DOCUMENT RESUME

ED 081 399 HE 004 586

AUTHOR	Smith, Donovan E.; Wagner, W. Gary
TITLE	SPACE: Space Planning and Cost Estimating Model for Higher Education.
INSTITUTION	California Univ., Berkeley. Ford Foundation Program for Research in Univ. Administration.
SPONS AGENCY	Ford Foundation, New York, N.Y.
REPORT NO	Pap-P-34
PUB DATE	Jul 72
NOTE	83p.
AVAILABLE FROM	Ford Foundation, 2288 Fulton Street, Berkeley, California 94720 (single copies free)
EDRS PRICE	MF-$0.65 HC-$3.29
DESCRIPTORS	Administrative Problems; *Computer Programs; Costs; Educational Finance; *Estimated Costs; *Facility Utilization Research; *Higher Education; Models; *Operating Expenses; Planning (Facilities); Scheduling; Simulation; Space; Space Utilization

ABSTRACT

This paper presents SPACE, a space planning and cost estimating simulation model designed to allow analysis of alternative class scheduling patterns and their consequent resource demands. Several illustrative examples of the model's use are given, with documentation of the validation procedures using data from the University of California. The examples show that changes in class scheduling patterns have no significant effect on total operating and capital costs. A listing of the computer program and the input data specifications are included in the appendix. (Author)

FORD FOUNDATION PROGRAM FOR RESEARCH IN UNIVERSITY ADMINISTRATION

Office of the Vice President—Planning
University of California

FORD GRANT NO. 680-0267A

RESEARCH DIRECTORATE

Charles J. Hitch — President, University of California

Frederick E. Balderston — Professor of Business Administration
Chairman, Center for Research in Management Science
University of California, Berkeley
Academic Assistant to the President

OFFICE ADDRESS

2288 Fulton Street
Berkeley, California 94720
(415) 642-5490

SPACE: SPACE PLANNING AND COST ESTIMATING MODEL FOR HIGHER EDUCATION

Donovan E. Smith

W. Gary Wagner

Paper P-34

July, 1972

TABLE OF CONTENTS

PREFACE

This is one of a continuing series of reports of the Ford Foundation sponsored Research Program in University Administration at the University of California, Berkeley. The guiding purpose of the Program is to undertake quantitative research which will assist university administrators and other individuals seriously concerned with the management of university systems both to understand the basic functions of their complex systems and to utilize effectively the tools of modern management in the allocation of educational resources.

In this paper we present SPACE, a Space Planning And Cost Estimating simulation model designed to allow analysis of alternative class scheduling patterns and their consequent resource demands. Several illustrative examples of the model's use are given, with documentation of the validation procedures using data from the University of California. The examples show that changes in class scheduling patterns have no significant effect on total operating and capital costs. A listing of the computer program and the input data specifications are included in the Appendix.

This research was initiated and conducted in the Office of the Vice President--Planning of the University of California and was partially supported by the California Coordinating Council for Higher Education. The authors wish to express their gratitude to Leonard Jay Jacobson of Mathematica for patient counsel which resulted in the avoidance of many pitfalls; to Maggie Hardy; and to John Lafler, whose many insights and ingenious "mathemachinations" greatly improved the initial design, and whose programming of the FAMSIX module made the whole thing possible.

LIST OF FIGURES AND TABLES

INTRODUCTION

A 1970 resolution by the California legislature called for an extraordinary increase in classroom utilization by the University of California and the California State Colleges. The California Coordinating Council for Higher Education (CCHE) sought to develop an objective mechanism for establishing realistic utilization standards with appropriate consideration of any demonstrable effects on both operating and capital costs. Mathematica, Inc., undertook and completed a mammoth mathematical modelling effort under severe time constraints.[1] Unfortunately, the Facilities Analysis Model (FAM) was not sufficiently flexible to allow detailed analysis of the alternatives under consideration. The SPACE project began as an attempt to modify FAM to be more accurate and more useful to physical planners in higher education.

The University's efforts at modification were soon abandoned as unworkable, and a new model called SPACE (Space Planning And Cost Estimating) was developed, drawing heavily on Mathematica's experiences but differing substantially in several fundamental respects. As a result the SPACE model is in operation at the University and, with a few modifications, is being prepared for implementation by the California State University and Colleges' Office of Analytic Studies.

SPACE is a computerized simulation model designed to provide planning data for managers of institutions of higher education. It is primarily concerned with the physical facilities for departments of instruction and research. SPACE relates enrollments, class scheduling policies, class

[1]Mathematica, Inc., "The CCHE Facilities Analysis Model," Vols. I-IV, Princeton, New Jersey, December 1970.

size policies, and faculty workload policies to physical resource needs and the resulting utilization rates of classrooms and class laboratories. SPACE also computes the faculty needs, the associated current costs, and converts the capital costs to comparable annual costs.

In its present stage of development, SPACE is confined to the "I&R" departments and thus cannot serve all the planning needs met by RRPM or CAMPUS. On the other hand, its moderate size and its concentration on physical resources provide an easily manageable tool for answering a significant number of what-if questions at a level of detail not available in the more general models. Furthermore, to our knowledge, SPACE is the only operational model with the capability of simulating both the time scheduling of classes and the assignment of classes to instructional rooms. As a tool for University planning SPACE can help improve the physical planning process by augmenting and refining the calculations of facilities needs--calculations frequently made without explicit consideration of such factors as class size policies and faculty workload policies.

It is with regard to these functional policy alternatives that SPACE should prove most useful. Typical what-if questions within the domain of SPACE include:

1. What if class schedules are extended beyond the normal daytime hours?
2. What if faculty workloads and/or staffing patterns are changed?
3. What if a specific new program is added (or a specific existing program is eliminated) at a particular campus?
4. What if classes larger (and/or smaller) than certain sizes are eliminated in certain (or all) programs?

Answering such questions in terms of the probable effects on resource requirements is a fundamental role of both statewide and campus academic and facilities planners. SPACE can reduce the staff effort and time required to perform these calculations and should also substantially improve the accuracy of the answers.

MODEL DESCRIPTION

Model Overview

SPACE is composed of two separate modules, FAMSIX and VARICOS, each of which is written in FORTRAN IV. The modules can be run separately or in tandem, with FAMSIX providing a machine-readable file for use as input to VARICOS.

FAMSIX performs sequentially the 6 basic operations listed below. These are repeated for each year of the planning horizon. In its current form, the maximum number of years in the planning horizon is 10.

1. A Gaussian pseudo-random number generator operates on weekly student hour input to produce a preliminary total of weekly room hours. The level of aggregation is class size range, discipline, class type (lab or non-lab), and course level.
2. Classes are assigned to hours of the week according to a priority schedule which reflects the user's preferences for the distribution of class hours. (Note: Classes are treated as integral units in that no fractional class hours are generated.)
3. The effects of scheduling on average class size (time-preferences) are computed using a combination of linear and exponential relationships. The initial distribution of classes to class size ranges is adjusted to account for this phenomenon while keeping the original total of weekly student hours intact.
4. Classes of each size are assigned to rooms of appropriate sizes by a randomization routine governed by user-defined parameters.
5. For each hour of the week, the current inventory of classrooms and class labs is compared to needs. If rooms are needed but not available, the inventory is checked for the availability of rooms which are larger than required and the overflow is assigned where possible. If there are no larger rooms available, or if there is an inadequate number, rooms of the appropriate type and size are "constructed."

PREFACE

This is one of a continuing series of reports of the Ford Foundation sponsored Research Program in University Administration at the University of California, Berkeley. The guiding purpose of the Program is to undertake quantitative research which will assist university administrators and other individuals seriously concerned with the management of university systems both to understand the basic functions of their complex systems and to utilize effectively the tools of modern management in the allocation of educational resources.

In this paper we present SPACE, a Space Planning And Cost Estimating simulation model designed to allow analysis of alternative class scheduling patterns and their consequent resource demands. Several illustrative examples of the model's use are given, with documentation of the validation procedures using data from the University of California. The examples show that changes in class scheduling patterns have no significant effect on total operating and capital costs. A listing of the computer program and the input data specifications are included in the Appendix.

This research was initiated and conducted in the Office of the Vice President---Planning of the University of California and was partially supported by the California Coordinating Council for Higher Education. The authors wish to express their gratitude to Leonard Jay Jacobson of Mathematica for patient counsel which resulted in the avoidance of many pitfalls; to Maggie Hardy; and to John Lafler, whose many insights and ingenious "mathemachinations" greatly improved the initial design, and whose programming of the FAMSIX module made the whole thing possible.

6. Utilization statistics are computed for each classroom size and for each class lab size, the class labs being further distinguished by discipline and level.

VARICOS is basically an accounting module with 4 component operations which are repeated for each year of the planning horizon:

1. Weekly room hours (generally but not necessarily from FAMSIX) and enrollment projections are operated on by functions defined in terms of workload and other parameters to compute faculty staffing needs by rank.
2. Faculty office and research space needs are computed along with the associated support space needs. These needs are compared to the existing inventory and new space is "built" where needed.
3. Faculty salaries, support costs, and facilities maintenance and operating costs are computed.
4. Two kinds of capital costs are computed. The first are project costs, i.e., what is commonly called total capital outlay. The second set of costs are the annual cash flow needed from the State or other funding agency. It is assumed that physical facilities are financed by the issuance of bonds, and that the issues are sequenced according to the costs incurred during the planning and construction period (i.e., the 4 years prior to the first usage of the facility).

FAMSIX - Module Description

This section details the operating logic of the six components of the FAMSIX module described briefly above. These calculations are repeated for each iteration of the test run. A program flow chart is included to assist the reader in understanding the sequencing of the components and their interrelationships within the model. The underlying mathematics are not spelled out, but examples are provided to give the reader a feel for the processes involved. An attempt has been made to provide enough detail so that a programmer examining the program code will have adequate guidelines but not so much that the non-technician will be bogged down.

The Generation of Initial Weekly Class Hour Totals from Weekly Student Hour Inputs

FAMSIX is driven by Lab and Non-lab Weekly Student Hour inputs. (These are displayed at the user's option in Table 101.) Historically the distribution of WSH for any given discipline and course level varies greatly across class sizes, both for Non-lab and for Lab classes. Since it is impossible to predict with certainty these distributions, FAMSIX operates under the assumption that the proportion of WSH in each of the 15 class size ranges varies normally for any category. It further assumes that the average class size in each class size range is constant.

Thus, for each discipline, course level, and class type, FAMSIX calculates the proportion of WSH in each class size range by a Gaussian pseudo-random number generator. For each category, the random number generator is given the mean proportion and the standard deviation for each class size range. It returns the proportion of WSH in the class size range (set equal to zero if negative). Since the 15 proportions thus determined generally will not sum to 1.0, they are scaled proportionately until they do sum to 1.0. The resulting proportions are then multiplied by the total WSH for the category to determine the number of WSH in each class size range.

Each of these numbers is then divided by the (fixed) average class size in the respective class size range to give initial numbers of Weekly Class Hours. Since the average class size generally will not exactly divide the number of WSH, the resulting WCH figures are rounded. These "integerized" WCH numbers are the numbers on which FAMSIX continues to operate. They are not the final numbers of Weekly Room Hours. They are displayed at the user's option in Table 211 (Non-Lab) and in Table 212 (Lab).

Note that if desired the mean values for class size distribution may be chosen to be negative inputs. In such cases, the category will have extremely different class size distributions from one iteration (year) to the next, and may even disappear in some iterations. This is a useful device for a category (discipline, level, and class type) in which such extreme variation is characteristic, either in fact or because the data are reported inconsistently.

The Assignment of Weekly Class Hours to Hours of the Week

The assignment of Weekly Class Hours to the hours of the week is made through the mechanism of a "priority schedule." There is a separate schedule for each class type (Lab and Non-lab). The priority schedule associates with each hour of the week zero, one, or more priority numbers. The relative number of such priority numbers associated with each hour represents the relative distribution of class hours to the hours of the week. The size of the priority numbers associated with any hour reflects the degree of preference for classes in that hour. Thus, if the 37th hour is assigned one priority number and the 1st hour is assigned 5 priority numbers, class hours will be scheduled into the 1st hour 5 times as often as they are scheduled into the 37th hour. Furthermore, if the priority number assigned to the 37th hour is large, e.g., 110, and if the set of priority numbers assigned to the 1st hour includes smaller values, e.g., 1, 15, 70, 105, and 116, then the 1st hour will tend to have larger classes scheduled in it than will the 37th hour.

The mechanism works like this: There are (in the model) 96 possible hours of operation in a week. There are 250 possible priority numbers, p , of which n are chosen to be associated with the 96 hours ($p = 1, 2, \ldots, n$; $n \leq 250$). FAMSIX treats the class hours as if they were ordered in a long list beginning with the largest classes and ending with the smallest. Within each class size range the class hours are ordered by course level and within course level by discipline. Then for hour h , with priority number p , the p^{th} class hour in the list and every n^{th} class hour in the list thereafter are scheduled for hour h . In the example above, if n were 200, hour 1 would receive the 1st, 201st, 401st,... class hours in the list. It would also receive the 15th, 215th, 415th,...; the 70th, 270th, 470th,...; the 105th, 305th, 505th,...; and finally the 116th, 316th, 516th,... class hours in the list. Hour 37 on the other hand would receive only the 110th, 310th, 510th,... class hours. Clearly the 37th hour will receive approximately one-fifth as many class hours as the 1st hour. Because of the ordering of the list from large classes to small, the 37th hour will also receive smaller classes on average than the 1st.

The Effects of Scheduling on Average Class Size - "Hour-Size Function"

Historical data gathered at the University reveal that, *ceteris paribus*, class size varies according to the hour at which the class is scheduled and the number of classes which are scheduled in the hour. Most classes would attract fewer students at 6 p.m. than at 10 a.m., and fewer on Saturday than on Monday. Furthermore, it is obvious that if a great many classes are offered in any hour, the last one scheduled will be smaller than it would have been if it had been scheduled at an equally attractive hour in which fewer classes were scheduled. This is true because some of the students who would otherwise be attracted to the class are more likely to have enrolled in other classes offered at that hour.

FAMSIX simulates this effect by altering the average class size in any given hour according to the "hour-size function." This function relates the expected average class size to an altered average class size by multiplying the expected size by a factor f . The product is the altered average class size. The factor f is determined by the following function:

$$f = c \cdot p^y;$$

where:

c = a scalar multiplier which is a function of the hour in question,

p = the proportion of WSH in the given hour, and

y = some exponent.[2]

The application of the function to the Weekly Class Hours generated by FAMSIX is somewhat complicated since FAMSIX assumes that the average class size in each class size range is fixed. Furthermore, it is not desirable to increase or decrease the total number of WSH appreciably. Consequently,

---

[2] The problem of determining reasonable values for c and y can be greatly simplified by the following procedure:

1) Set y equal to some value near -0.25. This value has been shown to be reasonable for U.C. studies.
2) Determine the approximate proportion of weekly student hours in each hour of the week according to the way classes are actually scheduled.
3) Solve

$$f = 1.0 = c\ p^y$$

for c for each hour. For the actual schedule, the function should leave class size unchanged. (Presumably the class-size-distribution inputs are derived from actual data.) Thus, using actual proportions, cp^y should equal 1.0.

FAMSIX leaves the number of WSH in each hour intact and changes the distribution of classes to the class size ranges. The net effect is that the number of class hours is altered so that the average class size over all class size ranges is increased or decreased by the factor f . This new number of class hours is then distributed to the disciplines and levels in the same proportions as the original number of class hours. Care is taken so that the number of weekly student hours within a discipline and level is not altered appreciably by this process.

Example

Suppose that there are only 3 class size ranges and that the fixed average sizes in those ranges are 10, 15, and 20. Further assume that for the hour in question the factor f = 1.15, and the initial distribution of class hours is as in the table below.

Size 1 (10)	Size 2 (15)	Size 3 (20)	Weekly Student Hours	Average Class Size
15	20	0	450	12.86

FAMSIX first changes the 20 classes of size 2 (i.e., 15 students each) so that the average will be, as nearly as possible, 15 x 1.15 = 17.25, retaining closely the 300 WSH generated by the original 20 classes of 15 students each.

Size 1	Size 2	Size 3	WSH	ACS
	9	8	295	17.35

FAMSIX then notes that it is 5 WSH short. Adding these to the 150 generated by the size 1 classes, it changes these 15 class hours so that the average will be nearly 10 x 1.15 = 11.5.

Size 1	Size 2	Size 3	WSH	ACS
9	4		150	11.5

Nothing could be done with the 5 WSH, so they are lost. (The greatest error in this process is a gain or loss of 1/2 the fixed average class size of the smallest class size range.)

The net effect of these changes is summarized below.

Size 1	Size 2	Size 3	WSH	ACS
9	13	8	445	14.8

The altered average class size target was 1.15 x 12.86 = 14.8 . Note that the initial number of class hours is 35. The final number determined by the hour-size function is 450/14.8 = 30 .

Assignment of Classes to Rooms

Each quarter or semester, some time before students enroll in their courses, departments determine their course offerings and the campus Registrar (or other class scheduling agency) must determine the facilities to be reserved for those courses. Using departmental predictions and past experience as guides, the Registrar is able to make some estimates of the class sizes which will be generated by those courses. Since it is generally impossible to determine the exact course enrollments and class sizes, the distribution of actual classes to class size ranges will differ from the predicted distribution. In an effort to minimize the amount of facilities reassignment, the Registrar will generally try to provide rooms so that classes which turn out to be larger than expected will seldom have to be reassigned to other facilities. The effect of this hedge against possible chaos is some "looseness" in the relationship of the sizes of the classes to the sizes of the rooms to which those classes are assigned.

FAMSIX simulates this effect in two stages. The first stage is accomplished with the help of the pseudo-random number generator. For each class size range, the probability distribution of classes to room size ranges is an input to the model. Each class hour generated via the hour-size function routine is associated with a "request" for a room (classroom in the case of non-lab classes and class lab in the case of lab classes.)

The size of the room is determined by the random number generator operating on the distribution parameters.

Each class hour is treated separately so that fractions of classes are not associated with room "requests." For example, suppose:

0.25 = probability that class of size 3 is associated with room of size 3;

0.75 = probability that class of size 3 is associated with room of size 4; and

5 = number of class hours of size 3 generated in some hour.

A strict application of the probabilities would yield 1.25 classes assigned to rooms of size 3, and 3.75 classes assigned to rooms of size 4. Since FAMSIX treats class hours as integral units, such a method is inadequate. FAMSIX, in fact, could assign all 5 classes to rooms of size 4, or all 5 to rooms of size 3. On average, however, 1/4 of all classes (across all hours and years) of size 3 would be associated with requests for rooms of size 3 and the rest with rooms of size 4.

For reasons which will become obvious after reading the next section, the parameters of the class-size-to-room-size distributions should not be identical to historical distributions. Rather, they should reflect the Registrar's effort to avoid chaos in logically identifying room size requests with predictions of class sizes. Thus, if it were possible to know class sizes with certainty before making room assignments, the most reasonable distribution would assign a class of size x to a room of size x with probability 1.

Spill-Up and New Construction

The second stage of the class to room assignment routine is the "spill-up" operation. For each hour of the week the room requests are compared with the current inventory, beginning with the requests for the largest rooms. If the inventory is inadequate to the needs for a particular room size, rooms of larger sizes are made available if they have not already been claimed. If rooms are still needed after the search has been made for unclaimed rooms of that size or larger, the model "builds" them, and they are added to the inventory. It is this spill-up process that requires the class-size-to-room-size distribution discussed above to be a theoretical distribution. Some spilling up occurs in fact and would be reflected in a historically derived distribution. Using the historical distribution would, therefore, result in spilling-up twice.

FAMSIX has one category of classrooms, and thus assumes that any non-lab class can be assigned to any classroom, provided only that the room is large enough. This assumption is not, of course, entirely realistic because some classrooms should have special facilities for certain non-lab classes--e.g., lecture-demonstration facilities for certain science lecture classes--and those specific classes should be assigned to those rooms, even if some of those classes are much smaller than the room. But it is impractical to include the capability of simulating those and other realistic complexities in FAMSIX's handling of non-lab classes, not only because the computer core requirements would be greatly increased, but also because the input data requirements would be inordinately large. Presumably, however, this simplification does not cause the classroom requirements computed by FAMSIX to be significantly different from those which would be generated by the more "realistic" model, at least in terms of the total required floor area.

Lab classes are treated differently than non-lab classes. A lab class must be assigned to a class lab appropriate to the particular level and discipline of the class. Thus, all Arts lab classes are assigned to Arts class labs. Currently, there is a similar one-to-one relationship for the level of the class and the level of the laboratory. This identity is a proxy for the real-life non-interchangeability of labs between sub-disciplines of a given discipline and some non-interchangeability among levels. Future versions of the model will allow lab classes of level x to be assigned to class labs of level y , providing that level y is at least as high as level x .

The final distribution of classes by size to rooms by size for each hour is displayed in Tables 401 (Non-lab) and 402 (Lab) at the user's option.

