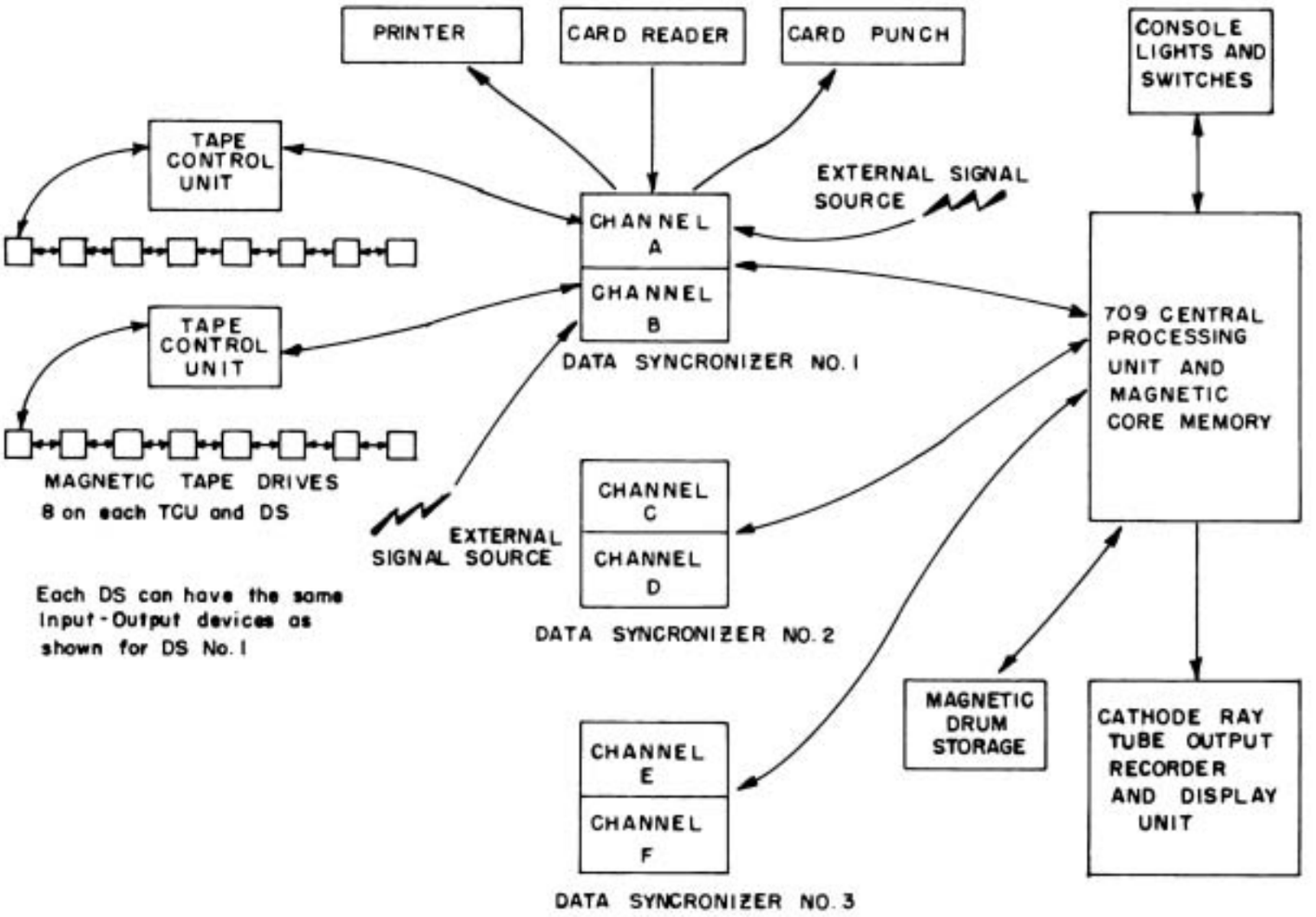
IBM 709

International Business Machines Type 709 Electronic Data Processing System (Advance Description)

MANUFACTURER

International Business Machines Corporation



SCHEMATIC SHOWING DATA FLOW FOR INPUT-OUTPUT FOR IBM 709 DATA PROCESSING SYSTEM

Picture by International Business Machines Corporation

APPLICATIONS

Engineering development, scientific research, production scheduling and control, logistics, procurement and supply and other areas.

