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Advanced Mobile Phone Service:

The Developmental System

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A developmental AMPS system has been implemented in the urban and suburban areas of Chicago. A Mobile Telecommunications Switching Office at Oak Park, Illinois, controls the ten cell sites used in the system. An Equipment Test, serving approximately 100 mobile users, was initiated in mid-1978. A Service Test, involving approximately 2000 tariffed mobile units, will follow the Equipment Test. This paper describes the developmental system, the activities which were prerequisite to the major system test phases, and the status of the system as of July 1978.

I. INTRODUCTION

In March 1977, the Federal Communications Commission authorized Illinois Bell Telephone (IBT) to construct and operate a developmental AMPS system in the Chicago area. Configured as an AMPS start-up cellular system using large cells and omnidirectional antennas to minimize initial equipment needed, the system was laid out to cover approximately 2100 square miles in the urban and suburban areas of Chicago.

This developmental system has ten cell sites and 136 voice channels controlled by a Mobile Telecommunications Switching Office (MTSO) located at Oak Park, Illinois.

Technical and economic evaluations of the system are being carried out with a two-phase program: an Equipment Test phase, using approximately 100 mobile units assigned to Bell System personnel in the area, began in July 1978; a Service Test phase, with IBT authorized to furnish tariffed mobile service for up to 2500 mobile users, is scheduled to follow the Equipment Test.

Section II of this paper defines the basic objectives of the developmental system.

Section III describes the system that has been implemented, including the cell-site locations and the anticipated coverage area, buildings constructed at nine locations, and a mobile installation and maintenance facility.

Section IV discusses the major activities that were prerequisite to the start of the two evaluation phases. These activities included: the manufacture, installation, and testing of cell-site equipment; the development of various software programs; the construction of buildings to house equipment; the integration of cell sites with the MTSO; and the procurement and installation of mobiles. This section also discusses system test and operation activities.

Section V describes the early preliminary system test and evaluation activity using the MTSO at Oak Park, Illinois, interconnected to experimental cell sites and mobile units in the Oak Park laboratory and in Whippany, New Jersey. Successful tests of basic call processing, using early versions of software designs, have decreased the amount of testing that otherwise would have been necessary as the Chicago system was placed on line.

Section VI describes tools for collecting and processing data from the Chicago system, including the Data Retrieval System (DRS), and the Mobile Telephone Laboratory (MTL) used for radio propagation measurements and system trouble-shooting.

II. DEVELOPMENTAL SYSTEM—PURPOSES AND OBJECTIVES

Most of the principal Bell System objectives for the Chicago AMPS developmental system can be loosely grouped into two categories that relate to the system's two phases of test and evaluation:

(*i*) Equipment Test objectives
(*ii*) Service Test objectives.

2.1 Equipment Test objectives:

(*i*) Complete all system shakedown and debugging activities necessary to assure a high-quality, reliable system during the Service Test period and in subsequent service.
(*ii*) Test prototype designs of Bell System-supplied components and confirm the suitability of non-Bell System manufacturers' mobile units and cell-site radio equipment.
(*iii*) Evaluate the basic engineering procedures used to lay out the system and apply experience gained to improve procedures for future systems.
(*iv*) Verify achievement of objectives for radio serving signal quality, including acceptable location/handoff procedures.
(*v*) Verify acceptability of system recovery procedures, call processing sequences, and the overall signaling plan.

(*vi*) Demonstrate co-channel operation using two of the 10 cells spaced at the appropriate frequency reuse distance for start-up cellular systems.

2.2 Service Test objectives:

(*i*) Verify quality of service anticipated and engineered for the Chicago developmental system, including voice circuit quality, low blocking rates, and overall technical performance.

(*ii*) Confirm viability and worth of AMPS by demonstrating that the public's needs for mobile telephone communications can be met at a satisfactory cost.

(*iii*) Collect data to support market study activities, including verifying various market research and sales prediction procedures currently being used to determine the future market for AMPS.

(*iv*) Collect data for estimating the average traffic generated per mobile and the geographical distribution of mobile traffic.

(*v*) Determine customer reactions and sensitivities to the basic service; mobile installation, operation, and maintenance procedures; and vertical services.

2.3 Overall developmental system objectives

During the overall test of the developmental cellular system, the objective will be to gain experience in:

(*i*) Engineering and implementing an AMPS system.

(*ii*) Selecting cell site locations.

(*iii*) Installing and testing AMPS equipment.

(*iv*) Operating and maintaining an AMPS system.

(*v*) Interacting with mobile customers and equipment radio suppliers.

III. DEVELOPMENTAL SYSTEM DESCRIPTION

The AMPS developmental system in Chicago has been engineered to represent a typical start-up cellular system. Figure 1 shows the anticipated 2100-square-mile coverage area with the locations of the 10 cell sites indicated by crosses and three-letter codes (explained in Table I).

For the start-up AMPS system, cell-site locations were chosen, where possible, to take advantage of existing high-elevation structures for antenna placement, and to minimize site location deviations from the ideal grid. The use of existing structures reduced the initial system cost and the possibility of potential delays caused by zoning problems.

The compromise achieved with this layout required only three new antenna masts to be erected. The remaining seven cell sites have antennas on existing structures. In Fig. 2, the circles represent the

