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TECHNOLOGY SURVEY OF COMPUTER SOFTWARE AS APPLICABLE TO THE MIUS PROJECT

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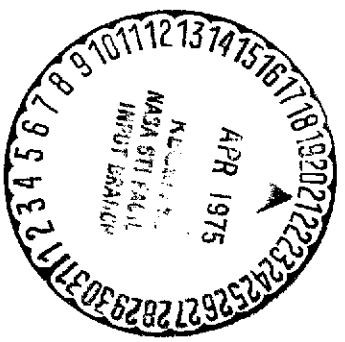
MODULAR INTEGRATED UTILITY SYSTEMS
improving community utility services by supplying electricity, heating, cooling, and water/ processing liquid and solid wastes/ conserving energy and natural resources/ minimizing environmental impact



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Existing computer software, available from either governmental or private sources, applicable to Modular Integrated Utility System Program simulation is surveyed. Several programs and subprograms are described briefly to provide a consolidated reference, and a bibliography is included. The report covers the two broad areas of design simulation and system simulation.

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TECHNOLOGY SURVEY OF COMPUTER SOFTWARE AS APPLICABLE TO THE MIUS PROJECT

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PREFACE

The Department of Housing and Urban Development (HUD) is conducting the Modular Integrated Utility System (MIUS) Program devoted to development and demonstration of the technical, economic, and institutional advantages of integrating the systems for providing all or several of the utility services for a community. The utility services include electric power, heating and cooling, potable water, liquid-waste treatment, and solid-waste management. The objective of the MIUS concept is to provide the desired utility services consistent with reduced use of critical natural resources, protection of the environment, and minimized cost. The program goal is to foster, by effective development and demonstration, early implementation of the integrated utility system concept by the organization, private or public, selected by a given community to provide its utilities.

Under HUD direction, several agencies are participating in the HUD-MIUS Program, including the Atomic Energy Commission, the Department of Defense, the Environmental Protection Agency, the National Aeronautics and Space Administration, and the National Bureau of Standards (NBS). The National Academy of Engineering is providing an independent assessment of the program.

This publication is one of a series developed under the HUD-MIUS Program and is intended to further a particular aspect of the program goals.

COORDINATED TECHNICAL REVIEW

Drafts of technical documents are reviewed by the agencies participating in the HUD-MIUS Program. Comments are assembled by the NBS team, HUD-MIUS project, into a Coordinated Technical Review. The draft of this publication received such a review, and all comments were resolved.

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TECHNOLOGY SURVEY OF COMPUTER SOFTWARE AS APPLICABLE TO THE MIUS PROJECT

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SUMMARY

This report represents a first look at existing computer software that could be applied to modular integrated utility system simulation. The report is not intended as a comprehensive list but as a survey of the types of programs available, either from governmental or private sources. Included are brief descriptions of several programs and subprograms, together with areas of simulation to which they might be applicable. This survey has been conducted to familiarize involved personnel with available programs.

INTRODUCTION

The Urban Systems Project Office at the NASA Lyndon B. Johnson Space Center (JSC) is committed to design and develop a modular integrated utility system (MIUS) and to provide analytical tools for MIUS design and performance analyses. Computer simulations are necessary for MIUS development, design, demonstration, and operation. Several existing programs that could be used, or modified slightly for use, for MIUS simulations are considered in this report.

SIMULATION OBJECTIVES

A simulation package must be developed for use both in initial MIUS analyses and in the necessary design and evaluation analyses for follow-on demonstration and production MIUS installations. The types of analyses required include, but are not limited to, the following.

1. Subsystem loading analyses
2. Sizing and matching analyses
3. Technical feasibility studies
4. Systems integration

5. Trade-off studies at system, subsystem, and component levels

6. Economic analyses, including capital costs, operating costs, and owning costs

7. Financial analyses, including various considerations for financing a system

8. Design optimization

9. Test and demonstration performance analyses

The simulation will provide the capability to perform these analyses for a wide variety of MIUS configurations and installation locations.

COMPUTER SOFTWARE REQUIREMENTS

To satisfy the MIUS simulation objectives, computer software capabilities are required in the following areas.

