Proposal for a Ph.D. Program in Computational Social Science

presented by

The Center for Social Complexity

in collaboration with

The College of Arts and Sciences,
The School of Computational Sciences,
The School of Information Technology and Engineering
and The Krasnow Institute for Advanced Study

George Mason University

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SUMMARY

The Center for Social Complexity, in collaboration with the College of Arts and Sciences (CAS), the School of Computational Sciences (SCS), the School of Information Technology and Engineering (ITE), and the Krasnow Institute for Advanced Study (KIAS) at George Mason University, proposes a new Ph.D. program in Computational Social Science—the new science of complex social systems and their investigation through computational models and related tools. The proposed Ph.D. program builds upon foundations already established by the new graduate courses in Computational Social Science, the new Certificate that GMU now offers in this field, and enhances interdisciplinary collaboration among faculty and students. Computational Social Science is a new and exciting frontier at the intersection of the social sciences, computational sciences, and complex adaptive systems. George Mason University is known for having a distinguished and extensive group of faculty and researchers with an active interest in computational social science, distributed throughout the main divisions of the University; primarily but not exclusively in CAS, SCS, ITE, and KIAS. This program proposed by the Center for Social Complexity is meant to nucleate faculty and students with the common purpose of providing advanced graduate training leading toward a Ph.D. The proposed curriculum includes a common core as well as elective coursework and interdisciplinary opportunities for joint faculty-student research projects. An important goal is also to enhance the University’s extramurally funded research. Unique features include exposure to interdisciplinary learning, information technologies, and international collaboration with comparable groups of computational social science in Europe, Asia, and Latin America. This new program contributes to George Mason University and to the Commonwealth of Virginia by consolidating and expanding our position on the frontiers of interdisciplinary science, ensuring a leadership position in this emerging field of 21st century higher education.
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1. BACKGROUND:

COMPUTATIONAL SOCIAL SCIENCE AT GMU

The field of computational social science has foundations in the pioneering work of Herbert A. Simon, Noam Chomsky, James March, Karl W. Deutsch, Jay Forrester, Lawrence R. Klein, Harold Guetzkow, and Thomas Schelling, as well as more recent contributions by Robert Axelrod, Robert Axtell, Kathleen Carley, Joshua Epstein, and others from a growing international scholarly community in North America, Europe, and Asia.1 Computational social scientists use a variety of computer models to investigate the nature of social systems and processes at many scales, such as human decision-making, group dynamics and social networks, complex organizations, and world systems. Examples of complex social processes investigated by computational social scientists include terrorism and conflict, bargaining and negotiations, urban transportation, cultural change, and market dynamics, among others. Nationally, the main professional association in this fledging field is the North American Association for Computational Social and Organizational Sciences (NAACSOS). The European Union counterparts are the European Social Simulation Association (ESSA) and the EU’s Network of Excellence on Complex Systems. A world federation is planned for 2005.

Active GMU interest in this new field began over a decade ago. In 1989 Herbert A. Simon participated in the founding conference of our Krasnow Institute for Advanced Study, co-sponsored with the Santa Fe Institute (alma mater of the science of complexity). Soon thereafter a group of GMU faculty members from virtually all of the main divisions of the University (CAS, SCS, ITE, SPP) began to interact with the Provost in what eventually would become a Faculty Committee on Computational Social Science. In 2002, following an international search, Professor Claudio Cioffi-Revilla was recruited as the first Director of the Center for Social Complexity for the purpose of leading GMU’s Initiative in Computational Social Science. The Center for Social Complexity held its inaugural conference in May 2003, with members of the National Academy of Sciences and other leading figures invited as guest speakers. Already in its first year the fledging Center for Social Complexity was recognized as the first non-European group in this field to be named an Institutional Member of the European Union’s Network of Excellence in Complex Systems Research. The Center plays an active leadership role in national and international networks (such as NAACSOS and ESSA, respectively), as well as in regional venues, such as the Washington Academy of Sciences.

Within this relatively short period, interest in GMU computational social science has surged:

- more than fifty faculty members identify themselves as affiliated with the Center for Social Complexity and CSS (see Appendix I);

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1 For purposes of this proposal, the following disciplines constitute the social sciences: anthropology, economics, geography, history, linguistics, political science, and sociology. History is included because a large area of research and teaching in computational social science is aimed at the replication of historical systems and processes through computer-based simulations.
• several research grant proposals have been submitted to the National Science Foundation, the Alexander von Humboldt Foundation, and other extramural sources, in support of CSS projects, including graduate student financial support (others are in preparation);

• a new graduate Certificate in CSS has been created and the first students have begun to enroll;

• new courses in CSS have been created and are now offered regularly and predictably to full-time as well as part-time students;

• a new computer simulation tool for students and faculty has been developed (called “MASON” = Multi-Agent Simulator Of Networks and Neighborhoods), in collaboration with GMU’s Department of Computer Science (Professor Sean Luke and his students);

• the flow of outside inquiries about our CSS initiative, from academic, government and business interests, is high and increasing;

• attendance by faculty and students at the monthly Seminar/Colloquium Series, hosted by the Krasnow Institute, is in strong and encouraging;

• external distinguished faculty members (e.g., Robert Axtell) have joined this new program with enthusiasm and some have been hired as adjunct faculty while new faculty lines become available;

• several theses and potential dissertation projects in CSS are already underway.

In the Fall of 2005 the Center for Social Complexity will relocate to occupy new space for faculty and students in the Research I Building of the Fairfax campus of GMU. This will provide the proposed Ph.D. Program in Computational Social Science with a uniquely advanced, state-of-the art facility. Graduate students in the proposed Ph.D. program will be exposed to a world-class research and training environment in this field.

The computational social science faculty at GMU is rostered in many different departments but is integrated by a uniquely strong common interest in models of social complexity, both theoretical and applied. Political science, computer science, cognitive science, geography, economics, anthropology, statistics, and sociology are among the traditional disciplines represented, with interdisciplinary collaborations that cover such broad areas as network dynamics, multi-agent systems, emergence of cooperation and collective action. These collaborations form a basis for external research collaborations with other universities, state and federal agencies, and private foundations.

The growing prestige and strategic location of George Mason University provide an advantageous and promising setting for the proposed doctoral program in Computational Social Science. Using the leadership of GMU’s new Center for Social Complexity, the Deans of the College of Arts and Sciences and the School of Computational Sciences,
and the Director of the Krasnow Institute for Advanced Study, recognize the value of this new interdisciplinary doctoral program to students and faculty, its strong consistency with the Mission of GMU in terms of focused interdisciplinarity and strong IT-orientation, and are enthusiastic in their support. The School of Information Technology and Engineering, the School of Public Policy, the Mercatus Center, and the Institute for Conflict Analysis and Resolution have also expressed interest in GMU’s Initiative in Computational Social Science and many of their faculty members and students actively participate in the activities of the Center for Social Complexity.

The core objective of the proposed Ph.D. program in Computational Social Science is to train graduate students to be professional computational social scientists in academia, government or business. Our program offers students a unique and innovative interdisciplinary academic environment for systematically exploring, discovering, and developing their skills to successfully follow careers in one of the areas of computational social science. The proposed Ph.D. program will also enrich the research environment for present and future faculty.
2. ACADEMIC ELEMENTS OF THE PROGRAM

2.1. Course of Study and Requirements

2.1.1 Expected entry-level background. The course of study and requirements are tuned to entry-level expectations and desired learning outcomes. Most students entering the program will come with one of two undergraduate backgrounds: (1) computation (computer science, programming, artificial intelligence, simulation, software engineering) and hence require greater training in one of the social sciences; or (2) one of the social sciences (anthropology, economics, geography, history, linguistics, political science, sociology), in which case additional training in computation will be required. (In the initial years students entering the program are not expected to have undergraduate background in computational social science as such, expect for rare cases. However, this assumption will be re-examined after a few years, as computational social science permeates undergraduate instruction.) Students already in possession of a Master’s degree relevant for computational social science are also expected to enter the program.

2.1.2 Requirements. The proposed curriculum requires 72 credit hours, with the following functional distribution and learning objectives:

18 credit hours of required CSS courses to provide a shared knowledge core regardless of prior background:
- CSS 600 Introduction to Computational Social Science (the “gateway” course)
- CSS 605 Object-Oriented Modeling for Social Science
- CSS 610 Computational Analysis of Social Complexity
- CSS 620 Origins of Social Complexity
- Plus two other core courses from among the following:
  - CSS 645 Spatial Agent-Based Models
  - CSS 650 Complexity Theory in the Social Sciences
  - CSS 692 Social Network Analysis

15 credit hours of discipline-based social science courses in a given area (e.g., anthropology, economics, geography, history, linguistics, political science, sociology), as approved by the student’s Advisor, to provide minimal domain-specific professional orientation.

15 credit hours of elective courses or independent research, as approved by the student’s Advisor, to provide further substantive or methodological specialization as needed.

24 credit hours of dissertation research to demonstrate doctoral-level originality and research excellence.

The 30 credit hours consisting of discipline-based social science courses, elective courses, independent research, and directed readings must be approved by the student’s Advisor and the Graduate Program Director.
Appendix II details the catalog descriptions of existing courses that may potentially count as electives, depending on a student’s intended specialization, course availability and other factors; and Appendix III contains the syllabi for new courses.

2.1.3 Credit for Prior Study. Following University rules, up to 30 credit hours of the required 48 may be waived based on prior Master’s-level training and the specific courses taken. A maximum of 24 credit hours of prior graduate coursework may be credited, provided such credits have not been used for another degree. The combined 30 credit hours of disciplinary and elective courses provide a mechanism for compensating for the diverse prior backgrounds of students (for example, computer science vs. economics). Examples: (1) a student arriving with a strong computation background (e.g., B.S. or M.S. in computer science) would use the 15 hours of electives to acquire additional social science training, in addition to the 15 hours of disciplinary social science courses; (2) conversely, a student with strong social science background (e.g., bachelor’s or master’s in economics) would use the 15 hours of electives to learn more about computational or computer science.

2.1.4 Recommended Extracurricular Activities. The following professional albeit extracurricular activities are also encouraged for advanced students: attending professional lectures and colloquia on campus and in the capital area; writing research grant proposals with faculty, with other students, or individually, especially proposals addressed to the National Science Foundation; writing and publishing in peer-refereed journals, including the most competitive disciplinary journals in the social sciences as well as the more specialized computational social science journals\(^2\); learning the art and science of excellent teaching\(^3\); presenting papers at professional conferences\(^4\). Foreign students, or American students with a writing deficiency are required to take one or more courses in ESL or in technical and scientific writing. The program director maintains a set of resources for writing and publishing in computational social science.

\(^2\) The main peer-refereed journals specialized in computational social science are: \textit{Journal of Artificial Societies and Social Simulation} (JASSS, an on-line journal), \textit{Computational and Mathematical Organization Theory} (CMOT, journal of the North American Association for Computational Social and Organizational Science, NAACSSOS), and \textit{Social Science Computer Review} (SSCR). Other peer-refereed methodology-oriented journals that publish computational social science research include: \textit{American Political Science Review}, \textit{Journal of Conflict Resolution}, \textit{Journal of Economic Behavior}, \textit{Journal of Mathematical Sociology}, \textit{Political Analysis}.

\(^3\) Students intending to pursue an academic career are strongly encouraged to take advantage of graduate teaching opportunities, including training opportunities offered by the Preparing Future Faculty Program sponsored by the Council of Graduate Schools and the Association of American Colleges and Universities. See \url{www.preparing-faculty.org}.

\(^4\) All major social science conferences (AAG, AEA, APSA, ASA, ) include one or more sessions or panels on computational social science. In addition, the following specialized conferences recur annually in North American, Europe, and Asia: Agent 2000 Workshop of the University of Chicago, Annual Conference of the North American Association for Computational Social and Organizational Science (NAACSSOS), Annual Conference of the European Social Simulation Association (ESSA), Model-to-Model (M2M) Workshop, Annual Meeting of the Association for Computational Linguistics (ACL), SIMSOC Annual Conference, and the Annual Conference of the International Social Agent and Gaming Association (ISAGA).
2.1.5 Time Required. The length of time required to complete the proposed program will vary, depending on a student’s time commitment, resources, and academic progress in the course of study (coursework, research, exams, dissertation). Assuming a student enters the program with proper undergraduate background, has focused research motivation, and full-time enrollment, the PhD could be earned in four years, assuming all academic requirements are met. Some students arriving with either a Master’s degree or with prior coursework in computational social science could take less than four years. Most students will require five or more years, depending on academic progress, funding, and other factors that are normally unpredictable. The next section provides an example based on a full-time “normal load.” A “light load” would take longer, up to the statutory limit allowed by the University (11 years). Students with the strongest research capabilities and professional potential will ordinarily be eligible for funding through extramural grants.

2.2 A Semester-by-Semester Example with a “Normal Load”

This example assumes the student has an undergraduate bachelor’s degree, no prior graduate training, and takes a normal load of 9 credit hours during each semester and 3 credit hours of independent research or directed readings during summer terms:

First Year

1st semester - Fall
   CSS 600 Introduction to Computational Social Science
   CSS 605 Object-Oriented Modeling for Social Scientists
   CSS 625 Complexity Theory on the Social Sciences

2nd semester - Spring
   CSS 610 Computational Analysis of Social Complexity
   CSS 645 Spatial Agent-Based Models
   CSS 692 Social Network Analysis
   This pattern satisfies all the core requirements by the end of 2nd semester
   Pass qualifying exam by end of 2nd semester by presenting a research paper

Summer
   Take 3 credit hours of independent study (27 credit hours of coursework remaining)

Second Year

3rd semester - Fall
   9 credit hours of social science or electives (18 credit hours of coursework remaining):
   ANTH 580 Evolution and Human Ecology
   ECON 611 Microeconomic Theory
   CSS 620 Origins of Social Complexity

4th semester - Spring
9 credit hours of social science or electives (9 credit hours of coursework remaining)
   ECON 895 Computational Economics
   ECON 880 Austrian Theory of the Market Process I
   GEOG 531/CSS 643 Land-Use Modeling Techniques and Applications

Summer
   Take 3 credit hours of independent study (6 credit hours of coursework remaining)
   Study for doctoral exams in Fall, 5\textsuperscript{th} semester

Third Year

5\textsuperscript{th} semester – Fall
   Take doctoral Candidacy exam. Become a doctoral candidate.
   Last 6 credit hours of social science, electives, or independent research
   CSI 606 Scientific Graphics and Visualization Tools
   CSS 800 Independent Study (e.g., Computational Statistical Data Analysis)
   First 3 credit hours of dissertation research (21 remaining): prepare proposal

6\textsuperscript{th} semester - Spring
   Defend dissertation proposal. ABD (all-but-dissertation) status. Start the dissertation project.
   9 credit hours of dissertation research (15 dissertation hours remaining)

Summer
   3 credit hours of dissertation research (12 dissertation hours remaining)

Fourth Year

7\textsuperscript{th} semester – Fall (student may start applying for a job for next summer or fall)
   6 credit hours of dissertation research (6 remaining)

8\textsuperscript{th} semester - Spring
   last 6 credit hours of dissertation research
   Dissertation defense
   Graduation, Ph. D. degree conferred

A somewhat heavier load or transferring prior graduate training or degrees could yield an earlier graduation, for example in December of the fourth year or sooner, so the student could in fact apply for a position during the Third Year. As noted earlier, however, most students will probably take five or more years, depending on numerous imponderable factors.

2.3 Non-Core Courses Available: Existing Discipline-Based and Other Potential Electives
The purpose of non-core courses in the proposed CSS Program (i.e., the 30 credit hours of courses that are discipline-based or other courses taken as electives) is to allow students to acquire a substantive specialization in a given area. Therefore, a large pool of potential courses is necessary, given the broad spectrum of social science phenomena and methodologies. Such a broad spectrum, both substantive and methodological, is reflected in the variety of academic units that offer potentially elective courses for computational social science. Note that in some instances the specialization may also have a strong methodological component, as is the case for GIS-supported agent-based social simulation modeling and other CSS specializations with strong methodological content.

The following existing courses, grouped by the corresponding sponsoring College or School, may be taken as electives, depending on a student's specialization in Computational Social Science. This list is not exhaustive; other courses may also be appropriate, as determined in each case. Catalog descriptions of the following courses are given in Appendix II. Special graduate courses offered by other universities and not available at GMU may also be approved for credit.

2.3.1 From the College of Arts and Sciences:

**Administration of Justice:**
ADJ upper-division courses by special permission (e.g. ADJ 475 Theory and Politics of Terrorism)

**Anthropology:**
ANTH 568 Human Origins
ANTH 580 Evolution and Human Ecology
ANTH 631 Refugees in the Contemporary World
ANTH 670 Regional Studies in Archaeology
ANTH 680 Readings in Archaeology
ANTH 684 Readings in Cultural Anthropology

**Biodefense:**
BIOD 601 Foundations of Biodefense Science and Technology
BIOD 708 Epidemiology of a Bioterror Attack
BIOD 709 Nonproliferation in Biodefense
BIOD 721 Coordinated Response to a Bioterror Attack
BIOD 722 Examining Terrorist Groups
BIOD 724 Incident Response Information Technology
BIOD 742 Modern Geographic Techniques in Detection as Tracking
BIOD 761 Dispersal Patterns of Biological Agents
BIOD 762 Into the Hot Zone: Working in a High Threat Environment

**Communication:**
COMM 602 Theories and Research of Mass Communication
COMM 605 Intercultural Communication
COMM 631 Approaches to Group Facilitation
COMM 634 Theories of Interpersonal Communication
COMM 635 Organizational Communication

Economics:
ECON 611 Microeconomic Theory
ECON 615 Macroeconomic Theory
ECON 623 American Economic History
ECON 632 Economic Systems Design - Principles and Experiments
ECON 676 Comparative Economic Systems
ECON 715 Macroeconomic Theory I
ECON 812 Microeconomic Theory II
ECON 816 Macroeconomic Theory II
ECON 817 Monetary Theory and Policy
ECON 825 Political Economy and Public Policy I
ECON 826 Political Economy and Public Policy II
ECON 828 Constitutional Economics
ECON 829 Economics of Institutions
ECON 842 Labor Economics
ECON 844 Industrial Organization and Public Policy I
ECON 846 Industrial Organization and Public Policy II
ECON 849 Public Finance
ECON 856 Urban and Regional Economics
ECON 861 Economics of the Environment
ECON 866 Economic Development
ECON 869 International Trade and Policy
ECON 871 International Monetary Economics
ECON 880 Austrian Theory of the Market Process I
ECON 881 Austrian Theory of the Market Process II
ECON 885 Experimental Economics
ECON 886 Economic Systems Design

Environmental Science and Public Policy:
EVPP 607 Fundamentals of Ecology
EVPP 637 Human Dimensions of Global Change
EVPP 638 Corporate Environmental Management and Policy
EVPP 641 Environmental Science and Public Policy
EVPP 648 Population Ecology
EVPP 650 Environmental Analysis and Modeling
EVPP 670 Environmental Law
EVPP 675 Environmental Planning and Administration

Geography:
GEOG 531/EVPP Land-Use Modeling Techniques and Applications
GEOG 631/EVPP Spatial Agent-Based Models of Human-Environment Interactions
GEOG 653 Geographic Information Analysis
GEOG 664 Spatial Data Structures
GEOG 795 Seminar in Regional Analysis

Government:
GOVT 605 Seminar in Congress and the Presidency
GOVT 606 Federalism and Changing Patterns of Governance
GOVT 631 Seminar in Comparative Politics and Institutions
GOVT 641 Seminar in Global Systems
GOVT 703 Seminar in the Courts and Constitutional Law
GOVT 725 Democratic Theory and Democratization
GOVT 731 Advanced Seminar in Comparative Politics
GOVT 741 Advanced Seminar in International Politics
GOVT 743 International Political Economy
GOVT 745 Issues in International Security