NUMERICAL SYSTEM

Internal number system	Alphanumeric or bin coded dec
Binary digits per arithmetic word	35 plus sign
Binary digits per logical word	36
Binary digits per instruction word	36
Characters per word	6
Binary digits per character	6
Instructions decoded	189
Instructions used	189
Arithmetic system	Fixed and floating point. Logical operation
Instruction type	One address

ARITHMETIC UNIT

Fixed Point Operation

	Microsec
Add time (includ. stor. access)	24
Instructions require integral multiples of 12 microseconds, which is the machine cycle time.	
Mult time (includ. stor. access)	72 - 240
Div time (includ. stor. access)	240
Logical operation	24

Floating Point Operation

	Microsec
Add time (includ. stor. access)	84
Mult time (includ. stor. access)	204
Div time (includ. stor. access)	216

Arithmetic mode	Parallel
Timing	Synchronous for Central Processing Unit

Operation	Asynchronous for Input-Output Devices Magnetic tape reading, magnetic tape writing, card reading, card punching, and line printing are concurrent with internal processing.

STORAGE

Media	Words
Magnetic Core (IBM 737 and 738)	32,768 or 8,192, or 4,096
Magnetic Drum (IBM 733)	16,384 or 8,192

Characters may be letters of the alphabet, decimal numbers, or any of eleven punctuation marks or symbols. If only numerical information is being processed, storage takes place in the binary number system. Thus, 327,680 decimal digits can be stored in the magnetic core storage unit. Storage units of 4,096 or 8,192 core storage registers are available. Up to 8 magnetic tape drives may be associated with each Tape Control Unit. Two Tape Control Units may be associated with each Data Synchronizer. Up to 3 Data Synchronizers may be utilized.

INPUT

Media	Speed
Card Reader (IBM 711 Mod. 2)	250 cards/min
Magnetic Tape (IBM 729 Mod. 1)	90,000 bin dig/sec

Magnetic tape speed is 75 in/sec at 200 char/in (1,200 bin dig/lineal inch). This totals 15,000 char/sec when operating in the binary coded decimal mode and the equivalent of 25,000 decimal digits/sec when operating in the binary mode. Rewind rate is 400 inches/sec average for 2,400 ft tapes. Variable length records and files may be made.

OUTPUT

Card Punch (IBM 721)	100 cards/min
Magnetic Tape	Same as above
Printer (IBM 716)	150 lines/min 120 alphanum char/line
CRT Recorder (IBM 740)	8,000 plotted points/sec 7-in. tube for photo recording
CRT Display	21-in. tube for visual display

CHECKING FEATURES

Magnetic Tape:
The double-gap read-write head offers immediate verification of tape when writing. A tape that is being written passes first over the writing gap, and then over the reading gap. Information that has been written is automatically read and both the vertical check for each character and the longitudonal check for each record is performed. If the record was incorrectly written, it will be detected and the check indicator will be turned on. Background noise and information signal levels are checked and must be at acceptable levels.

Line Printer:
Echo checking for each printed number.

Card-to-Tape:
Horizontal and vertical redundancy check on tape. Comparison of card information read at two stations.

Tape-to-Card:
Same as card-to-tape checking. Independent verification of the validity of written tapes.

Accumulator overflow check
Divide check
Floating point underflow and overflow check.

PRODUCTION RECORD

The information contained in this system description is preliminary to delivery of Type 709 Systems.

ADDITIONAL FEATURES AND REMARKS

Operating Features
Indirect addressing
Variable length multiplication and division. It is possible for the programmer to specify the number of bits in the multiplier or the number of bits that he wishes to have developed in the quotient. Unnecessary machine steps can be eliminated and considerable time saved.
High-speed conversion operations
Automatic detection of overflow and underflow in floating point arithmetic through a new trapping mode. In floating point operations, it is possible to develop a number which is either too large or too small to be represented in the range of numbers that can be accommodated by the floating point scheme used in this machine. These limits are approximately 10^{38} and 10^{-38}. These conditions are called overflow and underflow, respectively. When these occur during the execution of a floating point instruction, the contents of the address part of location zero are replaced by the location of the floating point instruction plus one. The machine takes its next instruction from location 2 and proceeds from there.
Interruption of processing by trapping as a result of an external signal.
Increased flexibility in using the three index registers that are provided.
Ability to perform interpreted or pseudo-operations at any point within a program.
A total of 104 new operations have been added to those of the 704. (Two have been replaced by more powerful operations so that the total number of operations in the 709 is 189.)
Convert instructions are included. For example, a simple program of three instructions can be used to replace leading zeros in a six-digit binary coded decimal numerical field by blanks. This program takes 144 microseconds to execute.
Zero skipping on multiplication. On all multiplication operations, including floating point multiplication, a zero product is created in 24 microseconds, if the multiplicand is all zeros. If a zero bit is encountered in the multiplier, the next digit is immediately examined. Multiply time will vary from 72 to 240 microseconds, depending on the number and distribution of zeros in the multiplier.
Adaptable to both commercial and scientific applications
Independent input-output control
Variable length input and output records
Special instructions for number system conversion, e.g., binary to decimal, decimal to binary
Full array of logical operations
Special instruction for facilitating compiling and interpreting
Indirect addressing
Facilities for real-time operations
36 internal sense indicators.

