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QUARTERLY TECHNICAL PROGRESS REPORT

January, February, March 1966

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DEPARTMENT OF COMPUTER SCIENCE · UNIVERSITY OF ILLINOIS · URBANA, ILLINOIS

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1. CIRCUIT RESEARCH PROGRAM

(Supported in part by the Office of Naval Research Under Contract Nonr-1834(15).)

W. J. Poppelbaum, Principal Investigator

Summary

Edward Carr and David Casasent have modified Paramatrix to expand its gap-filling facility. Following on this work, David Casasent and William Steiner have outlined a mechanism - Geomatrix - for the autonomous display of simple line drawings following principles outlined by Professor Poppelbaum.

In the field of Electro-Optics Steven Whiteside has begun investigations on the operation and storage properties of a matrix-organized electroluminescent panel.

Chushin Afuso has built a digital averaging unit for determining the mean frequency and its fluctuation of a fixed time interval of pulses in Random Sequence Coding.

1.01 Paramatrix System

1.01.03.1 Gap Filling

The gap-filling facility of Paramatrix (Phase I) is presently being implemented. In the processing of bubble-chamber photographs, etc., portions of the input pattern may be missing and Paramatrix must be capable of reproducing this lost information.

In doing this, Paramatrix uses straight-line approximations. A double-pole three-position switch is employed, the three positions corresponding to:

1. an information point
2. a no-information point
3. a gap.

1.01.03.2 Gap Filling Logic

In Figure 1 the box labeled "E.F." represents a PNP-NPN emitter-follower configuration, capable of supplying or accepting current. The input pattern information is present on the potentiometers, the doubly-gated diamond circuit has the Interpolator comparator output as one gate signal, and the second gate

signal is determined by the position of the aforementioned switch.

If the point under discussion is an information point, the potentiometer information becomes the analog input to the diamond and the second gate signal is set to "0", thus returning control of the diamond exclusively to the comparators. If the point in question is a no-information point, the resistance chain is open-circuited and the second gate signal remains at "0", thus inhibiting the operation of this diamond. If the point is part of a gap in the input pattern, the resistance chain is connected and the analog input to the diamond becomes the interpolated voltage present at the corresponding point on the resistance chain. The second gate signal is returned to a second switch which, when "on", enables Paramatrix to fill in any designated gaps.

The second bank of emitter-followers is present so that very large gaps can be spanned. In such an application only two end points need be specified and Paramatrix will construct the best straight line through them.

Figure 1. Gap Filling Logic.

1.01.15 Geomatrix

1.01.15.1 Principle

In systems such as the Paramatrix, digital-analog data are stored and displayed in a geometric format composed of a planar raster of points. Experience has shown that most practical information represented in this manner is a piecewise combination of segments of a few basic geometric shapes such as straight lines and circles.

The Geomatrix is a proposed electronic system, utilizing hybrid digital-analog circuits, which can generate these basic geometric shapes subject to certain boundary conditions. Such boundary conditions might be the two end points for a straight line segment and the two end points of a diameter for a circle.

Previous systems for performing this function have involved, generally speaking, generating electronically the equation of the geometric shape and laboriously testing raster points in order to see if they fit the equation. The basic idea of the Geomatrix is to associate with each raster point an "autonomous element" that determines if the point lies on the desired geometric shape. The ultimate success of such a system depends on whether these "autonomous elements" can be made inexpensively.

1.01.15.2 Electronic Configuration for Straight Line Segments

The scheme for generating straight line segments uses two resistor chains and several selector switching systems. Selection of an end point, Point 1, of a desired line segment is made by placing a known voltage E_1 on the node corresponding to Point 1 on each resistor chain. The second end point, Point 2, is selected in a similar manner using a second known voltage E_2 ($E_1 \neq E_2$), as shown in Figure 2. If the resistors in each chain are all equal, the voltages of the two bus lines crossing each raster point are equal if that raster point lies on the desired straight line segment. The inexpensive "autonomous element" in this case is a circuit which determines whether the two bus voltages at the raster point are equal. Such a circuit is described below.

Figure 2. Selection of Point 1 and Point 2.

1.01.03.3 Detection Circuit

Figure 3 shows the proposed detection circuit, using three transistors, two diodes, six resistors and a lamp.

The two diodes form an OR circuit, generating at V_0 a voltage given by $\text{Max}(V_1, V_2)$. The lamp is on or off according as V_0 is greater or less than some critical switching level $V_0^* = -\frac{R_b}{R_a} E$. When $U_1 \neq U_2$ only one input transistor is on and its collector current is chosen large enough to make $V_0 > V_0^*$. When $U_1 = U_2$, both input transistors are on and share the available current equally thus making $V_1 = V_2 = V_0 < V_0^*$.

Tests on this circuit show that its differential input sensitivity is 15 mV.

Figure 3. Geomatrix Detection Circuit.

1.02 Electro-Optics

1.02.14 Electroluminescent Panel

A prototype matrix electroluminescent panel has been obtained from Sigmatron, Inc. It is about one inch square and contains 784 ($= 28 \times 28$) intersections. The panel will be used as a display/storage device during studies of bandwidth compression and other information processing ideas.

Lighting up an intersection requires about 200 volts, rms AC, at 1 kc/s between the corresponding terminals. A preliminary design for a driver is shown in Figure 1.

Figure 1. Possible Driver for Electroluminescent Panel.

1.03 Random Sequence Coding

1.03.01.1 Digital Averaging Unit

In a random pulse sequence information is conveyed by the average number of pulses. According to the central limit theorem the average converges to the mean as the duration within which the average is taken tends to infinity. This means that if we wait longer we will obtain more accurate average values in the sense that their fluctuation about the mean is smaller.

There are two methods of taking average values of the number of pulses:

1) digital averaging, 2) analog averaging. An experimental digital averaging unit has been built and tested.

1.03.01.2 Principle

Figure 1 shows the block diagram and Figure 2 shows control signals of the unit.

Figure 1. Block Diagram of the Digital Averaging Unit.

- (a) CLOCK SIGNAL
- (b) REGISTER-RESET PULSE
- (c) TRANSFER GATE, G_2 , CONTROL PULSE
- (d) COUNTER-RESET PULSE
- (e) COUNTER GATE, G_1 , CONTROL PULSE

Figure 2. Control Signals of the Digital Averaging Unit.

During the counting period, T , the counter gate G_1 is open and random pulses are counted by the binary counter. While this is done the transfer gate G_2 is closed and the register is isolated from the counter. After having counted pulses for T , G_1 is closed. The reset pulse clears the register and then G_2 is opened so that each binary digit of the counter is transferred to an array of flipflops of the register. At the same time a digital-to-analog converter, which is directly connected to the register, converts the number of pulses from digital form into analog form. G_2 is then closed and the counter is reset. G_1 is opened again and the next cycle starts.

At the output terminal the voltage is proportional to the number of pulses accumulated during the counting period T . Since the register is cleared once each clock period, the output voltage changes with time in staircase-form, if the effect of the register-reset-pulse is overlooked. The height of each stair is proportional to the total number of pulses for a given counting period T which had ended just before the stair started (e.g. in Figure 3, V_1 is proportional to the number of pulses during $[t_1, t_2]$). Since the average number of pulses for each counting duration is obtained by dividing the total number of pulses by T , the staircase-like fluctuation of voltage indicates the fluctuation of the average number of pulses when the counting duration is T .

Figure 3. Output Analog Voltage.

The fluctuation of the number of pulses within T is completely smoothed out. As T increases, the relative fluctuation of the voltage with respect to the average voltage tends to zero.

1.03.01.3 Results of Experiments

In order to observe the effect of the counting duration T on the relative fluctuation, the clock period was varied while the average repetition rate of the random pulse sequence generator was kept constant at 380 kc/s.

To be specific we define the relative fluctuation by the relation:

$$\begin{aligned} \text{Relative fluctuation} &= \frac{\frac{1}{2} \times \text{voltage fluctuation}}{\text{average voltage}} \\ &= \frac{\frac{1}{2} \times \text{fluctuation of number of pulses per } T}{\text{average repetition rate} \times T} \end{aligned} \quad (1)$$

In measurement the average voltage is obtained by connecting a large capacitor (e.g. 8 μf) at the output terminal. Since the fluctuation changes randomly in time, it is not too well defined. Therefore we must content ourselves with rough values for the fluctuation.

As shown in Figure 2, the counter gate is closed while the contents of the counter are transferred to the register; then the counter is reset. Hence the counting duration T is less than the clock period T_0 by this interval. In this experiment the interval is about 4 μs and its effect may be neglected practically, i.e. $T_0 \approx T$.

Figure 4 shows the results of experiments. The 7-bit counter is able to count only up to 127. The accumulated number of pulses for clock periods beyond 250 μs exceeds the capacity of the counter. The measurements may be extended beyond this barrier, however. The fluctuation is obtained by measuring overflowed parts and the average value is obtained by adding the voltage corresponding to 128 n , where n is the number of times of overflow during a single counting duration.

The theoretical curve is also shown in the same figure. In this case $1/2 \times \text{fluctuation}$ is replaced by the standard deviation of the Poisson distribution, i.e. the theoretical curve is plotted according to the formula:

Figure 4. Counting Duration vs Relative Fluctuation.

Standard deviation for counting duration T

Average number of pulses for T

$$= \frac{\sqrt{380 \times 10^3 \times T}}{380 \times 10^3 \times T} \quad (2)$$

Comparison between the measured curve and the theoretical one indicates that they agree reasonably well. It seems that the measured fluctuation is roughly 30% larger than the theoretical standard deviation. Considering that the standard deviation of the normal distribution (the Poisson distribution is well approximated by the normal distribution in this case) contains 95.6% of the whole distribution, the measured fluctuation seems to contain more than 97.0% of the whole distribution.

Figure 5. The Normal Density Function, $\Phi(x)$.

The rate of convergence of the fluctuation is rather rapid until 10% is reached. It slows down beyond this value and we would have to wait for about 2 ms to reach 5% fluctuation. These values are functions of the average repetition rate of the random pulse sequence as shown in Equation (2) explicitly.

If we take 760 kc/s, for example, we need only 1 ms to get 5% fluctuation, we need 4 ms for 190 kc/s, and so on. For a fixed clock period, therefore, the fluctuation depends on the analog quantity which is represented by the average repetition rate of the random pulse sequence.

2. HARDWARE SYSTEMS RESEARCH

(Supported in part by the Atomic Energy Commission under Contract AT(11-1)-1469.)

W. J. Poppelbaum, Principal Investigator

Summary

The Artrix System is currently being built. Design aspects are reported in the following sequence: storage system, including video processing (William Kubitz and David Rollenhagen); the Processor (John Esch); circuitry for generating lines and circles (Al Irwin and Peter Oberbeck).

Tak Katoh is building an Analog Display on which lines, circles and ellipses can be drawn by operating a simple joystick control.

Douglas Sand discusses the choice of transfer media for use in optical Fourier Transform systems of the Pattern Transform Analysis project, and also reports on progress with computer simulation of such transforms.

2.10. Artrix System

2.10.11.1 Storage System

The design of the Artrix storage unit has proceeded in two stages; first, the development of the system logic, secondly, the development of the video processing circuitry. The system logic (Figure 1) includes all circuitry related to the control of information transfer between elements of the system, and the video processing circuitry (Figure 2) includes all circuitry related to the actual processing of information.

2.10.11.2 System Logic

The system is equipped with mode selector switches for placing it in one of the following five modes:

1. Write Display. When the ENABLE button of the light pen is depressed, all information is gated into the Display Memory (see Figures 1 and 2) when the information appears on the Monitor as the operator is writing.
2. Write Point. When a point on the Monitor is located and the ENABLE button of the light pen is depressed, the point is

stored in the Point Memory for use in constructions.

3. Construction. All video and deflection signals to the Display Memory, originating within the Artrix storage system, are deleted. The video and deflection inputs are relayed to the Processor where the constructions originate. Information corresponding to the location of points to be used in the construction is sent to the Processor prior to the construction.
4. Erase Display. When the ENABLE button of the light pen is depressed, the information to be erased is gated into the Erase Memory. A four-bit counter controls the following sequence of events: When the ERASE EXECUTE button is depressed, the information from the Erase Memory is inverted and added to the information from the Display Memory, and the composite signal is transferred to the TEMP memory for temporary storage. The information indicated for erasure has now been deleted in the composite signal. The entire contents of the Erase Memory and the Display Memory are then erased, and the composite information in TEMP is transferred back to the Display Memory for redisplay. Finally, TEMP is erased, thus completing the erase cycle.
5. Erase Point. Point erasure is accomplished in exactly the same manner as described above for the Erase Display mode, except that information from the point memory rather than the display memory is deleted.

2.10.11.3 Video Processing Circuitry

A common sync generator supplies the vertical and horizontal sync pulses to all four television cameras used in the system as well as to the Monitor. Vertical and horizontal ramp generators have been designed to deflect the electron beams in the four Memotron storage tubes. The ramp generators are also synchronized by the common sync generator.

The z-axis driver circuits will supply "beam bright-up" pulses to the Memotron tubes. All Diamond Gates will be the same as those currently employed in the Paramatrix system.

A video adder circuit has been designed to add the information from two storage units during the Erase mode of system operation.

Finally, several buffer circuits as well as the relay driver circuits have been designed. ILLIAC II relay driver circuits have been used where possible.

Figure 1. Artrix System Block Diagram.

Figure 2. Artrix Video.

2.10.05 Processor; Logical Section

2.10.05.4 Summary of Progress

Since the last report, in which the basic operating principles were explained, the details and final form of the Processor have been decided upon. The block diagram of the counters and the necessary interconnecting control signals is shown in Figure 1. All the logic necessary to generate the control signals has been designed and both the counters and the control logic are presently being prepared for wiring diagrams.

The SN7400 series of integrated circuits manufactured by Texas Instruments has been tested; it functioned well enough under all tests performed to warrant using it exclusively in the Processor. The necessary logic has been ordered and delivery is expected by mid-May 1966.

At the time of the last report three problems had to be solved, viz: synchronizing the horizontal and vertical master counters with the deflections of the Display and Storage systems, handling the interlacing of lines, and designing for lines with negative slopes. The solutions which were adopted to solve these problems are discussed in the following sections.

The remaining problems associated with the Processor are those related to construction and commissioning.

2.10.05.5 Synchronizing Vertical and Horizontal Master Counters with Display and Storage System Deflections

The beam of the T.V. monitor is gated off during retrace times by horizontal and vertical blanking signals. The T V. camera contains a crystal which is used to generate both a fixed frequency clocking signal at the beginning of each line and also all other control signals. The horizontal master counter is designed such that its output has the same frequency as the camera crystal oscillator and could be used instead of the oscillator. This technique ensures that the Processor and the Display and Storage system deflections are running synchronously and that all the horizontal counters of the Processor will have a maximum count exactly equivalent to the magnitude of one horizontal line deflection.

The procedure used to get the vertical counter's maximum count equivalent to the magnitude of the vertical deflection and to ensure synchronous operation was to detect when the vertical master counter overflowed and then gate off any more line counts until the end of the vertical blanking signal.

2.10.05.6 Interlacing

Because the Processor is to run synchronously with the deflections of the rest of the system, its design has to account for the T.V. camera's interlaced line deflection. The vertical interlaced deflection is characterized by the camera sweeping all of the even lines, then all of the odd lines. If each line is counted as it is swept out, the contents of the counter are successively 0, 1, 2, 3, ..., etc. Thus, the true count of the interlaced system can be obtained by counting the number of lines swept out directly and requiring that the 2^1 bit be the low order bit for this counting and that the 2^0 bit indicate even or odd sweeps.

2.10.05.7 Negative Slopes

In the Construct Line mode of operation the P_2 register functions as follows: Both its horizontal and vertical counters are started from zero when (x_1, y_1) is designated and stopped when (x_2, y_2) is designated. Since the operator can specify either end of the line first there are four possible classes of lines, depending on whether $x_1 < \text{or} > x_2$ and $y_1 < \text{or} > y_2$. If $x_2 > x_1$ and $y_2 > y_1$, there is no problem, for the horizontal and vertical counters of register P_2 contain the correct counts. If, however, this is not the case, then either or both of these counters of register P_2 contain the ones complement of the desired count because of the properties discussed in sections 2.10.05.5 and 2.10.05.6.

The problem of knowing whether or not to use the ones complement or the exact value was solved by adding an overflow flipflop to the end of each counter. Then the required count is the indicated value or its ones complement according as the overflow flipflop reads "0" or "1".

The problem of slope sign can be solved by plus or minus fullwave rectifying the output of the digitally controlled variable gain linear amplifiers according to the same flipflop signals, plus fullwave rectifying for logical "0" and minus for logical "1".

2.10.09.8 Line and Circle Generation

The block diagram of the Processor is shown in Figure 3. The function of each block is described throughout the report.

It has been decided that line and circle generation in the Artrix system will be done with Lissajous patterns using, at present, the functions:

$\sin(\omega t)$, $\cos(\omega t)$ and $-\sin(\omega t)$. These basic functions are generated by a sinewave oscillator and a transformer type phase-shifting network. The circuit for this generator is shown in Figure 4.

Lines are generated by using combinations of $+\sin(\omega t)$ and $-\sin(\omega t)$, depending on the slope of the line; circles are generated by using $+\sin(\omega t)$ and $+\cos(\omega t)$. The logical combination of these is described in section 2.10.05.7, and is accomplished by the relays shown in Figure 3. The radius of a circle, the length and slope of a line are all dependent on the amplitude of the sinusoidal functions. This is shown in Figure 5. If one can, therefore, control the amplitudes of the sinusoidal functions, one can draw lines and circles of all lengths, slopes and radii. Information regarding the amplitude of the desired functions is in digital form, so it becomes necessary to find a device that will vary the amplitude of the sinusoidal signal as specified by a digital input. The principle of this device was explained in detail in the last report. A final practical circuit is shown in Figure 6. The device is capable of producing a sinusoidal output whose amplitude varies from 0 to 511 in steps of one according to a digital input. A line generated by two sinewaves is actually twice as long as indicated by the digital information, since the sinewave goes negative as well as positive. In order to correct this a fullwave rectification of the sinusoids for line drawings will be necessary.

Since a line or a circle can be anywhere on the screen, one can see that a DC level is associated with the horizontal and vertical starting point of each line and center of each circle. Again, the information regarding the position of these points is given in digital form. A straightforward 9-bit D/A converter is used to supply the DC references for each construction. A schematic of the 9-bit D/A converter is shown in Figure 7.

The entire construction, therefore, consists of two parts: the horizontal and vertical sinusoidal waveforms, giving either a line or a slope; and the horizontal and vertical DC bias, giving the position of the drawing on the screen. These two signals are then mixed just before they are applied to the horizontal and vertical plates of the CRT. Figure 8 shows the schematic of the mixer.

In drawing a circle, the center and a point on the circumference are indicated. The circle then expands until it reaches the indicated point on the circumference. The radius increase is achieved by merely letting the horizontal and vertical sinusoids increase at the same rate simultaneously. The desired radius is reached when both sinusoids are simultaneously equal to the DC posi-

tions of the indicated point. This is accomplished by the three comparison circuits indicated in Figure 3. One should note that digital information is processed the moment a point is indicated. The various D/A processes are therefore processed simultaneously, depending on the availability of the digital signals.

Figure 3. Line and Circle Generator.

Figure 4. 10KC Sinewave Oscillator Amplifier and Phase Shifter.

Figure 5. Line (A) and Circle (B) Pattern.

Figure 7. 9-Bit D/A Converter.

Figure 8. DC Amplifier and Mixer.

2.10.17 Analog Display

2.10.17.9 Principle

In the x-y plane an ellipse centered at the origin has the equation:

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$

We can generate this on an oscilloscope screen by x and y sweeps of the form:

$$x = a \cos \omega t$$

$$y = b \sin \omega t$$

If we rotate the figure counter clockwise through an angle α and move its center to (ℓ, m) we get the general form of an ellipse:

$$x = \ell + (\cos \alpha) a \cos \omega t - (\sin \alpha) b \sin \omega t$$

$$y = m + (\sin \alpha) a \cos \omega t + (\cos \alpha) b \sin \omega t$$

It is evident that by changing the five parameters a, b, α, ℓ, m , we can draw a line, a circle, or an ellipse.

Example:

1. A line with positive slope through points $(x_1, y_1), (x_2, y_2)$ is drawn as follows: set $b = 0$, $a = \text{full scale}$, $(\ell, m) = (x_1, y_1)$ and vary α until line passes through (x_2, y_2) .

2. A line with negative slope through $(x_1, y_1), (x_2, y_2)$ where $x_1 < x_2$ is drawn in a similar way, but with the roles of a and b reversed.

3. A circle with center (x_0, y_0) and radius R is drawn by making $a = b = R$, $(\ell, m) = (x_0, y_0)$.

2.10.17.10 Implementation

Figure 1 shows a possible layout of the analog circuit:

Figure 1.

2.12 Pattern Transform Analysis

2.12.12.1 Transfer Media in Optical Fourier Transform Systems

The requirements for an optical diffraction-pattern system are basically simple: a high-intensity, reasonably coherent light-source; a transparency pattern to modulate a cross-section of the light beam; a lens system to orient and transform (if necessary) the modulated light beam; and a receiver to detect the desired diffraction pattern. If the light source produces a parallel light beam which is directed through the pattern transparency and then through a simple convex lens, a receiver located in the focal plane of the lens will detect the Fraunhofer or far-field diffraction pattern (essentially the spatial Fourier transform of the modulating pattern).

Most of these requirements are easily satisfied by techniques compatible with contemporary real-time communication systems: lasers produce highly coherent light of sufficient intensity to obviate long exposure times; excellent lens systems are available; and vidicons and image orthicons are quite adequate as

diffraction pattern detectors (if phase information can be neglected).

However, the pattern transparency requirement presents a serious obstacle to the development of a real-time diffraction pattern system. The diffraction effect requires the simultaneous modulation of an entire cross-section of the light beam. Present methods utilize photographic negatives or similar devices to represent the pattern in the required transparency form. These methods usually produce excellent transparencies but are mechanically complicated and necessitate a long time delay between the pattern reception (or conception) and the final "development" of the transparency. For a real-time diffraction pattern system it would be desirable to have a transparency medium with the intrinsic speed and simplicity of, say, a cathode ray tube display.

Such a transparency medium must effect simultaneous area modulation (amplitude and/or phase) of a light beam, while preserving the original coherency of the light (except for the modulation changes). The speed ideally should be compatible with, say, the frame-rate of commercial television transmission. The medium should also have image retention of sufficient duration to convert serially-transmitted pictures into parallel transparencies.

Several devices could potentially be used in this transparency system. Phase modulation could be produced by either a matrix of Anderson diodes or the Kerr electro-optic effect in a KDP crystal. An amplitude-modulated pattern could be produced by splitting the light beam into two beams, phase-modulating one, and recombining the two; polarization together with birefringent phase modulation will also produce amplitude modulation, with a greater power loss. With existing devices it is difficult to achieve direct amplitude modulation at a rate compatible with that of phase modulation devices.

If an acceptable transparency modulation medium is available it could readily be integrated with a suitable lens system and a vidicon detector to produce a real-time spatial Fourier transform system.

2.12.12.2 Progress in Computer Simulation of Optical Fourier Transforms

The computer program for numerical simulation of optical Fourier transforms presently consists of the following sections: a pattern formulation routine, a two-dimensional Fourier transform routine, an optical system simulation routine, and a graphical output routine. Additional routines will be developed to allow pattern correlation and analysis of spatial frequency statistics.

The existing sections are preliminary and are based on a 256-element pattern in a Cartesian coordinate system (16×16). Later the program will be ex-

panded to handle $M \times N$ element patterns and polar coordinate systems.

The present form of the pattern formulation routine constructs binary valued representations of alphabetic characters. The routine starts with a character in "skeleton" form (line end-points and curvatures specified on a standard unit square). The "skeleton" is given form according to one of several available "printing fonts" (the lines are properly oriented and thickened, serifs are added, etc.). The result is a matrix of binary values representing the character. Provision is allowed for the generation of "noisy" patterns, for character shading, etc.

The two-dimension Fourier transform routine is based on the iteration scheme described in the previous Quarterly Report (Fourth Quarter, 1965, §§ 2.12.12.1-3). This may be changed to incorporate a very fast Fourier transform algorithm developed by Gordon Sande at Princeton University.

The optical-system simulation routine adjusts the pattern transform to allow for the low-pass filter characteristics of various optical systems used to produce Fourier transforms.

The graphical output routine uses the system subroutine "X Y Z P L T" and the Calcomp plotter to generate pattern output. Of primary interest are the original pattern, its Fourier transform, and the transform adjusted for the simulated characteristics of the optical system. Each of these is a function of two coordinate variables requiring three dimensions for direct plotting. The subroutine "X Y Z P L T" projects the function onto a two-dimensional observation plane and plots the resulting projection on the Calcomp plotter.

3. SOFTWARE SYSTEMS RESEARCH PROGRAMS

(This work is supported in part by Contract No. AT(11-1)-1469 of the Atomic Energy Commission and in part by the University of Illinois.)

This section provides a description of the work in progress on the Illinois Time-Sharing System which is currently being implemented on the ILLIAC II/PDP-7/IBM 1401 hardware.

To summarize the work done this quarter: An interim time-sharing system is in operation and proving very valuable; SYSFBN, Sort-Merge, Garbage Collection, and INTAPE processor are being programmed to include the latest decisions on system organization; further planning and flow-charting of the final time-sharing system has been accomplished; the new Loader, Disk-Drum Program, and the PDP-7-ILLIAC-Console Interfaces are specified; research in graphical display has been started; segmenting of the old monitor (in order to obtain independent programs) and revisions in some of these segments is taking place; several demonstration programs which were written for Engineering Open House provided good experience for coding routines to be run in a time-shared system.

Weekly meetings are being held to keep all programmers supplied with the latest information on the design and progress of the system.

The sections of Part 3 are the responsibility of the following people:

Richardson, F. K. - Interim Time-Sharing System and Graphical Display

Greninger, L., Ellis, C. - Disk File Organization, File-by-Name, Sort-Merge

Otis, A. - PDP-7 Programming

Berg, Mary Ann - Loader, Library Search and Acquisition

Nuspl, S. - Disk-Drum Routine

Fisher, R.; Shepard, C. D. - Command Processor, Scheduler, General System Organization

Dahm, M. - Intape Processor

Lyon, R. - Garbage Collector

Neuhaus, P. - Miscellaneous

3.1 Interim Time-Sharing System (ITSS)

The implementation of a refined interim time-share system this quarter provides the first phase of the time-sharing project a reasonably reliable interactive system which can be used as a bootstrap device for a larger system. This research oriented time-sharing system became operational in February and provided for the operation of three consoles (three being the hardware limitation) in addition to the operators console with background batch processing continuing as always. SOC is no longer available as the interpretive desk calculator language since TIPSy, which allows for much more flexibility, has been introduced into the system. Refinements of the original system include more console commands (such as RESUME, CØRE, ØCTAL, LDCØRE, SVCØRE), elimination of known difficulties, sum-checking of programs coming off the System Tape, and special options to allow for checking the SPU channel from a console during regular time-sharing activities.

Priority on the three remote consoles used in time-sharing is given to system programming work concerned with developing the large scale time-sharing system. During periods when such work is not in progress, the general user is allowed to experiment with the system. Communication with the computer is via a "teletype" console connected to the telephone system through a Bell 101A1 Data-Set.

The fact that ITSS runs 12 hours a day with a minimum number of difficulties, allows diverse console activity, and maintains a batch processing load indicates both the flexibility and possible further uses of such a system. The increasing variety in the command repertoire is an indication of the spectrum of possible users.

The inclusion of the PDP-7 into the computer software complex will be the last step in this interim phase of time-sharing development. This is now planned and awaits implementation in the next quarter.

3.2 System File-By-Name (SYSFBN)

3.2.1 Use of SYSFBN

All user communication with the disk will be through SYSFBN which will handle linking, allocation of free space, scrapping of old files, etc.

SYSFBN reads and writes 256 word blocks into tracks on the disk. The user transmits BCD cards, 1403 printer lines or binary cards to and from SYSFBN. SYSFBN packs and unpacks these records in 256 word buffers for transmission to and from the disk. The first three words in each 256 word block contain linking information. The remaining 253 words contain packed variable length logical records. Preceding the actual records is a word which tells the type of record, backward and forward links, and the line number.

There are three main levels in the hierarchy of information contained on the disk file. They are:

1. MID - Master ID Dictionary
2. File Dictionaries
3. Files

The structure and material contained within these files have been defined and records at all three levels are written by SYSFBN itself.

A Programming Memorandum (No. 46) titled "Disk File Organization" was distributed on March 23, 1966.

3.2.2 SYSFBN

This last quarter refinements were made which make SYSFBN more convenient to use. A new type of file-buffer declaration was added whereby a file can be read from and written into from the same buffer. This permits the changing of single records within a file without recopying the entire file. To complement this new feature an additional read option was added which leaves the internal SYSFBN pointers pointing at the record just read instead of the (usual) next record. This permits an immediate write in order to change the record just read without having to first do a backward read to reposition the pointers. Variable length logical records were also designed into the system, thereby increasing the packing density on the disk by about a factor of three.

As a test of the practicality of these and previous changes, the SYSFBN package is being incorporated into the presently operating time-share system. This should yield useful performance data which will guide the development of the large scale time-sharing system.

A pertinent publication of February 18, 1966, was "Proposed SYSIO Changes".

3.3 Sort-Merge

The programming of Sort-Merge is continuing. A major change which has made re-programming necessary is the addition of one track at the end of "long" files. In this track the Sort-Merge routine builds a table with one entry for each of the previous tracks. Typically, the i^{th} entry in the table contains:

- (a) the disk address of the i^{th} track of the file,
- (b) the largest line number in the track (i.e. the number associated with the last logical record of the track).

This change allows Sort-Merge to use a more efficient technique for merging changes into a file. In addition, this table is extremely useful to other programs of the time-share system.

3.4 PDP-7 Programming

3.4.1 LTLTRAN

LTLTRAN was completely specified and virtually ready to be programmed. However, for many reasons (the foremost being that it was not completely compatible with Fortran II) it was decided that the project should be terminated for the present.

3.4.2 PDP-7-ILLIAC-Console Interfaces

A proposal of the specifications of the ILLIAC-PDP and PDP-console interaction interfaces (titled "ILLIAC-PDP-Console Interfaces") was distributed on March 31, 1966, and is awaiting final considerations.

Special characters, the recognition of commands from data, mode recognition, teletype messages, paper tape usage, and line numbering have all been

discussed at length. It is suggested that the PDP-7 and ILLIAC will communicate by way of 12 ILLIAC word buffers. The first two words are control words and the last ten words contain the 80 character line.

The overall PDP-7 to ILLIAC procedure is planned as follows: When the system starts up (PDP first), the ILLIAC will send an "ILLIAC-running" command to the PDP which will reply in turn (if on) with "PDP-running". From then on as users sign in, the PDP will start a user by sending to the ILLIAC the ID lines with the logical console number indicated. All input and output for that console is ignored by the PDP until an "ID OK" is received from ILLIAC. From then on the PDP will input, buffer, and send to ILLIAC all lines from that console. If the user is inputting lines, and the ILLIAC sends an output line, the current user input line and all other buffered but untransmitted input lines are deleted and output is initiated. When logout is requested the PDP ignores all input and output from and to the console, deletes all previous input, and sends a STOP and a LOGOUT command to the ILLIAC. When the PDP receives the "user logged out" notification from the ILLIAC, the logout message is sent to the console and the logical console set to unassigned.

Coding for the initial trial program which makes use of the PDP-7 as a Satellite Processing Unit (SPU) should begin shortly.

3.5 Binary Card Loader

The binary card loader for the time-sharing system is being rewritten; however, binary cards produced by the current system will be acceptable under the new system. The time-share loader will accept and require binary cards with the following format:

1. 12 punch in column 1 indicates a new format binary deck
2. 12 words per card instead of 14
3. Columns 73-76 will contain a label in BCD and 77-80 will contain the sequence number in BCD. Columns 73-80 are user requested numbers.
4. Column 4 contains a checksum for the card
5. Column 3 contains the sequence number in binary and is always NICAP or FORTRAN produced.

A program called NUBIN has been written to convert the present binary cards into new binary cards. This may prove valuable for those who wish to have the security of using binary cards with a checksum and who do not have a source deck readily available. At present, this program has not been sufficiently generalized to accept all of the current binary decks for conversion.

Under the new loader, duplicate entry points will be allowed. Binary files for loading will be pulled from the disk after searching the proper file dictionaries in accordance with a specified priority.

3.6 Disk-Drum Routine

The new ILLIAC II time-sharing system will incorporate a feature whereby the disk and drum will be seen by the user and other system programs as a single peripheral storage system. All references by the calling programs will be made to the specific tracks on the disk. All assignments and subsequent handling of drum blocks will be done automatically by the disk-drum routine in such a way as to try to optimize transfers and disk head movements.

The user and system programs will have a number of options available. The basic option is a direct read or write in which the core block and the disk track are specified. In the case of a write, the block being transferred to disk will almost always go first to the drum where it waits until the disk is ready to accept it. For a read option, only a drum to core transfer need be initiated if the track is already (or still) on the drum; otherwise, a seek and read are performed on the module specified and the block is read directly from disk into core. A "prepare" option will also be available to allow blocks to be transferred from disk to drum so that a subsequent "read" will be a fast drum to core transfer. The prepare command will always be a "NO-OP" for the program but it will have the effect of speeding up transfers in most instances (depending upon the state of the drum).

A minimum set of priorities will be included in the disk-drum program in order to insure that the drum will retain the most active tracks. Priority will be given to "preparation" transfers if the drum is less than half full and will be switched to drum-to-disk transfers if only a few free blocks remain on the drum. By preparing as many blocks as possible on the drum and by delaying drum-to-disk transfers as long as possible, optimization of disk head movement should be possible thereby attaining the goal of utilization of maximum disk transfer rates.

