A review committee with the following members visited Rutgers on December 14 and 15, 2006:

- David Clark, Senior Research Scientist, Computer Science and Artificial Intelligence Laboratory, Massachusetts Institute of Technology
- Michael Dunn, Dean of the School of Informatics, Professor of Computer Science and Informatics, Indiana University
- David G. Messerschmitt, Roger Strauch Emeritus Professor, Electrical Engineering and Computer Sciences, University of California at Berkeley, and Visiting Professor, Computer Science and Engineering, Helsinki University of Technology
- David L. Waltz, Director, Center for Computational Learning Systems, Senior Research Scientist, School of Engineering and Applied Science, Columbia University

The committee appreciates the generous time and active cooperation and support of all the reviewed units. Rutgers has some real strengths to build upon, and the committee was impressed with many areas of activity. Although clearly resource constrained, there is an opportunity to build on current strengths and bring the Computer Cluster to a new standard of excellence. We hope that our suggestions below are helpful guidance in achieving this. The following report is organized in accordance with the "charge" provided to the committee.

1. Current Issues in the Field

What are the ongoing issues and debates in the field of computer and information science and engineering, nationally and internationally, that should be attended to as Rutgers moves forward with a plan for enhancing its excellence?

Organization of academic disciplines

Three organizational structures have become commonplace:

- A single CS/CE/EE department is the model followed by some of the top-ranked computing programs (such as MIT, Berkeley, and Michigan). While such departments tend to be very large, and thus require some internal divisional structure, their advantage is that there is no need to set boundaries within a unified discipline that is fluid and changing.
• As at Rutgers, separate CS/ECE departments (Illinois, Carnegie Mellon) and CS/EE departments (Stanford) are more common than the first model, and are also found among the top-ranked programs. The greatest advantage is that CS is free to reside in a different school or college than ECE, although there is a trend to CS residing in or moving into engineering (as at Stanford). Some argue that residing in a different school leaves CS freer to collaborate with the physical and social sciences, although it is difficult to identify a real trend in this direction in practice.

• A unified "school of computing and information" is a yet another model and this seems to be a trend in response to the "information revolution." There have been a number of new schools that have been developed or transformed in this way, and there are now over 40 in the IT Deans Group, sponsored by the Computing Research Association (the leading organization for computing research in the country). The list can be found at http://www.cra.org/Activities/itdeans/participants.html. These include early examples such as the School of Computer Science at Carnegie Mellon and the College of Computing at Georgia Tech. More recent examples are the Bren School of Information and Computer Sciences at UC-Irvine and the School of Informatics at Indiana University. The examples just mentioned include computer science and certain broader aspects on information science, but a number of "information schools" discussed below typically grew out of library science programs and do not include computer science. Indeed it is difficult to find examples of schools that contain the whole range from library science on the one side to computer engineering on the other. The School of Computer Science and Informatics at Arizona State is an example that includes both computer science and computer engineering. A "school of computing and information" has many advantages connected to synergy and scale, but does typically still has the disadvantage of departmental "silos."

Change is underway, and a number of different models are being experimented with, with no consensus as to a best approach yet emerging.

**Dealing with the applications side of computing**

The applications side of computing is flourishing, expanding and growing rapidly in importance. Some of the models in evidence:

• Movement within the computing departments toward applications. This is strongly evident in increasing cross fertilization with the physical sciences (scientific computing, bioinformatics, statistics, etc.), but it is harder to identify computing departments with strong and increasing links to the social sciences and humanities and the professional schools (business, law, etc.). That is more the purview of the information schools.

• Faculty, research, and curriculum within various other departments with a strong computing component. This is increasingly evident in business schools with growing programs in management information systems (for example Rutgers' Ph.D. program in Information Technology, and MIT Sloan School, the latter hiring strongly qualified computer scientists), and law schools (Berkeley's Center for Law and Technology).

