A New B.S. in Computer Science  
Department of Mathematics, R.U.M.*

Prepared by the Computer Science Committee:

Robert Acar  
Dorothy Bollman  
Lourdes Morera  
Manuel Pérez  
Octavian Nicolio  
Avijit Purkayastha  
Jaime Seguel

1 Introduction
1.1 Title of Program: Computer Science  
1.2 Title of degree: Bachelor of Science in Computer Science  
1.3 Brief Overview.

The present program in computer science at R.U.M., which comprises an “option” for the B.S. degree in Mathematics, was initiated in 1973 in response to the demand both within and outside of Puerto Rico for personnel skilled in various computer related specialties. Currently, about half of the mathematics majors, or more than 200 students, are in the Computer Science Option. Graduates of this program currently occupy positions in government and industry throughout Puerto Rico and the United States. However, in spite of the popularity of this option and the success of its graduates in obtaining employment, it is time, and in fact past time, to expand this option to a full degree in computer science.

The new B.S. in Computer Science that we propose here has courses covering all nine subject areas that comprise computer science as identified by the ACM/IEEE-CS Joint Curriculum Task Force:¹ algorithms and data structures, architecture, artificial intelligence and robotics, database and information retrieval, human-computer communication, numerical and symbolic computation,  


*July, 1999
operating systems, programming languages, and software methodology and engineering. It satisfies all of the requirements of the Computing Sciences Accreditation Board and accreditation from this body will be sought as soon as the program is implemented.

The proposed program is based on the current Computer Science Option in Mathematics, but will require the introduction of three new courses: Computer Algorithms, Computer Science Practicum, and Database Systems. It will also make use of two doubly coded courses that currently exist in Computer Engineering. The new degree will require 40 credits in computer science and 25 credits in mathematics and statistics in contrast to the 18 credits in computer science and 35 credits in mathematics and statistics required by the current Computer Science Option in Mathematics.

This program will thus respond to a long time need for a fully accredited computer science program in Puerto Rico. It will also initiate a past due movement toward the development of Computer Science as an independent academic discipline on the island.

Today computer science is the basis for a variety of related sub-disciplines such as software engineering, artificial intelligence, scientific computing, among others. This diversification, which is due to the increasing complexity of the information processing phenomenon and its ever-expanding range of applications, demands an also increasing degree of specialization among computer scientists. Indeed, the Department of Electrical and Computing Engineering is proposing a new B.S. in Software Engineering, an area that was until very recently considered to be a subfield of computer science. (See Section 4 for an explanation of the differences between programs.)

Graduates of the program in computer science proposed here will be prepared to occupy positions in established companies both here and in the United States. They will also be prepared to contribute to a new software industry in Puerto Rico.

1.4 Start date: August, 2000

2 Justification.

The use of technology has grown exponentially in the last ten years. A decade ago there was virtually no Internet and no World Wide Web, few computers in the classroom, and robots in factories were still not commonplace. Today we are in the midst of an information technology revolution and we need look no farther than Puerto Rico to realize the profound effects of it.

The world economy has also drastically changed as manufacturing jobs are replaced by others, many of which are in information-based segments of the economy, in which computer scientists play vital roles. It is essential for Puerto Rico to have the necessary professionals to serve the needs of this new economy.

Unfortunately, Puerto Rico has not had a strong tradition in computer science education. There is not one computer science program in Puerto Rico that is accredited. Hispanic participation in computer science in general is in fact very low. This must be changed. Puerto Rico needs a fully accredited baccalaureate degree in computer science that will do for computer science what the UPRM school of engineering is doing for Hispanic engineers right now.
2.1 Relation of the program with the mission and objectives of the university and the department

The proposed program will provide well trained specialists in computer science to help satisfy Puerto Rico's needs for computing professionals in the computing, information, and communications industries. It is therefore very much in keeping with the university's mission of “directing its efforts towards the development of educated and cultured citizens and professionals qualified to contribute in an efficient manner to the cultural, social, and economic development of Puerto Rico.” More specifically, it is closely related to the primary mission of the Department of Mathematics to “develop competent professionals in pure and applied mathematics and related fields such as statistics, computer science, and mathematics education” as well as its objective of giving “our bachelor students a solid preparation for working in industry, private enterprise, and government, as well as preparing them for graduate studies”.

2.2 Academic reasons for establishment of the program.

Currently, over half of the department majors, 236 out of 449, are in the computer science option. However, these students repeatedly complain that the computer science option does not have enough courses available in computer science. In fact, in a recent survey of the students in the Computer Science option, 100% of them stated that they would like to have more courses in computer science available. There are important areas in computer science, such as databases and software engineering, that are not covered in the present curriculum, but which are nevertheless very important to graduates of the program in order to obtain the best jobs in computer science. Furthermore, there are many employers who prefer to hire people with degrees in computer science rather than those with degrees in mathematics (or computing engineering) with additional preparation in computer science. Our students deserve a complete B.S. in Computer Science.

The program proposed here will also provide strong preparation for graduate work in the computing sciences. It will, in fact, provide a valuable pipeline of candidates for the new Ph.D. program in Computing and Information Science and Engineering to be offered jointly by the Departments of Mathematics and Electrical and Computer Engineering at R.U.M.

2.3 Necessity of new program.

Computer Science is a well established discipline in which the great majority of U.S. universities established separate academic programs and departments over thirty years ago. The Computing Sciences Accreditation Board (“CSAB”), the agency that accredits baccalaureate degrees in the computing sciences throughout the United States, including Puerto Rico, was founded in the early 1980's. Currently there are over 150 computer science programs that are accredited by CSAB. Yet today, the University of Puerto Rico, the leading institution of higher education in Puerto Rico, has only 3 programs in this field. None of these covers all of the areas of computer science recommended by the Association of Computing Machinery (“ACM”) and the Institute for Electronic and Electrical Engineers (“IEEE”), the foremost organizations that define the goals and content of undergraduate programs in computing, nor is any one of them accredited by the CSAB.
On the other hand, there are five universities in Puerto Rico outside of the UPR system that offer bachelor degrees in computer science.

A large pool of highly qualified computing professionals, and especially computer scientists, is needed to support the research and development effort envisioned for the new Technological Corridor for Western Puerto Rico.

A baccalaureate program in computer science at UPR at Mayaguez is long overdue and it is imperative that action be taken now, for the sake of our students and the benefit of Puerto Rico. The program proposed here meets all the requirements of the ACM/IEEE-CS joint task force and accreditation by the CSAB will be sought as soon as possible.

