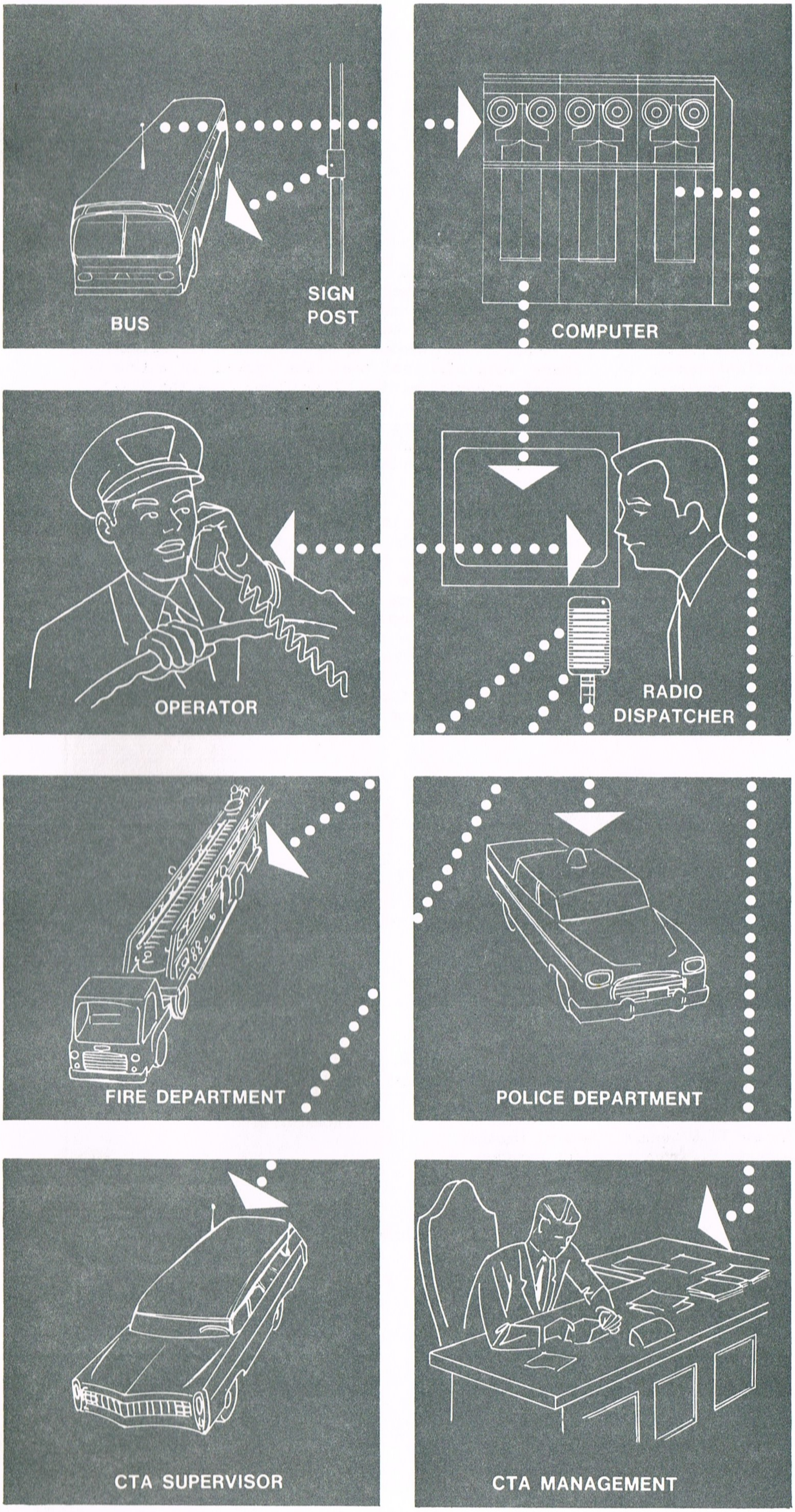


MONITOR-CTA

PROGRESS REPORT No. 4
JULY, 1970

Foreword

On March 14, 1968, a grant to the Chicago Transit Authority for a Mass Transportation Demonstration Project was approved. The project, designated as Monitor-CTA, is a test of a system designed to automatically monitor a transit bus fleet from a central location. It will test the effectiveness of a system in supplying information to supervisory and management personnel for improving service, providing up-to-date statistical data and increasing equipment and personnel efficiency. In addition, this project will test the hardware that will provide instantaneous identification and location of vehicles in the event of emergency. Included in the system will be two-way voice communication for obtaining descriptions of the operating conditions and giving instructions to Operators for alleviation of difficult situations.

This Mass Transportation Demonstration Project (Ill-MTD-6), now under the jurisdiction of the Department of Transportation, Urban Mass Transit Administration, was initially envisioned to cover the entire area served by the Chicago Transit Authority. This coverage would be limited to the late night, "owl service", between the hours of 12:00 Midnight and 5:00 A.M. in order to keep equipment requirements at a minimun and provide the riding public and operators with the benefits of the alarm and communication features of the system. It has become apparent that this preliminary idea will not test the system in a true operating environment. Therefore, once the system becomes fully operational, and supervisory and operating personnel have become accustomed to the system, equipment schedules will be devised for testing the system throughout the day on various size routes.

In order to summarize the current status of the project and furnish this data to DOT, the fourth progress report is hereby submitted. The first three reports have given background information into the development of the project concept and a detailed description of the hardware and software of the system to be used for the Demonstration. This report describes the plan for demonstrating the effectiveness of the system and gives the developments and finances for the period from July 1, 1969 to June 30, 1970.

Report issued August, 1970, by Chicago Transit Authority, Merchandise Mart Plaza, P. O. Box 3555, Chicago, Illinois 60654.

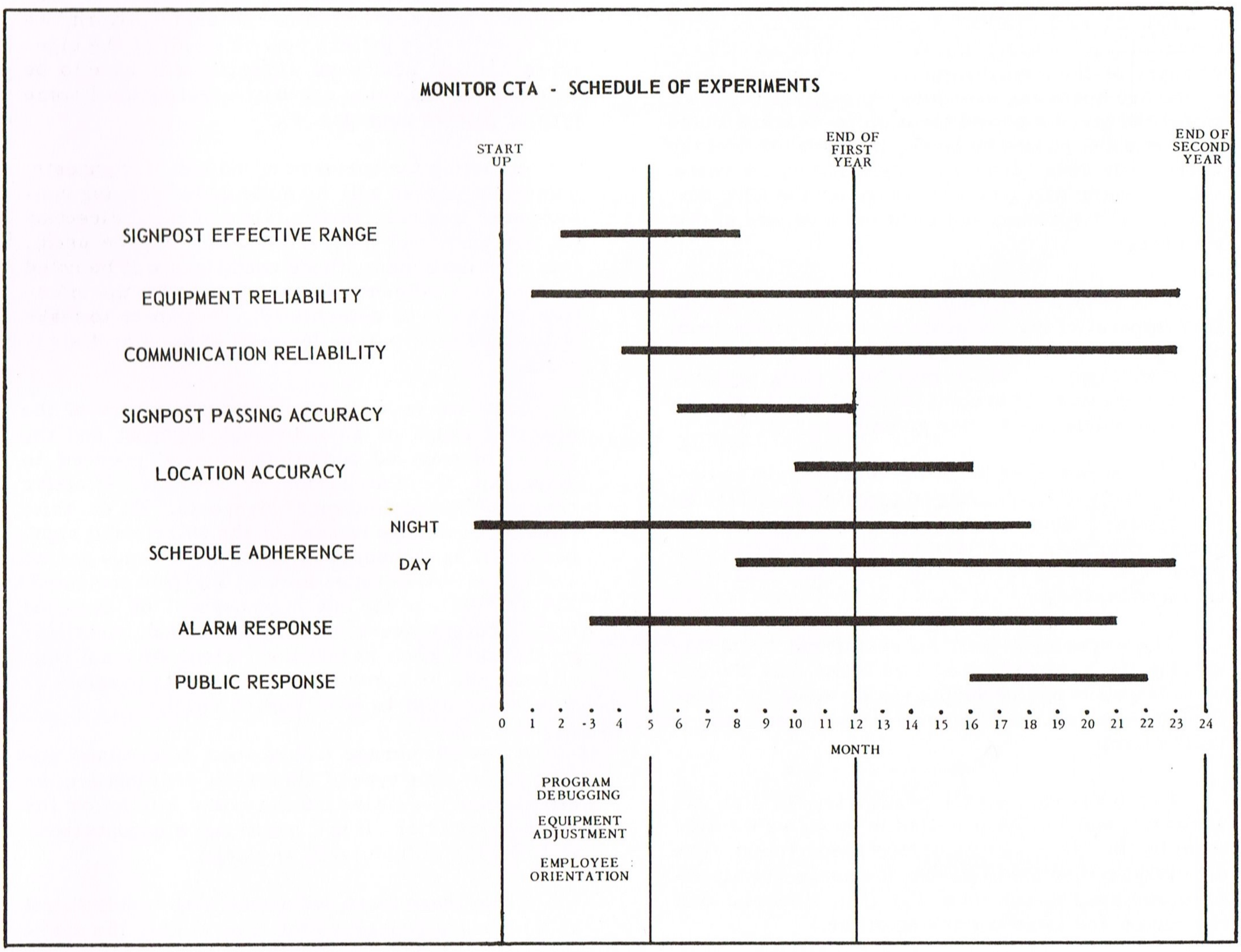
Plan for Experimental Evaluation of Automatic Vehicle Monitoring System

The purpose of this report is to describe in detail the experiments to be conducted for evaluation of the Chicago Transit Authority (CTA) Automatic Vehicle Monitoring (AVM) demonstration. This project, sponsored by the Federal Urban Mass Transportation Administration (UMTA), will apply modern radio communications equipment and a centralized on-line process-type computer to the operation of a major metropolitan bus system. The AVM system will provide automatic electronic monitoring of bus operations, 2-way voice communication between bus driver and dispatcher, and a secret driver-actuated emergency alarm. The experiments will yield measurements of the aspects of the system: technical performance, operational performance and growth-potential.