• Establishment of a separate “schools or information” (Michigan, Berkeley, Texas, Washington, Penn State, etc.) with a focus on the applications side of computing and
communication technology. Such a school can be viewed as having a relationship analogous to the one between architecture and civil engineering, the former focusing on esthetics, societal context, and relating to building occupants and the latter on structural integrity. In some cases these schools arose from and continue to serve the discipline of library science (Michigan) and in fewer cases do not have an explicit library science program (Berkeley).

- As at Rutgers, a very common model is traditional schools of library science extending their reach into information access intermediated by information and communication technology, usually accompanied by adding the term "information" to the name.

**Fluctuation in student enrollment**

Computer science has experienced fluctuations in student interest and enrollments nationwide, particularly at the undergraduate level. Enrollments seem to be tied somewhat to the waxing and waning of commercial tech activity, probably driven by the strong publicity of these trends in the mass media. In view of this likelihood, schools such as Rutgers should not be influenced too heavily by yearly enrollment changes, but rather be driven by longer term trends (five to ten year moving averages are probably appropriate). It is true that industry needs consistently exceed the available educational output, so the fluctuation is more in student supply than in industry demand. The prospects for computing-related disciplines remain very strong, especially as the applications of computing and communications spread across a wide variety of industries and disciplines. We believe this is particularly true in the vicinity of Rutgers.

**Domestic graduate students**

Computing disciplines at the graduate level have experienced a shortage of excellent US grad students and surplus of excellent non-US grad students. The limited number of US graduate students (in relation to capacity and research opportunities) have tended to congregate more heavily at the most renowned and highest ranked schools (such as the Ivy League, Stanford, CMU, USC, and the top public programs such as Berkeley, Michigan, and Illinois) while other schools have a heavy non-US enrollment. However, it is important to add that many, and probably most, foreign students have traditionally stayed in the US after graduation and represent a critical human resource to the US industry. Thus, it is ultimately a service to the local and US economy to attract and educate this foreign talent pool.

**Women and minorities**

Computing fields have a poor track record in attracting, retaining and promoting women and minorities. Rutgers' percentage of women CS faculty members is substantially lower than even the poor numbers of women in computing nationwide. Despite attempts by various organizations to improve the situation (see discussion below in Section 1d) overall progress is painfully slow and meager. Computing's undeserved reputation as a solitary activity probably is largely responsible, as is the lack of publicly visible role models. Progress will require changes in this stereotype, which will take time and the promotion of women and minorities into positions of power and visibility.
Research funding

It has become progressively more difficult in recent years to secure research funding, especially for fundamental theoretical research and for applications-centered research. In the area of theoretical research, the success rates of proposals to NSF -- the only sponsor of theoretical computer science -- is dismally low (under 10%). Funding is somewhat more readily available for military applications, but still well below needs. There is arguably a mismatch between the academic centering of computer science, which tends to look at fundamentals and foundations of the field, and industry, where most workers are concerned with applications and user-centric systems. There is little federal funding for research and training in this latter sort of activity, with the exception of military applications.

a. Are there topics/areas that seem to be in decline nationally?

It is difficult to think of any sub-disciplines that are in decline overall, but easy to identify subdisciplines that are moving to new challenges. New topics that arise (e.g. distributed wireless computing) lead to the transformation of existing research areas (e.g. networking protocols, operating systems, parallel computing).

While there are certainly areas of technology that mature, thus far they have been readily replaced by related new and exciting challenges. No field illustrates this better than library science. Certainly the ideal of a physically centralized archive (the traditional library) is being supplemented and even supplanted by a distributed information access based on digital assets and information and communication technology, but this does not by any means eliminate the traditional role of the "librarian" such as curation, stewardship, archiving, and information architect. Reflecting this, it is rare to see a "school of library science" that has not added the word "information" to its title, sometimes even eliminating the word "library", accompanied by substantive changes to curriculum and research. Another example is audio and video compression, a subfield of signal processing that is maturing but being replaced by ever more challenging problems such as image and video interpretation and understanding.

