specific points in the routine, or it will stop and wait for the operator to type in a number before it continues.

L. A. Ohlinger: Does that make it possible to replace a single word, are in effect erase the word and substitute another word?

J. R. Weiner: Very definitely. And incidentally, it has proved to be a very useful facility on many problems.

J. Naines (Northwestern University): Have you made use of transistors in UNIVAC?

J. R. Weiner: No. We have approximately 5,000 vacuum tubes in the UNIVAC, 18,000 crystals, and no transistors. About the time UNIVAC was started, which was approximately four years ago, there were no transistors available.

Dr. S. N. Alexander (National Bureau of Standards): I would like to point out one thing about the maintenance experience of the UNIVAC.

We tried to set it up so that the maximum possible useful time would be available to Census, and no holds were to be barred, including such things as borrowing spare chassis out of Machines 2 and 3 which were in production. Therefore, this represents an advantage which will not be available when the baby is taken home.

However, I think that this is not to be construed as criticism. It is just indicating that when you are trying to get Number 1 going, you will do anything possible to keep it going and learn what it is you need to fix in the machine in order for it to stand on its own feet.

I would also like to point out that the maintenance people available for this job are probably the peak quality personnel that will ever be allowed to maintain one of these machines. When it is maintained by the designers it gets a loving care that it will probably never receive again.

For this reason I would like to point out that you must weigh these facts with the records ascertained, trying to balance out how much this offsets the fact that it is Machine Number 1 which we are trying to learn a great deal about.

I hope the records on Machine Number 2 will become available in which it will be operated and maintained by people away from the plant but who have been trained at the plant by the Eckert-Mauchly personnel.

Would you care to add anything to that, Mr. Weiner?

J. R. Weiner: I would like to say that I agree with everything that Dr. Alexander has said. However, I would like to add a few comments.

The first UNIVAC was the first machine of its type and a rather ambitious machine. Although we have time listed which we call preventive maintenance time, a good bit of that time has been spent in hunting troubles down, and once they were hunted down and fixed they were troubles that would not recur in later machines; this has proved true on UNIVAC Number 2. We have not had the trouble on Number 2 that we had on Number 1. I would say also that perhaps 80 per cent of our time on Number 1 has been spent in trying to get input-output operation as reliable as computer operation, operation that would completely satisfy Dr. Alexander. I feel that we have probably succeeded in doing that to a very great extent on Number 2.

I certainly agree that you do not want to use $10,000-a-year engineers for maintaining UNIVAC, and I do not think we will. I would say the troubles we have had on Number 1, and we have had many, are not at all representative of the sort of thing you would expect on later machines.

B. V. Bowden (Ferranti, Ltd., England): I would like to ask what sort of magnetic tape you use in the memory?

J. R. Weiner: We use metal tape of our own manufacture. At the time we started working on UNIVAC, there was no tape available that we felt was sufficiently reliable, and we started our own tape development program. I think we were very fortunate in doing that. The tape is metal base and we put a magnetic plating on it. We do have pin holes, and other defects in the tape but we take care of them by punching out the occasional bad spots on the tape, before the tape gets to UNIVAC. In other words, we inspect every reel before it is used, punch out the bad spots and detect them automatically on UNIVAC, and do not write on those portions of the tape or read from them. We find that this procedure has worked out quite well.

Performance of the Census UNIVAC System

J. L. McPHERSON S. N. ALEXANDER

In June of 1948 the National Bureau of Standards acting on behalf of the Bureau of the Census contracted with the Eckert-Mauchly Computer Corporation for a UNIVAC System. This UNIVAC System, now generally known as the Census UNIVAC System, was accepted on March 30, 1951, and since that time has been devoted almost exclusively to tabulating results of the 1950 Census of Population and Housing.

We will try to present here certain facts about the acceptance testing and about operating experience. We also will indicate the inferences we have drawn from these facts. We are aware that any given body of facts may be, and often is, interpreted in a variety of ways depending upon just what it is that the interpreter is trying to prove. We will try carefully, therefore, to distinguish between our facts and our inferences. Furthermore, we will try to present the extremes of the conclusions that might be drawn from the facts. One of your authors is an engineer with some familiarity with the difficulties of physically realizing the grand promises frequently made for, and not always by, engineers. Your other author is in the business of producing statistics. He is interested in any tool that will increase the efficiency with which he conducts this business. For purposes of this paper, at least, each of us will do his best to be a good advocate for his devil.

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Acceptance Testing

At the time it was accepted the Census UNIVAC system consisted of a UNIVAC computer, four Uniservos, a Uniprinter, and a Card-to-Tape Converter. The question of the acceptability of this system was a difficult problem. Our contract for a UNIVAC System specified a variety of operating and performance characteristics, such as the instruction code, the execution time for each instruction, and the required tape speed in characters per second. However, we quickly decided that to test specifically for each of the detailed facilities required by the contract not only would be extremely difficult to plan and to monitor but also would provide information beyond our ability to interpret.

We wanted a device to do Census work. If there was a high probability that the

UNIVAC would do Census work efficiently we wanted to accept it and if not we wanted to reject it.