2.4 Employment opportunities for graduates of the program

There is a high demand for computer scientist professionals in the United States, Puerto Rico, and probably the whole world. According to a study by IEEE-USA (http://www.ieeeusa.\FORUM\POLICY/98mar24.html), the demand for database administrators, support specialists, and systems analysts will more than double in the next ten years. There are many employment opportunities for graduates in computer science both here and in the U.S., as evidenced by the many employers who visit our campus to recruit students in the computer science option. Recruiters seeking computer scientists that have visited our campus during just the last year include Motorola Electrónica de Puerto Rico, Oracle Caribbean, Helvetia del Caribe, Naval Undersea Warfare Center, Honeywell Inc., Hughes Electronics Corp., The Mitre Corp., Motorola Inc., Lucent Technologies, AT&T, Xerox Corp., USDC Bureau of the Census, Dept. of the Navy (Naval Command, Control & Ocean Surveillance Center), Allstate Insurance Co., and IBM Corp.

There are many other opportunities in the small companies that are emerging in Puerto Rico to support the increased use of information technology. The Department of Education of Puerto Rico\footnote{Demanda de Recursos Humanos para Puerto Rico y sus Proyecciones para el Nuevo Milenio (Año 2005), prepared by Amalia Labrés de Clarineco, June, 1997} estimates that the unemployment rate for computer systems analysts and scientists in the year 2005 will be 8.68\%, i.e., demand will exceed supply. With the growth of the Internet, Puerto Rico needs trained professionals that can help develop the support/service infrastructure for Puerto Rico's web needs.

In addition, one of the goals for developing a new economic model for Puerto Rico is the development of a software industry on the island, which includes the creation of a competitive Software Development Center (see Appendix IV). The new program in computer science proposed here has been designed with this goal in mind.

3 Relation of the program to the Strategic Plans of UPR.

The new B.S. in Computer Science is directly related to the following goals and strategies of the university.

(a) The university of Puerto Rico at Mayagüez:
“Make the student the foremost endeavour of the university.”

An essential part of this is to insure that “students have access to programs of excellence.” We thus owe it to them to offer a full fledged degree in Computer Science.

“Make RUM a completely rounded university of excellence.”

This includes “promoting curricular changes, not only in content but also in emphasis, in order to maintain our programs in tune with the necessities of our society.” It is therefore essential that we offer an academic program that is offered at virtually every major university in the world.

“Promote an entrepreneurial culture in the students.” One of the goals of the new program is to provide professionals for a software industry in Puerto Rico. Graduates of this program will have training in entrepreneurship, through a requirement in business administration, and will have the opportunity for hands-on experience in industry, through an internship provision of the program. These experiences are aimed at helping graduates of the program to directly contribute to the development of new and existing industries in Puerto Rico.

(b) The University of Puerto Rico system:

“Work towards the continuous update of the academic offering.” The new program includes various topics of vital importance in modern computing that are not currently available in present curricula of RUM.

“Highlight and promote the presence, participation, and contribution of the university in the social processes in Puerto Rico and abroad.” The professionals provided by this new program will play an important role in the economic development of Puerto Rico.

“Enhance creative and research activity.” In today’s economy there are many opportunities for research and creative development in computer science. This program will enhance Puerto Rico’s capability to participate. It will prepare talented students to pursue graduate studies in the computational sciences. In particular, it will be a pipeline for talented students with interest in research to the new Ph.D. program in Computing and Information Science and Engineering.

4 Relation of new program with others.

In order to understand the relation between the proposed program and others, it is very important to understand what “computer science” is and what it has in common with, as well as how it differs from, other fields of computing.

Computer science can be defined as the study of processes and machines that describe and transform information. At present, nine areas cover the field of computing:

- algorithms and data structures
- programming languages
- computer architecture
- numerical and symbolic computation
• operating systems
• software methodology and engineering
• database and information retrieval systems
• artificial intelligence and robotics
• human-computer communications

Some aspects of computing such as parallel and distributed computation pervade all of these areas.

There are various other disciplines that have computer science components. Those that are currently offered as degree options within the UPR system include computational mathematics, computer engineering, and computerized information systems.

Computational Mathematics involves mathematical aspects in the design and analysis of algorithms as well as their implementations as scientific software.

Computer engineering "encompasses all aspects of design, theory and practice relating to: systems of digital and analog computation and information processing; components and circuits for computing systems; relevant portions of supporting disciplines; applications, use, and programming of computing devices and information processing systems; and the use of computers in electrical and electronic engineering" (the Bulletin of Information, University of Puerto Rico, Mayaguez).

Computerized Information Systems is a field that "seeks to prepare a professional capable of developing and managing a computerized information system oriented to the needs of any organization." (the Bulletin of Information, University of Puerto Rico, Mayaguez).

Software Engineering "encompasses theory, technology, practice and applications of software in computer-based systems." An academic program in this discipline "must include approximately equal segments in software engineering, in computer science and engineering, in appropriate supporting areas, and in advanced materials." (Joint IEEE/ACM Steering Committee for the Establishment of Software Engineering as a Profession, http://computer.org/tab/Accred10.html)

4.1 Academic programs at RUM with computer science components.
• The Department of Mathematics offers a “Computer Science Option.” Students in this option graduate with a B.S. in Mathematics, but also take courses in computer science. Requirements in this program include 35 credits in mathematics courses and 18 credits in computer science.
• The Department of Electrical and Computer Engineering (ECE) offers an undergraduate degree in computer engineering. The emphasis is on computer hardware and the software issues associated with hardware design and implementation. Requirements in this program include 47 credits in engineering courses, 15 credits in computer science, and 6 credits of electives chosen from either computer science or electrical engineering.

The ECE department is currently designing a new baccalaureate degree in software engineering. The two new degrees, the B.S. in computer science and the B.S. in software engineering, will be a strong force in providing the educational base necessary for the development of Puerto Rico’s software industry. Discussions between key members of the ECE and Mathematics departments
are currently underway to identify resources that can be shared in order to optimize the quality of both programs. Indeed, one of the authors of this proposal is Dr. Manuel Perez of the ECE Department. This spirit of cooperation between the two departments is a continuation of the same cooperation that produced the proposal for the new Ph.D. in Computing and Information Sciences and Engineering.

- The College of Business Administration offers a B.S. in Business Administration with an option in Computerized Information Systems. While some courses in this program have some elements in common with computer science courses, this program constitutes a field distinct from computer science in both scope and aims. The emphasis is on business applications. There is not one single course in the program that is equivalent to any computer science course in this proposal.

4.2 Other academic programs in the UPR system that have computer science components.

- The Department of Mathematics and Computer Science at UPR at Rio Piedras offers a B.S. in Computer Science. There are currently 50 to 60 students enrolled in this program, which requires 27 credits in computer science and 14 credits in mathematics. The program has offerings in six of the nine core areas, but has no offerings in artificial intelligence, human-computer communications, or software methodology and engineering.

- The Department of Computer Science at the Technological University College at Arecibo (CUTA) offers a B.S. in Computer Science. This program requires 42 credits in computer science courses and has offerings in all core subjects except for human-computer interaction.

