminals is to add an additional SCC and split the assignment of terminals and DCCs. This allows active monitoring of both SCCs and, in the event of failure, all terminals can be switched to the operating unit while the failed unit is being repaired.

If a test site is required that is remote from the PC 1A, the SCC is connected through synchronous 4800 b/s data channel modems. The PC 1A is designed with a maximum of four synchronous links for KD terminal access. When a PC 1A fails, another PC 1A can be configured for alternate back-up use. The maximum number of separated test sites that can be supported by terminal back-up is therefore two, one local and one remote or local. The local requirement is necessary since at least one 52A test position has to be collocated with the PC 1A as a SARTS maintenance position, for initializing the system, assigning printers, and preparing the communication directories.

The capacities of the PC 1A were established based on a limited environment, or a limited time in an open environment, before a records and administration system would become available. It can handle 24 testers at one time, although in the back-up mode forty-eight 52A test positions can be assigned. In this mode, the system gives service to the first 24 people who log on, which means that log-off is necessary to share the testing over 48 positions. The PC 1A can handle a local RTS deployment of up to 50 and another 50 RTSs for alternate. In addition, it can handle 250 alien RTSs, and 25 alien PC 1As, in any combination, as long as no more than 50 RTSs are assigned to any one PC 1A. A PC-to-PC link, once established, can accommodate up to 10 accesses at a time, which can be in either direction or in mixed directions, so that other testers can utilize the same link in either direction. Asynchronous 1200 b/s links to PCs and RTSs from the PC 1A are limited to 48 links. Four of these can be equipped with Automatic Calling Units (ACUs) for outgoing DDD calls. The remainder can be assigned as private lines to RTSs or to PC 1As, or as incoming DDD lines in any combination up to the indicated limit.

5.6 SARTS maintenance position

The SMP is important to the system outside of its use in establishing the directories. It is an expanded 52A test position from which diagnostic strings can be run to check and isolate near-end and far-end equipment faults. Any or all 52A test positions could be given this capability on initialization from the minicomputer DECwriter. More than one SMP may be desirable during an equipment acceptance period when new far-end equipment is turning up.

5.7 Security

The security of the 1200 b/s data link to the far-end RTS is assured by a call-back process. Each RTS in a local area has the number of its primary PC 1A, and its alternate back-up PC 1A, stored in it. When an RTS is accessed via a DDD call by a PC 1A, the PC 1A identifies itself as being primary or alternate. The RTS then drops the call and calls the appropriate PC 1A, using its stored number. Each 52A test position associated with a PC 1A has talk-and-listen communication line numbers, and they are stored so that they can be sent to the far end which is being accessed by a tester for the purposes of dial-back to the position. This is never done until the PC 1A-to-RTS data link is secure. The local area far-end RTS's directory is provided in the PC 1A floppy disk. This information may be stored as a private line when high testing activity is expected, or as a DDD number where only occasional access is needed.

5.8 Identifying a remote test system

The RTSs are identified in the PC 1A directory by a Common Language Location (CLLI) code which is assigned to every Bell System location in the country. To take care of a second RTS in the same entity, an additional number is assigned along with the type RTS, and is also carried on the CLR card.

In addition to the local directory of RTSs, a PC 1A can also carry the directory of RTSs for the local area for which it may become the alternate. It would also carry the 52A test position assignments and the telephone numbers associated with those positions, for operating in the back-up mode. The alternate directories are fed in using a diskette from the alternate site.