Technical performance experiments are intended to measure the performance of the AVM system equipment and components. Equipment failures or malfunctions, delays in repairing or restoring equipment to proper working order, costly maintenance, etc. can have a negative effect on the value of the system. Accuracy is also an important technical performance factor. Experiments included in this category are: effective range of signposts, equipment reliability, communications reliability, signpost passing time accuracy, and location accuracy.

Operational performance experiments will attempt to measure what effect the AVM system has on CTA operations. We want to determine its effect on schedule adherence, safety, crime, operating difficulties, and in general, operator and public response to the system. Operational performance experiments will include schedule adherence, alarm response, and public response.

Growth potential will be evaluated in the daytime monitoring experiment. For this experiment, certain routes will be 100% equipped with radio-e-



quipped buses and monitored round-the-clock. From this experiment, we intend to determine whether or not the AVM system should be expanded from the initial 500 buses to the entire CTA fleet (approximately 3100 buses).

Technical Performance Experiments

Effective Range of Signposts

The range of a signpost transmitter can be varied by an internal adjustment which regulates the strength of the signpost signal. The maximum range is approximately 300 feet. Experience indicates that for optimal system performance, each signpost should be adjusted to the minimum range that will insure that every bus passing the signpost location will receive a valid signal. To this minimum range, some plus factor must be added to allow for normal variances in the system components and the effects of external conditions.

At some locations, signpost ranges will have to be set quite high in order to reach vehicles which do not operate within less than perhaps 150 to 250 feet of the transmitter. Still other locations will require the range to be set quite low so as to avoid transmitting to buses operating within say 200 to 350 feet of the transmitter. In such cases, these buses are operating over another distinct route for which the given signpost location is not a scheduled timepoint. It should be noted, however, that in the event a bus does report a signpost not on its route, the computer will give a message on the CRT display to the dispatcher and print out a record of this occurence.

For proper operation of the monitor system, it is imperative that vehicles receive a signal from all signposts passed along the scheduled route, but not from signposts which may be in close proximity to the route but are not included as timepoints in the schedule file for the given route.

The accuracy of locating vehicles and determining their time passing signposts is affected by the effective range of the signposts. Thus it becomes desirable to determine the statistical distribution of the effective range of the signpost location transmitters.

The experiment will be performed by slowly driving the radio-equipped test buses past the selected signpost and recording the distances at which the bus first starts and finally stops receiving a valid signal.

Three bus radios will be selected for this experiment, and will be installed in buses as we need them by the Shops and Equipment Department. The only requirements will be that the buses are standard equipped buses from the CTA fleet and that the radios are in good working order.

The radios on the selected buses will be modified to indicate the presence or absence of a valid signpost signal (i. e. a light or tone or both indicating that the unit is receiving a signal from a signpost.)

Distances from the signpost to the bus will be measured parallel to the center line of the street on which the bus is operating and rounded to the nearest five feet. The actual range of the signpost would be a radial distance from the signpost to bus. We are interested in an effective range however, which we interpret to be a distance measured along the path of vehicle travel, which is essentially parallel to the center line of the street.

Since the range of each signpost is to be set independent of the others, it will be necessary to take a rather large sample in order to get a good picture of the distribution of ranges in the total population. It is recommended that at least 30 signposts (25% of the total 120) be selected at random for the experiment. From these 30, three or four will be selected at random for exhaustive testing to determine the variance of an individual signpost. If the performance of these three or four signposts appears to follow the same pattern, we can assume this pattern applies to all of the signposts. If not, additional signposts will have to be selected for the same exhaustive testing until some type of pattern emerges.

In testing for variance of individual signposts, numerous passes will be made under varying conditions of weather, traffic, time of day, direction (of test bus), and mobile radio (three to be used). For each pass made, these conditions will be noted so that any influence they may have on the effective range can be determined. We expect to make at least 30 to 40 passes for each of the 3 or 4 signposts.

Once we have determined the variance of the effective range of an individual signpost and the effects of external conditions, we can proceed to determine the distribution of average effective ranges of the population of signposts. To do this, the effective range of each of the 30 selected signposts will be measured at least three times and an average effective range for that signpost computed. Extreme values for one signpost will be excluded in computing averages and additional measurements taken when necessary. Also, external conditions will be controlled as much as possible or compensated for to avoid biased results.

If the 30 average values thus determined appear to fit some type of statistical distribution, we can assume the entire 120 signposts will follow the same distribution. If not, additional signposts (possibly all 120 of them) will be tested.

From these tests, we should also be able to set up a standard procedure for determining the average effective range of a signpost. On a long-term basis, such a procedure would be most useful for setting up and maintaining electronic signposts.

The effective range of signposts affects the signpost passing time accuracy and location ac-accuracy. Therefore this experiment should begin as soon as possible after all signposts and mobile radios are installed and operable.

Signpost Passing Time Accuracy

The time that a bus passes a signpost is the basic measure of schedule adherence in the automatic vehicle monitoring system. Therefore, it is of primary importance to know the accuracy with which the AVM system is able to compute the signpost passing time. This experiment is intended to establish statistical parameters of AVM calculated passing times compared to actual passing times.

There are two sources of error in the AVM calculated passing time. One is created by the elapsed time clock in the buses. When a bus enters the effective range of a signpost, the clock is reset to zero. It remains zero until the bus leaves the effective range, then begins counting elapsed time in 12-second increments. Thus, we can get an error of up to 12 seconds when the bus is interrogated due to the bus clock.

The second source of error is created by the effective signpost range. To the computer, the bus appears to be at the signpost from the time it enters its effective range up until 12 seconds after it leaves the effective range. (The elapsed time counter shows no elapsed time before 12 seconds after leaving the effective range). The magnitude of this second error can vary considerably, depending on the range of the specific signpost, the speed, and duration of stops, if any, made by the bus within the effective range.

An analysis of the various positions of a bus with respect to a signpost should clarify the nature of the errors which will occur. The accompanying

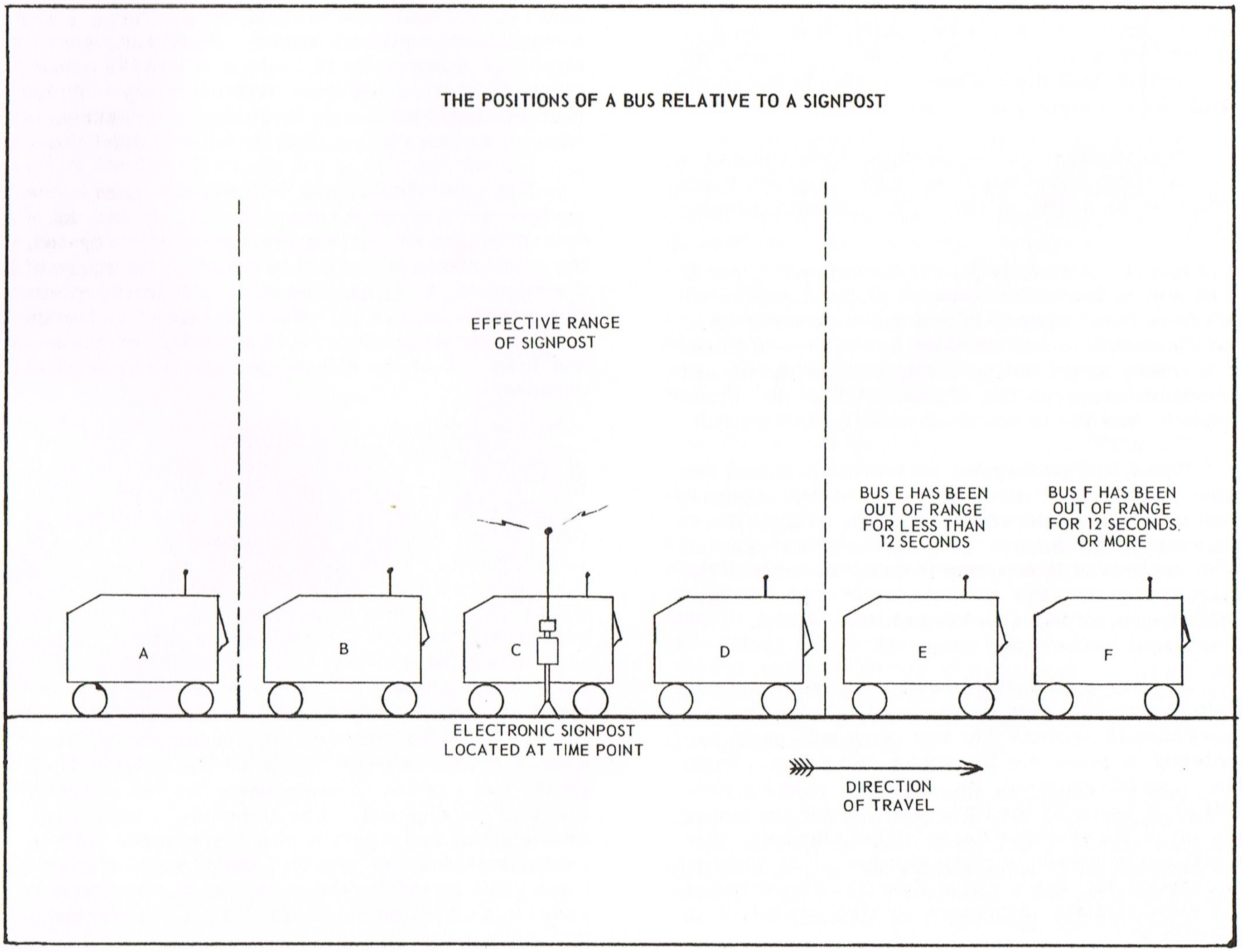


diagram illustrates a signpost located at a timepoint, the effective range of the signpost and the six possible positions of a bus relative to the signpost.