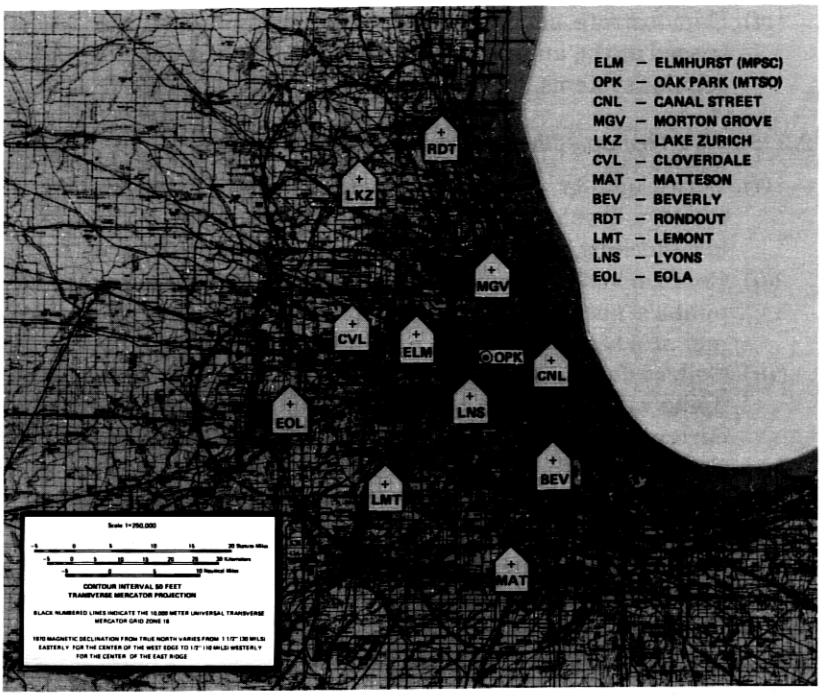

Fig. 1—Chicago service area.

Table I—Developmental system cell-site locations in Illinois and number of duplex voice channels assigned

Cell Site	Voice Channels	Antenna Height (ft)	Address
Beverly (BEV)	16	150	413 W. 105th Street Chicago
Canal Street (CNL)	26	550	10 South Canal Street Chicago
Cloverdale (CVL)	15	325	Schmale Road Cloverdale
Eola (EOL)	8	310	Drehl Road Eola
Lake Zurich (LKZ)	9	285	U.S. Highway 12 Lake Zurich
Lemont (LMT)	8	250	127th Street Lemont
Lyons (LNS)	16	150	8542 W. 44th Street Lyons
Matteson (MAT)	12	260	Vollmer Road Matteson
Morton Grove (MGV)	18	185	Narragansett Street Morton Grove
Rondout (RDT)	8	150	Bradley Road Libertyville Township
	136		

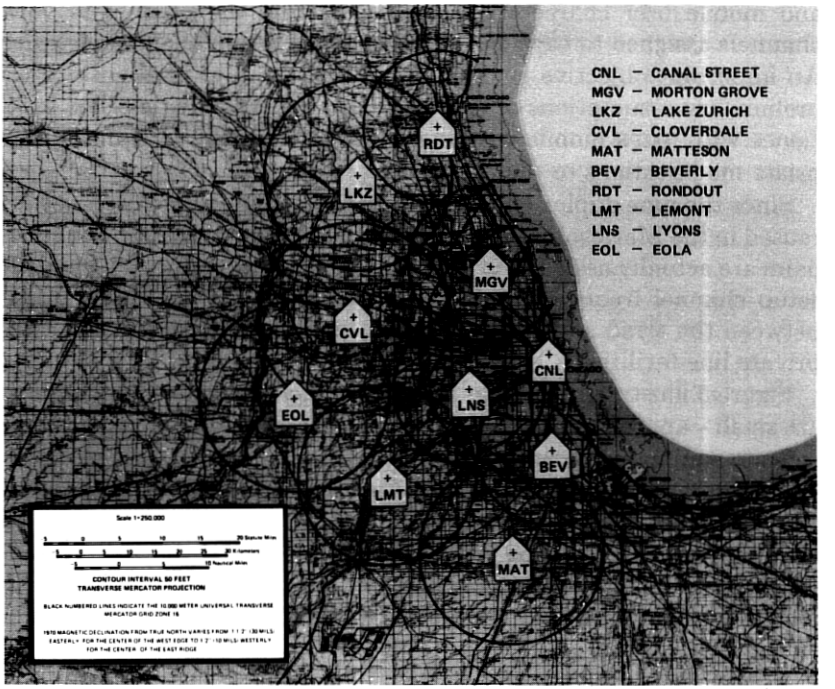

Fig. 2—Idealized coverage areas.

expected coverage area of each cell site. Variations in antenna heights and associated antenna cable losses lead to variations in the size of these circles. The circles represent the estimated ideal "36-dBμ contour"* that results from applying empirically derived 900-MHz path-loss and antenna-height advantage equations to the effective radiated power of each site. The idealized smooth contours will not be realized in practice, since propagation from each cell site will not be uniform in all directions.

For all cell sites except Canal Street, new buildings have been constructed to house cell-site equipment. Since the Canal Street location had available surplus floor space, it was the first to have cell-site equipment installed and made operational. The MTSO location at Oak Park, Ill., is indicated by a small circle in Fig. 1. AMPS software testing was carried out at this location, in addition to control of the developmental system as it came on line.

The system will serve approximately 2000 mobile units during the Service Test with an estimated 2-percent busy-hour blocking proba-

* On this contour, the approximate signal-to-noise ratio averages 18 dB. Studies have shown that this level of signal strength on the cell boundaries will provide the required overall quality of service for AMPS.

bility (based on certain assumptions about mobile traffic distributions and mobile user characteristics). Table I lists the number of voice channels assigned to each cell site using the current engineering rules. An important objective of the Service Test is an evaluation of these preliminary assumptions of traffic and user characteristics. The experience with AMPS mobile customers will serve as the basis for appropriate modifications to the engineering rules.

Since the nine duplex voice channels of the Lake Zurich cell site are reused in the Matteson cell, only 127 different voice channel frequency pairs are actually assigned to the developmental system, along with 10 setup channel frequency pairs. The required voice and data trunks between the MTSO and each of the cell sites is provided using tariffed private line facilities.

Figure 3 illustrates the floor plan of a typical cell site. The buildings are small—approximately 20 by 30 ft of floor space—with room for the cell-site equipment, power supply system, maintenance and test equipment, and maintenance personnel. Except during maintenance activities, the buildings are unattended. Figure 4 is a photograph of the Rondout cell site, showing the cell site building and the 150-ft monopole. Figure 5 shows the Cloverdale cell site, with the building at the foot of the 325-foot AT&T microwave tower and the antennas mounted on top of the tower.