5.9 Inter-PC communication

SARTS testers can communicate from one local area of far ends associated and controlled by their PC 1A to another area controlled by a different PC 1A, by either private line or DDD PC-to-PC communication links. The directories associated with this feature require the agreement of both areas. A tester in one area cannot clandestinely enter into the area controlled by another PC 1A. The home PC 1A has a telephone directory of foreign PC 1As associated with CLLI codes of offices where access is required. When a tester enters a CLLI code of an office not within the home PC's local area, the PC 1A will scan to find the foreign PC it is associated with, and make a call to set up a 1200 b/s data link to that PC. The home PC will give its CLLI code identification to the foreign PC. The alien PC will then drop the call and search its directory of authorized PC 1As. The CLLI code of the PC 1A is stored with the original home PC 1A's telephone number, which the foreign will call back to set up the secure DDD 1200 b/s data link for testing. In this way, authorized testers can test their circuits end to end without local help from other areas. Implications of priority are important in large-scale deployment, and means for providing a pecking order are being considered.

5.10 History log

In addition to the application code and management of the far ends and of the directory and diagnostics, the PC 1A holds a log of the tester's last 21 lines of commands. This allows review of the history of activity at a position for supervisory help in the event of a difficult problem. This log can be printed every 21 lines if a full paper record is desired.

VI. PRESENT-DAY OPERATING SARTS

6.1 SARTS configurations in the field

The far ends of most currently operating SARTS systems are made up of the Switched Maintenance Access Systems (SMAS) 4A, 5A, or 5B. They use the Remote Test System (RTS) 1A or 5A. The initial SARTS 1A components (using SMAS 4A and RTS 1A) were 8008 Intel-microprocessor-based. Early in 1978 it became clear that the additional processing power available, derived from the Intel 8080 CPU used in the RTS 5A, made the continuation of growth enhancements in the RTS 1A and the SMAS 4A controller uneconomical. The current SARTS generic applies to SMAS 5A or 5B and RTS 5A, and it contains many new testing features.

6.2 SMAS 5B concentrator

SMAS 5B is the access system used for SARTS 1A in the most general case. It uses a concentrator aimed at the least-cost access method for distributing-frame applications. It is useful for backfilling access into circuits made up of circuit elements that are cross-connected through distributing frames. Using this concentrator, it is possible to provide up to 40,000 4- or 6-wire access points. The concentrator is a 2-stage switch made up of crossbar switches and large wire-spring relays.

A 1X100-12 crosspoint crossbar switch makes the actual connection to the circuit. This indicates that designed into the system is an ultimate access of 1 out of 100, or 99 blocked circuit accesses when one access is made in a connector group. Since each 4-wire access point can be used as two 2-wire access points, the blockage is increased to 199 to 1 in 2-wire access points. Care must therefore be exercised when growing access points on circuits, so that all work operations made in any short period do not end up using the same 100-to-1 connector group preventing the job from being accomplished due to blocking. In high-access situations, for example, those in which the SMAS access is to be made over a "no-test" switch connection, a connector group would be dominated, and blocking would be intolerable to the other 99 access points. In these cases, a reduced equipment package made up of a few wire-spring relays provides a 1-to-1 connector. Since no connection can be made to the 99 other access points in that number group, this is called a "phantom connector." The switch connectors are piled up in groups of 10 behind a group connector. Forty group connectors are then connected to 20 maintenance lines back to the ports. Up to 20 simultaneous accesses can be made to the 40,000 possible points of access. These accesses can be to local ports or to remote ports via the RTS, depending on the equippage of a given office.

6.3 Development of SMAS concentrators

Unlike the SMAS 4A, the SMAS 5A concentrator is still a valid standalone system and not solely a part of SMAS 5B. The ultimate blocking is in the maintenance connector, which is 1-to-24 4-wire or 6-wire accesses. As in SMAS 4A, the 4-wire accesses in SMAS 5 can be used as two individual 2-wire access points (having an access capability of 1 out of 48).