Peripheral Operations:

Card-to-Tape	-	250 cards per minute
Tape-to-Card	-	100 cards per minute
Tape-to-Printer	-	150 lines per minute, 120 characters per line, or 500 lines per minute, 120 characters per line

The above peripheral equipment utilizes the IBM 727 Magnetic Tape Unit.

Data Synchronizer:

Features

Simultaneous operation of any combination of input and output functions and computing. Real-time facilities

Capacity

Up to 3 units may be used

2 input-output channels per unit

Maximum of 6 channels for simultaneous functions

Punched Card Input-Output

Up to 3 IBM 711 Card Readers

Up to 3 IBM 721 Card Punches

Line Printed Output

Up to 3 IBM 716 Printers

Magnetic Tape Input-Output

Up to 48 IBM 729 Magnetic Tape Units

Index Registers

Capacity

Three 15-bit registers

Advantages

Provide automatic address modification

Reduce programming time

Reduce length of program

Reduce storage requirements for instructions

Other Features:

IBM 774 Tape Data Selector

Independent storage and control unit enabling the rearrangement or direct transmission of data from a 727 Magnetic Tape Unit to any one of four output units: the 402, 403, or 407 Accounting Machine, or the 519 Document Originating Machine.

Magnetic Tape Compatability with:

650 Data Processing System

701, 702, 704 and 705 Data Processing Systems

704 Program Compatability

Programs written for a 704 with Floating Point Trap may be run on the 709 without alteration except for changes in input-output routines

FORTRAN (Automatic Formula Translation)

Advanced program for automatic translation of mathematical notation to efficient IBM 704 programs. The same logical concepts in FORTRAN may be used to construct a similar program translator for the 709.

IBM Service

Executive and Programming Schools

Applied Science Representatives in local IBM offices

Special Representatives in specific industries

Trained electronics maintenance engineers

COST, PRICE AND RENTAL RATE

RENTAL RATES FOR THE TYPE 709 SYSTEM

TYPE	DESCRIPTION	MODEL	MONTHLY CHARGE
709	Central Processing Unit	1	$10,000
736	Power Supply	2	1,100
741	Power Supply	2	1,400
741	Power Supply	3	1,600
746	Power Distribution Unit	2	1,300
746	Power Distribution Unit	3	1,300
711	Card Reader	2	800
716	Printer	1	1,200
721	Card Punch	1	600
729	Magnetic Tape Unit	1	650
755	Magnetic Tape Control	1	1,800
733	Magnetic Drum Storage	1	3,100 (8,192 words)
733	Magnetic Drum Storage	2	3,500 (Each additional 8,192 words)
737	Magnetic Core Storage	3	4,000 (4,096 words)
737	Magnetic Core Storage	4	3,200 (Each additional 4,096 words)
738	Magnetic Core Storage	1	20,000 (32,768 words)
740	CRT Recorder	1	2,700
780	CRT Display	1	150
766	Data Synchronizer	1	3,500
766	Data Synchronizer	2	3,500

Rental rates are subject to change.

Tape-to-card and card-to-tape conversion equipment is available as for other International Business Machines' Electronic Data Processing Systems.