1. Fluid-flow analysis

2. Thermodynamics

3. Thermal analysis

4. Chemical processing

5. Electrical power generation and distribution

6. Economic analyses

7. Financial analyses

Special-purpose routines are required to simulate such processes as the treatment of waste water by several techniques and the processing of solid waste. Computer programs to determine environmental loading of buildings and to provide capability for automatic design of air-conditioning and heating equipment and ducts are also desired for MIUS simulation.

The computer program used for simulation of the complete MIUS system should include a flexible executive structure and a good set of general-purpose routines. The flexible structure allows for user-definable logic, addition of special-purpose routines, and flexible input/output routines (including plot capability). The general-purpose

routines provide for data manipulation, editing, and a restart capability for parametric studies.

SIMULATION DEVELOPMENT

Development of the computer simulation required for the MIUS project has been divided into two parts: design simulation and system simulation.

Design Simulation

Program ESOP (Energy Systems Optimization Program) has been developed to calculate facility load requirements and then to evaluate the yearly operational characteristics of an MIUS designed to satisfy the loads. On the basis of these average hourly, daily, monthly, seasonal, and yearly loads, the fuel requirements for an MIUS and a conventional (commercial) system will be determined by program ESOP. This program is intended for use as a system-design tool to evaluate equipment options rapidly for MIUS applications.

The MIUS configurations analyzed currently by program ESOP consist only of energy-reclamation systems. Wastewater treatment processes and an economic data base are being developed for incorporation into program ESOP. Programs used in the development of ESOP are discussed in detail later in the report.

System Simulation

The final simulation phase will be an integration of the programs discussed in the preceding two paragraphs with a package for total economic and financial analysis. This effort will involve the development of a data base that will provide easy access to a large library including data on climate, equipment performance, construction costs, and component costs. Also, this data base will include routines necessary for interaction of the data files and simulation logic to provide automatic documentation, specification, and report-generation capability. Design-interaction logic will be an integral part of the system to facilitate rapid evaluation of several equipment combinations for development of an optimum MIUS design.

Simulation System Basis

A search has been made of software packages available at JSC for a system that could serve as a base for the MIUS simulation programs. Three candidate packages are discussed.

Program G-189A.- Program G-189A (Generalized Environmental/Thermal Control and Life Support System Analysis Program) was developed for the purpose indicated by the title. However, program G-189A is sufficiently generalized to become an excellent free-flow modeling system if the user is capable of performing required operations.

Excellent routines are included in program G-189A for simulating such functions as valving; heat, mass, and fluid flows; and thermomechanical properties and for performing mathematical operations. Although program G-189A has no power-distribution or chemical-processing routines, the software can be modified to accommodate these requirements if sufficient time and resources are available.

Program SINDA.- Program SINDA (Systems Improved Numerical Differencing Analyzer) analyzes a mathematical model of a physical system that can be represented by a resistance-capacitance network or, more succinctly, as a system of nodes connected by resistors and conductors. Options are a variety of methods for the solutions of the set of simultaneous equations; each method differs in machine speed, core space required, and solution accuracy. Subroutines make available various methods of solving for heating rates, several methods of computing convective heat-transfer coefficients, and numerous methods of calculating material phase changes.

Program SINDA operates as a preprocessor to perform the functions of reading input data, assigning relative numbers, packing data, and developing a pseudocompute sequence. Program SINDA has a large library of varied subroutines that can be called in any sequence, and the program operates with the subroutines in an integrated fashion. The language of the system is FORTRAN; after performing the preprocessing functions, program SINDA writes computational or operational blocks on a peripheral device and returns control and operation to the computer system software, while maintaining scaling and addressing internally. After the system processor completes the computational cycle, program SINDA resumes control and produces the desired outputs.

Program SINDA was designed for generalized systems analysis by representing the system in electrical analog, lumped-parameter form. Although program SINDA has been used

primarily for thermal analysis, its use is easily extended to include other classes of physical systems that can be modeled in this form, such as fluid systems, electrical systems, and acoustical systems.

Program SSFS.- Program SSFS (Space Shuttle Functional Simulator) consists of a set of six major components; only the preprocessor function, plot processor routines, and executive control programs will be applicable to MIUS needs. A requirement would exist to develop all algorithms required for MIUS simulation. The SSFS system structure, however, can be adapted readily to MIUS needs if time for complete simulation algorithm development is available.