One of the developmental system objectives discussed in the previous section involves determining customer reaction and sensitivity to installation and maintenance procedures. To avoid excessive customer inconvenience, a dedicated installation and repair facility in Elmhurst is being used in the Chicago developmental system. Termed the Mobile Phone Service Center (MPSC), it also serves as the base location for the Mobile Telephone Laboratory (MTL) and for the IBT craft force who maintain the ten cell sites. Spare parts and test equipment for the cell sites are housed at this location, as well as a small data-processing facility for rapid examination of MTL data. Figure 6 shows an external view of this building, while Fig. 7 is a floor plan showing the internal configuration. There are sufficient installation and repair bays at the center to handle the estimated numbers of customers per month during the Service Test. The size of the craft force and the amount of automated test equipment necessary to verify quickly the proper operation of an installed mobile have been determined based on processing Service Test customers efficiently and without undue inconvenience.

IV. MAJOR ACTIVITIES COMPLETED OR UNDER WAY

4.1 Cell-site equipment manufacture

Twelve complete sets of cell site equipment were assembled at the Western Electric factory in Burlington, North Carolina. Two sets of

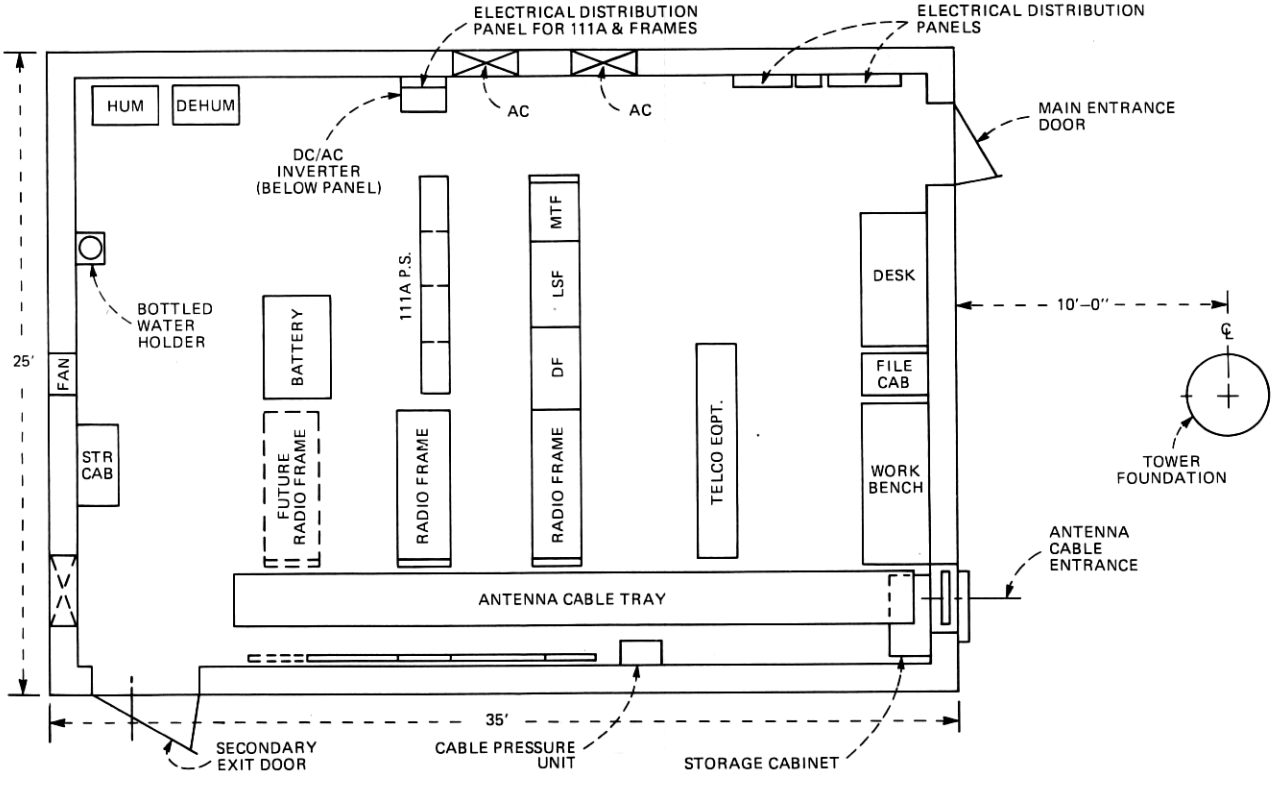

Fig. 3—Cell-site building layout.

