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ABSTRACT

The Huntington Computer Project has developed 17 simulation games which can be used for instructional purposes in high schools. These games were designed to run on digital computers and to deal with material from either biology, physics, or social studies. Distribution was achieved through the Digital Equipment Corporation, which disseminated teacher manuals, resource manuals, and student manuals to over 600 teachers and 25,000 students in 400 secondary schools during the 1972-73 school year; these target populations were expected to quadruple in the following year. Evaluation of the use of the computerized simulation games led to the conclusion that they made a significant contribution to learning. This was particularly true in situations in which students were denied direct experience with the phenomena being studied due to such problems as the students' inexperience with experimental techniques, the lack of laboratory equipment or time, difficulty or danger in obtaining adequate samples, and the impossibility of controlling extraneous variables in real life. Descriptions of six of the simulation games are appended to the report. (PB)

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THE USE OF COMPUTER SIMULATIONS IN HIGH SCHOOL CURRICULA

Huntington Computer Project

STATE UNIVERSITY OF NEW YORK AT STONY BROOK
COLLEGE OF ENGINEERING

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THE USE OF COMPUTER SIMULATIONS IN
HIGH SCHOOL CURRICULA

by

Marian Visich, Jr.† and Ludwig Braun‡

I. Abstract

During the period 1967-70, the National Science Foundation supported the exploration, by the Polytechnic Institute of Brooklyn, of the uses of digital computers in high school curricula. More than 80 high school teachers and more than 3,000 students in 30 school districts participated in this effort. The experience gained in this period indicated that simulations were potentially valuable educationally. In order to permit a more detailed exploration of the potentially, the National Science Foundation funded a two year effort for the period 1970-72 at the Polytechnic Institute of Brooklyn for the development of simulation materials to support high school curricula in biology, physics, and social studies. This effort was extended an additional two years at the State University of New York.

In the present paper the history and philosophy of the project is presented. In addition, several programs in each of the three curricular areas are presented as typical of the Huntington Computer Project simulation programs.

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II. History of the Huntington Computer Project

During the period 1967-70, the National Science Foundation supported* the exploration, by the Polytechnic Institute of Brooklyn, of the uses of digital computers in high school curricula. More than 80 high school teachers and more than 3,000 students in 30 school districts participated in this effort. The experience gained in this period indicated that simulations were potentially valuable educationally. In order to permit a more detailed exploration of this potentiality, the National Science Foundation funded (through Grant GW 5883) a two-year project for the period 1970-72 whose purpose was to develop simulation materials to support high school curricula in biology, physics, and social studies. (This project has been called Huntington Two). This latter effort was extended for two additional years at the State University of New York at Stony Brook through Grant WO-07647.

During the period 1970-72, the materials developed by the Huntington Two staff were distributed to some 175 teachers in 80 high schools around the United States for preliminary trial. During the 1971-72 school year, the appropriateness of these materials was measured by an independent evaluation committee.**

*Support was provided through Grant GW 2247 (the Engineering Concepts Curriculum Project), and Grants GE 5973 and GJ 79 (the Huntington Computer Project).

**The Evaluation Committee report is available from the project headquarters at SUNY at Stony Brook.

In order to broaden the distribution of the simulation packages, the Huntington Two staff sought a publisher for its material in the spring of 1972. A Selection Committee chose the Digital Equipment Corporation (DEC) as the publisher. During the 1972-73 school year, DEC sold 25,000 manuals associated with nine simulations in biology, physics, and social studies. It is estimated that these units were utilized in 400 schools, by 600 teachers working with over 25,000 students.

In an effort to increase teacher awareness of Project activities, the Huntington Two staff conducted a Resource Personnel Workshop* during the summer of 1973. This RPW was attended by forty high-school teachers and ten university professors from Colorado, Illinois, Minnesota, New Jersey, and New York. These people presently are conducting awareness conferences and seminars, as well as using the simulations in their own classrooms. Additionally, a proposal has been submitted to NSF to obtain support for an additional set of awareness conferences to be conducted at some twenty school systems around the United States during the 1974-75 academic year.

An additional eight simulation packages have been released to DEC since June, 1972. These additional units, plus the efforts of DEC (through advertisements and sales contacts) and of the

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*This RPW was supported by the National Science Foundation, through Grant WO-08331.

Project staff (through awareness conferences and presentations at national, regional, and local meetings) to increase teacher awareness of the availability of the packages, should push the number of students impacted well over the 100,000 mark during the 1973-74 school year.

III. A Rationale for Use of Simulations in Education

Few people would dispute the desirability of learning by direct experience. The investment of billions of dollars by our universities, and by our primary and secondary schools, in laboratory facilities is evidence enough. Generation after generation of students re-measure the acceleration due to gravity, or study the giant chromosomes of the drosophila fly, even though these things have been done by very capable scientists employing the most elaborate facilities available. How much easier (and how much less expensive) it would be to describe Millikan's oil-drop experiment, and its results, along with pictures of the apparatus, in a textbook--yet many physics laboratories in high schools and colleges are equipped with this apparatus, and, every year, legions of students repeat this experiment. Their e/m ratios are very imprecise compared to the carefully determined value of the physicist; however, they have benefitted from having had the experience themselves. This is as true for nonscientists who never again will have a laboratory experience, as it is for the student interested in physics who will spend his life in the laboratory.

Even though direct experience is very desirable, our students frequently are prevented from having such learning experiences. Some of the reasons for this are:

1) The necessary equipment is not available because of expense, or it is too complex or delicate to permit students to use it (e.g., in high-energy physics).

2) The sample size available in the real world is too small to permit generalizations. (This is especially true in the training of medical students in the diagnosis of disease. Medical students in New York State, for example, run into very few cases of malaria, and develop little experience with it.)

3) The experimental technique is difficult and must be developed over an extended period (e.g., in experiments in genetics, and in titration).

4) There are serious dangers to the student (e.g., where radiation or high temperatures are involved, where there may be explosive mixtures of gases, or where highly-toxic materials are required).

5) The time scale is too short or too long to permit the student to make observations (e.g., the study of the dynamics of population, or the run-a-way of a nuclear reactor--here, of course, there are other reasons for not permitting students to do the experiment.)