Commercially Available Design-Type Simulations

The broad group of commercially available programs for design-type simulations are intended to enable specific design of various components of the MIUS. Such parameters as size of ducts or pipes, quantity of refrigerant, and type of fuel will be determined from this type of simulation program.

Program ECUBE.- Program ECUBE (Energy Conservation Using Better Engineering) is a series of programs designed to assist architects and engineers to determine the energy requirements of a set of buildings and to assess the effect of changes in the buildings or in the energy system. Program ECUBE is basically a planning and design tool and can be used to evaluate several types of energy systems: diesel, gas-reciprocating, gas-turbine, all-electric, total-energy, and conventional. In each case, descriptive data collected by the designer are analyzed to produce a set of data describing the energy used for each system analyzed. The ECUBE series comprises three main and three auxiliary programs. The major programs are described briefly.

1. Program ER (Energy Requirements) calculates hourly thermal and electrical loads for an air-conditioning zone of a building. Allowances can be made for thermostat setback, for system shutdowns, and, more importantly, for the thermal storage and lag factors resulting from various operational modes. Program ER outputs peak annual heating and cooling periods and maximum monthly heating and cooling loads; monthly and yearly sums of energy requirements; and unitized annual loads in the form of units per square foot.

2. Program ESEC (Equipment Selection and Energy Computation) is used to determine annual energy consumption by various sets of energy systems required to meet the loads indicated from program ER.

3. Program EC (Economic Comparison), which is a section of program ECUBE, compares various options in terms of economics and desired rate of return. The program will compare alternate systems with some base or reference system in several different standard economic techniques as desired by the user. Furthermore, this program is not restricted to energy system selections but can be used to evaluate any type of project requiring concise financial evaluation.

Access to the ECUBE program series may be obtained by approval of a member of the American Gas Association. The software is resident on the Control Data Corporation CYBERNET Data Services Network. Processing may be done by way of remote terminal access, and charges will be based on computer resources used. Charges for running a complete set of ECUBE data decks depend on options used.

Energy_System_Analysis_Series.- The Energy System Analysis Series is a library of computer programs developed by Ross F. Meriwether and Associates, Inc., for hourly calculation of the annual energy consumption of various types of air-side systems and mechanical plants, for applying local utility rate schedules to these demands and consumptions, and for combining these costs with other owning and operating costs to provide yearly cash-flow projections. Each major step in a complete energy system analysis is handled by a different program; therefore, the engineer can evaluate the results of one part before making final decisions and proceeding with the next part. The various programs enable the user to evaluate different air-side system types, control temperatures, airflow quantities, operating schedules, heat-recovery or economizer cycles, equipment types and accessory combinations, competing energy sources, alternate utility rates, and the effect of various economic factors on total owning and operating costs. The seven programs in the library are as follows.

1. Program WDP (Weather Data Preparation) is a short program used to prepare National Weather Service WBAN 1440 weather data for use in subsequent programs.

2. Program ERCK (Energy Requirements Input Data Checked) is a short program that reads input data and prints them out in the form of utility service per unit area to help locate input errors.

3. Program ERE (Energy Requirements Estimate) calculates hourly thermal and electrical loads for a building (or building section) and simulates the operation of the air-distribution system in meeting these loads.

4. Program TCR (Total Coincident Requirement) sums the hourly loads from multiple ERE runs for various buildings or sections to determine total system loads and actual diversity.

5. Program EEC/B (Equipment Energy Consumption/B) simulates the operation of equipment responding to loads imposed by the building air-side systems to determine monthly and annual energy consumption.

6. Program MUC (Monthly Utility Costs) calculates the monthly and annual energy costs for each system on the basis of the local utility rate schedules.

7. Program ECS/B (Economic Comparison of Systems/B) combines typical-year energy costs and other annual operating costs with the initial investment and the associated owning cost factors to determine the total owning and operating costs annually for a period as long as 30 years.

An important distinction exists between design-point-load programs and energy-consumption programs. The Energy System Analysis Series is designed to calculate monthly and annual energy requirements and costs, not design-point heating and cooling loads. These programs begin with design-point loads for the overall building or for major building sections and distribute them throughout a full-year cycle of building operation. It is usually simple to use the summation of the zone-load components from some other program as input for the building energy requirements program. These programs are intended to supplement rather than replace existing load programs or calculation techniques. The programs afford an excellent means of evaluating and optimizing design by manipulation of the system to determine response to various weather conditions.

