LSC Use Only
Number: ________
Action: ________
Date: ________

UWUCC Use Only
Number: 92-45
Action: App
Date: 4/20/93
Senate App 5/4/93

CURRICULUM PROPOSAL COVER SHEET
University-Wide Undergraduate Curriculum Committee

I. Title/Author of Change

Course/Program Title: MA 451 Numerical Methods for Supercomputers
Suggested 20 Character Course Title: NUM METH/SUPERCOMPTR
Department: Mathematics
Contact Person: Dr. H. E. Donley

II. If a course, is it being Proposed for:

____ Course Revision/Approval Only
____ Course Revision/Approval and Liberal Studies Approval
____ Liberal Studies Approval Only (course previously has been approved by the University Senate)

III. Approvals

[signature]
Department Curriculum Committee

Gerald Buriok
Department Chairperson

____
College Curriculum Committee

W. I. Cole
College Dean *

____
Director of Liberal Studies (where applicable)

____
Provost (where applicable)

*College Dean must consult with Provost before approving curriculum changes. Approval by College Dean indicates that the proposed change is consistent with long range planning documents, that all requests for resources made as part of the proposal can be met, and that the proposal has the support of the university administration.

IV. Timetable

Date Submitted to LSC: ________

to UWUCC: ________

Semester to be implemented: ________

Date to be published in Catalog: ________

LSC Use Only
Number: ______
Action: ______
Date: ______

UWUCC Use Only
Number: ______
Action: ______
Date: ______

CURRICULUM PROPOSAL COVER SHEET
University-Wide Undergraduate Curriculum Committee

I. Title/Author of Change

Course/Program Title: CO 451 Numerical Methods for Supercomputers
Suggested 20 Character Course Title: NUM METH/SUPERCOMPTR
Department: Computer Science
Contact Person: Dr. Charles Shubra

II. If a course, is it being Proposed for:

______ Course Revision/Approval Only
______ Course Revision/Approval and Liberal Studies Approval
______ Liberal Studies Approval Only (course previously has been approved by the University Senate)

III. Approvals

Charles J Shubra
Department Curriculum Committee

Gary L Buterbaugh
Department Chairperson

______
College Curriculum Committee

W.A. Cole
College Dean *

______
Director of Liberal Studies (where applicable)

______
Provost (where applicable)

*College Dean must consult with Provost before approving curriculum changes. Approval by College Dean indicates that the proposed change is consistent with long range planning documents, that all requests for resources made as part of the proposal can be met, and that the proposal has the support of the university administration.

IV. Timetable

Date Submitted to LSC: ______
to UWUCC: ______

Semester to be implemented: ______

Date to be published in Catalog: ______

CONTENT AND FORMAT CRITERIA FOR NEW COURSE PROPOSALS AND MAJOR COURSE REVISIONS

New course proposals and major course revisions must be submitted in the form described below. This form applies to the submission of a single course or to a series of new courses tied to a new or revised graduate program proposal. If the course(s) is part of a new or revised graduate program proposal, the course proposal(s) must be appended to the program proposal.

PROPOSAL FOR A NEW GRADUATE COURSE OR MAJOR COURSE REVISIONS

Department: Mathematics

Course Number and Title: MA 551 Numerical Methods for Supercomputers

Person to Contact for Further Information: Dr. H. E. Donley

Approvals: Department Committee Chairperson Fred Morgan

Department Chairperson Gerald Buriok

College Committee Chairperson ______

College Dean W. G. Cole

A. Description and Academic Need

A1. Attach a detailed syllabus and course bibliography reflecting major course topics.

A1a. Course Syllabus - Refer to Appendix C for content and format requirements to be used in the preparation of this syllabus. Also, note that the committee here distinguishes between the COURSE SYLLABUS and the SEMESTER SYLLABUS.

-COURSE SYLLABUS. The university requires that each department maintain a file containing Senate approved versions of syllabi for each graduate and undergraduate course it offers. These syllabi of record describe basic features and content of each course. At the graduate level each syllabus has presumably been prepared in accordance with Graduate Committee guidelines, approved by department and college curriculum committees, the Graduate Committee, and has ultimately been approved by the University Senate. It is this document that is here required.