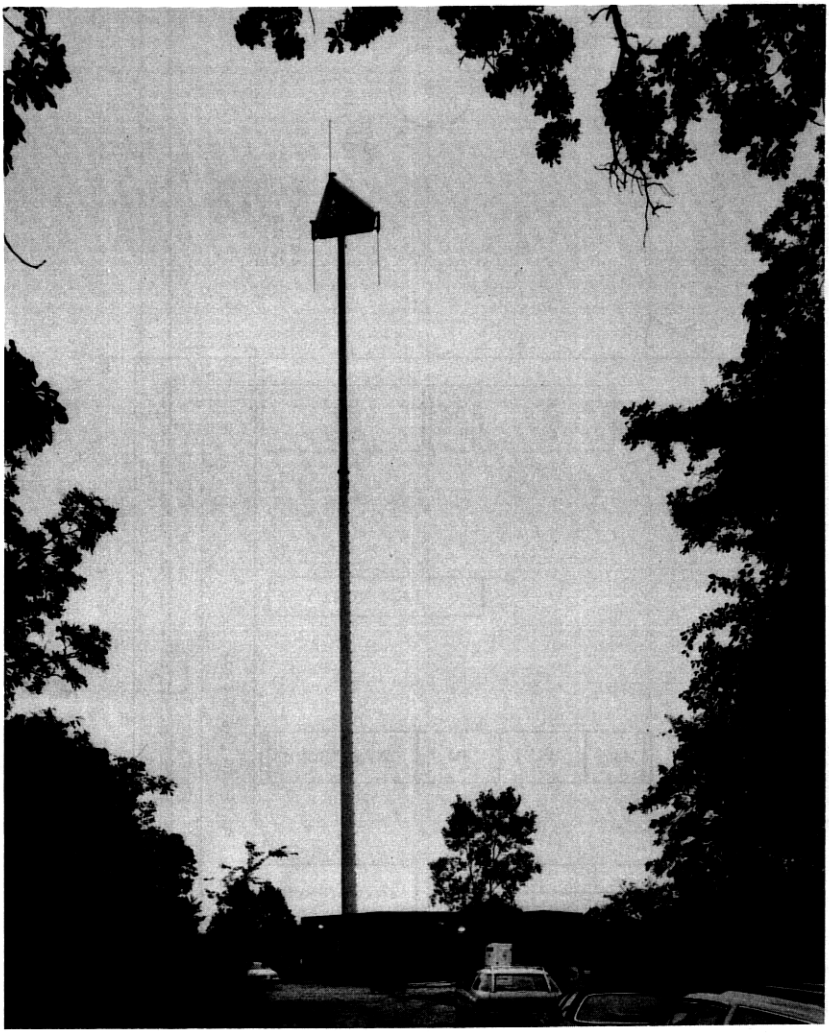

Fig. 4—Rondout cell-site building and mast.

equipment were used for early interface and software debug testing with the No. 1 ESS and mobile unit subsystems; one at the MTSO location at Oak Park, Illinois, and the other at the Bell Laboratories, Whippany, New Jersey, location where the cell site was designed. The remaining 10 sets of cell-site equipment were installed in the developmental system.

All cell sites were thoroughly factory tested before shipment. These tests included computer-driven wiring tests, manual tests, and tests with an HP-21MX minicomputer that thoroughly checked each cell-site

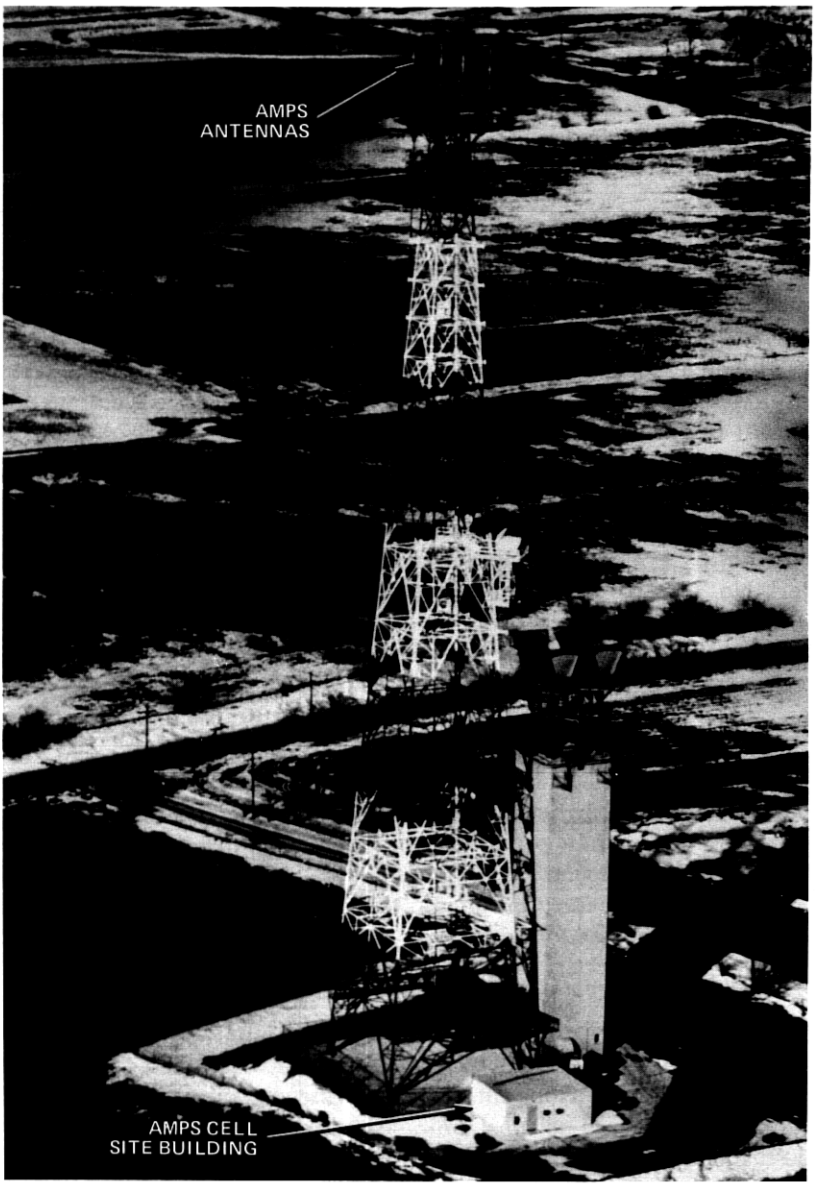

Fig. 5—Cloverdale cell site.

frame on a stand-alone basis. Tests of the interconnected frames ("string tests") included manual adjustments and alignments of each site's radio channels. Special software programs were loaded into the data frame programmable controller (PROCON), which executed and tested all the functional capabilities of the cell-site subsystem.

Fig. 6—The Mobile Phone Service Center in Elmhurst, Illinois.

4.2 Software development

The development of the software to be used in the No. 1 ESS MTSO for AMPS control and maintenance in the Chicago developmental system is basically complete.* As new capabilities were developed, they were incorporated into a new issue of the generic program, which was released for testing and debugging using the No. 1 ESS at the Oak Park laboratory. A cell site and four developmental mobiles, which were not part of the developmental system, were connected to the Oak Park No. 1 ESS to aid in the software testing and debugging effort. As each issue of the generic program stabilized, it was used to control the developmental system cell sites that were operational at the time.

Stored-program software has also been developed for the data terminal equipment, the maintenance and test frame equipment, and the data frame in the cell site.