- The Department of Computer Science at the Technological University College at Bayamon (CUTB) offers a B.S. in Computer Science. This program requires 39 credits in computer science courses and emphasizes computerized information systems and business applications. It has offerings in six of the nine core areas, but has no offerings in artificial intelligence, human-computer communications, or software methodology and engineering.

- The Department of Mathematics at the University College at Humacao offers a B.S. in Computational Mathematics. Requirements for this degree include 27 credits in mathematics and 15 credits in computer science.

    The first three programs are the only ones in computer science per se, but none of these is accredited by CSAB.

4.3 Academic programs in Puerto Rico outside the UPR system with computer science components.

- Inter American University offers a B.S. in Computer Science that requires 46 credits in computer science and 24 credits in mathematics. The required C.S. courses cover all nine core areas. In addition to these requirements, the student must choose 12 additional credits from one of three groups for specialization in either “Commercial Computation,” “Computer Systems,” or “Scientific Applications.” This program is the largest in Puerto Rico in terms of offerings.
• Metropolitan University offers a B.S. in Computer Science that requires 42 credits in computer science (including 3 credits in computer literacy) and 6 credits in mathematics (in addition to precalculus). It has offerings in 5 of the 9 core areas.

• Sacred Heart University offers a B.S. in Computer Science that requires 46 credits in computer science and 14 credits in mathematics (which includes 6 credits of precalculus). It has offerings in 7 of the 9 core areas.

5 Program description

5.1 Philosophy, goals and objectives.

The program will strive to provide the student with a broad perspective of the discipline, and be flexible enough to prepare him or her either for further graduate study, or for entry into the computing profession, as the student may choose. To that end, in addition to offering a solid core and a rich variety of electives, the program will strive to keep current both with recent technology and with any new theoretical developments in the field.

The program contains all nine areas identified by the ACM/IEEE-CS Joint Curriculum Task Force that should be common to all baccalaureate programs in computer science. Table 1 in Appendix II lists the courses of the program that corresponds to each of these areas. Furthermore, the required courses include all of the “knowledge units” that the joint task force recommends as common requirements for all computer science majors. Table 2 of Appendix II lists all of the required knowledge units and the courses that cover each required unit.

5.2 Profile of the graduate

The graduate of this program should have

• A general understanding of the nine major subject areas of computer science, algorithms and data structures, architecture, artificial intelligence and robotics, database and information retrieval, human-computer communication, numerical and symbolic computation, operating systems, programming languages, and software methodology and engineering, as well as the relationships between these areas.

• The ability to clearly define a problem and to determine its amenability to solution; to design, implement, and test solutions; to document and communicate solutions, including to the general public.

• The ability to work in a team environment throughout the entire problem solving environment, but at the same time have the self-confidence to lead and to try new ideas.

• A sufficiently strong foundation to continue lifelong learning and development. The field of computer science and many of its applications in information technology has changed dramatically in the past 5 years. The rapid pace of change is expected to continue or accelerate. For our
graduates to be successful in this field they must have a solid, broad foundation in computer science and good learning habits that facilitate lifelong professional development.

5.3 Program components.

5.3.1 Distribution of courses per area:

General concentration courses

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
<th>Prerequisite</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMP 3010</td>
<td>Computer Programming I</td>
<td>3</td>
<td>MATE 3171 or 3005</td>
</tr>
<tr>
<td>COMP 3110</td>
<td>Computer Programming II</td>
<td>3</td>
<td>COMP 3010 or equivalent</td>
</tr>
<tr>
<td>COMP 3075</td>
<td>Introduction to Data Structures</td>
<td>3</td>
<td>COMP 3110 or equivalent</td>
</tr>
<tr>
<td>COMP 4xoa</td>
<td>Computer Algorithms</td>
<td>3</td>
<td>COMP 3075</td>
</tr>
<tr>
<td>COMP 4036¹</td>
<td>Programming Languages</td>
<td>3</td>
<td>COMP 3075²</td>
</tr>
<tr>
<td>COMP 4016³</td>
<td>Computer Organization</td>
<td>3</td>
<td>COMP 3010</td>
</tr>
<tr>
<td>COMP 4000⁴</td>
<td>Software Engineering</td>
<td>3</td>
<td>COMP 3075</td>
</tr>
<tr>
<td>COMP 4006³</td>
<td>Operating Systems</td>
<td>3</td>
<td>COMP 4016</td>
</tr>
<tr>
<td>COMP 4046</td>
<td>Computer Graphics</td>
<td>3</td>
<td>COMP 3075 &amp; MATE 4031</td>
</tr>
</tbody>
</table>

In addition, 13 credits chosen from the following:

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
<th>Prerequisite</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMP 4xur</td>
<td>Undergraduate Research</td>
<td>1–6</td>
<td>Authorization of Director</td>
</tr>
<tr>
<td>COMP 4086</td>
<td>Computer Architecture</td>
<td>3</td>
<td>COMP 3110</td>
</tr>
<tr>
<td>COMP 5055</td>
<td>Parallel Computation</td>
<td>3</td>
<td>MATE 4061 and Authorization of Director</td>
</tr>
<tr>
<td>COMP 4998</td>
<td>Topics in Computer Science I</td>
<td>1–3</td>
<td>Authorization of Director</td>
</tr>
<tr>
<td>COMP 4999</td>
<td>Topics in Computer Science II</td>
<td>1–3</td>
<td>Authorization of Director</td>
</tr>
<tr>
<td>COMP 5045</td>
<td>Automata and Formal Languages</td>
<td>3</td>
<td>Authorization of Director</td>
</tr>
<tr>
<td>COMP 4025</td>
<td>Models of Computation</td>
<td>3</td>
<td>COMP 3010</td>
</tr>
<tr>
<td>COMP 4075</td>
<td>Programming Methodology</td>
<td>3</td>
<td>MATE 3020 &amp; COMP 3075 or Authorization of Director</td>
</tr>
<tr>
<td>COMP 4017</td>
<td>Database Systems</td>
<td>3</td>
<td>COMP 3075</td>
</tr>
<tr>
<td>COMP 4xai¹</td>
<td>Artificial Intelligence</td>
<td>3</td>
<td>COMP 4036</td>
</tr>
<tr>
<td>COMP 4xin</td>
<td>Computer Science Practicum</td>
<td>3–6</td>
<td></td>
</tr>
</tbody>
</table>

Total COMP credits required: 40

1 Proposed course number change
2 Proposed prerequisite change
3 Proposed course title change
4 Proposed dually coded course
Mathematics and statistics requirements