-SEMESTER SYLLABUS. The semester syllabus, on the other hand, is that prepared by an individual instructor for distribution to a particular class during a given

Course Descriptions

MA 451 Numerical Methods for Supercomputers 3c-01-3sh
Prerequisites: MA 121 and MA 122, or MA 123 or MA 127, MA 171, CO 250
Supercomputers make use of special computer architectures— vector and parallel processors—in order to achieve the fastest processing speed currently available. Students will be introduced to these features and will learn how numerical algorithms can be constructed to exploit supercomputers' capabilities. Students will gain practical experience in programming for the Cray YMP, in incorporating existing scientific software packages into user-written programs, in submitting remote jobs to the Pittsburgh Supercomputer Center, and in producing animated graphical output to summarize the typically large volume of output data generated by large scientific programs.

CO 451 Numerical Methods for Supercomputers 3c-01-3sh
Prerequisites: MA 121 and MA 122, or MA 123 or MA 127, MA 171, CO 250
Supercomputers make use of special computer architectures— vector and parallel processors—in order to achieve the fastest processing speed currently available. Students will be introduced to these features and will learn how numerical algorithms can be constructed to exploit supercomputers' capabilities. Students will gain practical experience in programming for the Cray YMP, in incorporating existing scientific software packages into user-written programs, in submitting remote jobs to the Pittsburgh Supercomputer Center, and in producing animated graphical output to summarize the typically large volume of output data generated by large scientific programs.

MA 551 Numerical Methods for Supercomputers 3c-01-3sh
Prerequisites: MA 121 and MA 122, or MA 123 or MA 127, MA 171, CO 250
Supercomputers make use of special computer architectures— vector and parallel processors—in order to achieve the fastest processing speed currently available. Students will be introduced to these features and will learn how numerical algorithms can be constructed to exploit supercomputers' capabilities. Students will gain practical experience in programming for the Cray YMP, in incorporating existing scientific software packages into user-written programs, in submitting remote jobs to the Pittsburgh Supercomputer Center, and in producing animated graphical output to summarize the typically large volume of output data generated by large scientific programs.

Course Syllabus

Course Objectives:
Students will
- understand the principles of vector and parallel computer architecture,
- submit jobs to remote computers,
- be able to optimize programs for vector and parallel computers,
- learn commonly used numerical methods for vector and parallel computers, and
- create computer-generated animations.

Outline:
1. Philosophy of Vector and Parallel computing (1 hour)
   A. Definition of supercomputer
   B. Introductory definition of vector and parallel computers
   C. Use of Graphics for I/O
2. Introduction to Cray/UNICOS (1 hour)
   A. Explanation of a sample batch file
   B. Introduction to Cray reference manuals
   C. Submitting remote jobs
3. Cray Architecture (3 hours)
   A. Pipelining
   B. Multiple functional units
   C. Vector operations
   D. Vector stride
   E. Chaining
   F. Memory banks and memory conflicts
4. Speedup and Amdahl's Law (1 hour)
5. Local graphics (1 hour)
6. Optimization of Fortran code (5 hours)
   A. Vectorizing loops
   B. Loops and subprograms
   C. IF statements
7. Basic Linear Algebra Subprograms (BLAS) Levels 1 and 2 (1 hour)
8. Numerical Algorithms for Vector Computers (12 hours)
   A. Integration
   B. Roots of non-linear equations
   C. Direct methods for systems of linear equations
   D. Iterative methods for systems of linear equations
9. Parallel Computers (2 hours)
   A. SIMD vs. MIMD
   B. Configurations of processors
   C. Cray architecture
10. Parallel computing (2 hours)
   A. General principles
   B. UNICOS commands
11. Basic Linear Algebra Subprograms (BLAS) Level 3 (1 hour)
12. Numerical Algorithms for Parallel Computers (12 hours)
   A. Integration
   B. Roots of non-linear equations
   C. Direct methods for systems of linear equations
   D. Iterative methods for systems of linear equations

Suggested Evaluation Methods:

Computer programs, including animations	40%
Tests	30%
Final exam	30%

Other types of evaluations may be included at the instructor's discretion.