Stored-program software for the logic unit of the Equipment Test mobiles also has been developed. The necessary capability was released incrementally via new programmable read-only memories installed in the logic units in use.

The three companies producing mobiles for the Service Test have developed the software required by their mobiles' designs.

4.3 Building construction

IBT contracted for the construction of the nine new cell site buildings required for the Chicago trial. All were completed by January 1978, except for the Rondout building, which was delayed because of a zoning problem. The mast foundation at the three sites using the 150-ft monopole mast required additional construction activity.

4.4 Cell-site installation, test, and integration

Installers of the Western Electric-Central Region (WE-CR) installed the 111A power plant and other peripheral hardware required for each

* It is anticipated that minor modifications will be made in the software based on experience gained during the Equipment Test.

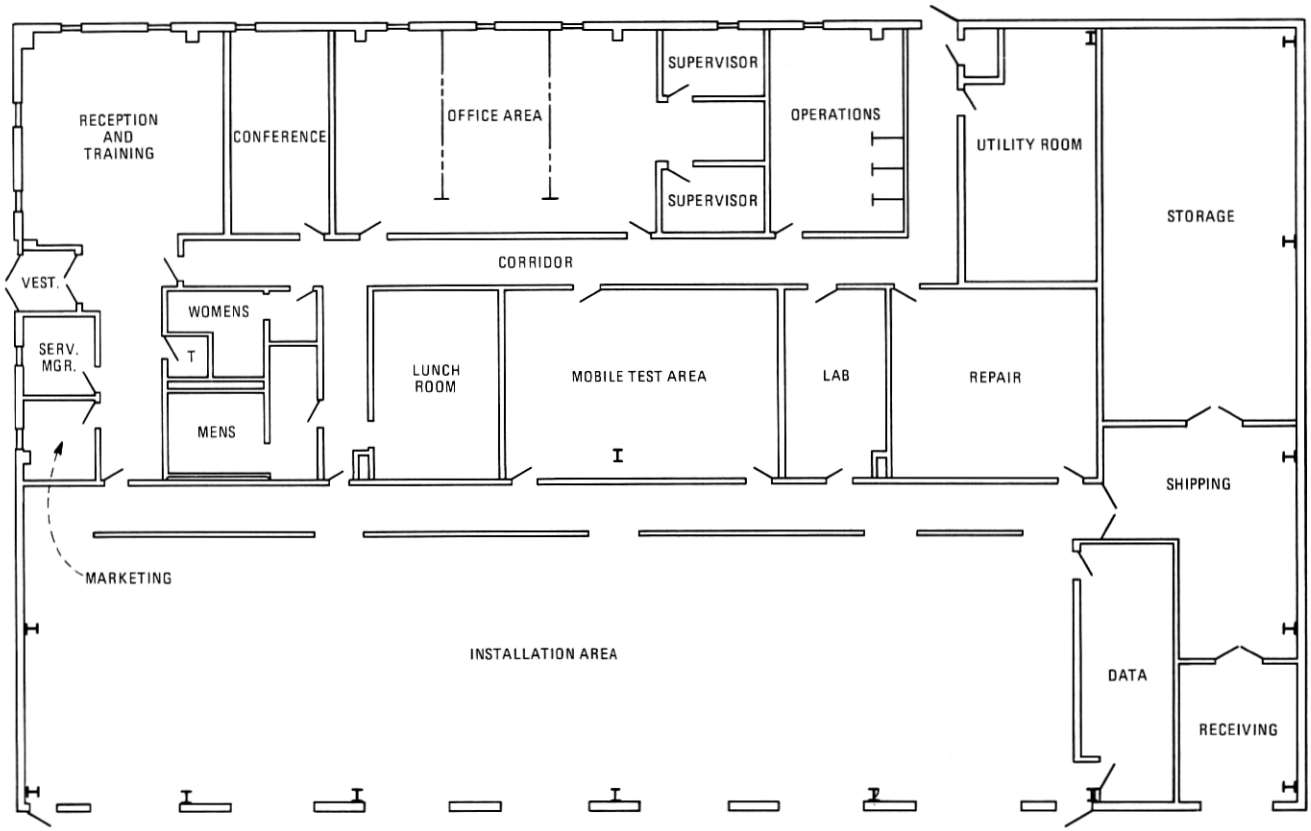

Fig. 7—Floor plan of Mobile Phone Service Center.

cell site, as soon as the building became available. IBT craftspeople installed the electronic equipment at each cell site except Canal Street, where WE-CR personnel did this work. IBT craftspeople, supported by Bell Laboratories and Western Electric-Merrimack Valley (WE-MV) installation engineers, also performed the installation testing of the cell sites using handbooks developed by WE-MV.

Installation test procedures included a large number of manual tests and final adjustments of equipment, followed by a rerun of the string test software programs used initially during factory testing. These tests involved 14 programs, each manually loaded into the data frame PROCON via a paper tape reader and a display, debug, and test (DDT) unit. Errors detected in the cell-site hardware were displayed as specific codes on a printer. Another program generated specific orders to, and received specific replies from, a single mobile unit, which was either the Mobile Telephone Laboratory (MTL) or an instrumented mobile-equipped automobile.

Another class of cell-site test used an HP-21MX minicomputer located at the Oak Park facility and patched into the voice and data trunks connecting the cell site to the MTSO. An autonomous cell-site-to-mobile test program was run, using either the MTL or a specially instrumented mobile-equipped automobile as the mobile. This program required the data frame operational software to be in use in the cell site and thus tested all hardware and software subsystems exclusive of the MTSO. All paging data transmission, voice transmission, supervisory, and fade and disconnect functions that take place between the cell site and mobile were tested.