Although the maintenance connectors can be stacked together in equipment bays and applied to provide access at the distributing frame, the basic deployment advantage is in their deployment throughout the office in the growth of facility terminals. Five Maintenance Connectors (MC) are stacked behind a Distributing Network (DN). The DN provides for two maintenance lines to five MCs (two lines to 120 four-wire accesses). The maintenance lines of two DNs are paralleled on the Stage 1 DN, which gives an access concentration of two lines out of 240 four-wire access points. Stage 1 DNs are arranged in quadrants to provide a 9600-to-20 maintenance line concentration. Four sets of quadrants can be used to make a capacity of 38,400 four-wire or

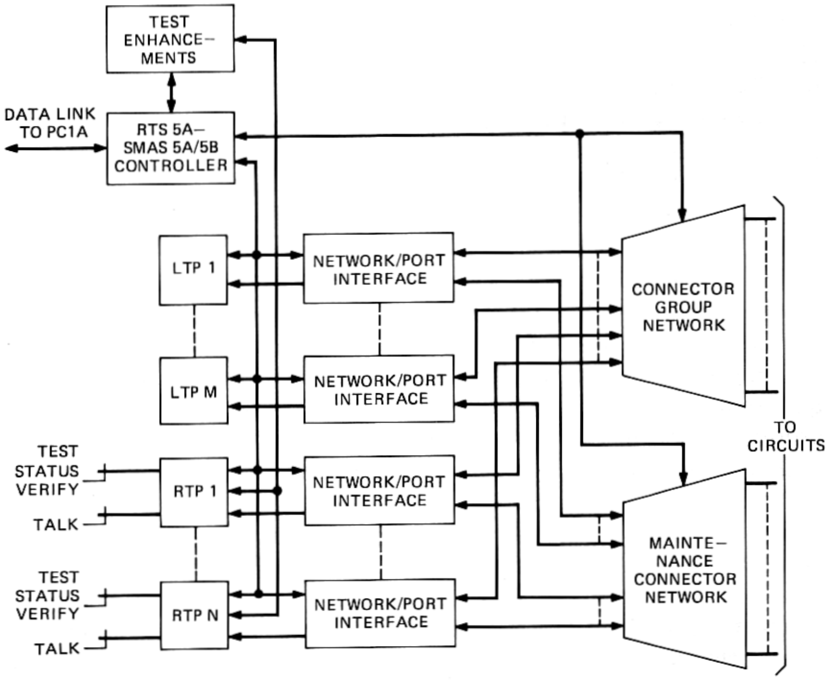

Fig. 7—SMAS 5B architecture.

6-wire access points. The total SMAS 5B could theoretically access 78,400 (40,000 plus 38,400) 4-wire or 6-wire access points, or twice that number of 2-wire accesses.

Since the common-control costs are a small part of the cost of access points in these sizes, an arbitrary limit, consistent with the 20 ports available, was set at 78,400 equivalent 2-wire access points. This does not include phantom connectors, also available in SMAS 5. Figure 7 shows the architecture of the SMAS 5B. It indicates how the separate systems come together at the port interface panel, which sorts out the leads (SMAS 4A and SMAS 5A).

6.4 Full split or bridge connections

Both concentrators are capable of full split and test in both directions of 2-wire and 4-wire access points. In the MC, the initial monitor access leaves the continuity of the circuit in the MC and provides a high impedance protection for hitless initial access. In the crossbar access, the continuity at initial access is in the port interface. Even with a 365-foot limitation, therefore, some services should not be applied if hitless operation is desired. The 6-wire access in SMAS 5B is not full splitting access, but it is characterized as a "fire-ax split" on the transmission leads. This is because the concentrator brings only eight active leads from either 6-wire or 4-wire access points. In a 4-wire access, the eight leads provide the contacts that accomplish the full split (i.e., eight leads: T, R/T, R; T1, R1/T1, R1) access. In a 6-wire access, the transmission leads are only accessed toward the drop, or the line when split (i.e., eight leads drop T, R/-; T1, R1/-; EL/ED ML/MD or line -/T, R; -/T1, R1; EL/ED; ML/MD). Access in the 6-wire system is generally confined to an office interface, and the "fire-ax split" provides all the functions required.