Required Textbook(s):
Golub, G., and J. Ortega, *Scientific Computing: an introduction with parallel programming*, Academic Press, 1993.

Resource Requirements:
There are no special materials required of the student.

Bibliography:

Levesque, John M., and Joel Williamson, *A Guidebook to Fortran on Supercomputers*, Academic Press, 1989.

An introduction to supercomputer architectures (requires a basic knowledge of architecture terms), writing Fortran code for vector processors.

Brawer, Steven, *Introduction to Parallel Programming*, Academic Press, 1989.

Basic description of parallel architectures, principles for parallel programming with examples given in Fortran, some applications, parallel C under Unix.

Krishnamurthy, E. V., *Parallel Processing: Principles and Practice*, Addison-Wesley Publishing Co., 1989.

Somewhat advanced. Theoretical introduction to parallel processes (requires some knowledge of computer architecture and programming languages), principles of parallel programming, applications to databases.

Akl, Selim G., *The Design and Analysis of Parallel Algorithms*, Prentice-Hall, 1989.

Requires some knowledge of the analysis of algorithms. Types of parallel computers, many applications—searching, sorting, numerical methods, operations research.

Bertsekas, Dimitri P., and John N. Tsitsiklis, *Parallel and Distributed Computation: Numerical Methods*, Prentice-Hall, 1989.

Somewhat advanced. Introduction to parallel processes; synchronous and asynchronous algorithms for numerical methods and operations research.

K. A. Galligan, Heath, Ng, Ortega, Peyton, Plemmons, Romine, Sameh, and Voigt, *Parallel Algorithms for Matrix Computations*, SIAM, 1990.

Advanced. Parallel algorithms for dense linear systems and sparse linear systems, extensive bibliography of 2016 references.

Dongarra, Jack J., Iain S. Duff, Danny Sorensen, and Henk A. Van der Vorst, *Solving Linear Systems on Vector and Shared Memory Computers*, SIAM, 1991.

Somewhat advanced. Introduction to vector and parallel processing, good descriptions of currently available vector and parallel computers, Basic Linear Algebra Subprograms (BLAS), dense and sparse linear systems, direct and iterative methods.

Gear, C. W., and R. G. Voigt, eds., *Selected Papers from the Second Conference on Parallel Processing for Scientific Computing*, SIAM, 1987.

Advanced. A collection of research papers, mostly on numerical methods, some on design of parallel algorithms in general.

Ortega, James M., and Robert G. Voigt, *Solution of Partial Differential Equations on Vector and Parallel Computers*, SIAM, 1985.

Advanced. In spite of its title, it is mostly about types of vector and parallel computers and direct and iterative methods for solving systems of linear equations. Extensive bibliography.

Course Analysis Questionnaire

Section A: Details of the course

A1. The academic need fulfilled by this course is to expose students to advanced computing technology involving parallel processing in supercomputers. Parallel computers are gaining importance in certain application areas, including differential equations and artificial intelligence. The clientele for which the course is designed include mathematics, applied mathematics, and computer science majors. Majors in the natural sciences may also be interested in taking this course. This course is not being proposed as part of the Liberal Studies program.

A2. This course does not require changes in the content of existing courses.

A3. Much of the course follows the traditional type of offering by the Mathematics Department. However, the course will be computer intensive and will use work stations at IUP which are linked to the Pittsburgh Supercomputer Center. This Center and the National Science Foundation are giving students free access to their computers and support staff for completing course work.

A4. This course has been offered as MA 481 Special Topics and CO 481 Special Topics during the spring semesters of 1991, 1992, and 1993. DEC workstations were purchased with an ILI grant from the NSF and access to the Pittsburgh Supercomputer Center is available on an on-going basis. Enrollment has been approximately ten, eight, and eighteen in the three offerings of the course.

A5. This course has been offered as a dual level special topics course for three years and it is intended to be proposed as a dual level course. The proposal has been presented to the Graduate Committee of the Senate as MA 551.

A6. This course will not be available for variable credit.

A7. Many Ph.D. granting institutions offer graduate level courses on high performance computing. Higher education institutions are beginning to offer similar courses at the undergraduate level, but these are still uncommon.