Program AXCESS.- Program AXCESS (Alternate Choice Comparison for Energy System Selection), which is owned by the Electric Energy Association, enables analysis by the design engineer of the two major areas of concern for energy supply studies. First, the energy-consumption amounts must be determined for various types of heating and cooling systems. Second, a tool for financial analysis is provided to meet the specific criteria of various owners and investors. The AXCESS program consists of four major parts, each of which will be described in succeeding paragraphs. It should be noted that only the first section has been computerized.

The energy analysis computer program provides an hourly calculation of energy usage in a building. The inputs to

the program are in three parts: structure design; weather data consisting of wet-bulb, dry-bulb, and cloud-cover information; and specifications for various systems under consideration.

Special emphasis is placed on specific causes of variance in energy use among systems. The major causes of such variance are the systems themselves. For example, performance curves are available for chillers and boilers, but these curves are different.

The depth of calculation provided by the energy analysis program depends on the detail of information made available. To illustrate, suppose the zoning arrangements are unknown for an office building having a restaurant on the top floor. If the engineer inputs the fact that there are four zones in the restaurant, the program will estimate all zones to be approximately the same size and to have the same equipment heat load. Solar loading will depend on zone exposure. Conversely, if a complete building design is input to the program, it will operate on these specifications and make predictions on those data. Program AXCESS allows for approximations in input data to enable growth of the system design with the system.

For skin loadings, the program allows for input of either summer and winter design skin loadings or solar and transmission loads for each surface (as calculated by the engineer), or hourly values of solar and transmission loads for each zone in the building (as output from some loads-calculation program). With calculations based on each loading to be met by the specific heating, ventilation, and air-conditioning system, the program next compares distribution systems. The simulations of 17 types of distribution systems are all modular; therefore, the program can be modified as new systems are made available.

Each air-simulation system has the capability of using an outside-air economizer and using exhaust heat by way of a heat-recovery system. When the distribution system loads have been calculated, the power system or energy conversion system determined for the projected design is input. Each of six basic loads from the distribution system (heating, cooling, reheating, preheating, zone reheating, and motor energy needed) may be supplied directly by a purchased fuel or by a primary system. A primary system is defined as a process for converting purchased fuel to a usable form. The basic generic types of primary systems modularly simulated in program AXCESS are as follows.

1. Heating by converting purchased fuel, as in a boiler or hot-air furnace

2. Either heating or cooling, such as a refrigerant-switch heat pump

3. Simultaneous heating and cooling such as a simultaneous heat pump or double-bundle chiller

4. Cooling only, as in a centrifugal or absorption chiller

5. Total facility electricity, heating, and cooling (i.e., a total-energy plant providing for waste-heat recovery)

6. Using a partial total-energy system, with supplemental electricity supplied by the local utility company or excess electricity provided to the power company

The program can handle simultaneously as many as 6 designs or different methods of meeting energy needs of a building having as many as 12 different distribution systems. The capability exists to handle as many as 180 heating and cooling zones in a building and as many as 30 energy uses other than for heating, ventilation, and air-conditioning. The program can also simulate use of waste from various primary systems to provide input to other systems if desired. For example, steam for a turbine-driven centrifugal chiller can be produced by a boiler system.

Two sections of the AXCESS program are checklists of major differences among systems. One section relates to first-cost differentials among alternate systems; the other section contains differentials in costs for operating personnel, maintenance, and unscheduled repairs.

The financial analysis section of program AXCESS enables consolidation by the engineer of information from the other three sections into a financial statement based on the owner's criteria. This section consists of a course for training participants to consider an investment choice, such as which energy system to use, from their clients' viewpoint. The course covers principles of accounting, economics, and finance necessary to understand investment analysis techniques. Concepts of cash flow, depreciation, tax efforts, and business investment are also covered. Theories of return on average investment, payback, yield or internal rate of return, and net present value are discussed at length. The situations to which each concept applies, as well as the strengths and weaknesses associated with each, are also explained.