At the time the UNIVAC system was submitted to the government for acceptance testing the only significant problem we had programmed for it was the tabulation of the Second Series Population Reports for the 1950 Census of Population. This program had never been used by the UNIVAC. It was not "debugged." For this and many other reasons it was not a suitable program to use for acceptance testing. However, its existence enabled us to estimate a statistic which proved very useful in designing an acceptance test. This statistic was the time it should take the UNIVAC to tabulate the Second Series Population data for one reel of population information. Our estimate was 20 minutes. (Later experience indicated that the actual average time per reel for this problem is 19.6 minutes.)

We must admit that we did not realize the importance of this 20-minute figure until we had explored several lines of approach to an acceptance test for the central computer. We had great difficulty in deciding just what would be a reasonable upper bound to set on the number of wrongly executed instructions per million. Moreover, we found that it was by no means easy to decide how we would go about determining how many orders the machine had wrongly executed, if any, in the course of a program.

We spent a considerable amount of time fruitlessly searching for a way to get to the heart of this problem. Then, happily, we sought the advice of Dr. Joseph F. Daly, Chief of the Statistical Methods Section, at the Bureau of the Census. He pointed out that the important consideration was not how many errors the machine made when things went wrong, but rather, how often it could be depended upon to get through a problem correctly. With Dr. Daly's help we finally concluded that what we wanted was a machine which would be fairly certain to operate satisfactorily throughout any given 20-minute running period. In addition, we felt that it would be reasonable to accept a machine which would be in operation at least 50 per cent of the time; for we assumed that if the computer had the required reliability, the problem of keeping it in operation most of the time would be mainly a matter of gaining experience in maintenance.

In order to arrive at a set of numerical specifications for the test, we took over one of the standard sequential sampling plans, using the 20-minute problem as a sampling unit. Since we could not take a random sample of such 20-minute units, the probabilities associated with the plan were perhaps not too meaningful. Nevertheless, it may be of some interest to note that if the chance that the machine would get through any particular 20-minute run was independent of its chances of getting through any other 20-minute run, then the plan had the following characteristics:

1. If the machine was such that on the average it would get through 90 per cent of its 20-minute problems successfully, the test would be almost certain to accept it (the chance of rejection being only 1 in 100).

2. If the machine was such that on the average it would get through only 70 per cent of its 20-minute problems correctly, the test would be almost certain to reject it (the chance of acceptance being only 1 in 100).

We prepared two routines to test the central computer. One of these was to test internal computation ability and the other was to test the communication between the computer and the magnetic tapes. Each of them was timed to require 20 minutes to complete. The following abstract from the acceptance test procedure for each of these two tests indicates the manner in which they were conducted:

"The test shall be rated as 'passed' if at the end of any test unit:

1. The 'down time' does not exceed the 'running time' and simultaneously:

2. The number of completed test units with one or more major defects does not exceed 0.186×(number of units completed) minus 3.41.

3. The number of completed test units charged with minor defects does not exceed one third of the total completed test units.

"The test shall be rated as 'failed' if at any time the number of completed test units with one or more major defects exceeds 0.186 × (number of units completed) plus 3.41."

Major and minor defects were defined in the test rules. "Down" time was defined as "total" time minus "running" time; and "running" time was computed by multiplying the number of completed test units by 20 minutes. Thus the UNIVAC was credited with having operated successfully for 20 minutes each time it produced an error free unit regardless of how long it might have taken to complete that unit.

In addition to the two tests of the central computer we designed a test for the Uniprinter and a test for the Card-to-Tape equipment. We will say more about them shortly. First we want to report on the performance of the central computer during the two tests applied to it. Certain calculations concerning the duration of these two tests can be made. These are:

	Computer, Hours	Communications, Hours
Minimum time possible to pass	6	7
Expected or average time to pass if 90% successful	9	$10\frac{1}{2}$
Expected or average time to fail if only 70% successful	7	8
Probable maximum length of test	$25\frac{1}{2}$	30

The test of computation ability was passed in 6 hours and 36 minutes, the test of communication between the computer and the magnetic tapes was passed in 9 hours and 28 minutes. One of the 18 test units successfully completed during the test of computational ability was charged with a minor defect. According to the test rules there could have been six units so charged. The test of the communication between the computer and the magnetic tape terminated with six of the 19 successfully completed test units charged with minor defects.

The Uniprinter test required a block of 60 words of information to be printed not less than 200 times. The constants in the formula for the Uniprinter test were such that we would be almost sure to accept a printer that would print 95 per cent of the 60 word blocks perfectly and almost sure to reject a printer that would print only 90 per cent of the blocks perfectly. Here the time computations indicated the following:

	Hours	Blocks
Minimum possible time to pass (1.5 minute units)	5	200
Expected or average time to pass if 95% successful	7	274
Expected or average time to fail if only 90% successful	$5\frac{1}{2}$	216
Probable maximum time	14	566

This test was passed in 6 hours and 10 minutes.