A8. The content of the proposed course is not specifically recommended or required by a professional society, accrediting authority, law or other external agency at this time. The content of this course cannot be incorporated into an existing course since no courses at IUP are taught using parallel computers. In order to meet the needs of the scientific community, computer manufacturers have produced vector and parallel computers. These new architectures require new algorithms, many of which make novel use of results from linear algebra and differential equations. Many of our students will be using one or both types of architectures in the future, and they need to become aware of the associated mathematical and technical difficulties.

Section B: Interdisciplinary Implications

B1. This course will be taught by one instructor. However, it is being proposed as a course which will be dual listed by the Mathematics Department and the Computer Science Department. It will be taught each spring semester, and the two departments will alternate the assignment of the instructor.

B2. Additional or corollary courses are not needed with this course now and are not anticipated later.

B3. The Computer Science Department offers CO 250 Introduction to Numerical Methods and CO 450 Applied Numerical Methods. These courses are taught using traditional algorithms and traditional computers. The Mathematics Department and the

Computer Science Department are jointly proposing this course, with the intention of dual listing it and alternating the assignment of the instructor of the course.

B4. Seats will be available to qualified students in the School of Continuing Education.

Section C: Implementation

C1. Resources needed to teach this course are already in place. The course has been offered as a dual listed, dual level course for the past three spring semesters (MA 481/MA 581/CO 481). Thus no change in the pattern of course offerings or instructor workloads will be needed. DEC work stations were purchased through an ILI grant of the NSF and are housed in 219 Stright Hall. The Pittsburgh Computer Center is granting supercomputer access for this course on an on-going basis. No laboratory supplies or other consumable goods are required for this course, nor are library materials required. Travel funds will be allocated to the instructor of this course in the routine manner through which such funds are available to any faculty member.

The following resources will be provided free of charge by the Pittsburgh Supercomputer Center (PSC): Student accounts on the PSC Cray YMP and VAXes, faculty preparation account on the PSC's Cray YMP and VAXes, VCR animated graphics generator, graphics routine GPLOT, and CRAY manuals. IUP will need to provide student accounts on the DEC stations and on the VAX. Several VCR tapes will also be required.

C2. This course requires three types of resources: local computers to display computer animations, student accounts on remote supercomputers, and network connections to communicate between the local and remote computers. The initial resources for displaying computer animations were funded by an NSF grant; however, as computers increase in power and decrease in price, upgrades are now becoming affordable in ordinary departmental expenditures. Most supercomputer sites across the country offer free student accounts for courses. This is being driven by the NSF requirement that sites funded by this agency must provide outreach programs to educational institutions. IUP has established and will continue to maintain a network connection to the Internet, giving students access to remote supercomputers.

C3. This course will be offered each spring semester and staffed in alternate years by faculty of the Mathematics Department faculty of the Computer Science Department. It is not designed to be restricted to seasonal semesters.

C4. One section will be offered each spring semester, listed as MA 451/MA 551/CO 451.

C5. Approximately twenty students can be accommodated in this course. There are five DECstations available in 219 Stright Hall through which the students can connect to the Pittsburgh Supercomputer Center. The enrollment in the class is limited by the number of DECstations available.

C6. No professional society recommends enrollment limits or parameters for a course of this nature.

C7. This course will not be a curriculum requirement. It will be an elective for the B.S. in Applied Mathematics and the B.S. in Mathematics, a mathematics content course for the M.S. in Mathematics, and a computer science elective for the B.S. in Computer Science.

Section D: Miscellaneous

Appendix: Graduate Student Experiences

Graduate students in MA 551 will be given special assignments in addition to those completed by all students in MA 451/CO 451/ MA 551. These may consist of programming assignments, theoretical homework assignments, and reports or presentations on reading assignments. Since Numerical Methods for Supercomputers is taught as a graduate course at many schools, there is a rich source of materials for students at this level (see the bibliography).

Suggested Evaluation Methods:

Graduate assignments	15%
Computer programs, including animations	25%
Tests	30%
Final exam	30%

Other types of evaluations may be include at the instructor's discretion.