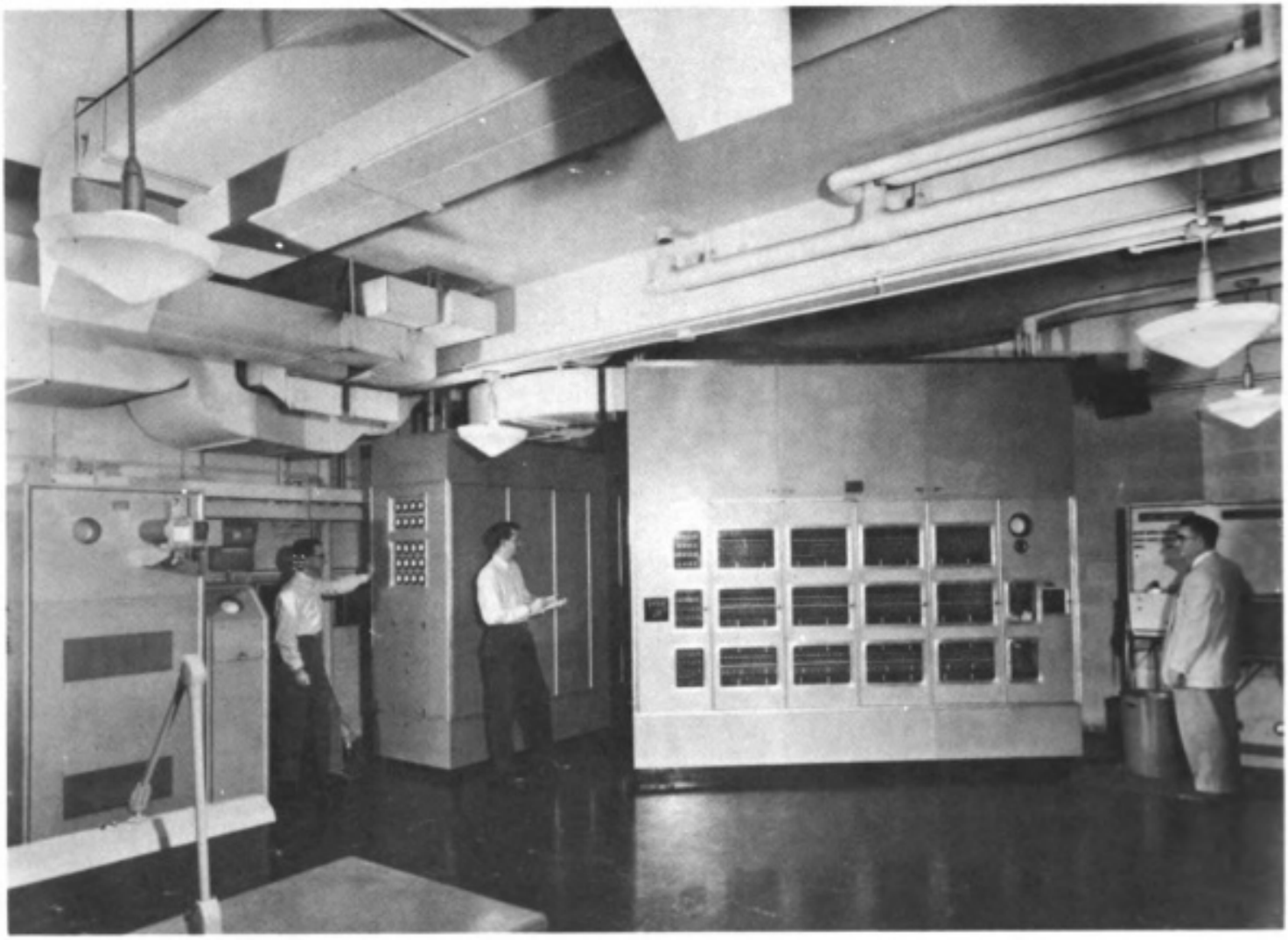
The IBM Type 709 System consists of several separate units under the control of the Central Processing Unit. A minimum system includes the types 709, 736, 741, 746, 737, 711, 716 and 766 units. The capacity of the system is flexible and may be expanded by the addition of storage and input-output units. All operations of the IBM 709 are controlled by a stored program of the single-address type. The system utilizes a set of instructions which provides flexibility by programming.

ILLIAC

Illinois Automatic Computer

MANUFACTURER

Digital Computer Laboratory
University of Illinois



Picture by University of Illinois

APPLICATIONS

Scientific research (See "Additional Features and Remarks" for more specific applications of the Illiac.)