For the Card-to-Tape equipment we decided that a device capable of successfully transcribing the information from punch cards to magnetic tape at an average rate of 70,000 cards per 8-hour shift would be satisfactory. This converts to about ten good reels of tape every 12 hours. There were necessarily two phases to this test. First the cards had to be run through the converter to produce the tape. Second the tape had to be run through the UNIVAC to determine whether or not it was satisfactory.

According to the conditions we established for this test it was necessary that the Card-to-Tape equipment produce ten "satisfactory" reels in 12 hours. The manufacturers were permitted to prepare as many reels as they could during the 12 hours. It was up to them how much time was spent running cards through the machine and how much time was spent making any adjustments they felt were needed.

It was not necessary for a reel of tape to be perfect in every respect to be satisfactory. There are two types of errors that the Card-to-Tape equipment can make.

1. It can record on the tape the pulse pattern for a character (or combination of characters) which is readable by the UNIVAC but which does not represent the character (or combination of characters) which appears in the punched card being transcribed.

2. It can record on the tape a pulse pattern which the UNIVAC cannot interpret. The check circuits in the UNIVAC are such that it stops when it encounters a pulse pattern it cannot interpret.

A satisfactory reel might contain a small number of the first type of errors but it could not contain any errors of the second type.

After 9 hours and 55 minutes of operation and maintenance the Card-to-Tape device was preparing the 16th reel. By then 14 reels had been tested by the UNIVAC and 11 of them were found to be satisfactory so the test was "passed."

Let us now recapitulate the results of the four tests. The UNIVAC passed the test of computing ability with ease. It passed the tape reading and writing test, but by no means as easily as it passed the computing test. The Uniprinter test and the Card-to-Tape test were both passed quite satisfactorily.

We were (and we are sure the manufacturers were) pleased and encouraged. We gladly accepted the UNIVAC system and proceeded to put it to work on Census tabulations as rapidly as possible.

Operating Experience

The Second Series Population Reports problem, which was the problem we thought we were ready to start on the UNIVAC, consists of four main parts. We call these parts: tallying, merging, dispersion, and summarizing. Each is a separate entity in the sense that each consists of a program of instructions recorded on a separate instruction tape. Furthermore, the output of the tallying is the input for the merging, the output of merging is the input for dispersion; and the output of dispersion is the input for summarization. The outputs of summarization are the Census tabulations we want to publish. Although these parts are separate and distinct they do not account for equal amounts of UNIVAC time. The tallying part is far and away the most time consuming. At least four or five times as much UNIVAC time is required for tallying as for the other three parts combined.

In the preceding paragraph we said we thought we were ready to start this problem when we accepted the UNIVAC system. More precisely we thought we were ready to start the tallying part. As it turned out, the program of instructions for this part contained a few errors and it was not until approximately a week after we accepted the UNIVAC that we had a corrected program and were actually "in business." Filled as we were with high hopes and expectations the week we spent in getting the last bug out of our instruction program was an investment we hated to have to make. Our patience wore thin. Like children at the circus we could not wait for the show to start. Now, about 8 months later, we are years and years wiser. Now we recognize what a phenomenally good job we had done preparing that program. We doubt that ever again will we be fortunate enough to succeed in debugging a program as complicated as our tallying routine in as short a time as one week.

By the middle of April 1951 we knew we had a tallying program that worked and that we had some employees who knew how to use it. These people, however, were skilled programmers. We needed their service to complete the programs for merging, dispersion, and summarizing and to develop programs for other Census work. For several weeks before we accepted the UNIVAC we had been training people to be UNIVAC operators but they had had no practical experience. Since the UNIVAC we accepted was the first one in the world and because right up to the time we accepted it the engineers who built it had been working on it, our operators had never manipulated the controls of a UNIVAC until they were taught how to run our tallying routine. We were pleased with the rapid progress these operators made. By about the middle of June we had enough confidence in them that we felt they could operate the UNIVAC without the supervision of a programmer. We then began full time operation, 24 hours per day, 7 days per week. Four 8-hour shifts per week the UNIVAC has been assigned to engineers for preventive maintenance. The rest of the time we have been operating it except for those times when a malfunction necessitated emergency maintenance.

One of the responsibilities of our operators is the maintenance of a log in which they must account for every minute. We have been quite satisfied with the way our operators have kept this log. In fact their ability to keep it has somewhat exceeded our ability to digest it.

We have summarized and analyzed the log for about 85 per cent of the period beginning June 20 and ending October 28. The missing 15 per cent consists of a few days early in July and a few days early in August. To the best of our knowledge and belief there is no reason to think UNIVAC performance was any different during these periods from its performance during the periods for which the log has been summarized.

We do not have time to present our summary and analysis in complete detail. Therefore, we will concentrate on just one phase of our analysis, namely the proportion of the time the UNIVAC has been useful to us. Remember we have been on a 24-hour-per-day 7-day-per-week schedule. Table I, "Summary of Census UNIVAC Log," provides practically all of the numbers necessary to follow our analysis.