6) The opportunity to experiment directly is not available (e.g., in studies of ecological, economic, political, or social systems, or in studies of human genetics, or spread of disease).

7) When it is desirable to measure variables which are difficult to access (e.g., the tension on a pendulum string, or the differential effects of the gravitational forces of the earth and the moon on an orbiting satellite).

8) When measurement and other noise obscures the important phenomena (in the computer, we can create a world in which there is no noise and in which instruments are perfect, and then show the student how noise and imperfect instruments obscure the data of interest).

9) There are times when it is useful to underscore the significance of natural laws by comparing their results with other laws (e.g., study of non-inverse-square-law gravitational systems,* or non-Mendelian genetics.)

*An excellent example of this is seen in the film, "Force, Mass and Motion", by Dr. Frank Sinden of The Bell Telephone Laboratories, Murryhill, New Jersey.

If any of the foregoing circumstances exists, the student normally is excluded from learning by direct experience. Typically, here, he learns by reading a textbook, or by attending a lecture on the subject. In both cases, the learning is less than completely satisfactory. (Who would accept a surgeon who has learned surgery solely from books and lectures?)

These advantages of simulation are especially valid in biology and social studies. Modern biology courses have turned dramatically from the study of taxonomy to a study of biochemistry, plant systems, animal systems, genetics, evolution, and ecology. To a very considerable extent, meaningful laboratory experiences in these areas are unavailable to high school students. The availability of computer simulation opens up a new path to knowledge for these students.

The situation in the social studies is even more difficult. Here, there essentially are no laboratories available to the student or to the teacher. Social studies teachers have begun to remedy this by bringing board games (e.g., Ghetto, Crisis, etc.) into their classrooms. These have become very popular; however, they are limited in scope and complexity compared to computer-based simulations, and the bookkeeping (looking up values in charts and graphs, doing arithmetic operations, recording values, etc.) is tedious. With computer simulations, these bookeeping operations are handled internally in the machine. In addition, because of the computer's capability to handle complex mathematical operations, computer simulations can be more comprehensive, and, so, more realistic than can board games.

It should be emphasized that it is not proposed here that simulations be used to replace good laboratory experience. Rather, it is proposed that simulations be used where such experiences are unavailable.

IV. The Need for Materials to Support Computers

It is clear that computers soon will be available to a large fraction of the high-school teachers and students in the United States. The advent of the mini-computer (both stand-alone and time-sharing) equipped with high-level languages like BASIC, already has made it possible for many high schools to make computer time available, through service bureaus, or through equipment purchase.

Even without large-scale integration of circuits, the cost of mini-computers in the PDP-8 class has halved every three years, on the average, over the past decade. Micro-computers, which do use large-scale integration, already are available to original equipment manufacturers for prices substantially under $500. There is no reason to suppose that the price and performance trends of the past decade will not continue into the foreseeable future.

Clearly, the economic inhibition against acquiring computing power for high school instruction is disappearing rapidly.

In the 1969-70 school year, 2,900 (or 13%) of 22,000 high schools interrogated*were using computers in instruction. In the State of Oregon, and on Long Island in New York State, half the high schools have some form of computer access for instruction. In Rhode Island all but a handful of the high schools have computers available for instruction. Every school in the Atlanta Public Schools has at least one terminal. In the Minneapolis-St. Paul area, and in Southern Minnesota, a large fraction of the high schools have computer terminals. These few observations are difficult to extrapolate into national statistics; however, they are indicative of a trend. It appears to be entirely reasonable to expect that, within the next five years, as computer costs continue to decline, fully half of our high schools will be making extensive use of computers in their educational programs.

A major inhibition to the use of computers in instruction at the high school level is the lack of adequate amounts of high quality computer-related materials. Frequently, even after a school system acquires a computer (or terminals into a computer), the teachers and administrators don't know what to do with it.

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*Survey of Computing Activities in Secondary Schools, American Institute for Research, October, 1970.

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There have been some cases where high school teachers or students have developed impressive computer materials; however, these instances are relatively rare. The student usually has a background which is not adequate for the development of suitable material; while the high school teacher, even when highly motivated and sufficiently talented and knowledgeable, is so heavily loaded with teaching and other responsibilities, that he has little time or energy for development of computer programs. The result of this is that many of the schools which have computers make very ineffective use of their computer time. (In most cases, most of the time available is used by a small cadre of students and teachers who sometimes are called "computer bums".)

There is such a serious shortage of adequate amounts of reasonably good computer material that it already has dampened the enthusiasm of many educators, and is likely to continue impeding substantially the development of this important educational tool, even when the cost of the computer time is within easy reach of every school.

This need is clearly evident from the large number of requests which have been received by the staff of Huntington Two for copies of its materials. During recent months, there has been a flood of requests for Huntington Two material from school district curriculum coordinators and computer-center directors, as well as from individual teachers.

Normally, such a need may be expected to attract commercial publishers; however, the combination of the large investment required, and the presently limited market, has resulted in a uniform lack of interest among publishers. Until there is an adequate market, publishers will not support or encourage the development of computer material; and until there is an adequate body of computer material, few schools other than the innovative ones, will be willing to invest money in computers.

This circle can be broken either by waiting a sufficient length of time for natural events to break it, or by providing the investment funds to support the development of materials until a "critical mass" has been reached. The second alternative significantly speeds up the natural process, and is the one which has been chosen by the National Science Foundation in its support of the Huntington Computer Project and other similar projects.

V. Huntington Computer Project Simulations

As mentioned in Section II, the Digital Equipment Corporation was chosen in 1972 to publish the simulation programs. Three manuals and a paper tape copy of the program are published for each of the simulation programs. In the Teacher's Manual the following information is provided for the teacher using the program:

- rationale and goals for the unit
- brief description of how to use the program
- what preparatory materials to provide for the students
- follow-up discussion questions
- sample run to give the teacher an understanding of the way the simulation program works.

The Resource Manual is designed to provide the teacher detailed information concerning the program and the subject matter covered, and contains the following information:

- detailed description of the model including the assumptions on which the model is based
- an in-depth discussion of the theoretical background of the subject when it is appropriate
- program listing and additional sample runs
- instructions for changing parameter values to realize different situations and suggestions for making modifications to change the program for specific purposes
- suggested student projects using the computer simulation
- bibliography of related books and films

The Student Manual contains instructions for the student for running the program and problems to be investigated using the simulation.

