Cornell in the Information Age

Initial Report of the Task Force
on Computing and Information Science

June, 1999

The Information Revolution is transforming society – creating new careers, new industries, new academic disciplines and the need for new programs of education and research. These changes affect how people work and think; two things that are fundamental to universities. While it is perhaps tempting to dismiss the information revolution as hype, or as a passing fad, the evidence runs quite to the contrary. For instance, about 1/3 of economic growth in the US since 1992 has been in computing and information technology\(^1\). Not only are the founders of new high technology companies often barely in their 20's, new careers are also appearing at traditional companies. For example, this year's ranking of the 500 best and worst jobs lists Web Site Designer as the top job in terms of pay, flexibility and satisfaction. This is a position that did not even exist 5 years ago, and that requires a combination of skills not easily found in today’s educational programs. The Internet and the Web are perhaps the most visible aspects of this change, but it is pervasive, touching nearly every field and discipline, from computational techniques in the physical and biological sciences, to new interactive media in the arts. This revolution has already brought fundamental social change, however we do not yet understand the impact of this change, nor do we know how much more is yet to come.

Being an informed citizen in the Information Age requires knowledge of computing systems, global communications networks, and interactive information resources. The requisite level of knowledge goes beyond simply being comfortable with computing tools. It requires the ability to apply computational ways of thinking to design, to writing, to experimentation, to artistic expression, and to problem solving – to the very core of human intellectual activity. Just as a higher education requires writing skills that go beyond the mechanics of sentence and paragraph structure, it is also beginning to require computational skills that go beyond the mechanics of programming and software packages. In the information age, our ideas are no longer constrained solely by what is physically realizable, but by what is computationally realizable. For example, an artist is now able to create an artwork that only exists when someone interacts with it – specifying a framework within which each visitor can create a work of art. A chemist is now able to search more effectively for new compounds by modeling them before ever going into the lab. Nearly every discipline is changing, not just because of new tools but because of new computational ideas and paradigms.

\(^1\) Source: Congressional testimony of Dr. Rita Colwell, Director National Science Foundation, March 4, 1999.
While the information revolution rests on fundamental advances in many fields, the core enabling disciplines are in the Computing and Information Sciences (CIS). It is the embodiment of knowledge and techniques in computer software and protocols that is driving the change. Perhaps the central underlying theoretical concept is that of the universal computational machine. While this is a theoretical notion, it has had immense practical consequences. Consider the meteoric rise of the World Wide Web, a fundamental change that has happened in just a few years. Such rapid change was only possible because many people already had computers – which are universal computational machines – in their homes and offices. Prior to the Web, people largely used these machines for word processing and calculation. These same computers have now been transformed from typewriters and calculators into global information resources. While we have gotten used to this notion of universality of computational devices, it is worth noting how different it is from physical devices, which are specialized to a particular function rather than being universal (e.g., physical universality would allow your refrigerator to function as a dishwasher).

The rapid and fundamental changes of the information age pose significant challenge as well as opportunity. In academia, one pressing challenge is the need for the faculty to stay ahead of, or in many cases to catch up with, the students. More students are seeking to combine computing with a liberal education in the arts and humanities, to prepare themselves for jobs that increasingly require both technical and creative skills. Another pressing challenge in academia is the need to attract and retain outstanding faculty in core Computing and Information Science (CIS) disciplines. Students with bachelors and masters degrees in these areas are commanding starting salaries higher than what tenured faculty are paid. Moreover, these industry jobs often provide the kind of intellectual challenge that attracts people to academic careers. While universities cannot match the financial opportunities in industry, we can and must strive to create an environment that is more intellectually stimulating. Instead, the large number of undergraduates seeking computing related jobs has caused enormous teaching loads, adding an incredible burden to those very same faculty who are enticed by exciting opportunities outside the university. We must do something to alleviate this strain (already over half a dozen Cornell faculty in CIS disciplines, several tenured, have departed in the past year; this is happening at many of our peer institutions as well).

In the tradition of Ezra Cornell, we believe that Cornell University should become an institution where anyone can bring ideas from Computing and Information Science to bear on their discipline of study. Cornell has a nearly unrivaled combination of depth and breadth upon which to build – with one of the top Computer Science Departments, outstanding research programs in Computational Science and Engineering coordinated by the Theory Center, the new Computational Genomics initiative, and pockets of computational expertise across the campus, in Engineering, Physical Science, Arts, Humanities and Social Science. We believe that it is crucial for Cornell to act quickly to capitalize on this strength, so that we are able to attract and retain the best faculty, and provide the best education for students whose interests in computing and electronic information resources are rapidly growing.
We can be the first university to broadly integrate Computing and Information Science into education for all students and into research and scholarship across the campus. While several other institutions have created new Schools, Colleges and Laboratories, these new units do not address the broad-based nature of computing education and research in the Information Age. Moreover, a number of the new programs are focused solely on research and graduate or professional education (e.g., Berkeley, MIT, Michigan).

Before turning to our deliberations and recommendations, we would like to stress that this is just the initial report of our task force. As a group of twelve people we undoubtedly did not take all of the relevant issues into consideration. Rather, we hope that these ideas will serve as the basis for productive discussions across the campus, in order to help produce a final report that truly guides Cornell towards being the leader in bringing ideas from Computing and Information to bear on every discipline.