NUMERICAL SYSTEM

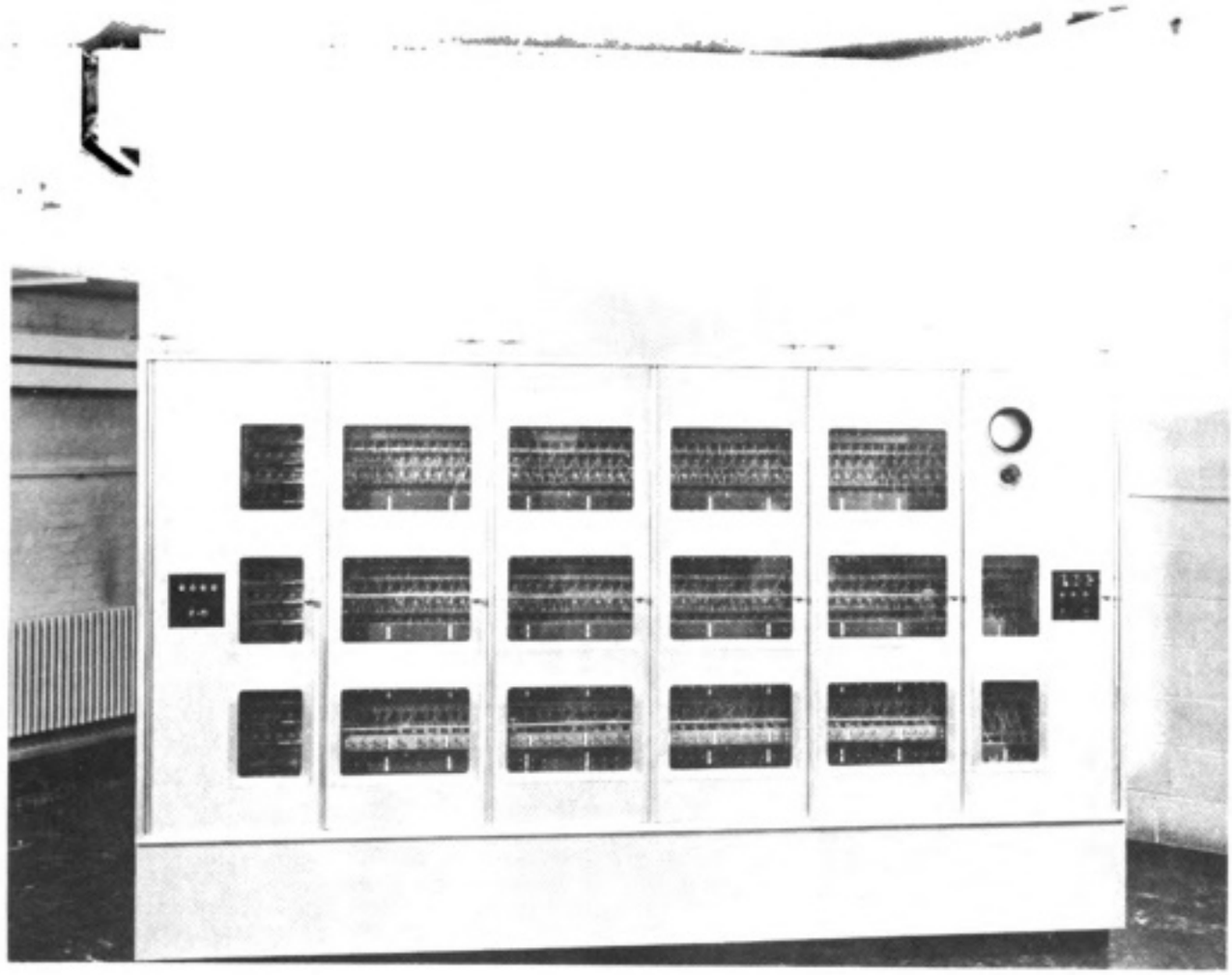
Internal number system	Binary
Binary digits per word	40
Binary digits per instruction	20
Instructions per word	2
Instructions decoded	112
Instructions used	62
Arithmetic system	Fixed point
Instruction type	One address
Number range	-1 to $1 - 2^{-39}$

The 20 digits (Half of a word) for the instruction are divided so as to utilize 8 digits for the instruction type (command digits), 10 digits for the address, and 2 digits are unused spares.

ARITHMETIC UNIT

	Inc. Stor. Access Microsec	Excl. Stor. Access Microsec
Add time	93	40
Mult time	665 - 865	620 - 820
Div time	950	900
Construction	Vacuum tubes	
Rapid access word registers	6	
Arithmetic mode	Parallel	
Timing	Asynchronous	
Operation	Sequential	

The figures for operation time including storage access include the access time for the operand and pro-rated access for the instruction.