The simulation programs currently available through Digital Equipment Corporation are listed below along with a brief description of each.

<u>Biology</u>

GENE1	A simple genetics experiment to demonstrate the statistical nature of the Mendelian Laws.
HARDY	The Hardy-Weinberg Principle (population genetics).
LOCKEY	Simulation of the lock-and-key model of enzyme activity.
MALAR	Control of malaria epidemic.
POLUT	Effects of pollutants on different bodies of water and the effectiveness of certain anti-pollution measures.
POP	A series of simple population models.
STERL	Control of an insect population by pesticides and the use of sterile male insects.
TAG	A sampling exercise on a simulated farm pond for investigating population size.

<u>Physics</u>

CHARGE	Millikan's oil drop experiment.
SCATR	Rutherford scattering: use of alpha-particle scattering to determine the atomic structure.
SLITS	Young's double slit experiment (interference of light waves).

Social Studies

ELECT 1,2	Hypotheses testing simulation of 14 past American Presidential elections.
ELECT 3	An election simulation that allows for the building of strategies to affect voter attitudes during an election.
MARKET	Simulation game engaging two companies in a one-product competition.
POLICY	A simulation game based on a socio-economic model of American society with six interest-group roles and making use of a simulated decision-making process.
POLSYS	How local government responds to different attempts by the community to influence its decisions.
SAP	A simple, interactive data analysis package for the social studies student.

Several computer simulation programs are described below to indicate the philosophy of the Huntington Computer Project.

POP

The POP program is designed to allow a student with little mathematical background to explore three models of population growth, The three models are:

1. a simple exponential (Malthusian) model
2. a logistic model with a density limiting factor
3. a modified logistic model with a low density correction that limits reproduction of the population at very low population densities

Figure 1 presents the results on an investigation of the population growth of a particular specie with the following characteristics

- initial population	1,000
- reproduction rate	2
- time unit per generation	5
- carrying capacity of environment	30,000

- low density effects important when population is less than 4,000

Figure 1a shows the results when the population grows exponentially. The points plotted by the computer have been connected by a solid line in the Figure for ease of interpretation. The effect of density limiting factor can be readily seen in Figure 1b. Comparison of the two figures shows that at the end of seven generations, the initial population grew to 27,381 when a carrying capacity of 30,000 was imposed in comparison to 128,000 for the exponential growth model. When low density effects are important for populations less than 4,000, the population grows at a much slower rate during the seven generations considered as shown in Figure 1c. At the end of seven generations the population was only 3,504. Increasing the low density population effect to 15,000, the population dies out within four generations (Figure 1d). With the POP simulation, the student can investigate the relationships between reproduction rate, carrying capacity of the environment and low density effects.

USPOP

USPOP is a simulation of population growth in the United States. It is based on a model similar to that used by United States Government demographers in their population projection studies. Several simplifying assumptions had to be made in order to fit the model on a mini-computer; but comparisons of USPOP and government projections indicate that errors due to these assumptions are relatively small. The model makes use of over 80 variables to delineate population behavior characteristics and was developed primarily to provide the student with a laboratory experience in population dynamics and to facilitate individualized learning about population factors. The student is permitted to investigate the effect of the following parameters on population growth:

1. fertility - average number of live births per woman over her reproductive lifetime.
2. birth distribution - percent of total fertility expressed by females of each age category
3. sex ratio of offspring
4. mortality rates
5. population distribution at beginning year

Census data for the year 1970 is contained in the program for the aforementioned parameters. Representative computer runs of the

USPOP program are presented in Figure 2. Figure 2a presents data on the population growth in the United States based on the assumption that the fertility remained constant at the 1970 value, namely 2.45. The results indicate that by the year 2000 the population of the United States would be 265.2 million. Figure 2b shows the effect of suddenly decreasing the fertility to 2.0 in the year 1975. As a result of the decreased fertility the projected population in the United States in the year 2000 is 244.9 million. In the Student Manual, the student has the opportunity of investigating the following five questions:

1. What effect will changes in fertility have on population by the year 2000?
2. What effect would delaying the birth of the first child have on population growth?
3. Will changes in infant mortality affect future population levels?
4. How does fertility affect the age distribution of the population?
5. What is the effect of mortality rate on age distribution in the population?
6. When will the population stabilize if we go to the zero-population growth birth rate immediately?

CHARGE

In 1911, R.A. Millikan conducted an experiment to determine the charge of an electron. In the experiment, an oil drop was permitted to fall freely between two horizontal metal plates. By measuring the terminal velocity of the oil droplet in freefall, Millikan was able to determine the size and mass of the droplet. Once the terminal velocity was determined, the droplet was ionized by x-rays. An electric field was applied between the two metal plates and directed so that it opposed the gravitational force on the ions. By adjusting the electric field, the droplet was made to remain stationary. For this condition, the gravitational and electric forces were balanced, and Millikan was able to estimate the charge carried by the drop. The CHARGE program is a modern version of the Millikan Oil Drop Experiment and is designed to demonstrate to a student the existence of a discrete unit of electric charge. Figure 3 shows a sample run of the CHARGE program. At the beginning of each run the computer calculates and prints out the terminal velocities of four latex spheres with randomly assigned charges corresponding to from zero to eight electrons that are drifting down in the absence of an electric field. A voltage can be applied to the horizontal plates by typing in a number between +1,000 and -1,000. The computer then calculates the velocity of the four spheres under the combined gravitational and electric forces. The voltage can be adjusted until one of the four spheres is stopped. For the sphere that is stopped, the charge on the sphere is then calculated.