The next step was to integrate the tested cell site and its operational software with the MTSO and its generic software; with the data terminal equipment and its resident software; and with the data- and voice-trunking facilities between the MTSO and the cell site. The integration commenced with the running of a cell-site initialization program called CLSI, part of the MTSO generic software program. This program initializes the data frame operational program and performs basic functional tests that ensure communication between the MTSO and the cell site. Basic simple call processing tests were then run on each voice channel of the cell site, including land-to-mobile and mobile-to-land calls. Finally, the resident cell-site diagnostic programs within the MTSO were employed to detect failed or suspect hardware and to confirm the system's ability to reconfigure cell site redundant equipment. With no major equipment problems apparent, integration of the cell site with the MTSO was considered complete, and it joined the previously integrated cell sites in participating in system operation and shakedown.

4.5 System test activity

As described in more detail in Section V, preliminary functional testing and debugging began in November 1976, with the No. 1 ESS

interconnected with an experimental cell site and fixed laboratory mobiles, all located in the Oak Park laboratory. Also tested was an experimental cell site at Whippany, New Jersey, controlled by an HP-21MX minicomputer simulating the MTSO control function. The tests at both locations led to the correction of numerous minor design problems that would not otherwise have been discovered until the developmental system testing was well under way.

System test planning was a continuing and evolving activity closely tied to the related activities of collection, processing, and evaluation of data. Planning included identifying required data, generating requirements for specific system tests to obtain the data, defining the data-collection technique, designing specific test plans, converting them to specific operating procedures, and planning the processing and analysis of the data.

System tests planned for the developmental system primarily address the confirmation of overall system performance of a commercially manufactured system, although some evaluation of specific technical functions are also being performed.

Specific tests not requiring the complete system were performed using the earliest available cell sites, while other tests requiring the complete system did not commence until May 1978.

A significant test activity, called partial week service, utilized the MTSO, all integrated cell sites, and all available mobiles operating as a system during weekends commencing in March 1978. This operational activity was very effective in discovering system problems in time for early correction.

Table II contains examples of other system-level tests currently being conducted.

4.6 Mobile procurement and installation activities

Two mobile designs are being used in the developmental system. OKI Electric Industry Company, Ltd., Tokyo, Japan, manufactured 135 mobile transceiver and control units for the Equipment Test phase of the program. In addition, OKI built 135 Bell Laboratories-designed logic units to control the transceivers. Early production models were subjected to exhaustive testing at Bell Laboratories, including environmental tests, and were placed into use in the experimental systems described in Section V. The production units underwent acceptance testing at the Mobile Phone Service Center in Elmhurst, Illinois.

Contracts for developing and producing approximately 2200 mobiles required for the Service Test were placed with OKI; with Motorola, Inc., Schaumburg, Illinois; and with E. F. Johnson, Waseca, Minnesota. These mobiles, to be leased to commercial customers during the Service Test, are manufactured to a specification requiring an integrated transceiver-logic unit and a standard interface between it and the control unit. Extensive testing of early production models of these

Table II—Examples of system-level tests being conducted

Facilities Used	Purpose	Procedures
	Service Area Coverage	
MTL Cell Sites	Evaluate engineering coverage and service quality.	Measure signal strengths at selected locations in the 2100-square-mile system area.
	Voice Channel and Data Channel Signaling	
HP-21 Minicomputer MTL Cell Sites	Validate forward blank and burst functions over the voice channel as tested and evaluated by the CTB. Evaluate data transmission over the forward setup channels.	HP-21 generates continuous stream of data messages from a cell site and MTL mobile measure data word error rates at various geographical locations having different propagation characteristics.
	Test and evaluate data transmission over the mobile-to-cell site reverse voice channel and the reverse setup channel.	Reverse setup channel and reverse voice data channel tests use MTL onboard mobiles to transmit large numbers of data messages to a particular cell site. HP-21 records errors that site encounters.
	Mobile Control Algorithm	
MTSO MTL Cell Sites DRS	Determine the general performance of the location and handoff algorithms and the resulting ability to control mobile operating frequencies to permit an adequate serving signal and to prevent excessive co-channel interference.	MTL makes a record of the serving cell site and serving signal strength for onboard mobiles and the actual mobile geographic locations. DRS records location and handoff events.
	System Reconfiguration	
MTSO Cell Site	Evaluate ability of generic MTSO diagnostic software to isolate and reconfigure any voice/data trunk group or other redundant equipment group within the data terminal equipment or cell sites.	Simulate equipment failure and note performance of MTSO system integrity programs.
	Cell Site Load Test	
MTL MTSO Cell Site Mobiles	Evaluate ability of a cell site to respond to increasing traffic levels.	Computer-driven MTL mobiles plus vehicles equipped with Equipment Test mobiles place heavy traffic through a selected cell site.

mobiles was performed by Bell Laboratories. Delivery of these mobiles to Chicago commenced in November 1978.

A minicomputer-based automatic mobile test set was used for preinstallation testing of the Equipment Test mobiles and the testing of installed units in Bell System personnel's vehicles. Initially used in the mobile test laboratory in Whippany to evaluate early production units,

the test set was moved to the Mobile Phone Service Center described in Section III and used to perform acceptance tests of the Equipment Test mobiles. Operating instruction and maintenance handbooks were prepared for this test set, and IBT craftspeople were trained to operate the unit prior to the installation of the first significant quantities of Equipment Test mobiles. A similar test set was developed for use with the Service Test mobiles.

A Cooperative Mobile Supplier Program permits any qualified manufacturer of an AMPS mobile design to participate in the developmental system test. This program creates the potential for future additional competitive suppliers of commercial Bell System-owned or customer-owned mobiles. At present, eight manufacturers have expressed an interest in participating in this program.

4.7 Developmental system schedule

The fabrication and factory testing of cell-site hardware were complete at the end of 1977. Cell-site building construction was likewise complete by year's end, except for the tenth cell site which required relocation because of a zoning disapproval. Cell-site equipment installations, tests, and integrations with the MTSO were completed by late May 1978, with the exception of the last cell site. System shakedown and debugging started in April 1978 and continued throughout the Equipment Test, from July 1978, to the end of the year. The system tests outlined in an earlier section are under way. The Service Test phase will follow the Equipment Test phase. Software development and mobile procurement activities are on schedules that coincide with the support of the Equipment Test and Service Test phases.