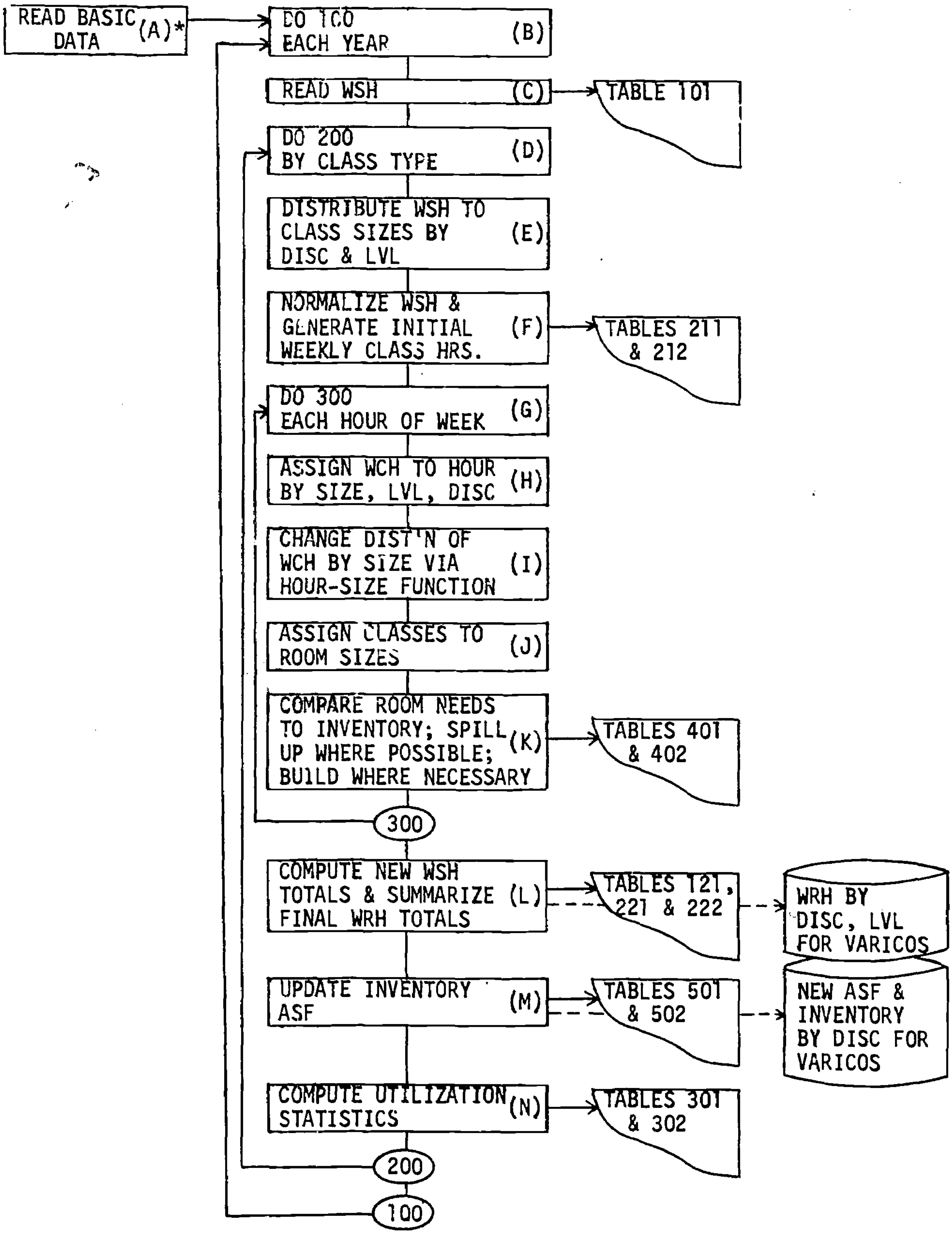
Utilization Statistics and VARICOS Interface

After all preceding steps are completed for all hours of the week, summary data are computed. Table 121 displays the final totals of WSH by level, discipline, and class type. These are computed by multiplying the final numbers of WCH (now identified as Weekly Room House, WRH) in each class size range by the fixed average class size in that range.

The final numbers of WRH for each discipline and level by class size are displayed in Tables 221 (Non-Lab) and 222 (Lab). The summary of these data, excluding class size information, is stored externally for use by VARICOS. The construction necessary to meet room requests is displayed in Tables 501 (Non-lab) and 502 (Lab). The classrooms to be constructed for use in the year in question are distinguished by size only. The labs

FIGURE 1

FAMSIX - Program Flow Chart



*Letters (A) - (N) are referenced in program listing. See Appendix.

are further distinguished by discipline and level.

The inventory of assignable square feet is calculated along with the ASF of newly completed space. This information is tagged by level and discipline for class labs. Classrooms are arbitrarily identified with Discipline #1. The ASF data are also stored externally for use by VARICOS.

Tables 301 (Non-lab) and 302 (Lab) are the final outputs of FAMSIX. They are displays of summary utilization rates for each room size and in total. (The information is further disaggregated into disciplines and levels for laboratory utilization summaries). The information displayed separately for classrooms and class labs includes the current inventory of rooms and stations, the number of WRH, WRH per room, Unweighted Station Occupancy, WSH per station, ASF per station, and ASF per WSH.

VARICOS - Module Description

This section details the operating logic of the four components of the VARICOS module described briefly in the model overview. These components are repeated for each iteration (year) of the test run. The general level of detail corresponds to that of the FAMSIX module description.

Faculty Requirements

Faculty needs are generated from enrollment projections, Lab and Non-lab weekly class hours (i.e., the weekly room-hours determined by FAMSIX), and a combination of student-faculty ratios and workload parameters. The routine provides for special handling of Teaching Assistants because of the important instructional role played by T.A.'s at the University of California.

VARICOS computes four categories of faculty: T.A.'s and 3 categories (not necessarily ranks) of non-T.A. faculty. The non-T.A. faculty will be referred to as "regular" faculty in this description. The computation takes place in four steps.

Step 1: Dividing the Workload

FAMSIX provides VARICOS with the number of WRH in each class type, course level, and discipline. VARICOS inputs include the proportion of WRH taught by T.A.'s and the proportion taught by regular faculty in each category of WRH. These proportions are applied to the appropriate WRH figures to give the number of WRH in each category which are taught by T.A.'s and the number which are taught by the regular faculty.

Step 2: Assigning FTE to the Workload

VARICOS inputs also include the number of Weekly Faculty Contact Hours (WFCH) per FTE, separately for T.A.'s and regular faculty, in each of the WRH categories. The division of T.A.-taught WRH by the workload parameter (WFCH/FTE-TA) in each category gives the number of T.A.'s needed. The same operation using regular faculty workload parameters provides a partial total of regular faculty needed. Additional regular faculty can be generated on the basis of T.A. supervision requirements. For each discipline and class type the supervision factor, regular faculty FTE per T.A. FTE, is multiplied by the number of T.A.'s generated and the product is then added to the regular faculty subtotal.

Step 3: Generating Faculty via Enrollments

Additional regular faculty may be generated from student-faculty ratios for each of the four student levels. Enrollments by level and major are multiplied by these ratios and the products added to the subtotals from Step 2. Step 3 thus serves two functions: first, it may be used as the basis for generating faculty strictly from enrollments by setting the workload parameters to zero; and, secondly, it may be used to augment the faculty generated from workload factors on the assumption that students generate a need for faculty to supervise independent study or other work not reflected in the WRH figures.

Step 4: Distributing the Regular Faculty to Ranks

For each discipline, the proportions of regular faculty in each of the 3 ranks (or other categories) are data inputs. These proportions are applied to the regular faculty discipline total to give, with the T.A. figures, the final numbers of faculty in each rank and discipline.

Office and Research Space

There are 5 types of space requirements computed by VARICOS and FAMSIX: 1) Classrooms; 2) Class labs; 3) Research labs; 4) Offices; and 5) Support space. The assignable square feet of the inventory and of the newly completed space are compiled separately. FAMSIX provides the figures for the first two space types and VARICOS computes the figures for the last three. In each non-class type of space, space-standards parameters are used to determine the space needs. The needs are compared to the current inventory. If the inventory is inadequate, the additional space needed is noted and added to the inventory. Each discipline has its own space and hence its own standards.

Research space requirements are computed as:

(ASF/Regular faculty) x (Regular faculty) + (ASF/TA) x (TA's) + (ASF/Level 3 majors) x (Level 3 majors) + (ASF/Level 4 majors) x (Level 4 majors).

Normally, student majors of levels 3 and 4 are identified with first and second stage graduate students.

Office space needs are computed according to the same formula, substituting the appropriate space-standards parameters.

Support space requirements are computed as:

(ASF/Total Research & Office ASF) x (Total Research & Office ASF) + (ASF/Total class lab ASF) x (Total class lab ASF).

Faculty Salaries, Support, M&O-Plant

Because FAMSIX and VARICOS are primarily intended to provide planning data related to class scheduling, no attempt has been made to compute total operating costs. VARICOS therefore concentrates on those variable costs which are most directly related to scheduling and to class-size policies, viz., faculty salaries, departmental support, and physical plant maintenance and operation.

Currently these computations are somewhat crude. Salaries are computed for each rank and discipline by multiplying the average salaries for each rank by the appropriate FTE figures. For each discipline the departmental support per regular faculty FTE is a data input. This parameter is multiplied by the regular faculty FTE to get the support costs. There is a single M&O-Plant factor for all types of space. The total M&O cost is the product of this parameter and the total inventory ASF.

All dollar figures are "constant salary dollars," i.e., faculty salaries and support costs are not inflated. M&O costs and construction costs are inflated, however, since these costs have been rising more rapidly than faculty salaries. The difference between the two actual rates of inflation is the inflation factor applied to the space costs.

Capital Costs and Outlay

For each space type and discipline, the capital outlay per additional ASF is a data input. For each year of the run, these parameters are applied to the newly completed ASF to give the capital outlay generated. Since planning and construction generally occur over a 4-year period prior to occupation, the capital outlay is spread back over the four years prior to the year the facility is first added to the inventory.

The outlay amounts, however, are not directly comparable to the salary, support, and M&O cost figures since they actually reflect a multi-period cash flow from the funding agency. VARICOS assumes that all of the facilities construction is financed through the issue of bonds and that the issues are sequenced according to the pattern of cost incidence during the planning and construction period. Therefore, the outlay figures are distributed over the four-year period preceding the first occupation of the facility and bonds are issued to meet those costs as they are incurred. The debt-servicing of the bonds represents the economic costs of capital construction which are most appropriately compared to the operating costs already computed. It is the debt-service payments, therefore, which are displayed for each year of the test run, along with the operating costs, in Table C. For each iteration, Table B displays the year's capital outlay and current inventories. Similarly, for each iteration, Table A displays the year's faculty requirements and their associated costs.

MODEL TESTS AND RESULTS

Model Characteristics

All initial testing of the model was performed with data from the Santa Barbara campus of the University of California. When it was impossible to generate parameters from the available UCSB data, data from other general campuses of the University were used.[3] The base year for all model tests was the 1969-70 academic year.

It was found that SPACE is robust with regard to most parameter changes and Monte Carlo perturbations when viewed from a macro level. Overall class sizes, faculty requirements, facilities requirements, and costs vary only slightly in response to modest parameter changes. On the other hand, class size distributions and resource requirements vary radically within particular disciplines and levels. This kind of variation was not only anticipated but consciously sought because historical data show substantially greater variation from year to year within disciplines than for the campus as a whole. It is one of the major goals of SPACE to demonstrate to University planners the ranges of needs which must be considered in facilities planning.

Throughout the period of the model's development, numerous test runs were made to determine the sensitivity of the results of parameter changes, and to validate particular routines by comparing the outputs with historical data. Additional test runs were made to test the flexibility of the model in answering what-if questions. The results were uniformly favorable. In the three sections which follow, seven of the test runs, typical of the lot, are discussed in relation to these purposes.

[3]Berkeley, Davis, Irvine, Los Angeles, Riverside, San Diego, Santa Barbara, and Santa Cruz.

Validation Tests: Comparisons with UCSB History and with Current Planning Methodology

For the purpose of validating the model, two types of tests were made: (1) straightforward comparisons of SPACE outputs with historical UCSB data, and (2) comparisons of SPACE-generated assignable square feet (ASF) requirements with the corresponding requirements computed by University of California planning officers using the traditional methodology.[4]

The first type of validation test was made using historical UCSB data for the majority of SPACE inputs. Where UCSB data were incomplete or inadequate, data from the University's other general campuses were adapted. Enrollment data were estimated by assigning target three-term-average headcount enrollment totals for undergraduate and graduate level students to each discipline and, within each discipline, to four student levels on the basis of historical proportions. This was done to reflect the uncertainty in enrollment projections in the planning process, even though actual enrollment data were available for the base year of the runs.

The complete data set for the validation tests will be referred to as the "reference data set," and the base run using this data set as "Run 10A." All sensitivity tests and validation tests involved comparisons with Run 10A. The reference data set includes: (1) a 67-hour week, i.e., every hour in which at least one class was scheduled at UCSB in Fall 1969; (2) a non-uniform distribution of class hours to the 67 hours, approximating the actual distribution at UCSB; (3) the Fall 1969 inventory of

[4]The methodology consists essentially of multiplying student credit hour projections by assignable square feet factors for each discipline and space type. The calculations of faculty-generated space are very similar to those of the SPACE model, except for the generation of the faculty requirements themselves.

facilities; (4) weekly student hour projections generated by applying a single induced course load matrix to the 10-year series of enrollment projections; (5) a theoretical class-size-to-room-size assignment matrix;[5] (6) estimated means and standard deviations of assumed Gaussian distributions of WSH to class-size ranges, reflecting 8-campus histories;[6] and (7) non-uniform hour-size factors for lab classes.[7]

Tables 1 and 2 show the WSH and WRH results for all non-lab classes in the validation runs 10A and 10B. The only difference between the two sets of data inputs is the starting point for the pseudo-random number generators; all other data are identical. A comparison of the 'actual' UCSB data with the outputs of the FAMSIX module shows that, for most of the class size ranges, the numbers of WRH correspond closely in both magnitude and variance. For the smallest and largest classes, however, the 'actual' figures did not include the classes scheduled in locations other than classrooms and class labs. The model includes more of the classes which are actually taught at UCSB than did the utilization reports which were the source of the 'actual' figures.

It is notable that the average class sizes for the non-lab classes vary modestly in the two runs (32.5 and 33.3 in 1969 to 35.7 and 32.9 in 1978, with 34.0 and 33.3 as the 10-year averages). This variation is typical of the historical averages. A similar result holds for lab class data. Also typical of UCSB history (and of the history of the other

---

[5] See pages 11-14 of this report for a discussion of this matrix.

[6] See pages 6-7 of this report for a discussion of these distributions.

[7] See pages 8-11 of this report for a discussion of these factors. N.B. $c = 1.0$ and $y = 0$ for lab classes; i.e., in the reference data set the hour-size factors leave the initial size distributions of lab classes unaltered by the scheduling process.

general campuses) is the more marked variation of class sizes within a given discipline. Tables 3 and 4 show historical and FAMSIX class size distributions in the physical sciences for each of the three course levels.

Comparisons of historical utilization statistics and the utilization statistics generated by Run 10A are presented in Tables 5 and 6. It should be noted that at least two large rooms which are not classrooms are used for large classes at Santa Barbara because the campus has no classroom (i.e., no room so classified) with more than 354 stations. Those 'non-classrooms' are excluded from the 'actual' classroom utilization statistics, and thus also from the classroom inventory in the input data to the model. SPACE 'constructed' three large classrooms f. the model-generated classes which were larger than the largest classroom in the Fall 1969 inventory.

The SPACE utilization statistics reflect, among other factors, the class-size-to-room-size assignments considered reasonable by the authors, and do not represent an attempt to reproduce UCSB's actual utilization rates.

The second type of validation test, comparison of the model's results with the traditional U.C. methodology, was performed by excluding the 1969 inventory from the reference data set. Because of differing assumptions regarding enrollment growth a meaningful comparison was possible only for the year 1970-71. Only for this year were enrollment inputs nearly identical in total for both sets of calculations. Table 7 shows the results for the model and the calculations of the U.C. space planners. The similarity of the two sets of results is considered by the authors to be adequate evidence of the viability of the model's methodology for augmenting the planning process.

Sensitivity Tests

The effects of the randomization procedures within the model on the final outputs have already been alluded to in the previous sections. One criterion for measuring the acceptability of class size perturbations is based on the similarity of the range of SPACE-induced variations from one run to the next with the range of historical variations from one year to the next. It might be argued that the actual historical variation in class size is an inappropriate base for making comparisons of Monte Carlo perturbations because of enrollment changes within the historical period. Two factors mitigate in favor of the comparison however. First, the only practical basis of comparison is historical variation. It is obviously impossible to reproduce exactly the conditions which lead to any historical outcome preparatory to experimenting with the actual system. Certainly, however, for any given student population, the class size distribution within any discipline and level is determined stochastically. Secondly, there is no clear trend in historical class-size averages induced by enrollment increases. Presumably any of the historical class sizes are possible for any of the historical enrollment totals; and consequently historical variations provide a good clue to the possibilities for any single year.

Tables 1, 2, 3, and 4 display the effects typical of a change in the starting point of the random-number generator (Runs 10A and 10B) on class size distributions. There is considerably greater variance within a discipline and level than there is overall. For non-lab classes the overall change in average class size from one run to the other averages 2.1%. The smallest change for any year is 1%; the largest change is nearly 6.5%.

The ten-year average of class size percentage differences for non-lab, graduate, physical science classes is 16%. The smallest change for any year is 3.4%; the largest change is 50%. These run-to-run variations are generally consistent with the 1967-1969 historical variations for this discipline, level, and class type.

The arguments legitimizing class-size comparisons of historical with Monte Carlo variations will not hold for resource needs. Historical data on resources expended at Santa Barbara reflect decision makers' preferences and political accident as much as actual need. In the test runs made so far, SPACE has computed faculty requirements on a workload basis, and space requirements of faculty and graduate students on the basis of CCHE standards. No effort has been made to simulate the politics which generate resources--only the operations which determine resource requirements. Nevertheless, variations of calculated resource needs are an important consideration in determining the acceptability of the model for planning. Variations much greater than 5% over the 10-year period seem unacceptable to the authors.

Tables 8 and 9 display summary data for Runs 1A and 1B.[8] Faculty requirements differ by 1.8%, classroom ASF-years differ by 12.2%, class-lab ASF-years by 1.0%, total ASF-years by 2.8%, salaries and support costs by 1.8%, total debt-service payments by 2.4%, and total variable costs by 2.0%. The 12.2% difference in classroom ASF-years is the only questionable variation. Run 1B constructed 3 more large classrooms than Run 1A; this accounts for the difference in floor area requirements.

---

[8]Runs 1A and 1B are identical to 10A and 10B respectively except for the exclusion of the 1969 inventory from the input data. These runs show what the model would build to handle UCSB's enrollments if it were starting a new campus. A comparison of these runs with the actual inventory gives some idea of excess physical capacity _if_ the CCHE space standards can be assumed to be reasonable.

Examining Policy Options

The usefulness of a simulation model depends in part on the ease with which alternative policy what-if questions can be posed and answered. The fewer parameters which must be altered, and the easier it is for administrators to develop an intuitive feel for what a parameter represents operationally, the more useful the model will be. SPACE was initially conceived to provide answers for one class of conditional questions, viz: What cost consequences would be associated with a change in the hourly pattern of class scheduling? The possibility of answering other what-if questions arose during the development of the model.

During the period of development and initial testing it was found that it is relatively easy to examine the resource impacts of adding or deleting academic programs, changing faculty workloads, or encountering significant shifts in enrollment patterns. In each case it was only necessary to make minor changes to one or two sets of data inputs. These data changes satisfied the criterion of reflecting operational changes in an intuitively identifiable manner.

Most of the what-if tests were concerned with changes in the patterns of class scheduling. Summary results of three such tests are tabulated in Tables 11 - 13. Table 10 is a summary of Run 10A, in which the class scheduling pattern approximated the actual pattern in Fall 1969. Changes in the class scheduling pattern were simulated by (1) changing the number of hours per week in which classes are scheduled; and (2) changing the relative proportions of classes scheduled in those hours. For Run 10A a non-uniform distribution of classes to the 67 scheduled hours of the week put approximately:

1/193 of the classes in each of the 23 least popular hours;
2/193 of the classes in each of the 6 next least popular hours;
3/193 of the classes in each of the 8 third least popular hours;
4/193 of the classes in each of the 16 fourth least popular hours; and
5/193 of the classes in each of the 14 most popular hours.

For Run 11A, 1/67 of the classes were scheduled in each of the 67 hours. This 'flat' distribution was duplicated for Run 12A but only for the 44 most popular hours, i.e., 1/44 of the classes in each of those hours. A 'lumpy' distribution similar to that of Run 10A was used for Run 12B, but again, only for the 44 most popular hours, e.g., 2/170 in each of the second least popular hours and 5/170 in each of the most popular hours.

The net effects of these appreciable schedule changes were negligible in terms of costs. In each case, class sizes declined in comparison to Run 10A and operating costs increased correspondingly. Facilities costs (debt service) changed only slightly. In general, flat distributions were more costly than lumpy distributions and the 67-hour week was more efficient than the 44-hour week from the standpoint of classroom utilization. The analysis of these and other such tests shows that as long as faculty-staffing is determined on a contact-hour basis, and as long as students show even modest preferences for some hours over others,[9] then even substantial alterations in classroom scheduling will do little or nothing to change costs.

[9] Input parameters representing very conservative estimates of the class-scheduling effects on class size were included in the reference data set and these were left unchanged for the comparison runs. During sensitivity tests, it was found that still more conservative estimates provided little hope for cost-savings resulting from changing class-scheduling patterns.

Table 14 summarizes the 10-year projections of six test runs. Note that the 2% change in total variable costs induced solely by random variations (Runs 1A and 1B) is greater than the percentage variation induced by a scheduling change which cuts by one-third the number of hours in which classes are scheduled (Runs 10A and 12B). Care should be taken in the comparison of single examples of what-if tests because of the range of results induced by random variations. It is possible that the low end of one range would overlap the high end of another. The results displayed in Table 14 are, however, typical of the many test runs which were made and are representative of the ranges of possible outcomes.