There is another way to ask the question, however, which is to ask which fields of academic research are demonstrating relevance and leadership with respect to the larger commercial and social context. The review committee did not deliberate this question, but some fields have become more relevant (developments in cryptography by the theory community), some fields have had to redefine themselves (the emphasis on distributed systems in the operating systems community), and some may be in a period of reduced influence (compiler design, which may see a revival with increased emphasis in compiling for highly parallel machines.) These should be seen as national trends, because they occur in a context of collective expectations for publication, tenure and promotion. However, it is possible for a well-positioned school to lead the re-definition of some particular sector.

b. Where are the likely areas of growth?

Here are some strong growth areas (in no particular order):

- Applications of computing and communications are growing explosively. Within academia, it is difficult to identify any disciplines that are not influenced by
computing and information. For example, in the physical sciences the capture, storage, processing, and simulation of scientific data can rightfully be identified as the third methodological leg of the scientific methods, along with theory and experimentation. Similarly, economics and other social sciences increasingly rely on computational methods, and even the humanities find information access, data storage, and simulation increasingly pervasive.

- **Organizational computing**, in which computing and communications have a pervasive influence over organizations of all types. Increasingly the management disciplines require attention to the pervasive role of computing and communications in processes and organizations. Management is today about the joint design of process, organization, and technology, with information and communications technology "embedded" within a larger management process and organization context.

- There is currently an explosion in **social computing**, by which we mean computing and communications as an element of personal life, friendships, and social interactions generally. This is evidenced by the exploding success and influence of self-publication models (such as blogs and video publishing), social intercourse intermediated by technology (such as social networking and relationship sites). The traditional media are increasingly being supplemented by "social media", and all aspects of society including political discourse are undergoing a revolution.

- **Software engineering** is the discipline that deals with the processes and projects in the creation, maintenance and evolution of software artifacts. This discipline is arguably underrepresented in academic programs relative to its importance and pervasiveness in practice. Today the discipline is being challenged by the new realities of organizational and social computing, which put dramatic new stresses on the capturing of needs and requirements, and particularly the need for holistic attention to social processes and organizations deeply integrated with information architectures and algorithms.

- **Machine learning** and adaptive systems are the basis of many applications, and are strongly influencing many other areas of computing. Data mining of business (especially web and financial) and scientific (especially genomic) data is transforming those fields. Machine learning substitutes for many aspects of software engineering for many modern application areas, notably speech and natural language processing, image and video processing, cybersecurity systems, failure prediction systems (e.g. for the electric power grid, rotating equipment such as generators, etc.), and many others. Notable successes have been web search systems and “Stanley”, the winner of the DARPA desert challenge for autonomous vehicles whose controls were constructed largely by learning from a skilled driver's behavior.

- **Human-centered computing** aims to augment humans, rather than replace humans with autonomous systems. Research has been most heavily driven by military and space applications, but there are wide opportunities for augmenting human abilities in dangerous activities (e.g. mining), control (flying, driving),
teleoperation, remote applications of expertise (e.g. expert medical examination and diagnosis via the web), etc. Much research here focuses on graphic presentation of data and mechanisms for natural physical interactions between humans, computers and mechanical systems.

- **Pervasive computing** combines aspects of several of the topics above with networking, communication (especially wireless), very inexpensive embedded processing (down to computing dust or paint) to envision future applications that potentially make all manufactured items trackable, active, and interactive. In the nearer term, applications based on networks of wireless systems offer the possibility of monitoring or controlling devices from anywhere.

- **New technologies** most notably include quantum computing, which could lead to radically more powerful processors; and nanotechnology, which is leading to ever tinier and cheaper computing devices, capable of interacting with matter at a much finer scale than is possible today, with implications for medicine, manufacturing, monitoring and measurement, etc. Rapid advances are occurring in other technologies like displays, batteries, etc.

c. **What trends do you see in how computer science at other universities is relating to and interacting with other units or fields of study?**

*Schools of information*

There has been a dramatic rise in schools that attend to information architecture and applications, such as "information schools", as previously mentioned. This is reflected to a limited degree in the LIS program at Rutgers, and especially its appointment of a computer scientist as the department head.