History:
HIST 601 Themes in U.S. History I
HIST 602 Themes in U.S. History II
HIST 605 Themes in European History I
HIST 606 Themes in European History II
HIST 610 The Study and Writing of History
HIST 613 The Colonial Origins of American Society
HIST 615 Problems in American History
HIST 616 U.S. Westward Movement
HIST 617 Topics in the American Civil War Era
HIST 618 The Age of Jackson, 1815-1854
HIST 619 The Constitution, Civil Liberties, and the Supreme Court
HIST 620 Development of the Early Republic, 1783-1815
HIST 621 Virginia and the American Revolution
HIST 623 Recent U.S. History, 1945 to Present
HIST 624 U.S. Diplomatic History
HIST 627 Urban Development of the United States
HIST 628 Immigration and Ethnicity in the United States
HIST 629 The Gilded Age and Progressive Era
HIST 630 U.S. Women's History
HIST 631 Era of the American Revolution
HIST 633 Reconstruction
HIST 711 Research Seminar in U.S. History
HIST 731 Research Seminar in European History
HIST 751 Research Seminar in Comparative World History

Mathematics:
MATH 653 Risk Theory
MATH 654 Survival Models and Construction of Tables
MATH 671 Fourier Analysis
MATH 672 Wavelet Theory
MATH 673 Dynamical Systems
MATH 674 Stochastic Differential Equations

Philosophy:
PHI 520 Current Issues in Philosophy of Science
PHI 560 Philosophical Foundations of Science
PHIL 621 Philosophy of Science

Public Administration:
PUAD 502 Administration in Public and Nonprofit Organizations
PUAD 504 Managing in the International Arena: Theory and Practice
PUAD 509 Justice Organizations and Processes
PUAD 510 Policing in a Democratic Society
PUAD 615 Administrative Law
PUAD 620 Organization Theory and Management Behavior
PUAD 621 Principles and Practices in Government Organization and Management
PUAD 622 Program Planning and Implementation
PUAD 634 Management of International Security
PUAD 640 Public Policy Process
PUAD 643 Public Policy Research
PUAD 644 Public Policy Models
PUAD 651 Virginia Politics, Policy, and Administration
PUAD 661 Public Budgeting Systems
PUAD 670 Human Resources Management in the Public Sector
PUAD 671 Public Employee Labor Relations
PUAD 680 Managing Information Resources
PUAD 691 Justice Program Planning and Implementation
PUAD 720 Performance Measurement
PUAD 727 Seminar in Risk Assessment and Decision Making
PUAD 729 Issues in Public Management
PUAD 732 Managing Technology Transfer
PUAD 738 Issues in International Security
PUAD 742 Program Evaluation
PUAD 749 Issues in Public Policy
PUAD 750 Federalism and Changing Patterns of Governance
PUAD 759 Issues in Local Government Administration
PUAD 769 Issues in Public Financial Management
PUAD 781 Information Management: Technology and Policy
PUAD 791 Justice Program Evaluation
PUAD 799 Issues in Justice Administration
PUAD 821 Doctoral Seminar in Theories of Organization and Bureaucracy
PUAD 840/PUBP 840 Research Seminar in Policy Governance I
PUAD 841/PUBP 841 Research Seminar in Policy Governance II

Sociology:
SOCI 523 Racial and Ethnic Relations: American and Selected Global Perspectives
SOCI 590 Gender, Race, and the Natural World
SOCl 599/NURS 611 Issues in Sociology
SOCl 607 Criminology
SOCl 608 Juvenile Delinquency
SOCl 609 Sociology of Punishment and Corrections
SOCl 611 Classical Sociological Theory
SOCl 612 Contemporary Sociological Theory
SOCl 614 Sociology of Culture
SOCl 619 Conflict and Conflict Management: Perspectives from Sociology
SOCl 635 Environment and Society
SOCl 640 Social Theory and Social Policy
SOCl 650 Issues in the Sociology of Health, Illness, and Disability
SOCl 651 (551) Health Care Systems
SOCl 660/860 Historical and Comparative Sociology
SOCl 686 Sociology of Aging
SOCl 692 Complex and Alternative Organizations

Telecommunications:
TELE 730 Telecommunications Management
TELE 750 Coordinating Seminar

2.3.2 From the School of Computational Sciences:

CSI 600/SYST 500 Quantitative Foundations for Systems Engineering
CSI 603 Introduction to Scientific Programming I
CSI 604 Introduction to Scientific Programming II
CSI 606 Scientific Graphics and Visualization Tools
CSI 607 Database Tools for Scientists
CSI 610 Introduction to Computational Sciences
CSI 639 Ethics in Scientific Research
CSI 660/ASTR 535 Space Instrumentation and Exploration
CSI 672/STAT 652 Statistical Inference
CSI 678/STAT 658 Times Series Analysis and Forecasting
CSI 702 High-Performance Computing
CSI 703 Scientific and Statistical Visualization
CSI 709 Topics in Computational Sciences and Informatics
CSI 710 Scientific Databases
CSI 735 Computational Neuroscience Systems
CSI 750 Earth Systems and Global Changes
CSI 758 Visualization and Modeling of Complex Systems
CSI 759 Topics in Earth Systems and Global Changes
CSI 771/STAT 751 Computational Statistics

2.3.3 From the School of Information Technology and Engineering:

Civil and Infrastructure Engineering:
CEIE 560 Public Transportation Systems
CEIE 561 Traffic Engineering
CEIE 562 Urban Transportation Planning
CEIE 600 Civil Engineering Infrastructure Planning and Management
CEIE 601 Infrastructure Modeling
CEIE 605 Infrastructure Systems Analysis

Computer Science:
CS 580 Introduction to Artificial Intelligence
CS 583 Analysis of Algorithms
CS 631 Object-Oriented Design Patterns
CS 635 Foundations of Parallel Computation
CS 652 Computer Graphics
CS 680 Natural Language Processing
CS 681 Designing Expert Systems
CS 685/ECE 651/SYST 672 Intelligent Systems
CS 687 Advanced Artificial Intelligence
CS 688 Neural Network Principles
CS 699 Evolutionary Computation
CS 777 Human-Computer Intelligent Interaction
CS 782 Machine Learning
CS 785 Knowledge Acquisition and Problem Solving

Information Technology:
IT 557 Introduction to Network Science
IT 657 Advanced Network Science
IT 811 Principles of Machine Learning and Inference
IT 812 Advanced Topics in Natural Language Processing
IT 842 Models of Probabilistic Reasoning
IT 852 Graphical Real-Time Simulation
IT 858 Logic Models in Artificial Intelligence
IT 860 Software Analysis and Design of Real-Time Systems
IT 861 Distributed Database Management Systems
IT 862 Computer Security Models and Architectures
IT 870 Organizational Informatics
IT 886/ECE 751 Information Theory
IT 890 Special Topics in Urban Transportation
IT 891 Special Topics in Applications of IT to Urban Systems Engineering
IT 894 Design and Inventive Engineering
IT 910 Advanced Topics in Artificial Intelligence
IT 915 Advanced Topics in Parallel Computation
IT 922 Concurrent Object-Oriented Systems
IT 941 System Identification and Adaptive Control
IT 944 The Process of Discovery and Its Enhancement in Engineering Applications
IT 950 Design and Management Aspects of Information Systems
IT 958 Basic and Applied Decision Support Systems Technology
Operations Research:
OR 635 Discrete System Simulation
OR 640 Global Optimization and Computational Intelligence
OR 643/SYST 521 Network Modeling
OR 675/STAT 678/SYST 675 Reliability Analysis
OR 681/SYST 573 Decision and Risk Analysis
OR 683 Principles of Command, Control, Communications, and Intelligence
OR 690 Optimization of Supply Chains
OR 719/STAT 719/CSI 775 Computational Models of Probabilistic Reasoning

Systems Engineering:
SYST 520 System Design and Integration
SYST 573 Decision and Risk Analysis
SYST 611 System Methodology and Modeling
SYST 621 Systems Architecture for Large-Scale Systems
SYST 680/ECE 670/OR 683 Principles of Command, Control, Communications, and Intelligence (C^3I)
SYST 683 Modeling, Simulation, and Gaming
SYST 684 Sensor Data Fusion
SYST 685 Estimation and Tracking: Principles and Techniques
SYST 781/INFS 781 Data Mining and Knowledge Discovery

Other selected courses offered by the School of Management, the School of Public Policy, or the Institute for Conflict Analysis and Resolution may also qualify as electives, depending on review of the syllabus and approval by the student’s Advisor and CSS Graduate Studies Director.

2.3.4 Non-core Courses from the Consortium of Universities of the Washington Metropolitan Area. Elective courses may also originate from the cross-registration mechanism offered by the Consortium of Universities of the Washington Metropolitan Area (CUWMA), comprising eleven other universities in the metropolitan area of the District of Columbia, in case a specifically necessary course is required for a student’s specialization. As with all non-core courses, CUWMA courses must be approved by the student’s Advisor and the CSS Graduate Studies Director.

2.4 Proposed New Courses

2.4.1 Fixed-content courses. The following new fixed-content courses are proposed in order to complete the necessary core and to make several key electives available (see Appendix III for syllabi). Not all courses will be initiated at the same time. Rather, they will be introduced as the problem evolves and student interest develops. Courses that help satisfy core requirements (marked with an asterisk *) will be introduced first, starting in AY 2005-06.
*CSS 605 Object-Oriented Modeling in Social Science (3:3:0) Prerequisite or co-requisite: CSS 600 or approval by instructor and program director. Presents and applies concepts and principles from the object-based modeling paradigm. Emphasis on the Unified Modeling Language (UML) as a tool for rendering the structure and operation of complex social systems and processes.

*CSS 625 Complexity Theory in the Social Sciences (3:3:0) Prerequisite: CSS 600. Examines social phenomena like language, terrorism, the internet, warfare, and wealth, that is based on power laws and far-from-equilibrium nonlinear dynamics. Emphasis on data analysis, modeling and interpreting complexity-theoretic dynamics.

CSS 630 Comparative Computational Social Science (3:3:0) Prerequisite: CSS 600. Application of the comparative method for analyzing different types of computational models in the social sciences. Strong cross-domain and interdisciplinary emphasis, akin to comparative economic systems, comparative government, or comparative linguistics.

CSS 635 Cognitive Foundations of Computational Social Science (3:3:0) Prerequisite: CSS 600, CSS 610 or permission of instructor. Examines cognitive foundations and information processing in computational social agents and compares to comparable human cognitive phenomena, including emotions, trust, reciprocity. Emphasis on modeling project.

CSS 640 Human and Social Evolutionary Complexity (3:3:0) Prerequisite: CSS 600, CSS 620, and permission of instructor. Examines the long-term evolution of human and societal complexity from a global, cross-cultural perspective, with an emphasis on computational aspects leading towards today’s globalization. Global history from the computational social science perspective.

CSS 650 Physics Methods for Analyzing Social Complexity (3:3:0) Prerequisite: CSS 600 and permission of instructor. Survey of complexity-theoretic tools including strange attractors, Ising models, correlation functions, ergodic theory, power spectra, meanfield theory, renormalization group. Emphasis on application to social, economic, or political systems.

CSS 655 Social Systems Dynamics (3:3:0) Prerequisite: CSS 600. Introduction to systems dynamics modeling of social systems governed by levels/rates or stocks/flows processes, with applications such global modeling, terrorism, urban dynamics, organizations, social and international conflict.

CSS 660 Computational Social Science of Spacefaring Civilization (3:3:0) Prerequisite: CSS 600, 610 and permission of instructor. Focus on goals, resources, history and modeling issues concerning human and social dimensions of the space program using CSS. Design and development of socially viable human communities in extreme environments.
CSS 665 Validation and Testing in Computational Social Models (3:3:0)  
*Prerequisite: CSS 600, CSS 610.* Examines empirically-related issues and testing methods for agent-based and other computational social science models, such as estimation, calibration, cross-implementation, replication and forecasting.

CSS 670 Philosophy of Computational Social Science (3:3:0) *Prerequisites: CSS 600 and core CSS courses.* Examines the epistemology of computational social science in terms of validity, criteria of progress, and research programs. Compares classic positivist standards with actual practice in the emerging computational social sciences.

CSS 675 Finite Event Analysis of Social Complexity (3:3:0) *Prerequisites: CSS 600 and permission of instructor.* Probabilistic and behavioral concepts, principles and models for analyzing complexity in social systems and processes. Emphasis on model-building from qualitative information.

CSS 680 Computational Linguistics (3:3:0) *Prerequisites: CSS 600 and permission of instructor.* Knowledge-based and data-drive models of language and psycholinguistic phenomena; speech recognition systems, synthesizers, parsing, automation, search engines, statistical natural language processing.

CSS 685 Computational Anthropology(3:3:0) *Prerequisites: CSS 600.* Computational models of ancient and modern societies from an anthropological perspective, from the ancient Assyrian Empire of Mesopotamia or the Anasazi of the American Southwest, to contemporary globalization. Adaptation and culture change are emergent phenomena in anthropological agent-based simulations.

CSS 690 Computational Sociology (3:3:0) *Prerequisites: CSS 600.* Survey of sociological models including urban segregation, collective action, and an introduction to social networks. Sociological theory and computational methods, including situation theory.

CSS 691 Computational Politics (3:3:0) *Prerequisites: CSS 600.* Computational modeling of political systems and processes, including systems of government, nationalism, elections, political institutions, war and peace, emergence of norms, political economy.

*CSS 692 Social Network Analysis (3:3:0) *Prerequisite: CSS 600.* Methods and applications that examine complex social systems based on relations, structures, connectivity, matrix representations, location, roles, interactions and other network properties. Applications to terrorism, cognition, organizations, and other social phenomena.

CSS 695 Agent-Based Computational Economics (3:3:0) *Prerequisites: CSS 600.* Survey of agent-based models in economics, covering trade and exchange, inequality and wealth distributions, securities markets, emergence of macroeconomic system from microeconomic behavior. Differs from “computational economics.”
CSS 700 Advanced Object-Oriented Modeling of Social Systems (3:3:0) Provides advanced training in social science OOM through special computational projects. Prerequisite: admission to doctoral candidacy.

2.4.2 Variable-content courses. Finally, the following variable-content courses are necessary to instrumentally support the new program:

CSS 739 Topics in Computational Social Science (3:3:0). Prerequisite: Permission of instructor. Selected topics in computational social science not covered in fixed-content computational social science courses. May be repeated for credit as needed.

CSS 796 Directed Reading and Research (3:3:0). Prerequisite: Permission of instructor. Reading and research on a specific topic in computational social science under the direction of a faculty member. May be repeated as necessary.

CSS 798 Research Project (3:0:0). Prerequisites: Twelve graduate credits from the core requirements and permission of instructor. Project chosen and completed under the guidance of a graduate faculty member, which results in an acceptable technical report.

CSS 799 Master’s Thesis (1-6:0:0). Prerequisites: Twelve graduate credits from the CSS core and permission of instructor. Project chosen and completed under the guidance of a graduate faculty member, which results in an acceptable technical report (master's thesis) and oral defense. Graded S/IP.

CSS 898 Research Colloquium in Computational Social Science (1:1:0). Presentations in specific research areas in computational social science by Center for Social Complexity associated faculty and professional visitors. May be repeated for credit; however, a maximum of three credits of CSS 898, 899, and 991 may be applied towards the Ph.D.

CSS 899 Colloquium in Computational Social Science (1:1:0). Presentations in a variety of areas of computational social science by Center for Social Complexity associated faculty and professional visitors. May be repeated for credit; however, a maximum of three credits of CSS 898, 899, and 991 may be applied towards the Ph.D.

CSS 909 Advanced Topics in Computational Social Science (3:3:0). Prerequisite: Permission of instructor. Covers selected topics in computational social science and socioinformatics not covered in fixed-content courses. May be repeated for credit as necessary.

CSS 996 Doctoral Reading and Research (1-12:0:0). Prerequisites: Admission to doctoral program and permission of instructor. Reading and research on a specific topic in computational social science under the direction of a faculty member. May be repeated as necessary.
CSS 998 Doctoral Dissertation Proposal (1-12:0:0). Prerequisite: Permission of advisor. Covers development of a research proposal, which forms the basis for a doctoral dissertation, under the guidance of a dissertation director and the doctoral committee. May be repeated as needed; however, no more than 12 credits of CSS 998 may be applied towards satisfying the doctoral degree requirements.

CSS 999 Doctoral Dissertation (1-12:0:0) Prerequisite: approval of dissertation proposal. Doctoral dissertation research under the direction of the dissertation director. May be repeated as needed; however, no more than 24 credits in CSS 998 and 999 may be applied towards satisfying the doctoral degree requirements.

2.5 First Year Evaluation, Candidacy Examination, and Doctoral Dissertation Proposal

During the first year every student will form a graduate studies committee, called the First Year Committee, consisting of the student’s Advisor plus 2 or 3 appropriately qualified individuals. At least 3 committee members, including the Advisor, must be tenure-line faculty in the SCS, CAS, ITE and/or Krasnow Departments. The purpose of this committee is twofold: (1) to assist the student in designing a specific Plan of Study for core and elective courses, based on the student’s entry record; and (2) to evaluate the student’s progress by the end of the first year and to issue a recommendation based on such progress. A student’s Plan of Study will become part of his/her file and will be reviewed periodically. A student with strong social science background upon entry will be advised to take a prevalence of computational courses as electives. Conversely, a student with strong computational background (e.g., excellent programming skills in Java or C++) will be advised to focus the elective courses on substantive social science content. The first year evaluation will be based on a comprehensive assessment of coursework, including grades, papers, and any other materials the student wishes to submit. Based on the evaluation the First Year Committee will encourage or discourage further continuation in the program. If continuation is recommended, the student may continue towards the next goal: passing candidacy exams. The First Year Committee must be approved by the CSS Program Director.

Assuming normal progress and continuation, during the second year every student shall form a Doctoral Dissertation Committee consisting of the student’s Advisor, who serves as Chair, plus 3 or 4 appropriately qualified individuals. The dissertation committee may simply be an enlarged first-year committee, or it may be a different committee, depending on the evolution of a student’s interests. At least 3 committee members, including the Advisor, must be tenure-line faculty in the SCS, CAS, ITE and/or Krasnow Departments. The Committee must be approved by the CSS Program Director. The purpose of this committee is to advise the student on preparations for the doctoral candidacy exams, and preparation, development and defense of the doctoral dissertation.
The Candidacy Examination is taken after a student has completed all core requirements and a majority of additional course work (18 + 15 credit hours). In the “normal load” example given earlier this corresponds to roughly the fifth semester into the program, or Fall semester of the Third Year. The purpose of the Candidacy Examination is threefold: (1) to assess the student’s substantive and methodological knowledge in computational social science as a whole (corresponding to the materials covered by the core courses) and in the chosen area of concentration (examples are given below); (2) to assess the students’ ability to integrate materials from different courses; and (3) to assess the student’s potential for a successful dissertation. Examples of areas of concentration and potential specializations include but are not limited to the following:

- Agent-based computational economics: trade, finance, decision-making under risk
- Computational political economy: voting, institutions, norms, inequality
- Computational linguistics: generative grammars, parsing, classifiers, inference
- Social network analysis: connectivity, structure, evolution of the WWW, cyberwarfare
- Computational anthropology: emergence of hierarchy, settlement patterns
- Computational political science: systems of government, conflict, cooperation
- Computational sociology: segregation, collective action, leadership, trust
- Complexity theory: power laws, potential theory, criticality, bifurcation
- Computational methodology: multi-agent systems, evolutionary computation, UML, GIS, visualization, sonification, computational epistemology

The Candidacy Examination shall consist of written and oral parts. The written part shall contain general and specialized questions. The latter shall be specified at least in part by the student’s chosen area of specialization. The written examination shall be prepared by the Program Director and the student’s Advisor, who shall solicit questions from the faculty. Each question in the written examination shall be evaluated in terms of A (high pass), B (pass), or C (fail). A grade of B+ or higher is necessary for proceeding to the oral exam. The oral exam shall cover the same or related material as the written exam, for the purpose of assessing the student’s ability to respond with knowledge and professionalism to questions of substance or method. The oral exam is public and may be attended by fellow students and interested faculty. Each portion of the Candidacy Examination may be retaken only once.