TABLE 1

Class-Size Distributions of Nonlaboratory Weekly Room-Hours in All Levels and Disciplines at UCSB

Class Size Code	& Range	Actual			FAMSIX Table 221 — Run 10A										
		1967	1968	1969	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	Mean
1	1-9	514	545	523	1058	795	605	714	713	774	876	769	853	799	795.6
2	10-19	1162	1050	976	1013	1172	1134	940	1114	1115	1172	1228	1394	1169	1145.1
3	20-29	1238	1303	1252	1329	1261	1071	1130	1272	1265	1160	1355	1298	1227	1236.8
4	30-39	273	312	381	381	364	333	377	369	348	319	327	349	315	348.2
5	40-59	322	253	354	195	350	360	322	242	371	320	283	321	352	311.6
6	60-79	111	121	154	187	164	138	116	168	169	153	180	157	140	157.2
7	80-99	74	80	60	132	100	57	83	72	81	124	79	85	117	93.0
8	100-149	97	89	115	51	81	83	108	89	75	88	78	95	116	86.4
9	150-199	32	55	58	44	32	35	31	61	40	23	46	46	57	41.5
10	200-299	37	35	48	49	26	36	31	24	25	25	30	45	35	32.6
11	300-399	15	12	3	26	23	29	30	23	21	23	33	20	24	25.2
12	400-599	1	4	4	8	12	11	12	10	16	13	7	7	17	11.3
13	600-799	4	0	0	6	3	6	4	3	3	8	8	11	5	5.7
14	800-999	0	0	0	4	8	6	6	7	6	8	7	4	6	6.2
15	1000 & up	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Sizes		3880	3859	3928	4483	4391	3904	3904	4167	4309	4312	4430	4685	4379	4296.4
WSH (1000s)		121	122	132	146	146	138	139	141	144	145	150	154	156	145.9
WSH per WRH		31.1	31.6	33.6	32.5	33.2	35.4	35.5	33.9	33.4	33.[illegible]	33.9	32.8	35.7	34.0
WSH excluded above (1000s)		26	24	25	Nearly all excluded actual WSH (and related WRH, primarily classes of less than 10 students and more than 300) are included in SPACE.										
Enrollments:		(3-term-average headcount. Estimated for FAMSIX before 1969 actual numbers were known.)													
Lower Div.		5385	5182	5163	5606	5425	5234	5229	5300	5417	5533	5651	5766	5992	5515
Upper Div.		4901	5305	6106	5703	5980	5605	5601	5675	5800	5926	6048	6175	6192	5871
Grad. Level		1490	1733	1985	1991	1786	1650	1641	1692	1722	1768	1817	1866	1914	1785
Total		11776	12220	13254	13300	13191	12489	12471	12667	12939	13227	13516	13807	14098	13171

TABLE 2

Class-Size Distributions of Nonlaboratory Weekly Room-Hours in All Levels and Disciplines at UCSB

Class Size Code	& Range	Actual 1967	Actual 1968	Actual 1969	FAMSIX Table 221 — Run 10B 1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	Mean
1	1-9	514	545	523	784	804	716	816	700	880	792	833	746	834	790.5
2	10-19	1162	1050	976	1198	1158	1050	1070	1086	1315	1275	1292	1185	1268	1189.7
3	20-29	1238	1303	1252	1310	1243	1091	1164	1278	1126	1313	1303	1250	1402	1248.0
4	30-39	273	312	381	323	382	306	356	339	313	364	374	377	393	352.7
5	40-59	322	253	354	277	398	349	298	305	361	355	296	349	343	333.1
6	60-79	111	121	154	163	151	122	116	129	125	180	192	149	190	151.7
7	80-99	74	80	60	101	100	96	111	114	92	91	90	105	129	102.9
8	100-149	97	89	115	82	46	89	111	116	68	88	78	82	81	84.1
9	150-199	32	55	58	35	48	37	35	35	50	22	52	31	59	40.4
10	200-299	37	35	48	49	23	33	29	30	26	16	22	55	24	30.7
11	300-399	15	12	3	19	29	30	12	22	34	25	20	34	23	24.8
12	400-599	1	4	4	6	9	13	12	6	9	13	17	12	5	10.2
13	600-799	4	0	0	7	4	4	7	1	6	4	4	5	6	4.8
14	800-999	0	0	0	6	7	4	5	6	3	7	5	3	6	5.2
15	1000 & up	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All Sizes		3880	3859	3928	4360	4402	3940	4142	4167	4408	4545	4578	4383	4763	4368.8
WSH (1000s)		121	122	132	145	145	138	138	140	142	147	149	153	157	145.4
WSH per WRH		31.1	31.6	33.6	33.3	33.0	34.9	33.4	33.5	32.2	32.3	32.6	34.9	32.9	33.3
WSH excluded above (1000s)		26	24	25	Nearly all excluded actual WSH (and related WRH, primarily classes of less than 10 students and more than 300) are included in SPACE.										
Enrollments:		(3-term-average headcount. Estimated for FAMSIX before 1969 actual numbers were known.)													
Lower Div.		5385	5182	5163	5606	5425	5234	5229	5300	5417	5533	5651	5766	5992	5515
Upper Div.		4901	5305	6106	5703	5980	5605	5601	5675	5800	5926	6048	6175	6192	5871
Grad. Level		1490	1733	1985	1991	1786	1650	1641	1692	1722	1768	1817	1866	1914	1785
Total		11776	12220	13254	13300	13191	12489	12471	12667	12939	13227	13516	13807	14098	13171

TABLE 3

Actual and SPACE Class-Size Distributions of Weekly Room-Hours in Physical Sciences at UCSB —— Run 10A

Class Type	Class Size	Number of Weekly Room-Hours in Each Class-Size Range of Each Class Type and Course Level																	
		Lower-Division Courses						Upper-Division Courses						Graduate-Level Courses					
		Actual			SPACE			Actual			SPACE			Actual			SPACE		
		1967	1968	1969	1969	1973	1978	1967	1968	1969	1969	1973	1978	1967	1968	1969	1969	1973	1978
Nonlab	1 1-9	0	1	6	4	1	2	5	4	0	6	3	5	17	9	19	30	27	0
	2 10-19	2	6	8	8	13	9	10	6	11	5	1	5	14	14	5	25	17	24
	3 20-29	10	10	10	5	4	4	15	12	9	14	10	13	1	1	14	2	4	9
	4 30-39	3	9	6	10	4	8	3	6	3	5	7	7	1	3	0	1	1	0
	5 40-59	9	6	9	4	9	6	0	3	9	3	3	3	0	0	2	0	0	0
	6 60-79	6	3	3	11	13	0	3	3	0	1	4	1						
	7 80-99	6	12	0	19	3	6	0	0	3	1	1	4						
	8 100-149	6	10	18	9	10	6	0	0	0	1	1	1						
	9 150-199	16	9	10	0	12	17	0	0	0	1	1	1						
	10 200-299	7	7	7	8	4	9	3	3	3	2	1	2						
	11 300-399	0	0	0	1	1	0												
	All Sizes	65	73	77	80	74	67	39	37	38	39	32	42	33	28	40	58	49	33
Total WSH (1000s)		6.8	6.4	7.0	6.6	6.6	7.1	1.5	1.6	1.8	1.7	1.5	2.0	.33	.40	.62	.64	.55	.58
WSH per WRH		104	87.6	90.4	82.3	88.6	106	37.8	42.5	46.8	43.3	48.3	47.4	10.0	14.1	15.4	11.0	11.2	17.5
Lab	1 1-9	61	27	47	13	55	89	20	0	8	9	3	3	6	0	0	2	1	5
	2 10-19	180	270	252	193	218	214	17	28	8	5	8	8	0	0	0	1	1	0
	3 20-29	124	34	50	102	68	86	0	0	0	1	1	1						
	4 30-39	2	0	0	0	0	0												
	All Sizes	367	331	349	308	341	389	37	28	16	15	12	12	6	0	0	3	2	5
Total WSH (1000s)		6.0	5.2	5.3	5.4	5.2	5.8	.31	.33	.17	.15	.16	.16	.02	0	0	.03	.02	.03
WSH per WRH		16.4	15.7	15.2	17.6	15.3	14.9	8.5	11.9	10.5	10.2	13.5	13.5	4.0	--	--	9.0	10.5	6.0

TABLE 4

Actual and SPACE Class-Size Distributions of Weekly Room-Hours in Physical Sciences at UCSB —— Run 10B

Class Type		Class Size	Number of Weekly Room-Hours in Each Class-Size Range of Each Class Type and Course Level																	
			Lower-Division Courses						Upper-Division Courses						Graduate-Level Courses					
			Actual			SPACE			Actual			SPACE			Actual			SPACE		
			1967	1968	1969	1969	1973	1978	1967	1968	1969	1969	1973	1978	1967	1968	1969	1969	1973	1978
Nonlab	1	1-9	0	1	6	1	3	7	5	4	0	0	6	1	17	9	19	21	17	25
	2	10-19	2	6	8	10	7	0	10	6	11	4	4	15	14	14	5	21	16	15
	3	20-29	10	10	10	7	14	0	15	12	9	14	17	11	1	1	14	4	4	5
	4	30-39	3	9	6	12	6	3	3	6	3	3	6	7	1	3	0	1	2	2
	5	40-59	9	6	9	6	9	6	0	3	9	3	3	3	0	0	2	1	0	1
	6	60-79	6	3	3	11	2	10	3	3	0	3	3	1						
	7	80-99	6	12	0	5	26	25	0	0	3	3	2	2						
	8	100-149	6	10	18	7	7	0	0	0	0	1	0	0						
	9	150-199	16	9	10	9	8	21	0	0	0	1	1	1						
	10	200-299	7	7	7	9	3	0	3	3	3	1	1	2						
	11	300-399	0	0	0	0	0	1												
		All Sizes	65	73	77	77	85	73	39	37	38	33	43	43	33	28	40	48	39	48
Total WSH (1000s)			6.8	6.4	7.0	6.7	6.4	7.2	1.5	1.6	1.8	1.6	1.6	1.8	.33	.40	.62	.62	.51	.61
WSH per WRH			104	87.6	90.4	87.5	75.8	98.9	37.8	42.5	46.8	49.7	38.2	41.2	10.0	14.1	15.4	12.9	13.0	12.7
Lab	1	1-9	61	27	47	133	87	64	20	0	8	2	5	2	6	0	0	3	1	0
	2	10-19	180	270	252	104	193	224	17	28	8	9	7	10	0	0	0	1	1	2
	3	20-29	124	34	50	128	75	86	0	0	0	0	1	1						
	4	30-39	2	0	0	0	0	0												
		All Sizes	367	331	349	365	355	374	37	28	16	11	13	13	6	0	0	4	2	2
Total WSH (1000s)			6.0	5.2	5.3	5.4	5.2	5.8	.31	.33	.17	.15	.16	.19	.02	0	0	.03	.02	.03
WSH per WRH			16.4	15.7	15.2	14.9	14.7	15.5	8.5	11.9	10.5	13.4	12.2	14.3	4.0	--	--	8.[illegible]	10.5	15.0

TABLE 5

Actual and SPACE Utilization Rates in All Classrooms at UCSB — Fall 1969 — Run 10A

Room Size (Stations)		No. of Rooms		Total Stations		Weekly Room-Hours Per Room		Station Occupancy Ratio		Weekly Student-Hours Per Station		Assignable Sq. Ft. Per Station		ASF per Weekly Student-Hour	
		Actual	SPACE	Actual	SPACE	Actual	SPACE	Actual	SPACE	Actual	SPACE	Actual	SPACE	Actual	SPACE
1	1-9	0	0	0	0	--	--	--	--	--	--	--	--	--	--
2	10-19	11	11	161	161	21.7	58.8	0.76	0.45	16.6	26.7	22.1	22.1	1.33	0.83
3	20-29	23	23	530	530	23.5	46.7	0.73	0.75	17.1	34.9	20.1	20.1	1.17	0.58
4	30-39	38	38	1,245	1,245	29.1	38.8	0.67	0.66	19.4	25.8	19.4	19.4	1.00	0.75
5	40-59	34	34	1,563	1,563	32.4	19.4	0.56	0.52	18.0	10.1	15.0	15.0	0.83	1.49
6	60-79	14	14	931	931	25.6	12.7	0.59	0.80	15.0	10.2	12.1	12.1	0.80	1.19
7	80-99	4	4	330	330	29.3	31.0	0.74	0.87	21.6	27.1	12.4	12.4	0.57	0.46
8	100-149	7	7	833	833	25.9	18.0	0.60	0.73	15.6	13.2	12.2	12.2	0.78	0.93
9	150-199	2	2	300	300	25.8	34.5	0.78	0.75	20.2	25.9	11.8	11.8	0.59	0.46
10	200-299	3	3	707	707	26.3	17.0	0.71	0.81	18.7	13.8	12.3	12.3	0.66	0.89
11	300-399	2	2	658	658	35.0	20.5	0.55	0.74	19.2	15.2	10.8	10.8	0.56	0.71
12	400-599	0	1	0	480	--	18.0	--	0.68	--	12.2	--	10.0	--	0.82
13	600-799	0	0	0	0	--	--	--	--	--	--	--	--	--	--
14	800-999	0	2	0	1,760	--	11.0	--	0.64	--	7.0	--	9.0	--	1.28
15	1000 up	0	0	0	0	--	--	--	--	--	--	--	--	--	--
All Sizes		138	141	7,258	9,498	27.8	31.8	0.64	0.48	17.9	15.3	14.7	13.4	0.82	0.87
Size Codes 1-11 only		138	138	7,258	7,258	27.8	32.2	0.64	0.54	17.9	17.5	14.7	14.7	0.82	0.84

Note: Run 10A began with the actual Fall 1969 facilities inventory, which included no classrooms larger than room-size code 11. SPACE therefore "built" larger classrooms for its large classes which corresponded to the actual classes that were scheduled in large rooms not classified as classrooms.

TABLE 6

Actual and SPACE Utilization Rates in All Classrooms at UCSB — Fall 1970 — Run 10A

Room Size (Stations)	No. of Rooms		Total Stations		Weekly Room-Hours Per Room		Station Occupancy Ratio		Weekly Student-Hours Per Station		Assignable Sq. Ft. Per Station		ASF per Weekly Student-Hour	
	Actual	SPACE	Actual	SPACE	Actual	SPACE	Actual	SPACE	Actual	SPACE	Actual	SPACE	Actual	SPACE
1 1-9	0	0	0	0	--	--	--	--	--	--	--	--	--	--
2 10-19	8	11	121	161	18.8	55.7	0.56	0.47	10.4	26.4	20.1	22.1	1.93	0.84
3 20-29	21	23	470	530	20.5	46.5	0.59	0.76	12.0	35.3	16.3	20.1	1.35	0.57
4 30-39	30	38	1,000	1,245	27.1	37.5	0.65	0.68	17.5	25.4	20.0	19.4	1.14	0.77
5 40-59	48	34	2,245	1,563	34.8	18.4	0.50	0.62	17.3	11.5	13.8	15.0	0.80	1.30
6 60-79	15	14	1,031	931	25.1	15.2	0.57	0.76	14.2	11.5	11.9	12.1	0.84	1.05
7 80-99	3	4	259	330	31.0	35.0	0.63	0.81	19.4	28.3	12.4	12.4	0.64	0.44
8 100-149	6	7	712	833	29.3	17.4	0.61	0.74	17.7	12.9	12.6	12.2	0.71	0.95
9 150-199	2	2	300	300	33.3	31.5	0.85	0.71	28.1	22.4	11.8	11.8	0.42	0.53
10 200-299	3	3	707	707	28.0	17.0	0.64	0.72	18.0	12.2	12.3	12.3	0.68	1.00
11 300-399	2	2	658	658	43.5	13.5	0.60	0.72	25.9	9.7	10.8	10.8	0.42	1.11
12 400-599	0	1	0	480	--	18.0	--	0.77	--	13.8	--	10.0	--	0.73
13 600-799	0	0	0	0	--	--	--	--	--	--	--	--	--	--
14 800-999	0	2	0	1,760	--	11.5	--	0.70	--	8.0	--	9.0	--	1.12
15 1000 up	0	0	0	0	--	--	--	--	--	--	--	--	--	--
All Sizes	138	141	7,503	9,498	28.6	31.1	0.62	0.49	17.8	15.4	14.0	13.4	0.78	0.87
Size Codes 1-11 only	138	138	7,503	7,258	28 6	31.5	0.62	0.55	17.8	17.3	14.0	14.7	0.78	0.85

TABLE 7

Computed Needs of Departments of Instruction & Research at UCSB in 1970-71 —— Run 1A

Discipline	Assignable Square Feet							
	Class Labs		Research & Office		Support Facilities		Total Departmental	
	AVP-PP[a]	SPACE	AVP-PP[a]	SPACE	AVP-PP[a]	SPACE	AVP-PP[a]	SPACE
General	0	0	0	2,998	0	449	0	3,447
Biological Sciences	20,483	18,168	52,100	52,174	7,259	7,826	79,842	78,168
Mathematical Sciences	0	0	10,690	10,801	535	1,072	11,225	11,873
Physical Sciences	22,845	22,976	70,220	71,650	9,307	10,680	102,372	105,306
Engineering Sciences	11,912	10,928	52,680	52,349	9,689	11,706	74,281	74,983
Psychology	9,612	5,784	13,620	12,636	1,743	1,560	24,975	19,980
Social Sciences[b]	21,108	2,768	66,775	60,823	5,152	5,958	93,035	69,549
Arts	57,264	39,968	40,020	45,998	9,729	6,899	107,013	92,865
Letters & Foreign Lang.	0	4,160	63,900	65,946	3,195	6,464	67,095	76,570
Education	308	3,680	13,270	17,694	1,358	2,654	14,936	24,028
Home Economics	0	3,624	0	3,788	0	521	0	7,933
Total Departmental	143,532	112,056	383,275	396,857	47,967[c]	55,789[c]	574,774	564,702
Classrooms	....	....	....	....	....	....	80,468[c]	96,722[c]
Total ASF	....	....	....	....	....	....	655,242	661,424

[a]Office of Assistant Vice President—Physical Planning (Tables P-N and N-1, dated 8/27/71).
[b]In AVP-PP's "N" tables, anthropology and geography are treated as "exceptional departments" with greater unit area allowances than other social sciences. The test runs of SPACE did not include this refinement.
[c]In AVP-PP's "N" tables, small amounts of I&R departmental support facilities are tabulated with the classroom ASF (4,759 ASF in this instance). SPACE includes the corresponding amount with the departmental ASF.

TABLE 8

Utilization Rates, Class Sizes, Faculty & Teaching Assistants, Assignable Sq. Ft., and Variable Costs
Run 1A: UCSB data; zero inventory; actual 67-hour schedule; randomizations initiated by IG = 1 and IX = 1

Measurement	1969-70	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79
Classroom Utilization										
WRH per Room	36.2	35.1	31.0	31.0	33.1	34.2	34.2	35.2	36.3	33.4
Station Occupancy	0.55	0.56	0.60	0.60	0.57	0.56	0.57	0.57	0.56	0.61
WSH per Station	19.8	19.7	18.5	18.5	18.9	19.2	19.4	20.1	20.4	20.4
ASF per Station	13.1	13.1	13.1	13.1	13.1	13.1	13.1	13.1	13.1	13.1
ASF per WSH	0.66	0.66	0.71	0.70	0.69	0.68	0.67	0.65	0.64	0.64
Average Class Size (WSH/WRH)										
In Classrooms	32.5	33.2	35.4	35.5	33.9	33.4	33.7	33.9	32.8	35.7
In Class Labs	16.2	16.5	16.4	16.8	16.1	15.9	16.5	16.4	16.5	15.0
FTE Faculty & TAs										
Teaching Assistants	208	210	196	189	204	208	203	217	231	218
Tenured Faculty	312	308	281	279	295	[illegible]	302	313	327	322
Non-Tenured Faculty	243	242	221	219	231	240	238	244	256	249
Other Faculty	178	171	155	154	164	171	169	172	179	181
Total Faculty & TAs	941	931	853	841	893	921	912	947	993	970
Assignable Sq. Ft. (1000s)										
Classrooms	96	97	98	98	98	98	98	98	99	101
Class Labs	102	112	128	130	133	135	135	135	138	141
Research Facilities	241	242	242	242	242	242	242	243	244	250
Office Facilities	150	155	155	155	156	156	158	160	165	166
Support Facilities	56	56	56	56	56	56	56	57	58	59
Total I&R ASF	645	661	679	681	685	686	689	691	703	716
Variable Costs ($1000s)										
Salaries & Support	14,873	14,667	13,439	13,369	14,103	14,518	14,460	14,931	15,551	15,390
M&O of Plant	1,246	1,289	1,336	1,355	1,375	1,392	1,411	1,430	1,470	1,512
Debt Service	4,826	4,870	4,890	4,907	4,930	4,975	5,044	5,103	5,124	5,124
Total Variable Costs	20,945	20,827	19,666	19,631	20,408	20,886	20,915	21,464	22,145	22,025
Cumulative Total	31,682[a]	52,509	72,175	91,806	112,214	133,100	154,015	175,479	197,624	219,650

[a]Includes debt service in preceding four years for facilities constructed by SPACE to meet 1969-70 needs.

TABLE 9

Utilization Rates, Class Sizes, Faculty & Teaching Assistants, Assignable Sq. Ft., and Variable Costs
Run 1B: UCSB data; zero inventory; actual 67-hour schedule; randomizations initiated by IG = 7 and IX = 3

Measurement	1969-70	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79
Classroom Utilization										
WRH per Room	36.0	35.8	32.0	33.7	33.9	35.8	34.7	34.9	33.5	35.5
Station Occupancy	0.55	0.46	0.48	0.46	0.46	0.45	0.47	0.47	0.51	0.48
WSH per Station	19.8	16.4	15.5	15.6	15.7	16.0	16.2	16.5	16.9	17.0
ASF per Station	13.0	12.3	12.3	12.3	12.3	12.3	12.5	12.5	12.5	12.5
ASF per WSH	0.66	0.75	0.80	0.79	0.79	0.77	0.77	0.76	0.74	0.74
Average Class Size (WSH/WRH)										
In Classrooms	33.3	33.0	34.9	33.4	33.5	32.2	32.3	32.6	34.9	32.9
In Class Labs	15.0	16.0	17.0	16.4	15.8	16.5	15.3	16.4	16.4	16.6
FTE Faculty & TAs										
Teaching Assistants	211	211	193	192	206	212	225	225	223	224
Tenured Faculty	313	316	280	290	298	310	321	323	314	331
Non-Tenured Faculty	244	242	217	229	231	239	260	257	248	257
Other Faculty	179	174	155	164	163	172	178	179	172	187
Total Faculty & TAs	947	942	845	874	898	933	964	983	958	1,000
Assignable Sq. Ft. (1000s)										
Classrooms	95	110	110	110	110	110	113	113	113	116
Class Labs	102	122	124	126	126	130	134	136	138	138
Research Facilities	242	246	246	246	246	247	247	247	247	251
Office Facilities	152	158	158	158	158	160	165	168	168	173
Support Facilities	56	57	57	57	57	57	58	58	58	60
Total I&R ASF	647	692	694	696	697	703	716	722	724	737
Variable Costs ($1000s)										
Salaries & Support	14,897	14,951	13,362	13,820	14,238	14,784	15,459	15,427	15,074	15,862
M&O of Plant	1,249	1,350	1,367	1,384	1,399	1,427	1,467	1,494	1,513	1,556
Debt Service	4,931	4,946	4,976	5,030	5,091	5,140	5,185	5,229	5,249	5,249
Total Variable Costs	21,076	21,247	19,705	20,234	20,728	21,351	22,111	22,150	21,836	22,666
Cumulative Total	32,015[a]	53,262	72,967	93,201	113,928	135,279	157,390	179,540	201,376	224,042

[a]Includes debt service in preceding four years for facilities constructed by SPACE to meet 1969-70 needs.