The advantages of a single disk-drum package are apparent from a programming and reliability standpoint. Since drum space assignment is already present in this package, no other program need also worry about optimizing drum space and drum accesses. In the context of a time-share system with its frequent swapping of active programs, absolute assignment of drum space is not only difficult but also wasteful of drum space.

With regard to the reliability of the drum, the disk-drum routine will not be dependent on the presence of both drums in order to run. If one drum is down, the time-share system will still function but at a reduced rate dependent on the number of I/O transfers requested.

3.7 Scheduler

The BJM (Between Jobs Monitor) portion of the Scheduler is now clearly specified. In particular, the tables governing jobs and their subtasks, the tables passed to NICAP, FORTRAN, and MACRO, and communication with the LOADER have been laid out. The programming of the BJM (sometimes referred to as the Batch Processor) will begin shortly. It will function entirely by files stored on the disk and will include three levels (i.e., private, local, and global) of library search. The library search will be conducted on file names rather than on entry points in order to allow a user to have multiple copies of a single subroutine residing on the disk. Programs which are not changed after they have been assembled once will not need to be assembled again, i.e., binary images are saved.

The remaining portion of the Scheduler is that which sequences the various jobs. It is progressing but is still not completely specified. One of the features it will incorporate is the ability to bring in certain processors (e.g., TIPSy) to service several consoles at once. Hopefully, this will significantly improve the system response time. Another feature will cause core loads to be brought to the drum by SYSDSK ahead of the time they are needed and to be sent to the disk via the drum when they are finished. Provided the average core load executes for long enough to hide the overlapped movement, this should again improve response time.

3.8 INTAPE Processor

The basic tasks of INTAPE have been specified for some time. One of its primary functions is to make jobs which are to be run under the Batch Processor look like console jobs in order to gain some system consistency. However, since INTAPE depends on ~~COMPRO~~ and the SCHEDULER and the latter two were in such a state of flux, many changes were made in the information required by INTAPE. The contents of the User Dictionary and of the Job Control Information have now been finalized.

The organization of the information to be set up by INTAPE has been defined and is consistent with the File-By-Name scheme without a loss of efficiency. The handling of Job Control Information was one of the obstacles which had to be overcome.

The INTAPE processor has been flowcharted and since the related components seem to be fairly well specified, programming has begun.

3.9 Garbage Collection

The Garbage Collector (GC) is a subroutine of the BOOTS system which dumps BOOTS' files onto tape in a usable format. It has been specified, written, and code-checked. Some frills need to be added.

GCL, No. 1, was written to reload the disk precisely as it was before dumping. This, however, was found to be useless and was scrapped. GCL, No. 2, which reloads the disk sequentially has been written but is not yet debugged.

A program called GCAFUL which is coded and is working dumps the disk track by track until a given cylinder is reached. Its converse called ~~RELOAD~~ (which reloads the disk from a tape in a track by track manner) is also coded and running.

3.10 Graphical Display

Preliminary reading and discussion is being carried on in order to determine ways in which a graphical display system can be used as a tool and/or as a means to a tool within the framework of computer applications. The topics which have been included in this study are the structure of languages, object code and data, methods of dealing with these structures, and the problems of communicating information about these structures with the individual using the graphical display system.

3.11 Miscellaneous - Modifications of Existing System Programs

1. There is an attempt being made to divide the old non-time-share monitor into modules which can be changed or removed without affecting the rest of monitor package. This should simplify the conversion to the new time-sharing monitor which in some areas will merely be an extension of the present one.
2. A tape SYSIØ program called "TSYSIØ" has been coded and checked. It will be used primarily by the user for I/O of his own BCD image tapes. This program will also be used by the INTAPE-OUTAPE processor for tape-disk operations. TSYSIØ is essentially an outgrowth of the existing SYSIØ program; more legal operations have been added.
3. The coding of an independent and low-core tape SYSAUX subroutine (to be run in interrupt allowed mode) is awaiting further information on control word assignment.
4. At present, a high-core subroutine (to be run in interrupt disallowed mode) which will handle all operations involving the interval timer is being written and tested. It should be completed very shortly.

3.12 Engineering Open House

Several demonstration programs were written for the 1966 Engineering Open House as experimental work in a time-sharing environment.

3.12.1 ILLIAC Demonstration Programs

The ILLIAC II was time-sharing 3 programs which could be used from a remote console at the same time batch processing was taking place. These programs were:

1. TIPSy - the remote console teletype language described in the last Quarterly Report.

2. GOMOKU - alias 5-in-a-row. This game is an interesting extension of the familiar game of TIC-TAC-TOE. The method of play is the same, but the board is virtually infinite. The object of the game is to form 5-in-a-rows horizontally, vertically, or diagonally. Play continues until one side or the other forms a 5-in-a-row. ILLIAC can play GOMOKU on a board which is 50 by 50 and can play a game which is even challenging to the author of the program.
3. SAVANT - This is an interactive question and answer program. It first asks a question and then utilizes a simple tree structure to decide on the basis of the console's response which question or comment to make next. Both the questions and the choice of answers are supplied by the program.

3.12.2 PDP-7 Demonstration Programs

The PDP-7 Open House Time-Share System consisted of three levels of programs. The primary or supervisory level is given the tasks of performing input/output for other programs and of switching users between active and inactive status. The secondary or monitor level scans users input for logic, program termination, and logout commands as well as interrogating the user for and providing him with a copy of a requested demonstration program. The demonstration programs constitute the third and lowest priority level in the system.

The maximum number of four users may be logged in at one time. Each user is assigned his own monitor and may request any one of the four available demonstration programs. Each user is allowed 10 milliseconds or less of continuous operation time, thus making worse case response (for a user doing only input/output) 1 character time. In practice, with the programs currently available, the response is instantaneous.

After an initial PDP-7 login, to obtain one of the demonstration programs, one merely typed the name of the required program and then the program was automatically loaded and run. The demonstration programs available were:

1. TIC-TAC-TOE— The PDP-7 plays TIC-TAC-TOE with the user. The PDP-7 asks if it can start; the user replies with YES or NO. Each square of the game board has a unique number. The moves are made by typing the number of the square into which the user wants to move.

2. ~~ONE~~-ARMED BANDIT—The PDP-7 "becomes" a slot machine with slightly less than honorable odds. Instructions are printed out when the program starts. One of eight possible choices in three different independent positions is picked by a random number generator. If two or three of the positions match, you win.
3. PUNCH-LINE—The PDP-7 requests a line of input which it then converts and punches out in large readable letters on paper tape at the user's console.
4. REVERSE—For this program, a line of input is typed and the PDP-7 responds by typing it backwards

3.13 Time-Sharing Hardware

3.13.1 Computer Controlled Display System

The specifications for the Computer Controlled Display System for ILLIAC II have been completed and the task analysis has been finished. The optimal method of interconnecting the CCDS to other sub-systems of the ILLIAC II complex is not well defined at this time; it is felt that this is largely dependent on the characteristics of the machine chosen as the processor of the CCDS. The task analysis of the role of the CCDS as a component of a larger system shows the two key ideas to be time-sharing and flexibility. The larger system, in which it is proposed to imbed the CCDS, is a multi-user, dual-processor configuration. From the standpoint of the Central Processor, the CCDS is but one of its many users (neglecting the fact that the language used in dealing with this user is abnormal); therefore, the data transfer between the Central Processor and the CCDS must be overlapped by some means. The need for flexibility in the CCDS interconnection arises from a basic tenet of this system: that the system shall serve as a vehicle for research in time-sharing systems.

The CCDS specifications are given in: "Procurement Specifications for a Computer Controlled Display System for ILLIAC II," by C. E. Carter and R. E. Willard, Department of Computer Science, File No. 550-68, March 28, 1966.

3.13.2 Satellite Processor Communications System

The I/O channels connecting ILLIAC II to the PDP-7 have been made available for systems code-checking. The primary functions of these channels, those related to data transfer between ILLIAC II and the PDP-7, are now performed properly. Some secondary functions of these channels, related to diagnostic capabilities, have not yet been debugged; work is proceeding in this area.

It is noteworthy that a large portion of the debugging of these channels was done under the existing time-sharing system on ILLIAC II. One remote console was allocated for the operation of engineering test programs for diagnosing problems in the channels. From this console it was possible to quickly generate, utilizing some pre-written interpretive command languages, programs to discover and isolate channel faults. The relative lack of interference between this engineering usage of ILLIAC II and the time-shared batch processing and conventional console usage is considered to be indicative of the potential of time-sharing on ILLIAC II.

Work was continued on the definition and implementation of a thorough set of diagnostics for the channels. The tests checking the ILLIAC side of the channels are complete and functioning satisfactorily, but the tests required on the PDP-7 side are still in need of definition. They will remain so until the final system (in which the diagnostics are to be embedded) is more fully developed.

4. ILLINOIS PATTERN RECOGNITION COMPUTER: ILLIAC III

(This work is supported in part jointly by the Atomic Energy Commission and the Advanced Research Projects Agency under Contract AT(11-1)-1018 of the Atomic Energy Commission.)

4.1 Programming System

4.1.1 IBAL-Compiler

Work on the IBAL (ILLIAC III Basic Assembler Language) translator during the quarter centered upon the definition and clarification of the data declaration capabilities of IBAL, and the modifications necessary in the translator to permit the use of these data declarations together with full block structure.

The data declarations will allow the definition of tree structured data files with four variants on all sizes of terminal elements (i.e., byte, halfword, word and double word). It was decided to include the following features in the first implementation:

- 1) Iteration of substructures, reevaluated at each encounter of the declaration, to allow dynamically changing files.
- 2) Conditional expressions, also reevaluated at each encounter of the declaration, to select a branch of the tree structured file.
- 3) Multiple expressions referring to a file, to indicate alternate access structures for the same data.
- 4) Format or macro declarations defining a generalized structure which may be inserted symbolically into any number of subsequent data declarations.
- 5) Labelling for any node of the structure.

The file declaration itself consists of a grouping of labels, terminal unit designators, parentheses and commas. Each opening parenthesis introduces a new level of branching, and defines a corresponding subscript in the file variables of the file. Labels may precede an opening parenthesis to name the node from which the enclosed branches emanate. Commas serve to separate the branches.

Associated with each file declaration are the following:

- 1) The actual physical locations for the file in storage.
- 2) The file access list, used to access a specified variable in the tree structured file.
- 3) The execution time code to handle storage allocation and modifications of the contents of the file access list necessitated by the dynamic nature of the file.
4. The file label table for this file.

Because of the nonuniform nature of the general file, each reference to a file variable is made through the file access list. This list conforms closely to the actual structure of the file. The label assigned to a file node refers to a node head in the file access list. The node head contains the number of branches currently leaving this node and, in the case of an iterated node, the current volume of the immediate substructure. Following the node head is a location for each branch, containing either a link to a lower level node or a file address (see Figure 1).

Figure 1.

Each iterated node causes execution time code to be produced which will change the volume and branch number information in the corresponding node head and modify all affected file addresses in the file access list. These changes take place at run time when the block whose head containing the file declaration is entered. Within this block the file is static, and is accessed in a standard way through the file access list. Execution time code is also produced to evaluate any conditional branching terms and to insert the results into the file access list.

Compilation algorithms to be used by the translator in processing the data declarations, as well as execution time accessing algorithms have been written.

Currently the programming necessary for the incorporation of these features into the IBAL translator being designed to run on the IBM 7094 is just beginning.

Manfred Paul and John C. Schwebel

4.2 Logical Design

4.2.1 Arithmetic Unit Design

The ILLIAC III arithmetic instructions have been specified and published as DCS File No. 691. The file also specifies arithmetic number format, and arithmetic error conditions.

Hardware design is now centered around the use of cascaded signed-digit subtractors (SDS). A block diagram of one stage of this subtractor is shown in Figure 4.2.1.1. Note that the minuend and difference are in a redundant form with digital values (2 bits/digit) of -1 , $+0$, $+1$ where each digit is of the form:

S M

where S = the sign of the digit (0 = +, 1 = -)

M = the magnitude of the digit.

Figure 4.2.1.2 Signed Digit Subtractor Stage.

The signed-digit subtractor incorporates the following features:

- 1) Least significant digit location need not be known, e.g., for least significant position carry injection.
- 2) Addition may be performed in some cells with subtraction in others.
- 3) Borrow propagation is not necessary during recursive steps of multiplication or division.
- 4) With a cascade of these subtractors, addition and subtraction may be interleaved in any manner.

Four of these subtractors will be cascaded to provide multiplication, radix 256, as indicated in Figure 4.2.1.2. The multiplicand is placed in the M-REG. The multiplier, stored in a register not shown, is recoded to radix 4 digital values of ± 2 , ± 1 , 0 and used to control the M-REG Selectors and the ADD/SUBTRACT Control (AS) of the signed digit subtractors.

Figure 4.2.1.2. Cascaded Stored-Digit Subtractors.

Division will be performed using a high radix version of SRT division. Quotient digits will be developed in a model division unit and used to control the M-REG Selectors and the ADD/SUBTRACT control of the subtractors in generating partial remainders. Assimilation of the 13 high order digits of the partial remainder is required after each pass through the subtractors.

Assimilation to conventional binary form is required before results are returned to the taxicrinic processor. Although this assimilation is a serial process, it will be accelerated by using a look-ahead scheme.

D. E. Atkins

4.2.2 I/O Processor Design

Substantial progress has been made in the last three months on the I/O Processor (IOP) design. At present, the final system design work is being done, and flow charting of the actual logic design is expected to begin shortly. The register arrangement of the IOP now greatly resembles that of a Taxicomic Processor.

During the period final consideration was given to the best overall machine configuration to input and output the many different types of data structures to be used with ILLIAC III. As a result, minor changes were made in design, but it was decided that no major revision was needed.

Work then proceeded to the problem of how to handle the various I/O operations under the constraints imposed by the multiprocessing concept. This is an extremely complex and difficult problem, and as a result, an optimal solution is practically impossible. However several workable schemes for sequencing have been advanced, one of which seems to be near-optimal. In this scheme, the IOP uses an associative memory to store the data rates of all the devices it services. By means of this Data Rate Memory and the executive program imposed program priorities, the Task Sequencer in the IOP can calculate both Tactical (local) Priority and Strategic (global) Priority which allow it to minimize the probability of "traffic jams" in data handling. These Tactical and Strategic Priorities are continually updated so that the IOP operation is as near optimal as possible. This scheme will most likely be used in preference to the others which we have evolved.

As a result of the work of the last period, several points of the IOP design have been fairly well specified. The IOP will operate in an asynchronous mode with its major cycle time governed essentially by core access and cycle times. Surprisingly, the major cycle time will be approximately the same for each of the four major operations to be carried out by the IOP--about 2.0 to 2.5 μ sec. The four major tasks to be carried out will be:

1. Handling of machine and Channel Interface Unit (CIU) interrupts,
2. Handling of CIU requests (data transfers, etc.),
3. Updating of instruction registers, and
4. Execution of commands in the various I/O programs.

The IØP will essentially consist of 22 units, of which 8 are associated with temporary storage, 8 with processing functions, and 6 with control functions. These units are:

<u>Storage</u>	<u>Processing</u>	<u>Control</u>
Data Pointer Registers	Permuter	Task Sequencer
Command Pointer Registers	Request Service Unit	Interrupt Control
Priority Registers	Exchange System Interface	Request Control
Data Rate Memory	CIU Interface	Update Control
Base Registers	Adder	Command Control
Instruction Register	Logic Register and	Instruction Decoder
Scratch Register	Associated Gates	
Distribution Register	Bounds Check Unit	
	Compare Unit	

A preliminary estimate of the number of boards involved in the complete I/O system was made in February 1966. At that time, the estimates were 528 boards per IØP, and 139 boards per CIU which adds up to 1640 boards per IØP and 8 CIU's. With two of these complete units as planned for the I/O system, this means there would have been about 3300 boards in the I/O system. It is expected that this estimate will now have to be revised slightly upward to between 3500 and 3600 boards based on more recent work.

G. N. Cederquist

4.2.3 Channel Interface Unit

All communication between the I/O devices on a channel and the IØP associated with that channel is via the Channel Interface Unit (CIU). The CIU acts as a buffer for data transfer through the channel. It also serves to match the standard X360 interface used by all I/O equipment to the ILLIAC III interface of the IØP.

The CIU contains three one-word buffer registers called A, B, and C. Data transmission between an external I/O device and the CIU over the X360 interface is by byte (8 data bits + flag bit) to receive information, the CIU assembles bytes into double words and transfers each double word to the IØP, which in turn transfers the double word on to core. During data transmission to an I/O device, the CIU receives double words from the IØP (which in turn retrieves them from core) and transfers the data a byte at a time to the X360 data bus. The CIU therefore requires servicing by its IØP only when it has a double word assembled or requires a double word. The IØP in turn, can service a number of channels in a time-shared manner and is thus used more efficiently.

The CIU provides one word of overlap. A double word assembled by the CIU is placed in the A and B registers. Assembly of the next double word may begin immediately in the C register with no interruption of the data transmission. If the A and B registers have not been cleared by the time C has been filled then an interrupt signal is generated and data transfer is terminated.

The order in which the CIU assembles bytes into double words and disassembles double words depends on the data format and the mode of operation as specified by the current channel command. The format of the data may be either BLOCK or LIST. The CIU operates in either the FORWARD mode (with READ or WRITE commands) or in the REVERSE mode (with the READ REVERSE command). Both block and list formats can be used for each mode of operation.

When the block format is being used, the CIU places eight data bytes in the A and B registers. When data is required in list format, the CIU reserves the left half of the A register for the link which it requests from the IØP. In WRITE operations the CIU ignores the link and only transfers data.

In the forward mode (most usual), data bytes are assembled from left to right in the order they are received (READ operation), or are removed sequentially from the left end of a double word (WRITE operation). In the reverse mode (READ REVERSE command) bytes are assembled in the reverse order, i.e., from right to left. In order to determine the type of data transfer to be used, the CIU partially decodes I/O device dependent commands, which it then transfers from the IOP to the selected I/O device on the channel.

The CIU provides an interface between the X360 lines from the I/O devices and the IOP. All transmission on an I/O channel (except for the special case of stream transmission) is fully interlocked with reply signals. The CIU interprets all incoming control signals (e.g., to shift data between registers, to generate a reply signal etc.) and propagates them on through the channel, having introduced delays if needed to meet X360 timing requirements. The I/O device control units on a channel and the IOP are responsible for all signal sequences associated with the initiation and termination of operations on that channel. The CIU alone is responsible for generating all reply signals associated with data transfer, thus freeing the IOP for other work. The CIU may also be set manually for stream transmission, in which case no reply signals are generated (by the CIU) during a READ operation.

A detailed flow chart of CIU operation was prepared this quarter. For design purposes the CIU was divided into three sections:

- 1) Data Register Unit; the logic design of this part has already been completed.
- 2) Main Control Unit (responsible for signal interfacing and decoding); this unit has essentially been designed.
- 3) Data Register Control Unit; the final design for this part of the CIU has yet to be done. A preliminary design (not X360 compatible) was prepared last fall and this will form the basis for the final version.

It is expected that work on the CIU design will be completed by late summer.

John P. Hayes

4.3 Fabrication

4.3.1 Circuit Boards

Relatively few new circuits designs are being generated at this time. Instead, existing designs are being checked and prototypes tested as a preliminary to full scale production. As of this date

- 1) Drawings for 68 circuit boards have been checked and approved for distribution;
- 2) 1000 type 1018-183-00 cards have been assembled by an outside firm and tested by the fabrication group;
- 3) 1110 prototype cards representing 97 card types have been built by the shop group and;
- 4) 6400 etched bases have been ordered from vendors.

All completed cards are to be measured against objective standards of threshold voltage, speed, leakage and other appropriate criteria. The design and construction of such test circuits is a continuing major effort.

Worst case analysis of input and output currents, power requirements and similar design parameters has been completed for all the circuits which are used in large numbers. The remaining circuits are being analyzed as time allows.

4.3.2 Power Turn-On System

The turn-on logic has been drawn in greater detail to facilitate checking the logic design and to provide detailed wiring information. As part of the checking procedure, sequence diagrams have been drawn which will later serve as a reference for maintenance personnel.

Prototypes of the circuits peculiar to the power turn-on system have been bench tested and approved or modified as necessary.

4.3.3 Pattern Articulation Fabrication

Wiring for the iterative array has been completely specified. This will allow the completion of border wiring and connection of the iterative array to the transfer memory when technician support becomes available.

Test procedures have been developed which will allow the 18,000 baby chips to be tested by unskilled help. It is essential that the baby chips be carefully checked before installation on the stalactite card since checking and repair are both much more difficult on the completed board. As an example of the tests, the flipflop chip is tested for

- 1) Minimum trigger amplitude for operation;
- 2) Maximum frequency of successful operation and;
- 3) Continuity of diodes and resistors.

4.3.4 Analog Deflection Circuitry

Experimentation in this area was limited principally to the deflection geometry of yoke and CRT. Major conclusions for the monitor displays are:

- 1) The presence of a pin cushion coil creates intolerable defocusing and neck shadow problems. Pin cushion can probably be ignored in the monitor and if not, can be corrected electronically rather than magnetically.
- 2) There is no simple defocusing function of deflection which would allow dynamic refocusing on the basis of deflection. In short, as the spot was deflected from the center it enlarged and became noncircular. Refocusing did not decrease the spot size measurable under this condition.

J. L. Divilbiss

4.4 Bibliography

During the quarter the following File Numbers, Reports and Specifications have been issued:

File Numbers

"ILLIAC III Communication Net: General Introduction," by B. H. McCormick, Department of Computer Science, File No. 688, February 7, 1966.

"ILLIAC III Component Locating System," by T. Kingery and D. Foster, Department of Computer Science File No. 690, January 11, 1966.

"ILLIAC III Arithmetic Instructions: Preliminary Specifications," by D. E. Atkins, Department of Computer Science, File No. 691, March 29, 1966.

Reports

"Methods of Binary Addition," by R. E. Wiegel, Department of Computer Science, Report No. 195, February 1, 1966 (M.S. Thesis).

"A Language for Describing Digital Computers," by J. A. Wilber, Department of Computer Science, Report No. 197, February 15, 1966 (M.S. Thesis).

"On the Automorphism Group of a Reduced Automaton," by M. Paul, Department of Computer Science, Report No. 200, February 22, 1966.

"New Method of Solution of the Traveling Salesman Problem," by E. S. Davidson, Department of Computer Science, Report No. 201, March 23, 1966.

Specifications

"Procurement and Design Specifications for Printed Wiring Boards," by F. P. Serio and E. Pelg, Department of Computer Science, File No. 550-63, January 11, 1966.

"Specifications for High Current Silicon Switching Transistors," by J. L. Divilbiss, B. H. McCormick and K. C. Smith, Department of Computer Science, File No. 550-64, February 1, 1966.

"Specifications for Teletypewriter Consoles for Use with the ILLIAC III Communication Net," by J. L. Divilbiss and B. H. McCormick, Department of Computer Science, File No. 550-65, February 7, 1966.

"Procurement Specifications for Printed Wiring Assemblies," by F. P. Serio and E. Pelg, Department of Computer Science, File No. 550-69, March 24, 1966.

C. Eddy

5. NUMERICAL METHODS, COMPUTER ARITHMETIC AND ARTIFICIAL LANGUAGES

(Supported in part by the National Science Foundation under Grant No. NSF-GP-4636)

5.1 Relationship Between Arithmetic Structure and Digital Probabilities

During the past quarter we have investigated two radix 2 adders operating on and forming numbers in signed-digit representation. The investigation is concerned with the transformations on probabilistic distributions effected by the adders, and the determination of steady-state distributions which characterize the adders and may be used to evaluate figures of merit for the performance of the adders. The investigation has not as yet come up to our initial expectations due to the gross and complex nature of expressions which pervade the entire analysis. We have had a measure of success in using numbers represented in SRT recodings as inputs to the adders. It appears that for a large class of input recodings the probability of any given digit of the output being zero is $\frac{1}{2}$. That this value of $\frac{1}{2}$ is attained at one pass, and for a diversity of inputs, is somewhat remarkable. Our energies are now directed to attempting analytical verification of hypotheses based on such findings as the above.

(F. Rohatsch)

5.2 Autonomous Arithmetic Unit Structures

A hand-calculated simulation of the proposed arithmetic structure was performed for some simple order sequences. This simulation made a number of inadequacies of the structure obvious. Several changes were made in the set of microinstructions which increased their compatibility with one another and which allowed a simple structure to be used. The other major result of this simulation was the conclusion that multiplier recoding could lower the average multiply time even though only a shift of one position is postulated. Adding and shifting took twice as many "micro-instruction delay times" as shifting only. Investigation of an appropriate recoding [right-directed; signed-digit to signed-digit] was started and is the major effort at present. A recoding was devised by analogy to SRT

division which appears to be very close to a minimal recoding. Unfortunately, the analogy is not close enough that the work of Shively¹ can be applied to determine the resulting shift average, the measure of minimality.

(M. Pisterzi)

5.3 Theory of Artificial Languages and Compilers

Dr. Jan Garwick of the Norwegian Defense Research Establishment and lecturer at Oslo University was a Visiting Professor of Computer Science in this Department from March 15 - April 15.

Dr. Garwick is chairman of the ACM subcommittee developing a new programming language which is more elegant, more powerful and permits more efficient optimization than does ALGOL 60. The language allows extensions of itself by proper declarations.

Dr. Garwick delivered a series of eight 50-minute lectures on the following topics.

1. Design of Compilers, especially ALGOL 60
2. Gargoyle: A Programming Language for Compiler Writing with Applications to ALGOL 60 and Gargoyle Itself
3. A New Programming Language and Some Problems in its Implementation.

Dr. Garwick is well acquainted with compiler work here and abroad. This series of lectures was a most informative one.

5.4 Number Theory

A paper containing some theoretical results and more than 40 new factorizations of numbers of the form $2^n \pm 1$ has been prepared and submitted to Math of Computation. This work is joint with John Brillhart.

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1. Shively, Richard R., "Stationary Distribution of Partial Remainders in S-R-T Digital Division," Department of Computer Science, University of Illinois, Urbana, Illinois 61801, Report 136, May 15, 1963.

The generally favorable referee's report has been received, and revision and retyping are in progress.

Some theoretical investigation has been made of two person positional games with complete information. Some specific work has been done on strategies in the 4^3 game ($4 \times 4 \times 4$ tit-tat-toe) but the game is still far from solution. A general result of Hales and Jewitt (1963 T.A.M.S.) concerning the k^n game is that if $k > 3^n$ there is a computable strategy which allows the second player a draw, thus solving the game. We have improved the above inequality to $k > n \log n$ and give a strategy for the second player which succeeds in many more general environments. A paper is being prepared for submission to Math of Computation.

Included in this paper will be a proof that there are infinitely many primes which do not occur in the sequence $2, 3, 7, 43, 139, \dots$ where $p_n =$ greatest prime factor of $1 + \prod_{i=1}^n p_i$. This result is joint with P. Erdős.

In the game of Waerden, players alternately choose numbers from $\{1, \dots, n\}$ without replacement. The first player to choose an A.P. of length r wins. In light of van der Waerden's theorem, the first player can win if n is large enough. Let $f(r)$ be the minimum number for which solution is a first player win. Then $f(2) = 3$ and it is easy to show that $f(3) = 5$. We have shown that $f(4) = 13$ but the determination of $f(r)$ in general seems hopelessly difficult.

In Conway's game, players alternately choose positive integers but may not choose any n which is a linear combination (with nonnegative integer coefficients) of previous n 's. Whoever first chooses 1 loses. Conway has shown that the first player will lose if he starts with 2, 3, 4, 6, 8, 9 or 12. If he starts with a prime > 3 , he has a theoretical win but the complete strategy is not known. Robert Norman conjectured that following 5, the first player should pair $5k + 2, 5k + 3$. We disproved this conjecture, showing that 5, 12, 13, 21, is a win for the second player. Study of Conway's game is continuing.

I will briefly describe some of the joint work with P. Erdős. Our main theorem is that the product of consecutive integers is never a power. The proof involves separate treatment for the case of $< 60,000$

consecutives with a method of ascent using a variety of arguments. The proof in the larger case is also quite complicated. When written up, this substantial paper will be submitted to the Landau memorial volume or the Acta Arithmetica.

For the case of a square the result was published earlier by Erdős, but we have the following improvement: Let $(n+1)(n+2) \dots (n+k) = \prod p_i^{a_i}$, and $n \geq k > 3$. Then for some i , $p_i > k$ and a_i is odd. For $k = 3$ this is false as shown by 48.49.50. This paper will probably be submitted separately to Acta Arithmetica.

Numbers n such that $n+i$ has only one prime factor $> i$ have been investigated. A paper concerning this and related matters has been submitted to the Illinois Journal of Mathematics.

We have outlined a method of proof that the least prime factor of $\binom{n}{r}$ is $\leq n/2$ where $n \geq 2r > 2$. The only exception is $n = 7 = 2r + 1$. We also have that the least prime factor of $\binom{n}{r}$ is $\leq n/r$ if $n > r 2^r$. Further work is in progress.

Lectures concerning computers or computations were presented at the Mathematics Department colloquium and at the University of Wisconsin, Ohio State University, Western Illinois University, Purdue (Fort Wayne), Earlham College, Wheaton College, Rosary College, St. Xavier College, and St. John Fisher College.

(J. L. Selfridge)

5.5 Numerical Analysis

Successive over-relaxation for the simplest finite difference approximation to Laplace's equation was further studied in one and two dimensions, both theoretically and experimentally, for the case in which different extrapolation factors are used for each point, or, for block methods, for each block of points.

In one dimension, two particularly interesting cases were studied, one in which after n steps for the $1 \times n$ problem, the error is reduced to zero, and the other in which after one forward iteration using current and back values, and a backward iteration using the last

two iterates, the error is reduced to zero. Both methods are numerically stable and both generalize to 2 or more dimensions in each of two ways:

- (1) $n - 1$ dimensional blocks of points are chosen and a sequence of extrapolation factors is chosen one per block such that the spectral radius of the iteration is small, but not zero.
- (2) an extrapolation matrix is used for each block and the error becomes theoretically zero in the same number of iterations as in one dimension.

Work is continuing in an attempt to implement the second method for general regions without involving an excessive amount of arithmetic.

(L. McDowell and D. B. Gillies, Principal Investigator)

6. COMPUTATIONAL PHYSICS

The anharmonic oscillator described by the Hamiltonian

$$H = \frac{p^2}{2} + \frac{a_2 q^2}{2} + \frac{a_4 q^4}{2} \quad (1)$$

is one of the simplest systems in quantum mechanics, but exact expressions for its eigenvalues and eigenfunctions are unknown. Approximate determination of the eigenvalues and eigenfunctions by perturbation theory is a textbook problem, and other approximations appear in the literature. In spite of the simplicity of this Hamiltonian it is used as a model for real physical systems;^{1,2,3,4} for example molecular vibrations in Diazomethane, Ketene, and Trimethylene Oxide.

It is extremely useful to have accurate solutions to a simple non-trivial problem, especially when it is a representative of a class of interesting problems, since they can then be used as a standard by which to judge simple approximative schemes applied to members of the class. Indeed, it was in the search of a standard to judge the accuracy of an approximation scheme we were using that led to our interest in this Hamiltonian. Systems with nonlinear forces are, of course, of wide interest and the one represented by Eq. (1) is certainly one of the simplest. For this reason we decided to calculate an extensive and accurate set of eigenvalues and eigenfunctions for this system.

So far as we know the most extensive tabulation of eigenvalues and eigenfunctions is by Sunney I. Chan and David Stelman.^{5,6} The method they used is worth mentioning. They put the Hamiltonian in matrix form, using harmonic oscillator wavefunctions as a basis. The problem now becomes one of determining eigenvalues and eigenvectors for the matrix equation

$$H\Psi = \lambda\Psi \quad (2)$$

One difficulty is that the matrix H is infinite and the first approximation is to truncate it so that it becomes an $N \times N$ matrix. In the calculations of Chan and Stelman $N = 100$. They then applied a standard Jacobi subroutine to diagonalize the matrix. Now it happens that H (after separating even and odd submatrices as shown later) is a band matrix with

$$(H)_{ij} \equiv 0 \quad \text{for } j \geq i + 3 \text{ and } j \leq i - 3 \quad (3)$$

and for such a case the use of the Jacobi subroutine is not particularly appropriate for an extensive eigenvalue calculation, since one should try to take advantage of the band form.

A better approach is to use the LR transformation as Rutishauser, and Gerson have done.^{7,8} Since the band form is preserved the storage requirements are proportional to N instead of N^2 .

We have used another standard method which is also proportional to N in its storage requirements, and, in fact, independent of N for the eigenvalue part of the calculation. Whether or not it is superior to the use of the LR transformation is not known. This method simply consists of locating zeros of

$$D(\lambda) = |H - \lambda I| \quad (4)$$

by Newton's method, and obtaining the initial approximation by extrapolation. Important details of this calculation are described below.

The Hamiltonian, Eq. (1), contains two parameters a_2, a_4 , however it can be transformed so that a one parameter Hamiltonian is obtained. Let

$$Q = \left(a_2 + a_4^{2/3} \right)^{1/4} q, \quad P = \left(a_2 + a_4^{2/3} \right)^{-1/4} p \quad (5)$$

$$\alpha = \frac{a_4^{2/3}}{a_2 + a_4^{2/3}} \quad (6)$$

Then

$$H = a_2 \left[\left(\frac{1}{1-\alpha} \right) \right]^{1/2} H(\alpha) \quad (7)$$

$$H(\alpha) = \frac{P^2}{2} + (1-\alpha) \frac{Q^2}{2} + \frac{\alpha^{3/2} Q^4}{2} . \quad (8)$$

It will furthermore be noted that the commutation relations are not changed by this transformation,

$$[q, p] = [Q, P] . \quad (9)$$

Thus we need only consider the Hamiltonian $H(\alpha)$; all of our results and future discussion apply to it.