6.5 Local interface for SMAS

A jack key and lamp panel is the local interface for SMAS 5B, replacing the local test ports of previous SMAS systems. See Fig. 8. SMAS 5B provides for measurement accuracy by measuring the resistance to the access point on a loopback each time that an access is made and by compensating ac measurements. This allows for MCs to be placed throughout the wire center on a "distributed" concentrator basis, thus minimizing office wiring. The jack key and lamp panel is the local interface to SMAS 5B. It terminates two maintenance lines and provides two ports for the tester. The tester uses a common-access module on the panel to allow for a thumb-wheel setting of an access point on a bid basis. The second access point is obtained by selecting a new one on the thumb wheel and bidding again. Local access is not encouraged in the SARTS environment, but this panel is useful for repair or on-site installation, allowing craftspeople to check all work prior to turning the circuit back to the SSC. This panel does not provide test equipment; portable "T-cart" equipment must be used on a common basis in the aisle of the installation.

VII REMOTE TEST SYSTEM

7.1 Port control

The on-site conditioning and testing of an accessed circuit is performed by the Remote Test System, RTS 5A in the latest generic,

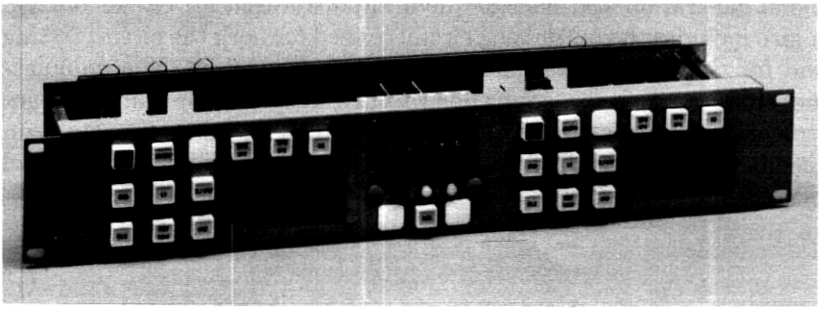

Fig. 8—SMAS 5B jack key and lamp panel.

under control of the PC 1A. It returns the test results and the conditions of testing via this processor to the 52A test position. The RTS 5A is structured as a multi-tasking microcomputer, capable of performing long-term functions interrupted by short-term requests. Every RTS is capable of providing up to 20 ports (or 18 if a local panel is used). Ports are assigned by the PC 1A to the tester requesting access from information supplied by the RTS on its initial access. A port is dedicated to a tester and to an access point for the duration of the access. Testing into the far end is therefore port-limited. Analysis has shown that 40,000 4-wire access points are adequately served by 10 ports in a fully SMAS-deployed remote test environment.

Ports do not contain the test equipment, but they do contain adjustable gain and loss elements, as well as ac impedance matching and dc configuration and control for supervision and signaling. The port also provides for configuration on a wire-by-wire basis, depending on the PC 1A requests. Ports also provide the communication hybrid, and the gain adjustments for the DDD communication links back to the 52A test position. The ports are serviced by the RTS 5A controller, to provide for short-term tests with common equipment in the configuration for making the desired tests. Table II shows the base-line port configuration and the common tests available without the enhancement packages. The base-line port consists of 21 plug-in cards 6 inches high; they are contained in 10 inches of frame depth in the 2-ft, 2-in.-wide frames. Two of these sets of plug-in packages are housed in an 18-in.-high nest and allow growth space for future port enhancements. In addition to the short-term bus to the controller for base-line tests, a long-term bus connection is provided for enhancements requiring longer time commitment of pooled tests (such as impulse noise) and interface enhancements (such as zero-loss test trunks) that can be replicated to serve the functions of specific services.