SLITS

The SLITS program simulates Young's Double Slit Experiment which was first performed in 1801 to demonstrate the wave theory of light. In the experiment, a source of monochromatic light is placed behind a narrow slit in an opaque screen. A second opaque screen with two narrow slits is located on the other side of the one-slit screen. As the light passes through the pair of slits, it forms an interference pattern of bright and dark regions which can be viewed on a viewing screen. Many high school physics laboratories have an experimental set-up to conduct the double slit experiment. The set-up is normally limited to a single monochromatic light of a given wave length, a fixed separation distance between the two slits, and a fixed distance between the screen with the two slits and the viewing screen. In the high schools where the experimental set-up is available, the SLIT program is usually run by the student after he first had a "hands-on" experience with the experimental set up. As a result, the student is able to explore parameter values over a wide range and to draw inferences about the interrelationships among the variable. Figure 4 presents sample runs of the SLITS program. At the beginning of the run the computer plots the interference pattern corresponding to a monochromatic light source of W = 6,000 angstroms, a slit separation of D = 0.5 millimeters and a distance between the screen with the two slits and the viewing screen of L=2 meters (Figure 4a). The student is then able to change each of the variables one at a time as indicated in Figures 4b to 4d. After the student has completed his investigation of the parameters, the program has a "self test" built into it to determine the student's degree of understanding of the relationship between the variables. The computer randomly selects a wave length for the light source which is not given to the student. The student must try to determine the selected wave length by varying L and D. An estimate within 10% of the actual value is an acceptable approximation.

MARKET

MARKET is a computer based game of competition between two companies who are competing for the market for a particular product. Figure 5 presents a sample run of the MARKET program. As can be seen in the computer run, the players are first informed of the fixed and variable production costs involved in the marketing of their product and of the initial value of their inventory, cash on hand and total assets. Each player is allowed to make marketing decisions quarterly and can determine the production level, the advertising budget and the unit price of the product for his company. After these decisions are made for a given quarter, the computer reports the results of the decisions with respect to performance on the market. For each company, the report lists:

a) profit

b) percentage share of the market

c) cash on hand

d) number of units sold

e) number of units in stock

f) total assets

Players make their decisions for the following quarter on the basis of these reports. Throughout the game a number of events occur at random that require changes in strategy. These include Presidential wage-price freeze, warehouse fires, strike by employees, and embezzlement by the Vice-President of the company. The game ends when one company goes bankrupt or attains 12 million dollars in total assets. The MARKET simulation was developed to give secondary school students a fundamental understanding of the consumer market and the variables which influence the market.

POLICY

POLICY is a simulation game which reflects the impact various interests groups have on the policy formation process at the federal level. It consists of a socioeconomic model of the American society, six interest group roles and a simulated decision making process. The six interest groups include business, labor, civil rights, military, internationalists, and nationalists. Each interest group role enters into the computer the magnitude of support or opposition they wish to direct toward each of 14 policies. Representative of the policies considered by the various interest groups is the following:

> The federal government, at a cost of $8 billion, should institute a program to provide medical care for low-income families. Ill health is one of the most basic problems of the poor. It is expected that over the long run this proposal will significantly improve the living conditions of the poor.

The program stores 18 socioeconomic indicators (including gross national product, unemployment rate, average weekly earnings, birthrate) which give a picture of the health of the American society. Each of the indicators has been assigned an initial value corresponding to its 1972 value. When a policy is adopted, the program generates new values for the indicators which reflect the state of the society following the adoption policy. Even if no

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one policy gains enough support among the participants, the program generates new values for the indicators. These values, while not reflecting the adoption of a policy by the government, reflect the state of the socioeconomic system as it would have developed over a period of one year.

VI. Conclusions

During the past six years the Huntington Computer Project has explored the uses of digital computers in high schools and the use of computer simulations as an educational tool in supporting curricula in biology, physics, and social studies. Based on this experience, it is the opinion of the Huntington Computer Project staff that the digital computer can contribute a great deal to the education of high school students as a general purpose simulator.

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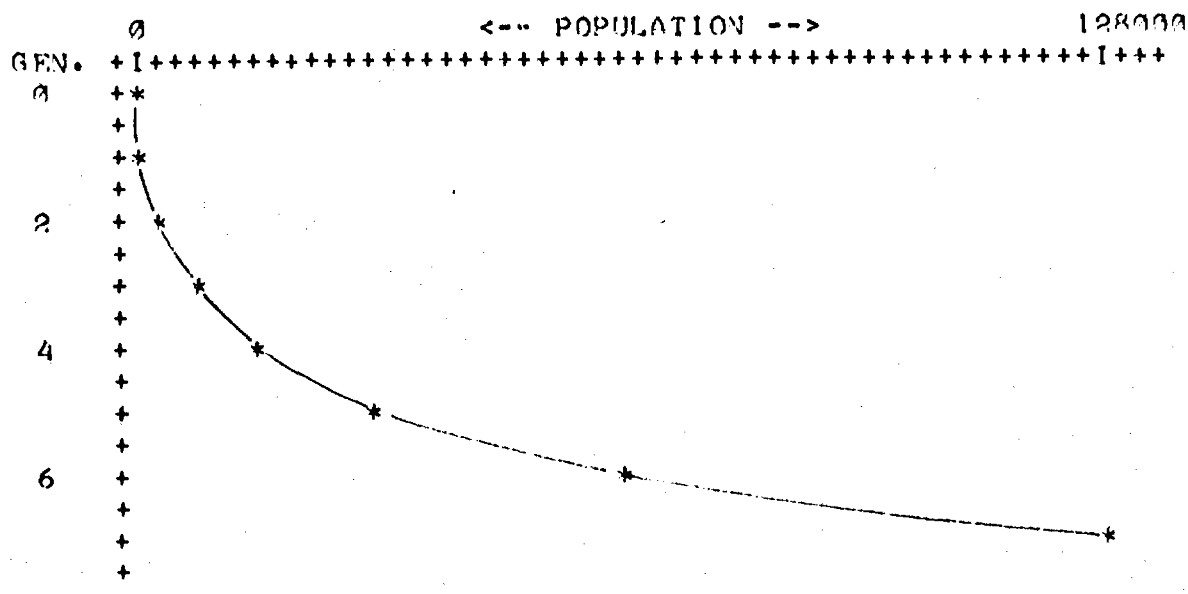
                POPULATION GROWTH SIMULATION