Bus A has not arrived at timepoint and is not within signpost range. Therefore, if bus A were interrogated, there would be no error (relative to this signpost).

Bus B has not arrived at timepoint but has entered the effective range of the signpost. If bus B were interrogated, it would be considered as having arrived at the timepoint - ahead of its actual arrival time. Generally, this type of error is not expected to be very great. If a run is ahead of time, and the operator is trying to get back on schedule, he would slow down or wait outside the range of the signpost. Therefore, except under extreme traffic conditions, we would expect the bus to be moving rapidly up to the timepoint once it comes within the range of the signpost. Assuming an effective range of 300 feet and an average bus speed of 15 miles per hour, the maximum error would be less than 14 seconds.

Bus C has arrived at timepoint. If the run is interrogated while at the timepoint, it will be considered as at the timepoint. Let us assume, for the present, that the bus does not stop at the timepoint for any significant length of time.

Essentially then, the arriving time equals the leaving time, and if bus C were interrogated, there would be no error in the AVM computed passing time.

Bus D has already passed the timepoint, but is still within the effective range of the signpost. If bus D is interrogated, it will be considered as at the timepoint - later than its actual arrival time. The error, again, is dependent on bus speed and effective range of the signpost. The magnitude would be similar to bus B but opposite in direction.

Bus E has already passed the timepoint and has gone beyond the effective range of the signpost within the last 12 seconds. Visually, though, bus E appears to be beyond the signpost, its elapsed time count is still zero and it would be treated the same as bus D. But now the error of the elapsed time increment has also begun to take effect. This error adds to the above error.

Bus F has already passed the timepoint and has been beyond the effective range of the signpost for more than 12 seconds The bus clock will have registered at least one 12-second increment. When bus F is interrogated, its computed passing time will be in error by the time required for the bus to get out of the effective range of the signpost. For a given trip passing a given signpost, this quantity is constant for any position E or F. The error of the elapsed time increment is also prevalent in position F.

To summarize, the error due to the effective range of the signpost will be maximum ahead of actual arrival time as a bus reaches position B, then it will decrease to zero as position C is approached. Leaving position C toward position D it will increase to a maximum later than actual arrival time and then hold constant for all possible positions E and F. Position A, in reality, is position F for the last previously passed signpost. The error due to the bus clock increment counter is a uniform distribution from 0 to 12 seconds - later than actual passing time.

Previously, we disregarded any standing time within the signpost range. In reality, there will generally be an interval that the bus is stopped and standing at the signpost. In the printed CTA schedules, the times shown for the start of each trip are leaving times, while the times shown for all intermediate timepoints are arriving times. Operating rules forbid arriving ahead of schedule but an operator is at liberty to leave as soon as he arrives (providing he did not arrive early, he had completed passenger exchange, and traffic and signals permit). Therefore we can assume there is a scheduled leaving time for each timepoint which is the same as the published arriving time. (There are a few special instances where a short wait, generally 1 to 3 minutes, is incorporated into the schedule and this assumption would not apply. These tips are handled in a special way in the schedule file and we can disregard them for this discussion.

The computer cannot tell exactly when a bus arrives and leaves a timepoint. All it can do is determine for each time the bus is interrogated, the relationship of the bus to the effective range of the signpost, i.e., the bus is not yet in the effective range, the bus is within the effective range now (or was within the last 12 seconds), or the bus has been out of the effective range for at least 12 seconds.

The philosophy to be followed in the AVM programming for interpreting interrogation replies is this: If a bus replies with a valid signpost and the elapsed time count is zero, the assumption will be that the bus arrived at the timepoint at the time of interrogation. If successive interrogations yield the same reply, the time of the interrogation first would be maintained as arriving time, but now we assume the bus still has not left the point. If a bus replies with a non-zero elapsed time, we know it has left the point. The leaving time would be computed as time of interrogation minus the elapsed time as reported in 12 second increments, six seconds for the average error of the elapsed time clock, and a factor to compensate for the effective range of the signpost. The computer is being programmed to add 6 seconds to the elapsed time to compensate for the error of the 12 second increment. The factor for the error due to the effective range must first be determined from the results of this experiment.

In this experiment we will make comparisons of actual arrival times and AVM computed arrival times as well as actual leaving times and AVM computed leaving times. In addition, a separate analysis of arriving and leaving times will be made so as to determine a distribution of bus standing times at the various timepoints to be observed.

To obtain data for this experiment, manual time checks will be taken at various signpost locations in the system. Traffic checkers will record both arriving and leaving times at the timepoint. By taking both times, we can determine standing times and study how it affects passing time accuracy. This manually obtained data will be compared to the AVM computed passing times and statistical parameters of the errors determined.

In order to gather a sufficient quantity of data, most of the data will have to be obtained from daytime operation so we will depend mainly on the routes which are selected for the daytime monitoring experiment. While operational requirements of the bus system prohibit a purely random selection of these routes, every effort has been made to select a typically representative sample of the whole system. Knowledge of the effective range of signposts to be used for this experiment is also required. Therefore, we will use those signposts from the random selection used in the effective range experiment which are located along the routes selected for daytime monitoring. Twenty-five percent of the 120 signposts are to be used for the effective range experiment. Applying this same ratio to the 34 signposts located along the nine routes selected for daytime monitoring, we expect to get a sample of 8 or 9 signposts. If we find that the data from these signposts is insufficient to establish reliable parameters of signpost passing time accuracy, we will select at random additional signposts for further testing.

Standard procedure at CTA requires that traffic checkers adjust their watches each day before going to work by calling CAthedral 8-8000 for the correct time. In order to synchronize the manual time checks with the computer calculations, the computer clock will be checked on days when manual time checks are being taken.

No special equipment or forms are required for this experiment. Manual time checks can be taken on standard CTA traffic survey forms, a copy of which is attached. The AVM system stores all pertinent data from bus interrogations on bulk and hard copies of the required information can be prepared.

The experiment cannot begin until the AVM system is in operation and large quantities of data will not be available until the system is ready for daytime operation.

Location Accuracy

While the primary function of the AVM system is to enforce schedule adherence, another significant feature is the emergency silent alarm. The success of this alarm feature depends on how accurately a vehicle in distress can be located. This experiment is intended to measure the accuracy of the bus location procedure.

When a bus operator activates the emergency alarm switch, the following information is relayed to the central computer: station number, run number, bus number, last signpost number and elapsed time count. The computer enters a program which calls out the block of schedule information containing this run. From the alarm data and information in the schedule file, the direction of the bus and elapsed time since passing the last signpost is computed to the nearest tenth of a mile. The garage number, run number, bus number, route name, last signpost name, direction and computed distance from last signpost are displayed as an alarm message on the dispatcher's CRT. The dispatcher uses this information along with his knowledge of the bus system and refers to a map of the area to determine the apparent location of the troubled vehicle. He then uses a direct line and reports the information to the police radio communications center who in turn will send police to the aid of the bus.

A uniformed CTA supervisor will be assigned to assist in this experiment. Testing will be done in the following manner. The supervisor will go out to a monitored bus route and board a radio-equipped bus. He will explain briefly to the operator what he intends to do. Then he will contact the dispatcher, identify himself and the run number and bus number and informs him that he is going to test the bus alarm. The dispatcher will record the run number and bus number, then resume his normal duties until the alarm message is displayed. The supervisor, at his discretion, will instruct the operator to activate the bus alarm. This will be done within a reasonable time after first notifying the dispatcher, say ten minutes at the very most. The supervisor will record the time and actual location and other identifying information while the dispatcher makes his determination of the bus location and records it with the run number and bus number previously recorded. After a minute or two delay, the supervisor will contact the dispatcher again to verify that the alarm was a test and it is now completed. Both supervisor and dispatcher reports will be forwarded to the Project Manager for analysis.

The actual location will be compared with the dispatcher's determinations and a statistical distribution of the errors established. Human errors by the dispatcher will be excluded from the distribution of errors but a frequency of such occurences will be calculated to determine the dispatcher's performance. Such errors could be more serious than those which are inherent to the system design and programming. For example, if the dispatcher measures from the wrong signpost or in the wrong direction, the police would be sent to a location totally removed from the bus in distress.

Distances traveled from last signpost will be calculated as a function of elapsed time and an average speed. Initially, this average speed will be a constant for the entire system. We believe this will be satisfactory for the late evening and owl service. A variable speed formula, dependent on the location and time of day may have to be developed to improve the location accuracy. An adjustment for the effective range and elapsed time clock errors will also be necessary.