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
<th>Prerequisite</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATE 3031</td>
<td>Calculus I</td>
<td>4</td>
<td>MATE 3172 or MATE 3005</td>
</tr>
<tr>
<td>MATE 3032</td>
<td>Calculus II</td>
<td>4</td>
<td>MATE 3031 or MATE 3144</td>
</tr>
<tr>
<td>MATE 3063</td>
<td>Calculus III</td>
<td>3</td>
<td>MATE 3032</td>
</tr>
<tr>
<td>MATE 3181</td>
<td>Discrete Mathematics</td>
<td>3</td>
<td>MATE 3031 or MATE 3144</td>
</tr>
<tr>
<td>MATE 4031</td>
<td>Linear Algebra</td>
<td>3</td>
<td>MATE 3032</td>
</tr>
<tr>
<td>ESMA 38da</td>
<td>Statistical Data Analysis</td>
<td>3</td>
<td>MATE 3031 or MATE 3144</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>20</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Business Administration Requirement
At least one of the following 3 credit courses:

- ADMI 3100  Business Development
- ADMI 3155  Creativity and Entrepreneurial Innovation

Humanities Requirement

- FILO xxec  Computer Ethics (3 credits)

**Courses in the Program which fulfill Faculty and Institutional Requirements**

- Precalculus  5
- Chemistry, Physics, or Geology  6
- Biological Sciences  6
- Spanish  12
- English  12
- Physical Education  2
- Social Sciences  6
- Humanities  6
- Free electives  12
- Recommended electives\(^1\)  6

**Total** .................................................. 73
**Grand total** ........................................... 139

\(^1\) Please see Appendix VIII
5.3.2 Departmental Courses: Requirements and Electives

1. COMP 3010 Introduction to Computer Programming I
2. COMP 3110 Introduction to Computer Programming II
3. COMP 3075 Introduction to Data Structures
4. COMP 4xca Introduction to Computer Algorithms
5. COMP 4036 Programming Languages
6. COMP 4016 Computer Organization
7. COMP 4009 Software Engineering
8. COMP 4006 Operating Systems
9. COMP 4046 Computer Graphics
10. COMP 4xur Undergraduate Research
11. COMP 5015 Artificial Intelligence
12. COMP 4086 Computer Architecture
13. COMP 5055 Parallel Computation
14. COMP 4998 Topics in Computer Science I
15. COMP 4999 Topics in Computer Science II
16. COMP 5045 Automata and Formal Languages
17. COMP 4017 Database Systems
18. COMP 4xin Computer Science Practicum
19. MATE 3031 Calculus I
20. MATE 3032 Calculus II
21. MATE 3063 Calculus III
22. MATE 3181 Discrete Mathematics
23. MATE 4031 Introduction to Linear Algebra
24. ESMA 3sda Statistical Data Analysis (previously proposed in a separate document)
5.3.3 Course descriptions:

COMP 3010. Introduction to Computer Programming I. Three credit hours. Three hours of lecture per week. Prerequisite: MATE 3171 or MATE 3005.

Introduction to the components of the computer. Programming in a high-level language to solve numerical and non-numerical problems; design, coding, verification and documentation of programs emphasizing programming style.

COMP 3110. Introduction to Computers II. Three credit hours. Three hours of lecture per week. Prerequisite: COMP 3010 or its equivalent.

Design, verification and testing of large programs. Programming techniques include recursion, modularity, use of pointers, and backtracking.

COMP 3075. Introduction to Data Structures. Three credit hours. Three hours of lecture per week. Prerequisite: COMP 3110 or its equivalent.


COMP 4xca. Introduction to Computer Algorithms. Three credit hours. Prerequisite: COMP 3075.

Introduction to the design and analysis of algorithms.

COMP 4036. Programming Languages. Three credit hours. Three hours of lecture per week. Prerequisite: COMP 3075 or its equivalent.

Basic aspects of programming languages including data, operations, sequence control, data control, storage management, operational environments, syntax, and semantics.

COMP 4016. Computer Organization and Assembly Language. Three credit hours. Three hours of lecture per week. Prerequisite: COMP 3010 or its equivalent.

Internal computer organization including the control processing unit, computer arithmetic, digital circuits, logical design, control units, and assembly language programming.

COMP 4006. Operating Systems. Three credit hours. Three lectures per week. Prerequisite: COMP 4016.

Structure and implementation of operating systems including scheduling, input-output, control and storage management, file systems and their organization, timing and synchronization.

COMP 4025. Computing Models. Three credit hours. Three hours of lecture per week. Prerequisite: COMP 3110.

Various models for the modern use of computers, including operations research and applications of probability and statistics.

COMP 4046. Computer Graphics. Three credit hours. Prerequisites: COMP 3075 and MATE 4031.

Introduction to computer graphics: graphics hardware and packages, user-interface design, geometric modelling and algorithms, image manipulation and compression.
COMP 5015. Artificial Intelligence. Three credit hours. Prerequisite: COMP 4036.
Introduction to the field of artificial intelligence; LISP; search techniques; games; vision; representation of knowledge; inference and theorem proving; natural language understanding.

COMP 4009. Software Engineering. Three credit hours. Prerequisite: COMP 4036.
Techniques used during the software development cycle; specification, design, testing, documentation and maintenance. Use of a procedure oriented language in the design and implementation of a software project.

COMP 4086. Computer architecture. Three credit hours. Three hours of lecture per week. Prerequisite: COMP 3110.
Introduction to the organization and architecture of computer systems including logic circuits, addressing and management of memory, design and organization of processors, input and output of data.

COMP 5055. Parallel Computation. Three credit hours. Three hours of lecture per week. Prerequisite: MATE 4061 or consent of the Director of the Department.
Introduction to the use of supercomputers: parallel architecture, design of algorithms for scientific computation and their implementation with parallel multiprocessors, and performance analysis.

COMP 4998. Topics in Computer Science. One to three credit hours. One to three hours of lecture per week. Prerequisite: consent of the Director of the Department.
The course will cover one or more topics chosen from the following general areas: hardware, computer systems organization, software, data, theory of computation, computer mathematics, information systems, computing methodologies.

COMP 4999. Topics in Computer Science. One to three credit hours. One to three hours of lecture per week per credit hour. Prerequisite: consent of the Director of the Department.
Special topics in Computer Science. The content of this course will vary according to interests and demand.

COMP 5045. Automata and Formal Languages. Three credit hours. Three hours of lecture per week. Prerequisite: consent of the Director of the Department.
Finite automata and regular languages; pushdown automata and context-free languages; Turing machines and recursively enumerable sets; linearly bounded automata and context-sensitive languages; computability and the halting problem; undecidable problems.

COMP 4017. Database Systems. Three credit hours. Three hours of lecture per week. Prerequisite: COMP 3075.
Introduction to database system architecture and design. The entity-relation model and the relational model. Queries, relational algebra, and the SQL language. Functional dependencies and normalization. The design and realization of database system projects.

COMP 4xin. Computer Science Practicum. Three to six credit hours. Prerequisite: Authorization of director of the department.
Practical experience in a computer science application jointly supervised by the department and a public or private organization. Written report required.