WHICH POPULATION MODEL? (1, 2, OR 3). TYPE IN NUMBER ?1


P(0)= ?1000
REPRO RATE= ?2
TIME UNIT PER GENERATION ?5
NO. OF GENERATIONS ?7
OUTPUT DESIRED: 1=TABLE, 2=GRAPH, 3=BOTH ?3

GEN.           TIME          POP.
------         ------        ------
 0              0             1000
 1              5             2000
 2              10            4000
 3              15            8000
 4              20            16000
 5              25            32000
 6              30            64000
 7              35            128000
```



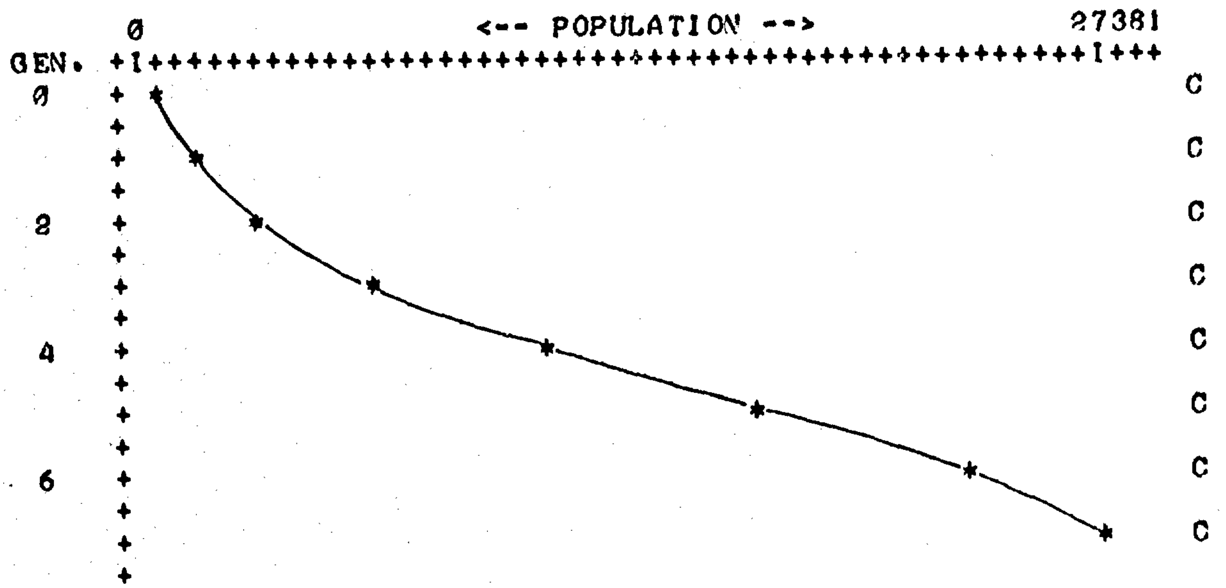
a) Simple Exponential Model

Figure 1 Sample Run of POP

```
ANOTHER RUN? (YES=1, NO=0) ?1

WHICH POPULATION MODEL? (1, 2, OR 3). TYPE IN NUMBER ?2


P(0)= ?1000
REPRO RATE= ?2
TIME UNIT PER GENERATION ?5
CARRYING CAPACITY ?30000
NO. OF GENERATIONS ?7
OUTPUT DESIRED: 1=TABLE, 2=GRAPH, 3=BOTH ?2
```

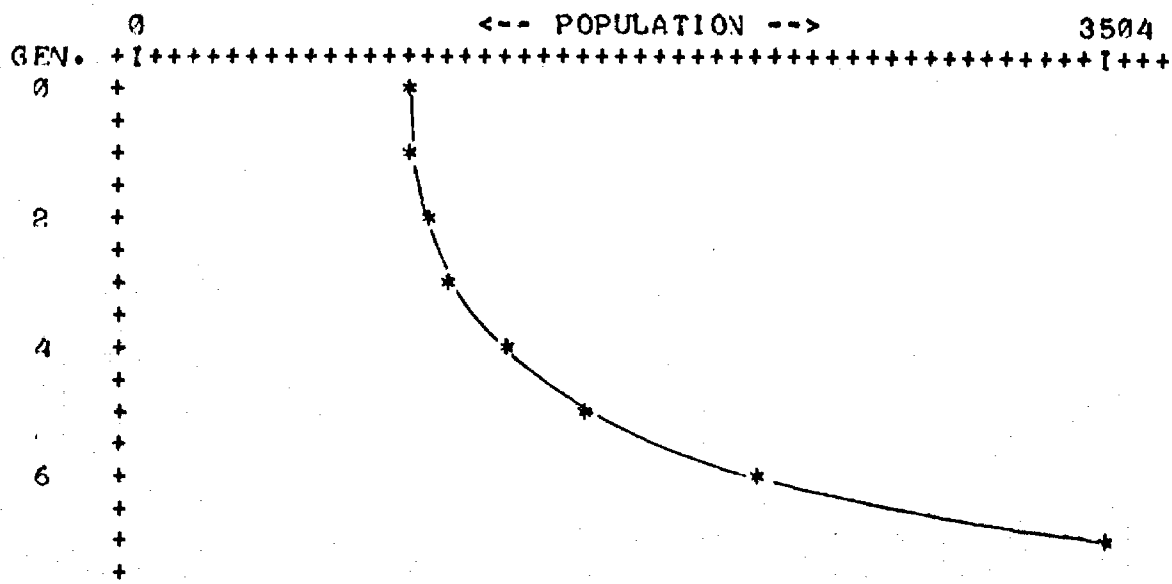


b) Logistic Model

Figure 1 Sample Run of POP

```
WHICH POPULATION MODEL? (1, 2, OR 3). TYPE IN NUMBER ?3

P(0)= ?1000
REPRO RATE= ?2
TIME UNIT PER GENERATION ?5
CARRYING CAPACITY ?30000
AT WHAT POP. DO LOW DENSITY EFFECTS FIRST BEGIN ?4000
NO. OF GENERATIONS ?7
OUTPUT DESIRED: 1=TABLE, 2=GRAPH, 3=BOTH ?2
```



c) Modified Logistic Model

Low Density Effects Below 4,000

```
P(0)= ?1000
REPRO RATE= ?2
TIME UNIT PER GENERATION ?5
CARRYING CAPACITY ?30000
AT WHAT POP. DO LOW DENSITY EFFECTS FIRST BEGIN ?15000
NO. OF GENERATIONS ?7
OUTPUT DESIRED: 1=TABLE, 2=GRAPH, 3=BOTH ?1
```

GEN.	TIME	POP.	
0	0	1000	
1	5	354	
2	10	48	
3	15	1	
4	20	0	POPULATION DIED OUT