The conclusion, most favorable to the UNIVAC system, that can be drawn from these data is that it was "available for use" 59 per cent of the time. This is an important statistic and we are

Table I. Summary of Census UNIVAC Log

June 20 to 26, July 8 to August 4, August 13 to October 28, 1951

	Minutes	Per Cent
Total in period	161,280	100.0
Regularly scheduled preventive maintenance	32,872	20.4
'Down"	33,667	20.9
Tallying	37,823	23.5
Success (945 reels)	23,499	14.6
Failure (723 reels)	14,324	8.9
Equipment fault (569 reels)	10,687	6.6
Census fault (131 reels)	2,854	1.8
Unknown (23 reels)	783	0.5
Salvaging	18,547	11.5
Success (497 reels)	11,745	7.3
Failure (329 reels)	6,802	4.2
Other*	36,854	22.9
Unexplained	1,517	0.9

* Other time includes time spent on merging, dispersion and summarization; time spent "proving in" routines, time during which problems other than the Second Series Population Reports were being run, time during which the UNIVAC was loaned to non-Census users.

encouraged by it. Remember for our acceptance test we had decided that a device which could be operable 50 per cent of the time would be useful to us.

Another conclusion, not nearly so favorable to the UNIVAC system, that also can be drawn from the same data, is that it was "useful" only 28 per cent of the time. This is probably at the extreme low end. The true measure of utility of the system during the period analyzed undoubtedly falls somewhere between 28 and 59 per cent.

The 59 per cent "available for use" is obvious from the table. It is "total time" minus the 20.4 per cent of the time allotted to regular preventive maintenance and the 20.9 per cent of the time spent on emergency maintenance.

The 28 per cent "useful" time requires some interpretation of the data shown in Table I and some estimates based on these interpretations. These are summarized in Table II.

Before we enter numbers in the "Useful" and "Lost" columns let us briefly describe a preliminary operation involved in the preparation of the Second Series Population Reports. The Census information for each person is recorded on a punch card. Before we can use the UNIVAC we must transfer this information to magnetic tape using the Card-to-Tape converters. One reel of tape accomodates slightly less than 10,000 punch cards. After the data has been recorded on tape we start the tally, merge, disperse, summarize sequence described earlier.

During the period on which this analysis is based we attempted to tally 1,668 reels. This tallying process accounted for approximately 22 per cent of all the time being analyzed. We succeeded in tallying 945 of the 1,668 reels and failed on the remaining 723. We will say more about the failures presently. First let us make a few comments about the successes. We know that if the UNIVAC functions properly in all respects it requires 20 minutes to tally a reel of data. At this rate the minimum time in which we could expect to tally 945 reels would be 18,900 minutes. Actually we spent 23,500 minutes on these reels. What caused this difference of 4,600 minutes? The explanation is that during the course of tallying some, but by no means all, of these reels the UNIVAC malfunctioned. For example, our log might show that 10 minutes after a given reel was started on the tallying process the UNIVAC failed and it was necessary to call a maintenance engineer. The 10 minutes was lost.

Table II

	Total, Minutes	Useful, Minutes	Lost, Minutes
Successful tally	23,499	18,900*	4,599
Tally failure, equipment fault	10,687		10,687
Tally failure, Census fault	2,854	2,854	....
Tally failure, unknown fault	783	783	....
Salvage	18,547	3,951**	14,596**
Subtotal	56,370	26,488	29,882
Subtotal, per cent	100.0	47.0	53.0
Other and unexplained	38,371	18,034†	20,337†
Maintenance	66,539		66,539
Total	161,280	44,522	116,758
Total, per cent	100.0	27.6	72.4

* 945 reels at 20 minutes per reel

** Of the 723 reels which failed on tally, 154 or 21.3% were not definitely attributable to equipment fault; here 21.3% of the time spent salvaging is classified as useful.

† Here the 38,371 minutes in the total column is distributed between useful and lost in the same proportion as the preceding subtotal.

After the UNIVAC was repaired it still took 20 minutes to tally that reel.

Now what about the 723 reels we were unable to tally. Our log is ambiguous about why 23 of these failed. For 131 of them the failure could be attributed to a mistake made by Census personnel. For example the Card-to-Tape operator may have fed the punch cards upside down. The failure of 569 reels we classified as "equipment fault." By this we mean that somewhere along the line the UNIVAC system failed. A typical case is the one where the tallying operation proceeds for several minutes, perhaps 12 or 15, and then the UNIVAC stops because it reaches a section of the input tape it is unable to read. This may be because the Card-to-Tape device malfunctioned when the cards were recorded on tape. It may be because the Uniservo on which the tape is mounted is not functioning properly. We believe, and we think the Eckert-Mauchly Company people agree with us, that malfunctioning of the Card-to-Tape equipment was responsible for most, but not all, the tally failures attributable to "equipment fault." In September the company made some changes in the Card-to-Tape which we, and they, hope will improve its performance significantly. As of October 28 it was not possible to say with assurance that these changes were beneficial but what little evidence was available indicated that they were.

We spent something over 14,000 minutes trying to tally reels on which we eventually failed. Of this 10,687 minutes was spent on the 569 reels which failed because of incorrectly operating equipment. This time was just as real a loss as the time the UNIVAC was not available for our use.