We will select routes on a random basis. The supervisor conducting the tests will be instructed not to favor certain locations such as major intersections or transfer points so as to avoid developing a pattern which could bias the dispatcher's locating efforts.

The selection of points will be to the discretion of the supervisor.

Initially, we will do about five days of testing. We would expect to get about 75 individual tests in this amount of time. These results should give a good indication of the location accuracy and what direction we should proceed in to improve it. Additional testing will be done as necessary.

Communications Reliability

An important measure of performance of the AVM system is the communication reliability. It is a measure of the system's ability to get back a valid reply when it initiates an interrogation cycle. Specifically, it can be stated as the ratio of the number of valid replies received to the total number of interrogations initiated.

The computer is being programmed to record counts of interrogations and replies received. We will keep record of the ratio of valid replies on a daily fleet-wide basis. An acceptable limit of reliability has not been established, but it will certainly have to be upwards of 95 percent. Below this level, the system would tend to become bogged down with invalid or no reply messages. We are hopeful of attaining a communications reliability level of around 99 percent.

We can also use the communications reliability data for diagnostic purposes. For example, a sudden sharp decrease in the ratio of valid replies would indicate some type of equipment failure such as perhaps a satellite receiver. A gradual decrease over a period of time would indicate a deterioration of some component equipment.

When the computer fails to receive a valid reply from a bus after two successive interrogations, a message is output on the dispatcher's CRT display. A permanent record of all CRT messages will be made and such messages can later be analyzed as to the reasons for not receiving valid replies. Also they can be used to isolate defective units of equipment. For example, if a certain bus consistently fails to return a valid reply, it becomes fairly evident that the equipment on that bus is not working properly. The same principle applies to signposts and satellite receivers.

We can also get a listing of every interrogation and every reply for a given day if we so desire. If there is a relatively high proportion of invalid replies which are non-recurring, that is, they do not occur twice in succession for a given bus and therefore no CRT message is output, we will want to study this detailed listing so as to establish the nature of these invalid replies.

The communications reliability ratio can be calculated for each day of operation from the time the system is installed and debugged for the duration of the demonstration. By plotting this ratio on a graph, we can observe the trends of communications reliability.

Equipment Reliability

An important factor in the operational effectiveness and long term costs of the AVM system is the reliability of the various components of the system. The performance capabilities of the system may be outweighed by frequent malfunctions or long waiting periods to repair or replace faulty components. Also, favorable initial costs of a system may be negated by unfavorable operating costs due to equipment maintenance.

In order to evaluate the reliability of the various component equipment of the AVM system, it will be necessary to keep records of equipment malfunctions and repairs or adjustments required. Measures of reliability will be mean time between failures and mean time required to repair the equipment. Other information we will want includes hours of use at time of first failure, cost of labor and cost of parts for each repair.

In order to gather the data required, maintenance records for each of the system components will be kept by the system supplier (Motorola). These records will include the date and time each malfunction was first discovered, the nature of the malfunction, corrective steps taken, parts and labor required for correction, and the date and time the unit was restored to normal operation.

The reliability of all the various components of the AVM system must be evaluated. This includes the signpost transmitters, the mobile units (bus radios), the fixed base station transmitters and receivers, the GE 4020 computer and peripheral equipment, and the control center (dispatcher's console, radio, and display equipment).

Data will be collected continuously over the two-year demonstration period, which should be ample to determine the failure rates of the various components of the system and the maintenance costs. The data should also be useful in developing schedules for preventative maintenance. One thing we will most likely not determine during this period is the useful life of any of the components, as we expect this to be considerably more than two years.

Operational Performance Experiments

Schedule Adherence

The primary objective of the AVM system is to improve schedule adherence in CTA bus operations. There are currently several sources of schedule adherence data available within the framework of the CTA organization. These include traffic surveys taken by the Schedule-Traffic Department supervisory force.

The Schedule-Traffic Department maintains a force of approximately 30 traffic checkers whose full-time job is to take traffic surveys, boarding and alighting counts, running time checks, and other forms of service checks and passenger counts. Their primary purpose is to provide data for determining the requirements in preparing schedules, although they also gather data for statistical reports and research and planning. Most of the traffic surveys for scheduling purposes are taken during the morning and afternoon rush periods which is when manpower and equipment are at a premium.

Reports by the supervisory force pertaining to schedule adherence include service surveys, service checks, 10-50 checks (same as service check, but assigned by radio), and schedule adherence reports.

To obtain the necessary information from these sources, for our purposes, would require considerable research through extensive volumes of data. Therefore, we have decided to obtain our schedule adherence data through special service checks (also referred to as 10-50's) which are specifically designed to meet our requirements.

The special 10-50's will be taken both before and after installation of the monitor system. The following procedure will be used in obtaining these service checks. The dispatcher will be given a list of routes and approximate time of day for which checks are desired. At the proper time, he will dispatch a radio car to each of the (proposed) signpost-equipped time points on the designated route. The supervisors will go to their assigned location and record their observations on specially-designed 10-50 forms which they will turn in at the end of their work shift to be forwarded to the project manager for processing.

Checks will be made at various times of the day and night. Only one route will be checked at a time. All points on a given route will be checked at the same time. The duration of any specific check will not exceed one-half hour in order to minimize the effort on schedule adherence once the operators become aware that the line is being observed by supervisory personnel.

Dispatchers will be supplied with a list of time points to be checked for each of the designated routes. In addition, they will have a list of which radio cars to dispatch to each point. In the event that a specified car is not available, the dispatcher will send an alternate car, if available, to that point. All supervisor's cars will be supplied with a quantity of special 10-50 forms.

From the data thus obtained, the statistical parameters (mean and standard deviation) of buses early, on time, and late will be computed. These can be compared for operation before and after monitoring begins. In addition to the overall comparison, individual comparisons will be made of:

(1) The same time point at various times of the day.

(2) Different time points on a route for the same period of time

(3) The same time point and same period of time but on different days.

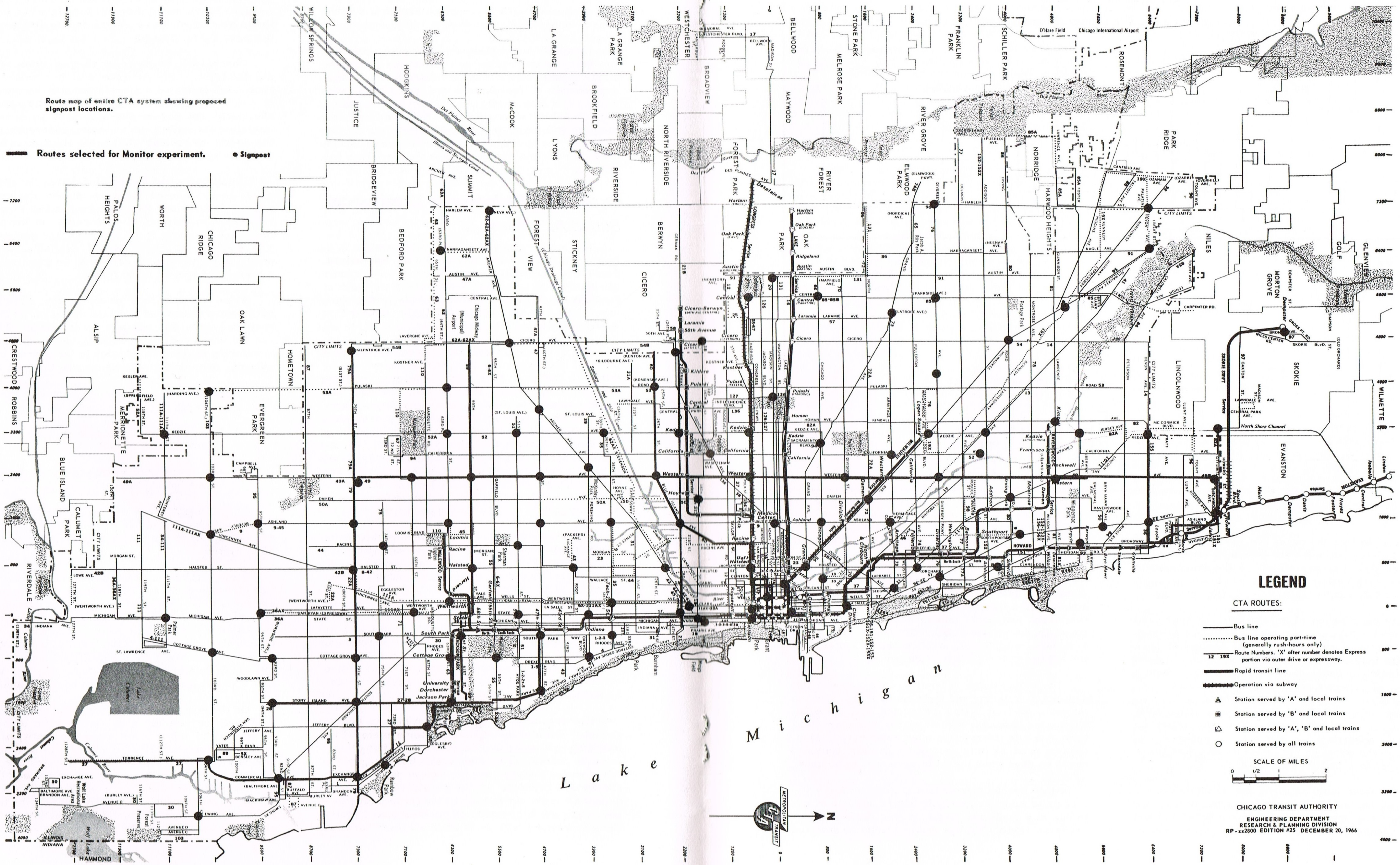
These comparisons will illustrate the normal variances which occur in schedule adherence and can be applied to the analysis of the effects of the AVM system.