A NEW HOME FOR COMPUTING AND INFORMATION

We believe that Cornell should create a central home for computing and information research and education, spanning the entire campus. Such a home would serve to bring together experts in computing with researchers and scholars in a variety of disciplines, including but not limited to three inter-disciplinary focal areas: Digital Arts and Culture, Human and Social Systems, and Computational Science. Such a home would provide fertile ground for emerging research and scholarly activities. Such a home would further provide a framework for creating new courses, new concentrations, and eventually new majors to better serve the educational needs of our students – who increasingly seek to combine computing with their disciplines of interest.

We have considered a number of ways in which to best create such a home. We hope that summarizing our discussions here will serve to frame broader campus discussions on how to create programs of education and research in computing and information that truly touch nearly every academic discipline at the university. Based on what other universities are doing in the computing arena, as well as by considering other cross-disciplinary programs at Cornell, we have identified four broad classes of existing structural models:

1. A department that has the bulk of the expertise, with additional expertise in a few other departments. Many disciplines at Cornell operate this way, including Computer Science. (A slight modification of this is having a small number of related departments, perhaps in different colleges, such as Physics and Applied & Engineering Physics).

2. A center or laboratory, with participation from faculty in a number of departments, focused on research rather than education. The Theory Center at Cornell operates this way.
3. *A division* or other structure that cuts across departments and colleges, focused on research and education. The former Division of Biological Sciences at Cornell operated this way.

4. *A college* or school, offering undergraduate degrees, focused on both research and education. In the computing area, Carnegie-Mellon and Georgia Tech both operate this way.

The main advantage that we see for the department model (#1) is that it involves little or no change, as this is what we currently have in place. However, we see several significant disadvantages with this model. First, we believe that the scale of interactions that are required would be unwieldy for any single department to manage – both in terms of the sheer number of faculty and the intellectual breadth. We envision research connections and new educational programs integrating computing with the arts, the humanities, the social sciences, engineering, the physical sciences, the life sciences, and the professional schools. The number of faculty involved and their disparate backgrounds call for focal areas, such as the three we identified above, that in and of themselves could be as large as many departments. The combination of these focal areas with core computing and information science could be the size of a small college, and far broader intellectually.

A second critical problem that we see with the department model is the necessity of maintaining the strength, identity, reputation and visibility of core activities such as the Computer Science Department and the Computer Engineering area. Adding a broad range of people to the departments that contain these core activities could easily be perceived as diluting their strength with “soft” or “applications” work. Thus we do not see the common home for broader activities fitting inside any single department. On the other hand, we do not believe that having multiple activities in departments scattered across the campus works well either, because of the substantial structural barriers to the development of broad collaborations and cross-disciplinary courses. We return to this issue with model #3 (a division).

The main advantage that we see for the research center model (#2) is that it can support cross-disciplinary research that would otherwise be difficult to undertake. The Theory Center has done quite well recently in building such research partnerships for computation in the Sciences and Engineering (Computational Science). The main problem with this model is that it has no educational component. Moreover we believe that it cannot, as departments and colleges rather than centers fill this academic role. In fact we view the current situation in Computational Science at Cornell as somewhat of a shame, because there is considerable research excellence but virtually no educational offerings, and certainly no educational programs, in this area. In our view simply building two other research centers, in Digital Arts and Culture and in Human and Social Systems, would yield the same problem. Moreover, we believe that in some areas it may be more difficult to start with research efforts, rather than scholarship and teaching.
We find little to argue for in the division model (#3). A division is a cross-cutting management structure that has little or no resources or authority (e.g., budget, faculty lines, etc.). As such, the director of a division is generally reduced to being a broker between deans and department chairs. This causes difficulties in coordinated hiring, in setting directions, and in building integrated curricula that are co-taught across colleges or other academic boundaries. It is our belief that unless a structure has resources to bring to the table, it can get little accomplished in terms of building ties. Moreover, a division acts to exclude those not within it, much as a college does, without many of the benefits of a college.

The main advantage that we see for the college model (#4) is that it is the de facto way of creating broad-based academic endeavors that involve both research and teaching. A college or school has financial resources, faculty lines, and a structure for creating programs of education and research within it. The main disadvantage that we see for this model is that it is divisive rather than enrolling. It is doubtful that a college could truly reach across the campus, building joint programs with units from the arts, humanities, engineering and sciences. In practice a college creates barriers to cross-disciplinary activities unless they happen to fall entirely within the college. A second critical drawback that we see with the college model is that it creates additional complications for undergraduates. In many ways, Cornell already has too many colleges – most students view themselves as being at the university more than being in a college. Moving between colleges is difficult for students to do, and it is hard to imagine that this would change. Adding another college would simply add to this difficulty.

We have discussed various pros and cons of each of these models, and believe that none of the models is best for Cornell. In the following section we discuss a different model, called a “Faculty”, that we believe will better achieve the goal of supporting broad-based programs of education and research in computing and information related areas.

RECOMMENDATIONS

Given the above consideration of possible structures, we recommend the establishment of a new kind of academic home for computing and information research, scholarship and teaching at Cornell. We are calling this home the Faculty of Computing and Information (FCI). The mission of the FCI is to create broad-based programs of education and research that span the campus. Given the high student demand and the fast pace of change in this area we believe that there must be a particularly tight coupling of education and research. Thus a key part of our reasoning is that the FCI have both teaching and research missions. We have chosen the term "Faculty" to highlight that while this proposed structure has some attributes of a college, it would also differ from a college in several critical regards. First, the FCI would have an undergraduate teaching role more like that of a department than that of a college, in that it would offer majors and minors in existing colleges. We further envision that the FCI would offer these programs in several if not all colleges at Cornell. Second, the FCI would have a large number of half-time joint appointments with faculty in the current colleges. We elaborate more on how the FCI could work below.
We view the name Faculty of Computing and Information (or FCI) as a placeholder. In particular, we believe that it is important for the name to connote breadth in the arts and humanities, not just in the sciences, engineering and social sciences.