TABLE 10

Utilization Rates, Class Sizes, Faculty & Teaching Assistants, Assignable Sq. Ft., and Variable Costs
Run 10A: UCSB data; actual inventory; actual 67-hour schedule; randomizations initiated by IG = 1 and IX = 1

Measurement	1969-70	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79
Classroom Utilization										
WRH per Room	31.8	31.1	27.7	27.7	29.6	30.6	30.6	31.4	33.2	31.1
Station Occupancy	0.48	0.49	0.53	0.53	0.50	0.50	0.50	0.50	0.49	0.53
WSH per Station	15.3	15.4	14.6	14.6	14.9	15.2	15.3	15.8	16.2	16.5
ASF per Station	13.4	13.4	13.4	13.4	13.4	13.4	13.4	13.4	13.4	13.4
ASF per WSH	0.87	0.87	0.92	0.92	0.90	0.88	0.88	0.85	0.83	0.81
Average Class Size (WSH/WRH)										
In Classrooms	32.5	33.2	35.4	35.5	33.9	33.4	33.7	33.9	32.8	35.7
In Class Labs	16.2	16.5	16.4	16.8	16.1	15.9	16.5	16.4	16.5	15.0
FTE Faculty & TAs										
Teaching Assistants	208	210	196	189	204	208	203	217	231	218
Tenured Faculty	312	308	281	279	295	302	302	313	327	322
Non-Tenured Faculty	243	242	221	219	231	240	238	244	256	249
Other Faculty	178	171	155	154	164	171	169	172	179	181
Total Faculty & TAs	941	931	853	841	893	921	912	947	993	970
Assignable Sq. Ft. (1000s)										
Classrooms	127	127	127	127	127	127	127	127	127	127
Class Labs	200	204	217	218	221	223	223	223	227	229
Research Facilities	257	258	258	258	258	258	258	258	260	263
Office Facilities	202	204	204	205	205	205	206	207	209	210
Support Facilities	59	59	59	59	59	59	60	60	61	61
Total I&R ASF	846	853	866	867	870	872	874	875	883	891
Variable Costs ($1000s)										
Salaries & Support	14,873	14,667	13,439	13,369	14,103	14,518	14,460	14,931	15,551	15,390
M&O of Plant	1,633	1,662	1,705	1,725	1,748	1,769	1,790	1,811	1,846	1,880
Debt Service	1,295	1,330	1,347	1,361	1,377	1,407	1,450	1,485	1,497	1,497
Total Variable Costs	17,801	17,660	16,491	16,455	17,228	17,694	17,700	18,227	18,894	18,766
Cumulative Total	20,563[a]	38,222	54,713	71,168	88,397	106,091	123,791	142,018	160,912	179,678

[a]Includes debt service in preceding four years for facilities constructed by SPACE to meet 1969-70 needs.

TABLE 11

Utilization Rates, Class Sizes, Faculty & Teaching Assistants, Assignable Sq. Ft., and Variable Costs
Run 11A: UCSB data; actual inventory; "flat" 67-hour schedule; randomizations initiated by IG = 1 and IX = 1

Measurement	1969-70	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79
Classroom Utilization										
WRH per Room	34.0	33.6	30.1	29.8	32.0	33.0	32.8	33.9	35.8	33.5
Station Occupancy	0.50	0.50	0.54	0.54	0.51	0.51	0.51	0.51	0.50	0.54
WSH per Station	16.9	16.9	16.1	16.1	16.4	16.7	16.9	17.4	17.9	18.1
ASF per Station	13.9	13.9	13.9	13.9	13.9	13.9	13.9	13.9	13.9	13.9
ASF per WSH	0.82	0.82	0.86	0.86	0.85	0.83	0.82	0.80	0.78	0.76
Average Class Size (WSH/WRH)										
In Classrooms	30.6	31.0	32.9	33.3	31.5	31.2	31.6	31.6	30.7	33.4
In Class Labs	16.2	16.5	16.4	16.8	16.1	15.9	16.5	16.4	16.5	15.0
FTE Faculty & TAs										
Teaching Assistants	218	222	206	200	215	220	213	230	244	229
Tenured Faculty	327	322	296	293	310	317	316	329	343	338
Non-Tenured Faculty	25[illegible]	255	235	229	243	252	248	257	268	260
Other Faculty	187	181	164	162	173	180	177	182	189	190
Total Faculty & TAs	987	979	901	883	940	968	955	998	1,044	1,017
Assignable Sq. Ft. (1000s)										
Classrooms	119	119	119	119	119	119	119	119	119	119
Class Labs	201	203	211	211	211	212	212	212	212	212
Research Facilities	259	260	260	260	260	260	260	261	263	267
Office Facilities	205	208	209	210	210	210	210	211	214	215
Support Facilities	60	60	60	60	60	61	61	61	62	63
Total I&R ASF	845	856	859	860	860	861	863	865	870	875
Variable Costs ($1000s)										
Salaries & Support	15,534	15,363	14,172	13,995	14,804	15,219	15,097	15,664	16,265	16,080
M&O of Plant	1,631	1,668	1,691	1,710	1,727	1,747	1,768	1,790	1,819	1,847
Debt Service	1,256	1,265	1,271	1,281	1,297	1,321	1,351	1,374	1,382	1,382
Total Variable Costs	18,421	18,296	17,134	16,985	17,828	18,287	18,216	18,828	19,466	19,309
Cumulative Total	21,179[a]	39,476	56,610	73,595	91,423	109,710	127,926	146,754	166,220	185,529

[a] Includes debt service in preceding four years for facilities constructed by SPACE to meet 1969-70 needs.

TABLE 12

Utilization Rates, Class Sizes, Faculty & Teaching Assistants, Assignable Sq. Ft., and Variable Costs
Run 12A: UCSB data; actual inventory; "flat" 44-hour schedule; randomizations initiated by IG = 1 and IX = 1

Measurement	1969-70	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79
Classroom Utilization										
WRH per Room	32.8	32.3	28.7	28.3	30.4	31.4	31.3	32.2	34.0	31.8
Station Occupancy	0.48	0.49	0.52	0.48	0.46	0.45	0.46	0.46	0.44	0.48
WSH per Station	15.7	15.7	14.9	13.6	13.9	14.2	14.3	14.7	15.1	15.4
ASF per Station	13.5	13.5	13.5	13.1	13.1	13.1	13.1	13.1	13.1	13.1
ASF per WSH	0.86	0.86	0.91	0.96	0.95	0.93	0.92	0.89	0.87	0.85
Average Class Size (WSH/WRH)										
In Classrooms	31.6	32.1	34.2	34.5	32.7	32.3	32.7	32.8	31.9	34.6
In Class Labs	16.2	16.5	16.4	16.8	16.1	15.9	16.5	16.4	16.5	15.0
FTE Faculty & TAs										
Teaching Assistants	213	215	200	193	209	214	207	222	236	223
Tenured Faculty	319	315	288	285	302	309	309	321	334	329
Non-Tenured Faculty	248	249	227	224	237	246	243	250	262	254
Other Faculty	182	176	160	158	168	176	173	177	184	185
Total Faculty & TAs	962	955	875	860	917	944	932	970	1,015	991
Assignable Sq. Ft. (1000s)										
Classrooms	125	125	125	133	133	133	133	133	133	133
Class Labs	204	216	216	216	218	218	221	221	221	221
Research Facilities	259	259	259	259	259	259	259	259	261	265
Office Facilities	204	207	207	207	207	208	208	209	211	212
Support Facilities	59	60	60	60	60	60	60	60	61	62
Total I&R ASF	852	867	867	875	878	878	881	883	888	893
Variable Costs ($1000s)										
Salaries & Support	15,183	15,020	13,777	13,663	14,451	14,842	14,761	15,282	15,878	15,709
M&O of Plant	1,644	1,689	1,706	1,740	1,763	1,781	1,805	1,827	1,855	1,885
Debt Service	1,324	1,352	1,374	1,388	1,406	1,431	1,460	1,485	1,494	1,494
Total Variable Costs	18,151	18,061	16,857	16,791	17,620	18,054	18,026	18,594	19,227	19,088
Cumulative Total	21,033[a]	39,094	55,950	72,741	90,361	108,415	126,441	145,035	164,262	183,350

[a]Includes debt service in preceding four years for facilities constructed by SPACE to meet 1969-70 needs.

TABLE 13

Utilization Rates, Class Sizes, Faculty & Teaching Assistants, Assignable Sq. Ft., and Variable Costs
Run 12B: UCSB data; actual inventory; "lumpy" 44-hour schedule; randomizations initiated by IG = 1 and IX = 1

Measurement	1969-70	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79
Classroom Utilization										
WRH per Room	31.9	31.4	27.8	27.6	29.6	30.6	30.5	31.4	32.3	30.2
Station Occupancy	0.49	0.50	0.49	0.49	0.47	0.46	0.47	0.47	0.46	0.50
WSH per Station	15.6	15.6	13.6	13.6	13.8	14.1	14.2	14.7	15.0	15.2
ASF per Station	13.5	13.5	13.1	13.1	13.1	13.1	13.1	13.1	13.2	13.2
ASF per WSH	0.87	0.87	0.97	0.97	0.95	0.93	0.92	0.89	0.88	0.87
Average Class Size (WSH/WRH)										
In Classrooms	31.9	32.5	34.6	34.9	33.1	32.6	33.1	33.1	32.2	35.0
In Class Labs	16.2	16.5	16.4	16.8	16.1	15.9	16.5	16.4	16.5	15.0
FTE Faculty & TAs										
Teaching Assistants	211	213	199	192	207	212	205	221	234	220
Tenured Faculty	316	313	286	282	299	307	306	318	331	327
Non-Tenured Faculty	246	247	225	221	235	245	241	248	260	252
Other Faculty	180	174	158	156	166	174	172	175	132	184
Total Faculty & TAs	954	947	867	852	908	938	924	962	1,007	984
Assignable Sq. Ft. (1000s)										
Classrooms	126	126	134	134	134	134	134	134	136	136
Class Labs	206	206	209	216	217	217	217	219	220	225
Research Facilities	258	258	258	258	258	259	259	259	260	264
Office Facilities	204	206	206	206	206	207	207	208	210	211
Support Facilities	59	60	60	60	60	60	60	60	61	62
Total I&R ASF	853	856	867	875	876	876	877	880	887	898
Variable Costs ($1000s)										
Salaries & Support	15,066	14,919	13,677	13,517	14,323	14,768	14,630	15,164	15,757	15,602
M&O of Plant	1,646	1,669	1,707	1,740	1,759	1,777	1,796	1,822	1,854	1,896
Debt Service	1,307	1,347	1,363	1,370	1,385	1,422	1,476	1,522	1,541	1,541
Total Variable Costs	18,019	17,935	16,747	16,627	17,468	17,967	17,902	18,508	19,152	19,039
Cumulative Total	20,851[a]	38,786	55,533	72,160	89,627	107,595	125,496	144,004	163,156	182,195

[a]Includes debt service in preceding four years for facilities constructed by SPACE to meet 1969-70 needs.

TABLE 14

Summary of Six 10-Year Runs of SPACE with UCSB Data

Performance Measurement	Starting With Actual Fall 1969 Inventory All Randomizations Initiated by IG = 1 and IX = 1				Starting With Zero Inventory Different Randomizations	
	"Lumpy" Schedule		"Flat" Schedule		"Lumpy" 67-Hour Schedule	
	67-Hour Week (Run 10A)	44-Hour Week (Run 12B)	67-Hour Week (Run 11A)	44-Hour Week (Run 12A)	IG = 1; IX = 1 (Run 1A)	IG = 7; IX = 3 (Run 1B)
Classroom Utilization (average in the 10 years)						
WRH per Room	30.5	30.3	32.9	31.3	34.0	34.6
Station Occupancy	0.50[a]	0.48[a]	0.52[a]	0.47[a]	0.57[a]	0.48[a]
WSH per Station	15.4	14.5	16.9	14.8	19.5	16.6
ASF per WSH	0.87	0.91	0.82	0.90	0.67	0.76
Average Class Size (average in the 10 years)						
In Classrooms	34.0	33.3	31.8	32.9	34.0	33.3
In Class Labs	16.2	16.2	16.2	16.2	16.2	16.1
FTE Faculty & TAs (average in the 10 years)						
Teaching Assistants	208	211	220	213	208	212
Regular Faculty	712	723	748	729	712	724
Total Faculty & TAs	920	934	968	942	920	936
Assignable Sq. Ft. in the 10th Year (in thousands)						
Classrooms	127	136	119	133	101	116
Class Labs	229	225	212	221	141	138
All Other I&R	535	537	544	539	474	483
Total I&R ASF	891	898	875	893	716	737
Total Variable Costs in the 10 Years (in millions)						
Salaries & Support	$ 145.3	$ 147.4	$ 152.2	$ 148.6	$ 145.3	$ 147.9
M&O of Plant	17.6	17.7	17.4	17.7	13.8	14.2
Debt Service[b]	16.8	17.1	15.9	17.1	60.5	62.0
Total Variable Costs[b]	$ 179.7	$ 182.2	$ 185.5	$ 183.3	$ 219.6	$ 224.0

[a]0.60 to 0.75 in most room sizes; overall ratio reduced by disproportionate effect of a few very large rooms.
[b]Includes debt service in preceding four years for facilities constructed by SPACE to meet first-year needs.

FUTURE DEVELOPMENTS

Planning models, like freeways, are never really completed. There are always old sections to be modified and new ones to be added. SPACE is no exception. One major weakness of the model is the non-interchangeability of class labs from one level to the next and from discipline to discipline. Originally this restriction was intended to serve as a surrogate for the actual non-interchangeability of lab facilities between fields <u>within</u> disciplines. However, for campuses which regularly schedule a certain percentage of their lab classes in class labs of the 'wrong' discipline, the current procedure is unnecessarily restrictive. Accordingly the Office of Analytic Studies, California State University and Colleges, is currently modifying the FAMSIX module to permit user-defined interchangeability of class labs.

Another questionable characteristic of the model is its inability to construct class facilities optimally. Occasionally the model will encounter a need for a new room of, for example, size 9 in one hour and a need for a new room of size 10 in the next. Because the model, in its current form cannot look ahead at construction time, it would build two rooms in this case when one would have served the purpose. By assigning the lowest priority numbers, i.e., the highest priority, to the most popular hours this problem can generally be avoided. However, an additional routine to 'take a second look' at the construction needs should be developed. The California State University and Colleges' Office of Analytic Studies is working on such a routine, although it appears to be expensive to run.

The staffing calculations in the VARICOS module are still somewhat simplistic. A more realistic model would include consideration of tenure status, death and retirement rates, and rank advancement probabilities. These features are still under consideration.

Finally, at least in principle, the model is adaptable to micro analysis of individual disciplines by treating the 33 'discipline' categories as individual departments or other course groupings with closely related facilities needs. The feasibility of using the model at that level of detail will be the next subject of investigation.

APPENDIX

INPUT SPECIFICATIONS: FAMSIX MODULE

1. IG, IX, S101, S210, S400 FORMAT (2I9, 3I1)

Two odd valued integers of 9 or fewer digits. IG is the starting value for the randomization of the distribution of weekly student hours to class sizes. IX is the starting value for the randomization which assigns classes of a given size to room sizes. S101, S210, S400 are print switches for Tables 101, 211 and 212, 401 and 402, respectively. Value = 1 means print, value = 0 means don't print. One card.

2. NCAMP, NRUN, NDATE, NUMYRS, NYEAR FORMAT (4A4, I2, I4)

Descriptors of the run. NCAMP is a 4-letter abbreviation for the campus name. NRUN is a 4-character alphameric code for the name of the run. NDATE is an 8-character alphameric code for the date the run is performed. NUMYRS is the number of years for which data is provided in this run. NYEAR is a 4-digit integer representing the base year for the run, e.g., 1970. One card.

2a. DNAME FORMAT (20A4)

4 cards. The first 3 cards contain 10 entries each, the last card 4 entries. Each entry is an 8-character alpha code for the name of a discipline. The entries are arranged in natural order, 1-34. The 34th entry must be the word "ALL." The entries should be left-justified in the 8-character fields.

3. ACS FORMAT (15F4.0)

The average class size in each class size range. One card, the entries of which read from left to right in ascending order of sizes.

<u>ITEMS 4 - 14 PERTAIN TO NON-LAB DATA</u>

4. NSTATS FORMAT (I3)

One card with one entry. The number of cards in data set 5 (which is equal to the number in data set 6).

5. WSHR, J, K FORMAT (15F4.3, 6X, I2, I1)

For each combination of discipline, J, and course level, K, one card is possible. Each card contains, in addition to the identifiers J and K, up to 15 values. These are the means of the distributions of weekly student hours to the 15 possible class size ranges in ascending order of size. For combinations of J and K for which all values are zero, no card is necessary.

6. WSHD, J, K FORMAT (15F4.3, 6X, I2, I1)

Same as data set 5 except the entries are standard deviations for the distributions rather than the means of those distributions. (The distributions are assumed to be Gaussian). For each card in data set 5 there must be a corresponding card in data set 6.

7. NOURS, NGRUMP FORMAT (2I3)

NOURS is the number of hours in the week during which classes are scheduled. The maximum value is 96. NGRUMP is the number of priority listings, i.e., the largest number in the priority schedule to which an hour of the week is assigned. The maximum value is 250.

8. GRUMP, GRUMP2 FORMAT (2I3)

There are NGRUMP cards, each with 2 entries. GRUMP is an integer in the interval 1 through 96. GRUMP2 is the priority assigned to the hour (an integer in the interval 1 through NGRUMP. The cards are to be ordered by hour in ascending order. Where there are multiple priority assignments to a given hour the cards may be ordered in ascending values of GRUMP2. For example, a set may begin with the ordered pairs: (1,6), (1,19), (2,5), (2,7), (2,35), (4,16), (5,1), (5,17), ... All values of GRUMP2 in the interval $1 \leq GRUMP2 \leq NGRUMP$ must be included. No values of GRUMP2 may be repeated.

9. YELP FORMAT (F10.0)

The exponent for the function relating class size to the hour of the week and the proportion of weekly student hours scheduled in classes during that hour. The form of the relationship is:

$$x = afp^y .$$

Here, x is the average class size in the hour;
- a is the average class size in all hours;
- f is a factor determined for each hour;
- p is the proportion of weekly student hours in scheduled classes during the hour; and
- y is an exponent which is not hour-specific.

10. FACT FORMAT (10F7.6)

The factor, f, in the function above. There are NOURS such values with 10 values per card. The first value on the first card is the factor for hour #1. The first value on the second card is the factor for hour #11, etc. Thus, if NOURS = 78 for example, there would be 8 cards.

11. DS8, L FORMAT (15F4.3, 10X, I2)

Proportion of classes of a given class size range which are assigned to rooms in each room size range. For each class size range (i.e., 15) there is one card. The cards are ordered in ascending values of class size range. L is the class size range identifier. The sum of the 15 values on each card must be 1.0.

12. NLREQ, NSTA, NLASF FORMAT (12X, 3I12)

Base year inventory. There are 15 cards, one for each room size range. The cards are ordered in ascending order of room size. Each card has 3 values. The first, NLREQ, is the number of rooms in the size range. The second, NSTA, is the total number of stations in the rooms of the size range. It is not the number of stations per room. NLASF is the total number of assignable square feet in rooms of the size range.

13. NLFNS FORMAT (15I4)

The number of stations in rooms which will be constructed by the model. There is one card with 15 entries. Each entry represents the stations per room for a given room size. The entries are ordered from left to right in ascending order of size.

14. FFPSNL FORMAT (15I4)

The number of assignable square feet per station for rooms to be constructed by the model. There is one card with 15 entries. Each entry represents the asf per station for a given room size. The entries are ordered from left to right in ascending order of size.

15. - 22.

These data sets are identical respectively to data sets 4 - 11 except that they represent LAB classes and rooms. Note that NSTATS, NOURS, and NGRUMP may have different values for lab and non-lab data.

23. NCARDS FORMAT (I3)

The number of cards in data set 24.

24. L, LREQL, NSTAL, LASF, J, K FORMAT (I2, 10X, 3I12, 20X, 2I2)

For each class-lab size, L, discipline, J, and level, K, for which there is non-zero data, there is one card. LREQL is the number of class-labs in the base year inventory for the L-J-K combination. NSTAL is the total number of stations in those class-labs. LASF is the total number of assignable square feet in those class-labs. The order of the cards is not important.

25. NCARDS FORMAT (I3)

The number of cards in data set 26 (which is equal to the number of set 27).

26. LFNS, J, K FORMAT (15I4, 8X, 2I2)

For each combination of discipline, J, and level, K, with non-zero data there is one card. Each card contains the number of stations in class-labs to be constructed by the model in each size range. There are 15 values per card, each representing the stations per lab for the 15 size ranges ordered from left to right in ascending order of size. The order of the cards is not important.