Upon passing the Candidacy Examination each student shall prepare and within a year defend a Dissertation Proposal, written in the form of an extramural research grant proposal. The student shall develop the Dissertation Proposal in consultation with the Dissertation Committee. The main criteria of evaluation shall be threefold: originality, importance, and feasibility. If successfully defended, the Dissertation Committee may recommend submission to an appropriate funding agency (NSF, NIH, or other). The Dissertation Committee may also recommend different or additional coursework as necessary for improving the dissertation project, as well as specific benchmarks that the project must attain. A student becomes a Ph.D. candidate (so-called ABD status) upon successfully defending the dissertation proposal. An ABD student may apply for a position that accepts applicants with an expected date for degree conferral.
2.6 Doctoral Dissertation

The Ph.D. dissertation is the detailed written report of an original and significant research contribution to computational social science. The following are some illustrative examples of dissertation topics in computational social science, some of them making hypothetical use of MASON (GMU’s own Multi-Agent Simulator of Networks and Neighborhoods):

- “An Agent-Based Computational Model of Post-9/11 al-Qaeda and Generalized Terrorist Network Dynamics”
- “A Computational Model of Wars and Alliance Networks: Towards a Generative Theory of War Tested on Long-Range Cross-Cultural Data”
- “Integration of GIS with MASON: A Spatial Multi-Agent Simulator Applied to Urban Metropolitan Development”
- “East vs. West: A Comparative Analysis of Early Civilizations in Mesopotamia and Mesoamerica Through Agent-Based Modeling”
- “Deutsch’s ‘Nerves of Government’ and Easton’s ‘Political System’: Comparing UML and Java Instantiations”
- “Probabilistic Potential Theory and Social Complexity: An Application to Ethnic Violence”
- “MASON in Space: Modeling and Analyzing Human Communities in Extreme Environments Through GMU’s Multi-Agent Simulator of Networks and Neighborhoods”
- “An Evolutionary Computational Analysis of the National Homeland Security System with an Emphasis on Bioterrorism Mitigation”
- “The Effect of Memory on Collective Intentionality: A MASON-based Model of Emergent Social Behavior”
- “The Philosophy of Computational Social Science: A New Test of Lakatos’ ‘Research Programme’ as a Viable Scientific Framework of Inquiry”

The essence of any dissertation in computational social science—as distinct from a dissertation in traditional social science or in computational science—is given by the unique combination of (1) an original and significant substantive research question drawn from one or more of the social sciences; and (2) an approach that is fundamentally (i.e., not secondarily or accidentally) computational and/or based on a complexity-theoretic analysis that involves a computational logic. Another set of examples may be found in the articles published in peer-refereed periodicals such as the *Journal of Artificial Societies and Social Simulation*, many of the Working Papers of the Santa Fe Institute, or proceedings of national or international professional conferences (Agent, NAACSOS, ...
ESSA, EUROSIS, Arrowhead) where advanced graduate students often present their dissertation research.

Parts of the dissertation should be publishable as refereed articles or refereed conference proceedings. Previously published content may be included in the dissertation, except when the work in question was not produced in a significant way by the student. Since computational social science research is frequently collaborative in nature, it is acceptable for a student to include in the dissertation the products of such collaboration, including work produced in conjunction with the Advisor or other members of the Dissertation Committee. If a doubt arises, the Dissertation Committee shall determine the status of any given item.

The dissertation defense shall take place upon recommendation of the student’s Dissertation Committee, at a time and place agreeable to all, with a minimum advance notice of two weeks. The defense is open to the public and fellow students and interested faculty and staff are encouraged to attend. However, only members of the Dissertation Committee may ask questions or make comments, following a presentation by the student candidate. The Dissertation Committee recommends that the graduate faculty of George Mason University accept the student candidate for the Ph.D. degree upon a successful defense and completion of any final revisions. The Chair of the Dissertation Committee shall ensure the implementation of any final revisions, if any are requested and agreed upon by the members of the Dissertation Committee. Additionally, the Dissertation Committee may also recommend publication of the dissertation in revised form.
3. ADMINISTRATION, ADMISSIONS AND ASSESSMENT

3.1. Administration

The proposed program in Computational Social Science will be administered by the Director of the Center for Social Complexity and a Graduate Studies Committee consisting of two computational social science faculty members with graduate studies program experience. Members of the Graduate Committee are appointed by the Deans and Directors from CAS, SCS, ITE and the Krasnow Institute, each unit alternating in staggered terms.

The Program Director has the following responsibilities:

♦ plan and implement course offerings in coordination with faculty members to ensure a reliable, multi-year schedule that students and faculty can depend upon;
♦ promote interdisciplinarity by cross-listings with other units and programs;
♦ ensure the availability of the Multi-Agent Simulator of Neighborhoods and Networks (MASON) system to students, in collaboration with the Evolutionary Computation Laboratory (EC Lab) of the Department of Computer Science at the University;
♦ plan and implement new courses as necessary;
♦ design and maintain all documentation pertinent to the program, including student records and written and web-based media;
♦ advise students with respect to course availability and requirements, available concentrations, potential faculty collaborations, and development of individual courses of study;
♦ coordinate with students and faculty members in the establishment of dates and guidelines for exams and requirements;
♦ assign fellowships and tuition waivers in consultation with the Graduate Committee;
♦ administer the admission process, including decisions on credit transfer from other institutions or programs; and
♦ act as the spokesperson and main contact for the program and offer leadership as necessary.

3.2. Admission requirements and procedures

The Fall semester marks the normal time of entry into the program, with February 15th of each year as the deadline for receiving applications. Only students with the need to take prerequisites in areas of deficiency will be admitted in the Spring semester (October 15 deadline), and they are expected to join the normal schedule in the Fall semester. Prior background for the Ph.D. in computational social science should include a Bachelor’s
degree in either one of the social sciences, in computer science, engineering, or in a relevant discipline, as well as undergraduate courses in these and related areas. Bachelor’s degrees in the physical or biological sciences are also eligible, but may be advised to take additional courses in social science or computer science as prerequisites to admission. Computer programming is not a prerequisite, but while in the program students are expected to develop significant expertise in the utilization of computational social science resources such as agent-based simulations or other computational tools. The program maintains a major simulation environment, the Multi-Agent Simulator of Neighborhoods and Networks (MASON), in collaboration with the Evolutionary Computation Laboratory (EC Lab) of the Department of Computer Science. Mathematics training beyond basic calculus is not required, but may be useful in some areas of specialization.

Application materials must include the following:

1) Completed application form;
2) Official transcripts for all undergraduate (minim overall 3.25 GPA) and graduate courses;
3) An updated curriculum vitae;
4) Three letters of recommendations by faculty members or individuals with direct knowledge of the student’s academic or professional capabilities;
5) A statement of purpose (maximum 2000 words) consistent with the research interests of at least one faculty member in the program;
6) The names of two faculty members that may be suitable as Advisors;
7) Graduate Record Examination (GRE) taken within the past five years prior to the date of application submission.
8) Test of English as a Foreign Language (TOEFL) as per GMU policies.

Items 1, 2, 3, 5 and 6 must be submitted jointly, as a package. Additionally, but not as a requirement, an applicant may submit prior work in computational social science, such as a simulation model or publications. The letters of recommendation must arrive directly from the recommenders and may be submitted electronically as .pdf attachments (send to: ccioffi@gmu.edu, with copy to complex@gmu.edu). Items 7 and 8 are forwarded to the program at the applicant’s request.

Each application is reviewed by the Program Director, who shares them with the faculty members listed by the applicant. The admissions decision is determined by an applicant’s credentials and matching faculty interests. The program may recommend that an applicant delay another year, pending completion of additional coursework. An interview with an applicant may be necessary in some cases. No specific set of qualifications guarantees admission to the program.
3.3. Financial Assistance

Depending on availability and competitive merit, the program offers internal and external financial assistance to students in the form of graduate research assistantships, graduate teaching assistantships, or fellowships.

3.3.1 Internal funding. Students in the first two years may be eligible for support from one of the following sources: University Research Fellowships, Provost’s High Potential Fellowship, and fellowships provided by the Center for Social Complexity, the College of Arts and Sciences, the School of Computational Sciences, the School of IT and Engineering, or the Krasnow Institute for Advanced Study. Research assistantships during the first two years normally include $18k in salary (12-month assistantship) plus a 21-credit tuition waiver (in-state or out-of-state, as applicable), and no teaching responsibilities. Teaching assistantships for third-year students who have not yet passed the Candidacy Examination, or have not obtained external funding may be available. A Teaching Assistantship has the same salary and tuition benefit as the Research Assistantship, but implies responsibilities corresponding to the teaching of one course for each of two semesters, or assisting faculty members (e.g. grading, partial teaching, etc.) in two courses for each of two semesters. Teaching assignments will be coordinated by the Program Director and by the Chairs of CAS, SCS, and ITE Departments. In order to qualify for a Teaching Assistantships, a student must take the Teaching Methods (PSYC 850) course, or courses deemed equivalent by the Program Director and by the Department Chair in which they will carry out their teaching responsibilities.

3.3.2 External funding. Competitive first year students are strongly urged to apply to NSF Graduate Fellowships as soon as possible during the first fall semester (for further information visit [http://www.ehr.nsf.gov/dge/programs/grf/](http://www.ehr.nsf.gov/dge/programs/grf/)). One or more faculty letters of support are normally required. All students are strongly encouraged to join faculty in collaborative research grant proposals capable of attracting external funding. Applying for such grants is seen as an integral part of graduate training. Extramural student funding always means a higher stipend for the student, financial relief for the program, and a significant level of scientific recognition for the student and the program.

The Center for Social Complexity also applies for NSF funding under a variety of programs. The IGERT Program is among the most significant, because it is tailored at new innovative programs such as the proposed program. In addition to IGERT, the Center for Social Complexity also applies for other NSF grants, either alone or collaboratively with other units from CAS, SCS, ITE, or Krasnow, under programs such as ITR, MRI, and the Human and Social Dynamics Priority Area. Obtaining external funding is an important strategy for providing relief to the University budget and gaining resources and greater visibility for the proposed program.

Experience with social science and other doctoral programs indicates that narrowly-defined disciplinary programs are often handicapped by the fact that the corresponding disciplinary program at NSF is severely under-funded relative to departmental demand, often in the single digits in terms of millions of dollars annually. By contrast, a truly interdisciplinary program in computational social science—combining social science,
computer science, and engineering—has potential credible access to much greater resources beyond the social science programs at NSF/SBE. This is why programs such as IGERT, ITR, MRI, HSD, and others are ideally suited as potential funding sources.

3.4. Planning and Advising

A preview of planning and advising for the proposed program was given in section 2.2 earlier, which illustrated a semester-by-semester normal load. The first phase in planning and advising originates when a student applicant identifies two or more faculty members that could serve as advisors or members of the First Year Committee (see section 2.5 earlier). The Program Director will work with students and faculty members to form the First Year Committee.

A student will form a Doctoral Dissertation Committee during the second year, to develop the Plan of Study and obtain advice in preparing for the Candidacy Examination. The Plan of Study may evolve as a result of student interest and skills, but any changes must be discussed and approved by the student’s committee. Advising continues throughout, after a student passes the Candidacy Examination, for preparing and defending the Doctoral Dissertation Proposal, and for preparing and defending the Doctoral Dissertation.

3.5. Learning Outcomes and Student Assessment Plan

Graduates are generally expected to demonstrate the ability to carry out independent and innovative interdisciplinary research in computational social science and specifically in their chosen area of specialization (examples of areas of specialization are detailed in section 2.5). Graduates shall demonstrate their knowledge and skills in theoretical and methodological domains by performing independent research that is publishable in peer-refereed venues. The core curriculum (detailed in section 2.1.2) is designed to cover the common knowledge base that all students are expected to master, in addition to chosen area of specialization. Although most grading and evaluation is necessarily carried out at the individual level, the nature of much of computational social science is such that learning in group projects is also necessary in order to develop the essential skills required by scientific teamwork.

After entering the program students are assessed in their courses (exams, presentations, research papers, special assignments), at the end of their first year, during the candidacy examination (both written and oral), during defense of the dissertation proposal and, finally, during defense of the doctoral dissertation. By the end of the program a student will have attained the following learning goals:

♦ Understand, apply, and be able to teach core concepts, principles and models in computational social science;
Understand, apply, and be able to teach substantive and methodological concepts in the chosen area of specialized disciplinary research;

Formulate a viable research question and design and implement a computational solution either alone or collaboratively;

Develop the necessary communication skills, both written and oral, for successful professional practice and career advancement;

Know how to participate effectively as a member of an interdisciplinary science team; and

Abide by the values and ethics of the scientific profession.

Graduates directed towards professions in academia, government, or the private sector will normally require somewhat different goals. Specifically, graduates directed towards academic careers must know how to teach, publish, and raise research resources. Graduates directed towards the private sector and government must ensure high performance in communications and collaborative skills. All graduates must bear witness to the pioneering nature of the Computational Social Sciences program at George Mason University and its contribution to building our 21st century civilization.

3.6. Evaluation of Program Effectiveness and Benchmarks

The proposed program shall be continuously evaluated along a set of dimension:

1) Number of applications received: By the target initialization date of Fall 2005 this will be the first or one of the very first programs in the country, so monitoring the application rate is important for understanding the concrete demand for and visibility of the new program. Benchmark: an increasing number of applicants.

2) Success in applying for and obtaining extramural funding: Success in this area will enable the program and the University to redirect resources to other areas, such as faculty and staff recruitment and needed infrastructure. Benchmark: Numerous grant applications and several successful awards.

3) Number of graduates and time taken to complete the degree: The ratio of full-time to part-time students is also important to monitor, given the nature of the new program and the different constituencies which it aims to serve. Benchmark: Most students will take five or more years and a few will complete the program in four years.

4) Success in placement of graduates in academic, government, or private sector jobs: The first jobs may not be specifically advertised for computational social science, given the novelty of this field, but computational social science skills are already in significant demand for a variety of positions involving the analysis, design, or management of complex social systems. Benchmark: Graduates will find employment in all three sectors: academic, government, and private.
In addition, soon after the first Ph.D. students graduate, the statutory review mandated by the SCHEV will be conducted and supplemented as necessary.

3.7. Relationship to Existing Ph.D. programs at the University

This is a new doctoral program, not a consolidation or spin-off of earlier programs. The closest program to this proposed program is perhaps the Ph.D. in Computational Science and Informatics, which is founded on or geared towards the physical sciences (for example: astronomy, meteorology, genetics, materials sciences), not the social sciences. The Ph.D. in Economics is also in the social sciences, but it too is distinct because it is not specifically computational in nature, nor does it cover any social science domains outside of economics (i.e., anthropology, geography, history, linguistics, political science, or sociology). So there is no overlap between the core requirements of this program and any other preexisting program, only “win-win” complementary. (In game theory this is called a positive-sum game where all stakeholders can win, not a zero sum game where what one wins the other loses.)

In fact, an important side-benefit of the proposed program is that it would significantly enrich the variety of attractive elective courses for students in other doctoral programs such as CSI or ECON, which is a clear recruitment and retention advantage to those and other programs. For example, the doctoral programs in Economics, Administration of Justice, Computational Science and Informatics, and others at George Mason University can benefit from CSS courses that are now available to their students. Already students from several other doctoral or masters programs (CSI, ECON, ADJ, ICAR) are benefiting from CSS courses that the new program is happy to provide. This trend is expected to grow as new CSS courses are offered and other units cross-list CSS courses or offer them as electives for their own degree.

3.8. Collaborative Efforts with Other Schools and Institutions

By definition, computational social science originated and continues to evolve as an interdisciplinary field with links to many other fields; it is no exaggeration to say that CSS thrives and relies upon interdisciplinary collaborations and synergies between the social and computational sciences. So by necessity, the main interdisciplinary collaborations involved in the proposed program involve an unusually large and diverse cluster of academic areas: the Center for Social Complexity (as the main sponsoring unit for leadership and administration), the College of Arts and Sciences, the School of Computational Sciences, the School of Information Technology and Engineering, and the Krasnow Institute for Advanced Study. This is because most of the courses and faculty affiliated with the program are also affiliated with one or (usually) more of these major divisions of the University. Students in CSS courses typically come from CAS, SCS, and ITE.
A concrete and early example of successful interdisciplinary collaboration was the development of the Multi-Agent Simulator Of Networks and Neighborhoods (MASON), jointly supported by the Evolutionary Computation Lab of the Computer Science Department in ITE (Professor Sean Luke, the inventor of MASON) and the Center for Social Complexity (Professor Cioffi-Revilla). MASON is used for both teaching and research projects, offering our own “home-grown” modeling environment for students in the CSS program (visit the new MASON web site at http://cs.gmu.edu/~eclab/projects/mason/). Another example is the frequent inclusion of CSS seminars in the seminar series of SCS (organized by Professor John Guillory). Joint conference papers, publications, and grant proposals to NSF and other agencies offer yet another indication of collaborative efforts. The Internal Advisory Board of the Center for Social Complexity includes members from several major divisions of the University (2002-2004: CAS, SCS, SPP).

In addition, the School of Public Policy and the Institute for Conflict Analysis and Resolution also benefit from CSS course offerings, seminars and other activities. For example, attendance at seminars and lectures sponsored by the CSS programs are typically attended by a broad audience of students and faculty from most major divisions of the University including CAS, SCS, ITE, SPP, ICAR, the School of Management and the Law School.

Externally, the Center for Social Complexity and faculty affiliated with the CSS program have numerous regional, national, and international collaborations. CSS courses are often attended by Virginia and DC-area students, including many in professional positions in government and private sectors. The External Advisory Board of the Center for Social Complexity includes experts from The Brookings Institution and Santa Fe Institute (Dr. Robert Axtell), the University of Chicago and Argonne National Lab (Dr. David Sallach), Carnegie Mellon University (Dr. Kathleen Carley), and the University of Surrey in UK (Dr. Nigel Gilbert). Faculty affiliates are involved in ongoing research collaborations with area government agencies (for example, DOD, NGS, NIH, NIST, NRL, NASA/Goddard), as well as national and international collaborations.

The Center is an active participant in all the major associations in the CSS field, including the following:

- North American Association for Computational Social and Organizational Sciences (NAACSOS) http://www.dis.anl.gov/naacsos/home.html
- European Social Simulation Association (ESSA) http://slice.uni-koblenz.de/~thkraeme/studienarbeit/index.php

Additional external relations are being established with relevant organizations and programs in Asia, (Tokyo Institute of Technology), Latin America (Instituto Tecnologico de Monterrey), and the Middle East, where the CSS program at GMU has increasing visibility.
4. JUSTIFICATION FOR PROPOSED Ph.D. PROGRAM

4.1. Student demand and projected enrollment

Empirical indicators of significant student demand for the proposed program:

(1) Increasing enrolment in CSS courses. For example, in Spring 2004 the new course CSS 600 Introduction to Computational Social Science registered 12 students, up from only 4 the first it was taught in Spring 2003. CSS 610 Computational Analysis of Social Complexity registered 12 students the very first time it was offered in Fall 2003. Students from economics, geography, computational science, and sociology also express strong interest in additional CSS courses.

(2) There is also increasing interest, especially among part-time working students, in the new Certificate in Computational Social Science, which requires 15 credit hours in CSS.

(3) Inquiries from Northern Virginia and DC-area students who wish to enroll in our new computational social science program and are not attracted to any of the other traditional social science programs in the region. For example, the Inaugural Conference of the Center for Social Complexity, held in May 2003, showed a large attendance by GMU and other area students from the University of Maryland, Princeton University, George Washington University, National Defense University, the University of Pennsylvania, and other institutions (e.g., University of Wisconsin). As well, the conference was attended by many analysts.

(4) Analysts, both junior and senior, from numerous corporations and government agencies regularly attend the seminar and special lecture series offered by the Center for Social Complexity, hosted at the Krasnow Institute for Advanced Study. Inquiries about courses and graduate programs offered or planned in Computational Social Science (Certificate, Masters, and Ph.D.) are common.

(5) The table below illustrates projected enrollments in terms of GRADS (annual number of graduates of the proposed program), HDCT (fall headcount enrollment), and FTES (annual full-time equivalent student enrollment). Since students are already taking CSS courses, several graduates are expected in years 2, 3, and 4, before the “target” 5th year of 2009-10. These projections are of course sensitive to projected faculty hiring and availability and external funding.
Project Enrollment:

<table>
<thead>
<tr>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>“Target” Year 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRADS</td>
<td>GRADS</td>
<td>GRADS</td>
<td>GRADS</td>
<td>GRADS</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>HDCT FTES</td>
<td>HDCT FTES</td>
<td>HDCT FTES</td>
<td>HDCT FTES</td>
<td>HDCT FTES</td>
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<tr>
<td>4</td>
<td>3</td>
<td>8</td>
<td>6</td>
<td>11</td>
</tr>
</tbody>
</table>

4.2. Employment Demand for Graduates

4.2.1 Outlook. The Commonwealth of Virginia faces economic, social, and educational challenges to which CSS is capable of responding by increasing the computational culture and capacity of social scientists in the area. Employment in homeland security, space research, urban systems, critical infrastructure, and national security are some of the areas most directly affected by CSS; areas that are vital for a prosperous, sophisticated, and secure Commonwealth capable of thriving in the midst of 21st century civilization.