**MATE 3031. Calculus I.** Four credit hours. Four hours of lecture per week. Prerequisite: MATE 3005 or MATE 3172.
Elementary differential and integral calculus of one real variable with applications.

**MATE 3032. Calculus II.** Four credit hours. Four hours of lecture per week. Prerequisite: MATE 3031 or MATE 3144.
Integration techniques, infinite series, vectors, polar coordinates, vector functions, and quadric surfaces; applications.

**MATE 3063. Calculus III.** Three credit hours. Three hours of lecture per week. Prerequisite: MATE 3032.
Differential and integral calculus of several variables, and an introduction to differential equations with applications.

**MATE 3181. Discrete Mathematics.** Three credit hours. Three hours of lecture per week. Prerequisite: MATE 3031 or MATE 3144.
Elements of propositional logic, set algebra, functions, sequences; complexity metrics for algorithms; elements of matrix algebra; properties of proofs; induction, recursion, counting principles; relations; graphs.

**MATE 4031. Introduction to Linear Algebra.** Three credit hours. Three hours of lecture per week. Prerequisite: MATE 3032.
Euclidean vector spaces, matrices and linear equations, spectral decomposition of normal operators.

**ESMA 3sda. Statistical Data Analysis.** Three credit hours. Two hours of lecture and one two-hour laboratory per week. Prerequisite: MATE 3031 or MATE 3144 and COMP3010.
Statistical data analysis including descriptive and inferential statistics and exploratory data analysis. Use of a simulation and statistical computer package.

### 5.3.4 Course syllabi.

Please see Appendix VI.

### 5.3.5 Course sequence:

The following illustrates a typical course sequence. This sequence requires a total of 139 credits.
### First Year

<table>
<thead>
<tr>
<th>Code</th>
<th>Course</th>
<th>Credits</th>
<th>Code</th>
<th>Course</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATE 3005 or 3143</td>
<td>Precalculus</td>
<td>5</td>
<td>MATE 3031 or 3144</td>
<td>Calculus I</td>
<td>4</td>
</tr>
<tr>
<td>ESPA 3101</td>
<td>Basic Spanish I</td>
<td>3</td>
<td>ESPA 3102</td>
<td>Basic Spanish II</td>
<td>3</td>
</tr>
<tr>
<td>INGL 3—</td>
<td>1st Year English</td>
<td>3</td>
<td>INGL 3—</td>
<td>1st Year English</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>EDFI —</td>
<td>Phys. Ed.</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total credits</strong></td>
<td></td>
<td><strong>17</strong></td>
<td><strong>Total credits</strong></td>
<td></td>
<td><strong>17</strong></td>
</tr>
</tbody>
</table>

### Second Year

<table>
<thead>
<tr>
<th>Code</th>
<th>Course</th>
<th>Credits</th>
<th>Code</th>
<th>Course</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATE 3032</td>
<td>Calculus II</td>
<td>4</td>
<td>MATE 3063</td>
<td>Calculus III</td>
<td>3</td>
</tr>
<tr>
<td>MATE 3181</td>
<td>Discrete Mathematics</td>
<td>3</td>
<td>COMP 4016</td>
<td>Computer Organization</td>
<td>3</td>
</tr>
<tr>
<td>COMP 3110</td>
<td>Intro. Comp. Prog. II</td>
<td>3</td>
<td>COMP 3075</td>
<td>Data Structures</td>
<td>3</td>
</tr>
<tr>
<td>ESPA 3—</td>
<td>Course above Basic Spanish</td>
<td>3</td>
<td>ESPA 3—</td>
<td>Course above Basic Spanish</td>
<td>3</td>
</tr>
<tr>
<td>INGL 3—</td>
<td>2nd Year English</td>
<td>3</td>
<td>INGL 3—</td>
<td>2nd Year English</td>
<td>3</td>
</tr>
<tr>
<td>EDFI —</td>
<td>Phys. Ed.</td>
<td>1</td>
<td>CISO 3122</td>
<td>Intro. Soc. Sci.</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total credits</strong></td>
<td></td>
<td><strong>17</strong></td>
<td><strong>Total credits</strong></td>
<td></td>
<td><strong>18</strong></td>
</tr>
</tbody>
</table>

### Third Year

<table>
<thead>
<tr>
<th>Code</th>
<th>Course</th>
<th>Credits</th>
<th>Code</th>
<th>Course</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATE 4031</td>
<td>Linear Algebra</td>
<td>3</td>
<td>ESMA —</td>
<td>Statistical Data Analysis</td>
<td>3</td>
</tr>
<tr>
<td>COMP 4xxa</td>
<td>Computer Algorithms</td>
<td>3</td>
<td>COMP 4036</td>
<td>Programming Languages</td>
<td>3</td>
</tr>
<tr>
<td>COMP —</td>
<td>Comp Sci Elective</td>
<td>3</td>
<td>COMP 4009</td>
<td>Software Engineering</td>
<td>3</td>
</tr>
<tr>
<td>FISI, QUIM or GEOL</td>
<td>Elective in Physics, Chemistry or Geology</td>
<td>3</td>
<td>FISI, QUIM or GEOL</td>
<td>Elective in Physics, Chemistry or Geology</td>
<td>3</td>
</tr>
<tr>
<td>ELECTIVE</td>
<td>Free Elective</td>
<td>3</td>
<td>FILO 3—</td>
<td>Computer Ethics</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total credits</strong></td>
<td></td>
<td><strong>18</strong></td>
<td><strong>Total credits</strong></td>
<td></td>
<td><strong>18</strong></td>
</tr>
</tbody>
</table>
### Fourth Year

<table>
<thead>
<tr>
<th>Code</th>
<th>Course</th>
<th>Credits</th>
<th>Code</th>
<th>Course</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMP 4006</td>
<td>Operating Systems</td>
<td>3</td>
<td>COMP —</td>
<td>Comp. Sci. Elective</td>
<td>3</td>
</tr>
<tr>
<td>COMP 4046</td>
<td>Computer Graphics</td>
<td>3</td>
<td>COMP —</td>
<td>Comp. Sci. Elective</td>
<td>3</td>
</tr>
<tr>
<td>COMP —</td>
<td>Comp. Sci. Elective</td>
<td>3</td>
<td>COMP —</td>
<td>Comp. Sci. Elective</td>
<td>1</td>
</tr>
<tr>
<td>ELECTIVE</td>
<td>Recommended Elective</td>
<td>3</td>
<td>ELECTIVE</td>
<td>Recommended Elective</td>
<td>3</td>
</tr>
<tr>
<td>ADMI —</td>
<td>Business Elective</td>
<td>3</td>
<td>ELECTIVE</td>
<td>Free Elective</td>
<td>3</td>
</tr>
<tr>
<td>ELECTIVE</td>
<td>Free Elective</td>
<td>3</td>
<td>ELECTIVE</td>
<td>Free Elective</td>
<td>3</td>
</tr>
</tbody>
</table>

| Total credits .................................. | 18 | Total credits .................................. | 16 |

### 6 Admission and enrollment.

#### 6.1 Admission requirements.

Students admitted to the program will be subject to all admission requirements of the University of Puerto Rico at Mayaguez, the College of Arts and Sciences, and the Department of Mathematics.