Picture by University of Illinois

STORAGE

Media	Words	Digits	Microsec Access
Electrostatic (CRT)	1,024	40,960	18 to 36
Magnetic Drum	12,800	512,000	1,280 to 16,900

Instructions for drum access require 40 binary digits with 14 binary digit addresses. This address specifies the location of the word desired. Subroutines are employed for block transfers between drum and electrostatic storage.

INPUT

Media	Speed
Punched Paper Tape	300 char/sec

Five hole teletype tape is used. Numerical data is read with a 4-hole code. Alphanumerical data employs a 5-hole code and a special instruction.

OUTPUT

Media	Speed
Punched Paper Tape	60 char/sec
Page Printer	5 char/sec
Cathode Ray tube	500 points/sec

A teletype BRPE Punch is used. The CRT has a 256 x 256 raster.

CIRCUIT ELEMENTS ENTIRE SYSTEM

Tubes	4,427
Tube types	27
Separate cabinets	4

Above figures exclude power supplies

POWER, SPACE AND WEIGHT

Power, computer	27.2 KW
Power, air cond.	7.0 KW
Space, computer	700 Cu ft. 100 sq. ft.
Weight, computer	4,000 lbs.
Capacity, air cond.	10 Tons

PRODUCTION RECORD

Produced	2
In production	Copies at Mich State and Iowa State
Operating	2

Two produced and operating are ILLIAC and SILLIAC. Both of these and the Mich and Iowa State computers under construction are of the IAS type. (For other members of this family of computers, see IAS Computer.) The SILLIAC is the University of Sidney, Australia version of the ILLIAC.

COST, PRICE AND RENTAL RATE

Approximate cost of basic system	$300,000
Approximate cost of additional equipment (Estimated)	200,000

PERSONNEL REQUIREMENTS

Daily Operation	Engineers	Tech and Operators
5-8 Hour shifts	4	3

RELIABILITY AND OPERATING EXPERIENCE

Average error-free running period	22 hours
Good time	2,921 hours
Attempted to run time	3,002 hours
Operating ratio (Good Attempted to run)	0.97

Figures based on period 1 June 56 to 30 Nov 56
Acceptance test 1 September 56

Above figures except the regular maintenance and engineering time, are based on the following:

a.	Regular scheduled maintenance and engineering	245 hours
b.	Unscheduled maintenance	81 hours
c.	Production and code check	2,389 hours
d.	Other "good" time (test Codes,etc)	532 hours
e.	Total errors during times b,c or d	132 hours

These figures are for the six month interval from 1 June to 30 Nov 1956..

INSTALLATIONS

Digital Computer Laboratory (ILLIAC)
168 Engineering Research Laboratories
University of Illinois
Urbana, Illinois

University of Sidney (SILLIAC)
Sidney, Australia

Iowa State College of Agriculture and Mechanic Arts
Ames, Iowa

Michigan State University (MICH STATE DIG COMP)
East Lansing, Mich.

The Iowa State college is presently building a copy of the Illiac. The University of Sidney has built a copy of the Illiac. The Illiac itself is a member of the family of machines orginally designed and constructed by the Institute for Advanced Study. (See IAS Computer).

ADDITIONAL FEATURES AND REMARKS

The first picture shows the cathode ray tube output unit on the extreme left. This unit contains the camera, controlled by Illiac instruction, visible on upper right corner of unit. In front of the gentleman on the left is the magnetic drum storage unit. In front of the gentleman in the center is the main unit, containing the electrostatic storage unit above and the control and arithmetic unit below. On the extreme right and behind the gentleman on the right is the input-output rack, containing the photoelectric reader on the left and the paper tape punch on the right. The second picture shows the main unit, with the electrostatic storage unit above and the control and arithmetic unit below.