*Joint faculty appointments*

There is a rapidly increasing use of joint faculty appointments between computing and other schools and departments. Sometimes these are resource-sharing arrangements (such as 50% appointments) and often they are "courtesy" or "zero FTE" appointments that strongly sanction involvement and collaboration. This serves as a form of quality control for the hiring of faculty of broad interests, encourages interdisciplinary research, and allows departments to be more outward looking. Compared to other universities, this mechanism appears to be used infrequently at Rutgers.

*Spread of computer fluency*

There is an increasing prevalence of computer-savvy faculty in other schools and departments, often associated with centers and programs with names like "management information systems", "bioinformatics", and "law and technology". Examination of this trend at Rutgers was beyond the scope of our review. We did note that there is a doctoral program in “information technology” in the School of Business, and find it puzzling that this was not included within the scope of the Computing Cluster.

*Research collaboration*

Increasing attention to applications within the computing disciplines generally results in more collaboration with relevant disciplines such as business, law, economics and the
social sciences more generally. This is also an area that appears to the reviewers as less developed at Rutgers compared to universities generally.

d. How can the severe under-representation of women and minorities be addressed?

Other universities have found that increasing attention to the applications of computing and communications attracts more minority and especially female representation. For example, the "information studies" programs generally have a strong female enrollment (in some cases approaching or exceeding 50%). Thus, increasing attention to applications and the associated interaction and collaboration with non-computing-centric disciplines would be highly beneficial.

Minority and female representation on the faculty is a strong enabler of student interest and enrollment. At Rutgers the CE program (three women out of ten faculty) is doing better than the CS department (two women out of approximately forty faculty) in this regard. Clearly redressing this will require faculty hiring. While minority faculty applicants are still unfortunately few in number, in our experience the availability of highly qualified women applicants has increased substantially in recent years.

In response to the problems of women in computing, several organizations, most notably CRAW (Computing Research Association -- Women) and NCWIT (National Center for Women in Information Technology), have worked to develop model programs to attract and retain women with some success, using mentoring of students and faculty, public presentations to students from K-12 through graduate school, conferences geared toward women (e.g. the Grace Hopper Conferences), etc. We recommend that Rutgers join the Academic Alliance of NCWIT so as to be in a position to learn best practices for encouraging women faculty and students. Other organizations have targeted minority students, including similar programs and conferences (e.g. the Richard Tapia conferences). Some programs -- such as Columbia's Gateway Lab that requires all entering freshmen in Engineering to work on team-based projects with community and university groups as clients -- seem to be making some difference in retention of women and minority students. It does seem clear that women and minorities tend to be attracted to universities where there are visible role models. We also point out that NSF has a special program BPC (Broadening Participation in Computing) that funds special initiatives to reach out to underrepresented groups.

We would recommend that Rutgers participate in organizations that aim to improve opportunities for women and minorities, to learn from and to network with other universities and individuals. One of the quickest ways to improve the situation at Rutgers would be to actively recruit charismatic senior women and/or minority faculty members.

2. Reputation of Rutgers Computer and Information Science and Engineering

In which areas are Rutgers programs in computer and information science and engineering best known nationally and internationally, and what is the basis for their reputation? Please comment on the strengths, weaknesses, and distinctive areas of Rutgers departments/programs/schools in these areas.
We identified the following programs and activities as particularly strong (in no particular order):

- **Theoretical computer science (DIMACS).** DIMACS has long been a leader in discrete math, attracting partnerships and memberships of local industries (AT&T, Lucent, IBM, NEC, etc.), several Rutgers departments, and nearby universities (especially Princeton). As research at local industries has in some cases been downsized, DIMACS has become a resource that provides industrial researchers with critical mass. DIMAC's K-12, teacher education and "special year" programs are outstanding. DIMACS has been remarkably successful in attracting long-term NSF support, something few on-going programs at universities have ever achieved. Fred Roberts' leadership and flexibility have been important contributors to DIMACS's success, with the most recent shift being to target the area of port security. Fred's intention to reduce his role in the near future is a cause for concern, though he seems to have a plan for this transition. Shifting much of its resources to more applications-oriented (vs. theoretical) research could split and/or weaken DIMACS.