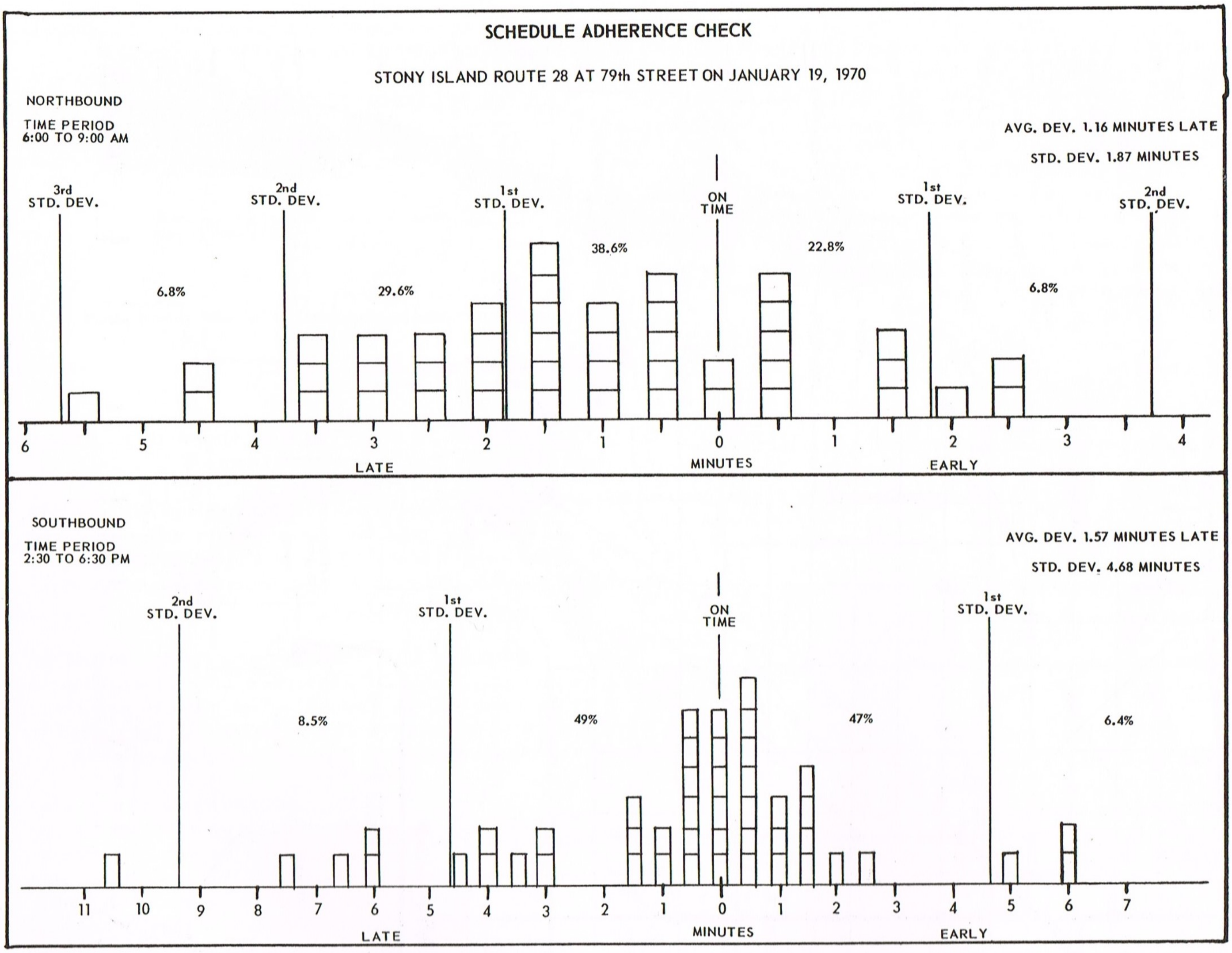
Some preliminary calculations on the distribution of buses early and late indicate that the average tends to be very near zero, but the variance is very high. We will not be looking at the averages but rather at the standard deviations as an indicator of schedule adherence. If the trend of the standard deviation decreases by a significant amount with the installation of the AVM system, this will indicate a closer adherence to the scheduled headways.

On the other hand, the arithmetic mean (average) early or late for a number of trips provides no meaningful information about the quality of the service. For examples, if every trip in a given period were operating exactly ten minutes late, the service provided within this period would be virtually the same as called for in the schedule (though not necessarily identical). The average of these trips would, of course, be ten minutes late and the standard deviation would be zero. The average

Route map of entire CTA system showing proposed signpost locations.

Routes selected for Monitor experiment. ● Signpost





does tell us that the buses are running quite a bit off schedule, but from the standard deviation we can see that they are all off by the same amount and hence we realize that the actual headways must be relatively equivalent to those in the schedule.

The distribution of buses early, on time, and late does not take into account the sequence in which these events occur. We are not concerned here with the mathematical details, but in fact, a given distribution of buses early or late can represent a number of different combinations of service headways rather than one unique combination. Thus, in order to measure the effectiveness of the AVM system, in addition to measuring the effect on schedule adherence, it will also be necessary to measure the effect on the actual headways of buses compared to scheduled headways.

The same data required for schedule adherence can be used to determine bus headways. We will compare the difference between scheduled and actual headways and the statistical parameters of the same for operation before and after AVM monitoring begins.

The AVM demonstration project is designed for monitoring late night and owl (early morning) bus service. However, the expense of such an installation is not justifiable unless it can be utilized for round-the-clock operations. We intend to so some daytime monitoring of certain selected routes during the two year demonstration period.

Basically, there is no difference between full daytime monitoring and night monitoring. But, in order to monitor a line during the day, a special file for the computer containing the necessary daytime schedule information must be prepared. Also, the line must be fully equipped with radio equipped buses on days when the AVM system is to be used.

Since special preparation is required and vehicles must be made available before daytime monitoring of a route can begin, it was decided that a cross-section of CTA bus routes should be selected in advance for this purpose. The first step was to eliminate all trolley bus routes and those motor bus routes which do not have owl service. Those routes are not designated for AVM night monitoring and will have a very limited number of electronic signposts located along them. Also, it would not be desirable to assign radio equipped buses to these routes, thus reducing their availability to the designated AVM equipped routes. (In the case of trolley buses, none are being equipped with radios since they are to be totally phased out during the next decade.)

From the remaining list of routes, we exclude those which are new or involved major revisions as a result of the opening of the new Dan Ryan, Englewood, and Kennedy rapid transit extensions. Traffic patterns on these routes will tend to fluctuate for a time as people experiment with using the various new services. These changing traffic patterns will affect running time and service requirements which in turn can affect schedule adherence. We wish to avoid these external influences in the schedule adherence experiment. Also, by using lines where no major revisions are anticipated, we will have available a great quantity of pre-AVM data comparable to that obtained after the AVM system is operating.

Three other lines, Jackson, Douglas extension, and Westchester were eliminated because they have no signposts located along their respective routes. Each route has only one owl run. These runs will be assigned radio-equipped buses for voice communication, but the lines will not be monitored.

We still had 36 routes left to select for daytime monitoring. Sixteen of these were excluded because we felt there would not be enough radio-equipped vehicles for daytime AVM operation. To be consistent, we established a guideline that if a route required more than 50 per cent of the total radio-equipped buses assigned to a given station, we would not have enough units available for daytime monitoring of that route. This is not unreasonable when we remember that night AVM operation must be maintained on all so designated routes.

This did not eliminate all of the longer and heavier routes, leaving only the shorter and lighter routes to choose from as might be expected. Because of the large variation in number of bus radios assigned to each of the 12 operating stations (3 at the smallest, 95 at the largest), we still had a good selection of routes to choose from. From the remaining 20 routes, nine have been selected for daytime monitoring. These routes range in length (between outer terminals) from 3.6 to 15.8 miles. They vary widely in service requirements and number of vehicles scheduled; the number of signposts varies from 2 to 9 with the spacing between signposts from approximately one to 3-1/2 miles. A list of these routes including mileages, vehicle requirements, and the number of signposts along each route is shown below:

ROUTES SELECTED FOR DAYTIME MONITORING

No.	Route Name	One Way Miles #	Weekday Buses* AM	Base	PM	Eve	Owl	No. of Signposts
49	Western Ave.	15.8	54	23	52	22	6	9
79	79th Street	10.2	28	10	29	11	3	7
27	South Deering	10.0	13	7	13	6	3	5
59	59th-61st	8.4	12	9	13	9	3	3
28	Stony Island	7.8	28	10	30	10	3	5
60	Blue Island-26th	7.5	17	10	19	9	3	5
21	Cermak Road	6.4	14	8	14	8	3	4
155	Devon-Sheridan	5.6	16	7	20	6	1	4
49B	North Western	3.6	7	5	8	4	2	2

#Between Outer Terminals
*Winter Schedules 1969-70

The map on pages 10 & 11 shows these routes and the signposts located on them.