Demand for Ph.D. graduates in Computational Social Science is new and originates from three sectors: academic, government, and private. While there are no direct projections for the specific field of Computational Social Science as of yet, the Bureau of Labor Statistics’ Occupational Outlook Handbook notes the following for Economists and Other Social Scientists:

- For social scientists in general: “Educational attainment of social scientists is among the highest of all occupations. […] Training in statistics and mathematics is essential for many social scientists. Mathematical and quantitative research methods increasingly are used in geography, political science, and other fields. The ability to use computers for research purposes is mandatory in most disciplines.” Job Outlook: “Overall employment of social scientists is expected to grow about as fast as the average [i.e., increase 10-20%] for all occupations through 2010. Prospects are best for those with advanced degrees, and usually are better in disciplines such as sociology, anthropology, and archaeology, which offer more opportunities in nonacademic settings.” Moreover, “some social science graduates will find good employment opportunities in areas outside traditional social science.

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For economists in particular: “Candidates who hold an advanced degree will have the best employment prospects and advancement opportunities.” Job Outlook: “Faster than the average [21-35%] for all occupations through 2010.” “Opportunities for economists should be best in private industry, especially in research, testing, and consulting firms, as more companies contract out for economic research services. The growing complexity [sic] of the global economy, competition, and increasing reliance on quantitative methods [sic] for analyzing the current value of future funds, business trends, sales, and purchasing should spur demand for economists. The growing need for economic analysis in virtually every industry should result in additional jobs for economists. […] An advanced degree coupled with a strong background in economic theory, mathematics, statistics, and econometrics provides the basis for acquiring any specialty within the economics […] Those skilled in quantitative techniques and their application to economic modeling and forecasting, coupled with good communications skills, should have the best job opportunities.”

Strong computational and quantitative-analytical content —those elements that make social scientists especially competitive and in demand— are core defining features of Computational Social Science.

4.2.2 Academic. There are at least two sets of separate academic demands for graduates of this program: demand for Ph.D.s in all fields of social science with a methodology component, and demand in CSS specifically. The former comes from the social science disciplines (anthropology, economics, political science, and sociology) and therefore represents hundreds of new positions annually nationwide; many more globally. For examples, a graduate from our program who develops a specialization in, say, agent-based computational economics/finance, would be competitive for academic positions in both economics/finance and in agent-based computational economics. Similarly for other academic positions in the social sciences. Note that the same is not true for traditional Ph.D. degrees in each of the social sciences, which are confined to a single discipline and hence face far fewer options.

By “moving first,” this new program at GMU is also able to set a visible professional standard and supply graduates for the first generation of academic jobs in this emerging field. This is reminiscent to the way in which the following “schools” emerged: economics at the University of Chicago, mathematics at New York University, political science at the University of Rochester, sociology at Columbia, or physics at CalTech. Ours will be “CSS at GMU.” Already the following universities are advancing their plans for graduate training in CSS:

- Carnegie Mellon University
- MIT
- University of California, Los Angeles
- University of Chicago
- University of Michigan
Other universities, such as Stanford, Harvard, and Yale will likely soon follow, so academic positions at these leading institutions and others should become available in the not-too-distant future. GMU graduates in CSS will be highly competitive for such positions.

4.2.3 Non-academic: government and private sectors. CSS activities at GMU—such as courses, conference, and extracurricular lectures—are attended by members of the government and private sectors, not just by students and faculty. For example, the Inaugural Conference of the Center for Social Complexity, in May 2003, was attended by managers and employees from the intelligence community, the National Science Foundation, the aerospace industry, the homeland security community, the transportation industry, as well as from Commonwealth and local government agencies. The same is true for the monthly lecture series in CSS held at the Krasnow Institute for Advanced Study, where government and private sector members of the public mix with academic members in attendance.

The simple reason for this strong and diversified demand for CSS knowledge from government and private sectors—which creates a multiplier effect—is that the field is primarily concerned with complex adaptive social systems, and these are often interconnected: fighting terrorism, integrating public services in large metropolitan areas and regional systems, biodefense preparedness, expanding financial markets, international security, managing large-scale supply chain systems, securing critical infrastructure, improving intelligence, are among the best-known examples. Globalization, in general, is a positive development for CSS, because globalization requires sophisticated computational and related IT-analytical tools, as well as advanced organizational solutions, or global society will not prosper. Over time we expect more and stronger, not less or weaker, demand for expertise in computational social science originating from private and government sectors.

4.3. Comparison with other programs in region and state

There are no other doctoral programs in CSS in the region or in the state, or in the nation for that matter. Ours is the first and other institutions are watching closely what we do; several will undoubtedly emulate our program.

For now at least the closest program is an NSF-funded Ph.D. program in “Computational Analysis of Social and Organizational Systems” (CASOS) offered at Carnegie Mellon University. However, the focus of this program is largely confined to organizational theory, not all the social sciences, and the degree is actually awarded by the School of Computer Science and the Institute for Software Research, not by a primary unit in the social sciences area (in CMU’s case that would be the Department of Social and Decision Sciences). Professor Kathleen Carley, director of this CMU program, is an invited member of the External Advisory Board of our Center for Social Complexity.

In the region, the most likely schools to follow us in offering a Ph.D. in CSS are the University of Maryland at College Park, Johns Hopkins University, and the University of Pennsylvania
Pennsylvania, because these have high potential capability and increasing interest. Again, by moving first GMU will have a considerable present and future competitive advantage.

4.4. Benefit to GMU as a whole

The new program in CSS is designed in the same spirit as the Mission Statement of the Board of Visitors (adopted January 1991). Specifically, this new program offers the University:

- A strategic contribution towards being “an institution of international academic reputation” (Mission Statement, Board of Visitors, January 1991), one day becoming a leading Research-I university, in cooperation with other leading programs, thereby building on strength;
- A new doctoral program that is consistent with and supportive of GMU’s Mission in providing Virginia students with an environment for synergistic interdisciplinary scholarship and the innovative invention and application of information technologies;
- A truly new cutting-edge doctoral program that is founded on critical needs of our 21st civilization, focusing on the emerging role of complex adaptive social systems;
- An exciting venue for unprecedented collaborative teaching and research, supported by advanced information environments such as MASON and other inventions that will emerge from the new Research I Building facility;
- A leadership position, with national and international visibility, in the emerging field of Computational Social Science, which will reinforce an active University presence in the transnational scholarly community;
- Additional significant capacity to attract external funding, beyond what can be accomplished by individual disciplines, given the significance of CSS for government and the private sector and the emerging national science Priority Area in Human and Social Dynamics;
- An additional competitive advantage in recruitment and retention of faculty in several fields (human, social and historical sciences, computational sciences, and allied fields), by offering uncommon scholarly opportunities and exciting challenges that are unique to our University and unavailable elsewhere.

[NOTE: An alternative approach is to copy the Mission Statement and annotate it with these points.]
5. AVAILABLE AND ADDITIONAL RESOURCES

Almost all the necessary resources are already available in terms of students, faculty, facilities, and financial resources; only a few critical needs remain to initiate the program by the target date of Fall 2005, namely student fellowships and faculty hires.

5.1. Student fellowships

Although some students will attend part-time, we expect most to attend full-time (as the CSS students that are currently enrolled) and hence require financial assistance. The best social science graduate student applicants at leading research universities receive offers consisting of a fellowship and tuition waiver. In most leading social science departments around the country (U. Michigan, U. Chicago, Stanford, Yale, and others ranked in the top ten), the most competitive students in the entering class (6-12 per year) are offered “no-strings-attached” fellowships for at least the first two years, often for the expected duration of four years. For example, the Department of Political Science at the University of Illinois at Urbana-Champaign offers six named graduate fellowships (e.g., the Charles E. Merriam Graduate Fellowship, the Quincy Wright Fellowship, and others), in addition to teaching and research assistants, such that “over 90% of our students receive financial support in the form of fellowships and teaching assistantships. In addition, the department awards aid for dissertation research, conference travel and summer programs.”6 Our request is much more modest but essential in order to make the program viable.

We request one high potential graduate research fellowship per year from the Provost’s Office, as well as XXX graduate research and teaching assistantships from CAS, SCS, ITE, and Krasnow. The CSS faculty involved in the proposed program normally seeks external funding from agencies such as the NSF under various programs (ITR, HSD, SBE, EITM), the McDonnell Foundation, DARPA, NIMA, and others. Tuition waivers are often required for students supported by faculty research grants.

Except for NSF Graduate Fellowships or comparable opportunities, the proposed program will not encourage research assistantships through outside grants in the first two years, because too much engagement with research during the early stages of a student’s career can have an adverse effect on the timely completion of core courses. By contrast, joining with faculty and other students in research grant proposals after the fourth semester is strongly encouraged.

5.2. Faculty

The proposed program in CSS enjoys broad support by the Mason faculty. Approximately 55 faculty members are affiliated in one form or another with the proposed program, as detailed in Appendix I. Affiliation is defined in terms of teaching core or elective courses, mentoring and advising graduate students, participating in

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6 http://www.pol.uiuc.edu/graduate/program.html
research grants, attending CSS events and other activities. What unites this large and diverse academic community at GMU is a focused interdisciplinary interest in complex social systems and computational modeling. Most faculty members have appointments in more than one unit, often across colleges or schools. Every social science is represented, including history, as well as computational science, mathematics, and the physical and life sciences.

Most collaborations in the proposed program are self-organized by faculty and students, and cross-unit collaborations constitute a great Mason tradition which the proposed program in CSS exploits and supports. In particular, interdisciplinary student dissertation committees of faculty members from various units have already proven viable in a number of areas that ordinarily could have fallen under the proposed Ph.D. program had one already existed. For example, one student recently developed and successfully defended her dissertation on a computational model for the emergence of an economic trading market (Debbie Duong). Her dissertation committee was chaired by a faculty member from the School of Computational Sciences (professor John Grefenstette), another faculty member was the director of the Center for Social Complexity (Professor Claudio Cioffi-Revilla, rostered in both CAS and SCS), another from the School of Information Technology and Engineering (Professor Kenneth De Jong, Computer Science), and another from the Krasnow Institute of Advanced Study (Robinson Professor Harold Morowitz, Biology). Our faculty is uniquely positioned to undertake these and similar doctoral training collaborations.

Professors Cioffi-Revilla, Parker, and the new Network Sociologist teach courses that cover almost the entire core, plus several electives. One new faculty position or 1.0 FTE is needed to complete coverage of the following core courses and offer two additional elective courses for a total of 4 CSS courses per year:

CSS 605 Object-Oriented Modeling in Social Science
CSS 610 Computational Analysis of Social Complexity

The new faculty position could be rostered in one of the social sciences and in SCS or ITE, depending on substantive domain. For example, these courses could be taught by an agent-based modeler in anthropology, economics, or political science; or by a computer scientist with training in one of the social sciences.

5.3. Part time personnel, postdocs and course buy-outs

The courses in the proposed program—both core and electives—would be taught mostly by faculty who already teach a full load in their home department(s). CSS courses are cross-listed in as many units or programs as is functionally appropriate, which helps in meeting and exceeding minimal enrolment levels. In addition, CSS courses offer additional attractive electives to a broad spectrum of other units and programs: Administration of Justice (ADJ), Anthropology (ANTH), Computational Science and Informatics (CSI), Economics (ECON), Environmental Science and Public Policy.
(EVPP), Geography (GEOG), Government (GOVT), History (HIST), Public Administration (PUAD), Sociology (SOC).

Hiring part-time adjunct faculty, postdocs, and course buy-outs are alternative strategies for covering elective CSS courses. Core courses ordinarily should be taught only by full-time faculty, because greater reliability is needed in scheduling.

5.4. Other resources

- The only other resources requested are a half-time administrative assistant position and advertising costs to publicize the new program. The director of the Center for Social Complexity will act as Graduate Coordinator for the proposed program.
Projected Resource Needs for Proposed Program

**Part A: Answer the following questions about general budget information.**

Has or will the institution submit an addendum budget request to cover one-time costs? 
Yes_____ No____

Has or will the institution submit an addendum budget request to cover operating costs? 
Yes__X___ No____

Will there be any operating budget requests for this program that would exceed normal operating budget guidelines (for example, unusual faculty mix, faculty salaries, or resources)? 
Yes_____ No__X__

Will each type of space for the proposed program be within projected guidelines? 
Yes__X__ No____

Will a capital outlay request in support of this program be forthcoming? 
Yes_____ No__X__
Part B: Fill in the number of FTE positions needed for the program.

<table>
<thead>
<tr>
<th></th>
<th>Program initiation year 2005 - 2006</th>
<th>Added (New)</th>
<th>Total expected by target enrollment year 2009 - 2010</th>
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<tr>
<td></td>
<td>On-going and reallocated</td>
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<td>On-going and reallocated</td>
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<tr>
<td>Full-time faculty</td>
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<tr>
<td>Part-time faculty</td>
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<tr>
<td>Classified Positions</td>
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<td>TOTAL</td>
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</table>

Part C: Estimated $$ resources to initiate and operate the program.

<table>
<thead>
<tr>
<th></th>
<th>Program initiation year 2005 - 2006</th>
<th>Total expected by target enrollment year 2009 - 2010</th>
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<tr>
<td>Full-time faculty</td>
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<tr>
<td>Part-time faculty</td>
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<td>Graduate assistants</td>
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<td>Classified positions</td>
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<td>Library</td>
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<tr>
<td>Telecommunication costs</td>
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<tr>
<td>Other resource needs (specify)</td>
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<td></td>
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<tr>
<td>TOTAL</td>
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</tbody>
</table>
Part D: Certification Statement(s)

The institution will require additional state funding to initiate and sustain this program.

_____ Yes _______________________________________________

Signature of Chief Academic Officer

_____ No _______________________________________________

Signature of Chief Academic Officer

If “no,” please complete Items 1, 2, and 3 below.

1. Estimated $$ and funding source to initiate and operate the program.

<table>
<thead>
<tr>
<th>Funding Source</th>
<th>Program initiation year 2005 - 2006</th>
<th>Target enrollment year 2009 - 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reallocation within the department or school (Note below the impact this will have within the school or department.)</td>
<td></td>
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<tr>
<td>Reallocation within the institution (Note below the impact this will have within the school or department.)</td>
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<tr>
<td>Other funding sources (Please specify and note if these are currently available or anticipated.)</td>
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</tbody>
</table>

2. Statement of Impact/Other Funding Sources.

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

If resources are reallocated from another unit to support this proposal, the institution will not subsequently request additional state funding to restore those resources for their original purpose.

_____ Agree _______________________________________________

Signature of Chief Academic Officer

_____ Disagree _______________________________________________
Signature of Chief Academic Officer
The goal of this program is to endow The Commonwealth, and the country as a whole, with world-class capabilities for solving the unprecedented interdisciplinary challenges posed by complex social systems. Twenty-first century civilization relies upon computational social science to prosper and conquer new frontiers that will enhance our quality of life, by helping defeat or mitigate complex problems (terrorism, human misery, WMD proliferation, global change) and exploit new opportunities (globalization, space, new technologies). Only the coordinated combination of social science, computational science, and selected components from the physical and life sciences can meet this challenge—and George Mason University is ready and eager to initiate the proposed program under the leadership of the Center for Social Complexity and with enthusiastic support from the College of Arts and Sciences, the School of Computational Sciences, and the School of Information Technology and Engineering.

The proposed program is viable and will meet its objectives, thanks to existing faculty and student interest in CAS, SCS, and ITE, excellent facilities and dedicated leadership offered by the Center for Social Complexity. Very few additional resources are needed to initiate the program in Fall 2005. GMU’s location in the Metropolitan DC area also offers additional opportunities and resources, in terms of student interest, adjunct faculty, potential research partnerships, and excellent research resources and facilities. The same program could cost much more or not be feasible at institutions ranked higher than GMU.

Overall the proposed new program in Computational Social Science will:

♦ provide The Commonwealth with new significant expertise in an area that is vital for understanding and managing complex social systems at many scales;
♦ endow GMU with a new and innovative degree in a field that is central to supporting and advancing 21st century knowledge and civilization;
♦ position GMU at another unique frontier of interdisciplinary science and engineering;
♦ enrich several existing programs in most major divisions of the University—CAS, SCS, ITE, and also SPP, ICAR—by providing new electives and resources in computational social science; and
♦ contribute towards GMU’s Mission in world-class interdisciplinary and IT-based scholarship.
7. EXECUTIVE SUMMARY

Background information

The Center for Social Complexity at George Mason University, with formal endorsements from [in collaboration with] the College of Arts and Sciences (CAS), the School of Computational Sciences (SCS), the School of Information Technology and Engineering (ITE), and the Krasnow Institute for Advanced Study at George Mason jointly proposes a new Ph.D. program in Computational Social Science (CSS). The proposed Ph.D. program takes advantage of existing courses in relevant fields, specific new and existing courses in computational social science, building on the new Certificate in CSS. Computational social science is a dynamic and emergent field that combines social science and computational science, capable of solving previously intractable challenges in complex adaptive social systems. George Mason University already has a significant latent community of faculty and students in this field, recognized nationally and internationally. The proposed new degree will exploit and organize these capabilities with minimal new resources. The new program will enhance Commonwealth and GMU capabilities in this field, ensuring us a leadership position in the regional, national, and international community.

What the new program will bring to the University

The new program will bring to GMU a new and valuable opportunity for students to obtain advanced graduate training in a field of vital importance to 21st century civilization; a rich pool of courses available as elective courses for numerous other existing programs in CAS, SCS, ITE and other major divisions of the university; new and viable opportunities to attract extramural research funding in support of faculty research and student training, including a powerful tool for private fundraising; increased visibility and recognition at regional, national, and international levels; new opportunities and tools for recruitment and retention of faculty, students, and researchers; a graduate program in harmony with and supportive of the basic Mission of the University, specifically in the areas of interdisciplinary science, scholarship, and information technologies, which are recognized areas of GMU excellence; a solid basis for future development of undergraduate courses and an undergraduate curriculum; another exciting channel for outreach to the community, through special presentations and related activities.

Where the students will come from

Many GMU students are already studying in CSS courses, attending special lectures and seminars, developing dissertation projects, and applying for grant proposals, both individually and in collaboration with faculty. A certain number of students presently enrolled in other programs is expected to transfer to the new program, depending on individual interests and career objectives. Other students are expected to apply and enter the program, arriving directly from recent prior undergraduate education, as well as from the government sector and the private sector. Yet another stream is expected to transfer
from other graduate at other universities that do not yet offer a Ph.D. degree in CSS. By the time the program officially starts in Fall 2005 several students will have already completed part or all of the core requirements. Our estimate of where outside students will come from is based on numerous inquiries received at the Center for Social Complexity, as well as from site visits to institutions and agencies in the region, nationally, and overseas, and from attendance at major national and international conference. In terms of background, most students will come with either a background from the social sciences, or from computer science. Since computational social science requires both, the program is designed to train each group by providing compensatory study and specialization according to individual interests and future employment objectives.

Where the students will go upon graduation

Doctoral graduates from the proposed program will have employment opportunities in three sectors: academia, government, and the private sector, depending on career plans, the chosen specialization and individual objectives. In the academic area the first job opportunities are in traditional university and college teaching positions in the social sciences, where employers are interested in hiring experts with computational methods in any of the social sciences. Jobs for computational social scientists, particularly agent-based modelers, already exist in anthropology, economics, geography, linguistics, political science and sociology. Local, state, national and international governmental institutions are also in need of computational social scientists for modeling complex systems in numerous areas: homeland security, intelligence, public health, transportation, national security, and education. Private sector employers include but are not limited to corporations that require analysis and modeling of complex social systems, think tanks, defense and homeland security contractors, risk assessment firms. Demand for computational social scientists is expected to be average to strong based on the 2005-10 employment outlook estimates by the Bureau of Labor Statistics.