Structure and Mission of the FCI

First and foremost, we believe it is critical that the FCI truly reach across the campus. To that end, we recommend that there be numerous half-time joint appointments between the FCI and other units (and between sub-units within the FCI). These joint appointments would pay half the salary and come with regular voting rights and responsibilities in the FCI (and in general some sub-unit of the FCI). We expect that as many as a quarter of the faculty lines, and thus half of the faculty, in the FCI would have such joint appointments. As the FCI would have faculty lines, we envision a Dean of the FCI to whom those faculty would report, and who would be responsible for educational and other resources. We recognize the difficulty that joint appointments place on junior faculty and on the tenure process. Thus we expect that initially joint appointments would go to tenured faculty. We further expect that mechanisms can be worked out to address the additional issues for non-tenured joint appointments (e.g., other institutions, such as Stanford, make significant use of these). We also recognize that some of the areas of scholarship, research and teaching envisioned in this report are speculative, in that it is unclear whether a large enough group with common interests will emerge to form an intellectual community and to provide a coherent program of courses. We thus believe that it may also be appropriate to initially have some joint appointments with a limited term.

We recommend that the FCI consist of four sub-units: (i) the current Computer Science Department (CS), and the inter-disciplinary focal areas of (ii) Digital Arts and Culture, (iii) Human and Social Systems, and (iv) Computational Science and Engineering. Of the three focal areas, Computational Science and Engineering is already quite strong at Cornell, with active research programs and with the Theory Center playing an important inter-disciplinary role. However, there are no academic programs associated with this research, and we believe that this focal area in the FCI could complement and enhance the Theory Center’s research role. The other two areas, Digital Arts and Culture, and Human and Social Systems, reflect emerging areas of research and scholarship. Other institutions are beginning to recognize these new areas. For instance, the Media Lab at MIT fits squarely within Digital Arts and Culture, and SIMS at Berkeley lies within Human and Social Systems. We expand a bit on these areas in the section entitled Background of the Recommendations, below. We believe it is critical that upon conception the FCI have faculty in all of these areas, not just in CS. The three focal areas cross every college boundary on campus, and thus we expect that the FCI would have joint appointments with faculty in every college. We also expect that the CS Department would have joint appointments with the focal areas as well as with other departments, in a manner that preserves and enhances the strength of CS at Cornell.
As noted above, we believe that the FCI must improve the educational opportunities in computing and information at Cornell. In so doing we envision that the FCI would have an educational role more like that of a department than that of a college, in that it would offer majors and minors but not admit its own students or set requirements other than those of a major or minor. The FCI would offer an undergraduate major in Computer Science (CS), as well as minors in new areas that align with the three focal areas. Eventually some of these minors might become new majors. The FCI would be responsible for teaching the courses and setting the requirements for each major or minor. The FCI would not have its own undergraduate admissions or undergraduate degree, but rather would offer its programs in many (if not all) colleges. Initially the only major offered by the FCI would be in Computer Science. This major is already a part of the programs in two colleges (Engineering as well as Arts and Sciences). This would remain exactly as it is now. However, it is anticipated that a CS major in other colleges would also be added. We further expect that the new minors offered by the FCI would also be available to students in any college, with the approval of their college. We believe that the FCI should have membership in the college curriculum committees of each college where its majors or minors are offered.

In order to broaden the educational opportunities for our students, we expect that the FCI would develop and offer new undergraduate minors (or concentrations) building on Cornell's excellence in research and graduate education. These minors could include areas such as Computational Science, Computational Mathematics, Interactive Information Systems, Visualization and Visual Expression, Cognitive Studies and other programs that fall within the three focal areas identified above. We further believe that the FCI should play a leading role in developing introductory computing courses that serve the needs of students in all areas. To that end, we recommend that the FCI establish and run an Undergraduate Computing Program, similar in many ways to the Knight Writing Program. This Program would have the goal of bringing fundamental ideas from computing and information science to students in all disciplines, while at the same time respecting the different educational contexts of various disciplines. We expand more on this Undergraduate Computing Program in the section entitled Background of the Recommendations, below.

The proposed structure of a Faculty of Computing and Information is intended to address the following organizational issues:

1. The need to bring together disparate activities in CIS-related disciplines, in order to help create broad-based programs of research and education that address the needs of the 21st century. We believe it is critically important to build programs that support and expand computational thinking across the campus: in Science and Engineering, the Arts and Humanities, and the Social Sciences. We have identified three corresponding focal areas that contain the seeds of such new programs (in Computational Science and Engineering there is already considerable activity, although the educational component is currently missing).
2. The need for any new structure to be truly inter-disciplinary, and to be inclusive rather than exclusive. This would be addressed both by the extensive use of joint appointments (with half-time salary and responsibilities) and by the fact that undergraduates who major or minor in CIS disciplines will be enrolled in the existing colleges.