```
ANOTHER RUN? (YES=1, NO=0) ?0
```

d) Modified Logistic Model

Low Density Effects Below 15,000

Figure 1 Sample Run of POP

```
DO YOU WANT REPORTS 1) EVERY 5 YEAR INTERVAL
OR 2) SELECTED YEARS ?1

YEAR AT START OF PROJECTION ?1975

DO YOU ASSUME STANDARD FERTILITY (1=YES,0=NO) ?1
WILL FERTILITY (1) STAY AT 2.45  OR (2) CHANGE SLOWLY
TO A NEW LEVEL ?1

DO YOU ASSUME STANDARD BIRTH DISTRIBUTION (1=YES,0=NO) ?1

DO YOU ASSUME STANDARD SEX RATIO (1=YES,0=NO) ?1

DO YOU ASSUME STANDARD MORTALITY (1=YES,0=NO) ?1

DO YOU ASSUME STANDARD POPULATION (1=YES,0=NO) ?1

REPORT:1)SHORT 2)LONG 3)GRAPH 4)CHANGE ASSUMPTIONS 5)END ?1

YEAR 1975      POP=  204.8  MILLION        FERTILITY 2.45

REPORT: ?1

YEAR 1980      POP=  214.5  MILLION        FERTILITY 2.45

REPORT: ?1

YEAR 1985      POP=  226.5  MILLION        FERTILITY 2.45

REPORT: ?1

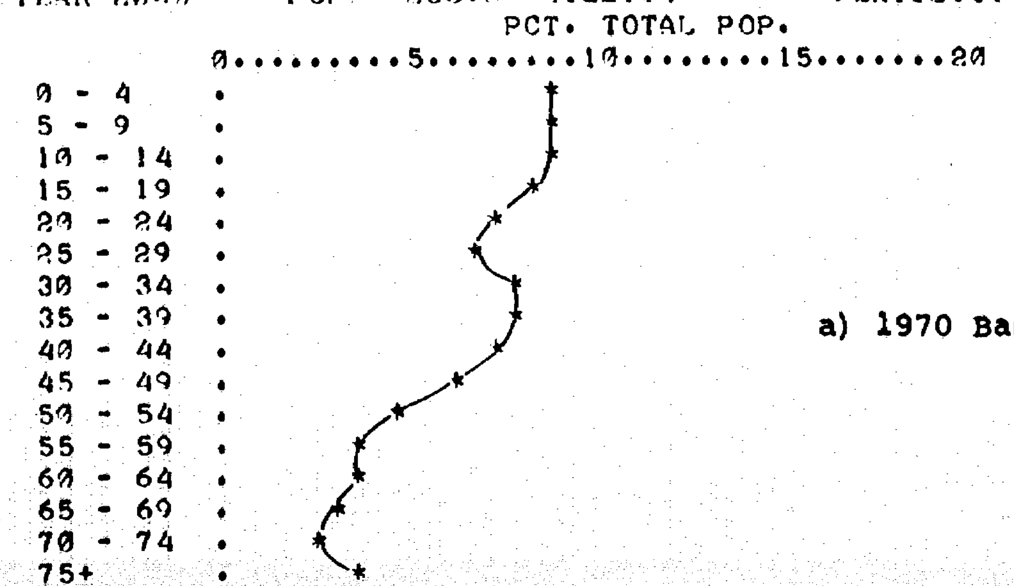
YEAR 1990      POP=  239.0  MILLION        FERTILITY 2.45

REPORT: ?1

YEAR 1995      POP=  253.1  MILLION        FERTILITY 2.45

REPORT: ?3

YEAR 2000      POP=  265.2  MILLION        FERTILITY 2.45
```



a) 1970 Base Data

Figure 2 Sample Run of USPOP

```
DO YOU WANT REPORTS 1) EVERY 5 YEAR INTERVAL
OR 2) SELECTED YEARS ?2

YEAR AT START OF PROJECTION ?1975

DO YOU ASSUME STANDARD FERTILITY (1=YES,0=N0) ?0
FERTILITY IN 1975  ?2.0
WILL FERTILITY (1) STAY AT 2  OR (2) CHANGE SLOWLY
TO A NEW LEVEL ?1

DO YOU ASSUME STANDARD BIRTH DISTRIBUTION (1=YES,0=NO) ?1

DO YOU ASSUME STANDARD SEX RATIO (1=YES,0=NO) ?1

DO YOU ASSUME STANDARD MORTALITY (1=YES,0=NO) ?1

DO YOU ASSUME STANDARD POPULATION (1=YES,0=NO) ?1

REPORT:1)SHORT 2)LONG 3)GRAPH 4)CHANGE ASSUMPTIONS 5)END ?1

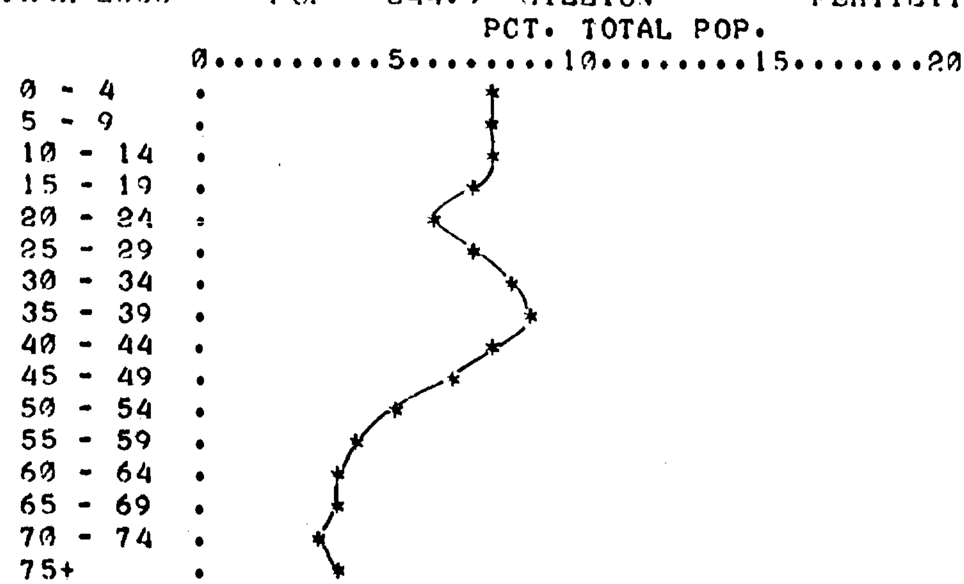
YEAR 1975      POP=  204.8  MILLION        FERTILITY 2
YEAR FOR NEXT REPORT ?1990