How the new program compares and contrasts to other such programs in the region

This will be a unique program; there are no other computational social science programs in the region. By moving first, GMU and the Commonwealth of Virginia will secure a leadership position.
Appendix I. List of Affiliated Faculty

Sergei Andronikov, Geography
Giorgio Ascoli, Krasnow Institute for Advanced Study
Robert Axtell, Center for Social Complexity
Sheryl Beach, School of Computational Sciences
James Beall, School of Computational Sciences
Daniel Carr, School of computational Sciences
Kenneth De Jong, Computer Science and Krasnow Institute
Daniel Druckman, Institute for Conflict Analysis and Resolution
Robert Dudley, Public and International Affairs
Catherine A. Gallagher, Public and International Affairs
James E. Gentle, School of Computational Sciences
Jack Goldstone, Mercatus Center
John J. Grefenstette, School of Computational Sciences
Gregory A. Guagnano, Sociology and Anthropology
John Guillory, School of Computational Sciences
Muhammad Habib, Applied and Engineering Statistics
Robert Harris, School of Management
Curtis Jamison, School of Computational Sciences
R. Christian Jones, Environmental Science and Policy
Menas Kafatos, School of Computational Sciences
Larry Kerschberg, Information and Software Engineering
Richard Klimoski, School of Management
Raj Kulkarni, School of Public Policy
Sean Luke, Computer Science
Stephen Mastrofski, Public and International Affairs
Edward Maguire, Public and International Affairs
Julianne Mahler, Public and International Affairs
Kevin McCabe, Interdisciplinary Center for Economic Science
Michael McDonald, Public and International Affairs
Ryszard Michalski, School of Computational Sciences
Harold Morowitz, Krasnow Institute for Advanced Study
James Olds, Krasnow Institute for Advanced Study
Mark Olson, Interdisciplinary Center for Economic Science
Ann Palkovich, Krasnow Institute for Advanced Study
Dawn Parker, Geography
Paula Petrik, History
Catherine Rudder, School of Public Policy
Laurie Schintler, School of Computational Sciences
J. Shukla, School of Computational Sciences
Vernon Smith, Interdisciplinary Center for Economic Science
James Snead, Sociology and Anthropology
Peter Stearns, History
Roger Stough, School of Public Policy
Daniele Struppa, Mathematics
Arun Sood, Computer Science
Iosif Vaisman, School of Computational Sciences
Steven P. Vallas, Sociology
Richard Wagner, Economics
Larry Walters, Public and International Affairs
Edward Wegman, School of Computational Sciences
David Wilson, Administration of Justice
David Wong, School of Computational Sciences
Appendix II. Catalog Descriptions of Existing Courses as Potential Electives

ADJ 475 Theory and Politics of Terrorism (3:3:0). Explores the origins of terrorism and traces its development from early states to a modern mode of conflict. National, regional, and global perspectives are presented.

ANTH 568 Human Origins (3:3:0). Prerequisite: Graduate standing or permission of instructor. Detailed survey of the genetic, morphological, and behavioral origins of hominids. Current interpretations and debates are discussed.

ANTH 580 Evolution and Human Ecology (3:3:0). Prerequisite: Graduate standing or permission of instructor. Examination of the complex relationships among human cultures, biocultural adaptation, and the natural world from an evolutionary perspective.

ANTH 631 Refugees in the Contemporary World (3:3:0). Prerequisite: Graduate standing. Seminar on the major refugee flows in the second half of the 20th century, with emphasis on the mechanisms for providing assistance, asylum, and resettlement.

ANTH 670 Regional Studies in Archaeology (3:3:0). Prerequisite: Permission of instructor. Regional survey of specific culture area in archaeology to be chosen by student and instructor.

ANTH 680 Readings in Archaeology (3:3:0). Prerequisite: Permission of instructor. Directed readings and research on a specific topic in archaeology to be chosen by student and instructor. May be repeated for a maximum of 6 credits.

ANTH 684 Readings in Cultural Anthropology (3:3:0). Prerequisite: Permission of instructor. Directed reading and research on a specific topic in cultural anthropology chosen by student and instructor. May be repeated for a maximum of 6 credits.

BIOD 601 Foundations of Biodefense Science and Technology I (3:3:0). Basic biology of living systems including cell structure and function, metabolism, genetics, and biodiversity. Areas covered are important to comprehending the technology and systems involved in biodefense. May not be used for credit toward a graduate degree in biodefense.

BIOD 708 Epidemiology of a Bioterror Attack (3:3:0). Prerequisites: BIOD 601, 602, 603, 604, and 605, or permission of instructor. This course will teach the basics of epidemiology as well as unique issues in epidemiology that biological agents used as weapons present. The course includes not only how a disease would spread naturally, but also how to prevent it from spreading. Also, students will learn differences in natural and unnatural outbreaks.

BIOD 709 Nonproliferation in Biodefense (2:2:0). Prerequisites: BIOD 601, 602, 603, 604, and 605, or permission of instructor. This course involves current issues in
nonproliferation of biological agents as a weapon of mass destruction. Students will study various theories in nonproliferation as well as look at nonproliferation in practice in recent history.

**BIOD 721 Coordinated Response to a Bioterror Attack (2:2:0).** *Prerequisite: BIOD 601, 602, 603, 604, and 605, or permission of instructor.* Provides information for defending against biological attacks. Topics to be covered are on-scene procedures following the initial discovery of such agents, site boundaries for biological agents, gross decontamination procedures, site set-up procedures, agent removal, and case studies of hypothetical infections. Students will learn the critical response requirements of a biological attack.

**BIOD 722 Examining Terrorist Groups (3:3:0).** *Prerequisites: BIOD 601, 602, 603, 604, and 605, or permission of instructor.* History of known organized terrorist activity, including study of common cultural and historical correlations. Study of groups' modus operandi. Latest developments in terrorist profiling.

**BIOD 724 Incident Response Information Technology (2:2:0).** *Prerequisites: BIOD 601, 602, 603, 604, and 605, or permission of instructor.* Effective information-sharing on bioterrorist incidents among federal, state, and local law enforcement agencies through databases and computer software.

**BIOD 742 Modern Geographic Techniques in Detection as Tracking (3:3:0).** *Prerequisites: GEOG 300 and GEOG 311 or permission of instructor.* Elective course on the utilization of GIS, remote sensing/satellite imagery, and spatial analysis techniques that can be used to monitor biological events and plan/coordinate response.

**BIOD 761 Dispersal Patterns of Biological Agents (3:3:0).** *Prerequisites: BIOD 601, 602, 603, 604, and 605, or permission of instructor.* Introduction to military and terrorist methods of dispersal patterns. Course covers the physics of aerosols, engineering and mechanics of building ventilation systems, and mechanical dissemination including hand-held, automatic, vehicle, and truck-mounted systems. Course also covers viability of specific agents involved.

**BIOD 762 Into the Hot Zone: Working in a High Threat Environment (2:2:0).** *Prerequisites: BIOD 601, 602, 603, 604, and 605, or permission of instructor.* Introduction course includes methodology of working in a Biosafety Level 3 or 4 environment. Special attention is focused on responding to a biowarfare or bioterrorism related event.

**CEIE 560 Public Transportation Systems (3:3:0).** *Prerequisite: CEIE 360. Credit is not given for both CEIE 460 and 560.* Analysis of public transportation systems in terms of their role in urban transportation. Topics covered include the history of public transportation in the United States, quantitative performance attributes of different modes, analytical techniques for planning and operation, and management and administrative concepts.
CEIE 561 Traffic Engineering (3:3:0). Prerequisite: CEIE 360 or 365 or equivalent. Credit is not given for both CEIE 461 and 561. Covers elements of traffic engineering analysis; system components of traffic operations: the driver, vehicle, and roadway; traffic flow design elements including volume, density, and speed; intersection design elements including traffic control device warrants, signal timing, delay, capacity, and accident countermeasures; and terminal design elements including inflow, outflow, and circulation.

CEIE 562 Urban Transportation Planning (3:3:0). Prerequisite: CEIE 360 or 365 or equivalent. Credit is not given for both CEIE 462 and 562. Covers technical and qualitative aspects of the urban transportation planning process. Topics include urban travel characteristics and data collection methods; the urban transportation modeling system, including land use, trip generation, trip distribution, mode choice, and trip assignment models; site traffic impact studies; environmental impacts; project and plan evaluation; and technology options for urban transport.

CEIE 600 Civil Engineering Infrastructure Planning and Management (3:3:0). Study of planning and management practices applicable to the life cycle of the physical urban infrastructure (e.g., roads, sewers, water distribution and other pipelines, telecommunications, and energy distribution systems). Includes the study of the relationship of urban growth and infrastructure reinvestment; mechanisms of deterioration; direct and indirect methods of assessment and degradation models; capital finance, budgeting, and programming; planning integration and coordination; quantitative applications in planning; uncertainty and reliability; public-private partnerships; operation and maintenance strategies; and future issues.

CEIE 601 Infrastructure Modeling (3:3:0). Prerequisite: CEIE 605. Concepts of modeling for infrastructure engineering. Covers modeling, simulation, optimization, deterministic and stochastic models, and limitations of modeling approaches. Also included are multiple objective, multiple decision maker problems, and case studies in areas such as transportation, water resources, the environment, energy, telecommunications, and construction.

CEIE 605 Infrastructure Systems Analysis (3:3:0). Prerequisite: STAT 344. Probability and statistics topics for analysis of infrastructure systems; Bayesian decision theory, decision trees; Monte Carlo analysis and stochastic models. Economic analysis of infrastructure projects and systems, including life-cycle costing concepts, utility theory, and multiattribute utility analysis.

COMM 602 Theories and Research of Mass Communication (3:3:0). Theories of mass communication that have guided the development of mass media. Emphasis on the major scientific and humanistic approaches to the question of mass media effects.

COMM 605 Intercultural Communication (3:3:0). Analysis of communication variables as they relate to communication across cultures. Topics include nonverbal
communication, time conceptualizations, perceptions and attitudes, values, social organization patterns, cultural norms, language, ethics, conflict across cultures, and research in intercultural communication.

COMM 631 Approaches to Group Facilitation (3:3:0). Introduction to various theoretical and practical approaches to group facilitation with in-depth focus and practice in one approach. Students participate in group sessions, analyze videotapes of decision-making groups, and practice methodologies for facilitating group interaction.

COMM 634 Theories of Interpersonal Communication (3:3:0). Prerequisite: COMM 301 or permission of instructor. Analysis of contemporary theories, concepts, and approaches to the improvement of interpersonal communication. Extensive examination of interpersonal communication research.

COMM 635 Organizational Communication (3:3:0). Analysis of communication systems and processes within organizations, both public and private. Specific topics include conflict management, group decision making, interviewing, technical presentations, and using various channels for improving internal and external communication for the organization.

CSI 600/SYST 500 Quantitative Foundations for Systems Engineering (3:3:0). Prerequisite: Math 213, 214. This course provides the quantitative foundations necessary for core courses in the Systems Engineering and Operations Research master's program and the certificate program in C 3I. Topics include vectors and matrices, differential and difference equations; linear systems; Fourier, Laplace and Z transforms, and probability theory. Engineering applications of the topics will be emphasized. Students will receive graduate credit for this course which will, when used on a plan of study, extend the minimum credit hour requirements for the degree.

CSI 603 Introduction to Scientific Programming I (1:1:0). Not applicable to the 48-hour course total for the CSI Ph.D. Prerequisite: CSI 601 or permission of instructor. Introduction to programming in C or Fortran. Emphasizes application and languages rather than theory. Features a combination of lecture and lab. Assignments are completed via a distance-learning web interface.

CSI 604 Introduction to Scientific Programming II (1:1:0). Not applicable to the 48-hour course total for the CSI Ph.D. Prerequisites: CSI 601 and 603 or permission of instructor. Introduction to programming in an object-oriented language such as C++. Features a combination of lecture and lab.

CSI 606 Scientific Graphics and Visualization Tools (1:1:0). Not applicable to the 48-hour course total for the CSI Ph.D. Prerequisite: CSI 601 or permission of instructor. Introduction to the use of scientific visualization tools for data analysis. Use of specific packages will be taught on a rotating basis. Packages include PV-WAVE, S-Plus, SV, XMGR, and the pnm tools.
CSI 607 Database Tools for Scientists (1:1:0). Not applicable to the 48-hour course total for the CSI Ph.D. Prerequisites: CSI 601 and 602 or permission of instructor. Introduction to database tools. Teaches the student how to deal with the relation model, on which database packages like Oracle are based. Under this language, database design concepts, table operations, triggers, sequences, and introduction to simple query language (SQL) will be covered.

CSI 610 Introduction to Computational Sciences (3:3:0). Not applicable to the 48-hour course total for the CSI Ph.D. Prerequisites: CSI 601, 602, 603, 604, 605, and 700 or permission of instructor. Covers advanced numerical methods, computer architecture, and scientific software development. Includes software design, construction, and validation techniques commonly used in industry. Also serves as an introduction to high-performance computing.

CSI 639 Ethics in Scientific Research (3:3:0). An examination of ethical issues in scientific research. Begins with a reflection on the purpose of scientific research and review of the foundational principles used for evaluating ethical issues. The course will equip students with skills for survival in scientific research through training in moral reasoning and teaching of responsible conduct. Students will discuss current ethical issues in research and will learn to apply critical thinking skills to the design, execution, and analysis of experiments. Important issues include, for example, the use of animals and humans in research, ethical standards in the computer community, and research fraud. In addition, currently accepted guidelines for behavior in areas such as data ownership, manuscript preparation, and conduct of persons in authority may be presented and discussed in terms of relevant ethical issues.

CSI 660/ASTR 535 Space Instrumentation and Exploration (3:3:0). Prerequisites: PHYS 262, MATH 213 or equivalent, or permission of instructor. Survey of the instruments, devices, and methods used for space and planetary exploration. Covers remote sensing of Earth and other solar system bodies. Planned manned and unmanned missions by United States and other countries.

CSI 672/STAT 652 Statistical Inference (3:0:0). Prerequisites: STAT 544 or permission of instructor. Critical aspects of probability, random variables and distributions, characteristic functions, and stochastic convergence. Optimal estimation, maximum-likelihood estimation, asymptotic theory, Bayesian methods, likelihood-ratio tests, statistical decision theory, sequential methods.

CSI 678/STAT 658 Times Series Analysis and Forecasting (3:0:0). Prerequisites: STAT 544 or CSI 672, or permission of instructor. Modeling stationary and nonstationary processes, autoregressive, moving average and mixed model processes, hidden periodicity models, properties of models, autocovariance functions, autocorrelation functions, partial autocorrelation function, spectral density functions, identification of models, estimation of model parameters, and forecasting techniques.
CSI 702 High-Performance Computing (3:3:0). Prerequisites: CSI 700 and CSI 701, or permission of instructor. Hardware and software associated with high-performance scientific computing. Computer architectures, processor design, programming paradigms, parallel and vector algorithms. Emphasis on the importance of software scalability in science problems.

CSI 703 Scientific and Statistical Visualization (3:3:0). Prerequisite: STAT 554 or CS 652, or permission of instructor. Covers visualization methods used to provide new insights and intuition concerning measurements of natural phenomena and scientific and mathematical models. Presents case study examples from a variety of disciplines to illustrate what can be done. Topics include human perception and cognition, an introduction to the graphics laboratory, elements of graphing data, representation of space-time and vector variables, representation of 3-D and higher dimensional data, dynamic graphical methods, and virtual reality. Students are required to work on a visualization project. Software tools on the Silicon Graphics workstation are emphasized, but other workstations and software may be used for the project.

CSI 709 Topics in Computational Sciences and Informatics (3:3:0). Prerequisites: Admission to Ph.D. program and permission of instructor. Covers selected topics in computational sciences and informatics not covered in fixed-content computational sciences and informatics courses. May be repeated for credit as needed.

CSI 710 Scientific Databases (3:3:0). Prerequisite: INFS 614 or equivalent, or permission of instructor. Study of database support for scientific data management. Covers requirements and properties of scientific databases, data models for statistical and scientific databases, semantic and object-oriented modeling of application domains, statistical database query languages and query optimization, advanced logic query languages, and case studies such as the human genome project and Earth-orbiting satellites.

CSI 735 Computational Neuroscience Systems (3:3:0). Prerequisites: CSI 734 (previously or concurrently), CSI 630, CSI 631, or permission of instructor. Overview of the nervous system and biological neural networks. Includes learning and memory, sensory systems, and motor systems. Stresses design and application of computational models. Students are required to propose and design a computational model that addresses some open issue in neuroscience.

CSI 741/ECE 721 Nonlinear Dynamical Systems (3:3:0). Prerequisites: Knowledge of linear algebra, advanced calculus, and differential equations. Contemporary topics in the field of nonlinear dynamical systems are illustrated in mathematical models from the natural sciences and engineering. Traditional qualitative analysis of difference and differential equations provides the background for understanding chaotic behavior when it occurs in these models. Topics include stability of equilibria and periodic orbits, bifurcation theory, Hamiltonian systems, Lyapunov exponents, and chaotic attractors.
CSI 750 Earth Systems and Global Changes (3:3:0). Prerequisite: Course in ecology, environmental geology, atmospheric physics, or permission of instructor. Introduction to the global system interactions responsible for global environmental change. Discusses the natural causes of past and present global changes, how human activities affect these global system changes, and the ecological and human consequences of these global changes. Topics include climate and hydrological systems, global warming, deforestation, ozone depletion, ecological system dynamics, introduction to climate and global change monitoring, satellite instrumentation and calibration, and model predictions.

CSI 758 Visualization and Modeling of Complex Systems (3:3:0). Prerequisite: Permission of instructor. Covers elements of modeling and analysis of Earth and space sciences data and systems. Concentrates on both sample projects and student-initiated projects as a means of using visualization and graphical analysis techniques as they apply to the modeling of complex data sets and systems. Several different analysis and visualization packages are used. Spacecraft data sets from the Naval Research Laboratory (NRL) Backgrounds Data Center and other NRL data sets are available for course projects. A perusal of data sets from the World Wide Web is also possible. Modeling and analysis are accompanied by appropriate readings from the current literature.

CSI 759 Topics in Earth Systems and Global Changes (3:3:0). Prerequisite: Permission of instructor. Covers selected topics in Earth systems and global changes not covered in fixed-content Earth systems/global changes courses. May be repeated for credit as needed.

CSI 771/STAT 751 Computational Statistics (3:3:0). Prerequisites: STAT 544, 554, and 652. Covers the basic computationally intensive statistical methods and related methods, which would not be feasible without modern computational resources. Covers nonparametric density estimation including kernel methods, orthogonal series methods and multivariate methods, recursive methods, cross-validation, nonparametric regression, penalized smoothing splines, the jackknife and bootstrapping, computational aspects of exploratory methods including the grand tour, projection pursuit, alternating conditional expectations, and inverse regression methods.

CSI 773/STAT 663 Statistical Graphics and Data Exploration (3:3:0). Prerequisite: Three hundred-level course in statistics; STAT 554 strongly recommended. Exploratory data analysis provides a reliable alternative to classical statistical techniques, which are designed to be the best possible when stringent assumptions apply. Topics include graphical techniques such as scatter plots, box plots, parallel coordinate plots, and other graphical devices; re-expression and transformation of data; influence and leverage; and dimensionality reduction methods such as projection pursuit.

CSI 775/OR 719/STAT 719 Computational Models of Probabilistic Reasoning (3:3:0). Prerequisites: STAT 652 or 664, or permission of instructor. Introduction to theory and methods for building computationally efficient software agents that reason, act, and learn environments characterized by noisy and uncertain information. Covers
methods based on graphical probability and decision models. Students study approaches to representing knowledge about uncertain phenomena, and planning and acting under uncertainty. Topics include knowledge engineering, exact and approximate inference in graphical models, learning in graphical models, temporal reasoning, planning, and decision-making. Practical model building experience is provided. Students apply what they learn to a semester-long project of their own choosing.

**CSI 873 Computational Learning and Discovery (3:0:0).** Prerequisites: CS 580 or equivalent, or permission of instructor. This course presents modern ideas, theories, and methods for computational learning and discovery, along with relevant applications. Application areas include medical diagnosis, earth science data analysis, and neuronal modeling. The course will include a background elucidation of fundamental concepts in computational learning, addressing in particular discovery of equations, theory of causality, and comparison with biological and cognitive models. Students will have an opportunity to make presentations on topics of their research interest, and to work on projects involving state-of-the-art systems.