Post_Office_Program.- A "Computer Program for Analysis of Energy Utilization Created for the U.S. Postal Service"

(the Post Office Program) for use in designing postal facilities is capable of performing the following functions.

1. Simulating the thermal response of a building to all sources of heat gains and losses

2. Accounting for all nonthermal energy requirements in the facility or on the sites

3. Translating the building operating schedule and site into total-energy demand and consumption costs, and identifying the peak capacity requirements of heating and cooling equipment

4. Enabling performance of an economic analysis for selecting the most economical equipment and energy source (gas, oil, steam, electricity, or combinations) in terms of total owning and operating costs

The Post Office Program is divided into four basic subprograms: (1) load calculation, (2) thermal loads plot, (3) systems simulation, and (4) economic analysis. Each is supported by a group of subsubprograms and routines. Of primary concern to MIUS simulation is the first of these, the loads subprogram. The other subprograms in this series are very system dependent; that is, they must be changed radically to accommodate a different type of energy system. The loads subprogram calculates thermal loads on a building on the basis of weather data, structure geometry and surroundings, thermal properties of wall and roof construction materials, fenestration, and structure operating schedules.

Program NBSLD.- Program NBSLD (National Bureau of Standards Load Determination) is available noncommercially from the National Bureau of Standards as "NBSLD, Computer Programs to Obtain Heating and Cooling Loads and to Estimate Room Air Temperature Change Using Thermal Response Factors." Inputs to the NBSLD consist of the following building parameters.

1. Schedules for occupancy, lighting, and equipment for an entire year, including work weekdays, weekend days, and vacation periods

2. Description of wall, roof, and floor construction, including thickness, number of layers, thermal conductivity of materials, surface descriptions, and type of foundations

3. Description of internal masses, including size, density, and thermal resistance

4. Psychrometric data for the locale

5. Orientation of the structure

The first printout page of results includes the physical description of each building component having a significant heat capacity. On the second page are the run number, the outside-air-temperature cycle, the inside-air-temperature cycle (if thermostat controlled), and a repetition of input geometrical data. Finally, information on the third page consists of the inside- and outside-air temperatures, the room heat fluxes at the inside surfaces of the building components expressed as British thermal units per hour per square foot, the air infiltration loss, and the net heat loss from the room at prescribed time intervals expressed as British thermal units per hour.

Other available programs.- Other useful programs are commercially available from various software producers. One group of design programs is intended for use as an aid to the construction industry. These programs are actively marketed by Automated Procedures for Engineering Consultants (APEC). Access is available only to a member of APEC or through a consultant member of APEC. The following are some basic types of design-aid programs available from many consultant and architectural firms through APEC membership.

1. For heating, ventilation, and air-conditioning:

   a. Load calculation

   b. Pipe duct, coil, fan, and plenum sizing

   c. Air-handler location

   d. Heat loads from lighting or other process-type needs

2. For electrical power systems:

   a. Generator sizing

   b. Distribution network planning

   c. Peak load calculations

3. For building analyses:

   a. Elevator service analyses

   b. Pollution abatement analyses

c. Structural design

A program available from the Environmental Protection Agency, the "Executive Digital Computer Program for Preliminary Design of Wastewater Treatment Systems," consists of a main program and subroutines to simulate approximately 12 types of water-treatment processes. The program will eventually include approximately 25 more processes and is operational on a 16 000-word IBM 1130 computer. Each subroutine computes the performance and cost of one water-treatment process. The program also includes a general print routine and a costing routine that sums the costs of individual processes used and adds engineering costs, contractor's profit, contingencies and omission, and land costs.

A program for estimating costs of building construction, IBIS (Integrated Building Industry System), was developed for the Department of Housing and Urban Development and is available from HUD.

CONCLUDING REMARKS

A technology survey of computer software has revealed several major computer programs that are pertinent to the development of MIUS simulations. This survey is meant to acquaint the MIUS team with the type of programs already available for use in the simulation of MIUS, but no attempt was made to cover all possible programs. The result, eventually, will be a much more thorough and comprehensive, yet less expensive, MIUS simulation package than would otherwise be attainable.

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National Aeronautics and Space Administration
Houston, Texas, January 7, 1975
386-01-00-00-72

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