Perhaps here is the place to interpolate some comments about UNIVAC tape reading and writing. There are approximately 1,000,000 characters recorded on each full reel produced by the Card-to-Tape device. To the best of our knowledge UNIVAC tape reading (and writing) speeds are at least twice those which have been attempted for any other computer. The UNIVAC reads tape at 10,000 characters per second. Here, then, is a requirement for an extremely high order of accuracy. The error frequency must be less than one in a million before we can successfully tally a reel. From the engineer's point of view the 945 reels that were tallied successfully are testimony that important progress in tape recording has already been achieved. From the user's point of view the 569 reels which were not acceptable to the UNIVAC represent a challenge to engineers to improve still more the fidelity of tape recording. To the engineers, we say that this may be the area in which the most important contributions can be made toward maximizing the usefulness of electronic computers for handling large masses of input, intermediate, and output data.

What do we do about reels we are unable to tally? At first we did the obvious thing; we reran the cards through the Card-to-Tape, device preparing new reels in the hope that we could successfully tally them. Then we decided to develop a program we called our "Salvage" routine. This was a routine to use the UNIVAC to reproduce the good parts of defective reels. It depended on the operator to substitute good information for the bad parts of defective reels.

The rules under which our operators worked this routine were technical and complicated. We will not go into them here. It will suffice to report that during the time we are analyzing there were 826 reels attempted on the "Salvage" routine. We succeeded in salvaging 497 of these and failed on the other 329. Here a success is the creation of a new reel that can be used as input for our tally routine. A failure represents a decision on the part of the operator that he cannot create a new reel without violating the rules relative to substitution of good information for bad.

It takes an average of 45 minutes to run a reel full of data on the Card-to-Tape device. When we introduced the Salvage routine we hoped we would get tallyable reels with a smaller investment of time than would be required if we reran at Card-to-Tape each reel which failed on the tally routine. As it worked out we did not save nearly as much time as we had hoped. It would have taken 37,170 minutes to rerun 826 reels on Card-to-Tape. We spent 11,745 minutes successfully salvaging 497 reels. In addition we spent 6,802 minutes on the 329 reels we were unable to salvage. These 329 reels had to be rerun on Card-to-Tape which required 14,805 minutes. Thus we spent a total of 33,352 minutes on these 826 reels which is about 4,000 minutes less than would have been required if we had not introduced the salvage operation.

This saving is about 10 per cent, which while it is not trivial, is significantly less than the 40 to 50 per cent saving we had hoped for.

As far as the UNIVAC itself was concerned the time spent on this salvaging operation was something we had not originally contemplated. In a sense that time is lost even though it does not appear in "down" time. If reels had not failed during the tallying operation there would have been no need for the salvage process. It would be unfair to the equipment to charge it with all the time spent salvaging because our own errors were responsible for our inability to tally some reels. However, since 78.7 per cent of the tally failures were because of equipment fault we may be justified in saying that 14,956 minutes spent salvaging was lost to us as far as the production of population statistics was concerned. Much of this lost time is chargeable to faulty recording by the Card-to-Tape device.

Now we can accumulate the "Useful" and "Lost" time for these items which are those for which our log is reasonably specific. These subtotals indicate that 47 per cent of this time was useful and the balance was lost.

At this point we can use these percentages to classify the "Other" and "Unexplained" time. We realize that this is quite arbitrary. It certainly can be argued that this overstates the "Lost" time because of the inclusion, in the total 38,371 minutes, of time spent "proving in" routines. We are, however, attempting to develop a lower bound for our measure of utility and in that light we believe this is justified.

Finally we add the maintenance time.

Now the totals indicate that 27.6 per cent of the time was "useful" and the balance was "lost." This then is how we estimate the lower or our two percentages. The truth undoubtedly lies somewhere between 28 and 59 per cent.

One very important general comment should be made before we conclude this paper. It is that we cannot point to a single case where we can say with certainty that our UNIVAC system produced a wrong answer that could be traced to malfunctioning of the equipment. The error detection circuitry prevents this. When a malfunction occurs the UNIVAC stops and refuses to deliver any answers It just will not deliver wrong answers.

We have had our troubles with our UNIVAC; we have lost patience with it many times; we have learned that we have very much to learn about how best to use it; and we have learned that the engineers have very much more to learn about how best to maintain it. We have on occasions been quite disappointed. But we have not been, and are not discouraged.

We are currently planning work which we believe will keep our UNIVAC system busy until the fall of 1952 at which time we expect to move it to Washington. Our estimates indicate that at its present levels of performance our UNIVAC system will accomplish this work at about one half the cost of doing it with any of the other tools which are available to us.

Discussion

J. W. Carr (MIT): Have you planned any programming so that you can process your log data itself? It would seem that possibly that would aid in producing statistics.

J. L. McPherson: The answer is no. We have found that programming time is at a great premium. I think that it is an interesting suggestion. The log is not a very orderly thing. Personally I would hesitate to try to program the summarization and analysis of it because I think it would be a job. I do not think it would be impossible by any means. We do not feel that we can turn our resources to that sort of thing with all the census work that is waiting to be programmed.