3. The need for any new structure to have the "real teeth" afforded by budgetary and other authority. This would be addressed by having a Dean of the FCI, with faculty lines, budget and other resources for computing and information education and research. We further envision that a Dean level position would be an asset to the central administration, providing an important source of input on issues relating to computing and information research and education.

4. The need for any new structure to be lightweight, not having a large administrative structure. This would be addressed by not having many of the normal roles of a college, such as an undergraduate student body with admissions, degrees, etc. We further expect that the Dean of the FCI would continue to have some teaching and research responsibilities – something that is critical in such a fast-moving area.

Goals of the FCI Structure

With these recommendations, we aim to achieve the following:

1. Enable Cornell to attract and retain the best faculty and students in the information age. The formation of the FCI will accomplish this by creating an exciting, fertile research environment in both current and emerging areas, offering innovative new courses, and reducing the high teaching loads and the resultant lack of faculty-student contact.

2. Increase the diversity of interests and backgrounds of students and faculty involved in research and education in computing and information. The FCI will broaden the reach of and the accessibility to computing-based programs across the campus. Particularly in the humanities and arts, this will greatly broaden the reach of CIS material beyond the traditional science and engineering arena.

3. Create inter-disciplinary programs of computing research and scholarship, and grow existing ones. Strong programs in these areas will at least double Cornell's research funding in Computing and Information Science, taking full advantage of the projected doubling in federal research funds for CIS. In addition, Cornell’s competitiveness for computing-related research awards in a wide range of science, art and humanities will be enhanced.

- In Computational Science and Engineering expand on the strong foundation provided by the Theory Center and Computational Genomics, developing and applying computational models and techniques that help reveal properties of the physical and natural world.
• In Human and Social Systems, help “understand and enhance the effects of information technology on people, our economy, society, culture and political system” (from PITAC report to President Clinton, February 1999), and apply computational models and techniques to the understanding of human cognition, perception, and activity.

• In Digital Arts and Culture, enhance the practice, performance, and exhibition of digital arts and digital expression, such as visual arts, theatre, film & video, music, architecture, creative writing, journalism; develop critical approaches to the internet, the culture of digitality, and the digital organization and distribution of knowledge; explore the theory of virtuality and the reality of virtual communities.

4. Create new educational programs that bring the ideas of computing and information science to all disciplines. Capitalize on our strengths in research and scholarship to develop new courses, new minors (concentrations) and eventually new majors in emerging CIS areas – complementing the research focal areas. Use the broader reach of these programs to increase the diversity of background and of interests among students and faculty in CIS disciplines.

• In Computational Science and Engineering exploit our current excellence in research to rapidly begin offering coordinated programs of courses leading to a minor (concentration) at both the graduate and undergraduate level in all of Cornell’s colleges.

• In Human and Social Systems as well as Digital Arts and Culture begin offering coordinated programs of courses. Formulate plans for new minors (concentrations) as the level of research and scholarly activity in these areas ramps up to support them.

• Promote CIS “literacy” across the campus by creating an office to support the creation and dissemination of more effective undergraduate teaching in computing campus-wide. This office would work with faculty and academic departments to create courses that cover the concepts as well as the mechanics of computing and information systems.

POSSIBLE IMPACT

While the design of this Faculty is intended to maximize the positive impact, there is the potential for any far reaching changes to have negative effects as well. Here we consider some of the possible impact on the College of Engineering. While this discussion focuses on Engineering, we expect that the campus wide discussions and the final report should address similar questions about other units in the university. Moreover, many of the issues here must also receive further consideration. To set the stage, let us consider in
more detail what would happen to the Computer Science Department (CS) with the creation of the FCI. CS is one of the largest majors in Engineering and also has substantial research ties with several Engineering departments. Any proposed change should not detract from the role of CS in the Engineering College.

The CS undergraduate program in Engineering would remain exactly as it is today, with CS as one of the central undergraduate majors for Engineering students, as well as being a source of both required and elective courses for students in other Engineering majors. CS would continue to participate on Engineering curriculum committees just as it does today. This is precisely the manner in which the CS major currently functions in the College of Arts and Sciences. Arts and Sciences has no budgetary or other authority over CS, however CS operates a fairly large major (around 50 students per year) in that College. CS also participates in curricular and admissions committees in Arts and Sciences. Moreover, the CS major in A&S is widely perceived as an asset by both the College of Arts and Sciences and by the CS Department. We expect that with the FCI this would remain true for Arts and Sciences and also be true for Engineering.

Another important issue is the impact of any change on the external perception and the rankings of the College of Engineering. We believe that the Faculty structure offers considerable flexibility in this regard. For instance, the faculty in the CS department could continue to be listed on the Engineering College roster (as is currently done for CS in Arts and Sciences). Moreover, the research support for CS faculty could be included in the external reporting of the Engineering College research expenditures, as is done now. We further expect a substantial number of joint appointments between Engineering and the FCI, in Computational Science and in Computer Engineering, making the close ties apparent both inside and outside Cornell.

The FCI would need to have faculty lines beyond those currently allocated for CS. This would be both for growth of full-time faculty, and for joint appointments with other units. Currently growth in the CS department has been completely within the confines of Engineering, which has caused considerable tension. Already some of this growth has been for ties with areas such as Cognitive Studies that are not particularly important to Engineering. With the FCI, the growth in both CS and particularly in other parts of the FCI will be even less appropriate to Engineering. It is arguably better for Engineering to not have to absorb this additional growth, particularly in areas such as the Arts, Humanities and Social Sciences. Another resource related issue is that joint appointments of faculty with the FCI would provide half-lines back to the Engineering College. We expect that there would be a number of such appointments.