Machine Use

The following shows the number of hours of machine time devoted to various activities for the month of July 1956:

Regular Maintenance and Illiac Engineering	38:11
Unscheduled Maintenance	8:56
Drum Engineering	30:06
R.A.R.	6:15
Leapfrog	40:32
Wasted	:06

Use by Departments

Computer Group	17:50
Physics	37:00
Control Systems Lab.	87:27
Structural Research	3:08
Struct. Res. (AF 24994)	13:46
T.A.M. (Task 53)	:25
Psychology	22:21
Psychology (MD 620)	4:32
Electrical Engineering	12:39
Elec. Eng. (AF 3220)	:05
Elec. Eng. (Nobs 1934(03))	1:40
Chemistry	28:07
Agriculture	25:16
MURA	114:14
Ill. Dept. of Pub. Welfare (Coan)	10:27
Ill. Dept. of Pub. Welfare (Hurley)	:39
Washington State College	6:17
University of Michigan	4:50
Demonstrations	1:06
Miscellaneous	31:17
	545:12

During July specifications were presented for the following 28 new problems:

MURA. Partial Differential Equation. The Illiac will be used for solution of the Dirichlet problem for a second-order elliptic partial differential equation in two variables by an iterative method. The problem will be solved for many different domains and boundary values.

Psychology. Factor Structure of Anxiety Responses Three 90 by 90 correlation matrices will be calculated and analyzed by the centroid method of factor analysis. A simple structure will be sought by use of the oblimax method and plotting with the cathode ray tube output.

Illinois State Geological Survey. Mixed-Layer Effects in Rhombohedral Carbonates. The problem is concerned with the computation of predicted X-ray diffraction diagrams for crystals made up of two kinds of atomic layers present in varying proportions and with varying probabilities of alternating with each other. Intensity from a single layer is computed from an exponential expression and the result from a succession of layers is obtained from a Markov chain model.

College of Medicine. Attitudes Toward Neurotic Children. Standard factor analysis routines from the Illiac and Psychology Program Libraries will be used to study the types of children that develop psychosomatic illnesses.

Computer. Frequency Analysis of Instructions and References to Store. This will be a study of the relative frequency of occurrence of different in-

structions and the frequency of references to storage locations for programs in the Illiac Library.

Electrical Engineering. Pattern of an Antenna in Front of a Conducting Screen. The relation for the pattern will be evaluated for a wide range of values of the three parameters giving azimuth, elevation and wavelength.

University of Michigan Psychology Department. Factorization of Psychological Variables. The Psychology program for estimation of communalities will be used to factor analyze a 75-variable correlation matrix. The purpose of the study is to identify the underlying dimensions of a number of tests among which are personality tests, social perception tests, vocational interest tests, economic interest tests, political interest tests, and humor preference tests.

Computer. Quotient of Two Polynomials. This program will evaluate the quotient $P(j\omega)/Q(j\omega)$ where P and Q are complex polynomials of degree 65 or less.

Civil Engineering. Simultaneous Equations. This is a check program, using the Illiac routine, for solving a set of 140 simultaneous linear algebraic equations.

T Economics. Molasses Demand Study. This is a statistical analysis of the demand for industrial molasses using the single equation least squares approach and the limited information system of equations approach.

Washington State College. Fruit Demand Study. Library Roution K-12 will be used to make a study of the demand of consumers for fruit as the season progresses. Data were taken on prices and quantities as well as quality and appearance for a number of fruits.

T Civil Engineering. Non-uniform Torsion of Bow Girders. Finite difference methods will be used to reduce the governing differential equations to sets of simultaneous linear algebraic equations which will be solved by one of the Illiac library programs.

Psychology. Analyses of Biological Correlations. This study is concerned with the applications of factor analysis to biology. A comparative study will be made with a series of correlation matrices ranging from size 10 by 10 to size 18 by 18 and dealing with characteristics of flies, aphids and bees.

University High School. Analysis of Mathematics Project Data. Standard library routines will be used to calculate product moments and to carry out some computations involving a covariance matrix. Data are scores on tests of various mathematical abilities collected from 500 high school students participating in the University of Illinois School Mathematics project.

T Physical Education. Relationship Between Body Structure and Weight Lifting Activities. The object of this study is to obtain prediction equations which will make it possible to predict performance from body measures. Twenty-seven body measurements and ten performance measures have been obtained on 241 subjects.

Electrical Engineering. Ladder Network Analysis. The problem is, given a ladder network, to calculate the impedance. The analysis is to be carried out in floating arithmetic and will consist of calculating the coefficients of two polynomials and then finding the roots of the polynomials.

Physical Education. Study of the Primary Components of Cardiovascular Tests. The study is directed at determining the relationship between cardiovascular tests in young boys seven to fifteen years of age and of determining the primary factors involved in the relationship. The analysis will make use of library routines.