27. FFPSL, J, K FORMAT (15I4, 8X, 2I2)

For each card in data set 26, there is a corresponding card representing the assignable square feet per station in labs to be constructed by the model. The sets are identical in form and specification except asf-per-station is to replace stations-per-lab.

ITEMS 28 AND 29 ARE TO BE REPEATED FOR EACH YEAR OF THE RUN (i.e., 28, 29, 28, 29, 28, ...)

28. WSH, J FORMAT (3F10.2, 39X, I2)

Non-lab weekly student hours. There are 33 cards, one for each discipline. If there are no weekly student hours, for a given discipline a card which is blank except for the discipline number in columns 70-71 must be included. The cards are ordered in ascending order of discipline. Each card contains 3 values, one for each course level. The first value is for level 1, the second for level 2, the third for level 3.

29. WSH, J FORMAT (3F10.2, 39X, I2)

Lab weekly student hours. This set is identical in form and specification to set 28 except Non-lab is replaced by Lab.

NOTE: The maximum number of disciplines is 33.
The maximum number of levels is 3.
The maximum number of sizes is 15.

INPUT SPECIFICATIONS: VARICOS MODULE

It is assumed that the following shall apply to card-input. If VARICOS is run in tandem with FAMSIX, the user may request that FAMSIX will write data sets 1, 13, and 14 onto tape or temporary disk storage. If this is done, it is assumed that the storage file will "look like cards."

1. NCAMP, NRUN, NDATE, NUMYRS, NYEAR FORMAT (4A4, I2, I4)

1 card. NCAMP is a 4-character alpha abbreviation for the campus name. NRUN is a 4-character alpha abbreviation for the name of the run. NDATE is an 8-character alpha abbreviation for the date of the run. NUMYRS is the number of years for which data is provided. (Maximum value is 10). NYEAR is the base year for the run (e.g., 1969).

2. DNAME FORMAT (20A4)

4 cards. The first 3 cards contain 10 entries each, the last card 3 entries. Each entry is an 8-character alpha code for the name of a discipline. The entries are arranged in natural order, 1 - 33.

3. A1, A2, B1, B2 FORMAT (6F10.0)

132 cards arranged in 33 sets of 4 cards each. The first card contains A1, the second A2, the third B1, the fourth B2 for each set. The sets are arranged by discipline in natural order. Each card contains 6 values: first Non-lab data for course levels 1-3 followed by Lab data for course levels 1-3. A1 is the proportion of weekly room hours in the appropriate level, type, and discipline which are taught by TA's. A2 is the same data for the non-TA part of the academic staff. (If there were no team teaching A1 + A2 would equal 1.0). B1 is weekly contact hours per FTE for TA's. B2 is the same data for the non-TA part of the academic staff.

4. FACSAL FORMAT (6F10.0)

1 card containing 4 values. Average yearly faculty salaries for the four faculty types. In order, these are: TA's, irregular ranks, regular non-tenured, tenured.

5. C2, D2 FORMAT (6F10.0)

33 cards arranged in natural order by discipline. Each card has 6 values: 2 for C2, and 4 for D2. The first C2 value is non-TA instructional staff per TA in non-Lab courses, i.e., supervision by non-TA faculty of TA's generated by non-Lab classes. The second C2 value is the Lab-class counterpart of the first. (Typical values are 0.1). The D2 values are non-TA faculty per student for each student level: LD, UD, Grad 1, Grad 2 in order. These values represent independent study workloads when A2, B2, and C2 are

5. (continued)

non-zero. They may be used to generate faculty on a strict student/faculty ratio by setting A2, B2, and C2 to zero. However, it is necessary to generate TA's via workload computation and the A1, B1 parameters.

6. SUPRAT, RKDIST FORMAT (6F10.0)

33 cards arranged in natural order by discipline. 4 values per card. The first value is discipline support $ per non-TA faculty. The next 3 values are the distribution of non-TA faculty by rank, i.e., proportion of non-TA faculty which are, in order, Irregular, Non-tenured, Tenured.

7. R1, R2, O1, O2, S1, S2 FORMAT (10F8.0)

33 cards arranged in natural order by discipline. 10 values per card. The first 2 values are research ASF/non-TA faculty and research ASF/TA. Then research ASF/Grad 1, and research ASF/Grad 2. O1 and O2 follow the same pattern replacing research ASF with office ASF. The ninth value, S1, is support ASF/research and office total ASF. The tenth value is support ASF/class-lab total.

8. CAPFAC FORMAT (10F8.0)

33 cards arranged in natural order by discipline. 5 values per card. These are capital cost factors for each type of space, i.e., $/ASF for classrooms, class labs, research, office, and supporting ASF. Each of these numbers will be multiplied by an index number (cf. Item 11 below) so it is possible to treat these numbers as multipliers of an overall cost/ASF index.

9. K, INASF (3-5, K), NDCHK FORMAT (I2, 3I10, I2)

Inventory of non-class ASF. For each discipline, K, with non-zero inventory of non-Class ASF there is one card. Each card contains in order: discipline number, inventory research ASF, inventory office ASF, inventory support ASF. The last physical card must additionally contain a 1 in cc. 34 to signal the end of the set.

10. SINFL, BR, BL FORMAT (2F5.0, I2)

One card containing 3 values. SINFL is an inflation factor - annual rate of inflation for physical facilities less annual rate for operating costs plus one - e.g., 1.01. BR is the rate of interest on bonds, e.g., 0.03. BL is the bond life, e.g., 25.

11. CSTDST, D4MNO, DPSQFT FORMAT (10F8.0)

One card containing 6 values. The first 4 values are the distribution of costs over the 4-year period of capital construction for any project, i.e., the

11. (continued)

proportion of the total project costs incurred in the first through fourth years of construction. The fifth value is the overall $/ASF figure for maintenance and operation of physical plant. The last value is the overall $/ASF figure for construction (or the comparable index figure - see Item 8 above).

ITEMS 12 - 14 ARE TO BE REPEATED IN ORDER FOR EACH YEAR OF THE TEST RUN

12. ENR, NDCHK, K FORMAT (4F5.0, I2, 46X, I2)

Enrollments by discipline and student level. For each discipline with non-zero enrollments, one card containing 5 values. The first four values are the enrollments for LD, UD, Grad 1, Grad 2, in order. The fifth value is the discipline number (cc. 69, 70). The last physical card must contain a 1 in cc. 22 to signal the end of the data group.

13. I, K FORMAT (2I2)
WRH FORMAT (3I4)

Weekly room hours by course level, discipline, and class type. For each combination of discipline and class type with non-zero weekly room hour data there are two cards. The first card contains two values, the class type, I, and the discipline number, K. The second card contains three values: the number of weekly room hours in each course level for that discipline and class type. The WRH are ordered LD, UD, Grad.

At the end of this group of cards, there must be one blank card to signal the end of the data group.

14. K, INASF, NWASF FORMAT (I2, 4I10)

33 cards containing 5 values per card. The cards are ordered serially by discipline. The first value is the discipline number. The next two values are the non-Lab and Lab inventories. The final two values are the non-Lab and Lab newly constructed ASF. The inventories include the new ASF.