#### 6.2 Enrollment projections for the first five years.

Enrollment in the Computer Science Option has averaged 199 during the last five years. It has fluctuated between 149 and 239 during the last seven years. (See Table 1 of Appendix III.) It has apparently stabilized to around 230 (236 in 1997-1998 and 231 in 1998-1999). The average number of graduates of the Computer Science Option during the last five years is 23. (See Table 2 of Appendix III.)

We expect that most of the students currently enrolled in the C.S. option will enroll in the new B.S. program in computer science. We also expect that the new program will attract entering freshmen as well as some students currently enrolled in other programs. Although there is the potential for considerable growth, we believe that it will be prudent to control growth in favor of maintaining quality. We project an enrollment of somewhere around 260 in five years.

### 7 Academic requirements for the B.S. in Computer Science

All candidates for graduation will be subject to all of the requirements of the University of Puerto Rico at Mayaguez, the College of Arts and Sciences, and the Department of Mathematics. In addition, the student will be required to attain a grade of at least C in each of the general concentration courses in computer science.
8 Faculty

8.1 Distribution of faculty necessary to offer program.

There are professors who can teach each of the general concentration courses. Some reinforcement or additional faculty training is needed for the Software Engineering and Computer Graphics courses. Reinforcement is also needed in networking, which will initially be given as a topic in Topics in Computer Science.

8.2 Projections for needed faculty for the next five years.

Initially, three additional Ph.D.s in computer science will be hired to fill the three new positions provided by the central administration (see Appendix IV). Although the primary role of these three computer scientists will be in research, it is nevertheless expected that they will provide leadership in the whole computing science effort within the Mathematics Department. They can also provide backup in and guidance in training present faculty in crucial areas such as the software, networking, and graphics courses mentioned above.

In addition to these, we will need four more computer scientists in order to round out the overall scope of expertise of the faculty. These will be hired to fill existing positions as they become available. Two of them could possibly be our recent M.S. graduates who are currently pursuing doctoral studies in the computational sciences in the United States.

8.3 Preparation of present C.S. faculty.

The following faculty, with the exception of Manuel Pérez, currently teach C.S. courses given in the Mathematics Department. Dr. Pérez teaches C.S. courses given in the Department of Electrical and Computer Engineering.

Robert Acar, Ph.D. Computer Science, University of Wisconsin. Teaching and research interests: data structures, computer algorithms, numerical analysis, computer graphics, computer imaging.

Dorothy Bollman, Ph.D. Mathematics, University of Illinois. Teaching and research interests: algorithms, parallel programming, functional languages, theory of computation.

Gladys Di Cristina, M.S. Mathematics, University of Puerto Rico at Mayaguez. Teaching and research interests: object-oriented programming, computer architecture, artificial intelligence.

Ana Gonzalez, M.S. Mathematics, University of Puerto Rico at Mayaguez. Teaching and research interests: object-oriented programming, data structures.

Haedeh Gooransarab, M.S. Computer Science, Ph.D. Mathematics, Purdue University. Teaching and research interests: numerical analysis, computer simulation.

Darrell Hajek, Ph.D. Mathematics, University of Florida. Teaching and research interests: computer organization, assembly language, Internet programming.
Cesar Herrera, M.S. Computer Science, Ohio University, doctoral studies in Computer Science, Universidad Central, Caracas, Venezuela. Teaching and research interests: databases, operating systems.


Octavian Nicolio, M.S. Computer Science, Indiana University; Ph.D. Computational Mathematics, Wichita State University. Teaching and research interests: programming languages, operating systems, computer algorithms, networking, compilers.


Avijit Purkayastha, Ph.D. Computational Mathematics, Northern Illinois University. Teaching and research interests: high performance computing, numerical linear algebra, data structures, programming languages.

Betty Ramirez, Ph.D. Computer Science, Polytechnic University of Madrid. Teaching and research interests: artificial intelligence, declarative languages, theory of computation.

Jaime Seguel, Ph.D. Mathematics, City University of New York. Teaching and research interests: parallel algorithms, high performance computing, numerical analysis.

Robert Smith, Ph.D. Mathematics, University of Miami. Teaching and research interests: computational models, computer simulation, data bases, artificial intelligence.

8.4 Training for the faculty.

It is very important for computer science faculty to maintain themselves up-to-date in the discipline. In keeping with this goal, a permanent computer science seminar will be established for both faculty and students.

The department will also hire exceptional graduates from the department’s M.S. programs on condition that they study for the Ph.D. in Computer Science.

9 Learning Resources

9.1 Inventory.

Learning resources presently consist of computer hardware (surveyed in Section 10), computer software, and library resources.

9.2 Software

The department has a full range of software for UNIX and Windows operating systems, including various industry supported compilers for languages such as C, C++, Java, FORTRAN, and Pascal,
as well as numerous public domain compilers and interpreters for a large variety of other modern languages. Symbolic and numerical computing packages include Mathematica and MatLab. Statistical packages include Minitab and SAS.

9.3 Library

The present collection of books in the areas of computer science, applied mathematics and statistics is adequate to begin with, but additional funds will be needed to improve the collection and maintain adequate acquisitions of both past, current and future publications and books.

The collection of all journals of mathematics is minimally adequate but those of the area of computer science should be improved. Greater effort must be made so that books and journals can be obtained easier and faster. In the very rapidly changing area of computing, many times a very new and exciting book can become obsolete between the time it is recommended and the time it actually arrives at the R.U.M. library.

Recent discontinuations of various journals have created gaps in several valuable collections. Substantial investments must be made to fill these gaps and additional library appropriations will be needed to reinstate needed journals that were discontinued. Although an efficient library system does not directly affect an undergraduate program, it does come into play for the higher level courses, for projects for graduating students who may have the possibility of joining the graduate programs offered by the department, and for attracting new faculty.

10 Physical Facilities and Equipment

10.1 Inventory of existing resources.

(a) Physical facilities: The new program will share the facilities with the Department of Mathematics, which has recently been relocated in Monzon. These facilities include 16 classrooms and four student laboratories. Another laboratory, the Scientific Computation Laboratory, is used primarily for undergraduate research projects. The Visualization Laboratory is used primarily for research. The department also has 35 offices in Monzon. Although these facilities are adequate to start with, additional space, as described in Section 10.2, is needed.

(b) Inventory of Computer Equipment: This is itemized according to laboratories. All facilities are connected to the Internet and have access to Office Suite Programs (Microsoft Office and Sun Star Office).

