The simulator is employed to determine a set of parameters defining a telephone "intercept" system with appropriate characteristics.

The intercept system is automatic and involves standard data processing components—data exchange, disk files, and audio response units.

A general purpose digital simulator and examples of its application

Part II — Simulation of a telephone intercept system

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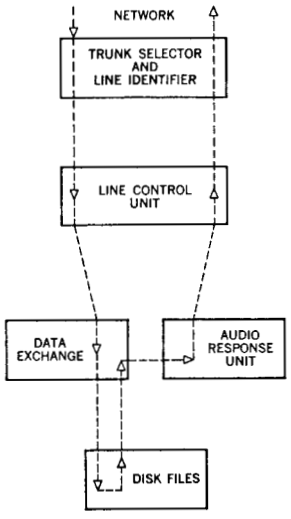
This part illustrates an application of the simulator to the design of a system that automatically intercepts specific telephone calls. The various components of this system interact in such a complex manner that simulation was found to be more expedient than mathematical analysis.

In a telephone network, some calls cannot be put through because new numbers have been assigned or units have been disconnected. Presently such calls are shunted to an operator who informs the calling party about the operational status of the number being called. The operator obtains the necessary information from a directory which is generally updated on a daily basis and reprinted monthly. The expense associated with the handling of such intercept traffic is substantial, consisting mainly of the operators' wages and the cost of intercept directories.

We will now describe the work undertaken to design an automatic system for a particular network. The general design of the system that evolved is shown schematically in Figure 1. In a semi-automatic alternative, which was also considered, the trunk line selector and line identifier unit was replaced by telephone operators. The system consists of the following basic components:

- A trunk selector and line identifier unit (or operator positions for the semi-automatic alternative) to relay intercepted calls to the system.

Figure 1 Intercept system flow diagram



The functional relationship of the system components is shown in Figure 1. The path of an intercepted call through the system is indicated by a dotted line. For the semi-automatic alternative system, calls are intercepted by operators, although the transaction flow is the same as for the fully automatic system.

The design problem at hand was to determine appropriate combinations of systems parameters and corresponding performance characteristics under specified environmental conditions.

design problem

The following system parameters had to be determined:

- Number of trunklines.
- Number of digital channels.
- Number of audio response lines.

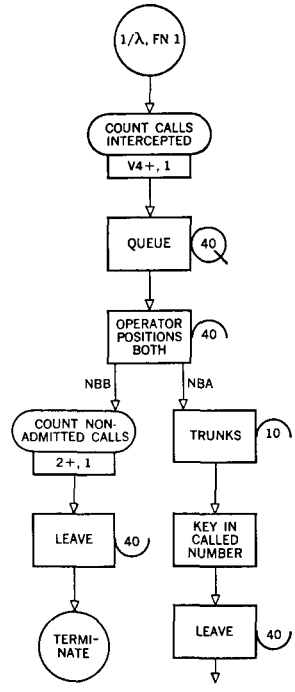
The performance characteristics to be considered were:

- Utilization of components: as high as possible.
- Holding times of components: as low as possible.
- Throughput rates of components: as high as possible.
- Ratio of terminated to intercepted calls: as low as possible.

Specified and fixed were the following environmental conditions:

- Anticipated volume of traffic: 3300 intercepted calls during a busy hour.
- Calls enter the intercept system in a completely random manner (inter-arrival times are exponentially distributed).
- Maximum ratio of terminated (unanswered) to intercepted calls: 1/100.
- Distribution of changed numbers (80 percent) and disconnected numbers (20 percent).
- Types of audio responses.

Figure 3 Initial part for semi-automatic system



The GPSS II model used to simulate the transaction flow for the automatic system is shown by the block diagram given in Figure 2. The model for the semi-automatic system is identical, with the exception of the initial part which is modified as shown in Figure 3. In these simulation models, the operator positions, trunklines, digital channels, and audio response lines were treated as storage devices labelled 40, 10, 20, and 30, respectively. The data exchange, the two control lines (request and acknowledge), and the two disk storage units were considered as facilities identified by the numbers 4, 1, 3, 5, and 6, respectively.

simulation models

The simulated operations are indicated in the blocks representing the operations. The holding time distribution of the storage devices was determined by TABULATE blocks at appropriate points in the model. SAVEX blocks counted the number of calls intercepted, terminated, force-disconnected, normally disconnected, or processed.