E. C. Berkeley (Edwin Berkeley and Associates): In your chart (Table I) of the use of UNIVAC time you show 22.9 per cent of time spent on other problems, including time during which the UNIVAC was loaned to noncensus users. On what basis is UNIVAC loaned to noncensus users who can use UNIVAC?

J. L. McPherson: Maybe this was just a fancy way of saying, "loaned to the manufacturer." Most of this was time that the Remington-Rand people were using the machine in accordance with an arrangement we made with them. This was in return for some programming assistance that they gave us. These people deserve a certain amount of sympathy. They worked, sweated, and slaved to produce a UNIVAC that operated. Finally they did, and along we came and accepted it and they did not have one. This is a situation which the company seems to be repeating.

In addition we have, as a part of the Federal Government, felt a certain responsibility to other parts of the Federal Government to let them try problems on our UNIVAC for purposes of evaluating it for their work.

I think it is correct to say that the only noncensus users have been either the Eckert-Mauchly programmers themselves, in accordance with our barter arrangement, or other Federal agencies which have made arrangements, generally with me, to get small amounts of time to try UNIVAC out on test problems.

A. Wertheimer (Navy Department): You said you estimate that the cost of using the UNIVAC will be about one-half of any other means. Can you tell us what you estimate it will cost you to maintain and operate the UNIVAC in Washington, if you can include also all appropriate costs, like the coders, operators, maintenance men, and so on?

J. L. McPherson: About $20,000 a month is what we are estimating.

L. A. Ohlinger (Northrop Aircraft Company): I would like to ask how many programmers and coders are employed in order to keep UNIVAC busy full time?

J. L. McPherson: We do not distinguish between programmers and coders. We have operators and programmers. You must remember the census job is such that once you have a program, you keep the machine busy on that one program for months. We have five operators and, I think, eight programmers.

P. C. Rapp (Bell Aircraft Corporation): I would like to ask if you have tried to do more or different things in view of the availability of the computer than you would have done with just punched card equipment?

J. L. McPherson: Yes, indeed. On this job that we are doing now, Second Series Population Reports—the proceedings of the meetings of the Association for Computing Machinery at Aberdeen about three years ago include a paper that tells how we carry this process much further with UNIVAC than we can carry it with punched cards.

The UNIVAC output, a sample of which you saw on one of Mr. Weiner's slides of a table showing population statistics classified by color, sex and age, is arranged almost exactly as we want to publish it. The punched card techniques we use do not usually provide the statistics in that arrangement.

If I can talk about the table Mr. Weiner projected for a minute—there were seven columns on that table namely (1) total both sexes, (2) total males, (3) total females, (4) white males (5) white females (6) nonwhite males (7) nonwhite females. I do not remember exactly how many lines there were on the table but the first few were (1) total

(2) under five years of age, (3) under one year (4) one or two years (5) three or four years. The UNIVAC output provided numbers for all columns and all lines. The punched card techniques we use would supply numbers for only the fourth through the seventh columns and the third through the fifth lines. We would have to compute manually the numbers for the other columns and lines. I do not want to say punched card equipment is incapable of producing an output as satisfactory as UNIVAC output, but it is true that using the abilities of the people we have at the Census we have not devised ways to get this kind of output from punched card equipment and we have obtained such output from the UNIVAC. We do not know how to do it using the punched card equipment and do it economically. So we feel that we are not only replacing a lot of punched card equipment but a lot of clerical work in the computation of derived statistics which has to take place when we use the punched card equipment.

W. H. MacWilliams (Bell Telephone Laboratories): Two questions about the salvaging in your table. I do not quite understand the basis of it since if you add the successful reels, 497, and the failures, 329, you come out with a larger number than the failures that you had to start with, 826 as compared to 723; and second, what was involved in the 329 reels that were failures to the end? Were you able to reprocess them or did those people just not get counted?

J. L. McPherson: As to the first question, this, I think, is simply because of the incompleteness of the time period. You should not expect the number that we tried to salvage to equal the number that we failed to tally. Some of these we tried to salvage could have been tally failures that occurred either prior to June 20, or during any one of the periods that are not accounted for, or it could be the second, third, or fourth attempt to salvage the same reel.

On the second point, I think all I can do is define successful salvaging. Successful salvaging is the creation, at the UNIVAC, of a reel which we then try to tally; whereas a failure in the salvage operation represents a decision that we must go back to the card to tape equipment and rerun the cards from which that reel was originally prepared. This decision is reached in terms of technical rules that we supply our operators.

J. B. Lindon (Consolidated Edison Company of New York, Inc.): Assuming that you initially punch the cards manually, assuming further that you did not have the cards and you were going directly to the tape, what factor of error do you think you would obtain? Also what factor of error exists between the cards and the tape?

J. L. McPherson: We have very little evidence on which we can base an answer to the first question. We have gone directly from manuscript to tape only in the case of our programs, using the Unityper that was described. We find on the average one out of every 60 words will contain an error. A word is 12 characters So this is one error in 720. We have told our operators who are doing this transcription to be extremely careful. I think we are getting something like four or five times this 720 per day which, if I can do some very quick mental arithmetic, would convert to something like the information for 30 people recorded on tape per operator per day. For 150,000,000 persons, it would take the Defense Budget to pay the operators, and we would still have every sixth person with an error.