The daytime monitoring operation will provide much of the data for the schedule adherence and other experiments. This is a must as the amount of data we can expect to get from the night monitoring is very limited.

Once the AVM system is operating, it will be supplying schedule adherence data in addition to the manual 10-50 checks. The manual and computer supplied data will of course be compared in the signpost passing time accuracy experiment.

Control data will be obtained prior to installation of the AVM system; and concurrent to its operation, data will be collected on similar non-instrumented routes. However, no post-AVM data will be collected. In order to obtain "post" data, the radio equipment would have to be removed from all buses. It would not seem wise to jeopardize the safety of employes and passengers merely for the purpose of data collection.

Silent Alarm Effectiveness

The silent alarm feature of the AVM system allows the bus operator to call for police assistance in any emergency without any overt action which might jeopardize his own safety or that of his passengers. Its primary intent was to inhibit holdups on buses which have increased at an alarming rate in the last few years. This problem has been largely eliminated now by the introduction of the new locked fare boxes on CTA buses. All fare collections are deposited into a locked vault to which the drivers have no access. The need for the alarm still exists, however, to react to other situations which occur on the buses such as assaults, disputes, fights, drunkedness, disorderly conduct, and vandalism. This experiment is intended to measure the effectiveness of the alarm feature in reducing crime on CTA buses.

It is the present policy that for every such incident which occurs, the radio dispatcher must fill out an unusual occurance report. These reports contain a description of the occurance and the corrective action taken. In the more significant instances, a special occurance report, similar to the unusual occurance report, is prepared by the station superintendent. These two reports will be used to supply the necessary information for this experiment. Station Superintendents and Dispatchers will be instructed to include the specific information pertinent to the evaluation of the alarm system.

The first thing we want to determine is how often the operator does or does not use the silent alarm when the need arises.

If there is a high frequency of instances in which the alarm is not used when it should be, it will be necessary to investigate further and determine the reasons for the operators not using the alarm and what steps to take in order to correct this situation.

The next item we want to determine is how long it takes for the police to come to the operator's assistance from the time the alarm is initiated. This includes the time required for the dispatcher to receive the message, determine the location of the bus and report it to the police and for the police dispatcher to radio units in the area and for these units in turn to reach the bus in distress. This entire sequence could take several minutes and a large variance can be expected from one instance to the next.

The third item we want to determine is how effective the alarm system renders the police at combating crime on buses. We want to know such things as, in how many instances is the attempted crime prevented by arrival of police, how often is the criminal apprehended at or near the scene, how often do the police arrive too late to be of any assistance, etc. ?

Finally, we want to measure the effect on the overall crime rate on CTA buses. We want to determine if there actually is a significant reduction in crimes on CTA buses due to the installation of the AVM system.

Public Response

The measure of Public response to the AVM system is primarily qualitative rather than quantitative. One way to measure this response is by an analysis of complaints and commendations before and after installation of the monitor system, in particular, those referring to service, safety, or the AVM system specifically. The CTA Public Information Department will keep a file of all publicity, complaints, commendations, etc. related to the AVM system throughout the two-year demonstration period.

It is doubtful that the system will produce any marked increase in riding since the owl services are used by very few people, and those only of necessity. Even a large increase in riding during these hours would not produce a detectable increase in the total revenue. We will take passenger checks during the evening hours before and after installation of the system to determine if there is an increase in riding on the monitored bus routes during this period.

We are of the opinion that this system will be well publicized by the local news media. After about one year of operation, we will study the public reaction to the AVM system. At this time we will also consider the desirability of taking a post car survey of passengers on some of the monitored night bus routes. We would ask the passengers such questions as; Did you know that this bus is equipped with a 2-way radio and electronic monitoring system? How often do you make this trip? Did you make this same trip before the installation of the radio-monitor system? Do you feel safer riding CTA buses since this system was installed? Do you feel the service has improved? Have you ever been on a bus when the operator used his radio or emergency alarm to call for assistance?

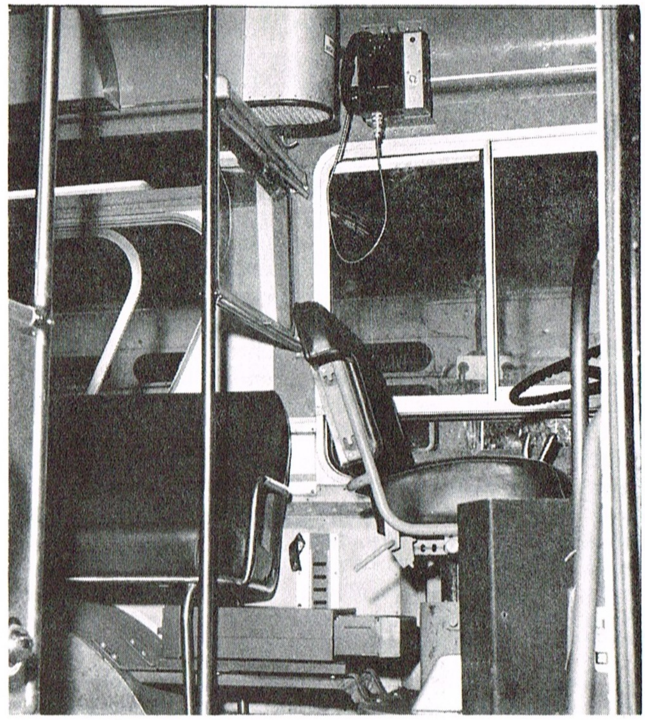
Such a survey will help in determining the attitude of those people who should be receiving the benefits of the AVM system.

Signpost Installation

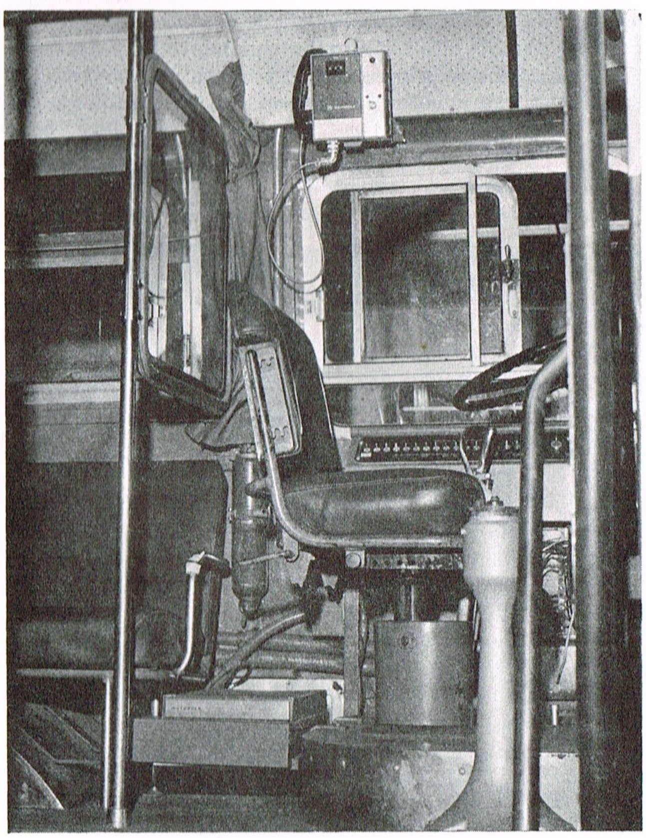
Discussions in previous reports explained the method to be used for installation of the signpost transmitters. These units were manufactured with no difficulty and shipped to Chicago Communication Services, the maintenance sub-contractor, for alignment and coding. Installation of 93 signposts atop traffic light controllers was accomplished by two City Electricians in approximately three weeks. The remaining 27 were installed at various locations by CTA Electricians. All installations were completed by February 21, 1970.

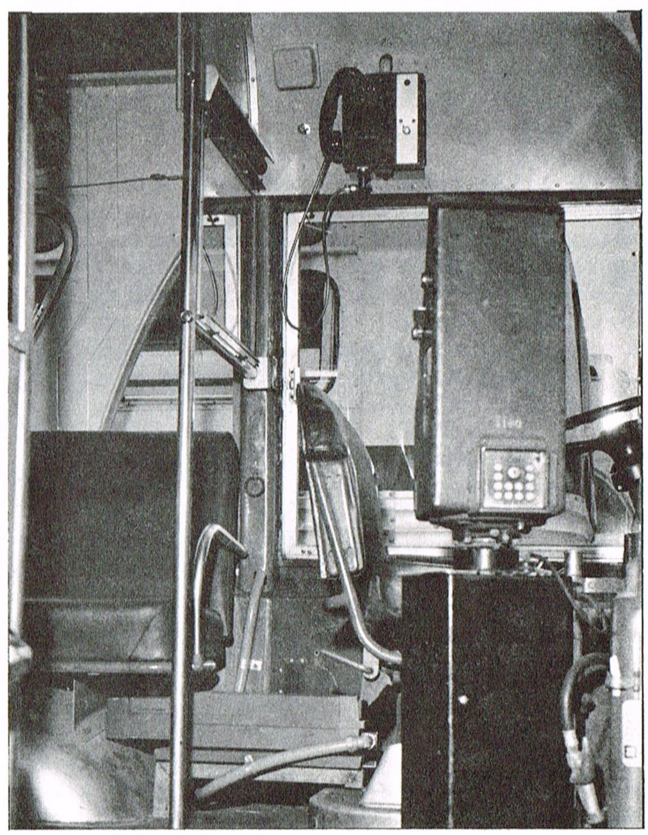
Bus Radio Installation

Prototype installations of the bus radios were made on each major class of bus to be equipped. "New Look" Flxible, "New Look" GM, and old (1959) Flxible. Once these installations were approved, test installations were made and sent to the manufacturer for testing and inspection. As a result of this testing, a filter was installed at the power input to suppress various electrical noise from affecting the logic circuitry. Finally a production line was instituted to make the regular installations. Though radio installation was intended to begin in June of 1969, units did not arrive until January of 1970.