It is a straightforward task to determine the matrix elements for $H(\alpha)$ using the number representation. Let a^+ and a be the creation and annihilation operators, defined by

$$a^+ |n\rangle = (n+1)^{1/2} |n+1\rangle, \quad (10)$$

$$a |n\rangle = n^{1/2} |n-1\rangle . \quad (11)$$

Then the position and momentum operators are

$$Q = \frac{1}{\sqrt{2}} (a^+ + a), \quad P = \frac{i}{\sqrt{2}} (a^+ - a) \quad (12)$$

and the matrix elements are

$$\langle n' | Q | n \rangle = \frac{1}{\sqrt{2}} \left((n+1)^{1/2} \delta(n'-n-1) + n^{1/2} \delta(n'-n+1) \right) \quad (13)$$

$$\langle n' | P | n \rangle = \frac{i}{\sqrt{2}} \left((n+1)^{1/2} \delta(n'-n-1) - n^{1/2} \delta(n'-n+1) \right) \quad (14)$$

where $n = 0, 1, \dots$, $n' = 0, 1, \dots$, and

$$\delta(X) = \begin{cases} 1 & \text{if } X = 0 \\ 0 & \text{otherwise} \end{cases}.$$

Then matrix elements of the terms in $H(\alpha)$ are computed from

$$\langle n' | Q^2 | n \rangle = \sum_{n''} \langle n' | Q | n'' \rangle \langle n'' | Q | n \rangle, \quad (15)$$

$$\langle n' | P^2 | n \rangle = \sum_{n''} \langle n' | P | n'' \rangle \langle n'' | P | n \rangle, \quad (16)$$

$$\langle n' | Q^4 | n \rangle = \sum_{n''} \langle n' | Q^2 | n'' \rangle \langle n'' | Q^2 | n \rangle. \quad (17)$$

Evaluating the expressions on the right we have

$$\begin{aligned} \langle n' | Q^2 | n \rangle = \frac{1}{2} \bigg(& ((n+1)(n+2))^{1/2} \delta(n'-n-2) + (1+2n) \delta(n'-n) \\ & + (n(n-1))^{1/2} \delta(n'-n+2) \bigg) \end{aligned} \quad (18)$$

$$\begin{aligned} \langle n' | P^2 | n \rangle = & -\frac{1}{2} \left(((n+1)(n+2))^{1/2} \delta(n'-n-2) - (1+2n) \delta(n'-n) \right. \\ & \left. + (n(n-1))^{1/2} \delta(n'-n+2) \right) \end{aligned} \quad (19)$$

$$\begin{aligned} \langle n' | Q^4 | n \rangle = & \frac{1}{4} \left(((n+1)(n+2)(n+3)(n+4))^{1/2} \delta(n'-n-4) \right. \\ & + (4n+6)((n+1)(n+2))^{1/2} \delta(n'-n-2) \\ & + 3(n^2 + (n+1)^2) \delta(n'-n) \\ & + (4n-2)(n(n-1))^{1/2} \delta(n'-n+2) \\ & \left. + (n(n-1)(n-2)(n-3))^{1/2} \delta(n'-n+4) \right) \end{aligned} \quad (20)$$

Now the matrix for the Hamiltonian is

$$\langle n' | H(\alpha) | n \rangle = \frac{1}{2} \langle n' | P^2 | n \rangle + \frac{(1-\alpha)}{2} \langle n' | Q^2 | n \rangle + \frac{\alpha}{2} \langle n' | Q^4 | n \rangle \quad (21)$$

and examination of this matrix will show that it consists of two disjoint submatrices corresponding to even n and odd n . Each submatrix is infinite and has the band form shown below

$$J = \begin{bmatrix} a_0 & b_0 & c_0 & 0 & 0 & \cdots & \cdots \\ b_0 & a_1 & b_1 & c_1 & 0 & 0 & \cdots \\ c_0 & b_1 & a_2 & b_2 & c_2 & 0 & 0 \cdots \\ 0 & c_1 & b_2 & \cdots & \cdots & \cdots & \cdots \\ 0 & 0 & c_2 & \cdots & \cdots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \ddots & \ddots & \ddots & \ddots \end{bmatrix} \quad (22)$$

where:

Even submatrix

$$a_i = (1+4i)\left(\frac{2-\alpha}{4} + \frac{3\alpha}{8}\right) + 3\alpha^{3/2} i^2 \quad (23)$$

$$b_i = ((2i+1)(2i+2))^{1/2} \left(-\frac{\alpha}{4} + \alpha^{3/2} \left(i + \frac{3}{4} \right) \right) \quad (24)$$

$$c_i = \frac{\alpha}{8}^{3/2} ((2i+1)(2i+2)(2i+3)(2i+4))^{1/2} \quad (25)$$

Odd submatrix

replace i by $i + \frac{1}{2}$ on the right side of the above equations for a_i, b_i, c_i .

Determination of the eigenvalues of the matrix $H(\alpha)$ consists now of separately determining eigenvalues for the two J matrices corresponding to the even and odd submatrices. The first step is to replace J by a finite matrix by simply truncating it so that the element in the lower right corner is a_{n-1} : the resultant matrix is called J_n . The eigenvalues of J_n are the zeros of

$$P_n(\lambda) = \det (J_n - \lambda I_n) \quad (26)$$

where I_n is the $n \times n$ identity matrix. Now the Newton iteration scheme is represented by the recurrence relation

$$\lambda^{(i+1)} = \lambda^{(i)} - \frac{P_n(\lambda^{(i)})}{P'_n(\lambda^{(i)})} \quad (27)$$

where

$$P'_n(\lambda) = \frac{d P_n(\lambda)}{d\lambda} \quad (28)$$

The trick that makes this approach promising is that the ratio

$$-\frac{P'_n(\lambda)}{P_n(\lambda)}$$

may be expressed as

$$-\frac{P'_n(\lambda)}{P_n(\lambda)} = \sum_{i=0}^{n-1} w_i, \quad (29)$$

where the w_i are easily computed from recurrence relations. This can be seen in the following way. Suppose Gauss elimination is done on the matrix

$$J_n - \lambda I_n, \quad (30)$$

thus producing an upper band matrix with elements $u_0, u_1, \dots, u_{n-1}$ on the main diagonal.

Then

$$P_n(\lambda) = \det (J_n - \lambda I_n) = \prod_{i=0}^{n-1} u_i \quad (31)$$

and

$$-\frac{P'_n(\lambda)}{P_n(\lambda)} = \sum_{i=0}^{n-1} \left(-\frac{u'_i}{u_i} \right), \quad (32)$$

thus

$$w_i = -\frac{u'_i}{u_i}. \quad (33)$$

It is straightforward to derive recurrence relations for the u_i 's and hence for the w_i 's; they are

$$u_{i+2} = a_{i+2} - \lambda - \frac{(b_{i+1}^*)^2}{u_{i+1}} - \frac{c_i^2}{u_i} \quad (34)$$

$$b_{i+2}^* = b_{i+2} - \frac{c_{i+1} b_{i+1}^*}{u_{i+1}} \quad (35)$$

$$w_{i+2} = \frac{1}{u_{i+2}} \left(1 + \frac{2b_{i+1}^* (b_{i+1}^*)'}{u_{i+1}} + \frac{(b_{i+1}^*)^2 w_{i+1}}{u_{i+1}} + \frac{c_i^2 w_i}{u_i} \right) \quad (36)$$

$$(b_{i+1}^*)' = -\frac{c_i}{u_i} ((b_i^*)' + b_i^* w_i)$$

for $i = 0, 1, \dots, n-3$

with

$$u_0 = a_0 - \lambda \quad (37)$$

$$u_1 = a_1 - \lambda - \frac{b_0^2}{a_0 - \lambda} \quad (38)$$

$$w_0 = \frac{1}{u_0} \quad (39)$$

$$w_1 = \left(1 + \frac{b_0^2}{(a_0 - \lambda)^2} \right) / u_1 \quad (40)$$

$$b_1^* = b_1 - \frac{c_0 b_0}{u_0} \quad (41)$$

$$(b_1^*)' = - \frac{c_0 b_0}{u_0} w_0 \quad (42)$$

The bulk of our computations were made for a matrix with $n = 201$; that is, the even submatrix and odd submatrix each had $n = 201$. Initially we attempted to determine the effect of truncating the infinite matrix with some numerical experiments on the even submatrix for the pure quartic oscillator (i.e., $\alpha = 1$). In these experiments we calculated the eigenvalues for the cases $n = 201, 401, 501, 601$. Letting $\lambda_j (j=0, 2, 4, \dots, 2(n-1))$ denote the eigenvalues we tabulated the maximum value of j which gives

$$\epsilon = | \lambda_j - \lambda_j(n = 601) | < 0.5 \cdot 10^{-16} \lambda_j (n = 601) . \quad (43)$$

n	j
201	54
401	106
501	132

From these observations it appears that λ_j is accurate to about 16 significant figures when

$$j \gtrsim 0.25 n . \quad (44)$$

For each α , the λ_j 's were calculated for successively increasing values of j . Starting values for the iteration on a particular λ_j were obtained by polynomial extrapolation on the last three λ_j 's. In most cases only three iterations were required before the convergence condition

$$\left| \frac{\Delta \lambda}{\lambda} \right| \leq 10^{-16} , \quad (45)$$

$$\Delta \lambda = - \frac{P(\lambda)}{P'(\lambda)} , \quad (46)$$

was satisfied. Since the convergence is quadratic, one more iteration would give approximately

$$\left| \frac{\Delta \lambda}{\lambda} \right| \approx 10^{-32} , \quad (47)$$

well beyond the precision retained in the calculation.

These calculations were done in double precision arithmetic. A portion of them was done on the CDC 3600 at Argonne National Laboratory; this machine has a double precision representation of 84 bits (excluding sign) for the fractional part of the floating point number. Another portion was done on ILLIAC II; this machine has a double precision representation of 88 bits. The eigenvalues $\lambda_0, \lambda_2, \dots, \lambda_{48}$ of the even submatrix ($n = 201$) for $\alpha = 0.1 (0.1) 2.0$ are shown in Table I.* The eigenvalues $\lambda_1, \lambda_3, \dots, \lambda_{49}$ of the odd submatrix ($n = 201$) for $\alpha = 0.1 (0.1) 2.0$ are shown in Table II. It will be noted that the case $\alpha = 0$ represents the harmonic oscillator for which the eigenvalues are

$$\lambda_j = j + \frac{1}{2} . \quad (48)$$

It will also be noted that the potential energy curve for the range $1 < \alpha \leq 2.0$ has a double minimum as indicated in the sketch below.

* Column headings by N in this table contain the indices of the eigenvalues.

The data in Tables I and II are plotted in Figures 1 and 2, respectively. The ordinate is the logarithm of the eigenvalue and the abscissa is α .

Since the computation procedure allows the possibility of skipping eigenvalues, we compared the trace of the matrix against the sum of the eigenvalues for a few cases. The regularity of the data between these check points allows us to assert that no eigenvalues have been skipped.

An interesting qualitative feature of the data is the behavior of the lowest eigenvalue, λ_0 as a function of α ; it has a minimum in the range $0 < \alpha < 0.3$ and

$$\lambda_0(\alpha=0) \approx \lambda_0(\alpha = 0.7) \quad (49)$$

Thus the ground state energy for the oscillator with potential energy approximately

$$V = \frac{0.3}{2} Q^2 + \frac{0.7^{2/3}}{2} Q^4 \quad (50)$$

(quite anharmonic!) is the same as for the harmonic oscillator

$$V = \frac{1}{2} Q^2 .$$

(51)

Calculations of the eigenvectors are now in progress and will be reported later.

Lloyd D. Fosdick and Peter Stuckey.

Table 1

N	ALPHA= 0
0	.5000000000000000E+00
2	.2500000000000000E+01
4	.4500000000000000E+01
6	.6500000000000000E+01
8	.8500000000000000E+01
10	.1050000000000000E+02
12	.1250000000000000E+02
14	.1450000000000000E+02
16	.1650000000000000E+02
18	.1850000000000000E+02
20	.2050000000000000E+02
22	.2250000000000000E+02
24	.2450000000000000E+02
26	.2650000000000000E+02
28	.2850000000000000E+02
30	.3050000000000000E+02
32	.3250000000000000E+02
34	.3450000000000000E+02
36	.3650000000000000E+02
38	.3850000000000000E+02
40	.4050000000000000E+02
42	.4250000000000000E+02
44	.4450000000000000E+02
46	.4650000000000000E+02
48	.4850000000000000E+02

Table 1 (Cont'd)

N	ALPHA= .1	N	ALPHA= .2
0	.4867678784988200E+00	0	.4827270038620096E+00
2	.2523434237131151E+01	2	.2635659077941682E+01
4	.4717430319665849E+01	4	.5131573311591835E+01
6	.7043579476516497E+01	6	.7881312047066258E+01
8	.9485129198198628E+01	8	.1083921914680466E+02
10	.1202993441310604E+02	10	.1397628751891955E+02
12	.1466869307910269E+02	12	.1727206955267062E+02
14	.1739400082416411E+02	14	.2071120259481541E+02
16	.2019979268383135E+02	16	.2428163038618188E+02
18	.2308098956917790E+02	18	.2797358559705116E+02
20	.2603326220799807E+02	20	.3177896054022644E+02
22	.2905286681859130E+02	22	.3569089464422858E+02
24	.3213652679722168E+02	24	.3970349150232584E+02
26	.3528134512811273E+02	26	.4381161762513637E+02
28	.3848473800045696E+02	28	.4801075497633212E+02
30	.4174438348146047E+02	30	.5229689019164932E+02
32	.4505818113901612E+02	32	.5666642957558647E+02
34	.4842421979551645E+02	34	.6111613267889009E+02
36	.5184075143112783E+02	36	.6564305956654538E+02
38	.5530616981343389E+02	38	.7024452836815532E+02
40	.5881899281218601E+02	40	.7491808068235806E+02
42	.6237784762446053E+02	42	.7966145307088797E+02
44	.6598145832515019E+02	44	.8447255333782616E+02
46	.6962863529491641E+02	46	.8934944061450207E+02
48	.7331826617852664E+02	48	.9429030850410703E+02

N	ALPHA= .3	N	ALPHA= .4
0	.4834210899139107E+00	0	.4869527317867749E+00
2	.2772726557686826E+01	2	.2916382064097160E+01
4	.5564120812170141E+01	4	.5983742743490689E+01
6	.8701756044609595E+01	6	.9472674320937059E+01
8	.1211617360345322E+02	8	.1329430945174586E+02
10	.1576539199982675E+02	10	.1739619023087427E+02
12	.1962065354825268E+02	12	.2174286013818953E+02
14	.2366075932419550E+02	14	.2630841266415702E+02
16	.2786929949306080E+02	16	.3107292148597306E+02
18	.3223311760422156E+02	18	.3602048826511505E+02
20	.3674138230914808E+02	20	.4113807454298911E+02
22	.4138498949063815E+02	22	.4641475530012935E+02
24	.4615615793106179E+02	24	.5184121731676195E+02
26	.5104814504112837E+02	26	.5740940830937513E+02
28	.5605504056679749E+02	28	.6311228341665602E+02
30	.6117161288553375E+02	30	.6894361701214942E+02
32	.6639319190356595E+02	32	.7489785978899777E+02
34	.7171557811673575E+02	34	.8097002808688429E+02
36	.7713497080904033E+02	36	.8715561672636616E+02
38	.8264791053256402E+02	38	.9345052933499502E+02
40	.8825123243370464E+02	40	.9985102192380785E+02
42	.9394202794598581E+02	42	.1063536566612370E+03
44	.9971761302682549E+02	44	.1129552636062902E+03
46	.1055755015768185E+03	46	.1196529087331110E+03
48	.1115133830097274E+03	48	.1264438669855757E+03

Table 1 (Cont'd)

N	ALPHA= .5	N	ALPHA= .6
0	.4922706437611452E+00	0	.4987486071181514E+00
2	.3060022258319975E+01	2	.3201074925799379E+01
4	.6384310657437799E+01	4	.6765721019309595E+01
6	.1019483168126235E+02	6	.1087397481597016E+02
8	.1438622396387809E+02	8	.1540597853417869E+02
10	.1889711128564486E+02	10	.2029249239117190E+02
12	.236863200983903E+02	12	.2548728799889924E+02
14	.2872391667438049E+02	14	.3095686412946110E+02
16	.339869608161023E+02	16	.3667560562807246E+02
18	.3945720010558433E+02	18	.4262316801762661E+02
20	.4511969803952674E+02	20	.4878292666395940E+02
22	.5096196187459941E+02	22	.5514099272692273E+02
24	.5697335783716660E+02	24	.6168555558765142E+02
26	.6314470357191986E+02	26	.6840642507752831E+02
28	.6946797433497676E+02	28	.7529470202794225E+02
30	.7593608534936178E+02	30	.8234253454430567E+02
32	.8254272681687895E+02	32	.8954293345871085E+02
34	.8928223635394293E+02	34	.9688962978719835E+02
36	.9614949866329366E+02	36	.1043769627214052E+03
38	.1031398654392382E+03	38	.1119997902809861E+03
40	.1102490905781013E+03	40	.1197534170915574E+03
42	.1174732771521935E+03	42	.1276335353143441E+03
44	.1248088325546059E+03	44	.1356361758211725E+03
46	.1322524368852739E+03	46	.1437576674536172E+03
48	.1398010021208329E+03	48	.1519946027351064E+03

N	ALPHA= .7	N	ALPHA= .8
0	.5059947167369638E+00	0	.5137540207567972E+00
2	.3338555377395963E+01	2	.3472157493397287E+01
4	.7129409850293432E+01	4	.7477103481852271E+01
6	.1151591730327878E+02	6	.1212564866177503E+02
8	.1636517034986947E+02	8	.1727293543076175E+02
10	.2160083037736454E+02	10	.2283610996797027E+02
12	.2717209534728311E+02	12	.2876016485141442E+02
14	.3304223051074638E+02	14	.3500538830088437E+02
16	.3918319346659277E+02	16	.4154150099808822E+02
18	.4557273944111757E+02	18	.4834450551190244E+02
20	.5219270886789766E+02	20	.5539482569080130E+02
22	.5902794282122355E+02	22	.6267612982235886E+02
24	.6606555936393484E+02	24	.7017454627094931E+02
26	.7329445040468654E+02	26	.7787811862060404E+02
28	.8070491997790571E+02	28	.8577641426818415E+02
30	.8828841688853808E+02	30	.9386023531854843E+02
32	.9603733243350935E+02	32	.1021213999775242E+03
34	.1039448442727965E+03	34	.1105525739062219E+03
36	.1120047938214263E+03	36	.1191471378439646E+03
38	.1202115885011217E+03	38	.1278990821147236E+03
40	.1285601227673300E+03	40	.1368029214280517E+03
42	.1370457135467189E+03	42	.1458536252499025E+03
44	.1456640468947651E+03	44	.1550465602916484E+03
46	.1544111335024156E+03	46	.1643774425531520E+03
48	.1632832712631948E+03	48	.1738422969863277E+03

Table 1 (Cont'd)

N	ALPHA= .9	N	ALPHA= 1.0
0	.5218553983756351E+00	0	.5301810452420914E+00
2	.3601877996709767E+01	2	.3727848968993369E+01
4	.7810448597206004E+01	4	.8130913009425113E+01
6	.1270729212691948E+02	6	.1326423559184126E+02
8	.1813646866638181E+02	8	.1896150051351699E+02
10	.2400907203263654E+02	10	.2512812725834146E+02
12	.3026618237595721E+02	12	.3170152349335945E+02
14	.3686531539487093E+02	14	.3863660024099198E+02
16	.4377410689233133E+02	16	.4589903340449557E+02
18	.5096692489640926E+02	18	.5346165369086626E+02
20	.5842287147406399E+02	20	.6130231950049973E+02
22	.6612452015453500E+02	22	.6940257395569738E+02
24	.7405707512103378E+02	24	.7774675113434103E+02
26	.8220778754727041E+02	26	.8632135598142224E+02
28	.9056553655997925E+02	28	.9511461932623135E+02
30	.9912051988226885E+02	30	.1041161695025720E+03
32	.1078640200168004E+03	32	.1133167842405688E+03
34	.1167882239369557E+03	34	.1227081993959682E+03
36	.1258860816041563E+03	36	.1322829589072494E+03
38	.1351511932531053E+03	38	.1420342952907004E+03
40	.1445777183864066E+03	40	.1519560331741920E+03
42	.1541603014192290E+03	42	.1620425104960667E+03
44	.1638940102790881E+03	44	.1722885134457925E+03
46	.1737742852167921E+03	46	.1826892222335313E+03
48	.1837968957599985E+03	48	.1932401654932585E+03

N	ALPHA= 1.1	N	ALPHA= 1.2
0	.5386481769342506E+00	0	.5471976495267606E+00
2	.3850259234269601E+01	2	.3969316318810443E+01
4	.8439774527362573E+01	4	.8738137549021079E+01
6	.1379927599929003E+02	6	.1431474170409788E+02
8	.1975265936507783E+02	8	.2051373593563384E+02
10	.2619998574600590E+02	10	.2723009204261437E+02
12	.3307519137784549E+02	12	.3439444638989565E+02
14	.4033072349455121E+02	14	.4195690282773662E+02
16	.4793040314840934E+02	16	.4987951743822207E+02
18	.5584560553064172E+02	18	.5813227995529826E+02
20	.6405301116401353E+02	20	.6669074940920490E+02
22	.7253318700239062E+02	22	.7553456310101283E+02
24	.8126964262595328E+02	24	.8464644524849380E+02
26	.9024817572284068E+02	26	.9401151974022280E+02
28	.9945640257413624E+02	28	.1036168172949757E+03
30	.1088834116819457E+03	30	.1134509119785478E+03
32	.1185195021409926E+03	32	.1235036467143752E+03
34	.1283559819952301E+03	34	.1337659217713788E+03
36	.1383850100932089E+03	36	.1442295289098901E+03
38	.1485994701554822E+03	38	.1548870193316952E+03
40	.1589928691382093E+03	40	.1657315971223886E+03
42	.1695592542222714E+03	42	.1767570322328928E+03
44	.1802931442885600E+03	44	.1879575886554218E+03
46	.1911894728068480E+03	46	.1993279645693887E+03
48	.2022435398229246E+03	48	.2108632420278426E+03

Table 1 (Cont'd)

N	ALPHA= 1.3	N	ALPHA= 1.4
0	.5557866554733838E+00	0	.5643839052209181E+00
2	.40852279C6534694E+01	2	.4198193013270564E+01
4	.9026956417094841E+01	4	.9307C58292835690E+01
6	.1481258909725769E+02	6	.1529447731954967E+02
8	.21247875443350C2E+02	8	.2195771852241280E+02
10	.2822293051153390E+02	10	.2918224382525297E+02
12	.3566523938497601E+02	12	.3689251732485133E+02
14	.4352266655124497E+02	14	.4503425661652095E+02
16	.5175558234952952E+02	16	.5356621245586940E+02
18	.6033265072424241E+02	18	.6245577891668812E+02
20	.6922835863331496E+02	20	.7167641321080445E+02
22	.7842145418716214E+02	22	.8120600987200414E+02
24	.8789391029543786E+02	24	.9102582049946161E+02
26	.9763020618793889E+02	26	.1011197052982315E+03
28	.1076168122540647E+03	28	.1114735965961432E+03
30	.11784181C2521530E+03	30	.1220751033360465E+03
32	.1282946065110030E+03	32	.1329132125104004E+03
34	.13896571C9902810E+03	34	.1439780591704045E+03
36	.1498465640575973E+03	36	.1552607461335131E+03
38	.1609293985906931E+03	38	.1667532004746585E+03
40	.1722071287148027E+03	40	.1784480577487650E+03
42	.1836732589522764E+03	42	.1903385674629960E+03
44	.1953218092435553E+03	44	.2024185150697123E+03
46	.2071472524698765E+03	46	.2146821569713460E+03
48	.2191444619392754E+03	48	.2271241658942088E+03

N	ALPHA= 1.5	N	ALPHA= 1.6
0	.5729663717251022E+00	0	.5815170442761521E+00
2	.4308398122374290E+01	2	.4416015877592423E+01
4	.9579163304936891E+01	4	.9843901567326739E+01
6	.1576182586016755E+02	6	.1621585916017273E+02
8	.2264550588649622E+02	8	.2331315716914740E+02
10	.3011119233107508E+02	10	.3101247242237190E+02
12	.3808C44375636466E+02	12	.3923256116397994E+02
14	.4649691177479885E+02	14	.4791508178019220E+02
16	.5531778961518473E+02	16	.5701572446504605E+02
18	.6450924781553070E+02	18	.6649947880676584E+02
20	.7404375256464284E+02	20	.7633785431932042E+02
22	.8389837648033242E+02	22	.8650713009164192E+02
24	.9405367651730919E+02	24	.9698719235384220E+02
26	.1044929166927443E+03	26	.1077607294119053E+03
28	.1152015110538252E+03	28	.1188126547932243E+03
30	.1261666130874406E+03	30	.1301296821C56455E+03
32	.1373768058133349E+03	32	.1417000041879031E+03
34	.1488218630868924E+03	34	.1535130460112639E+03
36	.1604925625027683E+03	36	.1655592710171867E+03
38	.1723805364854989E+03	38	.1778300269957236E+03
40	.1844781521660463E+03	40	.1903174217673914E+03
42	.1967784133139422E+03	42	.2030142216982145E+03
44	.2092748794150490E+03	44	.2159137679634001E+03
46	.2219615982522508E+03	46	.2290099067877900E+03
48	.2348330492455104E+03	48	.2422969308226176E+03

Table 1 (Cont'd)

N	ALPHA= 1.7	N	ALPHA= 1.8
0	.5900233497524661E+00	0	.5984760246303310E+00
2	.4521205083123691E+01	2	.4624111347956625E+01
4	.1010182730087482E+02	4	.1035343047606907E+02
6	.1665764141914382E+02	6	.1708810400137631E+02
8	.2396233114562701E+02	8	.2459447234791811E+02
10	.3188840594776311E+02	10	.3274100878727598E+02
12	.4035191274177800E+02	12	.4144113525066571E+02
14	.4929258228823276E+02	14	.5063271441515297E+02
16	.5866465090806642E+02	16	.6026857337378964E+02
18	.6843196567809623E+02	18	.7031145161371540E+02
20	.7856511045224888E+02	20	.8073103551578580E+02
22	.8903959643102712E+02	22	.9150209170138494E+02
24	.9983466073131434E+02	24	.1026032278254948E+03
26	.1109324344527835E+03	26	.1140160346115968E+03
28	.1223173466569095E+03	28	.1257244712588816E+03
30	.1339756851549180E+03	30	.1377144125943112E+03
32	.1458952650750550E+03	32	.1499733073831243E+03
34	.1580651736284004E+03	34	.1624899152287924E+03
36	.1704755701452041E+03	36	.1752541004029712E+03
38	.1831175268110995E+03	38	.1882566677939660E+03
40	.1959829003908590E+03	40	.2014892305964327E+03
42	.2090642273873782E+03	42	.2149441023151994E+03
44	.2223546375925553E+03	44	.2286142076663405E+03
46	.2358477820633909E+03	46	.2424930083577966E+03
48	.2495377725985098E+03	48	.2565744407291287E+03

N	ALPHA= 1.9	N	ALPHA= 2.0
0	.6068682972112964E+00	0	.6151952869916586E+00
2	.4724868019262525E+01	2	.4823597214689728E+01
4	.1059914640364030E+02	4	.1083936365167175E+02
6	.1750806721702232E+02	6	.1791825779279647E+02
8	.2521084759840413E+02	8	.2581257497441052E+02
10	.3357204418865422E+02	10	.3438306478063737E+02
12	.4250253088728851E+02	12	.4353812365953217E+02
14	.5193835664781035E+02	14	.5321203672757748E+02
16	.6183098011439334E+02	16	.6335493161942560E+02
18	.7214206509408997E+02	18	.7392742576831532E+02
20	.8284042625832990E+02	20	.8489748580454467E+02
22	.9390010696017724E+02	22	.9623845139498013E+02
24	.1052991033630800E+03	24	.1079277237274399E+03
26	.1170184812077129E+03	26	.1199458577096880E+03
28	.1290417431901513E+03	28	.1322759118165123E+03
30	.1413543628753400E+03	30	.1449029691291666E+03
32	.1539434330488641E+03	32	.1578137760019442E+03
34	.1667973949693424E+03	34	.1709964638765816E+03
36	.1799058262200615E+03	36	.1844403313190635E+03
38	.1932592719107856E+03	38	.1981356706043411E+03
40	.2068491085467637E+03	40	.2120736278687557E+03
42	.2206674329195958E+03	42	.2262460889726958E+03
44	.2347069704444506E+03	44	.2406455853433082E+03
46	.2489609988079793E+03	46	.2552652155627523E+03
48	.2634232838676436E+03	48	.2700985795234430E+03

Table 2

N	ALPHA= 0
1	.15000000000000000E+01
3	.35000000000000000E+01
5	.55000000000000000E+01
7	.75000000000000000E+01
9	.95000000000000000E+01
11	.11500000000000000E+02
13	.13500000000000000E+02
15	.15500000000000000E+02
17	.17500000000000000E+02
19	.19500000000000000E+02
21	.21500000000000000E+02
23	.23500000000000000E+02
25	.25500000000000000E+02
27	.27500000000000000E+02
29	.29500000000000000E+02
31	.31500000000000000E+02
33	.33500000000000000E+02
35	.35500000000000000E+02
37	.37500000000000000E+02
39	.39500000000000000E+02
41	.41500000000000000E+02
43	.43500000000000000E+02
45	.45500000000000000E+02
47	.47500000000000000E+02
49	.49500000000000000E+02

Table 2 (Cont'd)

N	ALPHA= .1	N	ALPHA= .2
1	.1483336908518436E+01	1	.1507015847538573E+01
3	.3602606590781932E+01	3	.3847943351784452E+01
5	.5865170430659228E+01	5	.6478111577605228E+01
7	.8250770007418804E+01	7	.9336317975453628E+01
9	.1074525925837136E+02	9	.1238678413300277E+02
11	.1233806897343910E+02	11	.1560539275327421E+02
13	.1602093390116253E+02	13	.1897453379206735E+02
15	.1878717358966123E+02	15	.2248066002640853E+02
17	.2163125145306359E+02	17	.2611295706961308E+02
19	.2454848756228957E+02	19	.2986254981359785E+02
21	.2753486260534330E+02	21	.3372199614594708E+02
23	.3058687898223283E+02	23	.3768494701240617E+02
25	.3370145923425813E+02	25	.4174590876182989E+02
27	.3687587048649481E+02	27	.4590007145930644E+02
29	.4010766522127013E+02	29	.5014318143767906E+02
31	.4339463684053262E+02	31	.5447144449460500E+02
33	.4673478314701338E+02	33	.5888145091066778E+02
35	.5012627748048698E+02	35	.6337011637608364E+02
37	.5356744513497375E+02	37	.6793463475554910E+02
39	.5705674394226672E+02	39	.7257243982186052E+02
41	.6059274812540673E+02	41	.7728117389313881E+02
43	.6417413475005697E+02	43	.8205866185967584E+02
45	.6779967226270166E+02	45	.8690288947210249E+02
47	.7146821072197822E+02	47	.9181198503750479E+02
49	.7517867341630691E+02	49	.9678420386938726E+02

N	ALPHA= .3	N	ALPHA= .4
1	.1546619718556795E+01	1	.1593459974367887E+01
3	.4118898690748462E+01	3	.4389224843079140E+01
5	.7094924441974354E+01	5	.7682308951306387E+01
7	.1037740088113917E+02	7	.1134571408423892E+02
9	.1391345285342428E+02	9	.1531271827266958E+02
11	.1766872866298343E+02	11	.1954071667912723E+02
13	.2161871682693171E+02	13	.2399963363759581E+02
15	.2574486068303483E+02	15	.2866686923988240E+02
17	.3003252206696781E+02	17	.3352469431015857E+02
19	.3446979816254498E+02	19	.3855875452774716E+02
21	.3904678163028651E+02	21	.4375714327681798E+02
23	.4375507158470971E+02	23	.4910979312024476E+02
25	.4858743603959623E+02	25	.5460805814045626E+02
27	.5353757061281958E+02	27	.6024441679280222E+02
29	.585992099525921E+02	29	.6601225415678843E+02
31	.6376954913441040E+02	31	.7190569836973642E+02
33	.6904203026791481E+02	33	.7791949514589528E+02
35	.7441337227392763E+02	35	.8404890975119052E+02
37	.7987995151506735E+02	37	.9028964920751134E+02
39	.8543846110262230E+02	39	.9663779968919095E+02
41	.9108586866940990E+02	41	.1030897755219551E+03
43	.9681938152987438E+02	43	.1096422771759871E+03
45	.1026364176551781E+03	45	.1162922563247544E+03
47	.1085345812801056E+03	47	.1230368865216814E+03
49	.1145116422390316E+03	49	.1298735383921998E+03

Table 2 (Cont'd)