The evidence we have with respect to the use of the card-to-tape equipment is that it makes practically no errors of commission. In our acceptance tests we were willing to accept a rate of $1^1/_2$ errors per thousand cards. We were well below that. I do not recall ever seeing any statistics that would indicate that it was making more than about 12 errors per thousand cards, and this was when we thought that the equipment was in pretty bad shape.

J. B. Lindon: Could we assume that you could safely impulse a tape from a card, store it away for some length of time, and then dig it out and process it? That is to say not process it immediately—say you had some statistical information that it was not imperative to process, you could defer processing it, would you have sufficient confidence in the card to tape impulsing to put it off, say, for six months of a year?

J. L. McPherson: Well, we do. We do not like to have to wait those times in some of this work, but we actually are just now getting around to making the second use of some information that we recorded on tape and used for the first time six and seven months ago.

J. L. Lindon: Would it not be true that samplings, instead of making the complete run of statistics, may reveal the information you want. That is to say, you would accumulate it on the tapes but only use it as conditions warrant supplying the information.

J. L. McPherson: Well, this sounds like a Utopian kind of Census life that a lot of us would like to lead. Many of us think we could use samples to provide a lot of information, but we do not feel that this would be generally acceptable to the public on the one hand, and secondly, we do not think we do not think we know too much about just which items to put in that category. I think probably most of the people here are familiar with one of Professor Von Neumann's theories. I think it reduces to about this: we should not publish the census report; we should just keep it on tape and when you want to know what the number of children of school age in your community is, you dial some proper combination on your telephone, and our machine reads it back to you. But this is a long-range view.

J. M. Bennett (Ferranti, Ltd., England): What is the size of your regular maintenance staff?

J. L. McPherson: I refer you to the gentleman on your right for this, rather the two gentlemen on your right.

S. N. Alexander (National Bureau of Standards): Because the Census machine is presently being maintained under contract by the Eckert-Mauchly Company, I think that figure should come from them. I would like to say that the Census has four people in training to take over this task, and I believe it is far from enough, but it is a difficult field in which to recruit these days, as those of you who are trying to get electronic engineers know. I will turn the question over to Mr. Weiner. He can give the number of men he applies to this job.

J. R. Weiner: (Eckert-Mauchly Computer Corporation): We have a rather large UNIVAC group. The people in that group work both on test and maintenance of the machines. It is not the sort of thing you can give a direct answer to and say, three, four, or ten. The point is we put as many people on as are required at any one time. We may have two technicians and one engineer on it at one time. We may have three or four engineers on it at another time. But in general I would say that it runs perhaps two technicians and an engineer on maintenance periods, and on the emergency engineering calls, one engineer comes in to handle it. If it turns out that it is beyond his capabilities, he gets in touch with another engineer who also comes in. But I do not know of any emergency calls that have occurred that two engineers have been unable to handle.

Now, as I mentioned before, it would be very nice to have the engineers on duty full time and when the machine does break down the engineer is there to fix it immediately. It is really a question of how long you want to take to fix the machine. It is a rather complicated device, and if you have one man there and he is not familiar with the entire machine—if something goes wrong on Uniservo, for example, he is going to get in touch with the man who knows the Uniservos inside and out to come in and help him. Does that answer your question?

J. M. Bennett: Yes. It has raised another one, though. Do you propose to continue maintenance when you go to Washington, for example, with these technicians under training?

J. R. Weiner: The people under training are engineers, and we hope that the Census Bureau will be able to maintain the machine with the people that are undergoing training. I think Dr. Alexander may have something to say on that also.

S. N. Alexander: We are trying very hard to see if we cannot get an arrangement whereby the Federal agency owning the equipment provides the day and night nurses and we hope that the Company will provide the physicians on call, so that when it looks like the patient is in a bad way we can get expert attention locally. This should not be too difficult because in the Washington area if everything goes well, there will be three such machines within another year, and this certainly will justify some backstopping by the supplier of skilled people capable of helping out.

I think there is a point to be emphasized here. This machine is really two kinds of machines in contrast to the ordinary computing machine. It has such an unusual input system that the special equipment associated with the input system and the mechanical auxiliaries require one kind of specialization and the internal electronics require another kind of specialization. While it is perfectly possible for a man to be reasonably familiar with everything, I think to do really good emergency servicing you will need specialists.

I would also like to add to this information that the electronics side of the machine behaves remarkably well in comparison to the mechanical and magnetic devices judging from the maintenance reports which come to us as the holder of the maintenance contract. It is in that area where the greatest development is needed, and incidentally where we are putting the greatest pressure on the Company, with respect to the delivery of UNIVACS 2 and 3. I think it is fair to say that there has been a response to this pressure. I expect to see Number 2 UNIVAC pass a more stringent acceptance test on the communication between the UNIVAC and the tapes.