To the extent that a strong CS department is important to Engineering, we believe that a structure such as the FCI will benefit Engineering because it will result in a stronger CS department at Cornell. With the current situation, the national problem affecting all computer science departments could strike Cornell as well. The majority of computer science faculty have exciting and lucrative opportunities elsewhere. Industry’s appetite for talent is creating a documented situation in which the computing and information field is “eating its seed corn”. We believe that by broadening the campus-wide expertise
in computing and information, the Faculty structure will make Cornell more attractive for core CS as well.

Bold action in the Computing and Information Sciences arena, such as the creation of the FCI, would likely attract substantial new resources to Cornell. Many alumni recognize, perhaps better than we do ourselves, the broad impact of computing and information science on our economy and our culture. They realize the importance of making sure that Cornell is a leader rather than a follower in the Information Age. We believe that these people can help us identify funds that would not otherwise be available. Moreover, there are substantial new government and foundation programs to support research, education and scholarship in inter-disciplinary areas that involve computing and nearly every subject. The FCI would make it clear to such agencies that Cornell is strongly committed to these areas. Given the substantial partnership between faculty in Engineering and the FCI, we believe that any increased flow of funds in this area would also have a positive impact on the College of Engineering.

BACKGROUND OF THE RECOMMENDATIONS

Cornell is in a unique position to create an interdisciplinary group of scholars, from a wide range of departments and fields, devoted to CIS research and teaching. By focusing our efforts and building together, we would be in a stronger position to create the research and educational partnerships for the future. We would be better positioned to leverage funding from federal agencies, private donors and foundations interested in supporting research in computing and information systems. We would be better able to create the new interdisciplinary programs that “educate for the future”. Above we identified three focal areas that we believe capture the main interactions between computing and other disciplines – these three areas fall along the lines of traditional divisions between fields, the Arts and Humanities, the Sciences and Engineering, and the Social Sciences. We believe that the FCI could provide a home to nurture what are now fledgling activities in many of these areas.

We recommend that the FCI have faculty in each of the three focal areas, in order to build activities that truly span the campus. Moreover we expect that many of these would be joint appointments with other academic units, including not only many departments on campus but also the professional schools. In this section we briefly describe some of the kinds of emergent or ongoing activities at Cornell that could help define the three focal areas. We stress that these are simply illustrative examples, and are not intended to delimit the scope of any of the areas. We hope that a number of faculty at Cornell will see their intellectual activities as overlapping with one of these focal areas. At the end of this section we also briefly describe the background rationale for an Undergraduate Computing Program, analogous in many ways to the Knight Writing Program.

Digital Arts and Culture
Visual literacy and the ability to express ideas in new multimedia formats are increasingly important in the information age. Skills in visual and multimedia digital communication and analysis are now important educational, artistic, and communication tools of equal social import to textual literacy and skills in writing.

At Cornell, we perceive interdisciplinary approaches to Digital Arts and Culture to intersect across three central axes: 1) Digital Arts: Practice, exhibition, and analysis of digital practice in visual arts, theatre, film & video, music, architecture, creative writing--from the studio to the web, from the library to the museum. 2) Digital Culture: Critical approaches to the Internet and the culture of digitality: the organization and distribution of knowledge (from cultures to sexualities), the web, games and mass culture, television and film, multimedia, public spaces (from libraries and museums to performance spaces, sports arenas, and congressional chambers). 3) Digital Theory: Theory of virtuality and virtual reality (from philosophy and psychoanalysis to literary and art theory to emergent internet communities), theory of digital art and performance.

Pedagogical and research initiatives organized around Digital Arts and Culture would establish a structure with which to capitalize on preexistent and emergent Cornell strengths in these areas. Cornell is home to a number of ambitious initiatives in the study and practice of digital arts and culture. Innovative research projects currently in place include: the Program of Computer Graphics; the MultiMedia Lab in the Art Department; digital production and performance initiatives in the Department of Theatre, Film, and Dance; the Digital Music Program; Cornell Digital Library; Cornell Digital Museum; the John S. Knight Writing Program; The Society for the Humanities; the Africana Studies Center Digital Catalogue of African Art; The Graduate Field in Film and Video Studies; The Einaudi Center Predissertation Workshop on Comparative Visualities; Academic Technology Services; the Herbert F. Johnson Museum of Art. Add to these projects, parallel initiatives in human social systems: The Program in Science and Technology Studies; The Human Computer Interaction Lab in the Department of Communication; the Theory Center Visualization Group. These initiatives have been recognized for their individual contributions to the development of research and performance in digital arts, visualization, performance, and the humanities.