V. EXPERIMENTAL SYSTEMS—TEST AND EVALUATION ACTIVITIES

Reference has been made to experimental systems established at the Oak Park and Whippany laboratories for early testing and debugging of an integration of all AMPS subsystems. Early versions of the MTSO generic software were developed and tested with a No. 1 ESS at Oak Park. The initial tests used a breadboard model of the cell site as the computer peripheral; from November 1976 to June 1978, a production cell site served as the MTSO peripheral. This cell site was connected to fixed nonradiating mobiles through a transmission simulator incorporating a Rayleigh fader. In May 1977, roof-mounted antennas were added at Oak Park to permit live radiation testing to mobile-equipped automobiles operating in the vicinity. A Bell Laboratories experimental FCC license was obtained for this purpose.

A production cell site installed at Whippany was connected to the Oak Park MTSO via leased voice and data trunks in February 1977.

Early system testing and debugging employed a fixed nonradiating mobile in the laboratory, connected to the cell site via a coaxial cable. Roof-mounted antennas were later added to provide a radiating capability, and testing continued under the control of an HP-21 minicomputer simulator of the MTSO, utilizing the Whippany cell site, and a mobile-equipped automobile.

The ability to investigate abnormal system performance caused by a hardware or software design problem at the responsible design location has greatly simplified the logistics of problem investigation and has accelerated problem correction.

The benefits derived from these experimental systems permitted:

(*i*) Ongoing development and early functional integration of the hardware and software subsystems of AMPS.

(*ii*) Development and refinement of procedures and techniques that were required to test and evaluate the developmental system.

(*iii*) Development, validation, and evaluation of installation and test procedures that were used on cell-site and mobile equipment.

(*iv*) Testing and debugging of the MTL system prior to assignment in the developmental system.

(*v*) Early training of technical personnel responsible for operating, maintaining, and testing the developmental system.

(*vi*) Early evaluation of operating, maintenance, and recovery procedures.

(*vii*) Early experience with and refinement of equipment field change procedures, configuration control, and failed unit and spares logistics.

Test activities involving the experimental systems at Oak Park and Whippany diminished as developmental system equipment became more available. The use of these systems has resulted in shorter key activity intervals in the Chicago trial.

VI. DATA COLLECTION AND PROCESSING

6.1 Data collection tools

Three major data collection systems were developed for the Chicago trial: the Data Retrieval System (DRS), the Mobile Telephone Laboratory (MTL), and a telemetry capability in a selectable number of mobile units employed during the Service Test. In addition, a number of less-sophisticated tools were developed, such as specially instrumented mobiles in automobiles. Finally, specific functions of certain test units (such as the HP-21MX minicomputer for autonomous testing and trouble-shooting of cell sites) supply data from the developmental system.

6.1.1 Data Retrieval System

The DRS is a peripheral system that has been added to the No. 1 ESS MTSO to collect data for following the progress of a particular call and the operation of various facets of a given system algorithm, as well as to collect statistical data on many calls. The conversion of recorded DRS data to formats compatible with an HP-21 minicomputer is part of the overall data processing and analysis activity in the developmental system.

6.1.2 Mobile Telephone Laboratory

The second major data collection facility is the Mobile Telephone Laboratory, assigned to the Chicago area on December 1, 1977. The MTL tests and evaluates the system from the mobile's viewpoint and performs system trouble-shooting and system data collection functions. Because AMPS logic is distributed among the MTSO, the cell site's data frame PROCON, and the mobile logic unit, the monitoring and recording of logic activities within the mobile during various stages of a call is necessary to evaluate the performance of the overall system. The MTL performs this task by controlling and monitoring its instrumented on-board mobile units. The MTL is also a calibrated laboratory for measuring signal and noise environments at selected locations in the Chicago coverage area. It also performs testing of cell sites using the on-board minicomputer-controlled mobile units to originate calls automatically with specific time relationships at specific geographical locations.

Figure 8 is a simplified block diagram of the MTL. An onboard HP-21MX minicomputer subsystem controls all major equipment functions. A major subsystem collects signal and noise information from sources within the system using a well-calibrated instrumentation receiver with a wide dynamic range and low noise figure. This measurement receiver is rapidly tuned to the frequencies of interest using an agile local oscillator controlled by the on-board computer. Another subsystem contains four mobile units that can generate traffic under HP minicomputer control, and whose detailed operations can be precisely monitored and recorded for both real-time and off-line analysis.

Test transmitters and receivers on the vehicle provide an autonomous test and calibration capability to ensure that data being collected have not been invalidated by any malfunction of MTL equipment. Finally, a position and timing system permits associating collected data with time, vehicle speed, and vehicle position within the system.

Data-recording peripherals associated with the HP-21MX on-board computer include both magnetic tape and disk equipment and permit real-time on-board data examination using CRT displays, typewriter outputs, and printer outputs.