FAMSIX - PROGRAM LISTING

```
C
C       THIS IS FAMSIX DESIGNED AND WRITTEN BY DONOVAN SMITH, W. GARY WAGNER,
C          AND JOHN LAFLER OF THE OFFICE OF ANALYTICAL STUDIES,
C          VICE PRESIDENT - PLANNING, UNIVERSITY OF CALIFORNIA.
C
C       THE CODING OF SUBROUTINE NLSPIL HAS BEEN ADAPTED FROM CCHE-FAM,
C          A PRODUCT OF MATHEMATICA INC.
C
C       COMMENTS REFER TO THE FLOW CHART OF FAMSIX BY BOX LETTER.
C
C       THIS PROGRAM HAS BEEN TIMED BY A BOOLE AND BABBAGE PRODUCT AND
C       FINE-TUNING PROGRAM CHANGES MADE FOR INCREASED EFFICIENCY.
C
C        WEEKLY STUDENT HOURS, CLASS SIZES AND ROOM HOURS ARE GENERALLY
C          CARRIED AS INTEGERS AND ROUNDED WHEN NECESSARY.
C
C        INTEGER*2 IS USED THROUGHOUT THE PROGRAM TO MINIMIZE STORAGE.
C
C        HERE FOLLOWS A DICTIONARY OF MOST VARIABLES USED IN THIS PROGRAM
C          EXCEPT THOSE OF THE FORM L,LL,JJJ ETC WHICH ARE LOCAL COUNTERS
C          OR DO LOOP ARGUMENTS.
C
C            ACS IS THE AVERAGE CLASS SIZE FOR 15 CLASS SIZE INTERVALS
C            ADUM IS THE TEMPORARY HOLDING VARIABLE HOLDING GAUSSIAN RANDOM NUMBER
C            AFT THE WORD 'AFTER' FOR TITLES
C            AWSH IS THE INITIAL COUNT OF WEEKLY STUDENT HOURS
C            BEF THE WORD 'BEFORE' FOR TITLES
C            DATA TEMPORARY VALUES ACCUMULATED FOR PRINT LINES
C            DNAME DISCIPLINE NAME FOR REPORT PRINTING
C            DS8 (FAM DATA SET 8) SHOWS PROBABILITY OF CLASS OF A GIVEN SIZE
C                BEING IN ROOM OF A GIVEN SIZE
C            FFPSL SPACE STANDARD: NUMBER ASF PER STATION FOR LABS TO BE BUILT
C            FFPSNL SPACE STANDARD: NUMBER ASF PER STATION FOR CLASS ROOMS TO
C               BE BUILT
C            FPS TEMPORARY VARIABLE: FEET PER STATION USED IN TABLES 301,302
C            FPWSH ASF PER WEEKLY STUDENT HOUR
C            GASP IN HOUR LOOP IS TEMPORARY VARIABLE HOLDING DISTRIBUTION OF
C               CLASS SIZES BY ROOM SIZES
C            IBLD TEMPORARY NUMBER OF ROOMS TO BE BUILT IN HOUR LOOP
C           IG IS THE VALVE USED IN GENERATING RANDOM NUMBERS FOR THE
C             VARIATION IN WEEKLY STUDENT HOURS.
C            INASF CURRENT NUMBER OF ASSIGNABLE SQUARE FEET FOR USE BY VARIOUS
C            IX IS THE VALUE USED IN GENERATING RANDOM NUMBERS FOR THE
C              VARIATION IN ROOM SIZE ASSIGNED TO A GIVEN CLASS
C            FACT IS HOURLY FACTOR USED IN ADJUSTING CLASS SIZE BY HOUR
C            GRUMP IS THE HOUR TO WHICH EACH PRIORITY IS ASSIGNED
C            GRUMP2 IS THE PRIORITY ORDER OF THIS PRIORITY
C           JUM IS A TEMPORARY VARIABLE REPRESENTING CELLS OF JWRH IN TURN
C           JWALK IS AN ORDERED LIST OF CLASS HOURS
C            JWRH IS USED TWICE. THE FIRST TIME IT IS THE WEEKLY ROOM HOURS
               DERIVED FROM THE ORIGINAL WEEKLY STUDENT HOURS. THE SECOND
C               TIME IT IS THE WEEKLY ROOM HOURS ASSIGNED IN THE HOUR SIZE
C               FUNCTION BY DISCIPLINE, LEVEL, AND SIZE FOR THAT HOUR.
C            KHCSZ SUMS OF CLASSES BY CLASS SIZE FOR TABLES 401,402
C            KHRSZ SUMS OF CLASSES BY ROOM SIZE FOR TABLES 401,402
C            KWRH HOURLY CLASS HOURS BY DISCIPLINE, LEVEL AND REVERSE SIZE
C               ALL CAREFULLY LUMPED AS SINGLE SUBSCRIPT
C            KKWRH HOURLY CLASS HOURS BY SIZE ONLY, USED IN HOUR SIZE FUNCTION
C            KWRHO SAME AS KWRH BUT PROPERLY SUBSCRIPTED
```

```
C          LASF NUMBER OF ASSIGNABLE SQAKE FEET IN LABS
C          LBLDL LAB ROOMS TO BE BUILT
C          LFNS IS THE NUMBER OF STATIONS BY SIZE FOR CLASS LABS TO BE
C            BUILT
C          LP IS USED FIRST AS THE SIMPLIFIED SUBSCRIPT OF FIRST JWRH. LATER
C             IT IS POINTER TO CURRENT PRIORITY TO BE USED IN HOUR LOOP.
C          LPP IS UDED AS POINTER TO EVERY CLASS HOUR WHEN MAKING UP JWALK. (LP
C             IS ONLY POINTER TO EVERY CELL OF CLASS HOURS.)
C          LREQ LASF SUMMED OVER DISCIPLINES FOR PRINTING
C          LREQL IS THE INVENTORY OF CLASS LABS AT ANY TIME
C          MREQ IS LREQL SUMMED OVER DISCIPLINE FOR REPORT PURPOSES
C          MWRH CLASSES OVER ALL HOURS BY DISCIPLINE, LEVEL, CLASS SIZE
C              AND ROOM SIZE FOR LABS.
C          MWRHO TEMPORARY COUNT OF ROOMS BY SIZE, DISCIPLINE AND LEVEL
C             WITHIN HOUR LOOP. UPDATED IN NLSPIL.
C          N1 IS THE NUMBER 1 REPRESENTING THE CARD READER IN INPUT
C          N5 IS THE NUMBER 2 REPRESENTING THE OUTPUT FILE FOR VARICOS
C          N6 IS THE NUMBER 6 REPRESENTING THE PRINTER IN OUTPUT
C          NCAMP IS THE NUMBER OF THE CAMPUS (FOR PRINTING)
C          NDATA TEMPORARY VALUES ACCUMULATED FOR PRINT LINES
C          NDATE IS THE DATE(8 CHAR FOR PRINTING)
C          NERR IS THE NUMBER OF ERRORS FOUND DURING READ IN OF DATA
C          NEWRH TOTAL WEEKLY ROOM HOURS OVER ALL HOURS.
C         NEWTOT IS FIRST JWRH SUMMED OVER DISCIPLINES FOR REPORTS
C          NGRUMP IS THE NUMBER OF PRIORITIES IN OCCURENCE FOR HOURS
C          NIT IS THE ITERATION NUMBER (FOR PRINTING)
C          NLASF TEMPORARY VARIABLE: USED FOR COMPUTING UTILIZATION RATES IN
C             TABLES 301,302
C          NLBLD NON-LAB ROOMS TO BE BUILT
C          NLFNS IS THE NUMBER OF STATIONS BY SIZE FOR CLASSROOMS TO BE
C            BUILT
C          NLREQ IS THE INVENTORY OF CLASSROOMS AT ANY TIME
C          NNHOLD NUMBER OF STATIONS: ORIGINAL + BUILT BY SIZE AND LEVEL
C          NO1 TABLE NUMBERS FOR TITLES
C          NONRH SUM OF NEWRH OVER DISCIPLINE FOR TOTAL LINES
C          NOURS IS THE NUMBER OF HOURS WHEN CLASSES MAY OCCUR
C          NPRO 'NON' OR BLANK FOR TITLES
C          NRMS THE SUM OF THE WEEKLY ROOM HOURS IN THAT HOUR(ONE NUMBER)
C          NROOM 'ROOM' OR 'LAB' FOR TITLES
C          NRUN IS THE RUN NUMBER (FOR PRINTING)
C          NSTA IS THE NUMBER OF STATIONS BY SIZE FOR CLASSROOMS
C          NSTAL IS THE NUMBER OF STATIONS BY SIZE FOR CLASS LABS
C          NWASF ASSIGNABLE SQUARE FEET OF NEW ROOMS & LABS FOR VARICOS USE
C          NYEAR IS THE NUMBER OF THE YEAR (FOR PRINTING)
C          S101 INPUT SWITCH TO PRINT TABLE 101
C          S210 INPUT SWITCH TO PRINT TABLES 211,212
C          S400 INPUT SWITCH TO PRINT TABLES 401,402
C          WRHS TEMPORARY COUNT OF ROOMS BY SIZE WITHIN HOUR LOOP, UPDATED
C             IN NLSPIL.
C          WRHSAV IS WEEKLY ROOM HOURS ASSIGNED IN THE HOUR SIZE FUNCTION BY
C             DISCIPLINE, LEVEL AND SIZE FOR ALL HOURS
C          WRHSUM TOTAL WEEKLY ROOM HOURS OVER ALL HOURS
C          WRHZUM CLASSES OVER ALL HOURS BY CLASS SIZE AND ROOM SIZE FOR
C             NON-LABS.
C          WSH  IS THE BASIC WEEKLY STUDENT HOURS BY DISCIPLINE,LEVEL
C            AND LAB-NON LAB AS READ IN (NOT DESTROYED)
C          WSH1 IS THE RANDOMIZED WSH INPUT OVER CLASS SIZE.
C          WSHD IS THE DEVIATION USED IN GENERATING RANDOM CHANGES IN
C            WEEKLY STUDENT HOURS
```

```
C         WSHR IS THE MEAN OF THE DEVIATION USED IN GENERATING RANDOM
C           CHANGES IN WEEKLY STUDENT HOURS
C         XDUM BECOMES THE CORRECTION RATIO TO STABILIZE THE WEEKLY
C           STUDENT HOURS BY DISCIPLINE AND LEVEL IN SPITE OF RANDOM-
C           IZING CLASS SIZE
C         YELP IS THE POWER FACTOR USED IN ADJUSTING CLASS SIZE BY HOUR
C
      DIMENSION ACS(15),      DS8(15,15,2), NDATE(2),     WSH(33,3,2),
     1          ADUM(15),     FACT(96,2),   NLASF(15),    WSHD(33,3,15,2),
     2          AFT(2),       INASF(2,33),  NPRO(2),      WSHR(33,3,15,2),
     3          AWSH(33,3,2),LASF(15,33,3),NRCOM(2),      WSH1(33,3,15),
     4          BEF(2),       LREQ(3,15),   NWASF(2,33),YELP(2),
     5          DATA(3),      NDATA(3),     NO1(6),
     6          DNAME(2,34)
C
      INTEGER*2 FFPSL(15,33,3), KWRHD(33,3,15),   NNHOLD(3,15),
     1          FFPSNL(15),     LBLDL(15,33,3),   NONRH(3,15),
     2          GASP(15,15),    LFNS(15,33,3),    NOURS(2),
     3          GRUMP(250,2),   LREQL(15,33,3),   NSTA(15),
     4          GRUMP2(250,2),  MREQ(3,15),        NSTAL(15,33,3),
     5          IBLD(15),       MWRH(15,15,33,3), WRHS(15),
     6                          MWRHD(15,33,3),   WRHSAV(3,15,33),
     7          JWALK(12500),   NEWRH(33,3,15),   WRHSUM(15),
     8          JWRH(3,15,33),  NEWTOT(3,15),     WRHZUM(15,15),
     9          KHCSZ(15),      NGRUMP(2),
     A          KHRSZ(15),      NLBLD(15),        S101,
     B          KKWRH(15),      NLFNS(15),        S210,
     C          KWRH(1485),     NLREQ(15),        S400
C
C     EQUIVALENCE STATEMENTS ARE FOR STORAGE EFFICIENCY EXCEPT FOR VARIABLES
C        KWRH AND KWRHD WHERE A FUNCTIONAL CROSS EXISTS.
C
      EQUIVALENCE (ADUM(1),NEWRH(1),WRHSUM(1))
      EQUIVALENCE (KWRH(1),KWRHD(1),MWRHD(1),WRHS(1))
      EQUIVALENCE(MWRH(1),WRHZUM(1))
      EQUIVALENCE (MWRH(6001),WSH1(1))
      EQUIVALENCE (LBLDL(1),NLBLD(1))
C
C     DATA STATEMENTS ARE FOR REPORT HEADINGS
      DATA NO1(1),NO1(2),NO1(3),NO1(4),NO1(5),NO1(6),NROOM(1),NROOM(2)/
     1'01','02','11','12','21','22','ROOM',' LAB'/
      DATA NPRO(1),NPRO(2)/'NON',' '/
      DATA BEF(1),BEF(2),AFT(1),AFT(2)/'BEF','ORE','AFT','ER'/
      N1=1
      N6=6
      N5=2
      NZERO=0
      NERR=0
C
C     FOR SIGNIFICANCE OF INPUT VARIABLES SEE INPUT DOCUMENTATION   (BOX A)
      READ(N1,900) IG,IX,S101,S210,S400
      WRITE(N6,901)IG,IX
      READ(N1,902) NCAMP,NRUN,NDATE,NUMYRS,NYEAR
      WRITE(N5,902)NCAMP,NRUN,NDATE,NUMYRS,NYEAR
      READ(N1,929) DNAME
      READ(N1,903) ACS
C
C     FCLEAR, KCLEAR(INTEGER*2), AND KKCLEAR ARE SIMPLE CLEARING ROUTINES
      CALL FCLEAR(WSHR,2970)
```

```
      CALL  FCLEAR(WSHD,2970)
      CALL  KCLEAR(LFNS,1485)
      CALL  KCLEAR(LREQL,1485)
      CALL  KCLEAR(NSTAL,1485)
      CALL  KKCLER(LASF,1485)
      CALL  KCLEAR(FFPSL,1485)
      DO 10 II=1,2
      READ(N1,904)NSTATS
      DO 11 M=1,NSTATS
   11 READ(N1,905) J,K,(WSHR(J,K,L,II),L=1,15)
      DO 12 M=1,NSTATS
   12 READ(N1,905) J,K,(WSHD(J,K,L,II),L=1,15)
      READ(N1,904) NOURS(II),NGRUMP(II)
      NGR=NGRUMP(II)
      DO 13 J=1,NGR
   13 READ(N1,904) GRUMP(J,II, GRUMP2(J,II)
      READ(N1,906) YELP(II)
      NOU=NOURS(II)
      READ(N1,907) (FACT(N,II),N=1,NOU)
      DO 14 LL=1,15
      READ(N1,908) L,(DS8(L,M,II),M=1,15)
C
C     VARIOUS DATA CHECKS ARE PERFORMED BUT THE PROGRAM ONLY STOPS AT
C        BEGINNING OF ACTUAL COMPUTATION IF ERRORS HAVE BEEN FOUND.
      IF(L.NE.LL) CALL ERROR(NERR,6)
C
C     DS8 IS MADE INTO A CUMULATIVE LIST
      DO 14 M=2,15
   14 DS8(L,M,II)=DS8(L,M,II)+DS8(L,M-1,II)
      IF(NERR.NE.0) STOP
      IF(II.EQ.2) GO TO 16
      DO 15 L=1,15
   15 READ(N1,909) NLREQ(L),NSTA(L),NLASF(L)
      READ(N1,910) NLFNS
      READ(N1,910) FFPSNL
      GO TO 10
   16 READ(N1,904) NCARDS
      DO 17 M=1,NCARDS
   17 READ(N1,911) L,J,K,LREQL(L,J,K),NSTAL(L,J,K),LASF(L,J,K)
      READ(N1,904) NCARDS
      DO 18 M=1,NCARDS
   18 READ(N1,912) J,K,(LFNS(L,J,K),L=1,15)
      DO19  M=1,NCARDS
   19 READ(N1,912) J,K,(FFPSL(L,J,K),L=1,15)
   10 CONTINUE
C
C     HERE STARTS MAJOR LOOP OF PROGRAM DOING ALL WORK FOR EACH YEAR(BOX B)
      DO 100  NIT=1,NUMYRS
      IF(NIT.GT. 1) NYEAR=NYEAR + 1
      DO 101 II=1,2
      DO 101 JJ=1,33
      READ(N1,928) J,(WSH(J,K,II),K=1,3)
      IF(JJ.NE.J) CALL ERROR(NERR,5)
  101 CONTINUE
      IF(NERR.NE.0) STOP
      CALL  FCLEAR(AWSH,198)
      CALL  KKCLER(INASF,66)
      CALL  KKCLER(NWASF,66)
C
```

```
C     TABLE 101
      IF(S101.EQ.0) GO TO 102
      CALL PEEP1(NO1(1),NCAMP,NYEAR,NIT,NRUN,NDATE,WSH,1,DNAME)
  102 CONTINUE
C
C     HERE STARTS LOOP FOR CLASS TYPE: 2=LAB, 1= NON-LAB.              (BOX D)
      DO 200 II=1,2
      CALL KCLEAR(WRHSAV,1485)
      NGR=NGRUMP(II)
      DO 201 J=1,33
      DO 201 K=1,3
      XDUM=0.
      DO 202 L=1,15
      ADUM(L)=0.
C
C     GAUSS IS RANDOM NUMBER GENERATOR FOR NORMAL DEVIATES
      IF(WSHD(J,K,L,II).GT. .0001.OR. WSHR(J,K,L,II).GT. .0001)
     1CALL GAUSS(IG,WSHD(J,K,L,II),WSHR(J,K,L,II),ADUM(L))
      IF(ADUM(L) .LT. 0.) ADUM(L)=0.
  202 XDUM=ADUM(L)+XDUM
      IF(XDUM.GT. .001) XDUM=1.0/XDUM
      DO 201 L=1,15
C
C     DISTRIBUTE WSH TO CLASS SIZES BY DISCIPLINE AND LEVEL            (BOX E)
  201 WSH1(J,K,L)=ADUM(L)*XDUM*WSH(J,K,II)
      DO 210 J=1,33
      DO 210 K=1,3
      DO 210 L=1,15
C
C     NORMALIZE WSH AND GENERATE INITIAL WEEKLY CLASS HOURS BY DIVIDING
C        BY AVERAGE CLASS SIZE AND ROUNDING TO INTEGERS                (BOX F)
  210 JWRH(K,L,J)=WSH1(J,K,L)/ACS(L)+.5
      IF(S210.EQ.0) GO TO 213
      CALL KCLEAR(NEWTOT,45)
      WRITE(N6,913) NO1(II+2),NCAMP,NYEAR,NPRO(II),NIT,NRUN,NDATE,BEF
      DO 211 J=1,33
      DO 212 K=1,3
      DO 212 L=1,15
  212 NEWTOT(K,L)=NEWTOT(K,L)+JWRH(K,L,J)
C
C     TABLES 211,212
  211 CALL PEEP2(J,JWRH(1,1,J),ACS,II,0,DNAME)
      CALL PEEP2(34,NEWTOT,ACS,II,0,DNAME)
C
C     THE DO 220 LOOPS ARE IN PREPARATION FOR PRIORITY SCHEDULING
C        WITHIN THE HOURLY LOOP. THE VARIABLE KWRH IS THE VARIABLE
C        KWRHD CONSIDERED IN THE FORTRAN STORAGE ORDER AS A ONE-DIMENSIONED
C     VARIABLE. JWALK IS AN ORDERED LIST OF POINTERS TO THIS VARIABLE
C     SORTED BY REVERSE SIZE OF CLASS, LEVEL AND DISCIPLINE. WHEN THE
C     PRIORITY ASSIGNMENT IS WANTED IT WILL BE EASY TO 'WALK' DOWN THE
C     JWALK LIST.
  213 LP=0
      LPP=0
      SUM=0.
      DO 220 LL=1,15
      DO 220 K=1,3
      DO 220 J=1,33
      JDM=JWRH(K,16-LL,J)
      LP=LP+1
```

```
      IF(JUM.EQ.0) GO TO 220
      SUM=SUM+JUM*ACS(16-LL)
      DO 221 M=1,JUM
      LPP=LPP+1
  221 JWALK(LPP)=LP
  220 CONTINUE
      LP=1
      IF(II.EQ.2) GO TO 230
      CALL KCLEAR(NLBLD,15)
      CALL KCLEAR(WRHZUM,225)
      CALL KCLEAR(WRHSUM,15)
      GO TO 231
  230 CALL KCLEAR(LBLDL,1485)
      CALL KCLEAR(MWRH,22275)
      CALL KCLEAR(NEWRH,1485)
  231 IF(S400.EQ.1) WRITE(N6,914)NO1(II),NROOM(II)
      NOU=NOURS(II)
      CALL KCLEAR(IBLD,15)
      CALL KCLEAR(JWRH,1485)
      CALL KCLEAR(KWRH,1485)
                    CALL KCLEAR(GASP,225)
C
C     HERE STARTS THE HOURLY LOOP                                     (BOX G)
      DO 300 N=1,NOU
C
C     CHECK TO SEE IF ALL REMAINING HOURS ARE EMPTY
      IF(LP.GT.NGRUMP(II)) GO TO 300
      NSW=0
C
C     CHECK TO SEE IF THIS HOUR HAS A PRIORITY AND SET SWITCH
  301 IF(GRUMP(LP,II).NE.N)GO TO 303
      NSW=1
      M=GRUMP2(LP,II)
      LP=LP+1
      DO 302 NN=M,LPF,NGR
      NNN=JWALK(NN)
C
C     ASSIGN CLASS HOURS BY PRIORITY(SEE LONG COMMENT ABOVE)          (BOX H)
  302 KWRH(NNN)=KWRH(NNN)+1
      GO TO 301
  303 CONTINUE
      IF(NSW.EQ.0) GO TO 300
      IF(S400.EQ.0) GO TO 304
      NRMS=0
      CALL KCLEAR(KHCSZ,15)
      CALL KCLEAR(KHRSZ,15)
  304 WHSUM=0
      DO 310 L=1,15
      KKWRH(L)=0
      DO 310 J=1,33
      DO 310 K=1,3
      IF (KWRHD(J,K,16-L) .EQ. 0 ) GO TO 310
C
C     FIND NUMBER OF CLASS HOURS BY SIZE AND HOUR IN PREPARATION FOR THE
C        HOUR SIZE FUNCTION ROUTINE.
      KKWRH(L)=KKWRH(L)+KWRHD(J,K,16-L)
C
C     WHSUM IS SUM OF WSH FOR HOUR AND IS NEEDED FOR FX.
      WHSUM=WHSUM+KWRHD(J,K,16-L)*ACS(L)
```

```
  310 CONTINUE
C
C      THIS GENERATES THE HOURLY SIZE VARIATION
       FX=FACT(N,II)*(WHSUM/SUM)**YELP(II)
C
C      THE HOUR SIZE FUNCTION APPLIES FX AND CHANGES ROOM HOURS        (BOX I)
            CALL HRSZFN(KKWRH,ACS,JWRH,        KWRHD,IX,IY,FX)
       KSWCH=0
C
C      NOTE THAT THIS LONG 400 LOOP IS BEING DONE BY YEAR, CLASS TYPE, HOUR,
C         DISCIPLINE, AND LEVEL AND THAT IT HAS DOUBLE AND TRIPLE LOOPS
C         WITHIN IT. EVERY OPPORTUNITY IS TAKEN TO BYPASS, BUT
C         CODING ADDED HERE COULD BE EXPENSIVE.
       DO 400 J=1,33
       DO 400 K=1,3
       DO 410 L=1,15
       IF (JWRH(K,L,J) .EQ. 0) GO TO 410
       NN=JWRH(K,L,J)
       WRHSAV(K,L,J)=WRHSAV(K,L,J)+NN
       JWRH(K,L,J)=0
       KSWCH=1
       DO 411 I=1,NN
C
C      RANDU IS A RANDOM NUMBER GENERATOR FOR A UNIFORMLY DISTRIBUTED
C         RANDOM VARIABLE ON THE CLOSED 0,1 INTERVAL
       CALL RANDU(IX,IY,RATIO)
       IX=IY
       DO 412 M=L,15
C
C      CLASSES ARE ASSIGNED TO ROOMS ACCORDING TO THE INPUT PROBABILITY
C         DISTRIBUTION (DS8). AT THIS POINT WE SWITCH FROM WEEKLY CLASS HOURS
C         TO WEEKLY ROOM HOURS.
       IF(RATIO.GT.DS8(L,M,II)) GO TO 412
       GASP(M,L)=GASP(M,L)+1
       IF(II.EQ.2) GO TO 413
       WRHS(M)=WRHS(M)+1
       GO TO 411
  413  MWRHD(M,J,K)=MWRHD(M,J,K)+1
       GO TO 411
  412  CONTINUE
       WRITE(N6,915)
       STOP
  411  CONTINUE
  410  CONTINUE
       IF(II.EQ.1) GO TO 400
       IF(KSWCH.EQ.0) GO TO 400
       KSWCH=0
C
C      NLSPIL ASSIGNS CLASSROOMS. ROOMS ARE NOT 'BUILT' IF A LARGER ROOM
C         IS FREE, BUT THE CLASS IS SPILLED UP.                         (BOX K)
       CALL NLSPIL(IBLD,        15,MWRHD(1,J,K),LREQL(1,J,K),GASP)
C
C      COLLECT DATA FOR TABLE 401 IF NECESSARY
       IF(S400.EQ.0) GO TO 414
       DO 418 L=1,15
       DO 417 M=1,15
       KHCSZ(M)=KHCSZ(M)+GASP(L,M)
  417  KHRSZ(L)=KHRSZ(L)+GASP(L,M)
  418  NRMS=NRMS+KHRSZ(L)
```

```
  414 DO 415 L=1,15
      DO 416 M=1,15
C
C     THIS LARGE MATRIX IS NECESSARY BECAUSE OF OCCUPANCY RATE REQUIREMENTS
      MWRH(L,M,J,K)=MWRH(L,M,J,K)+GASP(L,M)
  416 GASP(L,M)=0
      LBLDL(L,J,K)=LBLDL(L,J,K)+IBLD(L)
      IBLD(L)=0
C
C     SO YOU WON'T LOSE TRACK OF WHAT YOU HAVE ALREADY
      IF(MWRHD(L,J,K).GT.LREQL(L,J,K)) LREQL(L,J,K)=MWRHD(L,J,K)
      NEWRH(J,K,L)=NEWRH(J,K,L)+MWRHD(L,J,K)
      MWRHD(L,J,K)=0
  415 CONTINUE
  400 CONTINUE
      IF(II.EQ.2) GO TO 430
C
C     THIS CODING IS EXACTLY PARALLEL TO CODING STARTING AFTER 410, BUT
C        NOT BY DISCIPLINE AND LEVEL SINCE CLASSROOMS ARE INTERCHANGEABLE
      CALL NLSPIL(IBLD,15,WRHS,NLREQ,GASP)
      IF(S400.EQ.0) GO TO 419
      DO 421 M=1,15
      DO 421 L=1,15
      KHCSZ(M)=KHCSZ(M)+GASP(L,M)
      KHRSZ(L)=KHRSZ(L)+GASP(L,M)
  421 NRMS=NRMS+GASP(L,M)
  419 DO 420 L=1,15
      WRHSUM(L)=WRHSUM(L)+WRHS(L)
      NLBLD(L)=NLBLD(L)+IBLD(L)
      IBLD(L)=0
      IF(WRHS(L).GT.NLREQ(L)) NLREQ(L)=WRHS(L)
      WRHS(L)=0
      DO 420 M=1,15
      WRHZUM(L,M)=WRHZUM(L,M)+GASP(L,M)
      GASP(L,M)=0
  420 CONTINUE
  430 CONTINUE
C
C     TABLES 401,402
      IF(S400.EQ.0) GO TO 300
C
C     THE WEEKLY CLASS HOURS BY CLASS SIZE BEFORE THE HOUR SIZE FUNCTION
C        OR 'SPILLING UP' ARE CALLED 'BASE' IN THE TABLE
      WRITE(N6,916)N,KHCSZ,NRMS,KHRSZ
      WRITE(N6,999) KKWRH
  300 CONTINUE
C
C     WHEW, THAT ENDS HOURLY LOOP, NOW TO PICK UP THE LOOSE ENDS AND MAKE
C        UP THE REPORTS. THIS COULD PROBABLY HAVE BEEN DONE BY SUBROUTINE
C        BUT THE PROGRAMMER HAD A PING-PONG MATCH.
      DO 502 J=1,33
      DO 502 K=1,3
      DO 502 L=1,15
      AWSH(J,K,II)=WRHSAV(K,L,J)*ACS(L)+AWSH(J,K,II)
  502 CONTINUE
      IF(II.EQ.2) CALL PEEP1(NO1(5),NCAMP,NYEAR,NIT,NRUN,NDATE,AWSH,2,