Installations of radios on various bus types: New-Look Flxible (above), New-Look GM (below), and old Flxible (lower left).





Fixed Radio Equipment

A propogation study was performed to determine the optimum locations for the base station transmitters and the satellite receivers. Following this, site surveys were taken to see what might be available for antenna installation (the locations selected) for the satellite receivers are the chimneys of two water pumping stations, Roseland Pumping Station to the South and Mayfair Pumping Station to the North. The location chosen for the base station and central satellite receiver is Lake Point Towers, a 70 story apartment on the Lake Front. Once selected, arrangements were made for use of these sites, installation of equipment, and connection to the control center over telephone lines. Installation of the equipment at Lake Point was completed during January 1970 and operation of the site was begun immediately thereafter. Installation of equipment at the North and South locations was completed during February, 1970; However, difficulty in procuring the proper type of telephone line has prevented operation of these sites.

Control Center Equipment

Once the base station equipment was installed and ready for operation and the necessary phone lines provided, the control console connections were made. This involved connecting the two positions together, connecting the phone lines, and connecting the computer. Part of this work involved running a number of cables through the ceiling of the 7th floor, Merchandise Mart from Operations Control, where the consoles are located, to the Computer Room, a distance of approximately 800 feet. As soon as this work was begun, engineers began adjusting the equipment for operation.

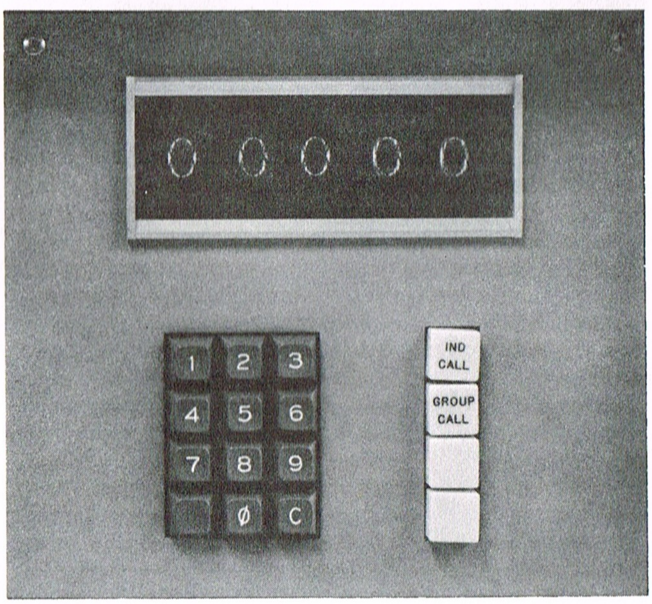
While the connections were being made in the console, GE engineers were at work installing and testing the computer. All of the cables connecting the various housings and peripherals together had to be installed. When this was completed and the power was connected, a series of programs supplied with the computer had to be run to test all of the computer hardward and insure everything was connected properly, undamaged from shipping, and working as intended. Then each test was rerun with all participants represented to demonstrate that the computer system was in perfect condition and ready for customer acceptance. This was all completed on February 1970.

System Debugging

After everything was connected and the power turned on, the effort to make the system operational began. As expected, the two-way voice communication worked as soon as the system was turned on; however, first attempts to use the voice identification and alarm were relatively unsuccessful. The first problem found was interference between the voting tones and the data tones. Each satellite receives the voice signal and compares the level against a pre-set value. This comparison is converted to a "voting" tone and sent over the phone line to the control center where the tones from all receivers are compared. The satellite with the best signal is then connected to the console speaker and the voice ID/Alarm Decoder. With the voting tones and the data tones on the same telephone pair, the tones would mix and cause improper decoding. To solve this problem, the frequencies of the voting tones were changed to values where the result of the mixing would not interfere with the data.

The other major problem was the conditioning of the telephone lines. A necessary characteristic of the phone lines is a linear phase delay in the audio range. On some lines there may be minor variations can be corrected with the addition of circuit components. With these corrections instituted on the phone lines to Lake Point Towers, operations from this location became very consistent. When these changes were made to the South side satellite receiver, no change of accuracy was noticed. Closer investigation revealed that these phone lines were nowhere near the necessary characteristics. Discussions with Illinois Bell Telephone Company disclosed that the lines supplied, did not meet the necessary qualifications; and, furthermore, it was questionable that Illinois Bell Telephone Company would supply this type of line. After further negotiations and clarifications, it was determined that Illinois Bell Telephone could supply these lines; and the necessary orders were placed. After the South lines were found to be unsatisfactory, all the other Illinois Bell Telephone lines were tested. The North lines were also unacceptable and though the lines to Lake Point Towers had the same char-

Selective call panel on Monitor console. Number "dialed" appears in window, then function button (IND CALL or GROUP CALL) is pushed to transmit call.



acteristics, the shorter distance made them somewhat acceptable. In order to improve operating conditions while these discussions took place, a temporary satellite receiver was set up at 61st Street and Calumet Avenue and connected over proven phone lines.

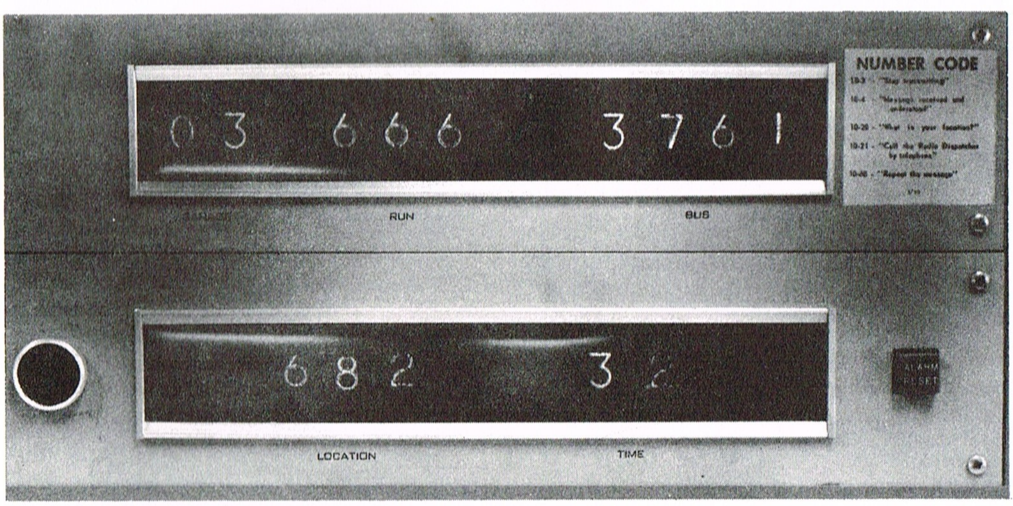
With the equipment at Lake Point Towers and the temporary South side satellite operating, work continued on the other problems which occurred. It appeared that a large percentage of the alarms coming in were false; the button was not pushed, but an alarm was transmitted. Another problem was a large amount of invalid replies; replies from an interrogated bus which decoded properly, however, the replied signpost number did not match any number in the system. These two problems were found to originate on the buses with the same cause, electrical noise. It was found that some of the solendids on the bus caused very large pulses when they were operated; so large that the filtering supplied was not sufficient to surpress the "disturbance". As a result the information in the location storage registers was destroyed and or the alarm control circuit was triggered. It took many hours of effort to track down and to verify these difficulties and many more hours to solve them.

Since these problems were noticed very soon after operation began, it was decided to limit the number of radio units installed on buses. These radios could be watched very closely for other problems, and if it became necessary to modify them, only a small number of buses would have to be tracked down to remove one. This was a fortunate decision because it was discovered that a number of changes were made between the first unit made and the last. These plus the "fixes" for other problems caused all the radios to be recalled by the factory. With these modifications, Motorola now expects all equipment to be installed and operating by August 1, 1970.

Though operation of the system has been limited by the hardware problems, sufficient data has been processed to test the system programming. Though there were some major problems which caused the system to stop, most of the problems were minor logical errors. With a multi-programming system, care must be taken to save the contents of various locations and registers when moving from one program to another; failure to do this may result in improper data in a particular location. Other minor errors were illegal instruction sequences, improper address modifications, and improperly formatted output.

The major problems were mostly related to core usage. Another feature of the operating system as it moves from one program to another is its ability to reserve areas in core memory for programs and data. If too much area is reserved, a condition can arise where a program which is running has no room to bring in its data and a data area created by one program has no room to bring in a program to complete its processing. In this situation the operating system goes into a "loop" looking for room which effectively stops the computer. Careful control of the program area requirements eliminated these problems.

The third area of program debugging would be better termed Operational Debugging. These are changes in the programming due to changes in the way things are done or due to a better method. Some of these changes were changing an alarm from a flashing message to a flashing line number, changing some data formats, combining two programs, allowing complete parallel operation from both CRT's, and delaying some invalid data decisions.