N	ALPHA= .5	N	ALPHA= .6
1	.1643603493807266E+01	1	.1695098940547669E+01
3	.4651632627526334E+01	3	.4904274017564379E+01
5	.8236889417228239E+01	5	.8761136356123650E+01
7	.1224738937695623E+02	7	.1309206007594273E+02
9	.1660463834997692E+02	9	.1780819017929393E+02
11	.2125899671696633E+02	11	.2285367512751377E+02
13	.2617563440519832E+02	13	.2818947665361759E+02
15	.3132848926017517E+02	15	.3378646250563852E+02
17	.3669718035658660E+02	17	.3962189688974164E+02
19	.4226524688833114E+02	19	.4567744606958987E+02
21	.4801906195548178E+02	21	.5193795201512613E+02
23	.5394712236726489E+02	23	.5839063256106600E+02
25	.6003956280713224E+02	25	.6502453526247442E+02
27	.6628781100724836E+02	27	.7183015050692943E+02
29	.7268433568811554E+02	29	.7879912904071451E+02
31	.7922245756029785E+02	31	.8592407045311519E+02
33	.8589620458152990E+02	33	.9319836135865329E+02
35	.9270019905216687E+02	35	.1006160492934716E+03
37	.9962956812935609E+02	37	.1081717428528341E+03
39	.1066798719016894E+03	39	.1158605314864304E+03
41	.1138470448566854E+03	41	.1236779202730163E+03
43	.1211273477174314E+03	43	.1316197762833938E+03
45	.1285173274160628E+03	45	.1396822840304082E+03
47	.1360137835300396E+03	47	.1478619081316928E+03
49	.1436137399080341E+03	49	.1561553617607351E+03

N	ALPHA= .7	N	ALPHA= .8
1	.1746918123872102E+01	1	.1798498840962840E+01
3	.5147075757468725E+01	3	.5380559773569735E+01
5	.9258473684583962E+01	5	.9732133164041681E+01
7	.1388827745534474E+02	7	.1464300741012943E+02
9	.1893829431150557E+02	9	.2000643146685193E+02
11	.2434705787912370E+02	11	.2575578052303776E+02
13	.3007171885680892E+02	13	.3184469865044454E+02
15	.3608036064762401E+02	15	.3823870442374525E+02
17	.4234810935933074E+02	17	.4491095269659079E+02
19	.4885492917139141E+02	19	.5183983727801533E+02
21	.5558426953168722E+02	21	.5900752210219211E+02
23	.6252218430890790E+02	23	.6639898598629826E+02
25	.6965673115821684E+02	25	.7400137191555323E+02
27	.7697754652133728E+02	27	.8180352699225340E+02
29	.8447553563068933E+02	29	.8979566711381842E+02
31	.9214264058235550E+02	31	.9796912625351607E+02
33	.9997166303486383E+02	33	.1063161648975485E+03
35	.1079561261303720E+03	35	.1148298209314824E+03
37	.1160901652131417E+03	37	.1235037916762081E+03
39	.1243684401062874E+03	39	.1323323392317167E+03
41	.1327860638061397E+03	41	.1413102135630298E+03
43	.1413385438706972E+03	43	.1504325892988639E+03
45	.1500217337572200E+03	45	.1596950132738935E+03
47	.1588317920532739E+03	47	.1690933605919208E+03
49	.1677651480397143E+03	49	.1786237975222098E+03

Table 2 (Cont'd)

N	ALPHA= .9	N	ALPHA= 1.0
1	.1849528885928388E+01	1	.1899836514900697E+01
3	.5605421723242773E+01	3	.5822372755689081E+01
5	.1018491486331035E+02	5	.1061918645911797E+02
7	.1536184364340672E+02	7	.1604929885548416E+02
9	.2102151565393937E+02	9	.2199057904864487E+02
11	.2709251019505541E+02	11	.2836710702758652E+02
13	.3352520717706838E+02	13	.3512619731430830E+02
15	.4028273553434017E+02	15	.4222873313747098E+02
17	.4733641225474610E+02	17	.4964430333C24664E+02
19	.5466316622301283E+02	19	.5734845869249259E+02
21	.6224396162900422E+02	21	.6532103437431499E+02
23	.7006277357824217E+02	23	.7354506062880191E+02
25	.781C589C80025027E+02	25	.8200602181143267E+02
27	.8636142298187458E+02	27	.9069133309288411E+02
29	.94818941E6816337E+02	29	.9958995941687354E+02
31	.1034692130415559E+03	31	.1086921308370517E+03
33	.1123039910720658E+03	33	.1179891251808479E+03
35	.12131586C1198964E+03	35	.1274730989853991E+03
37	.1304981078774068E+03	37	.1371369538294703E+03
39	.1398446244481528E+03	39	.1469742291330030E+03
41	.1493498202019024E+03	41	.1569790150919890E+03
43	.1590085582915210E+03	43	.1671458811672413E+03
45	.1688160986538748E+03	45	.1774698167531975E+03
47	.1787680511165526E+03	47	.1879461815024667E+03
49	.1888603358050876E+03	49	.1985706633903373E+03

N	ALPHA= 1.1	N	ALPHA= 1.2
1	.1949331662508476E+01	1	.1997972922767327E+01
3	.6032081032301828E+01	3	.6235153105168540E+01
5	.1103694090790426E+02	5	.1143986072491439E+02
7	.1670905130618573E+02	7	.1734413422906276E+02
9	.2291926241054560E+02	9	.2381216155414654E+02
11	.2958740311584010E+02	11	.3075973210536793E+02
13	.3665788929964691E+02	13	.3812850550708090E+02
15	.44C8947935698796E+02	15	.4587521869382753E+02
17	.5185012624540042E+02	17	.5396626773758087E+02
19	.5991407578511906E+02	19	.6237465611171273E+02
21	.6826009365793773E+02	21	.7107813110315904E+02
23	.7687031489077907E+02	23	.8005797508498729E+02
25	.8572946154773390E+02	25	.8929818394941770E+02
27	.9482429049466372E+02	27	.9878488735165174E+02
29	.1041431914169743E+03	29	.1085059268150708E+03
31	.1136758866033283E+03	31	.1184505407216386E+03
33	.1234132017955534E+03	33	.1286091239228324E+03
35	.1333468879765063E+03	35	.1389730408231212E+03
37	.1434694804988521E+03	37	.1495344776538579E+03
39	.1537741861291902E+03	39	.1602863240394520E+03
41	.1642547913243156E+03	41	.1712220768390242E+03
43	.1749055869054391E+03	43	.1823357611890547E+03
45	.1857213055711263E+03	45	.1936218650115066E+03
47	.1966970695864961E+03	47	.2050752841935510E+03
49	.2078283466283925E+03	49	.2166912763192055E+03

Table 2 (Cont'd)

N	ALPHA= 1.3	N	ALPHA= 1.4
1	.2045748305926264E+01	1	.2092663686234141E+01
3	.6432131491098588E+01	3	.6623498604868717E+01
5	.1182937478033724E+02	5	.1220670503787453E+02
7	.1795707779750848E+02	7	.1855001536605808E+02
9	.2467307412894746E+02	9	.2550517803222298E+02
11	.3188929680679153E+02	11	.3298043014854724E+02
13	.3954477261554705E+02	13	.4091227394582923E+02
15	.4759430672737999E+02	15	.4925366161562974E+02
17	.5600280693037446E+02	17	.5796807296150136E+02
19	.6474208878584759E+02	19	.6702618350954517E+02
21	.7378892560095968E+02	21	.7640383167158362E+02
23	.8312378413595305E+02	23	.8608070120472308E+02
25	.9272996555156547E+02	25	.9603942622772497E+02
27	.1025929953687258E+03	27	.1062649599812224E+03
29	.1127002025518485E+03	29	.1167441156707047E+03
31	.1230403503649431E+03	31	.1274652237669021E+03
33	.1336034252424481E+03	33	.1384178705746685E+03
35	.1443804215534446E+03	35	.1495926950162955E+03
37	.1553631913230711E+03	37	.1609812280662231E+03
39	.1665443205617636E+03	39	.1725757640552341E+03
41	.1779170288669446E+03	41	.1843692562033387E+03
43	.1894750869931397E+03	43	.1963552308572446E+03
45	.2012127484866045E+03	45	.2085277163670217E+03
47	.2131246924650406E+03	47	.2208811835621304E+03
49	.2252059753277276E+03	49	.2334104955210459E+03

N	ALPHA= 1.5	N	ALPHA= 1.6
1	.2138735701664722E+01	1	.2183987310368126E+01
3	.6809682847055738E+01	3	.6991065048271333E+01
5	.1257290405390969E+02	5	.1292888483835981E+02
7	.1912476354768434E+02	7	.1968288320590767E+02
9	.2631116255730766E+02	9	.2709332639841958E+02
11	.3403678435705366E+02	11	.3506147080312749E+02
13	.4223570262638317E+02	13	.4351904741701317E+02
15	.5085908648203424E+02	15	.5241550485692184E+02
17	.5986904128487426E+02	17	.6171162199662845E+02
19	.6923514506039945E+02	19	.7137591747600054E+02
21	.7893233606403938E+02	21	.8138246053577224E+02
23	.8893954404488823E+02	23	.9170945291836948E+02
25	.9923876070811105E+02	25	.1023382660071812E+03
27	.1098143842369802E+03	27	.1132527619699970E+03
29	.1206527425885589E+03	29	.1244388001273097E+03
31	.1317417377515515E+03	31	.1358838686268544E+03
33	.1430705744020095E+03	33	.1475768035341337E+03
35	.1546295490060703E+03	35	.1595075705234791E+03
37	.1664098832039290E+03	37	.1716670924226080E+03
39	.1784035902771557E+03	39	.1840471110116228E+03
41	.1906033667648110E+03	41	.1966400748585757E+03
43	.2030025034925555E+03	43	.2094390472515926E+03
45	.2155948117940177E+03	45	.2224376298569649E+03
47	.2283745617687478E+03	47	.2356298988358043E+03
49	.2413364301834024E+03	49	.2490103509413202E+03

Table 2 (Cont'd)

N	ALPHA= 1.7	N	ALPHA= 1.8
1	.2228444973701539E+01	1	.2272136856775286E+01
3	.7167984533007832E+01	3	.7340744541151364E+01
5	.1327544464414628E+02	5	.1361328400072303E+02
7	.2022572644942377E+02	7	.2075447326384036E+02
9	.2785365203759791E+02	9	.2859386302735311E+02
11	.3605716522454464E+02	11	.3702618817371142E+02
13	.4476573171960578E+02	13	.4597871934895440E+02
15	.5392713607791553E+02	15	.5539762828694267E+02
17	.6350087396143360E+02	17	.6524116674620816E+02
19	.7345443903421702E+02	19	.7547583468225843E+02
21	.8376105964647248E+02	21	.8607404511851549E+02
23	.9439823302282988E+02	23	.9701261211786071E+02
25	.1053467301870924E+03	25	.1082717244982090E+03
27	.1165898945016302E+03	27	.1198342224704912E+03
29	.1281131316670943E+03	29	.1316850717768382E+03
31	.1399035292277101E+03	31	.1438109714024662E+03
33	.1519495664104833E+03	33	.1562000544485120E+03
35	.1642408886471650E+03	35	.1688416557051871E+03
37	.1767681294700784E+03	37	.1817261280720643E+03
39	.1895227677949229E+03	39	.1948446954628814E+03
41	.2024970120987509E+03	41	.2081893334376489E+03
43	.2156837053556587E+03	43	.2217526712332804E+03
45	.2290762462146985E+03	45	.2355279105369438E+03
47	.2426685230446674E+03	47	.2495087575214320E+03
49	.2564548582865286E+03	49	.2636893655371895E+03

N	ALPHA= 1.9	N	ALPHA= 2.0
1	.2315091676972745E+01	1	.2357337971142646E+01
3	.7509616955827471E+01	3	.7674846375377869E+01
5	.1394302203525846E+02	5	.1426520889060252E+02
7	.2127016038706996E+02	7	.2177370431318583E+02
9	.2931546869241553E+02	9	.3001979944163281E+02
11	.3797056741957083E+02	11	.3889208698954029E+02
13	.4716059624490891E+02	13	.4831363446732703E+02
15	.5683016087366107E+02	15	.5822752450342620E+02
17	.6693630507238607E+02	17	.6858962584877266E+02
19	.774445636300211E+02	19	.7936453443919972E+02
21	.8832655771120579E+02	21	.9052310085372495E+02
23	.9955843764534821E+02	23	.1020408298312217E+03
25	.1111198266799190E+03	25	.1138967942428083E+03
27	.1229930761932761E+03	27	.1260728697974557E+03
29	.1351627244671259E+03	29	.1385531788074160E+03
31	.1476150929481307E+03	31	.1513236753144526E+03
33	.1603379784145860E+03	33	.1643718287892088E+03
35	.1733204138019622E+03	35	.1776863783938509E+03
37	.1865524793058641E+03	37	.1912571389129744E+03
39	.2000251510350984E+03	39	.2050748452708877E+03
41	.2137301782000002E+03	41	.2191310263699247E+03
43	.2276599823215437E+03	43	.2334179015548602E+03
45	.2418075736690477E+03	45	.2479282947783477E+03
47	.2561664813520743E+03	47	.2626555628453280E+03
49	.2707306944094865E+03	49	.2775935346921816E+03

Figure 1.

Figure 2.

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7. ILLIAC II SERVICE, USE, AND PROGRAM DEVELOPMENT

(This work is supported in part by Contract No. AT(11-1)-1469 of the Atomic Energy Commission and in part by the University of Illinois.)

7.1 ILLIAC II Program Development

7.1.1 System Program Development

Except for minor changes and improvements, the daily system is virtually in a completely specified and constant state. The System Tape Update Program was again modified. The main advantage to the latest revision is the use of the disk file for intermediate file storage and assembly, thus releasing tapes 6 and 7 for use and reducing the operation time to a fraction of the former operation time. Updating is still accomplished in the normal batch processing mode. It requires the core, 40 blocks of drum, two tapes, and 50 cylinders of disk in order to operate. The new version of the Update Program also performs sumchecks on every record coming off the old tape and produces sumchecks for every record written onto the newly generated tape. This eliminates the majority of errors caused by tape transmission. A newly revised description of the Update Program was distributed on February 8, 1966, in a memorandum titled "System Tape Update".

The Load-Procedure Program was modified in order to take advantage of the sumchecks created by the Update Program so that every program loaded into core from the System Tape has a sumcheck performed on it. Any error is typed out to the engineers and then further attempts are made at a successful loading of the program. This procedure seems to have drastically cut down the number of system failures.

All disk error messages are now recorded on the operator's teletype console. A further recoding of disk SYSAUX will eliminate all options not preceded by a seek. This is necessary in a time-sharing environment since the system can interrupt any user and reposition the disk heads for its own needs before returning to that user.

Changes are being made to the bootstrap and the load systems programs to enable the immediate loading of the 5 block monitor prior to the loading of any other program. A new version of the Special Register 34 dump routine made these modifications necessary. Further coding and code-checking will be necessary before the System Tape will include these changes.

Minor FORTRAN corrections have been put into the system and the MACRO PREPASS was added. Parts of MACRO are operational but many corrections and refinements still need to be done.

As of February 1, 1966, a formal consulting service for users of the ILLIAC II was established in the Digital Computer Laboratory. Use of the service has been increasing. Several training lectures were given by the system programmers in order to orient the consultants to ILLIAC II usage and system procedures. The establishment of this service has been most beneficial to all concerned.

The sections of Part are the responsibility of the following people:

Software System

Aaron, J. - Supervision
Brower, E. - Fortran Compiler
Slivinski, T. - Nicap and Macro
Lyon, R. - Library Subroutines

Operations and Maintenance

Carter, C. - Supervision
Huffman, W., Lopeman, H. - Records
Kerkering, T. - CalComp Plotter
Conroy, D., Holland, L., Huszar, G. - Test Programming

C. W. Gear, Project Director

7.1.2 FORTTRAN, the ILLIAC II Compiler

The FORTRAN compiler error involving exponentiation on an indexed variable was found and the input/output of a sequence of more than ten fixed point variables is now handled correctly. The System Tape has been updated to incorporate these corrections.

The length of the tables was increased by chaining two blocks to the previous set of four blocks necessary for the LABEL, VARIAB, CONST, and DIMEN tables. Several minor errors were corrected. An internal change in the organization of the FORTRAN compiler was made in order to make use of the NICAP pseudo order, COMMON.

Write-ups and flow charts are being made for those sections of the compiler presently lacking them.

Work has begun on changes in the FORTRAN compiler necessary for compatibility with the new time-sharing system and with the new Passes II and III of NICAP.

7.1.3 NICAP, the ILLIAC II Assembler, and the NICAP MACRO PREPASS

In order to make NICAP easier to update, Pass I was modified to generate fixed mnemonic and name tables which were previously loaded as part of the Pass.

A \$ octal option was added to NICAP. When a \$ is placed in the address field of an order, the address of that order is translated into an octal rather than a decimal number. This is particularly helpful in instructions where the bit pattern of the address is pertinent and also for engineering usage.

Work was begun on revamping the NICAP assembler to meet the needs of the new time-sharing system. A new type of line format is necessary because of the consoles. Changes in the use of internal storage are also needed. Since the drum will be used as an extension of core in the new system, internal storage will be shifted to the disk file. A third basic change to NICAP will make the assembler self-loading, i.e., each Pass will load the next one without the intervention of the loader.

A memorandum titled "MACRO Operational, \$MACRO" was distributed on March 24, 1966.

7.1.4 LIBRARY, ILLIAC II

This quarter saw the reorganization of the ILLIAC II LIBRARY and an increase in the staff concerned with the LIBRARY. Professor Fosdick has assumed responsibility for all matters connected with the LIBRARY. Henceforth, the report on the LIBRARY will appear in the section of the Quarterly Report concerned with Software Systems Research Programs. For this quarter, the phase-out of certain long standing routines will be described herein.

A SCRIBE entry was put into PRINT, READ, PUNCH, and the deck was thoroughly tested. This entry permits the user to receive a converted buffer of information rather than sending the buffer directly to the printer or card punch. A new version of LETTER was written using SCRIBE and it has been code-checked.

CCP5AX, the axis drawing and labeling routine for the CalComp Plotter, was changed and new symbols were added to CCP2SY using a new option. Both of these routines have been tested and are awaiting final approval.

7.2 CalComp, Digital Incremental Plotter

The use of the CalComp Plotter for February and March was over 200 hours each month. Between 50 and 60 tapes were processed each week with 10-15 of these tapes originating from a source other than the ILLIAC II. C.S.L. contributed 1-2 tapes a week and the remaining ones were from the Physics' S.M.P. group. The running time of these outside tapes ranged from 5 minutes to 8 hours each for an average of about 3 to 4 hours.

Several test runs of the 7094 Plotter Output System were made; general use of this system should begin in April.

Four part-time students were hired to operate the CalComp when the responsibility of operating the plotter and returning the finished results was removed from the computer operators' duties. It is apparent that when the 7094 begins to handle plotter output, a full-time plotter operator will be necessary in addition to the present part-time help. w

The amount of repair time for the plotter this quarter was small. The tape break switch arm was readjusted once, a main line fuse blew once (reason still unknown), and the chart drive springs broke once. The pen solenoid shorted and it was sent back to the factory for repair.

The CalComp Users Group met twice and another meeting was scheduled for April. Hopefully, the CalComp 780 System will be here for demonstration at that meeting.

7.3 Engineering Test Programming

The existing Delayed Add and Exponent Tests were revised. The former was changed in order to have it play a role in the larger A.E.C. test system. A green switch option was made available on the latter test.

The design of an Automatic Engineering System (A.E.S.) has been completed. This is the first step in making it possible for engineers to add and/or delete test programs within an overall diagnostic system. This system will have the added advantage of being able to use various input/output mediums such as magnetic tape, paper tape, and cards.

7.4 Engineering Maintenance

7.4.1 ILLIAC II Engineering Log Summary - January, February, March, 1966

<u>Error Analysis - ILLIAC II</u>	<u>January</u>	<u>February</u>	<u>March</u>	<u>Totals</u>
Advanced Control	0	1	0	1
Air Conditioning	0	1	1	2
Core 0	1	5	5	11
Core 1	2	1	2	5
Console	1	0	1	2
D/A Converter	1	0	0	1
Disk File (7631-B)	0	1	0	1
Disk File (1301-B)	0	0	2	2
Drum	3	2	0	5
Elliott Paper Tape Reader	1	0	1	2
Flow Gating	1	3	1	5
Interplay	*1	1	0	2
Interrupt and SRDP	1	2	1	4
MAU	0	1	0	1
MSRDP	0	0	1	1
Power Supplies	7	0	1	8
Power Supplies (I/O)	0	1	2	3
Special Registers	1	1	2	4
SPU	0	0	1	1
Systems Tape	0	0	1	1
Tape Units	3	11	13	27
1301A (Channel 3)	*1	0	3	4
1401	*1	0	0	1
1414A	0	0	2	2
1414B	*1	0	0	1
1414C	1	0	0	1
1414D	0	0	1	1
Unknown	<u>0</u>	<u>1</u>	<u>4</u>	<u>5</u>
Total	27	32	45	104

* Errors probably caused by human(s) accidentally applying +25V to the "bit 2" line.

7.4.2 Equipment Requiring Servicing

7.4.2.1 IBM Equipment Requiring Services of Customer Engineer

	<u>January</u>	<u>February</u>	<u>March</u>	<u>Total</u>
Selectric Typewriters	1	0	0	1
1301A (Disk File)	1	0	0	1
1401	1	1	0	2
1402	1	2	0	3
1403	0	4	2	6
Tape Units	4	7	8	19
Synchronizer (1414's)	<u>0</u>	<u>1</u>	<u>0</u>	<u>1</u>
Total	8	15	10	33

7.4.2.2 Off-Line Equipment Requiring Repairs

<u>Type Name</u>	<u>January</u>	<u>February</u>	<u>March</u>	<u>Total</u>
<u>Rented</u>				
026 Key Punch	6	4	3	13
514 Reproducer	1	1	2	4
557 Alph. Interpreter	1	1	3	5
1056 Card Key Punch	1			1
TTY ASR	2	3	3	8
<u>DCS Owned</u>				
Plotter 564		1	1	2
Plotter Tape Unit 670	1		1	2
TTY KSR	1	2	1	4
Tally Tape System	<u>2</u>	<u>1</u>	<u>—</u>	<u>3</u>
Total	15	13	14	42

7.4.3 Scheduled Diagnostic Engineering

7.4.3.1 Maintenance

a. Checking transistors	3 hours
b. Marginal DC voltage tests	21 hours
c. Checking collector, base bumps and zeners	2 hours
d. Component replacement tests (trying new transistors, semiconductors, etc., to replace obsolete items)	3 hours
e. Checking out spare chassis	5 hours
f. Checking card complements	2 hours
g. Checking spare cards for core 0	32 hours
h. Parity error modification checkout	4 hours
i. Thermal sensing circuit for air conditioning	5 hours
j. ICC6 (channel checkout)	63 hours
k. ICC7 (channel checkout)	51 hours

7.4.3.2 Component Failures

- a. Transistors in main machine
(main frame, core 1, interplay, drum, and
power supplies)

Main Machine	40,121
Power Supplies	<u>3,592</u>
Total	43,713

*Transistors replaced 33
*A catastrophe occurred in
core 0 which shorted 25
transistors at one time

- b. Semiconductors in main machine
(diodes, zeners, stabistors, etc.)

Total 81,946

Semiconductors replaced 0

- c. Number of printed circuit cards in
I/O equipment

Total	3,410
Cabinets not online at present (1050, PAU, 1301B)	
Total	404
On Line Total	3,006
Replaced (in channel 6 and 7 checkout)	32
Replaced	28
Number with dirty contacts	1
Total	61

7.4.3.3 Machine Modifications

- a. Parity error modification (Reference: Quarterly Report for October, November, December, 1965).
 1. Wiring completed and checked out during the month of March for channels 5, 6, and 7.
- b. D.C. clear
 1. Added a .1 ufd capacitor in parallel with existing .1 ufd capacitor to give an added voltage supply in D10 of the console on the UN-010 card.
- c. Manual set on all 140-01 printed circuit boards.
- d. Installed thermal sensing circuits in main frame and core 1 for the air conditioning.
 1. The circuits were installed in February and are set to trip at 37° C.
 2. A power drop caused by temperature will not latch a circuit and requires resetting before powering up.
- e. Made logical change in T9F for protected order on January 18, 1966.

7.4.3.4 Channel Interface Checkout

- a. The month of January was used to check out channel 6.
- b. The month of January was used to check out channel 7.
 1. On February 16 both channels were running AEC.

7.4.3.5 Transistor Checking

In December of 1965, a total of 1073 transistors were pulled from the machine for checking and analysis. The sample consisted of 613 of the SL66 type and 460 of the GF45011 transistors. Following is a list of the chassis that had the transistors removed: S6R, A6R, Q6R, A10R, Q13R, S8F, Q11F. Graphs have been made with the indicated tests and results.

α_1

NOTE:

TOTAL SAMPLE=1072
 S166=613
 GF45011= 460

LISTINGS ARE IN % OF TOTAL BY TYPE.
 QUANTITY IS IN PARENTHESIS.

EXCEPTIONS:

Q11F No.181 LEAD BROKEN

1072+1=1073 TOTAL SAMPLE

α_2

GF45011

NOTE:

TOTAL SAMPLE=1072
S166= 613
GF45011= 460

LISTINGS ARE IN % OF TOTAL BY TYPE. 1072+1=1073 TOTAL SAMPLE
QUANTITY IS IN PARENTHESIS.

S166

EXCEPTIONS:

Q11F No. 181 LEAD BROKEN

VEB2

GF450II

NOTE:

TOTAL SAMPLE= 1072
S166= 613
GF450II= 460

LISTINGS ARE IN % OF TOTAL BY TYPE.
QUANTITY IS IN PARENTHESIS.

S166

EXCEPTIONS:

Q11F No.181 LEAD BROKEN

1072+1=1073 TOTAL SAMPLE

NOTE:

TOTAL SAMPLE = 1072
 S166 = 613
 GF45011 = 460

LISTINGS ARE IN % OF TOTAL BY TYPE. 1072+1=1073 TOTAL SAMPLE
 QUANTITY IS IN PARENTHESIS.

EXCEPTIONS:

Q11F No.181 LEAD BROKEN

BV_{EBO}

NOTE:

TOTAL SAMPLE = 1072
 SI66 = 613
 GF450II = 460

LISTINGS ARE IN % OF TOTAL BY TYPE.
 QUANTITY IS IN PARENTHESIS.

EXCEPTIONS:

Q11F No.181 LEAD BROKEN

1072+1=1073 TOTAL SAMPLE

BV_{CBV}

NOTE:

TOTAL SAMPLE = 1071
 S166 = 613
 GF450II = 460

LISTINGS ARE IN % OF TOTAL BY TYPE.
 QUANTITY IS IN PARENTHESIS.

EXCEPTIONS:

Q11F No.181 LEAD BROKEN
 Q11F No.191 DECREASING

1071+2=1073 TOTAL SAMPLE

ICBO

NOTE:

TOTAL SAMPLE = 1072
 S166 = 613
 GF450II = 460

LISTINGS ARE IN % OF TOTAL BY TYPE. 1072+1=1073 TOTAL SAMPLE
 QUANTITY IS IN PARENTHESIS.

EXCEPTIONS:

Q11F No.181 LEAD BROKEN

7.5 Log Summaries

7.5.1 ILLIAC II Use

7.5.1.1 Summary of Use

January, 1966

Scheduled Engineering	63:00
Unscheduled Engineering	88:01
Engineering Development	89:21
Time-Sharing Development	200:00
Power Off	48:20
Idle	4:09
Miscellaneous (operating, tape rewind, tape skipping, tape mounting, rerun of failing problems)	30:22

Total Use

Training and Education	21:30
Training and Education (relinquish)	1:00
University Adm. Overhead Use	:28
System Update	6:32
System Dev.	61:30
System Modification and Imp.	54:47
Engineering Maint.	38:30
Customer Use	

In System	33:35
Special Short Shots	2:55

Customer Use	36:30
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Total Use	<u>220:47</u>
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Total Time	<u>744:00</u>
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February, 1966

Scheduled Engineering	60:00
Unscheduled Engineering	89:42
Engineering Development	110:35
Time-Sharing Development	123:03
Power Off	1:20
Idle	11:12
Miscellaneous (operating, tape rewind, tape skipping, tape mounting rerun of failing problems - starts of time-sharing system)	47:47

Total Use

Training and Education	11:35
Training and Education (relinquish)	:34
University Adm. Overhead Use	:02
System Update	8:55
System Development	31:09
System Modification and Imp.	45:26
Engineering Maint.	65:30
Customer Use	

In System	62:46
Special Short Shots	2:24

Customer Use	65:10
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Total Use	<u>228:21</u>
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Total Time	<u><u>672:00</u></u>
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March, 1966

Scheduled Engineering	69:00
Unscheduled Engineering	51:41
Engineering Development	188:39
Time-Sharing Development	204:32
Power Off	2:40
Idle	8:31
Miscellaneous (operating, tape rewind, tape skipping, tape mounting, rerun of failing problems, time-sharing starts and restarts)	41:22

Total Use

Training and Education	29:28
Training and Education (relinquish)	:02
System Update	9:37
System Development	10:48
System Modification and Improvement	31:22
Engineering Maintenance	26:49
Customer Use	

In System	67:04
Special Short Shots	2:25

Customer Use	69:29
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Total Use	<u>177:35</u>
Total Time	<u>744:00</u>

7.5.1.2 Summary of Machine Errors

January

Main Machine	10
Mag. Tape Channels	5
Power Supplies	7
Disk Channel	1
Drum	<u>3</u>
Total	<u>26</u>

February

Main Machine	16
Drum	2
Disk Channel	1
Mag. Tape Channel	11
Power Supplies	1
Air Conditioning	<u>1</u>
Total	<u>32</u>

March

Main Machine	18
Disk Channel	5
Tape Channels	17
Power Supplies	3
Air Conditioning	1
Satellite Channel	<u>1</u>
Total	<u>45</u>

7.5.1.3 Departmental Running TimeJanuary, 1966

Dept.	Number of Runs			Number of Specs			ILLIAC II Usage in Hours		
	T and Ed	Res	Total	T and Ed	Res	Total	T and Ed	Res	Total
AAE	241	4	245	9	4	13	4.933	.539	5.472
ADV	0	6	6	0	1	1	.000	.033	.033
Agron	23	3	26	1	1	2	.376	.041	.417
ASTRON	333	5	338	1	1	2	.929	.177	1.106
CE	140	5	145	2	1	3	1.917	.058	1.975
CHE	8	57	65	2	4	6	.045	.949	.994
DCS	383	350	733	4	8	12	4.265	13.339	17.604
DS	0	2	2	0	1	1	.000	.008	.008
EE	128	133	261	8	4	12	1.315	2.670	3.985
GSBA	36	0	36	2	0	2	.596	.000	.596
MATH	20	28	48	2	1	3	.260	1.037	1.297
MATRL	0	48	48	0	2	2	.000	.299	.299
ME	70	138	208	8	6	14	.965	.512	1.477
NHS	0	57	57	0	1	1	.000	.432	.432
NUCE	0	9	9	0	3	3	.000	.169	.169
PHYCS	0	559	559	0	20	20	.000	10.327	10.327
PSYCH	0	3	3	0	1	1	.000	.150	.150
SWS	0	3	3	0	1	1	.000	.005	.005
TAN	0	32	32	0	3	3	.000	1.218	1.218
VPP	0	6	6	0	1	1	.000	.278	.278
XSSS	0	264	264	0	1	1	.000	4.251	4.251
ZOOL	0	5	5	0	1	1	.000	.029	.029
SUB TOTALS	1382	1717	3099	39	66	105	15.601	36.521	52.122
SSUAD	0	28	28	0	1	1	.000	.471	.471
DCSSYS	243	1178	1421	1	5	6	5.898	47.304	53.202
TOTALS	1625	2923	4548	40	72	112	21.499	83.296	105.795

T and Ed = Training and Education
Res = Research

February, 1966

Dept.	Number of Runs			Number of Specs			ILLIAC II Usage in Hours		
	T and Ed	Res	Total	T and Ed	Res	Total	T and Ed	Res	Total
AAE	163	85	248	7	4	11	2.822	.617	3.439
ADV		25	25		1	1		.144	.144
AGEC		31	31		1	1		.283	.283
AGRON		56	56		1	1		.616	.616
ASTR	4	21	25	1	1	2	.096	.193	.289
CE	18	10	28	1	2	3	.144	.088	.232
CHE	4	64	68	1	2	3	.013	1.056	1.069
DS		3	3		1	1		.009	.009
DCS	374	787	1161	6	15	21	6.077	27.409	33.486
ECON		8	8		1	1		.048	.048
EE	21	78	99	6	6	12	.098	7.537	7.635
IE		10	10		1	1		.049	.049
ILR		2	2		1	1		.081	.081
MATH	488		488	2		2	1.350		1.350
MATRL		231	231		4	4		1.217	1.217
ME	119	160	279	4	7	11	.553	3.356	3.909
NHS		62	62		1	1		.728	.728
NUCE		8	8		1	1		.067	.067
PHYCS		430	430		18	18		9.496	9.496
SWS		10	10		1	1		.010	.010
TAM	75	105	180	3	4	7	.424	2.250	2.674
VPP		4	4		1	1		7.421	7.421
XSSS		197	197		1	1		2.399	2.399
ZOOL		19	19		1	1		.099	.099
SUB TOTALS	1266	2406	3672	31	76	107	11.577	65.173	76.750
SSUAD		8	8		1	1		.027	.027
DCSSYS		1167	1167		6	6		71.724	71.724
TOTALS	1266	3581	4847	31	83	114	11.577	136.924	148.501

T and Ed = Training and Education
Res = Research

March, 1966

Dept.	Number of Runs			Number of Specs			ILLIAC II Usage in Hours		
	T and Ed	Res	Total	T and Ed	Res	Total	T and Ed	Res	Total
AAE	542	195	737	12	6	18	8.084	2.910	10.994
AGE	3	2	5	2	1	3	.008	.021	.029
AGRON		62	62		1	1		.429	.429
ADV	7	14	21	1	1	2	.053	.121	.174
ASTR		16	16		2	2		.570	.570
BOT		2	2		1	1		.010	.010
CE	21	19	40	1	1	2	.078	.199	.277
CHE	208	61	269	2	4	6	1.976	1.081	3.057
DCS	916	464	1380	5	12	17	6.666	28.242	34.908
ECON		4	4		1	1		.025	.025
EE	413	250	663	6	8	14	2.340	4.462	6.802
IE		10	10		1	1		.099	.099
ILR		15	15		1	1		.931	.931
MATH	2588	40	2628	2	1	3	7.281	1.035	8.316
MATRL		167	167		5	5		1.001	1.001
ME	136	110	246	8	11	19	1.040	1.865	2.905
NHS		186	186		1	1		1.988	1.988
NUCE		52	52		3	3		.758	.758
PHYCS	94	717	811	1	21	22	.380	16.198	16.578
PSYCH		10	10		1	1		.030	.030
SWS		5	5		1	1		.032	.032
TAM	181	75	256	5	5	10	1.563	4.859	6.422
VPP		3	3		1	1		.041	.041
ZOOL		14	14		2	2		.143	.143
XSSS		162	162		1	1		2.432	2.432
SUB TOTALS	5109	2655	7764	45	93	138	29.469	69.482	98.951
DCSSYS		1282	1282		6	6		37.618	37.618
TOTALS	5109	3937	9046	45	99	144	29.469	107.100	136.569

T and Ed = Training and Education
Res = Research

7.5.2 IBM 1401-III Use

7.5.2.1 Summary of Use

January, 1966

Scheduled Engineering	34:15
Unscheduled Engineering	19:14
Maintenance	8:04
ILLIAC Prep.	272:10
Code Checks	18:59
Other (listing, reproducing, tape dump, reports, tape testing)	95:18
Idle	248:00
Power Off	48:00
Total	<u>744:00</u>

February, 1966

Scheduled Engineering	24:21
Unscheduled Engineering	4:47
Maintenance	9:05
ILLIAC Prep.	380:30
Tape Testing	1:30
Other (code checks, listing, reproducing, tape dump, reports, etc.)	127:62
Idle	123:45
Total	<u>672:00</u>

March, 1966

Scheduled Engineering	57:46
Unscheduled Engineering	11:03
Maintenance	9:40
ILLIAC Engineering	30:33
Tape Test	9:30
ILLIAC Prep.	358:30
Other (listing, reproducing, tape dump, reports, code checks)	140:30
Power Off	6:30
Idle	119:58
Total	<u>744:00</u>

7.5.2.2 Summary of Machine Errors

January

1401 Main Frame	1
1402 Card Reader-Punch	<u>1</u>
Total	<u>2</u>

February

1401 Main Frame	1
1402 Card Reader-Punch	2
1403 Printer	<u>4</u>
Total	<u>7</u>

March

1403 Printer	<u>2</u>
Total	<u>2</u>

7.6 Library Programming

7.6.1 ILLIAC II Library Development

During the last quarter a number of programs were added to the Library. They are listed below with brief descriptions:

F4-UØI-WLSQ-48-FR

IDENTIFICATION--A complete FORTRAN program for weighted least squares polynomial approximation.