     1  DNAME)
      CALL KCLEAR(NEWTOT,45)
      WRITE(N6,913) NO1(II+4),NCAMP,NYEAR,NPRO(II),NIT,NRUN,NDATE,AFT
```

```
      DO 500 J=1,33
      DO 501 K=1,3
      DO 501 L=1,15
  501 NEWTOT(K,L)=NEWTOT(K,L)+WRHSAV(K,L,J)
      CALL PEEP2(J,WRHSAV(1,1,J),ACS,II,1,DNAME)
  500 CONTINUE
      CALL PEEP2(34,NEWTOT,ACS,II,0,DNAME)
      IF(II.EQ.2) GO TO 520
      WRITE(N6,917)NO1(II),NCAMP,NYEAR,NROOM(II),NIT,NRUN,NDATE
      WRITE(N6,918)DNAME(1,34),DNAME(2,34),NZERO,NLBLD
      WRITE(N6,919) NO1(II),NCAMP,NYEAR,NIT,NRUN,NDATE,NROOM(II)
      CALL FCLEAR(DATA,3)
      CALL KKCLER(NDATA,3)
      NLASFT=0
      DO 510 L=1,15
      X=0.
      Y=0.
      Z=0.
      NN=0
      FPWSH=0.
      FPS=0.
      IF(NLREQ(L).EQ.0) GO TO 512
      NDATA(1)=NDATA(1)+NLREQ(L)
      ITEMP=NLBLD(L)*NLFNS(L)
      NN=ITEMP+NSTA(L)
      NSTA(L)=NN
      ITEMP=ITEMP*FFPSNL(L)
      NWASF(1,1)=NWASF(1,1)+ITEMP
      NLASF(L)=NLASF(L)+ITEMP
      NLASFT=NLASFT+NLASF(L)
      FPS=NLASF(L)/FLOAT(NN)
      NDATA(2)=NDATA(2)+NN
      Y=WRHSUM(L)
      Y=Y/NLREQ(L)
      DO 511 M=1,15
  511 X=X+ACS(M)*WRHZUM(L,M)
      IF(X.GT. .00001) FPWSH=NLASF(L)/X
      DATA(3)=DATA(3)+X
      X=X/NN
      IF(Y.GT. .0001) Z=X/Y
      GO TO 513
  512 IF(WRHSUM(L).EQ.0) GO TO 510
  513 WRITE(N6,920) L,NLREQ(L),NN,WRHSUM(L),Y,Z,X,FPS,FPWSH
      NDATA(3)=NDATA(3)+WRHSUM(L)
  510 CONTINUE
      X=NDATA(1)
      DATA(1)=NDATA(3)/X
      DATA(3)=DATA(3)/NDATA(2)
      DATA(2)=DATA(3)/DATA(1)
      FPS=FLOAT(NLASFT)/NDATA(2)
      FPWSH=FPS/DATA(3)
      INASF(1,1)=NLASFT
      WRITE(N6,921) NDATA,DATA,FPS,FPWSH
      GO TO 200
  520 WRITE(N6,917)NO1(II),NCAMP,NYEAR,NROOM(II),NIT,NRUN,NDATE
      WRITE(N5,922) NZERO,NZERO
      DO 521 J=1,33
      DO 521 K=1,3
  521 WRITE(N6,918)DNAME(1,J),DNAME(2,J),K,(LBLDL(L,J,K),L=1,15)
```

```
      WRITE(N6,919)NOI(II),NCAMP,NYEAR,NIT,NRUN,NDATE,NROOM(II)
      CALL KCLEAR(NNHOLD,45)
      CALL KCLEAR(MREQ,45)
      CALL KCLEAR(NONRH,45)
      CALL KKCLER(LREQ,45)
      DO 530 J=1,33
      DO 530 K=1,3
      NFT=0
      CALL FCLEAR(DATA,3)
      CALL KKCLER(NDATA,3)
      DO 531 L=1,15
      Y=0.
      X=0.
      Z=0.
      NN=0
      FPS=0.
      FPWSH=0.
      IF(LREQL(L,J,K).EQ.0) GO TO 533
      NDATA(1)=NDATA(1)+LREQL(L,J,K)
      ITEMP=LBLDL(L,J,K)*LFNS(L,J,K)
      NN= ITEMP + NSTAL(L,J,K)
      NSTAL(L,J,K)=NN
      ITEMP=ITEMP*FFPSL(L,J,K)
      NWASF(2,J)=NWASF(2,J)+ITEMP
      LASF(L,J,K)=LASF(L,J,K)+ITEMP
      INASF(2,J)=INASF(2,J)+LASF(L,J,K)
      LREQ(K,L)=LREQ(K,L)+LASF(L,J,K)
      NFT=NFT+LASF(L,J,K)
      NDATA(2)=NDATA(2)+NN
      Y=NEWRH(J,K,L)
      Y=Y/LREQL(L,J,K)
      DO 532 M=1,L
  532 X=X+MWRH(L,M,J,K)*ACS(M)
      DATA(3)=DATA(3)+X
      X=X/NN
      NNHOLD(K,L)=NNHOLD(K,L)+NN
      MREQ(K,L)=MREQ(K,L)+LREQL(L,J,K)
      FPS=LASF(L,J,K)/FLOAT(NN)
      IF(X.GT. .0001) FPWSH=FPS/X
      IF(Y.EQ.0.) GO TO 533
      Z=X/Y
  533 NONRH(K,L)=NONRH(K,L)+NEWRH(J,K,L)
      NDATA(3)=NDATA(3)+NEWRH(J,K,L)
      IF(LREQL(L,J,K).NE.0.OR.NEWRH(J,K,L).NE.0)
     1WRITE(N6,923)DNAME(1,J),DNAME(2,J),K,L,
     2                      LREQL(L,J,K),NN,NEWRH(J,K,L),Y,Z,X,FPS,FPWSH
  531 CONTINUE
      X=NDATA(1)
      IF(NDATA(1).EQ.0) GO TO 530
      DATA(1)=NDATA(3)/X
      DATA(3)=DATA(3)/NDATA(2)
      DATA(2)=0.
      FPS=FLOAT(NFT)/NDATA(2)
      FPWSH=0.
      IF(DATA(3).GT. .0001) FPWSH=FPS/DATA(3)
      IF(DATA(1).EQ.0.) GO TO 534
      DATA(2)=DATA(3)/DATA(1)
  534 WRITE(N6,924)DNAME(1,J),DNAME(2,J),K,NDATA,DATA,FPS,FPWSH
  530 CONTINUE
```

```
      DO 540 K=1,33
  540 WRITE(N5,925)K,INASF(1,K),INASF(2,K),NWASF(1,K),NWASF(2,K)
      WRITE(N6,919)NOL(II),NCAMP,NYEAR,NIT,NRUN,NDATE,NROOM(II)
      DO 550 K=1,3
      CALL FCLEAR(DATA,3)
      CALL KKCLER(NDATA,3)
      NFT=0
      DO 551 L=1,15
      IF(MREQ(K,L).EQ.0) GO TO 551
      NFT=NFT+LREQ(K,L)
      NDATA(1)=NDATA(1)+MREQ(K,L)
      NDATA(2)=NDATA(2)+NNHOLD(K,L)
      NDATA(3)=NDATA(3)+NONRH(K,L)
      Y=NONRH(K,L)
      Y=Y/MREQ(K,L)
      X=NONRH(K,L)*ACS(L)
      DATA(3)=DATA(3)+X
      X=X/NNHOLD(K,L)
      FPS=FLOAT(LREQ(K,L))/NNHOLD(K,L)
      FPWSH=0.
      IF(X.GT. .0001) FPWSH=FPS/X
      IF(Y.EQ.0.) GO TO 552
      Z=X/Y
  552 WRITE(N6,926)K,L,MREQ(K,L),NNHOLD(K,L),NONRH(K,L),Y,Z,X,FPS,FPWSH
  551 CONTINUE
      X=NDATA(1)
      IF(X.EQ.0) GO TO 550
      DATA(1)=NDATA(3)/X
      DATA(3)=DATA(3)/NDATA(2)
      DATA(2)=0.
      FPWSH=0.
      FPS=FLOAT(NFT)/NDATA(2)
      IF(DATA(3).GT. .0001) FPWSH=FPS/DATA(3)
      IF(DATA(1).GT. .0001) DATA(2)=DATA(3)/DATA(1)
  550 WRITE(N6,927)K,NDATA,DATA,FPS,FPWSH
  200 CONTINUE
  100 CONTINUE
  900 FORMAT(2I9,3I1)
  901 FORMAT(//' IG=',I9,'  IX=',I9)
  902 FORMAT(4A4,I2,I4)
  903 FORMAT(15F4.0)
  904 FORMAT(15I3)
  905 FORMAT(T67,I2,I1,T1,15F4.3)
  906 FORMAT(F10.0)
  907 FORMAT(10F7.6)
  908 FORMAT(T71,I2,T1,15F4.3)
  909 FORMAT(12X,3I12)
  910 FORMAT(15I4)
  911 FORMAT(I2,T69,2I2,T13,3I12)
  912 FORMAT(T69,2I2,T1,15I4)
  913 FORMAT('1FAM TABLE 2',A2,' FOR ',A4,' IN YEAR ',I4,':',
     1A3,'LAB WEEKLY ROOM HOURS BY DISCIPLINE'/' ITERATION',I2,', RUN ',
     2A4,', ',2A4,8X'FOR EACH CLASS SIZE AND COURSE LEVEL'//
     336X'THESE WEEKLY ROOM HOUR TOTALS ARE THE RESULT OF A GAUSSIAN'/
     446X'RANDOMIZATION OF THE CLASS SIZE DISTRIBUTION',2A3,' DISTRIBUTIN
     5G'/6X'CLASSES TO HOURS AND THEN TO ROOMS ACCORDING TO OSB'//
     627X'WEEKLY ROOM HOURS IN EACH COURSE LEVEL'/'0DISCIPLINE  CLASS SI
     7ZE',7X'1',10X'2',10X'3',9X'TOTAL'//)
  914 FORMAT('1FAM TABLE 4',A2,/20X'WEEKLY ROOM HOURS IN EACH HOUR'/27X
```

```
1'FOR CLASS ',A4,'S'//2X'HOUR',12X'      1       2       3       4       5
2    6       7       8       9       10      11      12      13      14      15    TOTAL
3 ')
915 FORMAT(1H0,'EGAD,I SPUN OUT OF LOOP 412')
916 FORMAT(1H0,I3,3X'CLASS SIZE:',16I6,/7X,'ROOM SIZE:',1X,15I6)
917 FORMAT('1FAM TABLE 5',A2,' FOR ',A4,' IN YEAR ',I4,':',
1'  NEWLY COMPLETED CLASS',A4,'S'/' ITERATION',I2,' RUN ',A4,', ',
12A4//13X'SIZE:       1       2       3',
2 '       4       5       6       7       8       9      10      11      12      13
3 14      15'/1X'DISCIPLINE  LEVEL'/)
918 FORMAT(3X2A4,4XI1,2X15I6)
919 FORMAT('1FAM TABLE 3',A2,' FOR ',A4,' IN YEAR ',I4,':  WEEKLY ROOM
1 ROOM HOURS AND UTILIZATION RATES'/'  ITERATION ',I2,' RUN',A4,
2', ',2A4,7X'IN CLASS',A4,'S'///9X'THESE NUMBERS OF WEEKLY ROOM HOU
3RS ARE AGGREGATIONS OF'/9X'THE FINAL NUMBERS IN ALL HOURS IN EACH
4ROOM SIZE'/9X'WITH ALL OTHER DATA CORRESPONDINGLY AGGREGATED'///
520X'ROOM   NO.    TOTAL    TOTAL WRH PER   UNWTD    WSH PER  ASF PE
6R  ASF PER'/' DISCIPLINE  LEVEL  SIZE  ROOMS  STATIONS   WRH     R
6OOM   STN OCC  STATION  STATION     WSH'/)
920 FORMAT(7X'ALL    ALL',2I7,I8,I9,F8.1,F9.3,3F9.2)
921 FORMAT(7X'ALL    ALL     ALL',I6,'*',I7,'*',I8,'*',F7.1,'*',F8.3,'*',
13(F8.2,'*'))
922 FORMAT(2I2)
923 FORMAT(3X2A4,I4,2I7,I8,I9,F8.1,F9.3,3F9.2)
924 FORMAT(3X2A4,I4,4X,'ALL',I6,'*',I7,'*',I8,'*',F7.1,'*',F8.3,'*',
13(F8.2,'*')/)
925 FORMAT(I2,4I10)
926 FORMAT(7X'ALL',I5,2I7,I8,I9,F8.1,F9.3,3F9.2)
927 FORMAT(7X'ALL',I5,4X'ALL',I6,'*',I7,'*',I8,'*',F7.1,'*',F8.3,'*',
13(F8.2,'*')/)
928 FORMAT(T70,I2,T1,3F10.2)
929 FORMAT(20A4)
999 FORMAT(7X,'BASE',7X,15I6)
    END
    SUBROUTINE HRSZFN(KKWRH,ACS,JWRH,          KWRHD,IX,IY,FX)
    INTEGER*2 KKWRH(15),JWRH(3,15,33),                   KWRHD(33,3,15)
    DIMENSION ACS(15)
C
C   THE FOLLOWING LOOP THROUGH STATEMENT NUMBER 12 HAS THE SOLE PURPOSE
C        OF ADJUSTING THE NUMBER AND SIZE OF WEEKLY ROOM HOURS UNDER
C        THE INFLUENCE OF THE CLASS SIZE FUNCTION. WEEKLY STUDENT HOURS
C        BY HOUR, DISCIPLINE AND LEVEL ARE KEPT APPROXIMATELY CONSTANT.
C        TO DO THIS THE FOLLOWING STEPS ARE PERFORMED:
C           1. THE CLASS SIZE FUNCTION(FX) IS FOUND.(IN MAIN ROUTINE)
C           2. FOR EACH CLASS SIZE A NEW ACTUAL CLASS SIZE IS FOUND BY
C              MULTIPLYING THE OLD NOMINAL CLASS SIZE BY FX.
C           3. THE STUDENT POPULATION IN THAT HOUR AND NOMINAL CLASS
C              SIZE IS REDISTRIBUTED TO THE TWO CLASS SIZES(OF THE RANGES
C              AVAILABLE) ON EITHER SIDE OF THE ACTUAL CLASS SIZE THAT
C              HAS BEEN FOUND. THIS IS DONE IN SUCH A WAY AS TO TRY TO
C              KEEP THAT ACTUAL CLASS SIZE AND TO KEEP THE STUDENT
C              POPULATION APPROXIMATELY CONSTANT.
C           4. THE NEW NUMBER OF WEEKLY ROOM HOURS BY HOUR AND CLASS
C              SIZE MAY BE BIGGER OR SMALLER THAN THE OLD NUMBER. IN
C              EITHER CASE THE NEW WEEKLY ROOM HOURS ARE DISTRIBUTED
C             (PROPORTIONALLY TO THE OLD)ACROSS DISCIPLINE AND LEVEL.
C           5. IN GENERAL IT SHOULD BE POINTED OUT THAT THE NUMBER OF
C              SPECIFIC CLASS SIZES LIMITS THE QUALITY OF THE ROUTINE.
C
```

```
      DIFF=0.
      DO 12  L=1,15
      LL=16-L
      IF (KKWRH(LL) .EQ. 0) GO TO 12
      IF (ABS (FX-1.) .LT. .01) GO TO 512
      IF (FX .GT. 1.)  GO TO 612
C
C  THIS IS WHEN CLASS SIZE WILL DECREASE
C  LLL WILL POINT TO HIGHER OF 2 NEW CLASS SIZES
C  KKWRH IS NUMBER OF ROOM HOURS ORIGINALLY ASSIGNED BY SIZE
      LLL=LL
      GO TO 1103
C
C  BUMP DOWN UNTIL CORRECT PAIR OF CL .S SIZES IS FOUND
 1101 IF (FX .GE. ACS(LLL-1)/ACS(LL)) GO TO 1102
      LLL=LLL-1
 1103 IF (LLL .NE. 1) GO TO 1101
C
C  IF WE ARE AT BOTTOM OF LIST ASSIGN EVERYONE TO RIGHT NUMBER OF
C  SMALLEST CLASSES
      NA=(KKWRH(LL)*ACS(LL)    )/ACS(1)+.5
      NB=0
      LLL=2
      GO TO 1106
C
C  FROM 1102 TO JUST BEFORE 512 IS ROUTINE TO FIND ACTUAL NUMBER OF
C  CLASSES OF TWO APPROPRIATE SIZES HAVING PINPOINTED THOSE SIZES (LLL)
 1102 A3=FX*ACS(LL)
      P=ACS(LL)*KKWRH(LL)+DIFF
      IF (P .GT. 0.) GO TO 1115
      DIFF=P
      GO TO 11
 1115 YY=P*(A3-ACS(LLL-1))/(A3*(ACS(LLL)-ACS(LLL-1)))
      NB=YY+.5
      NA=(P-A3*YY)/A3+.5
C
C  HAVING FOUND THE NUMBERS OF CLASSES IN EACH CLASS SIZE WE TRY TO SEE
C  IF THE LOWER CAN BE CHANGED TO A BETTER FIT (BECAUSE OF INTEGER
C  NUMBER PROBLEMS)
      NOUM=NA*ACS(LLL-1)+NB*ACS(LLL)+(NA+NB)*A3
      XX=(2.*P-NOUM)/(2.*ACS(LLL-1))
      NA=NA + XX + .5
      IF (NA .LT. 0) NA=0
      GO TO 1106
C
C  FX IS TOO SMALL TO BOTHER TO CHANGE
  512 DO 513 K=1,3
      DO 513 J=1,33
      JWRH(K,16-L,J)=KWRHD(J,K,L)
  513 KWRHD(J,K,L)=0
      GO TO 12
C
C  THIS IS WHEN CLASS SIZE IS TO INCREASE
  612 LLL=LL+1
      GO TO 1105
C
C  BUMP UP UNTIL CORRECT PAIR OF CLASS SIZES IS FOUND
 1104 IF (FX .LE. ACS(LLL)/ACS(LL))    GO TO 1102
      LLL=LLL+1
```

```
C  IF WE ARE AT TOP OF LIST ASSIGN EVERYONE TO RIGHT NUMBER OF LARGEST
C  CLASSES
 1105 IF (LLL .NE. 16) GO TO 1104
      NA=(KKWRH(LL)*ACS(LL)    )/ACS(15)+.5
      NB=0
C
C  THIS IS NODE WHICH SUBROUTINE MUST GO THROUGH
C  IF CLASSES TO BE ASSIGNED, CLASS SIZE PAIR IS FOUND AND NUMBER OF
C  WRH IN EACH HAS BEEN CALCULATED
C  ADUM AND DIFF CALCULATION IS TO KEEP RUNNING TOTAL OF ROUNDING ERROR
C  OF WSH AND ADJUST FOR IT IN NEXT LOWEST ROOM SIZE
 1106 ADUM=NA*ACS(LLL-1)
      IF(NB .NE. 0) ADUM=ADUM+NB*ACS(LLL)
      DIFF=ACS(LL)*KKWRH(LL)+DIFF-ADUM
      IF (NA+NB .EQ. 0) GO TO 11
C  XX WILL BE THE DISTANCE BETWEEN ORIGINAL WRH THAT WILL BE CHOSEN
C  FOR THE TOTAL OF THE TWO CLASSES.
C  YY WILL BE THE DISTANCE BETWEEN
C  THE CHOSEN WRH THAT WILL BE CHOSEN FOR THE HIGHER OF THE TWO
C  CLASSES.  IT MUST BE 1 OR GREATER.
C  IF NB=0 THAT MEANS ALL WRH ARE TO BE ASSIGNED TO LOWER CLASS SIZE.
C  POINTL IS POINTER TO THE NEXT ORDINAL WRH TO BE CHOSEN.
C  POINTH IS POINTER TO THE NEXT ORDINAL CHOSEN WRH TO BE USED AT
C  HIGHER CLASS SIZE
      YY=NA+NB
      POINTH=0.
      XX=KKWRH(LL)/YY
      IF(NB .EQ. 0) GO TO 1107
      YY=YY/NB
C  RANDOM NUMBER CALLS ARE USED TO MAKE STARTING WITH FIRST WRH A
C  RANDOM EVENT
      CALL RANDU(IX,IY,DUMM)
      IX=IY
      POINTH=DUMM*YY+.5
 1107 CALL RANDU(IX,IY,DUMM)
      IX=IY
      POINTL=DUMM*XX+.5
C  NTOTE AND NTOTE2 ARE RUNNING TOTALS OF ORIGINAL WRH AND CHOSEN WRH
C  SO FAR CONSIDERED.
 1110 NTOTE=0
      NTOTE2=0
C  NPT AND NPT2 ARE INTEGER ROUNDED VALUES OF POINTL AND POINTH
C  FOR COMPARISON WITH APPROPRIATE NTOTES.
      NPT=POINTL+.5
      NPT2=POINTH+.5
      DO 1108 J=1,33
      DO 1108 K=1,3
      IF (KWRHD(J,K,L     ) .EQ. 0) GO TO 1108
      NTOTE=NTOTE+KWRHD(J,K,L     )
      KWRHD(J,K,L)=0
 1114 IF (NPT .GT. NTOTE) GO TO 1108
      IF (NB .EQ. 0) GO TO 1112
      NTOTE2=NTOTE2+1
      IF (NPT2 .GT. NTOTE2) GO TO 1112
      L4=LLL
      POINTH=POINTH+YY
      NPT2=POINTH+.5
      GO TO 1113
 1112 L4=LLL-1
```

```
 1113 POINTL=POINTL-XX
      NPT=POINTL+.5
      JWRH(K,L4,J)=JWRH(K,L4,J)+1
      GO TO 1114
 1108 CONTINUE
      GO TO 12
   11 DO 10 J=1,33
      DO 10 K=1,3
   10 KWRHO(J,K,L)=0
   12 CONTINUE
      RETURN
      END
      SUBROUTINE KCLEAR(K,N)
      INTEGER*2 K(1)
      DO 1 L=1,N
    1 K(L)=0
      RETURN
      END
      SUBROUTINE RANDU(IX,IY,YFL)
C     SEE SCIETIFIC SUBROUTINE PACKAGE - FLAT DISTRIBUTION RANDOM NUMBERS
      IY=IX*65539
      IF(IY) 5,6,6
    5 IY=IY+2147483647+1
    6 YFL=IY
      YFL=YFL*.4656613E-9
      RETURN
      END
      SUBROUTINE GAUSS(IX,S,AM,V)
C      SEE SCIENTIFIC SUBROUTINE PACKAGE - NORMAL DISTRIBUTION RANDOM NUMBERS
      A=0.
      DO 50 I=1,12
      CALL RANDU(IX,IY,Y)
      IX=IY
   50 A=A+Y
      V=(A-6.)*S+AM
      RETURN
      END
      SUBROUTINE NLSPIL(IBLD,SS,NR,NLNR,MWRH)
C
C     THIS SUBROUTINE ASSIGNS CLASSES TO CLASSROOMS. IT STARTS WITH THE
C        LARGEST CLASSES. WHEN THERE ARE NOT ENOUGH ROOMS THAN A LARGER
C     ROOM IS SOUGHT. IF THERE ARE NOT ENOUGH LARGER ROOMS THAN A ROOM
C        IS BUILT.
C
C     NR IS THE NUMBER OF CLASSROOMS NEEDED OF A GIVEN SIZE
C     NLNR IS THE NUMBER OF AVAILABLE ROOMS OF A GIVEN SIZE
C     IBLD IS THE NUMBER OF ROOMS TO BE BUILT OF A GIVEN SIZE
C     NLEX IS THE NUMBER OF EXCESS ROOMS OF A GIVEN SIZE
C     MWRH IS AN ARRAY OF CLASS SIZE BY ROOM SIZE SINCE CLASSES MAY BE
C        ASSIGNED A ROOM SIZE NEED LARGER THAN THE ACTUAL CLASS BEFORE
C        ENTRY INTO THIS ROUTINE (THROUGH DS8).
C     K IS THE ROOM SIZE
      INTEGER SS
      INTEGER*2 IBLD(1),NLEX(15),NR(15),NLNR(1),MWRH(15,15)
      CALL KCLEAR (NLEX,15)
      K=SS
C
C     FIRST FOR EACH SIZE FIND THE EXCESS OR SHORTAGE OF ROOMS
      IF(NR(K) .GT. NLNR(K)) IBLD(K)=NR(K)-NLNR(K)
```

```
      IF (NLNR(K) .GT. NR(K)) NLEX(K) = NLNR(K)-NR(K)
   10 K=K-1
      IF (K .EQ. 0) RETURN
C     DITTO
      IF(NR(K) .GT. NLNR(K)) IBLD(K)=NR(K)-NLNR(K)
      IF (NLNR(K) .GT. NR(K)) NLEX(K) = NLNR(K)-NR(K)
      J=K+1
C
C     IF THERE IS NO SHORTAGE TRY THE NEXT SMALLER SIZE
   50 IF (IBLD(K) .EQ. 0) GO TO 10
C
C     IF THERE IS A SHORTAGE SEE IF A LARGER ROOM IS AVAILABLE
   40 IF (NLEX(J) .GT. 0) GO TO 30
      J=J+1
      IF(J-SS) 40,40,10
C
C     IF A LARGER ROOM IS AVAILABLE ASSIGN IT AND ADJUST ALL VARIABLES
   30 IBLD(K) = IBLD(K)-1
      NLEX(J)=NLEX(J) -1
      NR(J)=NR(J) + 1
      NR(K) = NR(K) - 1
C
C     FIND THE LARGEST CLASS SIZE IN THAT ROOM SIZE AND REASSIGN IT
C     KK IS THE CLASS SIZE
      KK=K
   70 IF (MWRH(K,KK) .EQ. 0) GO TO 60
      MWRH(J,KK)=MWRH(J,KK)+1
      MWRH(K,KK)=MWRH(K,KK)-1
      GO TO 50
   60 KK=KK-1
       IF(KK .NE. 0) GO TO 70
      WRITE(6,100)
      STOP
  100 FORMAT(' IMPOSSIBLE ERROR')
      RETURN
      END
      SUBROUTINE FCLEAR (A,N)
      DIMENSION A(1)
      DO 1 L=1,N
    1 A(L)=0.
      RETURN
      END
      SUBROUTINE KKCLER(N,L)
      DIMENSION N(1)
      DO 1 K=1,L
    1 N(K)=0
      RETURN
      END
      SUBROUTINE ERROR(NERR,N)
      NERR=NERR+1
      WRITE (6,100) N,NERR
  100 FORMAT('0ERROR NUMBER ',I2,' FOR A TOTAL OF ',I4, ' ERRORS. PROGRA
     1M WILL STOP AFTER READING THIS GROUP OF INPUT CARDS.')
      RETURN
      END
      SUBROUTINE PEEP1(NO,NCAMP,NYEAR,NIT,NRUN,NDATE,WSH,MC,DNAME)
      DIMENSION DATA2(3),WSH(33,3,2),DATA(3),NO(1),NDATE(2)
      DIMENSION SUBTOT(4,2),DNAME(2,34)
      N6=6
```

```
      WRITE(N6,119) NO(1),NCAMP,NYEAR,NIT,NRUN,NDATE
      IF(MC.EQ.2) WRITE (N6,120)
      IF(MC.EQ.2) GO TO 10
      WRITE(N6,121)
   10 WRITE(N6,130)
      Z=0.
      CALL FCLEAR(DATA2,3)
      CALL FCLEAR(SUBTOT,8)
      DO 260 J=1,33
      CALL FCLEAR(DATA,3)
      X=0.
      DO 261 I=1,2
      Y=0.
      DO 262 K=1,3
      DATA(K)=DATA(K)+WSH(J,K,I)
      SUBTOT(K,I)=SUBTOT(K,I)+WSH(J,K,I)
      SUBTOT(4,I)=SUBTOT(4,I)+WSH(J,K,I)
  262 Y=Y+WSH(J,K,I)
      IF(Y .NE. 0.) WRITE(N6,122)
     1DNAME(1,J),DNAME(2,J),I,(WSH(J,K,I),K=1,3),Y
  261 X=X+Y
      IF (X .NE. 0.) WRITE(N6,123)DNAME(1,J),DNAME(2,J),DATA,X
      Z=Z+X
      DO 260 K=1,3
      DATA2(K) = DATA2(K)+DATA(K)
  260 CONTINUE
      WRITE(N6,124) SUBTOT,DATA2,Z
       RETURN
  122 FORMAT(3X2A4, 9X,I1,17X,F9.1,3X,F9.1,3X,F9.1,5X,F9.1)
  123 FORMAT(3X2A4,27X,F9.1,'*',2X,F9.1,'*',2X,F9.1,'*',4X,F9.1,'*'/)
  124 FORMAT(5X,'ALL',12X,'1',15X,3(2X,F9.1,'*'),4X,F9.1,'*'/
     1         5X,'ALL',12X,'2',15X,3(2X,F9.1,'*'),4X,F9.1,'*'/
     2 5X,'ALL',29X,3(1X,F9.1,'**'),3X,F9.1,'**')
  119 FORMAT('1FAM TABLE 1',A2,' FOR ',A4,'  IN YEAR ',I4,      ':  WEEKL
     1Y STUDENT  HOURS IN EACH DISCIPLINE'/'  ITERATION',I3,'  OF RUN ',
     22A4,'  ON ',2A4,5X,'BY CLASS TYPES IN EACH COURSE LEVEL'/)
  121 FORMAT(/6X,'THESE',
     3 'NUMBERS OF WEEKLY STUDENT HOURS ARE THE AGGREGATED PRODUCTS OF'/
     46X,'THE PROJECTED ENROLLMENTS OF EACH STUDENT LEVEL AND MAJOR'/6X
     5'AND THE INDUCED COURSE LOAD MATRIX (NONLAB & LAB WSH PER STUDENT'
     6/)
  120 FORMAT(/6X,'THESE ARE THE FINAL AGGREGATED NUMBERS OF WEEKLY',
     1'STUDENT HOURS'/6X,'GENERATED BY FAMSIX.'/)
  130 FORMAT(//
     6    ' DISCIPLINE   CLASS TYPE   COURSE LEVEL:   1',11X,'2',11X,'3',
     79X,'TOTAL'/)
      END
      SUBROUTINE PEEP2(I,JWRH,ACS,II,KSWTCH,DNAME)
      DIMENSION ACS(15),NDATA(4),AVG(4),DNAME(2,34)
      INTEGER*2 JWRH(3,15)
      N5=2
      N6 = 6
      CALL FCLEAR(AVG,4)
      CALL KKCLER(NDATA,4)
      DO 1 L=1,15
      M=0
      DO 2 K=1,3
      M=M+JWRH(K,L)
      NDATA(K)=NDATA(K)+JWRH(K,L)
```

```
  2 AVG(K)=AVG(K)+ACS(L)*JWRH(K,L)
    IF(M .NE. 0) WRITE (N6,100)
   1DNAME(1,I),DNAME(2,I),L,(JWRH(K,L),K=1,3),M
  1 CONTINUE
    NDATA(4)=NDATA(1)+NDATA(2)+NDATA(3)
    IF (NDATA(4) .EQ. 0) RETURN
    WRITE (N6,101) NDATA
    IF(KSWTCH.EQ.1) WRITE(N5,103) II,  I ,(NDATA(K),K=1,3)
    AVG(4)=AVG(1)+AVG(2)+AVG(3)
    DO 3 K=1,4
    IF(NDATA(K).EQ.0) NDATA(K)=1
  3 AVG(K)=AVG(K)/NDATA(K)
    WRITE(N6,102) AVG
    RETURN
100 FORMAT (3X2A4, 7X,I2,8X,I4,7X,I4,7X,I4,7X,I5)
101 FORMAT (15X,'TOTAL WRH',4X,I4,'*',6X,I4,'*',6X,I4,'*',6X,I5,'*')
102 FORMAT(15X,'MEAN SIZE',4X,F6.1,5X,F6.1,5X,F6.1,5X,F6.1/)
103 FORMAT(2I2/3I4)
    END
```