**CS 580 Introduction to Artificial Intelligence (3:3:0).** Prerequisites: CS 310 and 330. Principles and methods for knowledge representation, reasoning, learning, problem solving, planning, heuristic search, and natural language processing and their application to building intelligent systems in a variety of domains. LISP, PROLOG, or an expert system programming language is used.

**CS 583 Analysis of Algorithms (3:3:0).** Prerequisites: CS 310, 330, and MATH 125. Topics include the analysis of sequential and parallel algorithmic strategies (such as greedy methods, divide and conquer strategies, dynamic programming, search and traversal techniques, approximation algorithms), the analysis of specific algorithms falling into these classes, NP-Hard and NP-Complete problems.

**CS 631 Object-Oriented Design Patterns (3:3:0).** Prerequisite: SWE 619 or 620 or CS 540 or 571 or a graduate course in object-oriented programming or equivalent. Principles of object-oriented design through design patterns. A study of the selection of appropriate object-oriented structure after the system requirements or requirements specification of the software system have been developed. Design patterns are created in the logic view of the software system. A study of generalized design solutions for generalized software design problems. A study of the reuse of design patterns. Once developed, design patterns may be specified in any object-oriented language.

**CS 635 Foundations of Parallel Computation (3:3:0).** Prerequisites: CS 583 and 540 or 571, or equivalent. Survey of the field of parallel computation. Three major parallel computing paradigms (MIMD computation, SIMD computation, and data flow computation) are covered. Emphasis is placed on the interfaces between algorithm design and implementation, architecture, and software. Parallel algorithms and parallel programming languages are examined relative to the architecture of particular parallel computers.
CS 652 Computer Graphics (3:3:0). **Prerequisite: CS 583.** Graphics principles and programming. Topics include graphics hardware, antialiasing, transformations, viewing, illumination, blending, texture mapping, color models, curves, surfaces, and animation.

CS 656 Computer Communications and Networking (3:3:0). **Prerequisites: CS 571 and STAT 344 or equivalent.** Techniques and systems for communication of data between computational devices and the layers of the Internet Protocol Suite. Topics include the role of various media and software components, local and wide area network protocols, network design, performance and cost considerations, and emerging advanced commercial technologies. Emphasis is on the TCP/IP family of protocols.

CS 680 Natural Language Processing (3:3:0). **Prerequisites: CS 540 and 580.** Explores the principles of the design of computer programs that respond appropriately to questions, commands, and statements expressed in human language, particularly English. Role of knowledge representation and linguistic theory. Students become familiar with current literature to implement a limited natural language processor.

CS 681 Designing Expert Systems (3:3:0). **Prerequisite: CS 580.** Design, construction, and evaluation of software systems that solve problems generally deemed to require human expertise. Focuses on the study and use of relevant languages, environments, mathematics, and logic. Case studies of successful systems are examined. Programming projects include development of tools or small-scale systems.

CS 683 Parallel Algorithms (3:3:0). **Prerequisite: CS 583; CS 635 recommended.** Examination of the design and analysis of parallel algorithms. Material focuses on algorithms for both theoretical and practical models of parallel computation. Algorithm design and analysis for the PRAM are considered, as well as for existing SIMD and MIMD type architectures. Topics include sorting, graph algorithms, numerical algorithms, and computational complexity.

CS 684 Graph Algorithms (3:3:0). **Prerequisite: CS 583.** Data structures and analytical techniques for the study of graph algorithms. Data structures discussed include disjoint sets, heaps, and dynamic trees. Algorithms treated include minimum spanning trees, shortest path, maximum flow, and graph planarity.

CS 685/ECE 651/SYST 672 Intelligent Systems for Robots (3:3:0). **Prerequisite: CS 580; or ECE 650; or SYST 611 or 555; or equivalent.** Review of recent developments in the area of intelligent autonomous systems. Applications of artificial intelligence, computer vision, and machine learning to robotics are studied. Topics include analysis and design of algorithms and architectures for planning, navigation, sensory data understanding, sensor fusion, spatial reasoning, motion control, knowledge acquisition, learning of concepts and procedures, self-organization, and adaptation to the environment.

CS 687 Advanced Artificial Intelligence (3:3:0). **Prerequisite: CS 580.** Exploration of foundational issues of artificial intelligence, such as the roles of knowledge and search,
the formalization of knowledge and inference, and symbolic versus emergent approaches to intelligence. Advanced programming techniques for artificial intelligence and their relationship both to the foundational issues and to the most important application areas for artificial intelligence are studied. Major programming project required.

**CS 688 Neural Network Principles (3:3:0).** *Prerequisite: CS 580 or equivalent.* Study of neural network models, algorithms, and applications. Several connectionist and biologically based models are introduced, and their capabilities and limitations are discussed. Variety of application areas are presented. Network simulation project is required.

**CS 773 Real-Time Systems Design and Development (3:3:0).** *Prerequisite: CS 656 or 671.* Real-time systems and the principles supporting their design and implementation. Emphasis is placed upon fundamental results from real-time scheduling theory and their relevance to computer system design. Topics include system design issues for real-time applications involving communication networks, operating systems, databases, and multimedia.

**CS 777 Human-Computer Intelligent Interaction (3:3:0).** *Prerequisites: CS 580 and 652 (or 682) or permission of the instructor.* Current and emerging issues in human-computer intelligent interaction and human-centered systems and their applications. Topics include video processing, visualization, virtual environments, adaptation and tutoring, image and scene modeling, analysis and synthesis, face and gesture recognition, speech and natural language processing. Term project and topical review required.

**CS 782 Machine Learning (3:3:0).** *Prerequisite: CS 681, 687, or 688 or permission of instructor.* Survey of the field of machine learning that is concerned with developing intelligent adaptive systems that are able to improve through learning from input data or from their own problem-solving experience. Topics provide broad coverage of past and current developments in machine learning, including basic learning strategies and multistrategy learning.

**CS 785 Knowledge Acquisition and Problem Solving (3:3:0).** *Prerequisite: CS 680, 681, or 687 or permission of instructor.* Principles and major methods of the basic stages of knowledge acquisition (systematic elicitation of expert knowledge, knowledge base refinement, and knowledge base optimization) in the context of general problem-solving methods. Case studies of successful knowledge acquisition and problem solving systems are presented. Projects include development or application of knowledge acquisition tools for knowledge-based systems.

**ECON 611 Microeconomic Theory (3:3:0).** *Prerequisite: Admission to the doctoral or master's program or ECON 306, ECON 311, and MATH 113, or permission of graduate coordinator.* Theory of behavior of consumers, firms, and resource suppliers. Theories of choice under conditions of risk and uncertainty. Partial equilibrium analysis of competitive and noncompetitive markets. General equilibrium analysis, welfare economics, and introduction to capital theory.
ECON 615 Macroeconomic Theory (3:3:0). Prerequisite: Admission to the master's program in economics or ECON 306, ECON 311, and MATH 108, or permission of graduate coordinator. Survey course covering monetary theory, theories of consumption and saving, budget deficits, economic growth, international finance, and monetary and fiscal policies.

ECON 623 American Economic History (3:3:0). Prerequisites: ECON 611 and 615, taken concurrently, or permission of instructor. ECON 637 is recommended. Growth and development of the American economy as well as the evolution of economic institutions.

ECON 632 Economic Systems Design - Principles and Experiments (3:3:0). Prerequisites: A course in linear and nonlinear optimization and a course in linear algebra. Introduction to the analytical and engineering principles used in developing exchange systems. Students will be required to become familiar with the literature on applied mechanism design and understand the behavioral aspects of auction systems, matching, assignment and transportation problems, and information markets. In addition, students will be introduced to methods for testbedding systems using experimental economics and statistical design.


ECON 715 Macroeconomic Theory I (3:3:0). Prerequisite: Admission to the doctoral program or permission of graduate coordinator. Classical, neoclassical, Keynesian, and post-Keynesian theories of income and employment determination. Theories of inflation and growth. The demand for money and its implications for the effectiveness of monetary vs. fiscal policy.


ECON 816 Macroeconomic Theory II (3:3:0). Prerequisites: ECON 611 and 715 or permission of instructor. Aggregate economic activity and price levels with emphasis on dynamic models. Topics vary.

ECON 817 Monetary Theory and Policy (3:3:0). Prerequisites: ECON 615 and 637 or permission of instructor. Theory of the mechanisms through which central banking affects economic activity and prices. Analysis of the demand for money and its relationship to economic activity. The development of monetary theory with emphasis on current theories and controversies in the field.

ECON 825 Political Economy and Public Policy I (3:3:0). Prerequisite: ECON 611 or
permission of instructor. Economic process of public policy formulation and implementation. Economic behavior of principals in policy making and execution.

ECON 826 Political Economy and Public Policy II (3:3:0). Prerequisites: ECON 611, 615, and 825 or permission of instructor. Specific issues related to political economy of public policy. Topics include privatization, political economy of deficit spending, regulation and deregulation, and the economics of rent seeking.

ECON 828 Constitutional Economics (3:3:0). Prerequisite: ECON 611 or permission of instructor. Analysis of existing and proposed elements of the "economic constitution." Emphasis on fiscal, monetary, transfer, and regulatory powers of government and on constitutional limits on such powers, especially in the United States. Also includes analysis of proposed changes in these limits.

ECON 829 Economics of Institutions (3:3:0). Prerequisite: ECON 611 or permission of instructor. Analysis of the framework of rules and institutions within which economic activities and transactions are carried out. Emergence and working properties of different institutions. Comparative discussion of classical and contemporary approaches to an economic theory of institutions.


ECON 849 Public Finance (3:3:0). Prerequisite: ECON 611 or permission of instructor. Theoretical and institutional analysis of government expenditure, taxation, debt management, and intergovernmental fiscal relations. Allocative and distributional effects of alternative tax and subsidy techniques. Principles of benefit-cost and cost-effectiveness analysis for government decisions.

ECON 856 Urban and Regional Economics (3:3:0). Prerequisite: ECON 611 or permission of instructor. Regional development and metropolitan growth economics including the locational decisions of households and firms, and problems associated with
high-density urban economic activity.

ECON 861 Economics of the Environment (3:3:0). Analysis of economic models of ecosystems and pollutant discharges into the environment. Methods of improving economic efficiency; review of public policies.

ECON 866 Economic Development (3:3:0). Prerequisites: ECON 611 and 615 or permission of instructor. Forces contributing to and retarding economic progress in developing countries. The role of foreign trade, economic integration, foreign investment, multinational corporations, and technological transfers.

ECON 869 International Trade and Policy (3:3:0). Prerequisite: ECON 611 or permission of instructor. Classical, neoclassical, and modern theories of international trade. A study of the theory and practice of world trade models such as project LINK. Analysis of foreign investment and economic growth, tariffs and nontariff barriers, and economic integration; recent developments with emphasis on natural resources.

ECON 871 International Monetary Economics (3:3:0). Prerequisite: ECON 615 or permission of instructor. Examination of the international adjustment mechanism, price and income effects, controls, and the monetarist approach. Development of the international monetary system, the demand for international reserves, capital movements, and the role of the International Monetary Fund.

ECON 880 Austrian Theory of the Market Process I (3:3:0). Prerequisite: ECON 611. Economic theory developed by Menger, Mises, Hayek, and others of the Austrian School and comparison with other currently popular theories.

ECON 881 Austrian Theory of Market Process II (3:3:0). Prerequisites: ECON 611 and 615 (ECON 880 is recommended). Continuation of ECON 880. Topics vary and include emphasis on market-process approach to analysis of capital accumulation, growth, money and credit institutions, inflation, unemployment, and industrial fluctuations.

ECON 885 Experimental Economics (3:3:0) Prerequisites: ECON 611 or permission of instructor. Designed for graduate students who have a desire to learn how experimental methods can be used to inform economic research and practice. Students are expected to have a working understanding of both basic economic concepts and multivariate calculus.

ECON 886 Economic Systems Design (3:3:0). Prerequisites: ECON 885 or permission of instructor. Exposes students to research in applied mechanism design. Topics represent the basic tools required to build, test, and implement mechanisms in an applied setting.

EVPP 607 Fundamentals of Ecology (3:3:0). Overview of concepts in physiological, population, community, and ecosystem ecology restricted to graduate students with little or no background in ecology.
EVPP 637 Human Dimensions of Global Change (3:3:0). Prerequisites: Graduate standing or permission of instructor. Examination of human dimensions of climate change, biodiversity loss, ozone depletion and related anthropogenic alterations of the biosphere.

EVPP 638 Corporate Environmental Management and Policy (3:3:0). Prerequisites: None. This course aims to provide an understanding of how environmental issues interact with business strategy decisions. Its emphasis is two-fold: to learn about proactive win-win environmental management strategies being implemented by the world's leading firms and to show how government policies and regulations can be designed to simultaneously promote higher environmental protection and competitiveness. Class sessions combine mini-lectures and participatory discussions.

EVPP 641 Environmental Science and Public Policy (3:3:0). Prerequisite: Course in ecology or permission of instructor. Effects of human activities on the environment. Airborne, waterborne, and solid waste material are considered with respect to sources, control, and effect on ecosystems.

EVPP 648 Population Ecology (3:3:0). Prerequisite: Course in ecology or permission of instructor. Survey of ecological models and theory. Topics include population growth and regulation, competition, predator-prey relationships, and models of community structure.

EVPP 650 Environmental Analysis and Modeling (4:3:3). Prerequisite: Course in ecology or permission of instructor. Students learn to conceptualize ecological systems, represent these conceptualizations mathematically, and develop and test models against field data. Multivariate models and dynamic simulation models are emphasized.

EVPP 670 Environmental Law (3:3:0). Prerequisites: Course in ecology, environmental biology, or permission of instructor. Study of environmental laws such as the National Environmental Policy Act and regulatory issues such as the Clean Water and Clean Air Acts. Emphasis on critical evaluation of alternatives to unresolved issues in environmental policies.

EVPP 675 Environmental Planning and Administration (3:3:0). Interaction of man and ecological systems; causes of damage or deterioration in the environment; content, oversights, and externalities in the management decision processes that affect the environment and the effectiveness of plan implementation; means of assessing environmental impact; and administrative approaches for minimizing environmental impact.

GEOG 653 Geographic Information Analysis (3:3:0). Prerequisites: GEOG 553 and 585. Exploration of existing and potential capabilities of geographic information systems in conducting spatial analysis and spatial modeling.
GEOG 664 Spatial Data Structures (3:3:0). Prerequisite: GEOG 310 or 550. The study of spatial data structures and their application in digital cartography, geographic information systems, and image-processing systems. Raster and vector data structures are examined, as well as attribution schemes and topological models. Data transformation, information loss, data quality, and the role of metadata are included.

GEOG 795 Seminar in Regional Analysis (3:3:0). Analysis and synthesis of physical and cultural elements of geography in a selected region. Should be taken near the end of the master's degree program and should provide an opportunity for the student to apply selective knowledge gained in previous systematic courses to a specific region.

GOVT 605 Seminar in Congress and the Presidency (3:3:0). Surveys the major institutions of public policy formulation and implementation at the national level in the United States with an emphasis on how public preferences are translated into public policy. The politics, procedures, and personnel of Congress, the presidency, and executive branch bureaucracies are the main focus.

GOVT 606 Federalism and Changing Patterns of Governance (3:3:0). Prerequisites: GOVT 510. Examines broad trends in governance, including both the theory and practice of key governance choices, with a particular focus on intergovernmental relations and the changing roles of federal, state, and local governments. Specific governance choices examined may include privatization, devolution, mandating, regulatory reform, and comprehensive federalism reform.

GOVT 631 Seminar in Comparative Politics and Institutions (3:3:0). Examines the theories and practices of governance, development, and conflict resolution in comparative national settings. Covers issues such as elections in presidential and parliamentary democracies, institutional forms, political cultures, and ideologies. Theories of comparative analysis and research reflecting alternative analytic perspectives are brought to bear on the institutions and political processes of nations and regions.

GOVT 641 Seminar in Global Systems (3:3:0). Prerequisites: Completion of all core courses. Application of the systems approach to an understanding of global politics. Emphasizes the properties and functions of global systems, such as population, food, disease, energy, trade, and so forth, and how the world's political systems interact with them. Discusses how governance at municipal to national to international levels is affected by global systems. Examines the role of nongovernmental organizations in global affairs.

GOVT 703 Seminar in the Courts and Constitutional Law (3:3:0). Analysis of the role, influence, and effects of the U.S. courts in creating constitutional legal norms and interpreting them. Special attention is paid to the First and Fourteenth Amendments as well the Commerce Clause. Instruction by lecture and discussion with students expected to read and analyze leading court cases.

GOVT 725 Democratic Theory and Democratization (3:3:0). Prerequisites: GOVT
Examines democracy in terms of versions of liberalism, theories of social capital and civic participation, and discourses about civil, political, and human rights. Deals with the following questions: How is democracy conceptualized both normatively and empirically? What underlying economic, social, and cultural conditions promote democracy? What role do institutions play in creating and sustaining a stable democratic society? Takes a broadly comparative perspective, focusing not only on the United States, but also on a variety of established and emerging democracies from around the world. Serves as an elective for students specializing in American government or in international politics and comparative governments.

**GOVT 731 Advanced Seminar in Comparative Politics (3:3:0).** Prerequisites: GOVT 540. Addresses theoretical and methodological issues central to the study of comparative politics by focusing on a specific topic (international development, race and ethnicity, social movements) or region (Latin America, Asia, Middle East, Europe/European Union, Africa, Russia). Assumes basic proficiency in comparative analysis (as provided in GOVT 540) and focuses on advanced modes of inquiry through in-depth analysis and discussion of selected issues and themes. May be repeated for credit when the topic is different and with permission of the department.

**GOVT 741 Advanced Seminar in International Politics (3:3:0).** Prerequisites: GOVT 540. Examines theoretical and methodological issues central to the study of international relations by focusing on a specific topic: American foreign policy, diplomacy, international law and organization, international relations theory, international ethics, human rights and humanitarian intervention, the environment, and others. May be repeated for credit when the topic is different and with permission of the department.

**GOVT 743 International Political Economy (3:3:0).** Prerequisite: GOVT 343 or equivalent. Examines the interplay of international politics and economics. Discusses theoretical perspectives and analytical tools available in the academic field of international political economy and applies these theories and tools to issue areas such as trade, investment, exchange rates, development, regionalization, and globalization. Explores how international economic and political forces increasingly shape domestic interests and how domestic politics in turn affect international political economy. This course mixes lecture and discussion.

**GOVT 745 Issues in International Security (3:3:0).** Prerequisites: GOVT 540. Examination of issues of topical interest in the general area of international security. Possible topics include nuclear strategy, arms control, U.S. defense policy, ethics and international security, and international terrorism.

**HIST 601 Themes in U.S. History I (3:3:0).** Survey of U.S. history prior to 1877. Designed for individuals entering the graduate program who need to strengthen their preparation in this area or who seek to enhance their knowledge of the latest interpretations in the field. Factual knowledge and its interpretation are stressed.

**HIST 602 Themes in U.S. History II (3:3:0).** Continuation of HIST 601.
HIST 605 Themes in European History I (3:3:0). Survey of European history from 1500 to 1815. Designed for individuals entering the graduate program who need to strengthen their preparation in this area or who seek to enhance their knowledge of the latest interpretations in the field. Factual knowledge and its interpretation are stressed.

HIST 606 Themes in European History II (3:3:0). Survey of European history from 1815 to present. Designed for individuals entering the graduate program who need to strengthen their preparation in this area or who seek to enhance their knowledge of the latest interpretations in the field. Factual knowledge and its interpretation are stressed.

HIST 610 The Study and Writing of History (3:3:0). Methodology of the historian including techniques of research, use of documentation and other sources, development of bibliography, and synthesis of material.


HIST 615 Problems in American History (1-6:1-6:0). Readings and discussion of bibliographies, interpretations, and research trends in topics selected by instructor. Course may be repeated when content differs.

HIST 616 U.S. Westward Movement (3:3:0). Investigation of continuity and change in the American West, focusing on such topics as economic development, ethnicity, rural and urban life, and the role of the federal government.

HIST 617 Topics in the American Civil War Era (3:3:0). Joint project of instructor and students into the various aspects of a common topic in the Civil War era with emphasis on historiography and historical method.