- **Artificial intelligence (CS).** Rutgers has had a strong AI program since the early days of computing, most visibly associated with the late Saul Amarel. Today Rutgers still has some strengths (especially with Michael Littman in machine learning) but many of its most visible faculty are nearing retirement, and have not been replaced. Several AI-related faculty have left for other universities or are on leave at start-ups or NSF (Haym Hirsh) and may or may not return. Without some targeted faculty hiring, Rutgers is unlikely to be a force in the field in 10 years.

- **Wireless communication, networks, and systems (Winlab).** Winlab is clearly one of the strongest programs at Rutgers and one of the strongest in its area in the world. Winlab's facilities are impressive, its leadership is excellent, and its researchers are impressive. The greatest concern here is the seven-mile distance between Winlab and most of the rest of Rutgers' computing activities. It's difficult enough to collaborate across two floors of the same building, let alone across seven miles of congested highways.

- **Signal processing, both image and speech (CAIP and CE).** CAIP was historically a force in the intersection of applications and computing, but in recent years it has lost most of its industrial partners, much of its funding, and most of its energy. CAIP lies along one of the major fault lines within the computing cluster, having collaborated tightly with CE, but little if at all with CS. While CAIP was a "brand name" of considerable value at one point, this value is today mostly dissipated.

- **Information access (LIS).** LIS computing-oriented faculty have among them many exciting ideas and programs. The new chair (Mike Lesk) has a computing background. The department has a long history of high visibility in information retrieval research (Nick Belkin). Prospects for collaboration with CS are excellent, with some on-going activity. While not as far removed as Winlab, LIS is nonetheless too far away for active collaborations and serendipitous interactions with the other departments. Its students range from computing-savvy to computing-phobic. The committee only met the computing-oriented part of the department, and it's unclear to
us whether the entire LIS activity would fit well with the rest of the computing groups on campus.

- **Protein databank.** The committee did not meet at all with Protein Databank faculty. Nonetheless this is a world-class activity with a very strong positive reputation, and interests that probably overlap those of the groups we did meet. Having an association with the Protein Databank would increase the luster of a combined computing effort at Rutgers. Whether an association with other computing groups would have sufficient mutual benefit to the Protein Databank is hard to say without further study.

- **Center for Computational Biomedicine Imaging and Modeling (CBIM).** The committee was favorably impressed by the high-fidelity modeling of physical processes (water, cloth, physical organs, etc.). While none of the committee members is expert in this area, this seemed to us to be an important and cutting-edge research activity. It was not clear how this fits today within an overall computing activity, or how it would fit in a future one. At most universities this activity would be a lab within a department, not a separate research unit. CBIM's location one-quarter mile from the main buildings is a handicap, and its location seems to have been chosen simply because there was no suitable space in the main buildings.

Due to our limited visit time, there are likely quality activities that we have left off the list (our apologies).

a. **Given your assessment, in what two or three areas is Rutgers best positioned to improve its excellence and stature?**

We have three suggestions.

**Pervasive computing**

This topic (or its other manifestations, such as ubiquitous computing and embedded computing and sensor nets) reflects the important reality that computing is not just "PCs", but is being integrated into most of the components of the world around us. The topic is thus fundamental, and it is also "hot", with many centers being started to study it. Rutgers cannot afford to ignore this trend, but it needs to decide how explicitly it wants to embrace it, since for objectives such as fund-raising one must find a distinctive point of view or approach. Rutgers is well positioned to move into this area: technology research can leverage WinLab, research related to information can leverage LIS, and some specific application research in DIMACS (the port security project) could be relevant. Given the nature of LIS, one way to distinguish a Rutgers initiative in this area would be to look at "pervasive information", or something along those lines. This topic also raises many larger social issues (e.g. privacy, surveillance, ownership and control of various sorts of information), and can be linked to the problems in social computing (below), with its opportunities for multi-disciplinary research.