Open UNIX laboratory:
1. 24 Sun Ray terminals
2. 1 Sun Ultra Enterprise 450 Server with four processors (web server, mail server and 1Gb RAM).
3. 16 PCs with LINUX networked and with access to Internet
4. One laser printer

Open PC laboratory:
1. 16 PCs using NT4 and Windows 2000 and networked with NT server
2. One color scanner

Closed UNIX laboratory:
32 networked Sun Sparc and Sun Ultra workstations with connection to the laser printer in the open UNIX laboratory. (This laboratory was equipped in part with funds from an equipment grant from NSF and matching funds from the university.)

Statistics/Computer Literacy Instructional Laboratory:
1. 21 Pentium Pros (11 pentium 200 and 10 pentium 600) using Windows NT 4.0 and networked with NT
2. 1 laser printer

Linux Laboratory
16 pentium 350 PCs connected to a Linux network

Scientific Computation Laboratory
1. 4 Sun Sparc 4
2. 1 Silicon Graphics
3. 1 laser printer
4. 1 Sun Ultra Enterprise 3000 Server with two processors
5. 1 Maspar I with 1024 processors (It is anticipated that this machine, now obsolete, will be moved to the open UNIX lab for use by students in operating systems.)

Items 1-3 of the Scientific Computation Laboratory were purchased with funds from research grants. Items 4 and 5 were purchased with funds from a research grant and matching funds from the university.

Visualization Laboratory
This laboratory is equipped with a Silicon Graphics 320 Visual Workstation with two processors and an Origin 2000 server with 6 processors.

10.2 Impact of the new program on existing facilities
In its new quarters in Monzon the Department of Mathematics has 16 classrooms. In several cases, current class size exceeds room capacities as specified by the fire code. In order to comply with the fire code, at least one additional classroom is needed and one other will be needed to accomodate the new courses that will be offered. Thus, at least two new classrooms are needed. The dean of Arts and Sciences has promised to try to make more classroom space available to us.

There is currently a big demand for use of the open laboratories. There are more that 800 users of the UNIX system and more than 500 users of PCs. Each new semester as more and more classes use the computer facilities, they become more overburdened. The department also needs more space for the teaching of mathematics, including a lab for the teaching of calculus (with say S.G.I.s running Mathematica) and at least one separate lab for the teaching of statistics. With a grant from the U.S. Department of Education that was recently awarded to two professors, the
department will be able to purchase 40 new computers to support mathematics instruction. This should help alleviate some of the demand for PCs.

It is not anticipated that the new program will significantly increase demand for laboratory use, at least not initially. However, within the next two or three years, space for the open laboratories should be expanded. More space will be needed in the first two to four years for additional specialized laboratories, including separate laboratories for networking, and computer graphics. More lab and office space will also be needed to accomodate the additional computer scientists that will be contracted for this and the other new computing programs that will be given by the department.

The department anticipates additional space to become available in Monzon when the Graduate Studies and the Press offices move back to their permanent quarters which are now being renovated. Several more offices can be made available by renovating old storerooms on the fourth floor of Monzon.

10.3 Necessity and availability of computer services for the new program.

The department has one full time systems/network administrator who oversees the maintenance of virtually all software and hardware in the student labs located in the open UNIX lab, the open PC lab, the closed UNIX lab, and the Statistics/Computer Literacy Laboratory. The systems administrator also maintains the software, hardware, and networking facilities of all faculty members of the Department of Mathematics, as well as that of the computer laboratory of the College of Arts and Sciences. This is clearly already more work than can be reasonably handled by one person.

Fortunately, during the past two years, the department has been able to benefit from the services of a second part time systems administrator who, with the help of another professor, maintains the software and hardware in the Scientific Computation Laboratory as well as that of the four members of the Scientific Computation Group. This person has been paid with grant funds, but unfortunately these funds have been exhausted and future funding sources for hiring a systems administrator are doubtful.

With the additional computer equipment and laboratories needed for the new program in computer science, one more full time systems administrator will be needed to help maintain the equipment and laboratories.

11 Accreditation and licensing of the program

11.1 Professional accreditation.

As mentioned in Section 2, the Computing Sciences Accreditation Board (CSAB) accredits baccalaureate computer science programs that are located throughout the United States, including Puerto Rico. Its two member societies, the Association for Computing Machinery and the Institute of Electrical and Electronic Engineers are the two largest technical, educational, and scientific societies in the field of computing. A priority aim of our program will be to attain accreditation by this organization.
The following is an a brief overview of evaluation criteria used by CSAB: (Details can be found at http://www.csab.org/criteria96.html.) Comments in italics indicate how well the proposed program measures up to the criteria.

11.1.1 Faculty.

There should be a minimum of the equivalent of five full-time computer science faculty. All should have competence equivalent to what would be acquired through graduate work in computer science. Those with primary commitment to the program should be able to teach a broad range of C.S. courses and to make scholarly contributions to the field. A majority should hold a “terminal degree” and some should have a Ph.D. in Computer Science or equivalent qualifications. Faculty time devoted to scholarly activities should average 25%. Under no circumstances should any faculty member teach more than 12 credits per semester and in this case he/she should have no more than two preparations.

Faculty should have broader ranges of C.S. teaching expertise. Currently, there is only one faculty member of the department who can teach Software Engineering and only one who can teach Computer Graphics. These gaps can be filled by faculty training and hiring new faculty (as mentioned in Section 8.2) Faculty time devoted to scholarly activities (which presently averages 15% among current C.S. faculty) must be increased.

11.1.2 Curriculum.

(a) Computer Science. The program should have at least 40 credits in computer science topics. Required courses in computer science, consisting of 40% - 60% of the total C.S. requirements should give equal emphasis to the following six areas: theoretical foundations of computer science, algorithms, data structures, software design, the concepts of programming languages, and computer elements and architecture.

The required C.S. courses of the program constitute 69% of the total C.S. requirements. Table 3 of Appendix II shows the contribution of each of the required courses to the six areas mentioned.

(b) Additional requirements. The program should require at least 15 credits in mathematics, including material in discrete mathematics, differential and integral calculus, and probability and statistics. It must also include at least 12 credits in science and another 30 credits in humanities, social sciences, arts and “other disciplines that serve to broaden the background of the student.”

The program requirements exceed these requirements.

11.1.3 Laboratory and Computing Resources.

Sufficient facilities, both hardware and software, must be available so that each student has adequate access to the appropriate equipment needed for each course. Adequate equipment must also be available to support scholarly activies of the faculty. At the very least each professor should have access to computers from his/her office for class preparation and research. It is also “critical” to have adequate support personnel to implement and maintain hardware and software.
These requirements are satisfied at present, but additional support personnel should be contemplated.

11.1.4 Students.

There must be appropriate standards to enable graduates of the program to function effectively as professional computer scientists. “The advisory function of the faculty must be recognized by the institution and must be given appropriate administrative support.”