The RTS 5A controller is a microprocessor-based unit which provides the intelligence for all SMAS 5B/RTS 5A operations. It includes the signal generation and measurement circuitry used for circuit testing. It also includes the outpulsing circuitry used for both the circuit testing and for the dial-up near-end/far-end interconnection. The enhancement bus extends the controller through addresses and into the enhancement package where the programmed multitasking CPU can accommodate the additional functions, performing timing and control as needed.*

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* Several papers are scheduled for later publication which describe the innovative design of the RTS 5A in detail.

Table II—Base-line SARTS-1A remote testing capabilities

Monitor	2-wire, 4-wire, and signal leads in split or nonsplit mode
Send	404, 1004, 2600, 2713, 2804 and at a level from +10 to −39 dBm in 1-dB steps
Measure	Noise 0–60 dBrn ± 1 dB with 3-KHz flat, C notch program or 15-kHz at 150, 600, 900, or 1200 ohms Level −50 to +10 dBm ± 0.1 dB at 150, 600, 900, and 1200 ohms Frequency 100 to 50,000 Hz ± 1 to ± 10 Hz DC voltage 0 to ± 200 V ± 1% AC voltage 0 to 200 V ± 1%, 20 Hz to 50 KHz DC current 0 to 200 mA ± 1% AC current 0 to ± 200 mA ± 1%, 20 Hz to 50 KHz Resistance 100 to 10 megohm ± 1% Capacitance 0.01 to 20 μf ± 1%
Talk	2-wire or 4-wire with talk level adjustable in 5 dB steps from −40 to +10 dB in a bridged or split mode
Ringing	2-wire and 4-wire simplex, 20 Hz at 86 V with 48 V dc in series along with 20 Hz at 105 V, non-tripable and 2600 Hz at 20 PPS
Dial	MF, *Touch-Tone*® dial or dp with loop start or ground start operation
Termination	Short, open, 732-ohm termination, battery-ground and DX
Reversals	Tip-and-ring reversals on 2-wire and 4-wire along with transmit and receive reversals in 4-wire circuit
Supervision	SX loop, SX battery ground normal and reverse, DX normal M and reverse M
Miscellaneous	test features, e.g., 3-ringer load, longitudinal noise measurements and coded ringing.

7.2 RTS enhancements available

The RTS enhancements have a great potential and versatility. More than one of the same type, for example, may be added, depending on the service needs of any given area. Enhancement modules have wired signatures which enable the RTS 5A controller to look at and identify its equippage. This informs the PC 1A so that it can assign each enhancement to testers, up to the limit of the equipped modules.

The enhancement bus feature provides a means for expanded development of the RTS so that it will adequately serve testing needs for the future of special service testing, including features not yet identified. In the present generic, features are available for most of the necessary data-parameter testing; for Digital Data System (DDS) loop-and-straightaway testing at the DSOA level; and for port connection to a specialized test center over a dedicated private line, or over a compensated DDD connection. The data-parameter tests performed by the controller and equipment in the present enhancement are:

(*i*) Impulse noise measurement.

(*ii*) Peak-to-average ratio (P/AR) measurements.

(*iii*) Nonlinear distortion measurements.

(*iv*) Phase jitter measurements.

(*v*) A frequency synthesizer capable of providing 1- to 160-kHz tones for gain-frequency runs if desired.

The features of the current RTS generic were identified by a SARTS enhancement task force, comprised of representatives from 16 Bell System operating companies. New enhancements, identified by this task force and other current users, will be developed in the future. The plug-in structure of the RTS allows enhancements to be introduced with a minimum of effort, once the decision has been made to introduce a new testing or maintenance function.

VIII. ECONOMIC CONCLUSIONS

The first operational SARTS was installed at San Diego on October 22, 1975 and put into service on February 3, 1976. The second SARTS went into service in New York City shortly thereafter. This installation was used for more efficient installation and maintenance of the special services required for the 1976 Democratic National Convention.[15]

Evaluations were made of these first SARTS installations by AT&T and Bell Laboratories, in conjunction with Pacific Telephone and New York Telephone. These installations became models for the economic evaluations of SARTS.