VARICOS - PROGRAM LISTING

```
C                  DICTIONARY OF VARIABLE NAMES
C   ALL               THE WORD 'ALL     '
C   A1                TA SHARE OF WRH WORKLOAD
C   A2                SHARE OF WRH WORKLOAD OF NON-TA ACADEMIC STAFF
C   BIGSUM            TOTAL VARIABLE COSTS PER YEAR
C   BL                BOND LIFE
C   BR                BOND INTEREST RATE
C   BUCKSM            FACULTY COST SUBTOTALS, ALSO SPACE COST TOTALS
C   B1                WCH/FTE FOR TA'S
C   B2                WCH/FTE FOR NON TA ACADEMIC STAFF
C   CAPCST            YEARLY COSTS OF CAPITAL CONSTRUCTION FROM YEAR (START - 4)
C   CAPFAC            CAPITAL COST FACTOR: INDEX=100
C   CSTDST            DISTRIBUTION OF CAPITAL EXPENDITURES OVER CONSTRUCTON PERIOD
C   C2                SUPERVISION OF TA'S:ACADEMIC STAFF/TA
C   DNAME             DISCIPLINE NAMES
C   DPSQFT            $/ASF: OVERALL AVERAGE
C   D2                FACULTY OVER-RIDE FACTOR: REGULAR FACULTY/STUDENT
C   D4MNO             $/ASF FOR M&O PLANT
C   ENR               ENROLLMENTS
C   EPF               EQUAL PAYMENT FACTOR
C   FAC               FTE FACULTY (TA,IRREG.,NON-TENURED,TENURED)=(1-4)
C   FACOST            SALARY COSTS
C   FACR              ACADEMIC STAFF LESS TA'S
C   FACSAL            AVERAGE FACULTY SALARIES BY "RANK"
C   INASF             ASF INVENTORY:NON-LAB,LAB,RESEARCH,OFFICE,SUPPORTING
C   INSUM             YEARLY TOTALS: INVENTORY ASF
C   JN                LOOP CONTROL FOR FINAL TABLE PRINT-OUT
C   NCAMP             CAMPUS NAME
C   NDATE             CALENDAR DATE OF RUN
C   NEEDS             TEMPORARY VARIABLE: NON-CLASS REQUIREMENTS
C   NIT               ITERATION NUMBER (N-TH YEAR OF RUN)
C   NRUN              NUMBER OF RUN
C   NUMYRS            NUMBER OF YEARS FOR THIS RUN
C   NYEAR             YEAR OF DATA DISPLAYED (INPUT AS FIRST YEAR OF STUDY)
C   NWASF             NEW ASF       :NON-LAB,LAB,RESEARCH,OFFICE,SUPPORTING
C   NWSUM             YEARLY TOTALS:NEWLY FINISHED ASF
C   NX                TEMPORARY VARIABLE:INVENTORY OF DISC. ASF TOTAL
C   NY                TEMPORARY VARIABLE: NEW DISCIPLINE ASF TOTAL
C   OOPS              OTHER OPERATING COSTS YEARLY TOTAL (SALARIES+SUPPORT $)
C   O1                OFFICE ASF/FACULTY
```

```
C  O2                    OFFICE ASF/GRAD
C  PLOP                  PLANT OPERATING COSTS: YEARLY TOTALS
C  PRJCST                PROJECT COST ESTIMATE
C  RKDIST                DISTRIBUTION OF NON/TA ACADEMIC STAFF TO "RANK"
C  RKSUM                 FTE FACULTY SUBTOTALS
C  RS                    SUM OF DEFLATED CONSTRUCTION COST FACTORS OVER PER-
C                        IOD OF CONSTRUCTION
C  RR                    CURRENT INFLATOR
C  R1                    RESEARCH ASF/FACULTY
C  R2                    RESEARCH ASF/GRAD
C  SINFL                 INFLATION FACTOR:CAPITAL RATE LESS OPERATING RATE+1(EG 1.01)
C  SUPCST                SUPPORT COSTS
C  SUPRAT                SUPPORT RATE: $/NON-TA ACADEMIC STAFF
C  S1                    SUPPORT ASF/RESEARCH AND OFFICE TOTAL
C  S2                    SUPPORT ASF/LAB TOTAL
C  TA                    TEMPORARY VARIABLE: FTE TA'S
C  WRH                   WEEKLY ROOM HOURS
C  X                     TEMPORARY VARIABLE: FACULTY TOTAL
C  Y                     TEMPORARY VARIABLE: SUM OF FACULTY AND TA SALARY COSTS
C  YY                    TEMPORARY VARIABLE:TOTAL FACULTY & SUPPORT COSTS
      INTEGER BL
      INTEGER WRH(2,3,33)
      INTEGER*2 NARR(14,4)
      DIMENSION ALL(2),A1(2,3,33),A2(2,3,33),BUCKSM(6),B1(2,3,33),
     1B2(2,3,33),CAPCST(14),   ,CAPFAC(5,33),CSTDST( ),C2(2,33),
     2DNAME(2,33),D2(4,33),ENR(4,33),FAC(4,33),FACOST(5),FACR(33),
     3FACSAL(4), INASF(5,33),INSUM(6),NDATE(2),NEEDS(3),NNASF(5,33),
     4NNSUM(6),OOPS(10),O1(2,33),PLOP(10),PRJCST(6),O2(2,33),
     5RKDIST(3,33),RKSUM(5),R1(2,33),R2(2,33),SUPRAT(33),S1(33),S2(33),
     6TA(2)
      DATA ALL(1),ALL(2)/'ALL ','    '/
      IN1=5
      IN2=1
      IOUT=6
      CALL FCLEAR(CAPCST,14)
      CALL NCLEAR(INASF,165)
      READ(IN1,900)NCAMP,NRUN,NDATE,NUMYRS,NYEAR
      JN=NUMYRS+4
      READ(IN2,901) DNAME
      DO 10 K=1,33
      READ(IN2,904)((A1(I,J,K),J=1,3),I=1,2)
      READ(IN2,904)((A2(I,J,K),J=1,3),I=1,2)
      READ(IN2,904)((B1(I,J,K),J=1,3),I=1,2)
   10 READ(IN2,904)((B2(I,J,K),J=1,3),I=1,2)
      READ(IN2,904) FACSAL
      DO 11 K=1,33
   11 READ(IN2,904) (C2(I,K),I=1,2),(D2(J,K),J=1,4)
      DO 12 K=1,33
   12 READ(IN2,904) SUPRAT(K),(RKDIST(J,K),J=1,3)
C  END OF INPUTS FOR FACULTY COMPUTATIONS
      DO 20 K=1,33
   20 READ(IN2,905) R1(1,K),R1(2,K),R2(1,K),R2(2,K),O1(1,K),O1(2,K),
     1 O2(1,K),O2(2,K),S1(K),S2(K)
      DO 21 K=1,33
   21 READ(IN2,905) (CAPFAC(I,K),I=1,5)
   22 READ(IN2,908) K,(INASF(I,K),I=3,5),NOCHK
      IF(NOCHK.EQ.0) GO TO 22
      READ(IN2,907) SINFL,BR,BL
      READ(IN2,905) CSTDST ,D4MNO,DP SQFT
```

```
      EPF=BR*((1+BR)**BL)/(((1+BR)**BL)-1.)
      RS=0.
      DO 23 N=1,4
      CSTDST(5-N)=CSTDST(5-N)/(SINFL**N)
   23 RS=RS+CSTDST(5-N)
C
C
      NYEAR=NYEAR-1
      DO 1000 NIT =1,NUMYRS
      NYEAR=NYEAR+1
      RR=SINFL**(NIT-1)
      CALL NCLEAR(NWASF,165)
      CALL NCLEAR(WRH,198)
      CALL FCLEAR(ENR,132)
  101 READ(IN2,906) K,(ENR(I,K),I=1,4),NOCHK
      IF(NOCHK.EQ.0) GO TO 101
  102 READ(IN1,902) I,K
      IF(I.EQ.0) GO TO 103
      READ(IN1,903) (WRH(I,J,K),J=1,3)
      GO TO 102
  103 CALL FCLEAR(FAC,132)
      CALL FCLEAR(BUCKSM,6)
      CALL FCLEAR(RKSUM,5)
      WRITE(IOUT,950)NYEAR,NDATE,NRUN,NIT,NCAMP,NYEAR
C
      DO 110 K=1,33
      CALL FCLEAR(FACOST,5)
      FACR(K)=0.
      SUPCST=0.
      DO 111 I=1,2
      TA(I)=0.
      DO 112 J=1,3
      IF(WRH(I,J,K).EQ.0) GO TO 112
      TA(I)=(A1(I,J,K)*WRH(I,J,K)/B1(I,J,K)) + TA(I)
      FACR(K)=FACR(K)+(A2(I,J,K)*WRH(I,J,K)/B2(I,J,K))
  112 CONTINUE
      FAC(1,K)=FAC(1,K)+TA(I)
      FACR(K)=FACR(K)+(C2(I,K)*TA(I))
  111 CONTINUE
      DO 113 I=1,4
  113 FACR(K)=FACR(K)+(D2(I,K)*ENR(I,K))
      X=FAC(1,K)+FACR(K)
      IF(X.LT.0.1) GO TO 110
      DO 114 I=2,4
  114 FAC(I,K)=FACR(K)*RKDIST(I-1,K)
      SUPCST=SUPRAT(K)*FACR(K)
      DO 115 I=1,4
      FACOST(I)=FACSAL(I)*FAC(I,K)
      BUCKSM(I)=BUCKSM(I)+FACOST(I)
      RKSUM(I)=RKSUM(I)+FAC(I,K)
  115 FACOST(5)=FACOST(5)+FACOST(I)
      YY=SUPCST + FACOST(5)
      BUCKSM(6)=BUCKSM(6)+SUPCST
      WRITE(IOUT,951)(ONAME(I,K),I=1,2),(FAC(I,K),I=1,4),X,FACOST,
     1 SUPCST,YY
  110 CONTINUE
      DO 120 J=1,4
      BUCKSM(5)=BUCKSM(5)+BUCKSM(J)
  120 RKSUM(5)=RKSUM(5)+RKSUM(J)
```

```
      OOPS(NIT)=BUCKSM(5)+BUCKSM(6)
      WRITE(IOUT,951)ALL,NNSUM,BUCKSM,OOPS(NIT)
C   END OF FACULTY COMPUTATIONS - START SPACE CALCULATIONS
      DO 130 K=1,33
  130 READ(IN1,910) K,INASF(1,K),INASF(2,K),NWASF(1,K),NWASF(2,K)
      CALL  FCLEAR(BUCKSM,6)
      CALL  NCLEAR(INSUM,6)
      CALL  NCLEAR(NWSUM,6)
      WRITE(IOUT,900)NYEAR,NDATE,NRUN,NIT,NCAMP,NYEAR
C
      DO 200 K=1,33
      NX=0
      NY=0
      CALL  FCLEAR(PRJCST,6)
      CALL  NCLEAR(NEEDS,3)
      IF(FACR(K).LT.0.1.AND.ENR(3,K).LT.0.1.AND.ENR(4,K).LT.0.1)GO  TO210
      NEEDS(1)=R1(1,K)*FACR(K)+R1(2,K)*FAC(1,K)+R2(1,K)*ENR(3,K)
     1+R2(2,K)*ENR(4,K)
      NEEDS(2)=O1(1,K)*FACR(K)+O1(2,K)*FAC(1,K)+O2(1,K)*ENR(3,K)
     1+O2(2,K)*ENR(4,K)
      NEEDS(3)=S1(K)*(NEEDS(1)+NEEDS(2))+S2(K)*INASF(2,K)
      DO 210 I=1,3
      IF(NEEDS(I).LT.INASF(I+2,K)) GO TO 210
      NWASF(I+2,K)=NEEDS(I)-INASF(I+2,K)
      INASF(I+2,K)=NEEDS(I)
  210 CONTINUE
      DO 211 I=1,5
      PRJCST(I)=NWASF(I,K)*CAPFAC(I,K)*RR*DPSQFT*RS
      PRJCST(6)=PRJCST(6)+PRJCST(I)
      NX=NX+INASF(I,K)
      NY=NY+NWASF(I,K)
      NWSUM(I)=NWSUM(I)+NWASF(I,K)
      INSUM(I)=INSUM(I)+INASF(I,K)
  211 BUCKSM(I)=BUCKSM(I)+PRJCST(I)
      IF(NX.EQ.0) GO TO 200
      WRITE(IOUT,961) (DNAME(I,K),I=1,2),
     A                         (INASF(I,K),I=1,5),NX,(NWASF(I,K),I=1,5),NY,
     1PRJCST
  200 CONTINUE
      DO 230     J=1,5
      NWSUM(6)=NWSUM(6)+NWSUM(J)
      INSUM(6)=INSUM(6)+INSUM(J)
  230 BUCKSM(6)=BUCKSM(6)+BUCKSM(J)
      DO 220 II=1,4
      XX=BUCKSM(6)*EPF*CSTDST(II)/RS
      NQ=NIT+II-1
      DO 220 I=NQ,JN
      CAPCST(I)=CAPCST(I)+XX
  220 CONTINUE
      WRITE(IOUT,961)ALL,INSUM,NWSUM,BUCKSM
      PLCP(NIT)=INSUM(6)*D4MNO*RR
 1000 CONTINUE
      J=NYEAR-3-NUMYRS
      WRITE(IOUT,970)NDATE,NRUN,NUMYRS
      DO 1001 I=1,4
      CALL  CONVR(NARR(1,1),11,CAPCST(I))
      WRITE(IOUT,971)J,(NARR(L,1),L=1,14),(NARR(L,1),L=1,14)
 1001 J=J+1
      DO 1002 I=1,NUMYRS
```

```
      BIGSUM=COPS(I)+PLOP(I)+CAPCST(I+4)
      CALL CONVR(NARR(1,1),11,COPS(I))
      CALL CONVR(NARR(1,2),11,PLOP(I))
      CALL CONVR(NARR(1,3),11,CAPCST(I+4))
      CALL CONVR(NARR(1,4),11,BIGSUM)
      WRITE(IOUT,971) J,NARR
 1002 J=J+1
  900 FORMAT(4A4,I2,I4)
  901 FORMAT(20A4)
  902 FORMAT(2I2)
  903 FORMAT(3I4)
  904 FORMAT(6F10.0)
  905 FORMAT(10F8.0)
  906 FORMAT(I5,I2,T1,4F5.0,I2)
  907 FORMAT(2F5.0,I2)
  908 FORMAT(I2,3I10,I2)
  910 FORMAT(I2,4I10)
  950 FORMAT('1VARICOS TABLE: A-',I4,48X'DATE: ',2A4/' RUN NUMBER: ',A4,
     147X'ITERATION NUMBER: ',I2//17X'FACULTY: REQUIREMENTS AND COSTS FO
     2R ',A4,' IN ',I4/)
  951 FORMAT(1X,2A4,3X'RANK:',12X,'1',9X'2',9X'3',9X,'4',4X'SUBTOTAL',6X
     1'TOTALS'/12X'FTE',4X,4F10.2,12X,F12.2/12X'SALARIES',4F10.0,F12.0/
     212X'SUPPORT',41X,2F12.0/)
  960 FORMAT('1VARICOS TABLE: B-',I4,48X'DATE: ',2A4/' RUN NUMBER: ',A4,
     147X'ITERATION NUMBER: ',I2,//18X'SPACE: REQUIREMENTS AND COSTS FOR
     2 ',A4,' IN ',I4/)
  961 FORMAT(/1X2A4,17X,'CLASSRMS  CLASSLAB  RESEARCH   OFFICE   SUPPOR
     1T       TOTAL'/11X,'INVENTORY',3X,6I10/11X'NEW ASF',5X,6I10/11X'PROJ
     2ECT COSTS',6F10.0)
  970 FORMAT('1VARICOS TABLE: C',53X'DATE: ',2A4/' RUN NUMBER: ',A4,49X
     1'YEARS THIS RUN: ',I2//30X'SUMMARY OF VARIABLE COSTS'//9X'YEAR',4X
     2'SALARIES/SUPPORT',3X'M&O-PLANT',5X'DEBT SERVICE  ', 9X'TOTAL'/)
  971 FORMAT(9X,I4,3(2X,14A1),5X,14A1)
  972 FORMAT(9X,I4,34X,14A1,5X,14A1)
      END
      SUBROUTINE FCLEAR(A,N)
      DIMENSION A(1)
      DO 100 I=1,N
  100 A(I)=0.
      RETURN
      END
      SUBROUTINE NCLEAR(M,N)
      DIMENSION M(1)
      DO 100 I=1,N
  100 M(I)=0
      RETURN
      END
      SUBROUTINE CONVI(NARR,NDIG,KVAL)
C        NARR IS INTEGER*2 ARRAY RETURNED AS (NDIG+(NDIG-1)/3) CHARACTERS
C           OF RESULT READING LEFT TO RIGHT IN ASCENDING SUBSCRIPTS.
C        NDIG IS THE LARGEST NUMBER OF DIGITS (INCLUDING MINUS SIGN) THAT
C           MUST BE ASSUMED FOR NVAL. NDIG MUST BE 2 < NDIG < 12.
C        KVAL OR FVAL ARE THE NUMBER TO BE TRANSLATED. THEY COME IN
C           THROUGH DIFFERENT ENTRY POINTS
C        NVAL IS THE VALUE TO BE TRANSLATED, CHANGED FROM EITHER KVAL
C           OR FVAL
C        NDIG, KVAL, FVAL, ARE NOT ALTERED BY SUBROUTINE.
C        ZERO RETURNS AS BLANK.
C        OVERFLOW (EITHER POSITIVE OR NEGATIVE) RETURNS AS * IN THE
```

```
C          RIGHTMUST POSITION.
C        A MINUS SIGN IS RIGHT ADJUSTED TO NUMBER.
C        NO ERROR CHECKING IS DONE.
      INTEGER*2 JUNK(14),NARR(1)
      DIMENSION NTEST(11)
      DATA JUNK /'0','1','2','3','4','5','6','7','8','9','-',' ',',',
     1'*'/
      DATA NTEST /10,100,1000,10000,100000,1000000,10000000,100000000,
     11000000000,2147483647,2147483647/
      NVAL=KVAL
    7 NEND=NDIG+(NDIG-1)/3
      K=JUNK(12)
      IF (NVAL .LT. 0) K= JUNK(11)
      N=1
      L=1
      M=3
      NEND2=NEND+1
      DO 1 J=1,NEND
    1 NARR(J)=JUNK(12)
      IF(NVAL .GE. NTEST(NDIG)) GO TO 6
      IF (NVAL .LE. -NTEST(NDIG-1)) GO TO 6
      NVAL =IABS(NVAL)
    2 DO 3 J=L,M
      JOKE=NVAL /N
      IF (JOKE .LE. 0) GO TO 4
      N=N*10
      KOKE=(NVAL /N)*10
      JOKE=JOKE-KOKE
    3 NARR(NEND2-J)=JUNK(JOKE+1)
      IF(M .EQ. NEND) GO TO 5
      L=M+2
      M=M+4
      IF (M .GT. NEND) M=NEND
      NARR(NEND2-L+1)=K
      IF(KOKE .EQ. 0) GO TO 5
      NARR(NEND2-L+1) = JUNK(13)
      GO TO 2
    4 NARR(NEND2-J)=K
    5 RETURN
    6 NARR(NEND)=JUNK(14)
      GO TO 5
      ENTRY CONVR(NARR,NDIG,FVAL)
      NVAL=FVAL+SIGN(.5,FVAL)
      GO TO 7
      END
```