In constructing the simulation models, it was assumed that an intercepted call that does not immediately find an available trunkline would be terminated. This termination would be equivalent to sending a "busy" signal to the calling party.

To ensure accurate simulation of the automatic telephone intercept system, great care was exercised in gathering the various input traffic data and in checking out the simulation model. The timing estimates for executing the various programs that were required by the multiplexor to process an intercepted call were provided by programming analysts. Information concerning the operational characteristics of communication facilities was obtained from telephone communications experts. The times required to transmit the various types of audio responses were determined by actual experimentation.

Table 1 System performance

System performance	*Run number* 1	2	3	4	*Average*
Average utilization in percent:					
Trunklines	72.40	71.49	72.94	71.74	72.16
Channels	12.09	10.05	11.06	9.77	10.74
Audio response lines	84.11	83.63	85.14	84.00	84.22
Data exchange	53.51	53.27	53.98	53.01	53.44
Disk file	14.09	13.68	13.68	13.52	13.49
Average holding time in seconds:					
Trunklines	47.725	47.276	47.590	47.754	47.586
Channels	1.989	1.663	1.810	1.623	1.771
Audio response lines	45.086	44.963	45.130	45.599	45.194
Data exchange	0.012	0.012	0.012	0.012	0.012
Disk file	0.304	0.302	0.298	0.299	0.301
Throughput rate in calls per minute:					
Trunklines (system)	54.6	54.7	55.5	53.8	54.6
Channels	54.8	54.3	55.0	54.3	54.6
Audio response lines	54.6	54.7	55.5	53.8	54.6
Intercepted calls	1650	1636	1646	1626	1639
Terminated calls	9	6	0	1	4
Percent terminated calls	0.54	0.36	0.00	0.06	0.24

Table 2 Operator performance

Operator performance	*Run number* 1	2	3	4	*Average*
Average utilization in percent	100	100	100	100	100
Average holding time in seconds	11.907	11.907	11.907	11.907	11.907
Throughput rate in calls per minute	60.1	60.1	60.1	60.1	60.1

simulation results

The system was simulated for the first 30 minutes of operation during a busy hour. This period is considered most critical, since the system must adjust to a sudden increase in the traffic volume during this interval. The simulation detected potential bottlenecks in the system. Consequently, different combinations of trunklines, channels, and audio response lines were tried to determine a combination which enables an intercepted call to go through the system without undue delay.

After a series of test runs to determine appropriate combinations of system parameters, the following line parameters were found to meet the design objectives: 60 trunklines, 15 channels and 50 audio response lines. These values were consistent with the fixed environmental conditions specified for the problem. The test runs also determined that a minimum of 12 operators is required for the semi-automatic intercept system in which operators rather than automatic trunk-selector/line-identifier devices are used. It was assumed that an operator can handle one call every 12 $\pm$ 2 seconds.