REPORT: ?1

YEAR 1990      POP=  228.5  MILLION        FERTILITY 2
YEAR FOR NEXT REPORT ?2000

REPORT: ?3

YEAR 2000      POP=  244.9  MILLION        FERTILITY 2
```



b) Effect of Fertility

Figure 2 Sample Run of USPOP

```
MILLIKAN OIL DROP EXPERIMENT

INSTRUCTIONS (1=YES, Ø=NO) ?1

INSTRUCTIONS -- AFTER EACH QUESTION MARK, (V=  ?), YOU MAY:

TYPE IN VOLTAGE BETWEEN -1ØØØ AND 1ØØØ (IN ORDER TO MAKE
THE VELOCITY PRINTED OUT AS CLOSE TO ZERO AS POSSIBLE),
REQUEST CALCULATION OF CHARGE FOR STOPPED DROP (TYPE IN 2ØØØ),REQUEST NE
W BATCH OF DROPS (TYPE IN 3ØØØ),
OR END THE PROGRAM (TYPE IN 4ØØØ).


             NO ELECTRIC FIELD

DROP:        1              2              3              4
             ---            ---            ---            ---
  VELOCITY
(METERS/SEC)
( X  1Ø↑-6 )
             -3Ø.4          -3Ø.3          -29.8          -3Ø

V= Ø    ?1ØØ
              2.6           -2             -1Ø.8          -3Ø

V= 1ØØ    ?97
              1.6           -2.8           -11.3          -3Ø

V= 97    ?93
              Ø.3           -3.9           -12.1          -3Ø

V= 93    ?94
              Ø.6           -3.7           -11.9          -3Ø

V= 94    ?92
             -Ø.1           -4.2           -12.3          -3Ø

V= 92    ?92.1
              Ø             -4.2           -12.3          -3Ø

V= 92.1    ?2ØØØ

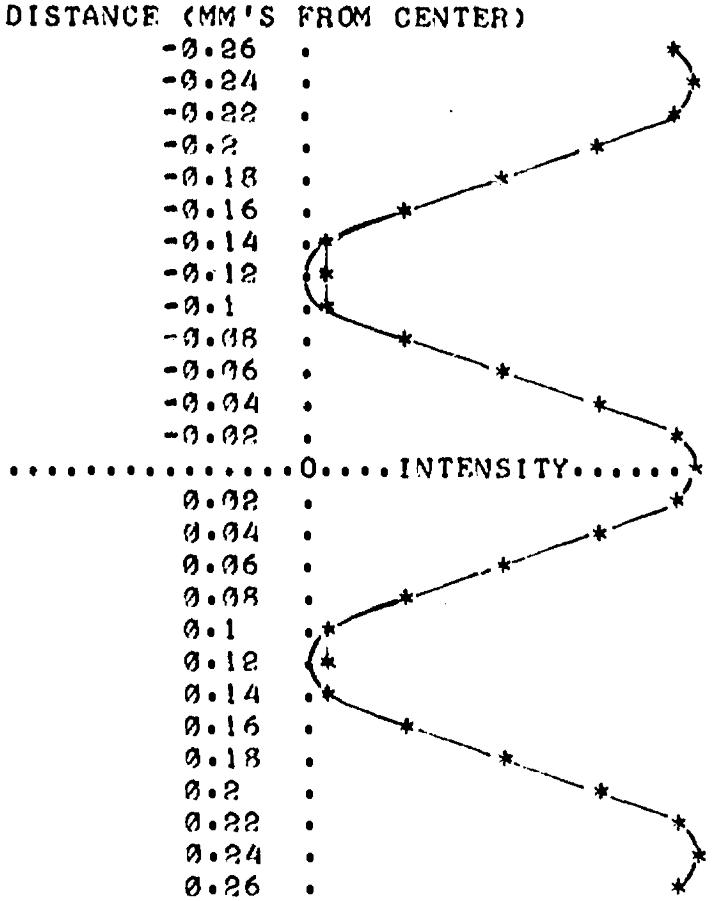
CALCULATION FOR WHICH DROP ?1

CHARGE ON DROP 1  IS 11.14  X 1Ø↑-19 COULOMBS.
```

Figure 3 Sample Run of CHARGE

YOUNG'S DOUBLE SLIT EXPERIMENT

L = 2 METERS   W = 6000 ANGSTROMS   D = 0.5 MILLIMETERS



ABOVE IS AN ILLUSTRATIVE RUN WITH PRE-DETERMINED VALUES FOR WAVELENGTH (W), DISTANCE BETWEEN SLITS AND SCREEN (L), AND SLIT SEPARATION - CENTER TO CENTER (D). NOW YOU MAY VARY THESE PARAMETERS, ONE AT A TIME.

a) Basic Interference Pattern

Figure 4 Sample Run of SLITS

```
*****

WHAT IS THE NEW SLIT SEPARATION (D) IN MILLIMETERS ?.25

L = 2 METERS     W = 6000 ANGSTROMS     D = 0.25 MILLIMETERS

DISTANCE (MM'S FROM CENTER)
        -0.26  .*
        -0.24  .*
        -0.22  .*
        -0.2   .*
        -0.18  .  *
        -0.16  .    *
        -0.14  .      *
        -0.12  .         *
        -0.1   .            *
        -0.08  .              *
        -0.06  .                *
        -0.04  .                  *
        -0.02  .                   *
...............O....INTENSITY......*
         0.02  .                   *
         0.04  .                  *
         0.06  .                *
         0.08  .              *
         0.1   .            *
         0.12  .         *
         0.14  .      *
         0.16  .    *
         0.18  .  *
         0.2   .*
         0.22  .*
         0.24  .*
         0.26  .*

WOULD YOU LIKE TO TRY ANOTHER VALUE OF D (1-YES, 0-NO) ?0
```

b) Effect of SLIT Separation

Figure 4 Sample Run of SLITS