PURPOSE--To compute the weighted least squares polynomial approximation for a function $y(x)$, whose values are known only at a set of n points $x_1, x_2, \dots, x_n$; the corresponding values are $y_1, y_2, \dots, y_n$ respectively. The weights, representing the relative accuracy of the values y_i , are $w_1, w_2, \dots, w_n$. The weighted least squares polynomial approximation of degree q is represented by

$$f_q(x) = \sum_{j=0}^q a_j x^j$$

C2-UØI-ROOT1-49-FR

IDENTIFICATION--A complete FORTRAN program for finding roots of a polynomial.

PURPOSE--Given a polynomial

$$f(x) = a_n x^n + a_{n-1} x^{n-1} + \dots + a_1 x + a_0 \quad (1)$$

where the a_i 's are real, this program uses Bairstow's method to locate the n roots of $f(x)$. It is a complete program, and the user need only prepare a data deck for the coefficients.

F4-UOI-WLSQ2-50-FR

IDENTIFICATION--A complete FORTRAN program for weighted least squares polynomial approximation using orthogonal polynomials.

PURPOSE--To compute the best weighted least squares polynomial $f(x)$ of degree k or less for a function $y(x)$ whose M values $y_1, y_2, \dots, y_M$ with associated weights $w_1, w_2, \dots, w_M$ are known only at the set of points $x_1, x_2, \dots, x_M$. At the option of the user the polynomial is tabulated, or plotted or both tabulated and plotted.

D1-UOI-ROMQ1-53-NI

IDENTIFICATION--Romberg quadrature.

PURPOSE--Romberg's method is used for numerical quadrature of $f(x)$:

$$I = \int_a^b f(x) dx .$$

This subroutine is written so that it may be used recursively to evaluate a k -fold integral. Automatic error control is a user option.

C2-UOI-CXRTR1-55-NI

IDENTIFICATION--CXRTR1 and CXRTC1 are entries for NICAP to find the N complex roots of an N th order polynomial with real coefficients or complex coefficients respectively. CXRTR and CXRTC are the corresponding entries for FORTRAN.

A2-UOI-MPYCX1-56-NI

IDENTIFICATION--MPYCX1 is a complex multiplication subroutine for NICAP.

A2-UOI-MPYCX-57-NI

IDENTIFICATION--MPYCX is a complex multiplication subroutine for FORTRAN.

A2-UOI-DIVCX1-58-NI

IDENTIFICATION--DIVCX1 is a complex division subroutine for NICAP.

A2-UOI-DIVCX-59-NI

IDENTIFICATION--DIVCX is a complex division subroutine for FORTRAN.

A2-UOI-CXSQT1-60-NI

IDENTIFICATION--CXSQT1 is a square root of complex argument subroutine for NICAP.

E4-UOI-QMINIM-62-FR

IDENTIFICATION--QMINIM, FORTRAN subroutine to find a minimum of a function of n variables on a given region.

PURPOSE--Given a function $f(x) = f(x_1, x_2, \dots, x_n)$
 $1 \leq n \leq 10$ and a region $l_1 \leq x_1 \leq u_1, \dots, l_n \leq x_n \leq u_n$ with initial guesses $s_1, \dots, s_n$, QMINIM finds a minimum of the function in the region using a combination of the method of steepest descent and the method of equal displacements.

C2-UOI-ROOT3-63-FR

IDENTIFICATION--A FORTRAN subroutine for finding roots of a polynomial.

PURPOSE--Given a polynomial

$$f(x) = b_n x^n + b_{n-1} x^{n-1} + \dots + b_1 x + b_0 \quad (1)$$

where the b_i 's are real, this program uses Bairstow's method to locate the n roots of $f(x)$.

Other subroutines completed in this period but not yet added to the library include:

- (1) a routine for solving ordinary differential equations using methods described by C. W. Gear (SIAM, Series B, Volume 2, p. 69, (1965));
- (2) a routine for polynomial Chebyshev fitting;
- (3) a routine for least square approximation by a function of the form

$$f(x) = Ae^{BX} + C$$

where A, B, and C are the parameters to be determined.

Programs currently at various stages of completion include:

- (1) Q - R algorithm (this program written by B. Parlett is being adapted to our system);
- (2) double precision solution of linear equations;
- (3) Fourier analysis;
- (4) least squares fitting by a function of the form

$$f(x) = AC + B(X-X_0)^2$$

where A, B, X_0 are the parameters to be determined; (5) multiple precision subroutines for elementary functions.

L. D. Fosdick, Project Director
S. Chase
M. Coane
J. Heiple

8. IBM SERVICE, USE, AND PROGRAM DEVELOPMENT

(Supported in part by the National Science Foundation under Grant No. NSF-GP-700.)

8.1 New Routines

J5-UOI-CCP1-101-SR

Plotting routine for the CalComp plotter. This routine is used to generate a magnetic tape containing plotter commands which will be read by the CalComp plotter. Using this program, the pen can be raised or lowered and then moved to a given position (X,Y) on the paper.

The entries to this program correspond to similar entries in the CalComp SCOP program PLOT, as follows:

<u>PORTHOS</u>	<u>SCOP</u>	<u>PURPOSE</u>
CCP1PL	PLOT	To move the plotter pen to a given point.
CCP1PS	PLOTS	To provide a buffer for storing plotter commands.
CCP1FR	FACTOR	To provide a scale factor.
CCP1OS	OFFSET	To set up offset and scaling factors.
CCP1PP	WHERE	To determine the current pen position.
CCP1BA	none	To write a block address on the plotter tape.
CCP1LM	none	Dummy to provide compatibility with the ILLIAC II routine CCP1.

Programmed by John T. Bagwell, Jr.

March 24, 1966

J5-UOI-CCP2-102-SR

Symbol and letter drawing routine for the CalComp plotter. This routine draws alphanumeric characters and special symbols of any specified size on the Calcomp plotter. Thus, labels and messages may be placed in graphs, points may be marked, etc.

Each noncentered character plotted is generated by connecting points on a 4 by 7 grid. If the character

has a height H, then its width is $\frac{4}{7} H$, and consecutive characters are $\frac{6}{7} H$ from lower left corner to lower left corner. Each centered symbol plotted is generated by connecting points on a 4 by 4 grid.

This program corresponds to the CalComp subroutine SYMBØL. A description of that program will be found in the CalComp SCØØP Manual.

Programmed by John T. Bagwell, Jr.

March 21, 1966

J5-UOI-CCP3-103-SR

Floating point number conversion for the CalComp plotter.

This routine converts a floating point number to BCD characters and plots it on the CalComp plotter.

This routine is adapted from the CalComp SCØØP routines NUMBER and BCDFL.

Programmed by John T. Bagwell, Jr.

February 24, 1966

J5-UOI-CCP4-104-SR

Scaling routine for the CalComp plotter. Given an array X and a length S in which X will be plotted, this routine will determine a starting point and step size for plotting the values of X.

CCP4SC finds a number $A \leq$ the minimum X and a DX such that

$$A = R * 10^n \leq \text{minimum } X$$

$$A + S * DX \geq \text{maximum } X$$

where R is a member of a set of "round" numbers, which are

1.0, 1.5, 2.0, 2.5, 4.0, 5.0, 8.0

S is the size of the plot, and n is some integer.

This routine corresponds to the CalComp SCØØP routine SCALE. The method used in CCP4SC is taken principally from: Dixon, W. J. and Kronmal, R. A., The Choice of Origin and Scale for Graphs, J.A.C.M. 12 (1965), 259-261.

Programmed by John T. Bagwell, Jr.

February 25, 1966

J5-UOI-CCP5-105-SR

CalComp plotter axis drawing routine. This routine will draw an axis line for a graph, putting a BCD label on the axis and putting numeric values every inch along the axis.

This program corresponds to the CalComp routine AXIS. A description of that program will be found in the CalComp SCOP Manual.

Programmed by John T. Bagwell, Jr.

February 25, 1966

J5-UOI-CCP6-106-SR

Line and curve drawing routine for the CalComp plotter.

This subroutine takes a set of points and connects them by line segments.

This program corresponds to the CalComp subroutine LINE, a description of which may be found in the CalComp SCOP Manual.

Programmed by John T. Bagwell, Jr.

March 3, 1966

Q0-UOI-CTN1-107-SR

Logical tape number substitution routine. The input/output with conversion subroutines .TAPRD and .TAPWR, and all subroutines that execute FORTRAN and MAD input/output statements referring to tapes, have the capability of substituting another logical tape number for the one supplied by the calling sequence. This subroutine sets up a table of pairs of tape numbers - a standard PORTHOS number to replace a given non-standard number. This table has the form expected by the system subroutine that makes the substitution. Programs which refer to logical tape numbers standard at another installation may most simply be made compatible with PORTHOS by use of this subroutine.

Only logical tape numbers appearing in the calling sequences of .TAPRD and .TAPWR and in MAD and FORTRAN I/O statements can be changed by use of this subroutine. In particular, logical tape numbers in calls of Execution Coordination ("low core") subroutines cannot be changed.

Programmed by H. George Friedman, Jr.
John K. Moore

February 25, 1966

B3-UOI-EXP3-98-SR

Exponentiation. EXP3 raises a floating point base to a floating point power.

February 23, 1966

E2-UOI-LSQ3-99-SR

General curve fitting. LSQ3 is a complete program for a fit of a general curve to given data using the method of least squares, using double precision arithmetic wherever possible.

Given a set of N values of an independent variable X_i with the associated weight W_i and a corresponding set of values of the dependent variable Y_i , the program determines the coefficients of the function, of order M , which gives the best fit in the least squares sense to the set of Y_i .

Programmed by Margaret Ann Griffin
February 23, 1966

8.2 Log Summaries

Table I - IBM 1401-I

Summary of Use

January, 1966

Scheduled Engineering	11:40
Unscheduled Engineering	10:47
Maintenance	18:37
7094 Preparation	509:44
Listing	20:39
Code Check	4:51
Tape Dump	3:11
Reproduction	4:32
SMP	16:30
Tape Label	:25
Illiac Preparation	3:05
Idle	20:12
	<hr/>
Total	<u>624:13</u>

Table II - IBM 1401-I

Summary of Machine Errors

January, 1966

1402 Card Reader Punch	13
1403 Printer	6
729 V. Tape Drives	2
	<hr/>
Total	<u>21</u>

Table I - IBM 1401-II

Summary of Use

January, 1966

Scheduled Engineering	33:15
Unscheduled Engineering	14:53
Maintenance	14:31
7094 Preparation	458:39
Listing	17:46
Code Check	8:31
Tape Dump	6:39
Reproduction	1:00
SMP	34:26
Illiac Preparation	1:25
Idle	31:43
	<hr/>
Total	<u>622:48</u>

Table II - IBM 1401-II

Summary of Machine Errors

January, 1966

1402 Card Reader Punch	9
729 V Tape Drives	2
	<hr/>
Total	<u>11</u>

Table I - IBM 7094

Summary of Use

January, 1966

Scheduled Engineering	44:35
Unscheduled Engineering	16:42
Machine Maintenance	17:43
Air Conditioning	4:44
Idle	15:19
Miscellaneous (Operator training, tape rewind, tape skipping, tape mounting, both system and user, destruction of clock reading)	47:42

TOTAL USE

Training and Education	30:02
University Administrative Overhead Use	10:13
System Modification and Improvement	28:07
System Updating	1:43

Customer Use

In System	326:40
Relinquish	

AGEC	5:14
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PHYCS	<u>45:06</u>
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50:20

Special Short Shots

:22

377:22Total Use 447:27Total Time On 594:12

Table II - IBM 7094

Summary of Machine Errors

January, 1966

729 Tape Drive	7
1301 Disk Storage	1
7094 Air Conditioning	1
1401 Malfunction ¹	<u>1</u>
Total	<u>10</u>

¹ 1401 error causing 7094 to read input tapes in wrong mode.

7094 Table III January 1966

Dept ¹	Number of Runs			Number of Specs			7094 Usage in Hours-Minutes		
	T and E ²	Res	Total	T and E ²	Res	Total	T and E ²	Res	Total
AAE	83	70	153	4	5	9	2 42.3	1 5.0	3 47.4
ADV	0	4	4	0	1	1	0.0	0.4	0.4
AGE	0	21	21	0	2	2	0.0	6.9	6.9
AGEC	45	94	139	2	11	13	41.9	8 35.0	9 17.0
AGRON	268	200	468	1	19	20	2 22.7	4 25.1	6 47.9
ANGEN	0	1	1	0	1	1	0.0	0.1	0.1
ANS	0	81	81	0	4	4	0.0	2 2.0	2 2.0
ASTR	12	101	113	1	2	3	11.0	1 13.0	1 24.0
BECBS	0	164	164	0	4	4	0.0	9 23.9	9 23.9
CCCHE	0	8	8	0	1	1	0.0	7.7	7.7
CCPSY	0	37	37	0	1	1	0.0	25.4	25.4
CE	707	1036	1743	5	52	57	5 41.6	32 46.8	38 28.5
CHE	33	1587	1620	2	44	46	7.4	54 16.2	54 23.7
DCS	120	60	180	4	7	11	1 29.3	1 48.7	3 18.0
DS	0	95	95	0	3	3	0.0	41.4	41.4
ECON	1	42	43	1	3	4	0.2	36.5	36.8
ED	0	47	47	0	5	5	0.0	1 2.1	1 2.1
EDADM	0	8	8	0	2	2	0.0	18.2	18.2
EE	220	417	637	7	15	22	2 9.8	7 0.0	9 9.8
ENGLS	0	15	15	0	1	1	0.0	9.2	9.2
FOR	0	5	5	0	1	1	0.0	6.2	6.2
FT	0	3	3	0	1	1	0.0	3.7	3.7
GENE	34	0	34	1	0	1	7.4	0.0	7.4
GEOI	0	31	31	0	1	1	0.0	7.2	7.2
GSBA	137	27	164	3	1	4	1 52.8	5 10.3	7 3.2
HEC	0	2	2	0	1	1	0.0	5.9	5.9
HORT	0	16	16	0	4	4	0.0	14.3	14.3
ICR	0	109	109	0	2	2	0.0	1 55.5	1 55.5
IE	26	3	29	3	1	4	5.9	2.3	8.3
IGPA	0	54	54	0	2	2	0.0	31.6	31.6

7094 Table III January 1966 Continued

Dept ¹	Number of Runs			Number of Specs			7094 Usage in Hours-Minutes		
	T and E ²	Res	Total	T and E ²	Res	Total	T and E ²	Res	Total
ILR	0	5	5	0	1	1	0.0	3.7	3.7
INADM	48	4	52	2	1	3	11.9	0.9	12.8
IREC	0	4	4	0	2	2	0.0	3.1	3.1
LIR	0	3	3	0	1	1	0.0	31.3	31.3
MATH	2338	6	2344	2	1	3	7 17.2	4.0	7 21.2
MATRL	0	413	413	0	9	9	0.0	9 49.0	9 49.0
ME	420	839	1259	15	28	43	4 19.1	21 55.9	26 15.1
MKTG	0	5	5	0	1	1	0.0	8.5	8.5
MMPE	0	107	107	0	5	5	0.0	36.9	36.9
MUSIC	0	11	11	0	1	1	0.0	10.1	10.1
NHS	0	75	75	0	2	2	0.0	46.8	46.8
NUCE	14	210	224	2	10	12	24.2	4 4.0	4 28.3
OIR	0	158	158	0	1	1	0.0	3 52.2	3 52.2
PHYCS	3	3071	3074	1	39	40	0.8	170 47.4	170 48.2
PSYCH	20	683	703	1	24	25	8.9	14 40.5	14 49.4
REC	0	8	8	0	1	1	0.0	15.2	15.2
SCONS	0	148	148	0	1	1	0.0	2 10.1	2 10.1
SCS	0	1	1	0	1	1	0.0	1.6	1.6
SGS	0	32	32	0	1	1	0.0	13.3	13.3
SOC	0	1	1	0	1	1	0.0	0.5	0.5
SOCW	0	11	11	0	1	1	0.0	11.0	11.0
SRL	0	8	8	0	1	1	0.0	10.1	10.1
SWS	0	338	338	0	20	20	0.0	7 51.0	7 51.0
TAM	28	144	172	2	6	8	6.2	1 9.4	1 15.7
UNIHI	0	64	64	0	2	2	0.0	2 32.0	2 32.0
USGS	0	30	30	0	1	1	0.0	10.3	10.3
VPH	0	6	6	0	1	1	0.0	1.3	1.3
VPP	0	18	18	0	1	1	0.0	3.3	3.3

7094 Table III January 1966 Continued

Dept ¹	Number of Runs			Number of Specs			7094 Usage in Hours-Minutes		
	T and E ²	Res	Total	T and E ²	Res	Total	T and E ²	Res	Total
VTED	0	2	2	0	1	1	0.0	2.2	2.2
WPGU	0	1	1	0	1	1	0.0	1.4	1.4
XSS ³	0	75	75	0	1	1	0.0	21.8	21.8
ZOOL	0	14	14	0	4	4	0.0	8.3	8.3
Subtotal	4557	10833	15390	59	368	427	30 1.7	377 21.7	407 23.5
DCSS ⁴	0	606	606	0	21	21	0.0	28 6.5	28 6.5
XDCS ⁵	0	41	41	0	1	1	0.0	1 43.4	1 43.4
SSUAD ⁶	0	267	267	0	2	2	0.0	10 13.1	10 13.1
Total	4557	11747	16304	59	392	451	30 1.7	417 24.7	447 26.5

1 See list of departmental codes following

2 Training and Education

3 Special Short Shots

4 System Improvement and Modifications

5 System Updating

6 University Administrative Overhead Use

Table I - IBM 1401-I

Summary of Use

February, 1966

Scheduled Engineering	26:55
Unscheduled Engineering	9:32
Maintenance	12:12
7094 Preparation	459:40
Listing	24:20
Code Check	8:05
Tape Dump	6:07
Reproduction	2:06
SMP	18:28
Tape Label	:17
Illiac Preparation	:28
Idle	6:47
Total	<u>574:57</u>

Table II - IBM 1401-I

Summary of Machine Errors

February, 1966

1402 Card Reader Punch	5
1403 Printer	2
729 V Tape Drives	3
Total	<u>10</u>

Table I - IBM 1401-II

Summary of Use

February, 1966

Scheduled Engineering	6:43
Unscheduled Engineering	35:19
Maintenance	15:11
7094 Preparation	442:03
Listing	26:40
Code Check	14:11
Tape Dump	12:15
Reproduction	3:25
SMP	30:40
Tape Label	2:05
Illiac Preparation	1:45
Idle	4:25
	<hr/>
Total	<u>594:42</u>

Table II - IBM 1401-II

Summary of Machine Errors

February, 1966

1401 Main Frame	1
1402 Card Reader Punch	19
1403 Printer	3
729 V Tape Drives	3
	<hr/>
Total	<u>26</u>

Table I - IBM 7094

Summary of Use

February, 1966

Scheduled Engineering		39:19	
Unscheduled Engineering		1:00	
Maintenance		16:31	
Idle		14:34	
Miscellaneous (Operator training, tape rewind, rerun of failing problems, tape skipping, destruction of clock reading)		46:56	
Total Use			
Training and Education		17:51	
University Administrative Overhead Use		7:24	
System Modification and Improvement		41:35	
System Updating		3:19	
Customer Use			
In System		332:54	
Relinquish			
AGEC	3:18		
PHYCS	62:38		
		<u>65:56</u>	
Special Short Shots		:27	
		<u>399:17</u>	
			<u>469:26</u>
			<u>587:46</u>

Table II - IBM 7094

Summary of Machine Errors

February, 1966

729 VI Tape Drive	3
7094	2
716 Printer	<u>1</u>
Total	<u>6</u>

7094 Table III February 66

Dept ¹	Number of Runs			Number of Specs			7094 Usage in Hours-Minutes		
	T and E ²	Res	Total	T and E ²	Res	Total	T and E ²	Res	Total
AAE	64	74	138	3	3	6	23.6	1 1.9	1 25.6
ADV	19	0	19	1	0	1	21.5	0.0	21.5
AGE	7	21	28	1	3	4	1.0	8.5	9.5
AGEC	42	166	208	1	14	15	46.9	6 24.8	7 11.7
AGRON	62	177	239	2	14	16	26.8	2 56.9	3 23.7
ANGEN	0	27	27	0	1	1	0.0	6.4	6.4
ANS	0	80	80	0	5	5	0.0	1 33.9	1 33.9
ANTH	44	6	50	1	1	2	1 15.2	5.4	1 20.6
ASTR	0	122	122	0	2	2	0.0	49.9	49.9
BECBS	0	107	107	0	4	4	0.0	1 12.8	1 12.8
BOT	0	1	1	0	1	1	0.0	0.1	0.1
CCCHE	0	21	21	0	1	1	0.0	29.0	29.0
CCDME	0	1	1	0	1	1	0.0	0.1	0.1
CCENE	0	15	15	0	1	1	0.0	15.1	15.1
CCPSY	0	41	41	0	1	1	0.0	30.6	30.6
CE	90	921	1011	5	40	45	1 10.4	34 22.0	35 32.4
CHE	295	1931	2226	4	52	56	1 14.0	68 32.9	69 46.9
DCS	191	47	238	6	5	11	1 59.0	28.9	2 28.0
DOW	0	44	44	0	1	1	0.0	20.0	20.0
DS	0	105	105	0	6	6	0.0	1 20.3	1 20.3
DUE	0	6	6	0	1	1	0.0	5.5	5.5
ECON	16	74	90	1	5	6	8.8	1 15.1	1 23.9
ED	0	51	51	0	7	7	0.0	1 27.3	1 27.3
EDADM	0	9	9	0	1	1	0.0	29.8	29.8
EDTES	0	3	3	0	1	1	0.0	1.6	1.6
EE	70	500	570	6	24	30	1 34.7	9 15.4	10 50.2
ENGLS	0	34	34	0	1	1	0.0	45.1	45.1
FIN	5	0	5	1	0	1	0.8	0.0	0.8
FOR	0	14	14	0	1	1	0.0	31.0	31.0
FT	0	22	22	0	1	1	0.0	12.1	12.1
GENE	14	0	14	1	0	1	5.0	0.0	5.0

7094 Table III February 1966 Continued

Dept ¹	Number of Runs			Number of Specs			7094 Usage in Hours-Minutes		
	T and E ²	Res	Total	T and E ²	Res	Total	T and E ²	Res	Total
GEOL	0	26	26	0	1	1	0.0	13.1	13.1
GSBA	46	9	55	2	1	3	3 37.3	2 38.4	6 15.8
HORT	0	35	35	0	4	4	0.0	23.8	23.8
ICR	0	94	94	0	3	3	0.0	1 20.0	1 20.0
IE	21	18	39	2	1	3	4.8	10.6	15.4
IGPA	0	47	47	0	1	1	0.0	26.8	26.8
ILR	0	1	1	0	1	1	0.0	0.1	0.1
INADM	4	9	13	1	1	2	0.5	10.9	11.4
IREC	0	42	42	0	2	2	0.0	10.4	10.4
LIR	0	4	4	0	1	1	0.0	1 14.2	1 14.2
MATH	2	6	8	1	1	2	0.3	2.0	2.4
MATRL	0	461	461	0	10	10	0.0	14 4.3	14 4.3
ME	284	710	994	13	27	40	2 1.3	20 21.4	22 22.7
MKTG	0	10	10	0	1	1	0.0	15.1	15.1
MMPE	0	42	42	0	3	3	0.0	39.0	39.0
MUSIC	0	1	1	0	1	1	0.0	1.9	1.9
NHS	0	83	83	0	3	3	0.0	28.3	28.3
NUCE	32	152	184	2	8	10	2 25.0	4 44.7	7 9.7
OIR	0	129	129	0	1	1	0.0	5 32.5	5 32.5
PHYCS	5	2954	2959	1	33	34	0.7	173 47.5	173 48.2
PSYCH	0	717	717	0	25	25	0.0	19 19.3	19 19.3
REC	0	3	3	0	1	1	0.0	2.7	2.7
SCONS	0	52	52	0	1	1	0.0	34.6	34.6
SCS	0	9	9	0	1	1	0.0	34.2	34.2
SGS	0	46	46	0	1	1	0.0	13.2	13.2
SOC	0	4	4	0	2	2	0.0	3.5	3.5
SOCW	0	29	29	0	1	1	0.0	50.1	50.1
SWS	0	301	301	0	13	13	0.0	8 37.3	8 37.3
TAM	37	231	268	5	9	14	12.7	2 2.4	2 15.1
UNIHI	0	34	34	0	2	2	0.0	3 0.2	3 0.2

7094 Table III February 66 Continued

Dept ¹	Number of Runs			Number of Specs			7094 Usage in Hours-Minutes		
	T and E ²	Res	Total	T and E ²	Res	Total	T and E ²	Res	Total
USGS	0	12	12	0	1	1	0.0	5.0	5.0
VPH	0	17	17	0	1	1	0.0	2.5	2.5
VPP	0	28	28	0	1	1	0.0	24.7	24.7
VTED	0	38	38	0	3	3	0.0	54.8	54.8
WPGU	0	4	4	0	1	1	0.0	5.2	5.2
XSS ³	0	122	122	0	1	1	0.0	26.6	26.6
ZOOL	0	59	59	0	4	4	0.0	28.0	28.0
Subtotal	1350	11159	12509	60	370	430	17 51.4	399 15.6	417 7.0
DCSS ⁴	0	1045	1045	0	26	26	0.0	41 35.4	41 35.4
XDCS ⁵	0	54	54	0	1	1	0.0	3 19.2	3 19.2
SSUAD ⁶	0	252	252	0	2	2	0.0	7 24.2	7 24.2
Total	1350	12510	13860	60	399	459	17 51.4	451 34.4	469 25.8

1 See list of departmental codes following

2 Training and Education

3 Special Short Shots

4 System Improvement and Modifications

5 System Updating

6 University Administrative Overhead Use

Table I - IBM 1401-I

Summary of Use

March, 1966

Scheduled Engineering	7:28
Unscheduled Engineering	6:12
Maintenance	14:29
7094 Preparation	509:56
Listing	20:53
Code Check	35:41
Tape Dump	3:31
Reproduction	9:48
SMP	25:35
Tape Label	:15
Illiac Preparation	3:21
Idle	14:52
Total	<u>656:21</u>

Table II - IBM 1401-I

Summary of Machine Errors

March, 1966

1402 Card Reader Punch	5
1403 Printer	1
729 V Tape Drives	5
Total	<u>11</u>

Table I - IBM 1401-II

Summary of Use

March, 1966

Scheduled Engineering	4:20
Unscheduled Engineering	14:16
Maintenance	15:14
7094 Preparation	511:24
Listing	16:21
Code Check	26:21
Tape Dump	4:32
Reproduction	2:15
SMP	29:05
Tape Label	:05
Illiac Preparation	4:22
Idle	9:25
Total	<u>645:05</u>

Table II - IBM 1401-II

Summary of Machine Errors

March, 1966

1401 Main Frame	2
1402 Card Reader Punch	8
729 V Tape Drives	5
Air Conditioning	2
Total	<u>17</u>

Table I - IBM 7094

Summary of Use

March, 1966

Scheduled Engineering	42:15
Unscheduled Engineering	7:26
Maintenance	16:27
Idle	20:34
Miscellaneous (Operator training, tape rewind, both system and user, system tape mounting, destruction of clock reading, rerun of failing problems)	93:27
Total Use	
Training and Education	23:00
University Administrative Overhead Use	10:00
System Modification and Improvement	48:19
System Updating	5:42
Customer Use	
In System	307:54
Relinquish	
AGEC	28:32
PHYCS	<u>65:55</u>
Relinquish total	94:27
Special Short Shots	<u>:59</u>
Customer Use Total	<u>403:20</u>
Total Use	<u>490:21</u>
Total Time On	<u>670:30</u>

Table II - IBM 7094

Summary of Machine Errors

March, 1966

716 Printer	1
721 Punch	1
729 VI Tape Unit	2
740 CRT	1
1301 Disk File	1
Interrupt Button	1
	-
Total	<u>7</u>

7094 Table III March 1966

Dept ¹	Number of Runs			Number of Specs			7094 Usage in Hours-Minutes		
	T and E ²	Res	Total	T and E ²	Res	Total	T and E ²	Res	Total
AAE	275	181	456	7	5	12	1 47.1	7 0.3	8 47.5
ADV	26	13	39	1	1	2	18.4	29.1	47.5
AGE	24	88	112	2	4	6	3.6	48.6	52.3
AGEC	1	367	368	1	13	14	0.3	32 44.3	32 44.6
AGRON	30	169	199	2	15	17	16.2	2 57.5	3 13.8
ANGEN	0	26	26	0	1	1	0.0	25.6	25.6
ANS	0	109	109	0	4	4	0.0	1 0.1	1 0.1
ANTH	69	0	69	2	0	2	59.3	0.0	59.3
ASTR	0	190	190	0	2	2	0.0	1 5.6	1 5.6
BECBS	0	68	68	0	3	3	0.0	2 21.3	2 21.3
BOT	0	12	12	0	2	2	0.0	5.2	5.2
CCCHE	0	4	4	0	1	1	0.0	5.3	5.3
CCDME	0	6	6	0	1	1	0.0	10.2	10.2
CCENE	0	22	22	0	1	1	0.0	32.2	32.2
CCPSY	0	25	25	0	1	1	0.0	18.2	18.2
CE	645	1090	1735	5	42	47	3 30.2	42 57.2	46 27.5
CHE	518	1937	2455	4	53	57	2 13.4	53 28.0	55 41.5
CP	20	1	21	1	1	2	34.4	3.2	37.7
CRC	0	16	16	0	1	1	0.0	39.7	39.7
DCS	139	268	407	3	9	12	34.9	4 31.1	5 6.0
DOW	0	145	145	0	1	1	0.0	1 42.1	1 42.1
DS	0	119	119	0	5	5	0.0	51.6	51.6
ECON	36	122	158	1	7	8	26.8	1 15.8	1 42.7
ED	0	79	79	0	8	8	0.0	2 14.2	2 14.2
EDADM	0	3	3	0	1	1	0.0	6.7	6.7
EDTES	0	34	34	0	1	1	0.0	45.5	45.5
EE	603	603	1206	10	23	33	2 6.1	7 37.6	9 43.8
ENGLS	0	23	23	0	1	1	0.0	52.1	52.1
FIN	6	0	6	2	0	2	0.7	0.0	0.7
FOR	0	24	24	0	2	2	0.0	42.0	42.0