J. Belzer (Battelle Institute): Mr. McPherson, I would like to know whether this equipment will at any time be available outside of the Census Bureau, or will the load of the Census Bureau still be great enough to keep it going, or perhaps do you feel you will need another UNIVAC?

J. L. McPherson: We certainly feel we have enough UNIVACS right now. We think that eventually we will have no trouble keeping three or four busy when we are in the relatively low phases of the 10-year cycle of census work. This I cannot document with statistics, however. We do not want another UNIVAC tomorrow certainly, because we are still learning how to make this one sit up and bark, and until we feel we know a good deal more about the one we have we will not be too anxious to get another.

We do have peaks and valleys in our use of the equipment. For example, as of right now the UNIVAC is short of work because we have had a rather unhappy two weeks most recently with the card-to-tape equipment. What the card-to-tape equipment has been turning out has been not acceptable; consequently, there is nothing for the UNIVAC to do. If somebody happens to have a nice, big, important problem in his back pocket and it is all programmed, and he said to me this afternoon, "Will you do it," maybe I could do it for him. By tomorrow afternoon this golden opportunity may be gone.

E. C. Carlson (Mutual Life Insurance Company): Can you tell me just how much equipment, tabulating or otherwise, you are replacing with the UNIVAC?

J. L. McPherson: I think I have to just say no, I cannot. I am afraid I cannot elaborate much on that. The Census has a tremendous installation of tabulating equipment, and UNIVAC has taken a big load off that equipment, but we have a tremendous census, too, so that we did not cancel out any equipment. We have plenty of work for the UNIVAC and all the other equipment that we have.

It might be interesting and amusing and enlightening to sit down and try to estimate just how much different equipment we would use to do jobs that we plan to do with UNIVAC. The fact is that on the one hand, those of us who know UNIVAC, have been too busy just trying to make UNIVAC work, and those of us who know the other equipment have been too busy making that equipment work.

B. V. Bowden (Ferranti, Ltd., England): Are you going to use the same equipment for the census of production as well as the census of population? Are you going to use the same equipment for doing other censuses, such as the census of production, the census of distribution, and the census of the retail trade and that kind of thing as well as the census of population?

J. L. McPherson: We are in the process of trying to answer that question ourselves. My own answer is yes, I would like to think that we will have a complete large-scale electronic computer processing of the so-called economic census. However, this is by no means certain.

If I predict, I will guess that we will do part of it using punch card equipment and part of it using the UNIVAC.

In the long run, we think the censuses will be tabulated through the use of the electronic equipment. At the Census we do a tremendous amount of what we call current survey work, much of which is based on small samples, and it is my own opinion that never will punch card equipment be replaced by this kind of equipment for the processing of some of the smaller samples. But the censuses of population, agriculture, retail trade, and manufacturing will in time be processed on this kind of equipment. The next economic censuses are for the fiscal year ending in 1953, I believe, which means that we get into the processing of those some time in the summer of 1954.

We hope, by then, to have techniques worked out for using the UNIVAC for those censuses.

The Burroughs Laboratory Computer

G. G. HOBERG

In early 1950 the Research Division of the Burroughs Adding Machine Company developed a need for a computing installation of moderate size which would, among other objectives:

1. Serve as a proving ground for new ideas and devices.

2. Provide data on large-scale-computer reliability.

3. Offer a means for indoctrinating a large number of inexperienced people in the various phases of realizing and operating a digital computer.

4. Produce useful solutions of engineering problems associated with a research program.

5. Solve business problems in a manner which would simulate their handling by contemplated smaller and relatively special-purpose commercial machines.

At this time Burroughs had already developed a line of unit-packaged computer-type electronic pulse circuits to facilitate research and development work on computer components, circuits, and systems. Known as pulse-control units, these system building blocks were based on similar ones in use at Project Whirlwind at the Massachusetts Institute of Technology, where the idea for this type of equipment originated in 1947. Large-scale use of such units to simulate the control and storage portions of the Whirlwind I computer, when only its arithmetic element had been constructed, established the intriguing possibility of their exploitation in the synthesis of directly useful high-speed digital-computer systems.

Engineering Approach

Although the already designed pulse-control units were thought to be somewhat too versatile and too bulky for use as mere low-level logical components throughout a complete computer, they offered what seemed to be a very reasonable solution to the problem of obtaining a flexible computing installation economically and in a short time. In May 1950, a decision was made to design and construct a computer which was to utilize pulse-control units wherever feasible.

In addition to pulse-control units, components which were considered at its inception to be suitable for the Burroughs Laboratory Computer were standard teletype equipment and a magnetic drum. Both of these were purchased.

G. G. Hoberg is with the Burroughs Adding Machine Company, Philadelphia, Pa.

Particularly important contributions to the realization of the Burroughs Laboratory Computer were made by Edward W. Veitch, who was responsible for the logical design, and whose intimate knowledge of the logic resulted in the 48-hour checkout of the machine; Harry Kenosian, who designed the standard pulse-control units; and Joseph Chedaker, who assisted in the over-all physical design and who supervised all installation and construction work.

Credit also is due to the many other members of the Research Division without whose efforts and co-operation this project could not have succeeded.