To compare SARTS with an older, nonautomated system, an area involving four wire centers used a force of craftspeople consisting of 31 installer testers and 22 maintenance testers, making a total of 53 people, prior to SARTS. Two years after its installation, SARTS use allowed the reduction of this number to a total of 23 installers and 11 maintenance testers. An additional force of seven people was also released because 24-hour coverage was not required, except in the centralized test location. Productivity with SARTS is such that the number of circuits tested in the area will be nearly doubled in the future with no additional force requirements.

A Bell System maintenance task force was assembled in the fall of 1977, having as its charter to make recommendations that would reduce overall Bell System maintenance expenses. This task force made many recommendations and identified numerous operation support systems and operation plans for consideration. The SSC/SARTS/CMS 3 combination was strongly recommended as a means for reducing the costs of special services. Implementation teams were formed at AT&T to provide operating companies with the necessary assistance to identify their present costs and savings, using SARTS in an SSC deployment.

The VF access which SMAS provides for special-service circuits is only the first step to per-channel testing. Per-channel access in digital facilities will provide a much more economical alternative for testing certain sets of circuit conditions. In the future, RTSs will operate directly on the bit streams of digital facilities.

IX. FUTURE SPECIAL SERVICE CENTERS

Although the first SARTS was operating in early 1975, the first certified* Special Service Center did not come into being until late 1978, in San Diego. Prior to this installation, remote test sites worked with a variety of methods, consistent with the smallest change in organizational structure and current methods available. AT&T network operations provided a set of methods which exploited the remote testing capabilities of SARTS and provided full responsibility for installation and maintenance in the SSC. In fact, all circuit records are on paper, and administration and communication is conducted by paper flow and telephone conversations.

In the future, the SSC, as shown in Fig. 5, will be equipped with a CMS 3B record-keeping and administration system. CMS 3B will provide for the flow of information and work, from the work center to work centers in and out of the SSC, consistent with the methods developed for the SSC. The circuit record will be available in the system as a *Dataspeed*® 40/4 screen display, totally eliminating the need for paper CLRs. It is the intention, ultimately, to home identical 52A test positions on a CMS 3A minicomputer driving the SARTS PC 1A. This coupling of

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* By AT&T.

SARTS and CMS in the SSC environment clearly provides an opportunity for many future efficiencies.

The information available sufficiently identifies the circuit elements which would allow a CMS program using circuit records and access-point data to direct SARTS testing automatically. In the future, this combined system will monitor and check installation progress, based on due dates in the CMS 3A administration data base. It also will lead to an automatic system for trouble sectionalization. This will occur when SARTS is directed by CMS to test from office to office, and between offices, until an out-of-limit condition is found.

Possibilities exist with the combined SARTS-CMS system for routine verification of circuits at the customer's convenience, similar to CAROT testing. Besides the automation of the SSC, work is progressing on more efficient and less costly methods for obtaining access and making remote tests. Presently, developments are under way to permit direct access to digital channels within digital switches and in digital cross-connects. Preliminary development on a digital remote test port is proceeding, which will allow port testing directly on the digital signal without the necessity for conversion to analog signals.

X. SUMMARY

Remote testing has been a desire of testers of the telephone system since the days when operators listened for clicks indicating that a connection had been made. In rudimentary form, it was part of early radio and carrier systems that included signals for monitoring purposes. Controlled remote-test systems began with the introduction of test desks. They were used in one office to test telephone lines in other central offices within a restricted area over dedicated facilities. Later, dial-up systems to remote test equipment were evolved which enabled testing all telephones by dialing into them through message switches. It was not until private-line systems grew that size became apparent, the complexity of services became difficult to maintain, and special-service testing became critical. SARTS is the culmination of a development to provide a base for nationwide end-to-end remote test capabilities. It has implications for all future remote testing systems which allow automatic one-person testing from centralized locations.

XI. ACKNOWLEDGMENT

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