Approve the post of an academic advisor, a member of the computer science faculty, who would receive 6 hours of release time for academic advising of C.S. majors.

11.1.5 Institutional Support.

Faculty Support. There should be reasonable teaching loads and competitive salaries to attract and retain high quality faculty. There should be support for faculty members to attend national technical meetings. There must be support and recognition of scholarly activities.

Current salaries are below U.S. averages. For example, the average salary as of January, 1998 for an assistant professor of computer science was $58,297 (Computer Research News, March, 1998). There should be more administration support and encouragement for research and release time to do it.

Administration. Adequate time must be assigned to the administration of the program. The upper levels of administration should provide the support and atmosphere for the the program to function effectively within the institution. See 11.1.4.

Library. The technical collection must include up-to-date books and appropriate journals. More books are needed and the acquisition process made faster.

Office Secretarial Support. There should be modern office equipment available and adequate secretarial support.

Presently adequate.

Laboratory and Computing Support. The institution should acquire adequate laboratory and computer equipment and provide for adequate support personnel to maintain it.

Presently adequate, but funds should be budgeted for hiring an additional systems administrator and more funds for acquiring equipment.

11.1.6 Assessment of Program Effectiveness.

This should be evaluated and documented on a regular basis. Results of assessment should be used to maintain quality and effect improvements. More details of the evaluation process can be found in Section 16.

11.2 Licensing by the Council of Higher Education (CES).

We expect that the results of our efforts to satisfy the CSAB will also meet the standards of CES.
12 Administration of the new program

The program will be administered by the “Computer Science Committee,” consisting of three professors who will be elected on an annual basis by the “computer science faculty,” as well as a student consultant chosen by the computer science majors. The computer science faculty is defined to be all faculty members whose primary teaching or research responsibilities are in computer science. This committee will advise the director of the department on curriculum, teaching assignments of C.S. courses, equipment and laboratory needs, personnel decisions, and all other matters that either directly or indirectly concern the program. The president of the Computer Science Committee, who will be elected by the committee, will serve as a liaison between the computer science faculty and the director of the department. The student consultant will serve as a liaison between the computer science faculty and the student body.

It is anticipated that the computer science program will eventually form its own department and thus have its own administrative structure, under which it can develop its full potential.

13 Economic aid for students

On the average, the department hires about 5 undergraduate student assistants per semester. These students help the systems administrator in software and hardware maintenance chores. These students benefit not only economically, but learn a great deal about computer systems as well. With the new expanded program and the possible addition of more laboratories, we would expect that the need for student help will increase.

Another source of economic aid for students is through research grants. Currently there are several students who receive financial aid from NSF and NASA grants for their research work. The Department of Education grant recently approved for the purchase of computers for mathematics instruction could also provide opportunities for several students.

Some of our better students in the Computer Science option have participated in summer research programs for undergraduates at U.S. universities. These programs typically pay stipends that include room and board and transportation as well as a cash stipend. Participants in these programs thus have the opportunity of not only earning money during the summer, but also of learning about research. The department will continue to identify such programs and encourage qualified students to apply.

In addition to the above possibilities, the computer science practicum of the new program, COMP 4xin, will also afford opportunities for both valuable experience, as well as economic support. We will also investigate the possibility of obtaining scholarships from computer-related companies, especially those who have facilities in Puerto Rico.

14 Budget

As noted before, physical space for the open UNIX laboratory should be expanded within the first two to three years. This could be accomplished by moving the LINUX system to a separate operating systems laboratory and converting the open UNIX laboratory to a strictly UNIX (or Solaris)
environment. Special laboratories will also be needed for computer graphics and networking. Funds for remodeling space for the operating systems, computer graphics and networking laboratories are as follows:

<table>
<thead>
<tr>
<th>Laboratory</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating systems laboratory (600 sq. ft.)</td>
<td>$30,000</td>
</tr>
<tr>
<td>Computer graphics laboratory (600 sq. ft.)</td>
<td>$30,000</td>
</tr>
<tr>
<td>Networking laboratory (600 sq. ft.)</td>
<td>$30,000</td>
</tr>
<tr>
<td><strong>Total for remodelling for laboratories</strong></td>
<td><strong>$90,000</strong></td>
</tr>
</tbody>
</table>

Funds needed to complement the equipment that we now have in order to fully equip these laboratories are as follows:

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 workstations for UNIX laboratory</td>
<td>$80,000</td>
</tr>
<tr>
<td>20 workstations for computer graphics laboratory</td>
<td>$100,000</td>
</tr>
<tr>
<td>Equipment for networking laboratory</td>
<td>$30,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$210,000</strong></td>
</tr>
</tbody>
</table>

We anticipate the possibility of obtaining grants to cover half of the cost for equipping these three new laboratories (i.e., $105,500). In this case, the total needed for laboratory expansion would be as follows:

<table>
<thead>
<tr>
<th>Category</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remodelling</td>
<td>$90,000</td>
</tr>
<tr>
<td>Computer Equipment</td>
<td>$105,500</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$195,000</strong></td>
</tr>
</tbody>
</table>

An additional systems/network administrator is also needed. The cost for hiring such a person is $30,000 per year.

Other operating expenses will be covered by the current budget of the Department of Mathematics. In this regard it is important to take note of the budget for purchasing computer equipment. Fortunately, such funds have been made available during the past four years in the following amounts:

- 1995-96 $184,338
- 1996-97 $141,320
- 1997-98 $118,963
- 1998-99 $116,000

But unfortunately, as can be seen, these funds have suffered a yearly decrease. It is very important, that sufficient funds be provided in order to maintain the computer equipment up-to-date. This includes replacing computers at least every four years. We estimate the minimum amount needed for this, including maintenance, at $200,000 per year.
15 Financial Resources

The department currently has three active computer science related grants. One of these, “Infrastructure for Computer Science Research in Puerto Rico,” funded by CISE-NSF, has provided funds for computer equipment, which have been used to enhance computing equipment for researchers in computational mathematics and their students. Another, “Undergraduate Research and the Computational Mathematics Group” has been used mainly to support undergraduate research in computing. The third, sponsored by the National Institute of Health, supports research in software development for crystallographic FFTs.

16 Evaluation

The program will be continually evaluated and the information obtained from the evaluation will be used to effect improvements. Assessment tools will include questionnaires given at least once a year to both current students as well as a statistical sampling of former students. Results of this evaluation will be documented and analyzed by the Computer Science Committee and communicated to the director of the department. Advice will also be solicited from computing professionals in industry and government, especially those representing organizations that have hired graduates of our program.

One of the first milestones to determine if the program meets the projected standards of excellence is accreditation by the CSAB. Other measures of success will be the percent of graduates that are hired for computing positions in industry, as well as the percent of graduates accepted in graduate programs in computing.