7094 Table III March 1966 Continued

Dept ¹	Number of Runs			Number of Specs			7094 Usage in Hours-Minutes		
	T and E ²	Res	Total	T and E ²	Res	Total	T and E ²	Res	Total
FT	0	4	4	0	1	1	0.0	1.6	1.6
GENE	37	0	37	2	0	2	13.0	0.0	13.0
GEOL	0	22	22	0	2	2	0.0	6.7	6.7
GSBA	13	12	25	1	1	2	47.7	58.0	1 45.7
HED	0	1	1	0	1	1	0.0	0.2	0.2
HORT	0	44	44	0	5	5	0.0	51.0	51.0
ICR	0	178	178	0	2	2	0.0	3 54.8	3 54.8
IE	43	36	79	3	1	4	13.4	37.3	50.7
IED	0	4	4	0	1	1	0.0	5.9	5.9
IGPA	0	19	19	0	1	1	0.0	12.7	12.7
ILR	0	11	11	0	1	1	0.0	1.5	1.5
INADM	7	0	7	1	0	1	6.2	0.0	6.2
IREC	0	46	46	0	3	3	0.0	10.3	10.3
LIR	0	2	2	0	1	1	0.0	33.5	33.5
MATH	35	0	35	2	0	2	6.9	0.0	6.9
MATRL	0	452	452	0	11	11	0.0	8 49.0	8 49.0
MCBIO	0	6	6	0	2	2	0.0	4.1	4.1
ME	541	708	1249	17	28	45	4 20.4	14 11.3	18 31.7
MMPE	0	87	87	0	5	5	0.0	1 12.5	1 12.5
NHS	0	74	74	0	2	2	0.0	37.3	37.3
NUCE	18	189	207	1	10	11	27.1	5 17.7	5 44.9
OIR	0	144	144	0	1	1	0.0	5 43.5	5 43.5
PEM	0	9	9	0	1	1	0.0	2.3	2.3
PHYCS	38	3520	3558	1	42	43	7.1	149 48.3	149 55.4
PHYSL	0	6	6	0	1	1	0.0	1.0	1.0
PLPA	0	1	1	0	1	1	0.0	10.0	10.0
POLS	0	1	1	0	1	1	0.0	1.6	1.6
PSYCH	57	937	994	1	28	29	11.2	16 33.1	16 44.3
REC	30	4	34	1	1	2	6.8	10.8	17.7
SCONS	0	99	99	0	1	1	0.0	1 28.6	1 28.6
SCS	0	33	33	0	1	1	0.0	2 5.7	2 5.7
SGS	0	23	23	0	1	1	0.0	4.9	4.9
SOC	55	12	67	1	4	5	22.8	27.0	49.9
SOCW	0	27	27	0	2	2	0.0	1 27.8	1 27.8

7094 Table III March 1966 Continued

Dept ¹	Number of Runs			Number of Specs			7094 Usage in Hours-Minutes		
	T and E ²	Res	Total	T and E ²	Res	Total	T and E ²	Res	Total
SPCH	0	1	1	0	1	1	0.0	1.8	1.8
SWS	0	414	414	0	18	18	0.0	8 47.6	8 47.6
TAM	209	325	534	6	14	20	3 4.3	4 31.3	7 35.6
UNIHI	0	59	59	0	2	2	0.0	2 37.0	2 37.0
USGS	0	8	8	0	1	1	0.0	3.5	3.5
VPP	0	28	28	0	1	1	0.0	52.3	52.3
VTED	0	99	99	0	3	3	0.0	51.7	51.7
WPGU	0	5	5	0	1	1	0.0	6.9	6.9
XSS ³	0	203	203	0	1	1	0.0	59.3	59.3
ZOOL	0	94	94	0	7	7	0.0	44.7	44.7
Subtotal	3475	13691	17166	78	421	499	22 59.6	403 20.7	426 20.4
DCSSY ⁴	0	1600	1600	0	23	23	0.0	48 18.9	48 18.9
XDCS ⁵	0	151	151	0	1	1	0.0	5 41.7	5 41.7
SSUAD ⁶	0	273	273	0	2	2	0.0	10 0.2	10 0.2
Total	3475	15715	19190	78	447	525	22 59.6	467 21.5	490 21.2

1 See list of departmental codes following

2 Training and Education

3 Special Short Shots

4 System Improvement and Modifications

5 System Updating

6 University Administrative Overhead Use

Quarterly Summary of Departmental Running Time
January, February, March 1966

Dept ¹	Number of Runs			Number of Specs			7094 Usage in Hours-Minutes		
	T and E ²	Res	Total	T and E ²	Res	Total	T and E ²	Res	Total
AAE	422	325	747	14	13	27	4 53.0	9 07.2	14 00.2
ADV	45	17	62	2	2	4	39.9	29.5	1 09.4
AGE	31	130	161	3	9	12	4.6	1 04.0	1 08.6
AGEC	88	627	715	4	38	42	1 29.1	47 44.1	49 13.2
AGRON	360	546	906	5	48	53	3 05.7	10 19.5	13 25.2
ANGEN	0	54	54	0	3	3	0.0	32.1	32.1
ANS	0	270	270	0	13	13	0.0	4 36.0	4 36.0
ANTH	113	6	119	3	1	4	2 14.5	5.4	2 19.9
ASTR	12	413	425	1	6	7	11.0	3 08.5	3 19.5
BECBS	0	339	339	0	11	11	0.0	12 58.0	12 58.0
BOT	0	13	13	0	3	3	0.0	5.3	5.3
CCCHE	0	33	33	0	3	3	0.0	42.0	42.0
CCDME	0	7	7	0	2	2	0.0	10.3	10.3
CCENE	0	37	37	0	2	2	0.0	47.3	47.3
CCPSYC	0	103	103	0	3	3	0.0	1 14.2	1 14.2
CE	1442	3047	4489	15	134	149	10 22.2	110 06.0	120 28.2
CHE	846	5455	6301	10	149	159	3 34.8	176 17.1	179 51.9
CP	20	1	21	1	1	2	34.4	3.2	37.6
CRC	0	16	16	0	1	1	0.0	39.7	39.7
DCS	450	375	825	13	21	34	4 03.2	6 48.7	10 51.9
DOW	0	189	189	0	2	2	0.0	2 02.1	2 02.1
DS	0	319	319	0	14	14	0.0	2 53.3	2 53.3
DUE	0	6	6	0	1	1	0.0	05.5	05.5
ECON	53	238	291	3	15	18	35.8	3 07.4	3 43.2
ED	0	177	177	0	20	20	0.0	4 43.6	4 43.6
EDADM	0	20	20	0	4	4	0.0	54.7	54.7
EDTES	0	37	37	0	2	2	0.0	47.1	47.1
EE	893	1520	2413	23	62	85	5 50.6	23 53.0	29 43.6
ENGLS	0	72	72	0	3	3	0.0	1 46.4	1 46.4
FIN	11	0	11	3	0	3	01.5	0.0	01.5
FOR	0	43	43	0	4	4	0.0	1 19.2	1 19.2
FT	0	29	29	0	3	3	0.0	17.4	17.4
GENE	85	0	85	4	0	4	25.4	0.0	25.4

Quarterly Summary of Departmental Running Time
January, February, March 1966 Continued

Dept ¹	Number of Runs			Number of Specs			7094 Usage in Hours-Minutes		
	T and E ²	Res	Total	T and E ²	Res	Total	T and E ²	Res	Total
GEOL	0	79	79	0	4	4	0.0	27.0	27.0
GSBA	196	48	244	6	3	9	6 17.8	8 46.7	15 04.5
HEC	0	2	2	0	1	1	0.0	05.9	05.9
HED	0	1	1	0	1	1	0.0	0.2	0.2
HORT	0	95	95	0	13	13	0.0	1 29.1	1 29.1
ICR	0	381	381	0	7	7	0.0	7 10.3	7 10.3
IE	90	57	147	8	3	11	24.1	50.2	1 14.3
IED	0	4	4	0	1	1	0.0	05.9	05.9
IGPA	0	120	120	0	4	4	0.0	1 11.1	1 11.1
ILR	0	17	17	0	3	3	0.0	05.3	05.3
INADM	59	13	72	4	2	6	18.6	11.8	30.4
IREC	0	92	92	0	7	7	0.0	23.8	23.8
LIR	0	9	9	0	3	3	0.0	2 19.0	2 19.0
MATH	2375	12	2387	5	2	7	7 24.4	06.0	7 30.4
MATRL	0	1326	1326	0	30	30	0.0	32 42.3	32 42.3
MCBIO	0	6	6	0	2	2	0.0	4.1	4.1
ME	1245	2257	3502	45	83	128	10 40.8	56 28.6	67 09.4
MKTG	0	15	15	0	2	2	0.0	23.6	23.6
MMPE	0	236	236	0	13	13	0.0	2 28.4	2 28.4
MUSIC	0	12	12	0	2	2	0.0	12.0	12.0
NHS	0	232	232	0	7	7	0.0	1 52.4	1 52.4
NUCE	64	551	615	5	28	33	3 16.3	14 06.4	17 22.7
OIR	0	431	431	0	3	3	0.0	15 08.2	15 08.2
PEM	0	9	9	0	1	1	0.0	02.3	02.3
PHYCS	46	9545	9591	3	114	117	08.6	494 23.2	494 31.8
PHYSL	0	6	6	0	1	1	0.0	1.0	1.0
PLPA	0	1	1	0	1	1	0.0	10.0	10.0
POLS	0	1	1	0	1	1	0.0	1.6	1.6
PSYCH	77	2337	2414	2	77	79	20.1	50 32.9	50 53.0
REC	30	15	45	1	3	4	6.8	28.7	35.5
SCONS	0	299	299	0	3	3	0.0	4 13.3	4 13.3
SCS	0	43	43	0	3	3	0.0	2 41.5	2 41.5
SGS	0	101	101	0	3	3	0.0	31.4	31.4
SOC	55	17	72	1	7	8	22.8	31.0	53.8

Quarterly Summary of Departmental Running Time
January, February, March 1966 Continued

Dept ¹	Number of Runs			Number of Specs			7094 Usage in Hours-Minutes		
	T and E ²	Res	Total	T and E ²	Res	Total	T and E ²	Res	Total
SOCW	0	67	67	0	4	4	0.0	2 28.9	2 28.9
SPCH	0	1	1	0	1	1	0.0	1.8	1.8
SRL	0	8	8	0	1	1	0.0	10.1	10.1
SWS	0	1053	1053	0	51	51	0.0	25 15.9	25 15.9
TAM	274	700	974	13	29	42	3 23.2	7 43.1	11 06.3
UNIH	0	157	157	0	6	6	0.0	8 09.2	8 09.2
USGS	0	50	50	0	3	3	0.0	18.8	18.8
VPH	0	23	23	0	2	2	0.0	3.8	3.8
VPP	0	74	74	0	3	3	0.0	1 20.3	1 20.3
VTED	0	139	139	0	7	7	0.0	1 48.7	1 48.7
WPGU	0	10	10	0	3	3	0.0	13.5	13.5
XSS ³	0	400	400	0	3	3	0.0	1 47.7	1 47.7
ZOOL	0	167	167	0	15	15	0.0	1 21.0	1 21.0
Subtotal	9382	35683	45065	197	1159	1356	70 49.2	1179 45.8	1250 35.0
DCSS ⁴	0	3251	3251	0	70	70	0.0	118 00.8	118 00.8
XDCS ⁵	0	246	246	0	3	3	0.0	10 44.3	10 44.3
SSUAD ⁶	0	792	792	0	6	6	0.0	27 37.5	27 37.5
Total	9382	39972	49354	197	1238	1435	70 49.2	1336 08.4	1406 57.6

1 See list of departmental codes following

2 Training and Education

3 Special Short Shots

4 System Improvement and Modifications

5 System Updating

6 University Administrative Overhead Use

9. PROBLEM SPECIFICATIONS

(Supported in part by the National Science Foundation under Grant No. NSF-GP-700.)

9.1 Research Problem Specifications

During the first quarter of 1966, 127 problem specifications were submitted to the Department for computation. The following brief descriptions of these problems have been prepared for inclusion in this report by those submitting them. T indicates a calculation associated with a thesis.

1820-61002 Mechanical Engineering. Non-Diffuse View Factors. Experimental evidence confirms that most surfaces of engineering importance do not radiate thermal energy in a completely diffuse manner. As a result, available results for radiation view factors based on diffuse theory may be of limited value. The purpose of this study is to determine the influence of the non-diffuse character of surface emission on radiation view factors. The computer will be utilized to numerically evaluate the view factors for some representative surfaces and surface arrangements. Only standard library routines will be required for the calculations. (R. G. Hering)

1821-61003 Mechanical Engineering. Radiating Convection Fins. Convection fins are widely used to increase heat dissipation in heat transfer equipment. Although the rates of dissipation by convection and radiation are comparable, most investigations have not considered the radiative transfer mechanism. It is the intent of this study to include the radiative transfer process and thereby ascertain its influence on the energy dissipation. An analysis has been completed and the resulting integral differential equation requires numerical solution. The computer will be utilized to obtain solutions for a wide range of pertinent parameters. Only standard library routines are required for the numerical calculations. (R. G. Hering)

1822-61004 Mechanical Engineering. A Critical Study of Approximate Methods in Radiative Transfer. Radiative transfer in absorbing-scattering media is governed by integral equations with singular kernels. Great difficulties are encountered when solutions of these equations are attempted. As a result, numerous approximate methods of analysis have been proposed.

Very few of these have been substantiated by comparison to the exact results available. It is the intent of this study to ascertain the validity of these methods by critically examining them. The computer will be used to obtain results for the approximate methods of analysis for those conditions for which exact numerical solutions are available. Only standard library routines will be required. (R. G. Hering)

1823-61005 Mechanical Engineering. Polarization Effects on Radiative Transfer. Although it is recognized that the emission and reflection of thermal radiation is polarized, a definitive study of the effects of polarization on radiative transfer is unavailable. The purpose of this study is to investigate the influence of polarization on the radiant heat transfer. Also of interest are the conditions under which major influences are observed. An analysis including the effects of polarization has been completed. Numerical solution of the governing integral equation is required. Standard library routines are only involved in the numerical calculations. (R. G. Hering)

1824-61006 T Nuclear Engineering. Space-Time Dependent Reactor Kinetics. Wigle-40 is a one dimensional, two energy group, time dependent diffusion theory program. It is designed to calculate the space time behavior of the neutron flux in a reactor during a transient.

The program will be restricted to one dimensional slab geometry with zero gradient or zero flux boundary conditions. The parameters in the diffusion equation will be specified as linear functions of time. The basic equations are

$$\nabla \cdot D_1 \nabla \phi_1 - \Sigma_1 \phi_1 + \chi_1 (\gamma \Sigma_{f_1} \phi_1 + \gamma \Sigma_{f_2} \phi_2) (1 - \gamma_1 \beta) + \sum_{i=1}^I$$

$$(c_{1i} + \delta c_{2i}) \lambda_i + s_1 = \frac{1}{v_1} \frac{\partial \phi_1}{\partial t}$$

$$\nabla \cdot D_2 \nabla \phi_2 - \sum_2 \phi_2 + \chi_2 (\gamma \sum_{f_1} \phi_1 + \gamma \sum_{f_2} \phi_2) (1 - \gamma_2 \beta) + \sum_{ri} \phi_1 + \sum_{i=1}^I$$

$$(1 - \delta) c_{2i} \lambda_i + s_2 = \frac{1}{v_2} \frac{\partial \phi_2}{\partial t}$$

$$- \lambda_i c_{1i} + \gamma_1 \beta_i \gamma \sum_{f_1} \phi_1 = \frac{\partial c_{12}}{\partial t} \quad (i = 1, 2, \dots, I).$$

$$- \lambda_i c_{2i} + \gamma_2 \beta_i \gamma \sum_{f_2} \phi_2 = \frac{\partial c_{22}}{\partial t}$$

Standard difference equations will be used in order to solve these coupled equations. (H. Hassan)

1825-61007 T Material Research Laboratory. Optical Properties of Semiconductors. Index of refraction data of Ga (As_{1-x}P_x) crystals will be curve fit using a theoretical formula. Reflectivity will be calculated, using the values of index of refraction calculated from the curve fit formula. Knowing values of reflectivity and measured values of absorbance, absorption constant can then be calculated using a formula for multiple internal reflections within the crystal. (George D. Clark)

1826-61008 Chemistry and Chemical Engineering. The Concentration Effect on the Nuclear Magnetic Resonance of Styrene. The project concerns the effect of varying concentration of certain phenylethylenes on the absolute nuclear magnetic resonance signal of the vinyl protons. Styrene has a nuclear magnetic resonance spectrum which can not be interpreted precisely without a computer program. The chemical shifts of the vinyl protons will be calculated at various wt./wt. percentages of styrene and solvent. (James S. Smith)

1827-61009 T Physical Education for Men. Training and Its Influence on Physical Performance and Selected Physiological Measures. The functional importance of certain physiological measures to energy metabolism has been well established. However, the quantitative significance of some of these measures to higher energy metabolism levels, as demonstrated by individuals in the trained cardiovascular endurance state, has not been adequately ascertained.

The purpose of this study is two-fold: (1) to investigate the effects of a highly oriented aerobic continuous running training program and a highly oriented anaerobic interval or "tempo" running program on physical performance capacity; and (2) to quantify changes in selected cardio-respiratory and hematological measures resulting from participation in these two training programs. (W. Gualtiere)

1828-61010 Physics. Analyses of Decay Spectra. Programs will be written to analyze complex decay spectra into components with different half lives, and to analyze complex gamma ray pulse height spectra. Standard least squares procedures will be used. (Nefkens)

1829-61011 T Physics. Thermodynamic Properties of Solid Neon. The research problem involves a series of standard calculations of varying lengths and degrees of complexity, some of which may be related, others not. Among these calculations there will be some involving the solving of a number of simultaneous transcendental equations; others will involve calculating matrix elements for a large number of sample points, finding the eigenvalues of each of the matrices, calculating several moments of the resulting eigenvalue distribution and performing various summations with these moments.

The research problem is a calculation of various thermodynamic properties such as specific heats, expansivities, Debye temperatures, compressibilities, etc. starting from a determination of the interatomic potential between neon atoms and application of a new theory of anharmonic effects in lattice dynamics. (Alfred Kugler)

1830-61012 Physics. S. Wave Resonance. A study will be made of S wave meson-banyon scattering resonances in a multi-channel problem described by a multi-component Schrödinger wave equation with a matrix potential due to vector meson exchange. The floating point Nordsieck method integrator program will be used to solve the differential equations. (H. W. Wyld)

1831-61013 Chemistry and Chemical Engineering. Stereochemistry. The postulate that the ^{13}C -H coupling constant in nuclear magnetic resonance spectroscopy reflects the amount of s-character in the C-H bond has been successful in correlating a large number of data in which the s-character of this C-H bond is increased as result of the inclusion of the carbon atom in a three- or four-membered ring. We have a system in which the opposite sort of strain, resulting from the attachment of three way bulky groups to a central carbon atom, seems to have brought about a change in hybridization increasing the p-character of the C-H bond. An x-ray crystallographic structure determination is being undertaken to confirm the postulated deformation from tetrahedral symmetry at this carbon and to allow for a more quantitative extension of theory to cover such cases. Other work on nuclear magnetic spectroscopy of cyclic compounds is aimed at the determination of conformational preferences of various groups attached to carbocyclic rings. (J. C. Martin)

1832-61014 Veterinary Physiology and Pharmacology. Radioisotope Analysis in Feeds. The radionuclide content of animal feedstuffs is measured using a 5" x 4" NaI(Tl) crystal detector. The detector output is fed to a 400-channel pulse-height analyzer. The analyzer readout is by means of punched paper tape. Information on paper tapes is transferred to IBM cards with the aid of the ILLIAC II Computer.

In feedstuffs, mixtures of 4 to 6 radionuclides are encountered, and a quantitative analysis of individual nuclides in the mixture is desired. Known quantities of the individual nuclides are assayed in the same counting geometry as the feedstuff to produce "library" tapes. The IBM 7094 generates a least squares fit between known library spectra and an unknown mixture spectrum, giving the fraction of each library radionuclide present in the unknown. (A. R. Twardock)

1833-61015 T Psychology. Analysis of Human Performance in Processing Visual Information. Horizontal lists of nonsense shapes differing in amount of stimulus redundancy (complexity) are presented to human subjects in a timed visual-search task which requires the subject on each trial to locate a given "target" shape in the list. Some parameters of human performance being investigated in this task are: form and amount of stimulus redundancy; number of targets in the display; duration of target display; continuous or discontinuous target display during visual search; delay between target offset and appearance of list to be scanned; age differences; practice effects; and the influence of noise and list-background factors. The basic measure is speed of successful search, using the slope of the plot of search time against target position in the list.

The computer will be used (1) to perform necessary transformations of the raw search-time data and (2) to obtain the mean, standard deviation, simple linear regression coefficient, and intercept of the transformed search-time scores plotted against target positions in the list for each subject for each within-subjects treatment cell. (3) Further, analyses of variance of several experiments will be performed using the slope coefficients, each experiment containing 3, 4, or 5 independent factors. (Roderick Forsman)

1834-61016 Psychology. Anderson's Rat Experiment. As a complement to on-going multivariate investigations of rat behavior, a re-analysis of previously published animal data has been undertaken. Two early studies (1934-1938) have been selected for analysis by modern techniques. In one case the intercorrelations of 20 measures for 54 rats and in the other intercorrelations of 47 measures for 51 rats were reported. In each study one variable had to be eliminated as psychometrically unsuitable. The problem thus reduces to the following: (a) Listing of two matrices, one 19 x 19, the other 46 x 46 (for accuracy of transcription check); (b) Calculation of latent roots by means of locally prepared Jacobi type program; (c) Utilization of the program referred to in (b) above to the estimate communalities; (d) Extraction of factors by means of the program in (b) above; (e) Initial oblique rotation employing MAXPLANE program as developed by Laboratory of Personality Analysis and Group Behavior; (f) Final visual rotation to simple structure. (Weiffenbach)

1835-61018 T Electrical Engineering. Electromagnetic Plasma Diagnostic Techniques. In the course of analyzing correlated microwave and optical measurements of plasma characteristics, there arise a series of short analytical problems which are slightly too large for the specifications of 28018 problems. We will run such short problems under this problem number. The first problem to be run will be an analysis of the dependence of the resonant frequency of a microwave cavity on electron density in the cavity. We will use the BES1 routine in the 7094 library to compute Bessel functions needed in the analysis. (Michael E. Fein)

1836-61019 Theoretical and Applied Mechanics. Difference in Principal Stresses for a Stresses Wave in an Elastic Material. The equation for the difference in principal stresses along the direction of impact for a stress wave propagating in a material has been derived using an elastic analysis. This equation is

$$(\sigma_x - \sigma_y)_{y=0} = \frac{\frac{2}{\pi} H \left(t - \frac{x}{a} \right) \left[2 \left(\frac{b^2 t^2}{x^2} - \alpha^2 \right) + 1 \right] \left[2 \left(\frac{b^2 t^2}{x^2} - \alpha^2 \right) + \alpha^2 \right] \frac{bt}{x^2}}{\left[\frac{b^2 t^2}{x^2} - \alpha^2 \right]^{1/2} \left[4 \frac{bt}{x} \left(\frac{b^2 t^2}{x^2} - \alpha \right) \left(\frac{b^2 t^2}{x^2} - \alpha^2 + 1 \right)^{1/2} - \left[2 \left(\frac{b^2 t^2}{x^2} - \alpha^2 \right) + 1 \right]^2 \right]}$$

$$- \frac{\frac{8}{\pi} H \left(t - \frac{x}{b} \right) \left[\left(\frac{b^2 t^2}{x^2} - 1 \right) \left(\frac{b^2 t^2}{x^2} - 1 + \alpha^2 \right) \right]^{1/2} \frac{b^2 t^2}{x^3}}{4 \left[\frac{b^2 t^2}{x^2} - 1 \right] \frac{b^2 t^2}{x^2} - 1 + \alpha^2 \left[\left(\frac{bt}{x} \right) - \left[2 \left(\frac{b^2 t^2}{x^2} - 1 \right) + 1 \right]^2 \right]}$$

$$b^2 = \frac{E}{2(1+\nu)\rho} \quad \text{and} \quad \alpha^2 = \frac{1-2\nu}{2(1-\nu)} \quad \text{where } E \text{ is Young's Modulus, } \nu \text{ is}$$

Poisson's Ratio, and ρ is the density. The computer will be used to evaluate $x (\sigma_x - \sigma_y)_{y=0}$ as a function of $\frac{bt}{x}$ and these results will be compared with those found experimentally using the methods of dynamic photoelasticity. (M. Stippes)

1837-61020 T Electrical Engineering. Space Filter. This program computes the input impedance, the efficiency and the far field pattern of an array of monopoles which are arrayed in a log-periodic fashion over a ground plane. The program has the capability of having every element active, every other element active or every third element active. The type of loading on the parasitic or non active elements is quite arbitrary.

The main part of the program is the calculation of the mutual impedance matrix Z , and the solution of the equation $[I_F] = [U + YZ][I_b]$ where I_F = the driving currents, U = unit matrix, Y = diagonal matrix of monopole loads, and I_b = monopole base currents. With the base currents the patterns are normalized to that of a single quarter wave monopole over a ground plane. Three of these patterns are plotted simultaneously for each set of parameters. (K. E. Jones)

1838-61021 T Vocational and Technical Education. Knowledges in Child Development. The purpose of this study is to ascertain both the unique and common knowledges needed by homemakers and employees in child-related occupations. Selective samples of child development specialists, state licensing officials of day care centers, employees in child-related occupations, and mothers will be interviewed. Data will be collected and analyzed on items of knowledge in child development and guidance needed by mothers and workers in occupations related to child care. The specialists and licensing officials were selected to offer expert judgment concerning knowledges mothers and child care workers should have.

Statistical procedures utilized for this study will include the t test, one way anova, and Duncan's Multiple Range test. Each knowledge item is to be tested independently to determine whether there are significant differences in the depth of understanding needed among jobs related to child care. The judgments of experts in the field will be compared with judgments of practitioners in each job. Duncan's Multiple Range test is to be utilized to determine which items of knowledge are significant to each job. Items which may be grouped under a single heading will be compared among the jobs related to child care. (Ruth E. Whitmarsh)

1839-61022 Chicago Circle Department of Material Engineering. Foundations of Shell Theory. Systems of differential equations governing the motion of cylindrical shells are established. The analysis consists of the application of the boundary layer technique to the equations of three-dimensional orthotropic elasticity. Comparison is made with previous theories which contain thickness effects as well as with the results of the exact three-dimensional theory. Numerical results are given for the propagation of waves in an infinite shell. The computer is used to establish the wave velocity - wave length spectrum. (O. E. Widera)

1840-61023 T Education. Basic Study Skills. This research effort seeks to determine how measures of a selected group of basic study skills are inter-related and how each of these is related to measures of general achievement, mental ability and selected reading abilities. The population includes three sixth-grade classes in a community comprised of people who are mainly from an upper-middle class suburban community. The computer will be used with the pretest data to determine whether or not the three groups differed significantly with regard to the skills tested at the beginning of the experiment. T-tests will be used to give some information about the present status of the groups involved. (Frederick Rodgers)

1841-61024 Department of Computer Science. ILLIAC II Time Sharing. The computers will be used in development of the ILLIAC II Time Sharing System. (Gear)

1842-61025 Division of University Extension. Correspondence Summer Enrollments. This project is to measure differences between persons who enroll in correspondence courses during the special summer enrollment period and those who enroll at other times of the year with respect to previous education experience; occupation of enrollees; courses taken; course completion rate and course level. (Harold Wecke)

1843-61026 T Education. A Study of the Supplementary Income of Male Professional Personnel in Selected School Districts in Illinois. The primary purpose of this study is to provide a detailed description of the male professional personnel in a sample of school districts in Illinois regarding the nature and incidence of supplementary employment. The nature and incidence of supplementary employment will be studied in relation to the personal, experiential, and economic characteristics of these men. An additional purpose is to ascertain the extent to which differences exist among male professional personnel regarding the extent to which they supplement their income. The third purpose is to investigate the relationship of the per cent of total income earned from supplementary sources to selected variables.

The sample includes 20 representative districts each from elementary, secondary, and unit (12 grade) districts. The sample of districts was selected by standard random methods and was representative of elementary, secondary, and unit school districts by size in average daily attendance and wealth in assessed valuation per pupil.

Correlational methods will be utilized to ascertain if any of the variance in the per cent of total income earned from supplementary sources is accounted for by the variables of size of district, wealth of district, average professional salary of women in the school district, number of years of professional experience, age, the number of dependents, training level, average salary of men in the school district, and the average professional salary in the school district. t-tests or analysis of variance statistical designs may be utilized to test differences within and between groups of teachers, administrators, and other professional specialists. Analysis of variance may also be utilized to test differences between and within groups of school districts. (James L. Elliott)

1844-61033 Industrial Administration. Selected Determinants of Effective Leadership. The purpose of this project is to investigate a number of suggested determinants of effective leadership in formal organizations. A theoretical framework for the investigation, leading

to the selection and development of the determinants and criterion measures, is provided in the work of Bernard Bass (1960). Certain leader behaviors and characteristics are treated as the determinants of effective leadership; the criterion measures are work group task performance and work group satisfactions. Determinants and criterion measures are quantified through a variety of standardized and experimental instruments. Subjects are first-line supervisors and subordinates assigned to a naval ammunition depot.
(Ken Rowland)

1845-61034 Agricultural Economics. Experimental Farm Record Processing. The objectives of this research problem are to: 1. Develop and test computer programs that will process farm business transactions to provide (a) farm financial statements, (b) farm business analysis factors, and (c) comparative business analysis statements for Illinois farmers. 2. Apply and test linear programming and simulation techniques to farm business planning methods. 3. Determine the operating cost of electronic processing methods in objectives 1 and 2, and to evaluate the potential farmer demands for, and benefits from, computer applications to farm business analysis and farm planning methods. Computers and associated electronic equipment will be applied in an experimental operating procedure to classify and aggregate farm business transactions, to prepare farm business financial statements, and to use these data as inputs for farm planning methods.

A program routine will be developed as part of the project; also an existing FORTRAN program from Purdue will be tested and modified if necessary for use on C.S.L. computers. (Allan G. Mueller)

1846-61039 T. Chicago Circle Department of Energy Engineering. Solution of the Energy Equation for two Dimensional Stagnation Point Flow with Radiation. The problem is the solving of the energy equation for flow in the region of a two dimensional stagnation point. Both convective and radiative modes of heat transfer are involved. Mathematically, it is the numerical solution to an ordinary-non linear integral-differential equation. Standard library routines are involved. (N. A. Macken)

1847-61040 State Water Survey. Vertical Velocity. The program will perform some crude numerical vertical integrations of wind velocity components for a number of stations. The results will be printed out in map form. These maps will be analyzed manually to obtain fields of vertical velocities at various heights.

An integral of the form:

$$\int_s^h \left(\frac{P}{P_h} \right)^{\frac{1}{\Gamma}} u dz$$

is to be approximated by the summation:

$$\sum_{i=1}^{\text{final}} \left(\frac{P_i}{P_h} \right)^{\frac{1}{\Gamma}} U_i \Delta Z_i = \left(\frac{P_1}{P_h} \right)^{\frac{1}{\Gamma}} U_1 \frac{Z_2}{2} + \sum_{i=2}^{\text{final}} \left(\frac{P_i}{P_h} \right)^{\frac{1}{\Gamma}} U_i \frac{Z_{i+1} - Z_{i-1}}{2}$$

Where Z_i is the height and P_i and U_i are the variables evaluated at the height Z_i .

P_h and Γ are constants. (Pieter Feteris)

1848-61041 Chemistry and Chemical Engineering. X-Ray Structures of Cycloadducts. Complete three-dimensional x-ray crystallographic structure determinations will be undertaken for certain organic molecules from the cycloadduct category. Standard computational techniques for analyzing experimental data will be used. (J. E. Baldwin)

1849-61042 Chemistry and Chemical Engineering. Evaluation of Two- and Three-Center Integrals. This work involves the calculation of molecular properties over two or three molecular centers. The computer is used to calculate the radial integral using an expansion technique and a Simpson's rule integration. (H. D. Todd)

1850-62001 Chemistry and Chemical Engineering. Solution to Orr Somerfeld Equation. The Orr Somerfeld equation is a fourth order; linear, ordinary differential equation with non-constant coefficients. No general analytic solution has been found, but asymptotic solutions for limiting cases and a few numerical solutions have been reported in the literature. It is the purpose of this work to attempt the solution to this equation by various numerical methods, and to determine which method is most applicable to this author's work. (Gerald W. Cook)

1851-62002 T Chemistry and Chemical Engineering. Flame Stability. The stability of laminar premixed and diffusion flames will be studied by the method of small disturbances and by complete numerical solution of the nonlinear transport equations. Of particular interest is the behavior very near ignition and extinction conditions. Problems to be studied include liquid droplet burning, solid burning, laminar flame propagation, and flames in boundary layers. The digital computer will be employed in the solution of eigenvalue problems and nonlinear partial differential equations. (R. A. Schmitz)

1852-62003 T Vocational and Technical Education. Teacher and Youth Communication. This study deals with communication between teachers of vocational agriculture and youth from socio-economically disadvantaged families. The specific problem is to measure and compare the connotative meaning of a selected list of concepts for teachers of vocational agriculture and socio-economically disadvantaged youth. Another objective of the study is to ascertain the degree to which the teacher of agriculture understands the values and meanings of concepts held by socio-economically disadvantaged youth. Meaning will be measured by using a paper and pencil technique called the Semantic Differential. Ten, seven-step scales bound by adjectives opposite in meaning are checked by the students. Twelve student classifications of twenty students each will have their responses on such an instrument compared by a multivariate analysis of variance. The Hotelling's T^2 test will be used to compare the different classifications of students

with the teacher group... The accuracy with which teachers can predict the meaning their students place on words will be measured by having the teacher mark an instrument as he thinks his student marked it. The difference between the student's response and that predicted for him will be tested for significance by applying the paired t-test to each prediction. (Martin B. McMillion)

1853-62004 T Education. College Image and Organizational Character. This is a study of college image and organizational character as perceived by various groups in a junior college. Respondents, answering two separate questionnaires, reveal their attitudes toward and opinions regarding a particular junior college in Northern Illinois. The two research instruments are the College and University Environment Scales, developed by C. Robert Pace of the University of California at Los Angeles, and a modified version of a college and university questionnaire developed by Burton R. Clark at the University of California at Berkeley. The Pace instrument was administered to three groups totaling 240 persons, while the Clark instrument was administered to five groups totaling 370 persons. Administration of the instruments was begun on September 9 and was concluded by December 1, 1965.