HIST 618 The Age of Jackson, 1815-1854 (3:3:0). Survey of the social, cultural, intellectual, economic, and political changes in the United States during a period of rapid growth and expansion. Among the topics studied are the second-party system; the growth of sectionalism, nationalism, and expansionism; industrialization and the spread of the market economy; the rise of romantic reform and evangelical religion; and the growth of abolitionist and proslavery movements.

HIST 619 The Constitution, Civil Liberties, and the Supreme Court (3:3:0). Investigation of the evolution of civil liberties in American history and the interaction of the three branches of government in applying the various constitutional guarantees. Students read extensively in Supreme Court decisions as well as in the secondary literature, and undertake independent research.

HIST 620 Development of the Early Republic, 1783-1815 (3:3:0). Investigation of the breakdown of the Confederation, the Constitutional Convention, and the role of the
revolutionary ideology of republicanism. Leadership and policies of the republic in a hostile international context are discussed. Students read extensively in the monographic literature and prepare a research paper.

**HIST 621 Virginia and the American Revolution (3:3:0).** Detailed examination of Virginia society on the eve of the American Revolution and its role in the events from 1750 to 1789. Combines lectures on and discussion of major themes, ideas, and personalities.

HIST 623 Recent U.S. History, 1945 to Present (3:3:0). Selected political, social, economic, diplomatic, and cultural forces that shaped the post-World War II American experience.

**HIST 624 U.S. Diplomatic History (3:3:0).** Study of selected issues in American foreign relations and changing historical interpretations of American diplomacy.

**HIST 627 Urban Development of the United States (3:3:0).** Examination of the growth of cities in the United States, the process of urbanization, and the significance of cities in American history. Students become familiar with major issues and bibliography of American urban history.

**HIST 628 Immigration and Ethnicity in the United States (3:3:0).** Examination of immigration and ethnicity in America since 1840. Consideration of why immigrants came, from where, under what circumstances, and the ways in which they adapted to America. Examination of immigration policy and American attitudes toward immigration and ethnicity. Conducted as a readings colloquium.

**HIST 629 The Gilded Age and Progressive Era (3:3:0).** Examines the history of the United States from 1877 to 1918, with attention both to the history of reform movements and politics, and the social history of the period. Students become familiar with major issues and historical literature of the period.

**HIST 630 U.S. Women's History (3:3:0).** Wide-ranging survey of the burgeoning field of women's history, emphasizing critical evaluation of sources and interpretation. Readings are selected to represent a variety of approaches to the history of women, which may include material culture studies, medical history, history of sexuality, political history, and social and cultural history.

**HIST 631 Era of the American Revolution (3:3:0).** Examines the history and historiography of the revolutionary era, with a special emphasis on the social and ideological interpretations of the period. Includes the events leading up to the War for Independence, the war itself, and the social and political effects of the war on American society.

**HIST 633 Reconstruction (3:3:0).** Examines the panoply of political, social, economic, and constitutional concerns during the period 1863 to 1880, as the North and South
struggled over the outcome of the Civil War. Among the many important questions to be addressed are those of political institutions and power in the postwar North and South, and the place of the former slaves in society, politics, and the economy.

**HIST 711 Research Seminar in U.S. History (3:3:0).** Prerequisite: HIST 610 or permission of department. Research in specialized topics using primary sources. Maximum of six credits may be earned.

**HIST 731 Research Seminar in European History (3:3:0).** Prerequisite: HIST 610 or permission of department. Research in specialized topics using primary sources. Maximum of six credits may be earned.

**HIST 751 Research Seminar in Comparative World History (3:3:0).** Prerequisite: HIST 610 or permission of department. Research seminar requiring comparative research and analysis. Organized around a significant topic or theme in the field of world history. Topics vary from year to year. A maximum of six credits may be earned.

**IT 557 Introduction to Network Science (3:3:0).** Prerequisites: Bachelor's degree in math, science, or engineering; Math 114 and 351. This course is the first of a sequence of two intended to provide a broad treatment of the principles and technologies of modern telecommunications, combined with computing, that create computer networks. Emphasis is on providing sufficient breadth and depth to allow a technical professional to function as an effective entry-level network engineer. This course includes modules in telecommunications principles, telecommunications carrier systems, data communications, local area networks, and wide area network protocols.

**IT 657 Advanced Network Science (3:3:0).** Prerequisite: IT 557 or permission of instructor. This course is the second of a sequence of two intended to provide a broad treatment of the principles and technologies of modern telecommunications, combined with computing, that create computer networks. Emphasis is on providing sufficient breadth and depth to allow a technical professional to function as an effective entry-level network engineer. This course includes modules in wireless telecommunications, network security, network management, and advanced network protocols.

**IT 811 Principles of Machine Learning and Inference (3:3:0).** Prerequisite: CS 80, 681, or permission of instructor. Presentation of unifying principles that underlie diverse methods, paradigms, and approaches to machine earning and inference. Reviews the most known learning and inference systems, discusses their strengths and limitations, and suggests the most appropriate areas of their application. Students get a hands-on experience by experimenting with the state-of-the-art learning and inference systems and work on projects tailored to their research interests.

**IT 812 Advanced Topics in Natural Language Processing (3:3:0).** Prerequisite: CS 680. Advanced treatment of topics in syntax, semantics, and generation of linguistic output. Implementation and applications are also discussed.
IT 842 Models of Probabilistic Reasoning (3:3:0). Prerequisite: STAT 544 and OR 681. Survey of alternative views about how incomplete, inconclusive, and possibly unreliable evidence might be evaluated and combined. Among the views discussed are the Bayesian, Baconian, Shafer-Dempster, and Fuzzy systems for probabilistic reasoning.

IT 852 Graphical Real-Time Simulation (3:3:0). Prerequisite: CS 652 or IT 875. Current research in advanced computer graphics and its applications in realistic real-time simulations. Topics include physically based modeling, real-time simulation, distributed interactive simulation (DIS), network virtual environments (NVE), and virtual reality (VR).

IT 858 Logic Models in Artificial Intelligence (3:3:0). Prerequisite: CS 580. Examination of the relevance of logic theory to artificial intelligence. Familiarizes students with a variety of formal logics that are used in artificial intelligence, as well as ongoing research in new logics. Topics include first-order predicate calculus, resolution and nonresolution theorem proving, nonmonotonic logic, assumption-based reasoning, the relationship between symbolic and quantitative theories of uncertainty, temporal logics, and their application to planning and metareasoning.

IT 860 Software Analysis and Design of Real-Time Systems (3:3:0). Prerequisite: SWE 623. Background for students who want to conduct research in the software engineering of real-time systems. Students gain an understanding of key real-time software system analysis, design concepts and methods, and how they are used in the development of large-scale, real-time software systems. Students also gain an understanding of the potential impact of emerging technologies in this field. Term project in the design and analysis of a complex real-time software system is undertaken.

IT 861 Distributed Database Management Systems (3:3:0). Prerequisite: INFS 614 or equivalent. Topics in distributed database management including transaction management, concurrency control, deadlocks, replicated database management, query processing reliability, and surveys of commercial systems and research prototypes.

IT 862 Computer Security Models and Architectures (3:3:0). Prerequisite: INFS 767 and INFS 780. This course covers modern computer security models and architectures in the context of large-scale distributed systems, including cross-enterprise systems. Models for role-based access control, lattice-based access control, and delegated administration are studied and compared with respect to formal and pragmatic criteria. Architectures to implement these models based on public-key infrastructure, trusted servers, and other components are studied.

IT 870 Organizational Informatics (3:0:0). Prerequisite: doctoral status or permission of instructor. An examination of the effects of informatics on national and international policy; setting of international policy on informatics; ethical and social change in governments and organization; shaping of national policy in informatics; industry growth; and research methods from various scientific discipline.
IT 886/ECE 751 Information Theory (3:3:0). Prerequisite: ECE 630 or STAT 644 or equivalent or permission of instructor. Introduction to information theory, the mathematical theory of communication systems. Topics include: measures of information: entropy, relative entropy and mutual information, the Shannon-McMillan-Breiman theorem and its applications to data compression, entropy rate and the source coding theorem, Huffman, arithmetic and the Lempel-Ziv codes, the method of types, channel capacity and the channel-coding theorem, the joint source-channel coding theorem, differential entropy, the Gaussian channel, rate distortion theory, and vector quantization.

IT 890 Special Topics in Urban Transportation (3:3:0). Prerequisite: CEIE 660,560 or equivalent; or permission of instructor. Special topics and recent developments in Urban Transportation. Possible subjects include traffic safety analysis, simulation in transportation, intelligent transportation systems, and advanced public transportation systems. Congestion management, travel demand management, geographic information systems in transportation, innovative refinancing and public-private partnerships in transportation, information technology in transportation. May be repeated for credit when topics are distinctly different.

IT 891 Special Topics in Applications of Information Technology to Urban Systems Engineering (3:3:0). Prerequisites: CEIE 670 or permission of the instructor. Special topics and recent developments in the area of Information Technology as applied to civil engineering. Possible topics include inventive engineering, design engineering, network computing, building and using intelligent agents in engineering, proactive design, etc. May be repeated for credit when topics are distinctly different.

IT 894 Design and Inventive Engineering (3:3:0). Prerequisite: SYST 573, CEIE 670, or OR 681 or permission of instructor. Topics include evolution of engineering, design engineering, inventive engineering, general design methodology, conceptual versus detailed design, axiomatic design theory, inferential design theory, engineering method in design, design paradigms, case-based design, proactive design, design evaluation, virtual design studio, Internet and browsers in design, creative problem solving, problem solving methods, and computer tools to support design creativity.

IT 910 Advanced Topics in Artificial Intelligence (3:3:0). Prerequisite: Graduate course in artificial intelligence. Special topics in artificial intelligence not occurring in the regular computer science sequence. Requires substantial student participation. Subject matter may include continuation of existing 600- or 700-level courses in artificial intelligence and/or other topics. May be repeated for credit when subject matter differs.

IT 915 Advanced Topics in Parallel Computation (3:3:0). Prerequisite: IT 815. Discussion of current research topics in parallel computation. Topics vary according to student and faculty interest. Possible topics include formal models of concurrency, specification and design of parallel programming languages, logic programming in a parallel environment, and parallel distributed processing (neural networks).
IT 922 Concurrent Object-Oriented Systems (3:3:0). Prerequisite: IT 822. Comparative study of existing concurrent object-oriented approaches to problem analysis and software construction. Introduces current research issues in concurrent object-oriented systems, concurrency models, and concurrent object-oriented programming languages and development tools.

IT 941 System Identification and Adaptive Control (3:3:0). Prerequisite: ECE 621 or permission of instructor. Advanced treatment of identification and adaptive control. Topics include identification algorithms, their convergence and accuracy, and computational aspects; model reference and self-tuning adaptive control, transients, stability and robustness; and intelligent schemes to improve robustness. Students are also required to study the literature and to complete a computer project.

IT 944 The Process of Discovery and Its Enhancement in Engineering Applications (3:3:0). Prerequisite: IT 842 or permission of instructor. Study of ingredients of imaginative reasoning as it concerns the efficient discovery of new ideas and valid evidential test of them. Topics include different interpretations of Peirce's theory of abductive reasoning, other forms of reasoning, Hintikka's analysis of the process of inquiry, and current attempts to design systems that provide assistance in discovery-related or investigative activities.

IT 950 Design and Management Aspects of Information Systems (3:3:0). Prerequisite: INFS 790 or equivalent. Impact of organizations and management of information systems (IS) and vice versa. Topics include problems of introducing IS; the effect on organizational economic and political framework; participative design and new techniques for specification, analysis, design, and implementation of IS; rapid prototyping and expert systems; possible conflicts; methods in life-cycle management; and economic analysis.

IT 958 Basic and Applied Decision Support Systems Technology (3:3:0). Prerequisite: SYST 642. Analysis of tools, techniques, and methods that contribute to the design, development, application, and evaluation of interactive computer-based decision support systems. State of the art and state of the expectation of basic and applied decision support systems technologies like requirements definition, software engineering, analytical methods assessment, and structured evaluation are analyzed.

MATH 653 Risk Theory (3:3:0). Prerequisite: MATH 351 or STAT 644 required. MATH 555 recommended but not required. Economics of insurance, individual risk models for short term, collective risk models for single period, collective risk models over an extended period, and applications of risk theory. Material included in this course corresponds to the Society of Actuaries Exam: Risk Theory.

MATH 654 Survival Models and Construction of Tables (3:3:0). Prerequisite: MATH 556 or permission of instructor. Nature and properties of survival models, methods of estimates from complete and incomplete data, tabular and parametric models, and

**MATH 671 Fourier Analysis (3:3:0).** Study of fundamental ideas in Fourier analysis. Topics include orthonormal systems, Fourier series, continuous and discrete Fourier transform theory, generalized functions, and an introduction to spectral analysis. Applications to the physical sciences, linear systems theory, and signal processing are used to motivate and integrate these topics.

**MATH 672 Wavelet Theory (3:3:0).** Prerequisites: Some knowledge of advanced calculus and computer literacy. Study of the theory and computational aspects of wavelets and the wavelet transform. Emphasizes computational aspects of wavelets, defining the Fast Wavelet Transform in one and two dimensions. Developing the appropriate numerical algorithms. Includes developing the theory of wavelet bases on the real line, discussing multi-resolution analysis, splines, time-frequency localization, and wavelet packets.

**MATH 673 Dynamical Systems (3:3:0).** Prerequisites: Elementary courses in linear algebra and differential equations. Contemporary topics in the field of nonlinear dynamical systems are illustrated in mathematical models from physics, ecology, and population dynamics. Traditional qualitative analysis of difference and differential equations provides the background for understanding chaotic behavior when it occurs in these models. Topics include stability theory, fractals, lyapunov exponents, and chaotic attractors.

**MATH 674 Stochastic Differential Equations (3:3:0).** Prerequisites: MATH 214 and MATH 351. Introduction to stochastic calculus and differential equations. Wiener process, Ito and Stratonovich integrals, Ito formula, martingales, diffusions, and applications. Simulations and numerical approximations of solutions.

**OR 635 Discrete System Simulation (3:3:0).** Prerequisite: OR 542 or STAT 354 or 344, or equivalent, and knowledge of a scientific programming language. Computer simulation as a scientific methodology in operations analysis, with emphasis on model development, implementation, and analysis of results. Discrete-event models, specialized languages, experimental design, and output statistics are covered. Extensive computational work is required.

**OR 640 Global Optimization and Computational Intelligence (3:3:0).** Prerequisite: MATH 203 or equivalent and knowledge of a scientific programming language. An introduction to global optimization in the context of large-scale, nonconvex mathematical programs and numerical methods for the solution of such problems. Topics covered include: high-level survey of traditional mathematical programming algorithms; critical comparison of metaheuristics and artificial intelligence (AI) algorithms to traditional mathematical programming algorithms; probabilistic search, multi-start methods, statistical tests of performance and confidence, simulated annealing, genetic algorithms, neural networks, Tabu search, homotopies and tunneling; the traveling salesman problem,
the Steiner problem, Stackelberg-Cournot-Nash mathematical games and other classical nonconvex optimization problems.

**OR 43 Network Modeling (3:3:0).** Prerequisites: OR 541 or permission of instructor. An introduction to network problems in operations research, computer science, electrical engineering, and systems engineering. Solution techniques for various classes of such problems are developed. Topics include minimal-cost network flow, maximal flow, shortest path, and generalized networks; plus stochastic networks, network reliability, and combinatorially-based network problems. The complexity of each problem class is also analyzed.

**OR 675/STAT 678/SYST 675 Reliability Analysis (3:3:0).** Prerequisite: STAT 544 or 554 or permission of instructor. An introduction to component and system reliability, their relationship, and problems of inference. Topics include component lifetime distributions and hazard functions, parameter estimation and hypothesis testing, life testing, accelerated life testing, system structural functions, and system maintainability.

**OR 681/SYST 573 Decision and Risk Analysis (3:3:0).** Prerequisite: OR 542 or MBA 638. Application of analytic reasoning and skills to practical problems in decision-making. Topics include problem structure, and analysis and solution implementation, emphasizing contemporary approaches to decision analytic techniques.

**OR 683 Principles of Command, Control, Communications, and Intelligence (C 3I) (3:3:0).** Prerequisite: ECE 528 or OR 542 or equivalent. Fundamental principles of C 3I are developed from a descriptive, theoretical, and quantitative perspective. The principles and techniques are applicable to a wide range of civilian and military situations. Topics include C 2process; modeling and simulation for combat operations; detection, sensing, and tracking; data fusion and situation assessment; optimal decision making; methodologies and tools of C 3I architectures; tools for modeling and evaluations of C 3systems such as queuing theory are also included.

**OR 690 Optimization of Supply Chains (3:3:0).** Prerequisites: graduate standing, mathematics through linear algebra, and STAT 344. This course focuses on both supply chain optimization from an enterprise-wide perspective, and supply chain optimization from a business-to-business e-commerce concern. Thus the course is concerned with optimizing the value of goods and services and assuring a reasonable return on such sales. The course describes both heuristic and exact algorithms for scheduling, production, inventory management, logistics, and distribution. New software that enables such optimization is presented, as are manufacturing and service examples from the public and private sectors. New techniques to handle risk, quality of data, and robustness of solutions are presented. Students perform case studies using state-of-the-art software.

**OR 719/STAT 719/CSI 775 Computational Models of Probabilistic Reasoning (3:3:0).** Prerequisites: STAT 652 or 664, or permission of instructor. Introduction to theory and methods for building computationally efficient software agents that reason, act, and learn environments characterized by noisy and uncertain information. Covers
methods based on graphical probability and decision models. Students study approaches to representing knowledge about uncertain phenomena, and planning and acting under uncertainty. Topics include knowledge engineering, exact and approximate inference in graphical models, learning in graphical models, temporal reasoning, planning, and decision-making. Practical model building experience is provided. Students apply what they learn to a semester-long project of their own choosing.

PHIL 520 Current Issues in Philosophy of Science (3:3:0). Prerequisite: Graduate standing or permission of instructor. Advanced exploration of the current issues addressing the structure of scientific knowledge. The fundamental question is, What are the rational standards for acquiring knowledge of the physical world? This question is explored from rival philosophical perspectives: the logical-empiricist perspective of the Received View, represented by R. Carnap and C. Hempel; the problem-solving perspective of the historicists T. Kuhn and L. Laudan; and the rationalism of W. Newton-Smith; and the antirealism of V. van Fraassen.

PHIL 560 Philosophical Foundations of Science (3:3:0). Prerequisite: Graduate standing or permission of instructor. Focuses on metaphysical questions concerning the nature of physical reality, as presented within major scientific theories of the modern era. Questions are explored within the scientific/metaphysical principles of Kepler, Galileo, Boyle, Newton, Kant, Faraday, Einstein, and Bohr.

PHIL 621 Philosophy of Science (3:3:0). Prerequisites: Graduate standing. An exploration of whether and how scientific advances can be achieved. Special attention is paid to relativism and rationalism debates and to the role of technology in science.

PUAD 502 Administration in Public and Nonprofit Organizations (3:3:0). Graduate introduction to the field of public administration. Focuses on structure, functions, and processes of the executive branch agencies of national, state, and local governments. Emphasis on nonprofit organizations as co-actors with government in the policy-making/policy implementation nexus.

PUAD 504 Managing in the International Arena: Theory and Practice (3:3:0). Theoretical and empirical examination of the international system that both affects and is affected by the decisions, behaviors, and subsystems of state and nonstate (organizational) actors.

PUAD 509 Justice Organizations and Processes (3:3:0). Examination of the structures, practices, and performance of organizations involved in the administration of justice (law enforcement, courts and legal agencies, corrections, regulatory and related agencies, private organizations). Explores the applicability of various theoretical perspectives on organizational processes and considers the extent to which processes operate as a system. Focus is on comparing formal goals and system expectations to actual practice.
**PUAD 510 Policing in a Democratic Society (3:3:0).** Fundamental issues in policing a democratic society. Topics include the police mission; impact of the police subculture; defining, recognizing, and measuring good police work; moral hazards of policing (corruption, brutality, and deception); the promotion of integrity, discretion, and control; impact of police practices on crime and disorder; securing the support of the public; and the legitimacy of police, community policing, and other reforms.