```
*****

WHAT IS THE NEW DISTANCE FROM SLITS TO SCREEN (L) IN METERS ?.5

L = 0.5 METERS    W = 6000 ANGSTROMS    D = 0.5 MILLIMETERS

DISTANCE (MM'S FROM CENTER)
        -0.26  .    *
        -0.24  .                   *
        -0.22  .    *
        -0.2   .    *
        -0.18  .                   *
        -0.16  .    *
        -0.14  .    *
        -0.12  .                   *
        -0.1   .    *
        -0.08  .    *
        -0.06  .                   *
        -0.04  .    *
        -0.02  .    *
..............O....INTENSITY......*
         0.02  .    *
         0.04  .    *
         0.06  .                   *
         0.08  .    *
         0.1   .    *
         0.12  .                   *
         0.14  .    *
         0.16  .    *
         0.18  .                   *
         0.2   .    *
         0.22  .    *
         0.24  .                   *
         0.26  .    *
```

c) Effect of Screen Separation

Figure 4 Sample Run of SLITS

```
*****

WHAT IS THE NEW WAVELENGTH (W) IN ANGSTROMS ?3ØØØ

L = 2 METERS     W = 3ØØØ ANGSTROMS     D = Ø.5 MILLIMETERS

DISTANCE (MM'S FROM CENTER)
        -Ø.26  .              *
        -Ø.24  .                   *
        -Ø.22  .              *
        -Ø.2   .    *
        -Ø.18  .*
        -Ø.16  .    *
        -Ø.14  .              *
        -Ø.12  .                   *
        -Ø.1   .              *
        -Ø.Ø8  .    *
        -Ø.Ø6  .*
        -Ø.Ø4  .    *
        -Ø.Ø2  .              *
...............O....INTENSITY......*
         Ø.Ø2  .              *
         Ø.Ø4  .    *
         Ø.Ø6  .*
         Ø.Ø8  .    *
         Ø.1   .              *
         Ø.12  .                   *
         Ø.14  .              *
         Ø.16  .    *
         Ø.18  .*
         Ø.2   .    *
         Ø.22  .              *
         Ø.24  .                   *
         Ø.26  .              *

WOULD YOU LIKE TO TRY ANOTHER VALUE OF W (1-YES, Ø-NO) ?Ø
```

d) Effect of Wavelength

Figure 4 Sample Run of SLITS

```
DO YOU WANT INSTRUCTIONS(TYPE 1 FOR YES, 0 FOR NO) ?1

MARKET SIMULATES THE COMPETITION BETWEEN TWO COMPANIES
SELLING A PRODUCT DIFFERENTIATED BY BRAND ADVERTISING.
THE QUANTITY EACH COMPANY SELLS IS DEPENDENT UPON PRICE
AND ADVERTISING BUDGET. THE GAME ENDS WHEN ONE
COMPANY GOES BANKRUPT OR REACHES  12  MILLION IN
TOTAL ASSETS.

ARE YOU BEGINNING THE GAME OR CONTINUING
(TYPE 1 FOR BEGINNING, 2 FOR CONTINUING) ?1


FIXED PRODUCTION COST= 250000  DOLLARS/QUARTER
VARIABLE PRODUCTION COST= 20  DOLLARS/UNIT
WITH NO ADVERTISING AND A SELLING PRICE OF 50 DOLLARS/UNIT
A COMPANY WILL SELL  25000  UNITS (PRINTED AS  25 )
WAREHOUSE CHARGE FOR INVENTORY= 5  PER CENT
INTEREST CHARGE ON BORROWED MONEY= 5  PER CENT



UNITS AND DOLLARS BELOW ARE IN THOUSANDS


QUARTER  0

PROFIT  MARKET SHARE  CASH ON HAND  NUMBER SOLD  INVENT.  ASSETS
 0       0             5000          0            100      7000
 0       0             5000          0            100      7000



COMPANY  1
PRODUCTION LEVEL ?10
ADVERTISING BUDGET ?500
UNIT PRICE ?55


COMPANY  2
PRODUCTION LEVEL ?10
ADVERTISING BUDGET ?0
UNIT PRICE ?50


QUARTER  1

PROFIT  MARKET SHARE  CASH ON HAND  NUMBER SOLD  INVENT.  ASSETS
 760     64.28         6460          45           65       7760
 415     35.71         5715          25           85       7415
```

a) Instructions and Quarter 1

Figure 5 Sample Run of MARKET

BEST COPY AVAILABLE

```
COMPANY  1
PRODUCTION LEVEL ?10
ADVERTISING BUDGET ?500
UNIT PRICE ?52.50


COMPANY  2
PRODUCTION LEVEL ?30
ADVERTISING BUDGET ?400
UNIT PRICE ?53


QUARTER  5

PROFIT  MARKET SHARE  CASH ON HAND  NUMBER SOLD  INVENT.  ASSETS
 700       53.57          9356           45          41     10217
 603       46.42          8550           39          64      9894

THE PRESIDENT HAS JUST IMPOSED A WAGE-PRICE FREEZE ON THE
ECONOMY, AND YOU MAY NOT RAISE THE PRICE OF YOUR PRODUCT
OVER THE NEXT 2 QUARTERS.




COMPANY  1
PRODUCTION LEVEL ?30
ADVERTISING BUDGET ?400
UNIT PRICE ?55


COMPANY  2
PRODUCTION LEVEL ?60
ADVERTISING BUDGET ?500
UNIT PRICE ?53


QUARTER  8

PROFIT  MARKET SHARE  CASH ON HAND  NUMBER SOLD  INVENT.  ASSETS
 570       45.67         11080           37          36     11836
 606       54.32         10808           44          49     11837

COMPANY 2  HAS SUFFERED FIRE DAMAGE IN ITS WAREHOUSE
ALL UNITS WERE DESTROYED. YOUR INSURANCE WILL REIMBURSE YOU
IN THE AMOUNT OF 771  DOLLARS FOR THESE UNITS

NEW LABOR CONTRACT - VARIABLE PRODUCTION COST NOW= 22  DOLLARS/UNIT
```

b) Quarters 5 and 8

Figure 5 Sample Run of MARKET