Alarm and Call-in panel on Monitor console with alarm being displayed. Location is the number of the last signpost passed and time is the time since that signpost was passed in minutes and tenths. During normal two-way communications, only the garage and run number are displayed.

Finances

Budget & Forecast

The balance sheet shows the expenses incurred since the last progress report by quarter. On the last progress report, various errors appeared. These errors have been corrected on this report.

These expenses cover most of the installation costs. A small number of radio accessory installation costs. A small number of radio accessory installations on the buses are yet to be made plus the costs involved with the installation of the radios. Other costs due to finalization are also forthcoming under the other installation items.

Only a portion of the radios have been delivered and paid for, therefore, these costs will also appear in future periods.

ITEM

Staff Salaries

Employee Benefits

Travel

Construction or Rental Contracts

- Install Equipment - Buses
- Install Equipment - General Office
- Install Equipment - Wayside Beacons
- Install Equipment - Communications

Consultant Contracts

- Institute of Public Administration
- Data Analysis
- Final and Progressive Reports

Other Project Costs

- Communication Equipment - Mobile
- Communication Equipment - Signposts
- Communication Equipment - Base Station & Satellites
- Display Equipment
- Maintenance
- Computer & Peripherals
- Programming
- Operation
- Marketing
- Printing Final Report

Contingencies

Total Project Cost

* Corrected

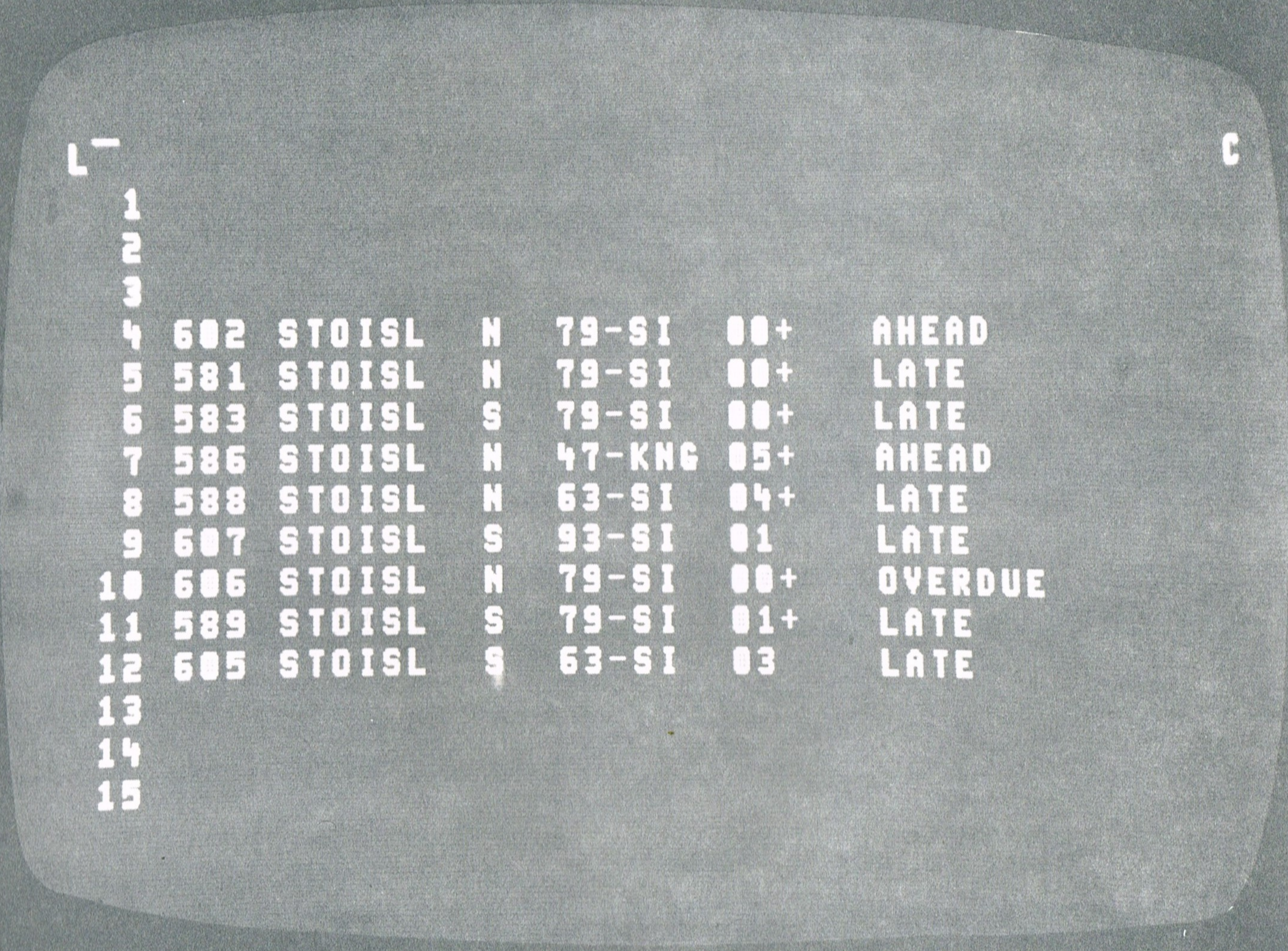
Glossary

AVM	Automatic Vehicle Monitoring
CRT	Cathode Ray Tube (TV Screen)
DAYTIME MONITORING	AVM on a daytime or round-the-clock basis
DISPATCHER	Operations Control personnel assigned to work at the AVM system console
HEADWAY	Time interval (Scheduled or actual) between successive trips on a given route
MONITOR SYSTEM	Automotive vehicle monitoring system
NON-MONITORED ROUTE	A bus route which is not intentionally equipped with electronic signposts and is not monitored by the initial AVM system
OPERATOR	A bus Driver
OWL SERVICE	Transit service which is provided during the early morning hours (approximately 1:00 a.m. to 5:00 a.m.)
POINT MAN	Supervisor assigned to work at a specific location or point on the system
RUN NUMBER	Number assigned to portions of work comprising an operators days work or run
SIGNPOSTS	Low power transmitters located at strategic points along bus routes
SUPERVISORS	Uniformed outside supervisory personnel
TIME POINT	Intermediate points on a bus route for which arrival times are shown on the published schedule

REVISED BUDGET	COSTS April 1, 1968 to June 30, 1969*	July 1, 1969 to September 30, 1969	October 1, 1969 to December 31, 1969	January 1, 1970 to March 31, 1970	April 1, 1970 to June 30, 1970	June 30, 1970
$ 65,000.00	$ 21,793.28	$4,196.63	$ 7,174.08	$ 5,514.87	$ 4,516.57	$ 43,195.43
16,250.00	5,448.43	1,049.06	1,793.52	1,378.72	1,129.14	10,798.87
1,505.00	1,527.84	-	-	-	-	1,527.84
84,000.00	143.71	-	5,582.62	48,182.03	50,479.10	104,387.46
68,000.00	106.71	-	3,342.93	37,367.73	37,667.12	78,484.49
5,000.00	37.00	-	206.35	3,490.94	12,502.96	16,200.25
6,000.00	-	-	2,033.34	7,156.23	15.24	9,241.81
5,000.00	-	-	-	167.13	293.78	460.91
136,988.00	85,436.66	21.00	193.80	-	-	85,651.46
86,988.00	85,000.00	-	-	-	-	85,000.00
25,000.00	-	-	-	-	-	-
25,000.00	436.66	21.00	193.80	-	-	651.46
1,582,000.00	8.30	-	282,477.39	155,663.96	179,077.55	617,227.20
1,020,000.00	-	-	-	123,380.69	174,595.31	297,976.00
39,000.00	-	-	37,643.75	9,906.25	-	47,550.00
24,000.00	-	-	-	20,677.00	-	20,677.00
102,000.00	-	-	102,000.00	-	-	102,000.00
125,000.00	-	-	-	-	-	-
150,000.00	-	-	141,672.00	14.55	200.00	141,886.55
25,000.00	8.30	-	-	-	-	8.30
75,000.00	-	-	-	1,507.59	4,282.24	5,789.83
2,000.00	-	-	1,161.64	177.88	-	1,339.52
20,000.00	-	-	-	-	-	-
114,257.00	486.00	77.80	13.35	-	8.60	585.75
$2,000,000.00	$114,844.22	$5,344.49	$297,234.76	$210,739.58	$235,210.96	$863,374.01

Back Cover

On the back cover is the actual CRT display during a day of test operation. The numbers along the left side are line numbers used for "bookkeeping". Lines 1, 2 & 3 are reserved for a alarms and computer status information. The rest of the lines are for schedule information giving the run number, route name (Stony Island in this instance), direction of travel, timepoint that information is associated with, deviation from schedule using "+" to indicate half minutes, and relation of deviation to schedule. The difference between "LATE" and "OVERDUE" is that in the former the run has reached and probably left the timepoint while in the latter has not yet reached the timepoint. Characters in the upper left and right corners indicate the status of the display controller.



L C
1
2
3
4 602 STOISL N 79-SI 00+ AHEAD
5 581 STOISL N 79-SI 00+ LATE
6 583 STOISL S 79-SI 00+ LATE
7 586 STOISL N 47-KNG 05+ AHEAD
8 588 STOISL N 63-SI 04+ LATE
9 607 STOISL S 93-SI 01 LATE
10 606 STOISL N 79-SI 00+ OVERDUE
11 589 STOISL S 79-SI 01+ LATE
12 605 STOISL S 63-SI 03 LATE
13
14
15