**PUAD 615 Administrative Law (3:3:0).** Law as a guiding and controlling force in public-sector operations. Covers application of legal processes to administrative practices and situations, and administrative determination of private rights and obligations.

**PUAD 620 Organization Theory and Management Behavior (3:3:0).** Consideration of behavior within the context of public organization and the consequent changes required in management. Focus on such issues as perception, attitude formation, motivation, leadership, systems theory, communication and information flow, conflict theory, and decision theory.

**PUAD 621 Principles and Practices in Government Organization and Management (3:3:0).** Prerequisite: PUAD 620. Major management theories applicable to the American federal system. Emphasis is on organization, structure, and operations. The relationship of theories to management practices in contemporary American administration is explored.

**PUAD 622 Program Planning and Implementation (3:3:0).** Prerequisite: PUAD 620. Practical exploration of implementing public law in the American federal system. Construction of organizational apparatus, development of operational plans, and systems of control and evaluation necessary to implement government programs are studied. Emphasis is on coordinating tasks and resources required for effective program implementation.

**PUAD 634 Management of International Security (3:3:0).** Examination of theory and practice of managing international security. Emphasis is on interplay of organizational structure and bureaucratic dynamics in the international context. Theory and practice of crisis management and coordination and comparison of security methods and techniques are presented.

**PUAD 640 Public Policy Process (3:3:0).** Processes of making public policy, including detection of public issues, consideration of alternatives, and adoption and implementation of solutions. Highlights the major actors in the policy process, as well as the environment within which they work.

**PUAD 643 Public Policy Research (3:3:0).** Prerequisite: PUAD 640. Examination of major concepts, designs, and methods used in applied policy research. The underlying logic of policy inquiry, and the use of quantitative and qualitative techniques, is explored. Includes case applications of each of the major styles of inquiry, and the steps in planning, administering, and reporting policy research.
PUAD 644 Public Policy Models (3:3:0). Prerequisite: PUAD 640. Approaches to modeling policy problems. Includes an analysis and comparison of the dominant paradigms in the policy sciences. Assumptions and implications of different models and their utility for analysis, implementation, and evaluation are reviewed.

PUAD 651 Virginia Politics, Policy, and Administration (3:3:0). Prerequisite: PUAD 502. Cultural, demographic, constitutional, and socioeconomic environment of public administration in Virginia. Governmental agencies, legislative functions, executive leadership, staff agencies, state-local relationships, intrastate regionalism, and administrative customs peculiar to Virginia are covered.

PUAD 661 Public Budgeting Systems (3:3:0). Survey focusing on the policy and theoretical framework of revenue and expenditure choices at all levels of government. Topics include development, theories, and structure of budgeting; political, economic, and managerial aspects of public budgeting; public policy implications; and budgetary reform movements and their successes and failures.

PUAD 670 Human Resources Management in the Public Sector (3:3:0). Prerequisite: PUAD 502. Overview of the range and complexity of functions, responsibilities, and expectations of human resource staff and line managers within the public sector. Focus is on human resources management within the context of political, legal, and managerial systems. Human resource functions, such as hiring, performance, and development, are also presented.

PUAD 671 Public Employee Labor Relations (3:3:0). Public employee labor relations, including unionization, representational elections, bilateral policy negotiations, administration of agreements, management rights, union and membership security, the strike issue and grievance procedures, impact on public administration, and assessment of future developments.

PUAD 680 Managing Information Resources (3:3:0). Prerequisite: Admission to M.P.A. program or permission of instructor. Examination of how managerial and analytical functions in public organizations can be performed via end-user computer applications. Provides in-depth coverage of selected database and decision support packages, and gives attention to logic and integration of application software.

PUAD 691 Justice Program Planning and Implementation (3:3:0). Prerequisites: PUAD 502 and 509. The development and construction of organizational systems to implement government policies and programs. Emphasis on dealing with real-world challenges, constraints, and opportunities to create feasible plans, performance-monitoring systems, and secure multiple agency coordination. Applications of planning and implementation principles to actual projects in justice agencies.

PUAD 720 Performance Measurement (3:3:0). Methods used by managers to systematically assess performance. Includes practical tools such as focus groups, survey
research, cost/benefit analysis, benchmarking, and comparison methods for revealing outcomes and impacts. Prepares managers to use information more effectively in developing programs and services and formulating policy, and covers reporting techniques to communicate performance results.

PUAD 727 Seminar in Risk Assessment and Decision Making (3:3:0). Prerequisite: 12 graduate credits. Examination of decision making under risk and uncertainty. Readings introduce the major intellectual perspectives on the topic and are drawn from a variety of disciplines, including biology, economics, law, and psychology. Emphasis is on making actual decisions under uncertainty.

PUAD 729 Issues in Public Management (1-3:1-3:0). Prerequisites: PUAD 502 and nine graduate credits. May be repeated with different topic. Current issues in management of public organizations in contemporary American government. Practical applications of theories and analysis to managerial problems are included. Competence in improving management in selected government settings is emphasized.

PUAD 732 Managing Technology Transfer (3:3:0). Prerequisite: 12 graduate credits. Examination of how governments, businesses, and international organizations manage cooperation and competition in the transfer of technology. Case studies on East-West, West-West, and North-South relations are included.

PUAD 738 Issues in International Security (1-3:3:0). Prerequisites: PUAD 504 and nine graduate credits. May be repeated with different topic. Examination of issues of topical interest in the general area of international security. Possible topics include nuclear strategy, disarmament, American defense policy, and international terrorism.

PUAD 742 Program Evaluation (3:3:0). Prerequisites: PUAD 502 and 611. Practical exploration of assessment techniques used in studying the results of public programs and policies, including evaluation of implementation strategies and impacts. Draws on multiple approaches such as cost analysis, field research, experiments, productivity analysis, surveys and questionnaires, and qualitative studies.

PUAD 749 Issues in Public Policy (1-3:3:0). Prerequisites: PUAD 502 and nine graduate credits. Examination of significant current issues in public policy in contemporary American government. Emphasis is on practical applications of theories and analysis to policy problems. Competence in improving policy analysis in selected government settings is also emphasized.

PUAD 750 Federalism and Changing Patterns of Governance (3:3:0). Prerequisites: PUAD 502 and nine graduate credits. Examination of broad trends in governance, including both the theory and practice of various governance choices. Choices include privatization, decentralization of governmental activity, grants-in-aid and growth of mandates, changing role of state and local governments, proposals for reforming federalism, and regulatory reform.
PUAD 759 Issues in Local Government Administration (1-3:3:0). Prerequisites: PUAD 502 and nine graduate credits. May be repeated with different topic. Management and policy formulation in American local governments. Addresses environments, institutions, and actors involved. Contemporary problems, such as education, criminal justice, transportation, land use, economic development, and environmental impact, are examined.

PUAD 769 Issues in Public Financial Management (1-3:3:0). Prerequisites: PUAD 502 and nine graduate credits. Current issues in budgeting and financial management in contemporary American government. Practical applications of administration and management issues and policy choices at all levels of government are emphasized.

PUAD 781 Information Management: Technology and Policy (3:3:0). Prerequisite: PUAD 680 or permission of instructor. Examines the challenges that organizations encounter as they move to a more technologically sophisticated information and communication environment. Organizational policy issues evolving from new technologies, including privacy, security, authentication, content control, intellectual property, and taxation, are studied, focusing on the effectiveness of previous policy solutions and analyzing proposed solutions.

PUAD 791 Justice Program Evaluation (3:3:0). Prerequisites: PUAD 611 and 612. Practical exploration of assessment techniques used in studying the need for and consequences of justice programs and policies. Covers needs assessments, process, and impact evaluations. Includes design and measurement issues for assessing the performance of justice programs and interpretation and presentation of results. Course emphasizes designing a program evaluation for a justice agency.

PUAD 799 Issues in Justice Administration (1-3:1-3:0). Prerequisites: PUAD 502 and nine graduate credits. Exploration of current issues in justice administration. Consideration of diverse perspectives on current and emerging issues concerning the administration of justice. Emphasis on use of theory and evidence to evaluate different viewpoints on issues. Course topics vary, typically focusing in one or more areas such as the following: law enforcement, corrections, legal issues and public law, crime control, conflict resolution, victimization experience, technological innovation, public participation in the justice process, and cross-national comparison of justice systems.

PUAD 821 Doctoral Seminar in Theories of Organization and Bureaucracy (3:3:0). Prerequisite: PUAD 620 or equivalent, or permission of instructor. Examination of key issues in organization theory and behavior. Issues include organization design, interorganizational coordination, intelligence and decision-making systems, leadership and motivation theories, and theories or organizations as agents of political and social change. Case studies are used.

PUAD 840/PUBP 840 Research Seminar in Policy Governance I (2:2:0) to (4:3:1) (variable credit). Prerequisite: Admission to doctoral program or permission of instructor. A survey of the major institutions that formulate and implement public policy
in the United States. Examines translation of public preferences into public policy and decisions about which societal and economic functions are most appropriately carried out by governments and which are best accomplished by private institutions and individuals.

**PUAD 841/PUBP 841 Research Seminar in Policy Governance II (2-4:2-3:0-1).**
*Prerequisite: Admission to doctoral program. This course is the second of a two-semester sequence (PUAD 840, 841) in the governance and public management policy concentration.* The division of responsibilities between the several levels of government and between the public and private sectors. Focuses on the impact of these divisions on the development of public policy in several policy areas, such as urban governance, environmental policy, and health care.

**SOCI 523 Racial and Ethnic Relations: American and Selected Global Perspectives (3:3:0).** *Prerequisite: Undergraduate senior status in sociology, graduate standing, or permission of instructor.* Demographic purview of racial and ethnic groups in the United States; racial and ethnic groups as human-social-minority groups. Factors making for minority status including personality factors, group cultural factors; reactions of racial and ethnic minorities to minority status; programs, methods, social movements, and philosophies seeking to change minority group status.

**SOCI 590 Gender, Race, and the Natural World (3:3:0).** *Prerequisites: Undergraduate seniors, graduate standing, or permission of instructor.* Advanced study of the links among gender, race, and nature using a social-psychological framework, original sources, and seminar discussion format. A critical analysis of the ideologies that underpin the interlocking narratives of gender, race, and nature and an examination of the role of science in production of those ideologies.

**SOCI 599/NURS 611 Issues in Sociology (3:3:0).** *Prerequisite: Undergraduate senior status in sociology or graduate status.* Contemporary topics in sociology including issues in sociological theory, crime and delinquency, advanced research methods, social and cultural change, urban sociology, medical sociology, sociology of aging, and rural sociology. Course may be taken only once for credit.

**SOCI 607 Criminology (3:3:0).** *Prerequisite: Graduate standing or permission of instructor.* Crime and crime causation. Topics include social basis of law, administration of justice, and control and prevention of crime.

**SOCI 608 Juvenile Delinquency (3:3:0).** *Prerequisite: Graduate standing or permission of instructor.* Sociology of adolescent behavior. Sociological factors that determine which behaviors and social categories of adolescents are likely to be labeled and treated as delinquent.

**SOCI 609 Sociology of Punishment and Corrections (3:3:0).** *Prerequisite: Graduate standing or permission of instructor.* Understanding the development of the modern penal system as interpreted by various perspectives, including Durkheim, Marx, Weber, Foucault, Elias, and Garland. Exploration of recent trends and problems, including social
control and violence in prisons, race and gender disparities in punishment, and alternative rehabilitation and prevention strategies.

**SOCI 611 Classical Sociological Theory (3:3:0).** *Prerequisite: Graduate standing or permission of instructor.* In-depth examination of major issues in classical (pre-1930) sociological theory. Durkheim, Marx, Weber, Mead, and others are analyzed, and the social and intellectual context of their theories is emphasized.

**SOCI 612 Contemporary Sociological Theory (3:3:0).** *Prerequisite: Graduate standing or permission of instructor.* Schools in contemporary sociological theory such as structural-functionalism, conflict, exchange, symbolic interactionism, ethnomethodology, humanist sociology, and critical theory are examined. Contemporary theorists are analyzed in relation to the schools.

**SOCI 614 Sociology of Culture (3:3:0).** *Prerequisite: Graduate standing or permission of instructor.* Analysis of 20th-century debates in American culture, and cultural politics, with emphasis on art and popular culture, the news media, and competing notions of "the public." In-depth readings in cultural sociology cover a variety of theoretical and methodological approaches.

**SOCI 619 Conflict and Conflict Management: Perspectives from Sociology (3:3:0).** *Prerequisite: Graduate standing in sociology or conflict analysis and resolution, or permission of instructor.* Deals with the sociology of conflict. Such major sociological theories of conflict as those of Marx, Weber, Simmel, Dahrendorf, Coser, and Collins are presented. The role that sociological conflict theory plays in undergirding conflict management practices is stressed.

**SOCI 635 Environment and Society. (3:3:0)** *Prerequisite: Graduate standing.* Overview of human ecology and environmental sociology, emphasizing selected topics. Focuses on theory, since theory makes it possible to generalize from understandings derived in an analysis of a particular problem and apply them to other problems.

**SOCI 640 Social Theory and Social Policy (3:3:0).** *Prerequisite: Graduate standing or permission of instructor.* Major theories of social organization and social change as a means of understanding social policy development. Concentration is on social policies in American society.

**SOCI 650 Issues in the Sociology of Health, Illness, and Disability (3:3:0).** *Prerequisite: Graduate standing or permission of instructor.* Social context of disease and medical care, the position of the professions in the medical care structure, the delivery of medical care, and the physician-patient relationship under different systems of practice.

**SOCI 651 (551) Health Care Systems (3:3:0).** *Prerequisite: Graduate standing or permission of instructor.* Changing health care systems are rapidly affecting patient providers and health and quality of life of the society. Analysis and theories of change in
health care systems and their impacts on society and various stakeholders. For-profit and nonprofit organizations and their impacts are examined. Comparative cross-cultural analysis of health care systems.

**SOCI 660/860 Historical and Comparative Sociology (3:3:0).** Prerequisites: Graduate standing or permission of instructor. Seminar in the theory and methods of historical and comparative sociology, primarily for students with a background in sociological theory and methods. Examination of the basic approaches and research data of history and sociology, a survey of the development of the field, and an analysis of exemplary studies.

**SOCI 686 Sociology of Aging (3:3:0).** Prerequisite: Graduate standing or permission of instructor. Analysis of sociological issues in aging. Issues include class and cultural factors, problems of work, retirement, attachment and loss, and ageism. Different theories of aging are examined.

**SOCI 692 Complex and Alternative Organizations (3:3:0).** Prerequisite: Graduate standing or permission of instructor. Classical and contemporary theories and analysis governing formal organizations, their development, characteristics and relationships to society are examined. Alternative conceptualizations to bureaucracy considered such as learning organizations, self-help groups, feminist collectives, cooperatives, and social movement organizations. Nonprofit, governmental, and business organizations are dissected.

**STAT 781/SYST 781/INFS 781 Data Mining and Knowledge Discovery (3:3:0).** Prerequisite: STAT 663/CSI 773 or STAT 554 or CS 580 or STAT664/SYST 664 or CS 650 or INFS 614 or 623 or permission of instructor. Concerned with statistical and computational methods and systems for deriving user-oriented knowledge from large databases and other information sources, and applying this knowledge to support decision making. Information sources can be in numerical, textual, visual, or multimedia forms. Covers theoretical and practical aspects of current methods and selected systems for data mining, knowledge discovery, and knowledge management, including those for text mining, multimedia mining and web mining. Content may vary from semester to semester.

**SYST 520 System Design and Integration (3:3:0).** Prerequisite: Graduate standing. System design and integration methods are studied and practiced, including both structured analysis and object-oriented based techniques. The course includes the development process of functional, physical, and operational architectures for the allocation and derivation of component-level requirements for the purpose of specification production; examination of interfaces and development of interface architectures. Life cycle of systems is addressed; generation and analysis of life cycle requirements. Software tools are introduced and used for portions of the systems engineering cycle. Students are expected to develop a system design for a system of their choice using both the structured analysis and object-oriented techniques presented in class, and they will make presentations on these designs.
SYST 521/OR 643 Network Analysis (3:3:0). Prerequisites: MATH 213 and MATH 203 or equivalent; OR 441 or OR 541. Network nomenclature. Elementary graph theory. Linear and nonlinear network models: multi-commodity flow, mathematical games and equilibria on networks, network design and control. Dynamic network models. Applications to transportation, telecommunications, data communications, and water resource systems.

SYST 573 Decision and Risk Analysis (3:3:0). Prerequisite: STAT 344 or equivalent. Study of analytic techniques for rational decision making that address uncertainty, conflicting objectives, and risk attitudes. This course covers modeling uncertainty; rational decision-making principles; representing decision problems with value trees, decision trees, and influence diagrams; solving value hierarchies, decision trees, and influence diagrams; defining and calculating the value of information; incorporating risk attitudes into the analysis; and conducting sensitivity analysis. (Offered concurrently with SYST 473. Students may not receive credit for both SYST 473 and SYST 573.)

SYST 611 System Methodology and Modeling (3:3:0). Prerequisite: SYST 500 or equivalent. This course provides a broad, yet rigorous, introduction to methodologies for Systems Engineering. Emphasis is on systems modeling and performance. Topics include system model and behavior analysis, linear and nonlinear systems, discretization and linearization, optimization, dynamic programming and optimal control. These methodologies address system performance issues and assist in the evaluation of alternative system designs. Resource allocation for planning and control is also introduced.

SYST 621 Systems Architecture for Large-Scale Systems (3:3:0). Prerequisite: SYST 510 or equivalent. Introduction to system architecture for the technical description of large-scale systems. An intensive study of the relationships between the different types of architecture representations and the methodologies used to obtain them. Systems engineering approaches for transitioning from functional descriptions to structure and architectural descriptions. Analysis of existing architectures and design of new architectures. The role of modeling, prototyping, and simulation in architecture development. Executable models of system architectures and performance evaluation. The role of the systems architect, the systems architecting process, and systems management of architecture and design activities. System interoperability, integration, and interfaces. A case study of a large-scale system conceptual architecture will be used to demonstrate application of systems architecture principles.

SYST 680/ECE 670/OR 683 Principles of Command, Control, Communications, and Intelligence (C 3I) (3:3:0). Prerequisite: ECE 528 or SYST 611 or equivalent. This course provides a broad introduction to fundamental principles of Command, Control, Communication, and Intelligence (C 3I). The principles and techniques are applicable to a wide range of civilian and military situations. Modeling and simulation of combat operations are discussed. The sensing, fusion, and situation assessment processes are studied in detail. Optimal decision-making rules are derived. The concepts of C 3 architectures are discussed. Tools to evaluate and design C 3 systems such as queuing
theory are also developed.

**SYST 683 Modeling, Simulation, and Gaming (3:3:0).** *Prerequisites: MATH 213, SYST 500 or equivalent and graduate standing.* Develops methods for designing combat models and games. Existing combat models are critical to the C 3I process. Exercises and games are used to demonstrate the value of properly developed C 3I modules in a combat simulation.

**SYST 684 Sensor Data Fusion (3:3:0).** *Prerequisites: SYST 680 or ECE 670.* Examines design issues in multisensor fusion systems. Studies the use of probability, evidence, and possibility theories for object identification. Studies Bayesian networks, blackboard architectures, and spatial and temporal reasoning for situation assessment.

**SYST 685 Estimation and Tracking: Principles and Techniques (3:3:0).** *Prerequisite: ECE 528 or OR 542 or STAT 544 or equivalent.* Principles and estimation techniques for static and dynamic systems, linear and nonlinear, discrete and continuous time. Estimation for kinematic models, track initiation, bearing-only tracking, tracking maneuvering targets with adaptive filtering, MM (Multiple Model) and interactive MM algorithms. Tracking single target in clutter, nearest neighbor algorithm, tracking and data association, Multiple hypothesis tracking. Tracking performance evaluation.

**TELE 730 Telecommunications Management (3:3:0).** *Prerequisite: Graduate standing.* Surveys the strategic and organizational issues in the field of telecommunications management. Focus is on strategic management and oriented toward the executive management level of telecommunications firms.

**TELE 750 Coordinating Seminar (3:3:0).** *Prerequisite: Open only to students in the M.A. or M.S. in Telecommunications programs with at least 18 credits of course work.* Topics include specific telecommunications problems in management, law, engineering, education, and communication. Focuses on the ways a problem in one area can create or solve a problem in other areas.