The Pace instrument contains 150 items all of which are answered either true or false on the Digitek form DS1201. There are five scales of thirty items each. For each respondent a score must be obtained on each of the five scales. Each individual's separate scale scores should be arrived at by counting the number of items answered in the keyed direction (therefore, each respondent will have five separate scale scores). Within each testing group, the scores of individuals should be distributed and averaged, providing a mean and standard deviation which is the group's score on the scale. The obtained mean scores should be compared for significance using t tests for independent groups. It is hoped that the computer will provide this information.

The modified Clark questionnaires were administered in five editions -- one edition for each type of respondent involved in the research (i.e. student, alumni, faculty, etc.). The questionnaire items vary in number from five to forty-four depending upon the particular edition. For each edition of the questionnaire frequency counts for each item were made and a total percentage score listed. This information was hand processed. (David A. Hagstrom)

1854-62023 Aeronautical and Astronautical Engineering. Turbulent Combustion Studies. Turbulent flame propagation velocity is being measured on a large burner. The computer will be used primarily to reduce data obtained from this burner in many repetitive runs. It will also be used to construct a rather simple phenomenological theory for the propagation of turbulent flames and to calculate flame temperatures and properties. (R. A. Strehlow)

1855-62024 T Civil Engineering. Rotative and Lateral Slip of Railway Wheels on Rails. Standard library routines are used in solving the problem of finding the relation between the rotative and lateral slip of railroad wheels on rails. Many tests are performed and the results are recorded on oscillograph tapes. Measurements are taken from these graphs by using an IBM reader which reads the measurements and punches them into cards. (Mohamed Talha)

1856-62025 T Civil Engineering. Network-Topological Methods for Structural Analysis and Design. A procedure for the analysis and design of structural systems based on network-topological methods is to be developed. Linear, lumped-parameter systems subject to dynamical inputs will be considered. The computer will be used to obtain transfer functions relating outputs to inputs in symbolic form from the topology of the system. These transfer functions can be used to determine the response for a given input in an analysis problem or can be used in design. In the design problem, the design parameters can be selected so as to produce a desired magnitude of response and to optimize some objective function, using a nonlinear programming method on the computer. (D. R. Lagerquist)

1857-62033 Electrical Engineering. Capillary Instability of Jets. The computer will be used to find approximate solutions to coupled differential equations which arise in the study of the instability of circular jets of liquid. The computer will be used to simulate an analog computer using MIDAS in order to obtain these solutions. (John H. Schneider)

1858-62045 Division of Waterways. River Basin Analysis for Planning. The primary purpose will be the development of programs applicable to the solution of problems encountered in planning for the development of water resources in Illinois. A regionalized solution to the hydrologic response of river basins will be developed using a non-linear basin response model. (R. Prasad)

1859-62046 T Chemistry and Chemical Engineering. Molecular Orbital Calculations. It is the purpose of this research to modify a presently functioning program for molecular orbital calculations. Specifically, more realistic coulomb integral values will be obtained, taking into account intramolecular charge distributions. Following this stage, the modified program will be used to obtain molecular wave functions for organometallic molecules. (A. F. Schreiner)

1860-62050 Physics. Analysis of Neutron Resonance Cross Sections. Recently new and accurate measurements have been performed of the neutron cross sections of the fissile elements. Appropriate methods and codes have been developed for the analysis of these data. From various laboratories, data are being made available for an analysis at Illinois. During this year, the plutonium isotopes will be investigated, and it is hoped to gain information about the spin states involved in some of the low-energy neutron reactions. (F. T. Adler)

1861-62051 Electrical Engineering. Antenna Research. The problem which is to be studied concerns the optimization of broadband antenna arrays and other devices associated with antennas. The class of broadband structures currently being studied are called log-periodic (LP). This is because the structures are composed of cells or units which are connected in series, but which differ electrically from the adjacent cell by a scale factor.

It has been found possible to build some devices this way which have a number of electrical properties which remain relatively constant or pseudo-frequency-independent over the band of interest. The research work on LP structures has only recently been expanded to cover structures other than antenna arrays. These include directional couplers and integrated amplifiers. (Paul Ingerson)

1862-62052 T Political Science. Judicial Voting Behavior of Some Foreign Supreme Court Judges. The problem involves correlating certain background characteristics of about seventy-five U.S. and other English speaking Supreme Court justices with various aspects of their voting behavior and justification patterns. The computer will be used to do the correlation of the fifty or so variables for each judge. (Susan Welch)

1863-62054 Economics. Urban Location Analysis. This project will undertake an empirical analysis of the factors affecting the location and relocation of manufacturing firms within urban areas. The basic method of analysis will be a single equation regression model with number of firms making a location decision as the dependent variable and locational factors such as land availability, access to various amenities, input prices, and other urban characteristics as the independent variables. Observations are on geographic units within the urban area. (H.F. Williamson)

1864-62057 Electrical Engineering. Boundary-Value Problems Related to Plasma Waveguides. The main objective of this research is to solve boundary-value problems concerning electromagnetic wave propagation in a waveguide partially filled with a plasma medium. It is intended to solve for the dispersion relation in a source-free waveguide and for the input impedance of a small antenna used to excite the wave. Therefore, transcendental equations and numerical integrations will be solved. Bessel function subroutines will be used often. (C. Liang)

1865-62058 T Electrical Engineering. Semiconductor Amplifier Noise Analysis. Cascaded semiconductor R.F. amplifiers have an optimum configuration for minimum noise figure. The data obtained for individual semiconductor devices will be utilized in a computer program which will evaluate noise figure as a function of device configuration, source conductance, operating point, and gain. Standard library routines will be used to minimize system noise figure. (John Robertson)

1866-62059 Electrical Engineering. Group Dynamics Simulation. Small task-oriented groups will be simulated using an enlarged and refined version of "SIMULNET II," an algorithm which was recently developed and coded into FORTRAN in the Electrical Engineering Department. The program will follow each simulated group participant through a group session, determining his speaking times, his changes in opinion and status, and his shifting perceptions of other participants. The formation and interaction of coalitions within the simulated group will also be modeled. Parallel experiments using actual groups are being planned. (Paul Weston)

1867-62060 Electrical Engineering. Speech Vocal Tract Simulation. The vocal tract and the speech therefrom is to be simulated by means of mathematical models of the equivalent electrical circuits. The parameters of the circuits and the excitation functions will be represented as functions of time by means of series expansions similar to Fourier and harmonic functions. The result will be a function of time which will then be converted to analog form and tested to see if it is similar to the sounds of speech. (M. L. Babcock)

1868-62061 T Physics. Study of Continuous - Discrete Optimization Schemes. Optimization problems are of interest for many fields of engineering. A method has recently been developed to treat mixed continuous-discrete systems. Linear and quadrature programming routines will be used to explore the computational feasibility of the general method of approval. (F. T. Adler)

1869-62062 Education. Family Food Practices of Tenth Grade Students at Champaign High Annex. A questionnaire developed by Dr. Elizabeth Simpson containing 52 questions plus 7 personal data items was given to 425 students at Champaign High Annex. The purpose of this study is to gain some knowledge of the family food practices in this community. Three null hypotheses will be tested. (1) A comparison of the family food practices will be made in the homes where the mother works outside the home and where the mother is a full-time homemaker. (2) A comparison will be made between the family food practices of boys and girls. (3) A comparison will be made between the family food practices of girls who are presently taking home economics and those who are not taking home economics. Percentages will be computed for the frequencies of responses for each item as they relate to each of the three hypotheses. Chi-square technique will be used to determine the statistically significant differences, whenever possible. (E. Simpson)

1870-62063 Electrical Engineering. Multi-level Modelling of a Simple Environment. This problem is groundwork for an artificial intelligence project exploring the three-part relation among (a) intuitive or mental-image representation of an environment, (b) organization of symbolic entries in memory, and (c) the semantic level of natural language. Subroutines will be coded in IPL-V capable of creating and manipulating list structures to model a class of hypothetical entities having the character of binary computer registers, and upon which logical processes may be performed. Also included in the modeling power of the system will be the ability to represent some of the processes by which the above model representations are themselves achieved. These representational devices will all be put under control of a program having an organized store of "definitions" which each generate calling sequences to produce a required model of an entity or process. The names of these definitions will be organized within a list structure which reflects logical relations among the modeled entities. (Paul Weston)

1871-62064 Physics. Tunneling Between Superconductors. The effect of magnetic impurities on the tunneling of supercurrent between two superconductors separated by a thin oxide layer is to be calculated by the formula:

$$I \simeq |M|^2 \int_{-\infty}^{\infty} dw \int_{-\infty}^{\infty} dw' \frac{f(w') - f(w)}{w - w'} P(w) P(w'),$$

$$\text{where } P(w) = \operatorname{Re} \left\{ \frac{\tilde{\Delta}(w)}{\sqrt{w^2 - \tilde{\Delta}^2(w)}} \right\} = \operatorname{Re} \left\{ \frac{\Delta}{\sqrt{\Omega^2(w) - \Delta^2}} \right\}$$

$$f(w) = [e^{\beta w} + 1]^{-1}$$

$$\Omega(w) = w + 2i \Gamma_s \Omega(w) / [\Omega^2(w) - \Delta^2]$$

$$\tilde{\Delta}(w) = \Delta - 2i \Gamma_s \tilde{\Delta}(w) / [w^2 - \tilde{\Delta}^2(w)].$$

Here Γ_s is the inverse life time due to spin flip scattering by magnetic impurities, and $|M|$ is the matrix element of the tunneling interaction. $\beta = \frac{1}{T}$. T is the temperature of system. Δ is the BCS gap. Re means to take the real part. $i^2 = -1$. (Michel)

1872-62065 T Material Research Laboratory. PhD Thesis Data Reduction.. The computer will be used to obtain 4th order polynomial least square fits of one set of data for equipment calibration; to analyze isothermal relaxation curves in terms of sums of exponentials; to reduce temperature spectral data; and to represent the results graphically using the CalComp plotter. (Howard B. Aaron)

1873-62074 T Theoretical and Applied Mechanics. A Comparison of the Holzer method with the Theoretical Solution for the Peak Frequencies of a Multi-Degree of Freedom Vibrating System. In order to determine the frequencies for which the amplitudes are maximum in a damped multi-degree of freedom vibrating system, the Holzer method is quite popular. This popularity is due to the fact that the theoretical solution for these

frequencies cannot easily be expressed in an explicit form. The Holzer method is an approximate method based upon heretofore unverified assumptions. Therefore, in order to compare the Holzer method with the theoretical solution, it is necessary to resort to an experimental analysis. By using the computer to generate the large amount of numerical results necessary, a comparison may be made. (W. D. Dittmer)

1874-62075 T Department of Computer Science. Grammar Language. A computer language will be developed which will enable grammars to be written and checked out. The grammars are of the transformational Context-Sensitive Phrase Structure type developed by Noan Chomsky. The grammars that may be written using the language to be developed include both natural languages such as English and artificial (computer) languages.. (C. W. Gear)

1875-62084 T Agricultural Economics. The Effects of Financing Constraints On Farms in Thailand. Maxima are sought among production, marketing, and financing alternatives available to Thai farmers subject to constraints that can be expressed as linear equalities and inequalities. Simplex methods will be used to generate solutions of linear programming models formulated to describe the alternatives and constraints. (T. Onchandra)

1876-62086 Chemistry and Chemical Engineering. Complex Impedance Parameter Calculation. The problem is part of a general investigation into the electrochemical properties of the tin oxide semiconducting electrode. The computer will be used to transform experimental readings of amplitude and phase angle into complex parameters which may be more readily interpreted. (C. A. Vincent)

1877-62087 Astronomy. Reduction and Analysis of Stellar Spectra. Atmospheric parameters for several late-type (cool) stars with large variations in abundances will be determined. Some ten spectrographic plates are involved; the digitized data will be secured in the form of

punched paper tape, which must be processed on-line on ILLIAC II. Preliminary runs indicate that it will take approximately 10 to 15 minutes per plate read-in time, plus the conversion to relative intensities. The information will be plotted with the CalComp plotter. Absorption line strengths will be measured from the tracings. Analysis of the atmospheric parameters will be done with the IBM 7094. (Lee Paul)

1878-62093 Chemistry and Chemical Engineering. Double Layer Capacity. One of the theories involved in the determination of the electrical double layer is the solvation theory. The computer will be used in an attempt to verify the solvation theory by analyzing experimental results obtained by measuring the capacity of the electrical double layer. By fitting the values of varying constants, it is hoped that the form of the experimental curve will be approached, thus verifying the solvation theory. (Pance Kirkov)

1879-62094 Natural History Survey. Fish Population Dynamics. This research problem is concerned with fish population dynamics in Illinois lakes and ponds. Frequent collections of fishes will be made from a number of lakes and ponds, and the 7094 Digital Computer will be used to determine changes in species composition, length-weight relationships, and reproductive states of approximately 20 different species of fishes over a 12 month period. (William F. Childers)

1880-62095 Civil Engineering. Three Dimensional Consolidation of Soils. An important and practical problem in soil mechanics is the prediction of the time rate of settlement of foundations underlain by compressible clays. In many practical problems, the geometry is sufficiently complex that general solutions have not been developed. The cases of interacting rectangular or strip footings causing three dimensional flow of water from the underlying compressible soils is a common and important problem of this type that has not been solved. The problem will be studied for both isotropic and for anisotropic soils using numerical procedures. The method consists of replacing the foundations with a series of equivalent point

loads, calculating the pore water pressures induced at selected grid points in the clay using the Boussinesq equations, and then solving the general three dimensional differential equation of consolidation using first forward differences for the time term and second central differences for the terms involving flow along the three cartesian coordinate axes. The analysis will apply to rectangular footings of various length-width ratios that are founded in, on, or above the compressible clay layers. Only homogeneous clay layers are considered. (J. D. Campbell)

1881-62096 Medical Center Computer Laboratory. Assorted Problems for Testing Purposes. It is intended to develop the capability of sending computer problems from the Medical Center to the Urbana Computer Laboratory via the Chicago Circle facilities. Under this initial request, a variety of problems of a routine nature will be submitted. As the capability is developed, additional problem specification numbers will be requested for individual problems. (Dr. Marbarger)

1882-62097 T Physics. Resonance Studies with the Schrodinger Equation. A multichannel Schrödinger equation using a potential matrix will be used to obtain a phase shift analysis and thus a determination of resonances. Different cases will be considered. The computer will be used to solve integral equations by an approximation technique and thus obtain the phase shifts. The following steps will occur: the examination of π N scattering starting with an exchange Feynman diagram; the constructions of approximations for the propagator; and obtaining the potential, which will then be plugged into the Schrödinger equation to get the resonances. (Jose Katz)

1883-62098 T Physics. Beam Design. The purpose of the program is to calculate the magnetic gradients required in a series of bending magnets which will focus particles of an arbitrary momentum. The method is as follows: Particles will be described by their position, X , and slope, X' . Define $\vec{X} = \begin{pmatrix} X \\ X' \end{pmatrix}$. A quadrupole magnet in this representation is a transfer matrix, Q . The computer will generate the matrices and multiply to form $Q \cdot \vec{X}_{in} = \vec{X}_{out}$. This will be repeated for each element (quadrupole). (William Hassenzahl)

1884-62099 T Chemistry and Chemical Engineering. Turbulent Heat Transfer. The nature of the problem being studied is one of attempting to describe the temperature distribution in a turbulent flow field. Several coupled differential equations have been developed which are too complicated to be solved manually. Since the computer affords a good method of performing numerical analysis the problem is being prepared for the IBM 7094 computer. (Alan Leviton)

1885-62100 T Speech and Theatre. Ethos In Persuasion. The purpose of this study is to discover the main and interacting effects of selected methods of enhancing the speaker's credibility in persuasive public speaking. In addition, this study will also attempt to discover the effects of an appeal for overt expression of attitude change. The dependent variables are two levels of pre-existing belief about the speaker's competence and trustworthiness, as well as two levels of belief strength about the speaker's competence and trustworthiness as developed by particular internal message additions. A third independent variable is the presence or absence of an appeal for overt expression of the attitude and belief change. The dependent variables are attitude change toward the concept, belief change about the proposition, belief and attitude change about the substantive arguments in the speech, and a commitment to overt behavior. The method of analysis will be a 2x2x2 analysis of variance, and a complete intercorrelation of all dependent measurements. (Biddle Phillips)

1886-62101 T Theoretical and Applied Mechanics. Stress Analysis of Cylindrical Shells with Unsymmetrical Circumferential Line Loads. It is proposed to perform a theoretical stress analysis of thin cylindrical shells when subjected to certain axially unsymmetrical circumferential line loads. The solution of the governing partial differential equations of thin shell theory yield, after certain assumptions are made about the nature of the solutions, sets of

algebraic equations which must be satisfied in order that boundary conditions, consistent with the applied loads, be satisfied. Numerical solutions to these equations will furnish the coefficients of certain infinite series which are representations of the required solution to the stress problem. The number of terms in each of these series which will be evaluated will depend on the rate with which the series converges. Computation will therefore consist basically of setting up sets of non-homogeneous algebraic equations and obtaining solutions by some method such as matrix inversion. (C. Todeschini)

1887-62105 T Aeronautical and Astronautical Engineering. Hypersonic Ramjet. The problem concerns the performance analysis of a hypersonic ramjet over a range of operating conditions. To solve the three basic equations, an iterative method has to be used since one of the equations, the reaction equation, cannot be expressed as an explicit function of the variables. The computer will be used to find the solution so that a complete study of the performance under a wide range of operating conditions can be made. (Gary L. Vieth)

1888-62106 T Physiology. Estimation of Compartmental Model Parameters. In describing the effective microcirculation in muscle as measured by uptake or washout of radioisotopes, a linear compartmental model is often helpful. A program to compute the parameters of such a model is needed. The National Institutes of Health (NIH) has offered to provide the Physiology and Biophysics Department with a copy of SAAM, a program for stimulation, analysis, and modeling of biological kinetic data. This program is written in FORTRAN II for assembly and execution under the IBM FORTRAN monitor. The NIH program will be listed and punched. Those parts pertaining to linear compartmental analysis will be translated for use here and evaluated. (Fred Downey)

1889-62107 Department of Computer Science. Study of Artificial Language Algorithms and Grammars. The purpose of this study is to develop and test algorithms for the analysis and reduction of phrase structure and simple precedence grammars. These algorithms will then be used to assist in the development of mechanical languages suitable for the description of complex processes on modern computers, such as the translation of procedure-oriented computer languages. Symbolic processing techniques will be used almost exclusively. (B. E. Squires)

1890-62108 T Electrical Engineering. Modification and Debugging of MIMIC Subroutine. The MIMIC analog-digital simulator program is a subroutine written in FORTRAN IV for use with the IBSYS Monitor. The problem herein named involves rewriting MIMIC for use on the University's 7094 system without need for complete relinquishment of the system. It also involves devising a method for the solution of general differential equations with unknown initial conditions by methods of iteration (e.g., solution of the response of a system involving hysteresis to a nonlinear driving function). (Dennis Christenson)

1891-62109 Civil Engineering. Finite Element Solution of Plate and Shell Problems. The objective of the research program is the stress analysis of plates and shells, including in-plane forces. The basic method used is the finite element technique. The computer is used to generate and solve the set of simultaneous equations resulting from the finite element idealization. The Choleski, or square root, method is used for the solution of the equations. (D. Pecknold)

1892-63001 Civil Engineering. Champaign-Urbana Traffic Analysis. The problem consists of model development and traffic assignment for the Champaign-Urbana area. Models will be developed by use of multiple linear regression programs as well as Department of Commerce, Bureau of Public Roads standard traffic analysis programs. The traffic analysis consists of determining the amount of generated traffic, location of generated traffic, and assignment of this traffic to a highway network. (R.H. Mortman)

1893-63002 Agronomy. Evaluation of Plant Nutrient Levels. Multiple regression analysis techniques will be used to measure the effect of selected plant nutrition factors on corn yields and the chemical composition of the corn plant. Selected soil fertility factors such as fertilizer applications and soil test values will be evaluated as to their effect on chemical composition and yields. The effects of micronutrient levels in the plant on corn yields will also be studied. The feasibility of use of this evaluation technique on the nutrient status of the plant will also be considered. (Walker)

1894-63004 T Civil Engineering. Anchorage Zone Stresses. Concentrated prestress forces produce transverse stress distributions in the ends of prestressed concrete beams. The problem is to determine the variation of these stresses over the depth of the section as a function of cross section shape, prestress distribution and prestress force. The computer will be used to solve the equations for the stress at a given number of points evenly spaced over the depth of the section. (W. A. Welsh)

1895-63005 Student Counseling Service. Comparison of Programmed and Face-to-Face Counseling. Programmed and face-to-face counseling will be compared in regard to a number of student reactions and variables reflecting student characteristics and success. Student test data and other information about students and student reactions to the two types of counseling will be compared in terms of differences between means and between percentages. These data will also be correlated with first semester scholastic achievement. Mean differences will be computed comparing the groups regarding scholastic achievement and frequency of counseling appointments during the first semester in college. (Ewing)

1896-63006 T Physics. Theory of Proximity Effect in Superconductors. The proximity effect of superconductors is governed by an integral equation:

$$\Delta(x) = \int_a^b H(x, x') \Delta(x') dx$$

where a and b are constants and $H(x, x')$ is a sum of known functions,

$$\sum_{\gamma=0}^N H_{\gamma}(x, x'),$$

where N is a known cutoff. $H_{\gamma}(x, x')$ consists of a sum of exponential functions, and depends on an implicit parameter T.

It is desired to find an approximate solution of this integral equation by a perturbation-iteration method starting with a fairly good zero order approximation, $\Delta_0(x)$. The program is written to test the magnitude of successive higher order terms, and determine whether the perturbation zero will converge for some value of T. The parameter T is also measured experimentally, and can be compared with the value determined by the above method. (Robert Yeh)

1897-63007 T Electrical Engineering. Synthesis of a Band-Pass Filter. The thesis is an investigation of the optimum magnitude-frequency response of a band-pass filter, assuming that the elements used in the filter are not ideal, namely, the design will account for the losses due to the fact that the elements are not ideal. The computer will be used to check the validity of the theoretical concepts involved and the mathematical theory behind the improvement of the response. Since the calculation of the magnitude response and the iterative computations are all time-consuming, the computer will help facilitate the calculation. (David Zein)

1898-63008 Psychology. Worker Preferences for Fringe Benefit Options. As is often the case in field research in psychology many different independent variables contribute to the effect measured in the dependent variable under investigation. In the study of worker preference for time-off benefits, five causal variables were measured. The analysis of the relationship of these five variables with the dependent variable, mean preference, will be studied statistically. (James G. Goodale)

1899-63009 T Chemistry and Chemical Engineering. Nonlinear Interfacial Mechanics. This research problem is a theoretical investigation of the nonlinear aspects of interfacial cellular convection. An asymptotic perturbation technique is employed in integrating the system of nonlinear partial differential equations which characterize the system. The computer is used in integrating the systems of ordinary differential equations which are generated in the analysis and in performing some of the complex phase space algebra which must be performed. (R. L. Sani)

1900-63010 Electrical Engineering. Biomath. The problem of immediate interest is that of a population model. At first the numerical value of certain parameters will be determined, using the least squares method, from population data already available. Then these values will be introduced into the integro-differential equations which describe this population model. Subsequently an attempt will be made to solve these equations numerically using the computers. The magnitude of the determined parameters will dictate the proper numerical method. As the project proceeds, further insight into the formulation of "better" population problems will be gained. (Alfred Inselberg)

1901-63011 Electrical Engineering. Electron Density and Temperature in a Gas Discharge. This research effort is an attempt to find equations which correctly predict the measured performance of afterglow plasmas in argon. The computer will be used for numerical solution of differential equations which describe the electron loss processes in a gas discharge. The Runge-Kutta method of solving differential equations will be used. (Roland Wright)

1902-63012 Agronomy. Research with Sudangrass. This research project involves testing new sudangrass hybrids for their possible use as a forage crop in Illinois. New hybrids are higher yielding and have lower prussic acid content. New hybrids are tested with present varieties with mean yields and analysis of variance calculated. The analysis of variance is used to determine significant differences among varieties and hybrids. Yield data will be collected for 3-4 cuttings. Data will be collected on yield (in tons/acre) and prussic acid content. (Burger)

1903-63013 Civil Engineering. Data Analysis-Density Measurement by Radioisotopes. In apparatus which measures density by gamma ray transmission it is convenient to express the calibration curve in terms of an apparent cross section per electron for the apparatus. This is calculated knowing the count rates obtained on specimens of known density and composition. The computer program will calculate the apparent cross section per electron for a large number of calibration specimens in order to study the variation of this parameter with specimen size and density. (Preiss)

1904-63020 T Botany. Similarities of Prairie Communities. The calculation of similarity coefficients is useful in determining if the natural vegetation of an area can be grouped into basic units called communities. Stands within an area are sampled, and then compared on the basis of frequencies, densities, and importance values of the species they share. The computer facilitates the large number of calculations necessary to compare each stand with the remaining stands. The formula for calculation of the similarity coefficients, K, is: $K = \frac{2w}{a+b} \times 100$, where w is the sum of the lowest values of density, etc., of species shared by two stands, and a and b are the sums of all densities, etc., in the first and second stands respectively. (Redmann)

1905-63021 T Electrical Engineering. Optimization of Signal-to-Noise Ratio for a Horn-fed Paraboloid. The system being studied is a microwave antenna. The antenna consists of a paraboloid reflector with a conical horn feed. The problem is to determine the aperture distribution of the horn if the field at the aperture is linearly polarized and an optimum signal-to-noise ratio for the horn feed is desired. All numbers in this problem are real. The computer will be used to do the following: 1. Generate Bessel functions of the first kind. 2. Calculate a number of definite integrals. 3. Invert a matrix. 4. Solve a simple eigenvalue problem. (Ted Morange)

1906-63022 Material Research Laboratory. Magnetic Resonance Data Analysis. This research problem is concerned with the electronic properties of metals, and in particular the electron charge distribution around various defects in metals. In one specific case, these defects are impurity (solute) atoms dissolved substitutionally on the solvent lattice. The charge density around these atoms, considered as point scatterers, varies with the distance from them in an oscillatory, radially symmetric fashion. The phenomenon can often be described using a phase shift analysis to describe the scattering process and outgoing waves. The computer will be used to augment the analysis procedure. The results of the computer analysis will be compared with experimental data obtained by the nuclear magnetic resonance method. This data is interpreted in terms of electric field gradients at nuclear sites within the metal; the latter are computed using the above phase shifts. (T. J. Rowland)

1907-63024 Electrical Engineering. Electron Trajectory Calculations. In analyzing the operation of the "Dynamic Crossed Field Photomultiplier", information is needed on the motion of electrons in a crossed electric and magnetic field. The equation of motion for an electron can be obtained from the Lorentz force equation by ordinary techniques of differential equations. The computer will then be used to find the solutions to this equation of motion for a wide variety of parameters in order to find the best operating condition for the "Dynamic Crossed Field Photomultiplier". (O. L. Gaddy)

1908-63025 Microbiology. Hypersensitivity in Mice.

An enumeration of tissue mast cells in various stages of degranulation was made in the skin sections of experimental, hypersensitive mice and control, non-sensitive mice. The specimens were obtained at various time intervals after sensitization and at various time intervals after challenge with the specific antigen. The computer will be used first to determine which of five possible methods is the most significant method for classifying the stages of degranulation. Second, the computer will be used to detect variations from the normal distribution of these stages in groups of animals determined by time and by whether they are experimental or control mice. Third, the computer will be used to correlate variations in the distribution of stages of degranulation, and presumptive indication of hypersensitivity with three other methods for determining hypersensitivity. (Joan McCamish)

1909-63026 Nuclear Engineering. Neutron Pulse Propagation and Thermalization. This research is concerned with neutron thermalization in crystalline materials such as graphite or beryllium and also multiplying media such as a heavy water-natural uranium lattice. Calculations are mainly concerned with the analysis of neutron pulse propagation through the medium - the measured propagation velocity and pulse shape changes give information about neutron thermalization parameters. The analysis requires a double Fourier analysis in both time and space dimensions. The transformed data is then compared directly with theory in the transformed domain. Considerable numerical work is involved, but fairly standard techniques are used. The results are generally presented graphically using a plotting subroutine. (G. H. Miley)

1910-63028 Physics. Surface Impedances. The research problem is to calculate the fraction of incident electromagnetic energy which will be absorbed by the surface of a superconducting metal. This fraction, called the surface impedance, depends on the electron density, mean free path, and energy gap in the superconductor. The computer will calculate

the normal state conductivity, which is a function of frequency and wave numbers, from a simple equation. It will then integrate to find the superconducting state conductivity, both the real and the imaginary part. By integrating a well-known function of the superconducting conductivity over wave numbers, the surface impedance at selected frequencies will then be calculated. The results will be compared with experimental data.

(D. M. Ginsberg)

1911-63029 Nuclear Engineering. Motion of Electron in Crossed Fields. The problem of studying the motion of an electron in crossed electric and magnetic field will be studied by the student as a special problems course. This is done so as to give the student training in the operation of the computer to solve nuclear engineering problems.. (M. E. Wyman)

1912-63033 T Civil Engineering. Effects of Organics on Ion Exchange of Soils. The transport of radioactive ions in the environment is in part determined by the ion-exchange properties of the soil. The presence of natural organics on the surface and in ground water may effect the ion-exchange reaction between the radioactive ions and the soil. This research will investigate the effect of natural organics on the ion-exchange reaction between radioactive ions and the soil. The solutions, such as the reaction equilibrium constants and parameters involved in the system, will be calculated by use of the computer. (B. T. Kown)

1913-63030 T Electrical Engineering. Determination of Number Density and Temperature of High Density Plasma using High Intensity Laser Interaction. The purpose of this project is to determine the number density and temperature of a high density plasma using high intensity laser interaction. Computational problems are encountered when correlating experimental results of the scattering study, particularly the responses produced by the random distribution of the constituents. The computer will be utilized to evaluate and reduce data and to integrate standard distribution functions. Standard library routines should be sufficient. Parameters involved will include: 1. number density of electrons, 2. temperature, 3. resulting doppler shift, and 4. geometric considerations. (Henry Merkelo)

1914-63031 Chemistry and Chemical Engineering. Ultracentrifugation. Several hydroxyterpene dehydrogenases have been isolated and purified from P. putida grown on camphor. These enzymes appear to have approximately the same molecular weight, as determined by gel filtration. A more accurate measure of molecular weight and estimate of physical homogeneity can be obtained upon ultracentrifugation of these proteins.

The Biochemistry Division's ultracentrifuge has recently been equipped with a Raleigh interference optical system. The results of an ultracentrifuge run are recorded as fringes on a photographic plate. These fringe positions are read with a microcomparator. By calculating the change in fringes as a function of distance from the axis of revolution, it is possible to determine the molecular weight of solute molecules and obtain a measure of their homogeneity.