Cornell faculty associated with these innovative research projects have given equal attention to the development of a pedagogy in what could be termed "digital studies." Creative initiatives in computer instruction in writing, cinema, music, and art have introduced students and faculty to new trends in scholarly production that promise to revolutionize the means and nature of academic production in the future. Just as a growing number of courses are managed through websites, strong efforts have been made by a broad group of humanities, arts, and social science faculty and instructors to introduce students to the latest digital developments in their fields. This includes courses on the impact of computer technology on society, the globalization of communications, the history and theory of electronic art, critical approaches to the Internet, the theory of virtuality, and digital practice in art, theatre, cinema, dance, music, and architecture.
Other temporary initiatives have contributed immensely to Cornell's visibility as a leading research center of digital visualization. Cornell has hosted such a significant grouping of conferences and exhibitions this past year alone to position itself at the forefront of this field. Exemplary of the fruits of increased interaction and communication is the forthcoming international tour of the exhibition, Contact Zones: The Art of CD-Rom (http://contactzones.cit.cornell.edu). Cosponsored by The Society for the Humanities and CIT with the aid of the Library and the Johnson Museum, this was the first international exhibition of CD-Rom art in the United States (and largest such exhibition to date) and will begin an international tour this summer in Mexico City. Translation of the exhibition website in Spanish will permit the Cornell server to offer the first bilingual American art catalogue on the web. In addition, this year's annual theme of the Society for the Humanities, "The Virtual: Old and New," brought to Cornell leading theorists and practitioner of digital culture who offered an innovative set of courses on the topic – certainly the most cohesive curriculum of its kind to have been offered by any institution, from courses on the history of the philosophy of the virtual to courses on digital art and virtual reality. Similarly, this Spring's workshop cosponsored by The Society for the Humanities and ATS, "Artistic Discourses of Digitality," assembled at Cornell an international grouping of theorists and artists. Cornell also has benefited from collaborations between the Graduate Program in Film and Video Studies and the Park School of Communications at Ithaca College in bringing leading digital artists and theorists to both campuses. Another innovative conference this past Fall, "French and Francophone Cinematic Futures," cosponsored by French Studies, Cornell Cinema, and The Society for the Humanities, staged at Cornell an exciting gathering of film scholars who considered the move of film into the digital future. On a related front, the Theory Center sponsored a workshop in May on "Virtual Worlds in Formal and Informal Education." Finally, the Routes Radio project developed by Society Fellow, Reginald Woolery, through ODL, provides Cornell's first real-time web radio network, and one that brings together practitioners and thinkers from various disciplines (http://www.odl.cornell.edu/events/routesradio).

Given the promising results of these early efforts to teach and research the arts and humanities in "virtual form," Cornell is poised to position itself as a leading East Coast center of such research and pedagogy. What makes Cornell unique in this field is the potential of its collaboration in digital visualization between research projects in computing science, social science, the humanities, and the arts. If such projects were encouraged to collaborate in jointly sponsored research and pedagogy, they could provide the framework for one of the East Coast's leading centers in digital visualization and performance. Few institutions can boast of these results nor imagine the expansion of their potential.

Human and Social Systems

The Provost's Task Force on the Future of the Social Sciences at Cornell contains examples of the computational modeling problems and data management problems that Cornell faculty are investigating. The very nature of these problems illustrates the transformation of the social sciences made possible by the unprecedented amount of
digital data now available and the opportunities to computationally mine it for knowledge about social systems. As one example, the Cornell Institute for Social and Economic Research (CISER) has launched a project to provide formal support for a variety of confidential data access modalities (U.S. Census Bureau, U.S. Bureau of Labor Statistics, U.S. Social Security Administration, other national statistical agencies, etc.) in order to promote the use of confidential data for nonproprietary scientific research. CISER, CIT and the Theory Center have already begun to implement parts of this plan. There are many other large data sets that arise in the social sciences, involving such issues as the analysis of temporal processes (such as state dependence and duration) and multilevel modeling.

However, the overlap of computing and information science and the social sciences is far greater than just the application of computational methods for data mining and analysis. To take just one example, consider the study of judgment and decision making at both the individual and group levels. The standard “rational-actor” model in decision theory, widely used in economics and political science, has assumed that decisions are made by rational individuals. Roughly speaking, a rational individual is one who seeks to maximize his expected gains. Among other assumptions, it is always implicitly assumed that these individuals have unlimited computational resources to allow them to compute which actions will indeed maximize their expected gains. Much of the focus at Cornell has been to challenge and elaborate this traditional model. This work has shown that, while intuition and judgmental rules of thumb function reasonably well in many settings, they also give rise to systematic departures from the behaviors predicted by the rational-actor model.

Computer science provides a fruitful viewpoint on issues such as rational decision making and the presence of computational limitations. If we build software agents to help us on the Web, they will have to make decisions. But if we are to program them, we must take into account the computational problems involved with making such decisions. It may be very difficult to compute what the best decision is. There is work actively going on now in computer science to design approaches to making sensible decisions in the presence of resource limitations. This work may help clarify some of the systematic deviations from the standard model that have been observed. At the same time, computer science is being influenced by the work in decision theory, and there are current efforts at Cornell to see how decision theory can be applied to design better, more adaptive computer algorithms.

Once we move to a multi-agent, dynamic setting, we encounter a host of new issues, ranging from problems of game theory to questions of how social systems, institutions, and organizations adapt and evolve. Again, there is a surprising commonality of concerns between the work going on in the social sciences in these areas and work in distributed computing within computer science. Issues such as coordination and stability are as important in distributed computing as they are in societies and organizations. There are also ties between both these computer science and social science models and the nonlinear and dynamical systems models used in mathematics and physics.
Cornell has exceptional strength in the social sciences in the area of Social Adaptation and Decision Research, which is currently centered in three existing interdisciplinary programs at Cornell: the Center for Behavioral Economics and Decision Research (BEDR), Cognitive Studies, and the Multi-Disciplinary Research Program on Organizations and Institutions (MRPOI). It is also exceptionally strong in the areas in computer science most naturally aligned with these areas -- distributed computing and artificial intelligence. Indeed, there is active work in computer science on decision theory and adaptive systems. Preliminary collaborative efforts have already begun; a structure such as the FCI would certainly encourage more, and help Cornell become a leader in this emerging area.