Chemistry. Data Fitting. An empirical equation is to be determined from data consisting of molar extinction coefficients of a solution in which several first-order chemical reactions are taking place.

Electrical Engineering. Network Analysis. The problem is concerned with the determination of the poles and zeros of an equation which is given as a function of five parameters.

Dairy Science. Effects of Weather on Daily Milk Production. Observations on daily milk and fat production were collected in a dairy herd at ten-day intervals during the summer months for the past five years. Also recorded were the maximum and minimum temperatures, relative humidity, and wind velocity for each of the sample days and for the three days preceding the sample day. The effect of each of the factors and of combinations of them will be studied.

University of Michigan Psychology Department. Study of Marital History Variables. This is a factor analysis problem in which data were obtained from a study of 300 engaged couples assessed on about 400 variables. The study began 20 years ago and the subsequent marital history has been followed, most of the original subjects being re-tested after 20 years of marriage.

Psychology. Dimensionalization of Difficulty. Messick's technique is used to obtain scalar distances between pairs of words on data obtained when a list of 14 words was given to each of two groups of 40 subjects.

Dairy Science. Seminal Characteristics of Dairy Cattle. Thirteen characteristics were observed twice weekly over a period of one year. Library Routine K-2 will be used to analyze the data.

Agricultural Economics. Supply and Demand for Milk. Library Routine K-12 will be used to solve a 3-variable multiple correlation problem to show the influence of income and price upon the per capita milk consumption. A simple correlation of milk prices and milk production will also be carried out.

Economics. Optimal Partition of Discrete Points. The original economic problem is to divide a population into groups or categories such that members within the same group are homogeneous in the sense of having numerical measures nearly the same. The problem differs from analysis of variance and other classification problems in statistics in that the groups are not defined in advance but are defined as a result of solving the problem. The method of solution is to have the Illiac systematically identify, list and compute values for certain relevant partitions, reducing the number by application of several basic principles.

Physics. Processing of Superconduction Transition Data. Experimental data consist of a sequence of 31 numbers which must be summed and normalized and then plotted. The Illiac will be

used to carry out the computations with the results being plotted and photographed on the cathode ray tube output.

Civil Engineering. Natural Frequency with Rotational Restraint. The problem is an extension of structural frequency analysis which generally has a determinantal equation of n^{th} order corresponding to n degrees of freedom. Inclusion of rotational restraint at the base requires a system having n+1 degrees of freedom.

Electrical Engineering. Calculation of Network Function. From the topological relations of a network it is possible to write an expression for the driving point function, to pick all possible combinations of v-1 elements (where v is the number of vertices in the network), and determine whether or not they represent a tree of the network.

Error Frequency and Analysis

The machine is normally used for "engineering" and maintenance between 7:00 A.M. and 11:00 A.M., and for a check of its performance between 5:30 and 6:00 P.M. of each weekday. Since the periods between 7:00 and 11:00 A.M., together with certain irregular periods like Saturdays and Sundays, are devoted to a heterogeneous group of functions, it is more instructive from an error standpoint to look at the periods between 11:00 A.M. and 7:00 A.M. of the next day in order to make an observation of the error frequency in the machine. This is the actual period when the machine is designated for use. With this in mind, a summary table has been prepared using the period between 11:00 A.M. and 7:00 A.M. of the next day. This table lists the running time when the machine was operating, the amount of time devoted to repairs because of breakdowns, and the number of failures while the machine was listed as running. During the 5:30-6:00 P.M. period (when the machine is checked) if no errors are found, the time is given to the "running" column. Each failure was considered to have terminated a running period and was followed by a repair period in preparing this table. Since the leapfrog code is our most significant machine test, the length of time which it has been used on the machine is listed separately together with the number of errors associated with that particular code. This information for the month is presented in Table II.

It is important to notice that any interruption of machine time that was not planned for is considered a failure in this table. In rare cases where the failure is not known until a later time, it is possible that no repair period is associated with the failure. This over-all system has been adopted because it makes it possible for a machine user to estimate directly the probability that the machine will be "running" at any instant of time and the probability of a failure during any given interval of running time.

Table III presents a summary of errors or interruptions for July.

TABLE III

Reader Errors	7	White Switch Error	1
Punch Errors	7	Scope Output Errors	2
Drum Errors	3	Control Error	1
Power Supply	1	Power Line Failure	1
		Memory Error	1
		TOTAL INTERRUPTIONS AND ERRORS	24