The computer will be used to perform these calculations, do a least squares fit of the data, and give a CalComp plot of the experimental results. (R. L. Prairie)

1915-63032 T Psychology. Desensitization and Relaxation Project. This study has compared four psychotherapeutic conditions, using several measures of "improvement." Included are measures tapping three factors found in previous studies of personality (anxiety, introversion-extroversion, process-reactive). It is of interest to compare the new measures developed for this study with these "marker" variables. Therefore, an intercorrelation and factor analysis of all the measures is proposed. The correlation matrix is to be subjected to a principal components factor analysis, and factors with eigenvalues greater than unity are to be rotated to a varimax criterion. SSUPAC will be used. (Ray M. Zeisset)

1916-63034 T Electrical Engineering. Magnetic and Electrical Circuit Analysis. The computer is to be used to solve for the dynamic parameters of a non-linear magnetic device as a variety of static parameters and driving functions are used and to optimize two or more of these parameters within currently attainable tolerances. (R. Wallingford)

1917-63035 State Water Survey. Radar Reflectivity and Rain Rate Determination. Data from time-lapse movies of a maser-equipped MPS-34 radar will be analyzed for comparison with hourly airways weather data. Calculations of radar reflectivity, rain rate, and accumulated rainfall will be made from the radar data using the computer. The correlation between these parameters and selected weather features will be determined. (R. E. Rinehart)

1918-63036 Agricultural Economics. Church Involvement in Community. This project is a study of the involvement of pastors and officers of nine denominations in Illinois in the organizations of their communities. Actual involvement in organizations as well as what the respondent feels to be ideal organizational involvement is assessed. Opinions on contemporary issues are also assessed. Frequencies and percentages will be calculated for tabulated responses and mean scores of categorized responses will be calculated to ascertain the degree of involvement. Data was obtained from questionnaires distributed throughout the state with the aid of the Illinois Council of Churches. The computer results will be used in the preparation of a report for the State of Society Conference. (D. E. Lindstrom)

1919-63037 State Water Survey. Drop-Size Data Printout. Drop-size data have been obtained in natural rainfall in several geographical locations. It is desired that these data, now on cards, be printed out in a suitable format that can be used in printed reports. Some minor calculations will be made; however, the program will use primarily input and output routines. (A. L. Sims)

1920-63043 T Zoology. Bird Diversity and Habitat Selection. An analysis will be made of bird species diversity in a desert mountain range. The study encompassed eight plant communities ranging from desert to that of subalpine. Rank correlations will be computed between vegetation height volumes and specific bird-use patterns. A species diversity index will be calculated and applied in the analysis of the bird communities. (Russell Balda)

1921-63044 Economics. Study of Monte Carlo Estimates by Quadratic Programming. Currently very little is known about the properties of least squares estimations in econometric models where the estimations are subject to inequality constraints. This project will attempt to gain some insight into this problem by making estimates using a quadratic programming technique. (T. A. Yancey)

1922-63045 Mechanical Engineering. General Heat Transfer Problems. Equations of the form

$$\frac{\partial T}{\partial t} = \frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + S$$

where T = a potential, x, y are space coordinates, t = time, and S = a source function are treated in the study of heat transfer. Many minor cases will be studied using finite differences, relaxation, and random walk techniques. (L. D. Savage)

1923-63046 Physics. Analysis of SMP Data. This problem specification replaces 59030. (Mortara)

1924-63047 Physics. Analysis of SMP Data. This problem specification replaces 59030. (Mortara)

1925-63048 Psychology. Water and Alcohol Stress in Hypophysectomized Rats. The research problem is an attempt to assess the role of ADH in the regulation of water balance in hypophysectomized and normal rats under stress produced by water deprivation, and intragastric loads of water and alcohol. The computer will be used to analyze the data. SSUPAC routines - Correlations, ANOVA, and transformations - will be used. (O'Kelly)

1926-63049 Aeronautical and Astronautical Engineering. Reactive Gas Mach Stems. While the nature of unreactive gas Mach stems is reasonably well understood, the structure of reactive Mach stems that occur in propagating detonations have not been investigated in detail. In this program, we are starting such a quantitative experimental investigation. The computing machine will be used for data reduction and for Mach stem structure calculations using different models so that we may compare our experimental results to theory. (R. A. Strehlow)

1927-63051 T City Planning. Eisenhower Expressway Impact on Adjacent Land Values. The problem is to determine the impact of Chicago's Eisenhower expressway-rapid transit facility upon adjacent land values. Percent change in land value will be correlated with each city block's distance to (1) the nearest inbound expressway ramp, (2) the nearest outbound expressway ramp, and (3) the nearest rapid transit stop. Percent change in land value along the expressway route will be compared with change in control areas and in the entire city. If correlations appear significant, regression analyses will be conducted to construct a mathematical simulation model of the situation. (Paul Holley)

1928-63052 T Health Education. Health Interest Inventory. The purpose of the present study is to determine the health interests of college students as determined in selected college and university classes and to ascertain differences, if any, existing among certain identifiable student groups. Since interests are a vital factor in learning and since students are the best source of their own interests, it would seem the health educator should utilize this source in the development of a college health education curriculum. Further, since college students today come from a wide variety of social, cultural, economic and educational backgrounds, it would seem the health educator should periodically determine the interests of the college student in order to maintain a highly personalized approach to the instruction of health education on the college level. A number of studies

were previously done in the area of students' health interests. From the examination of these studies, it was decided that the inventory method is the best suited to determine the health interests of a large sample of college freshman. The inventory was constructed and a four point scale was selected.

The statistical methods to be employed are mainly those of the summation of the scores of the entire sample and of the individual groups according to sex, population of home community, location of home community geographically, the type of college attending, and the high school health education background of the subjects. From this, rank orders of individual health items and of health topic areas will be ascertained, along with percentage of interests. Finally, reliability of the instrument will be determined in scoring two groups (test-retest method). (Webster)

1929-63053 Zoology. Taxonomy of Gophers. The overall project is an analysis of variation of approximately 250 individuals of three subspecies of pocket gophers, Thomomys talpoides pygmaeus, Thomomys talpoides bridgeri, Thomomys talpoides ocus from numerous localities in Utah, Idaho, and Wyoming. The measurements, in millimeters and fractions thereof, were obtained directly from preserved specimens and from data recorded on their specimen labels. The specimens are in the United States National Museums and several university museums. These data are to be utilized in an analysis whereby means are compared from place to place, their differences regarded as significant if greater than the two standard deviations obtained for the two series being compared. Such significant differences permit classification of the kinds of gophers in the study area. Resemblances indicate evolutionary relationship. Correlation coefficients are used to determine redundancy in characters. (Chas A. Long)

1930-63054 Physiology. Quinine Preference. "Finickiness" represented in food intake is defined as a decrease from a baseline record of food intake for twenty-four hours. It has been noted in self selection experiments that infant rats do not adjust their diet to take in an

adequate amount of nutritive food, while adult rats can perform this task quite easily. In looking at the problem, animals are presented with quinine in varying amounts mixed into a stock diet. Three groups are initially used. Normal adult ad libitum, normal infant ad libitum, and static Hyperphogics ad libitum are used and compared as to finickiness. The comparison is then made between groups on the percentage drop from baseline of food intake per one hundred gram body weight. SSUPAC routines for transformation and t test will be used. (J. W. Greenfield)

1931-63055 T Electrical Engineering. Antenna Impedance in a Warm Plasma. A biconical antenna of length l , encased in a dielectric sphere of radius l and immersed in a warm plasma, is treated as a rigorous boundary value problem. Under certain simplifying assumptions the fields in the plasma may be represented as a superposition of electromagnetic and plasma (acoustic) modes, each of which satisfies a suitable wave equation. Upon matching the fields at the surface of the dielectric sphere a doubly infinite set of equations results which are exactly soluble for a thin antenna. For a thick antenna a variational expression has been derived for the terminal admittance. The terminal admittance in each case is in the form of an infinite series. The coefficients are terms containing Legendre Polynomials of integral order k , and Hankel functions of the second kind of order $k+1/2$. These series will be summed by means of a suitable convergence procedure. For a biconical antenna completely immersed in a warm plasma it appears that an exact solution is not possible at present. This will be treated by the induced emf method. The solution will be in the form of an integral, for which a numerical integration may be necessary. (James W. Carlin)

1932-63056 Microbiology. Monte Carlo Simulation of Gene Redundancy. The program is to simulate the passing and synapse of certain redundant gene patterns in a population of flies, using a pseudo-random number generator to pair individuals within successive generations and also to give values for comparison with a set of threshold probabilities. The initial results will be a set of frequency distributions, giving the gene redundancy frequencies for succeeding generations. (K. C. Atwood)

1933-63057 T Geology. Calculation of Statistical Parameters of Sedimentary Rocks from Thin Section Data. The object of this research problem is to obtain information about the size distribution of the grains making up a sedimentary rock by examining the size distribution of the grains in a thin section of the rock. The size data obtained from a thin section are corrected for the bias introduced by sectioning and then various statistical parameters are calculated. These include the first, second, third, and fourth moments, the first, second, and third quartiles, an estimate of the largest grain present, and Trask's sorting coefficient. The size distributions will be compared with a normal distribution and with a log normal distribution through the use of chi-square tests. (James E. Lacey)

1934-63058 Civil Engineering. Operation Cushioned Cars. This problem involves the simulation of a long train in which the cars are equipped with cushioning devices. The purpose of the analysis is to find the causes of excessive forces in the drawbars, which often result in broken couplers. Presently the train model is represented by a locomotive combination and freight cars. The couplers have free slack between the pulling faces. Under impact energy is absorbed through use of a coefficient of restitution. Later models will represent the couplers as a spring and dashpot system with free slack.

Simulation basically involves linearizing the propulsive and resistance force acting on a car or set of cars so that its equation of motion may be found from solving a linear differential equation. Knowing the motion of all cars the location of successive collisions between cars may be determined. Once a collision takes place the velocities of the cars involved change and a recycling of the procedure is necessary until a limiting velocity is reached or the magnitude of the collisions become negligible. (Gregory Martin)

1935-63061 Department of Computer Science. Superconducting Quadrupole Design. The current distribution in a cylindrical quadrupole lens made up of superconducting strips is given. The magnetic field at any point inside is to be computed. (J. N. Snyder)

1936-63067 Geography. Computer Graphics Applied to Epidemiology. The aim of this study is to explore the utility of computer graphics in plotting rates of disease morbidity and mortality and other data from census agencies or field survey. Two study areas will be used. Data for the city of Chicago will be plotted by census tracts and data for four counties in southern Illinois by point location. The computer offers a means to produce maps of disease indices in relation to other relevant data in comparatively short time - a feature which should greatly improve the utility of such maps for public health studies. (Armstrong)

1937-63068 Plant Pathology. Field Corn Disease Research. This research project involves testing of stalk rot and leaf blight in hybrids and inbreds. It also is concerned with developing resistant lines, inbred and hybrids to the above mentioned diseases. In this connection lines, inbreds and hybrids will be tested in replicated trials, and analyses of variance will be used to test for differences. Plants will be rated as to their disease resistance. (Hooker)

1938-63069 Institute for Research on Exceptional Children. Illinois Test of Psycholinguistic Abilities Discriminal and Correlational Analysis. A number of psycholinguistic skills have been assessed for unselected and dyslexic seven year old children, for whom intelligence quotients and reading levels are available. Using the SSUPAC multiple correlation program, the respective weightings of each psycholinguistic skill will be found in order to predict most accurately I.Q. and reading age. Using multiple discriminant analysis, the appropriate weighting of each psycholinguistic skill for discrimination between dyslexics and controls will also be estimated. (John McLeod)

1939-63070 T Theoretical and Applied Mechanics. Vibration of Thin Plates. It is desired to determine the natural frequencies of thin plates of circular, elliptic, square, rectangular, and triangular shape. Natural modes and frequencies will be plotted and tabulated. This will facilitate the design of plates and the synthesis of the dynamic behavior of various plates. The Ritz's energy method will be used. This method yields a set of linear homogeneous algebraic equations with eigenvalues λ . The λ 's are dimensionless numbers from which frequencies are found. For each value of λ , there is a corresponding column matrix $|X|$, from which the vibrational mode can be determined. (B. C. Sun)

1940-63071 T Economics. An Econometric Analysis of the Import Demand for Natural Rubber. The research problem is an estimation of parameters for: 1) a single equation model of the import demand for natural rubber in the U.S., 1953 - 65; 2) a simultaneous equation model of import demand for natural rubber during the same time period. Data is quarterly and seasonally adjusted. The problem falls under K-class estimation procedures. In the first model the parameters are estimated by ordinary least squares; in the second model two stage least squares is the method used. Since the demand functions in both models are in multiplicative form, a transformation into logarithms is necessary. The virtue of this approach is that the resulting parameters are also elasticities and useful for economic analysis. (Philip Swan)

1941-63072 Astronomy. Spectrophotometry of Eclipsing Binary Systems. Spectral types, absolute visual magnitudes, and equatorial rotational velocities will be determined for the component stars of selected early-type eclipsing binary systems. The state of synchronism between axial rotation and orbital revolution of the stars will be determined and interpreted in terms of tidal interaction and mass exchange in the system. The observational data consist of spectrograms with intensity calibrations, from which intensity tracings must be made. With the microphotometer and digitized paper tape output at the Observatory, transmission tracings

and intensity calibrations will be obtained. This material will be processed in the computer to give direct intensities, and plotted to reconstruct the complete intensity tracing of the spectrum. (Edward Olson)

1942-63073 T Theoretical and Applied Mechanics. Potential Accelerating Effects of Chemical Deicing Damage by Traffic and other Environmental Induced Stresses in Concrete Bridge Decks. The research problem is concerned with empirical analysis of concrete specimens under conditions and stresses similar to those of concrete bridge decks. A thin section analysis is made of portions of these specimens and the data obtained is used to compute properties of the specimen. The computer is used in the calculation of these properties. The computations are an application of Simpson's rule for finding irregular areas. No methods other than standard library routines are involved. (Joseph P. Callahan)

1943-63074 Theoretical and Applied Mechanics. Stresses in Railway Car Wheels. Two problems are currently under study. The main problem is the prediction of thermal stresses at elevated temperatures in specimens made from railway car wheel materials. An iterative approach will be used to approximate elastic and plastic strains for different given axisymmetric time-temperature relations.

A second problem which will periodically be explored will require the computer to analyse large quantities of Rosette strain gage data for determining the magnitudes and directions of principal strains in statically loaded railway car wheels. (H. R. Wetenkamp)

1944-63075 T Sociology. Public Definitions of Deviant Behavior. This study is a cross-cultural analysis of public attitudes towards deviant behavior. The data, to be obtained in Austria and in the United States, involve a composition of the types of behavior considered deviant and an analysis of social distance towards and amount of personal contact with specified types of deviant behavior. A further phase of the study will

explore differences in definitions of certain mores embodied in the respective legal codes and the broad socio-cultural features to which the major differences may be attributable. (Hazel Chambers)

1945-63077 Agricultural Engineering. Evaluation of Channel Routing Methods. The precision and efficiency of two routing methods for predicting stage and discharge along an open channel with unsteady, nonuniform flow are to be evaluated through a comparison of calculated and observed hydrographs. One method requires the solution of the one-dimensional continuity and hydraulic equations for open channel flow:

$$\frac{\partial y}{\partial t} + \frac{\partial q}{\partial y} = I(x, t)$$

in which y is depth of flow, q is discharge, and I is lateral inflow (all three variables time and space dependent); and

$$\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + g \frac{\partial y}{\partial x} = g (S_o - S_e) - \frac{uI}{y}$$

in which u is average velocity of flow at a point, g is the gravitational constant, S_o is bed slope, and S_e the energy gradient. Solutions to these nonlinear partial differential equations will be obtained through both implicit and explicit finite difference methods. One objective is to determine the relative efficiency in terms of required computational time for the implicit and explicit solution procedures.

The second routing method requires the solution of a sequence of equations of the form

$$Q = (1 - C) q_2 + C q_1$$

in which Q is the outflow from a given reach at time $t + \Delta t$, q_2 is outflow at time t , and q_1 is inflow at time t . C is an empirical routing coefficient.

The computer will also be used to process data for the observed hydrographs to be used in the comparison. (R. N. Fenzl)

1946-63080 T Theoretical and Applied Mechanics. Behavior of Thin Shells of Revolution using Conformal Mapping. This program is intended to explore the possibilities of applying conformal mapping procedures to the analysis of the deformational behavior of shells of revolution of a rather general geometric configuration. Initially, internal pressure loading will be assumed. The transformation which will map the unit circle onto the meridian of the shell is to be determined approximately by reducing a Fredholm integral equation of the second kind to a set of linear equations. The solution of this set of linear equations results in a one to one correspondence between a set of points in the real plane and a set of points in the image plane, from which the transformation is determined. (T. Moriarty)

9.2 Instructional Problem Specifications

During the first quarter of 1966, 23 instructional problem specifications were submitted to the Department for computation. The following brief descriptions of these problems have been prepared for inclusion in this report by those submitting them.

I272-61001 Mechanical Engineering 406. Heat Conduction in Solids. This is a special problem assigned to students in ME406. It is concerned with the transient behavior of thermal contact resistance. An analytical solution in the form of an infinite series has been obtained. We are attempting to obtain numerical results for the several values of the relevant parameters involved. (B. T. Chao)

I279-61044 Aeronautical and Astronautical Engineering 216. Gas Dynamics. The machine will be used to generate answers to relatively complex gas dynamic problems so that the student may check the answers with hand calculations. The programs will also be used to prepare tabulations of gas dynamic properties useful for the student in problem solving. (R. A. Strehlow)

I283-62007 Aeronautical and Astronautical Engineering 262. Aerodynamic Ejectors in Propulsion Laboratory. The senior aeronautical students study the behavior of aerodynamic ejectors, which requires a flow field analysis by the method of characteristics. Depending on the input conditions, a long iteration procedure is often required. To optimize a staged ejector system one has to solve N partial differential equations simultaneously, where N is the number of stages considered. A closed form analytical solution is only possible for special simple cases. (J. L. Loth)

I289-62013 Aeronautical and Astronautical Engineering 296. Reaction Control Analysis. This problem is an analysis of the relationship between some of the parameters governing the operation of a reaction control system. The computer will be used to obtain such information as the time variation of the supply pressure, thrust and total impulse. (L. Sentman)

I296-62020 Aeronautical and Astronautical Engineering 264. Interpretation of Experimental Results. Experimental data for flight vehicle structural components will be analyzed and evaluated. Empirical relations will be generated using least square techniques. (H. H. Hilton)

I297-62021 Aeronautical and Astronautical Engineering 429. Viscoelastic Analysis. Computer programs will be developed for the solution of integral-differential equations used in viscoelastic theory with temperature dependent material properties. (H. H. Hilton)

I298-62022 Economics 272. Econometric Project. Each student in the class will be required to formulate a very simple econometric model of his choosing. Each student will be encouraged to relate his model to work in some related class. They will gather the appropriate data and estimate the models using appropriate techniques. Primary emphasis will be placed on interpreting the results and comparison of the outcome with published work on the same topic. SSUPAC provides all necessary estimation techniques, although students may choose to use other programs. (R. Resek)

I322-62056 Finance 455. Financial Ratio Analysis. The computer time is to be used in running the Final Analysis Program (FRAPI) developed specifically for the graduate/undergraduate courses in financial analysis. The Program is designed to save computational time for the student. (Paul J. Swanson, Jr.)

I329-62072 Industrial Engineering 286. Linear Programming. IE 286 is a basic course in operations research, and linear programming is a part of the course. The students, after learning the manual method of solving an L. P. problem, will use the 7094 to find answers for other problems assigned. (Lloyd Lehn)

I330-62073 Department of Computer Science 393. EE 393 Problems. The analysis and synthesis of a variety of computer circuits will be calculated. The principal library subroutine to be used is the simultaneous linear equations routine. (S. R. Ray)

I331-62076 Civil Engineering 497. Analytical and Numerical Aerotriangulation. The problems involved in this course deal with the extension of control by setting up mathematical models to represent the orientation of stereo aerial photographs. This process involves the solution of non-linear condition equations by the method of least squares. (H. M. Karara)

I336-62081 Aeronautical and Astronautical Engineering 241. Aerospace Vehicle Design. The computer will be used to aid in the design of an aerospace vehicle in the following ways:

- 1) Repetitious calculations which are required for comparison of various designs of vehicle and propulsion system components;
- 2) Long or difficult calculations such as rocket nozzle contour or propellant tank heat balance;
- 3) Mission analysis studies;
- 4) System optimization by formulating performance programs to represent an entire system. (V. P. Roan)

I339-62085 Electrical Engineering 389. Receiver Design Problems. The problems which are to be put on the computer are part of a large problem of designing a radio receiver. One of the problems consists of gain calculations over a specified band of frequencies. The same operation is repeated many times. The other problem consists of calculating the points for a tracking curve in which certain specified values are given and by means of simple algebraic manipulations the actual intermediate frequency is calculated. This problem is put on the computer for several reasons as follows:

- 1) the same operation is repeated many times to cover the entire band of frequencies;
- 2) accuracy to at least 5 significant figures is required;
- 3) students are given a chance to apply some of the principles learned in Math 195. (P. F. Schwarzlose)

I340-62088 City Planning 338. Neighborhood Survey. A representative sample of Champaign residents are being interviewed to ascertain their family characteristics and the ways in which they view their community, their participation in community activities, and similar other factors. Use of the computer will permit analysis and correlation of many variables in a short time period. (B. L. Oxman)

I348-62110 Mechanical Engineering 306. Industrial Heat Transfer.

Students will be using the computer for numerical solutions of: (i) the Laplace Equation, (ii) Poisson's Equation, and (iii) the diffusion equation. The Gauss-Seidel iteration technique will be employed for cases (i) and (ii). Canned routines are not acceptable due to the large number of unknowns which are sometimes present. Various explicit and implicit schemes will be employed in the solution of the transient problems governed by the diffusion equation. (A. M. Clausing)

I354-63018 Civil Engineering 264. Behavior of Reinforced Concrete Members. The following two programs are available in the Department of Civil Engineering for the study of behavior of reinforced concrete members: (a) A general program for calculation of load-deflection relationship for the entire range of load. The beam is simply-supported, and deflections are at midspan. The program applies to any stress-strain diagram for concrete and steel, any geometry of section, and any type of static, short-time load. (b) A general program for obtaining the interaction diagram for reinforced concrete columns subjected to bending. In this case the stress-strain diagram for concrete is a combination of parabola and straight line, and the stress-strain diagram for steel is elasto-plastic. The programs will be made available to the students after they have mastered the theory and are able to solve the problem manually. The programs will be used to study the influence of all the variables on the shapes of the load deflection diagrams for beams, and the interaction diagram for columns subjected to bending. (N. Khachaturian)

I355-63019 Civil Engineering 368. Behavior of Prestressed Concrete Beams. A general program is available for calculation of the load-deflection diagram of a prestressed concrete beam. The beam is simply-supported, and the deflections are at midspan. The program applies to any stress-strain diagram for concrete, prestressed steel, and non-prestressed steel. The beam section may have any geometry, and the load may be any static, short-time load. The program will be made available

to the students after they have mastered the theory and are able to solve the problem manually. The program will be used to study the influence of all the variables on the shape of the load-deflection diagram.

(N. Khachaturian)

I356-63023 . Geography 495. Economic Areal Variation. This is a class problem designed primarily to introduce students to data preparation and use of computer facilities. Multiple correlation and related programs will be used to analyze a simple problem of areal variation between states of a number of economic factors. (Armstrong)

I357-63027 . . . Electrical Engineering 251. Gaussian Distribution. This class problem involves the calculation of various characteristics of a Gaussian Distribution, including mean, median, standard deviations, and variance. (J. O. Kopplin)

I361-63041 . Astronomy 401. Model Stellar Atmospheres. The problem is the construction of a model stellar atmosphere, i.e., the determination of temperature, pressure etc. as a function of optical depth in the atmosphere of a star. The procedure involves a number of numerical integrations. (James Kaler)

I364-63059 . Nuclear Engineering 495. Nuclear Power Reactor Economy Study. The student will set up the relationships and examine the effects of varying the parameters involved in a nuclear power economy study (e.g. fuel cycle, plant factor, Federal Income Tax, etc.). The student will also optimize various of the specific parameters within the nuclear system itself. Besides learning an accurate and consistent approach to nuclear economy studies and optimization, the student will become familiar with the use and merits of the use of modern high-speed computing equipment, languages, and techniques in solving this type of repetitious and otherwise time consuming problem. (D. F. Hang)

I365-63060 Nuclear Engineering 495. Laser Calculations. The computer will be used to calculate the densities of excited states in a Helium-Neon Laser System. The mathematical procedure will be to solve coupled, first order differential equations. It is hoped to utilize a program written for this purpose at General Motors.

The study of this problem has a twofold purpose. It provides a means of studying excited states in atoms as well as serving as an effective means of developing computer techniques which are being learned in Math 195. (George H. Miley)

I368-63064 Astronomy 404. Stellar Model Calculations. Various aspects of the calculation of the physical structure of a stellar interior will be investigated, and hopefully several complete models calculated. The mathematical problem can be treated as the simultaneous integration of four first-order differential equations expressing the conditions of hydrostatic equilibrium, mass conservation, energy conservation, and the relation between energy flux and temperature gradient at every point in the stellar interior. The equation of state, relations expressing the dependence of radiative opacity and thermonuclear energy generation on physical variables, and four boundary conditions permit a unique solution. In the process, a pair of eigenvalues representing stellar luminosity and radius must be found. An alternative technique, in which the differential equations are transformed to difference equations and solved by relaxation methods, may be attempted. (Edward Olson)

9.3 Blanket Class Problem Specifications

During the first quarter of 1966, 79 problem specifications were submitted to cover all assigned problems in the following courses:

J273-61017	Physics 341.
J274-61036	Mechanical Engineering 215.
J275-61037	Mechanical Engineering 214.
J276-61038	Mechanical Engineering 264.
J277-61035	Mechanical Engineering 263.
J278-61043	Chemistry and Chemical Engineering 381.
J280-61045	Theoretical and Applied Mechanics 392.
J281-62005	Nuclear Engineering 441.
J282-62006	Agronomy 441.
J284-62008	Aeronautical and Astronautical Engineering 391.
J285-62009	Electrical Engineering 331.
J286-62010	Electrical Engineering 451.
J287-62011	Aeronautical and Astronautical Engineering 232.
J288-62012	Chemistry and Chemical Engineering 490.

J290-62014 Graduate School of Business Administration 573.

J291-62015 Graduate School of Business Administration 574.

J292-62016 Industrial Administration 373.

J293-62017 Industrial Administration 373.

J294-62018 Department of Computer Science 395.

J295-62019 Mechanical Engineering 410.

J299-62026 Electrical Engineering 322.

J300-62027 Electrical Engineering 498.

J301-62028 Electrical Engineering 296.

J302-62029 Nuclear Engineering 458.

J303-62030 Mechanical Engineering 302.

J304-62031 Mechanical Engineering 271.

J305-62032 Mechanical Engineering 260.

J306-62034 Department of Computer Science 295.

J307-62035 Theoretical and Applied Mechanics 315.

J308-62036 Theoretical and Applied Mechanics 314.

J309-62037 Advertising 482.

J310-62038 Electrical Engineering 296.

J311-62039 Mechanical Engineering 207.

J312-62040 Psychology 493.

J313-62041 Mechanical Engineering 271.

J314-62042 Mathematics 149.

J315-62043 Mathematics 195.

J316-62044 Department of Computer Science 996.

J317-62047 General Engineering 288.

J318-62048 Theoretical and Applied Mechanics 451.

J319-62049 Theoretical and Applied Mechanics 467.

J320-62053 Chemistry and Chemical Engineering 398.

J321-62055 Electrical Engineering 323.

J323-62066 Graduate School of Business Administration 552.

J324-62067 Civil Engineering 391.

J325-62068 Civil Engineering 391.

J326-62069 Industrial Engineering 350.

J327-62070 Theoretical and Applied Mechanics 412.

J328-62071 Industrial Engineering 386.

J332-62077 Sociology 495.

J333-62078 Theoretical and Applied Mechanics 462.

J334-62079 General Engineering 242.

J335-62080 General Engineering 393.

J337-62082 Agricultural Engineering 356.

J338-62083 Agricultural Engineering 156.

J341-62089 Anthropology 490.

J342-62090 Mechanical Engineering 221.

J343-62091 Aeronautical and Astronautical Engineering 427.

J344-62092 Theoretical and Applied Mechanics 432.

J345-62102 Mechanical Engineering 256.

J346-62103 Mechanical Engineering 332.

J347-62104 Mechanical Engineering 257.

J349-63003 Nuclear Engineering 455.

J350-63014 Physics 303.

J351-63015 Psychology 306.

J352-63016	Recreation 490.
J353-63017	Mechanical Engineering 995.
J358-63038	Agricultural Economics 230.
J359-63039	Psychology 390.
J360-63040	Sociology 386.
J362-63042	Industrial Engineering 237.
J363-63050	Mechanical Engineering 342.
J366-63062	Aeronautical and Astronautical Engineering 216.
J367-63063	Aeronautical and Astronautical Engineering 261.
J369-63065	Electrical Engineering 272.
J370-63066	Electrical Engineering 250.
J371-63076	Electrical Engineering 393.
J372-63078	Economics 371.
J373-63079	Theoretical and Applied Mechanics 426.

10. GENERAL LABORATORY INFORMATION

10.1 Personnel

The number of people associated with the Laboratory in various capacities is given in the following table:

	<u>Full-time</u>	<u>Part-time</u>	<u>Full-time Equivalent</u>
Faculty	15	1	15.5
Visiting Faculty	4	3	5.5
Graduate Research Assistants	5	62	35.75
Graduate Teaching Assistants	0	1	.12
Professional Personnel	9	1	9.75
Administrative and Clerical	17	1	17.5
Other Nonacademic Personnel	<u>67</u>	<u>99</u>	<u>105.75</u>
TOTAL	117	169	189.87

The Computer Advisory Committee consists of Professor J. R. Pasta, Head of the Department; Professor J. N. Snyder, Associate Head of the Department; Professors L. D. Fosdick, H. G. Friedman, C. W. Gear, D. B. Gillies, N. T. Hamilton, D. J. Kuck, B. H. McCormick, S. Muroga, T. A. Murrell, J. Nievergelt, W. J. Poppelbaum, S. R. Ray, J. E. Robertson and D. E. Slotnick.

10.2 Bibliography

During the quarter, the following publications were issued by the Laboratory.

File Numbers

- [1] Atkins, Daniel E., "ILLIAC III Arithmetic Instructions: Preliminary Specifications," File No. 691, March 26, 1966.
- [2] Beatty, J. C. and S. Muroga, "File Memory Addressing," File No. 686, January 15, 1966.
- [3] Carter, C. E., and R. E. Willard, "Procurement Specifications for a Computer Controlled Display System for ILLIAC II," File No. 550-68, March 28, 1966.
- [4] Divilbiss, J. L., B. H. McCormick and K. C. Smith, "Specifications for High Current Silicon Switching Transistors," File No. 550-64, February 1, 1966.
- [5] Divilbiss, J. L., and B. H. McCormick, "Specifications for Teletypewriter Consoles for Use With the ILLIAC III Communication Net," File No. 550-65, February 7, 1966.
- [6] Hassler, E. B., "Description and Analysis of the IBM 2741," File No. 687, January 31, 1966.
- [7] Kingery, Thomas, and David Foster, "ILLIAC III Component Locating System," File No. 690, January 11, 1966.
- [8] Kubitz, W. J., and D. C. Rollenhagen, "Specifications for Multifunction Storage Unit Type I," File No. 550-66, February 22, 1966.
- [9] Kubitz, W. J., and D. C. Rollenhagen, "Specifications for Closed Circuit TV Camera System," File No. 550-67, March 11, 1966.
- [10] McCormick, B. H., "ILLIAC III Communication Net: General Introduction," File No. 688, February 7, 1966.
- [11] Nievergelt, Jurg, "What is Numerical Analysis? An Introduction to Some Basic Concepts," File No. 689, February 17, 1966.

- [12] Serio, F. P., and E. Pelg, "Procurement Specifications for Printed Wiring Assemblies," File No. 550-69, March 24, 1966.
- [13] Serio, F. P., and E. Pelg, "Procurement and Design Specifications for Printed Wiring Boards," File No. 550-63, January 11, 1966.

Report Numbers

- [14] Bayer, Rudolph, "The Automorphism Group of a Strongly Connected Automaton and its Quotient Automata," Report No. 199, February 14, 1966.
- [15] Bayer, Rudolph, Jerome Cohen and Robert Penka, "The Alcor-Illinois-7090 Post-Mortem Dump Description and Imbedding Instructions," Report No. 198, February 10, 1966.
- [16] Davidson, Edward S., "New Method of Solution of the Travelling Salesman Problem," Report No. 201, March 23, 1966.
- [17] Paul, Manfred, "On the Automorphism Group of a Reduced Automaton," Report No. 200, February 22, 1966.

Theses

- [18] Haas, Melvin E., "An Interactive, Time Share System For a Small Computer," (M.S.), Report No. 196, February 1, 1966.
- [19] Wiegel, Roger E., "Methods of Binary Addition," (M.S.), Report No. 195, February 1, 1966.
- [20] Wilbur, John A., "A Language for Describing Digital Computers," (M.S.), Report No. 197, February 15, 1966.

10.3 Numerical Analysis

"The Algebraic Eigenvalue Problem - I," by Professor D. B. Gillies,
Department of Computer Science, University of Illinois, Urbana
Illinois, March 3, 1966.

"The Algebraic Eigenvalue Problem - II," by Professor D. B. Gillies,
Department of Computer Science, University of Illinois, Urbana
Illinois, March 10, 1966.

"The Algebraic Eigenvalue Problem - III," by Professor
L. D. Fosdick, Department of Computer Science, University of
Illinois, Urbana, Illinois, March 17, 1966.

"The Algebraic Eigenvalue Problem - IV," by Professor
L. D. Fosdick, Department of Computer Science, University of
Illinois, Urbana, Illinois, March 24, 1966.

"The Algebraic Eigenvalue Problem - V," by Professor Donald Secrest,
Department of Chemistry, University of Illinois, Urbana, Illinois,
March 31, 1966.

10.4 Colloquia

"On Lasers for Digital Devices," by Dr. W. F. Kosonocky, RCA Laboratories, David Sarnoff Research Center, Princeton, New Jersey, January 10, 1966.

"Chebyshev Polynomial Interpolation for Differential Equations," by Dr. John Mason, University of Maryland, College Park, Maryland, January 17, 1966.

"Computer Organization for Array Processing," by Mr. D. N. Senzig, of IBM, San Jose, California, January 24, 1966.

"The On-Line Station as a Research Tool," by Professor Harry D. Huskey, Department of Electrical Engineering, University of California, Berkeley, California, February 14, 1966.

"Reduction of Complex Relations Through Cylindrance," by Professor W. Ross Ashby, Department of Electrical Engineering and Biophysics, University of Illinois, Urbana, Illinois, February 14, 1966.

"Influence of Software Developments on Machine Design," by Professor Christopher Strachey, Massachusetts Institute of Technology, Cambridge, Massachusetts, February 28, 1966.

"The Numerical Solution of Two Point Boundary Value Problems," by Professor S. D. Conte, Head, Computer Sciences Department, Purdue University, Lafayette, Indiana, March 7, 1966.

"On the Numerical Solution of Nonlinear Volterra Integral Equations," by Professor James T. Day, Mathematics Research Center, University of Wisconsin, Madison, Wisconsin, March 14, 1966.

10.5 Drafting

During the quarter, a total of 484 drawings were processed by both drafting sections:

	<u>General and ILLIAC II</u>	<u>Pattern Recognition</u>
Large Drawings	15	6
Medium Drawings	6	102
Small Drawings	35	7
Layouts	0	62
File Numbers	0	0
Report Drawings	43	28
Changes	3	129
Miscellaneous	42	0
Semiconductor Coding	<u>0</u>	<u>6</u>
TOTAL	144	340

(K. Law, L. Prendergast)

10.6 Shops' Production

Job orders processed and completed during the first quarter of 1966, are as follows:

<u>Facility</u>	<u>AEC 1018</u>	<u>AEC 1469</u>	<u>Other</u>
Machine Shop	46	28	3
Electronics Shop	33	31	0
Etch Shop	20	10	4
Layout Shop	36	21	0

Wiring of 381 standard printed circuit boards during this period, accounted for 10,046 diodes and 3,199 transistors.