Another area of rapidly increasing importance is that of developing a better understanding of how the Information Revolution is changing society and the economy. For instance the emergence of new global “citizens of the net”, who share common interests but may be of different nationalities, creates the potential for substantial change in the ways that nation states operate. The free flow of information across many borders is already altering how people learn and inform one another. Internationalization and changes in forms of communication raise fundamental questions about copyright and intellectual property. The PITAC report to President Clinton identifies these societal issues as being critical for further study, and recommends that they receive a substantial increase in government funding. Cornell has the opportunity to build on its strength in the Social Sciences and in Computing, including existing programs such as Science and Technology Studies, and building new ties between Computing and the Law School and Business School.

Computational Science and Engineering

The coming decades will be marked by the development of increasingly interdisciplinary approaches to science. However, doing “interdisciplinary science” of the same quality as “disciplinary science” is a challenge. The goals, methods, approaches and standards can differ wildly from one field to another, even between two closely related physical sciences such as geology and meteorology. When one tries to work at the interfaces between, for example, a biological and a physical science, problems multiply.

Computing provides a common thread for collaborative work across disciplines. It is no accident that much of the strongest interdisciplinary science being done today is computer-based modeling. In many branches of science, modeling and simulation have become a “third way”, complementing theory and experimentation. Reorganizing the Computing and Information Sciences at Cornell in a way that opens access across disciplines and encourages collaboration will foster exciting and viable research directions. These new directions will be precisely those in which we can expect to see the greatest student interest and research support over coming decades.

Here we briefly provide some examples of how a reorganization and broadening of CIS can inspire such initiative in the Sciences and Engineering, as well examples of the
continuing and ever-growing requirements within emerging disciplinary lines of inquiry. We stress that these are only illustrative examples, there are many such projects underway at Cornell, some of which benefit from inter-disciplinary interaction with computational experts and some of which do not.

**Earth System Science.** A systems approach to better understanding our planet has developed hand-in-hand with advances in computing and information science. From the very beginning of large-scale computation, solutions of the equations that govern atmospheric motion and thermodynamics have been used to push the edges of computing ability. Because the earth system is intractably large, computer modeling provides the only laboratory for experimentation. It also provides challenges in the design of computer algorithms and simulations. Cornell has significant efforts in many areas of earth system science, including climate modeling, satellite observations, ecosystem dynamics, agricultural systems, and biogeochemistry. We have special interests and strong programs in regions all over the world, including the Amazon Basin, northern Africa, Patagonia, and the Himalaya, as well as in Tompkins county watersheds, local ecosystems, and New York state agriculture. One can envision a centralized earth system science modeling effort through which, for example, climate models are made available for “experiments” designed by ecosystem scientists or geologists (or both). Such a facility would foster interactions that would improve existing models, and encourage joint efforts to couple models of climate system sub-components. Coordinated activities at Cornell would complement efforts at national laboratories to develop comprehensive models of the entire earth system, in the best traditions of university science with in-depth collaboration between deep-thinking scientists. Such efforts are increasingly attractive to funding agencies such as NASA, NSF, and NOAA.

**Engineering and Physical Science.** There are many cross-disciplinary activities in computing coordinated by the Theory Center. These efforts in Computational Science span a broad range of departments and several Colleges at Cornell. For example, the NSF project on "Crack Propagation on Teraflop Computers" is joint between Computer Science and Civil and Environmental Engineering. The goal is to simulate fracture in macroscopic engineering parts like airframes and gears, using parallel adaptive finite-element methods. In order to solve these problems for realistic size problems, new computational techniques are also needed. The project is researching areas such as 3D mesh generation, preconditioners for iterative solvers, compilation methods for sparse matrix computations, and automatic load-balancing on parallel computers. These technologies will permit engineers to simulate crack growth in 3D systems consisting of a million degrees of freedom (including systems with many interacting cracks) in about an hour on a parallel machine with roughly a hundred processors.

**Life Science.** Cornell is undertaking a major effort in Computational Genomics, with cooperation between several departments and colleges. In addition to this large effort, there are a number of other activities in Computational Biology. For example, the study of protein shape can be greatly aided by the use of advanced computational techniques. Random mutations of proteins are the elementary steps of evolution. Databases of protein structures and sequences suggest that the shapes of proteins are better conserved than the
sequences during the course of evolution. A single three-dimensional shape seems to accommodate an exponentially large number of sequences that share no more than a few percent of identical residues. Widely different sequences can share the same global topology and three-dimensional structure. Answering many of the fundamental questions about protein function and shape seem best addressed by the use of computational models and techniques, including the development of new computational methods. The biological questions include issues such as whether it is possible to find a single or a few mutations that cause a dramatic change in the stable shape of the protein, or whether it is possible to trace remote evolutionary relationships between species by following structures and not sequences (since structures seem better preserved than sequences). Questions of this form are computationally hard and require the design of new models and new computational algorithms, making them an interesting challenge for computer scientists as well as biologists.