Behavior of the system defined by this set of values was measured

Figure 4 Calls intercepted during each three-minute interval

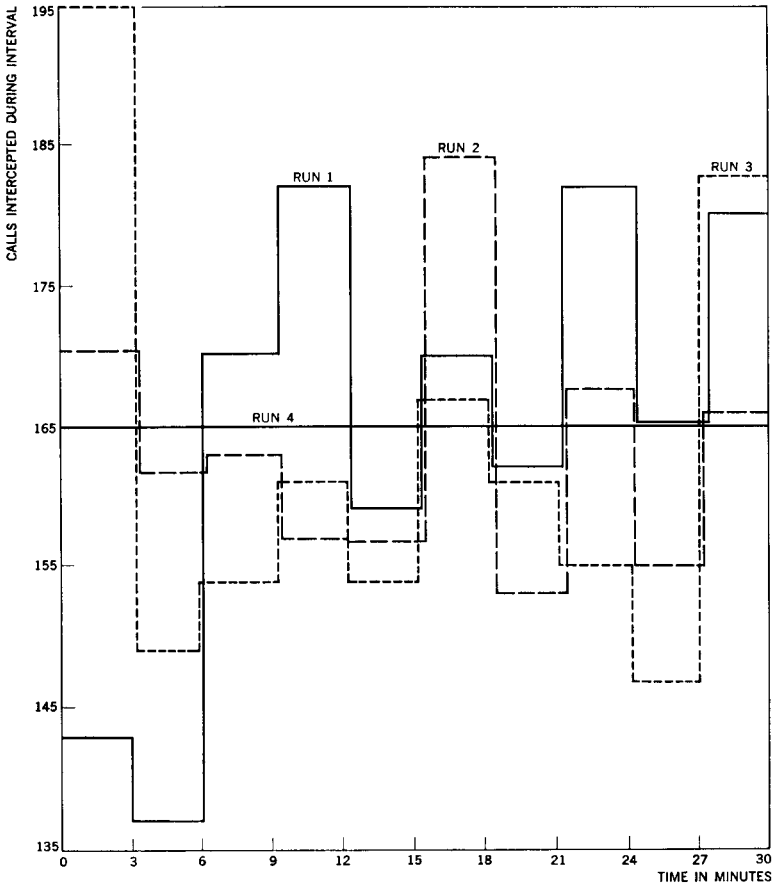
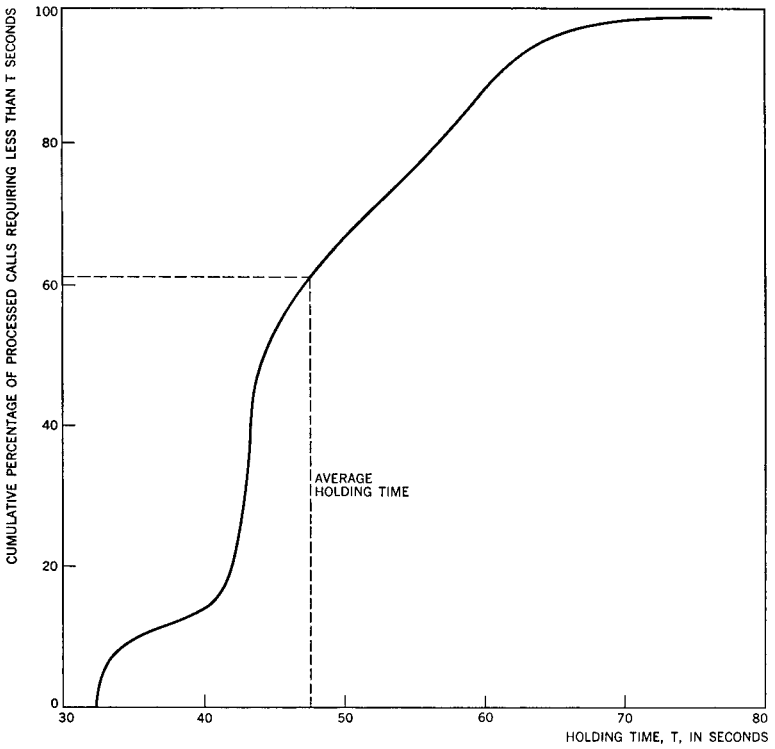


Figure 5 Cumulative distribution of trunkline holding times



by four separate simulation runs. Poisson distributions were used as system input for the first three runs. (Empirical evidence supports the assumption that the pattern of incoming calls is approximately Poisson.) In the fourth run, a uniform distribution—defined by the mean of the first distributions—was used.

Simulation results are given in Tables 1 and 2. Table 1 pertains to both the automatic and semi-automatic systems. Operator performance data for the semi-automatic system is given in Table 2. The consistency of results between runs will be noted.

The nature of inputs is displayed indirectly by Figure 4, in which the number of calls intercepted during each three minute interval is graphed for each run. The distribution of trunkline holding times (transit times through the system) varied only slightly among the four runs. The graph corresponding to one of the runs is given in Figure 5.

In an ideal telephone intercept system, 100 percent of the intercepted calls would be served. However, such a system is not practical from the system design point of view, since it would require additional components which would be idle most of the time, even during rush-hour traffic. Such overdesign could not be justified for the elimination of an already very low percentage of terminated calls.