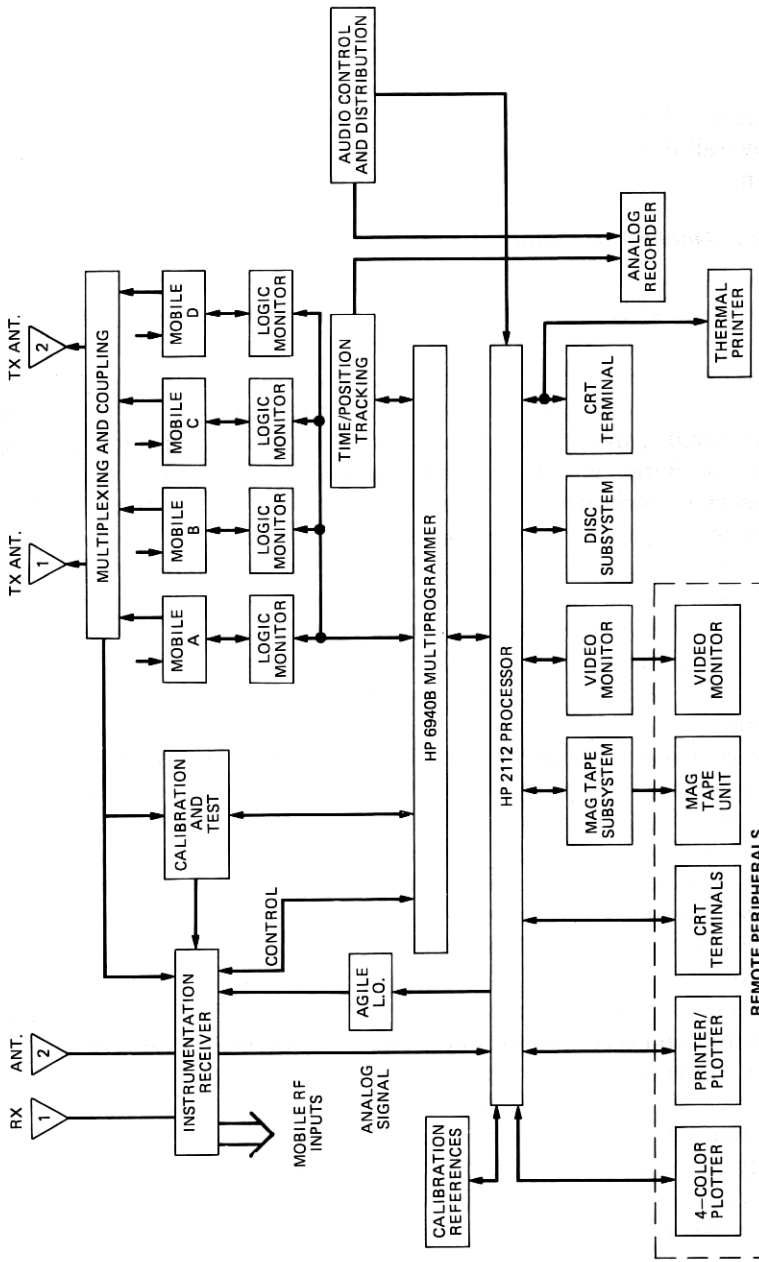

Fig. 8–Mobile Telephone Laboratory—block diagram.

6.1.3 Mobile unit telemetry

Certain data are desired on the performance of the mobile telephone equipment and, in particular, the interaction of the user with the system during the Service Test phase of the developmental system. For this purpose, a significant number of Service Test mobile units are designed to monitor many of their own actions and telemeter basic information about customer usage characteristics to the MTSO.

Control of the telemetry resides in the MTSO, which indicates to the mobiles whether or not telemetry is to be sent and the interval between transmissions. If telemetry is to be sent, the mobile autonomously initiates telemetry requests at the specified intervals. Upon receiving a request, the MTSO orders the mobile via the setup channel to send its accumulated telemetry information over the reverse setup channel. The DRS retrieves all telemetry data for subsequent analysis.

6.2 Mobile monitor and control units

Figure 9 is a photograph of mobile monitor and control units (MCU) housed in the glove compartment of a special test automobile. Each MCU is a unit of special test equipment electrically connected to the transceiver unit and the logic unit of an Equipment Test mobile telephone installed in the test automobile.

The two MCU units have the following features:

(*i*) A continuous display of the channel number to which the mobile transceiver is tuned.

Fig. 9—Mobile monitor and control units.

(*ii*) A continuous indication of the received (integrated) signal strength of the mobile unit.

(*iii*) A provision for switching the mobile unit to a manual operation mode where the mobile is tuned continuously to a channel selected by the vehicle operator. This mode is used for establishing duplex voice communications in preparing for and controlling particular segments of a test involving the vehicle.

(*iv*) A display of the mobile unit transmitter on-off state.

(*v*) A continuous display indicating which of the two receive diversity antennas is being used.

(*vi*) An ability to disconnect the diversity function and to select manually one or the other of the two antennas.

Three such specially equipped test automobiles have been used in the experimental systems at Whippany and at Oak Park and in the Chicago developmental system.

6.3 Data processing plans and facilities

The overall Chicago developmental system data processing program includes the following functional tasks: rapid (quick-look) verification that data were collected as intended; validation that the data truly represent actual system or subsystem performance; manipulation of data to produce outputs for analysis; further manipulation to add certain data to a larger data base; and manipulation of this larger data base to develop results of statistical significance as a function of some parameter, such as time or location.

The requirements for, and the uses of, Chicago developmental system data fall into two separate categories: system troubleshooting and system test and evaluation. System troubleshooting data requirements typically consist of specific test results, such as event listings, plots, and statistics compiled during a particular daily test over a period of time. System test and evaluation activities generally require larger amounts of data, typically collected over longer periods of time and in numerous geographical locations. Although both types of data are needed during the trial period, system troubleshooting is the predominant need for the early time frame, and initial data-processing efforts are concentrated here.

Two data facilities have been assembled for processing data collected in the developmental system. The first of these is a quick-look data-processing facility for MTL data located in the Mobile Phone Service Center building. It consists of additional computer peripherals in a room adjacent to the parked MTL and connected to the MTL computer via umbilical cables. This arrangement permits converting the MTL data collection equipment into a data-processing laboratory to allow preliminary validation of data and decisions on follow-up near-term activities to be based on observed test results. Software programs to

reduce and manipulate data for this quick-look function have been designed.

The other facility with a data-processing capability built around an HP-21MX minicomputer has been developed at Bell Laboratories, Whippany. Data reduction software processes DRS, HP-21MX, and MTL data collected and validated in Chicago. This system has the ability to merge DRS and MTL data for specific analysis tasks.

VII. CONCLUSION

A sophisticated developmental system for testing AMPS has been installed in Chicago. The investment of the Bell System in this trial is substantial in terms of design, development, and test activities completed and anticipated, and in terms of procurement costs for the MTSO, the cell sites, the mobiles, and the land and buildings required by the system. Successful completion of the Equipment Test and Service Test phases will add considerable technical information to the base of knowledge of cellular systems to be used in establishing standards for the service, as well as providing unique market-related information. The future of AMPS, and of the Chicago developmental system, will depend upon the results of the technical and market tests, as well as upon regulatory actions.