Undergraduate Computing Program

To better prepare our students for the information age, we propose that Cornell develop an Undergraduate Computing Program. This program would in large part be patterned after the Knight Writing Program. Its goal would be to teach all students the fundamental ideas of computing and information systems, in a context where they can apply these ideas within their own areas of study. While the Computing Program would have the goal of educating all students, we do not envision a computing requirement for all students until there is a campus mandate to do so. We strongly encourage a timely campus-wide discussion about what computing curriculum might be required of all students. Just as Writing Seminars go beyond the mechanics of writing, the Computing Program must go beyond the mechanics of programming or software packages. Our students must learn how to think computationally, not just how to use computational tools – although the tools will be taught as a necessary prerequisite.

There are many parallels between introductory computing and introductory writing. In computing, there is an inherent tension between the concepts that the computer scientists want to teach and the tools that the other disciplines want their students to learn. A similar tension exists between mechanics and concepts in writing, and the Writing Program has developed a careful balance between these needs. Computing courses such as CS100 teach fundamental principles of object oriented design and iterative versus recursive processes, currently using the Java language. In many areas of science and engineering, however, the faculty want students to learn particular programming languages or software tools such as Fortran or Matlab. There often is a disconnect between the principles that are taught in CS100 and these particular tools, leading to frustration for faculty in other departments.

It would be nearly impossible for a single department to offer versions of CS100 tailored to each discipline. Even with the current situation, where "only" about 1/3 of Cornell students take CS100, this is not possible. This failure to meet the needs of the disciplines has been a source of frustration for a number of departments, some of which now teach their own introductory computing courses. It is also a source of frustration for the CS
department, which finds that those other courses generally teach little in the way of fundamental principles that apply more broadly. Thus we propose to follow a model more like the Writing program, although we do not envision the Computing Program necessarily having small classes and sections (however in some disciplines that could be highly beneficial).

We propose that a Computing Program office be created, overseen by a FCI faculty member (probably at least initially a faculty member in the CS department). This office would set curricular standards and help in the development of computing courses across the campus, much as the Knight Writing Program does for Writing Seminars. Initially we do not envision computing being a campus-wide requirement, but we recommend exploring this option over the next few years. The Computing Program office would not only set standards, but would work closely with departments that wish to offer Computing Courses, in order to develop curricula that both serve that department's needs and serve the need of providing a broader computing education. We expect that the office would employ some professional staff to both administer the program and to work with departments across campus.

We believe that there could be substantial opportunity in integrating the Computing Program with planning for the new North Campus as a potential location for classrooms, additional labs, and faculty contact. For instance, one problem with many computing courses is the lack of contact between students and faculty or course staff. In part this is because much of the work by the students takes place outside the normal 8-4 time period for classes. Increasingly students have the necessary computers in their dorm rooms to do this work, but may still need to return to central campus for access to teaching staff. It appears that it could be advantageous to hold tutoring sessions in the living groups, and have faculty or course staff available at the “off hours” when students really do their work.

We further propose that the Computing Program office be active in "teaching the teachers", much as the Knight Writing Program does. One of the major educational challenges of the moment is that entering students often know more about computing tools than the faculty (and even graduate students) who are teaching them. Thus we must both bring faculty and teaching assistants up to the level of the students, as well as preparing them to teach the concepts that incoming students do not generally know. Again, an analogy to the Writing Program can be useful here. Most incoming students are adequately skilled in the mechanics of writing but not with how to use writing as a means of clarifying their own thinking. Similarly, more and more incoming students are skilled in the mechanics of computing but not in how to use computational ideas in their thinking.

A program for teaching teachers could take several forms. One could envision faculty with computational expertise co-teaching courses with other faculty. One could also envision summer programs for faculty and teaching assistants. We expect that in order to be successful, there must be adequate resources available to create such programs without placing an added burden on any of the faculty involved (either instructors or participants).
Thus it will be important to be able to buy out faculty teaching responsibilities and to pay summer salaries for faculty and teaching assistants involved in teaching the teachers programs. We hope and expect that such a program would be attractive to both foundations and private donors.

NEXT STEPS

The task force solicits reactions to this initial report as well as other suggestions for what Cornell should do in this critically important area. We are happy to meet with groups of faculty, students and staff to further discuss the issues raised in this report as well as other pertinent issues. Please contact the task force chair, or any other members (names and email are on the following page).
MEMBERSHIP OF THE TASK FORCE

Daniel Huttenlocher, Chair (dph@cs.cornell.edu)
Associate Professor of Computer Science and Chair of FABIT

John Abowd (jma7@cornell.edu)
Professor of Labor Economics

Thomas Coleman (coleman@cs.cornell.edu)
Professor of Computer Science and Director of Theory Center

Robert Constable (rc@cs.cornell.edu)
Professor and Chair of Computer Science

Kerry Cook (khc6@cornell.edu)
Associate Professor of Soil, Crop and Atmospheric Science

Geraldine Gay (gkg1@cornell.edu)
Associate Professor of Communication

Marcia Lyons (ml113@cornell.edu)
Visiting Assistant Professor of Art

Polley McClure (pam28@cornell.edu)
Vice President for Information Technologies

Timothy Murray (tcm1@cornell.edu)
Professor of English

Robert Richardson (rcr2@cornell.edu)
Professor of Physics and Vice Provost for Research

Saul Teukolsky (saul@spacenet.tn.cornell.edu)
Professor of Physics and Astronomy

Sarah Thomas (set9@cornell.edu)
University Librarian