**Applications of computing and communications**

Greater attention to the applications of computing and communications generally is a natural extension of the current activities, and one that is aligned with both the needs of the field and the national trend. This would be a good focus for increasing the level of collaboration across the Computing Cluster and especially with other academic units in
the University. What applications? Almost all fields, both academic and commercial, offer big opportunities. In providing some focus, Rutgers could be guided by two considerations. (a) What potential application areas are strongest at Rutgers and demonstrate the greatest interest in computing? Although detailed examination of this question was beyond our scope, two areas that did come up were Statistics and Business. (b) What are the strongest local industries, who might provide both financial support and participate in the research? Obvious examples here include telecommunications (where there are already good contacts), pharmaceuticals (the Protein Databank could provide a good starting point), and finance.

**Social computing**

Social computing is wide open and ripe with opportunity. This seems a particularly appropriate focus for Rutgers given its strong humanistic tradition and a good starting point in the LIS program. Social computing is also well aligned with the technology being developed in existing research centers such as image/video, signal processing, and wireless networking as these all focus on human interaction and mobility. Rutgers strength in artificial intelligence is also very relevant, as machine learning could play a big role (an existing example at Rutgers is artificial intelligence applications to the legal systems). An initiative in social computing would seek to strongly involve the humanistic disciplines, such as the humanities and social sciences, in a shared vision of greatly expanding the beneficial role of computing and communications in social endeavors of all sorts (such as interpersonal, organizations, communities, and society).

b. **How can Rutgers best leverage its strengths in these two or three areas to make significant advances in computer and information science and engineering and related areas?**

The key critical need is to find groups of people with common interests, and with the energy to create and pursue ambitious plans. Plans should be novel, preferably unique, but also timely, doable with near term knowledge, hardware and software. This is analogous to the kind of planning that DARPA does for its projects, and that NSF sometimes does for new initiatives. The key ingredients for success here are the particular common interests of Rutgers researchers, the needs of local industrial partners, fostered by encouragement, organizational aid and incentives -- both for individuals and groups -- from the university.

c. **What resources and actions are needed to make significant advances in these areas?**

New initiatives and new collaborative groupings could be driven either bottom-up or top-down. The CCC seems well-positioned to generate bottom-up proposals for projects and organizational changes. The Rutgers administration will need to make sure that any CCC proposals are given serious consideration in a timely manner, and to provide feedback for improvements (if needed) and synergistic support in seeking resources for worthy ideas. Alternatively, or in addition, Rutgers administration (or CCC) could identify resources and institute competitions for good ideas to utilize them. As an example of this type of top-down approach, in early 80s Committee member David Waltz participated in one of two small committees competing for a new Center at the University of Illinois. High level Illinois administrative people appointed the committees, arranged the meetings and
pushed both groups. Both proposals were presented to a donor (anonymous at the time), and Waltz’s group’s proposal eventually became the Beckman Center (~$45M).

In the absence of a big donor, a similar method could nonetheless be instituted by Rutgers administrators to get good internal "seed" proposals. A natural incentive could be the use of high quality open space (e.g. the current CAIP space). Particularly excellent proposals could be polished professionally and added to a Rutgers capital campaign, and might also become NSF Center proposals. Other possible incentives include support for new faculty lines, equipment, or post-docs.

d. What key strategic decisions should Rutgers consider as it decides how to advance excellence in computer and information science and engineering?

**Organization**

We believe that major organizational changes could be very beneficial. This is discussed in more depth in response to question 7c.

**Local culture**

We have mentioned elsewhere the need to place an emphasis in academic personnel and academic leadership on greater collaboration and interdisciplinary effort. But it should also be recognized that Rutgers is in a region with a strong industry, and this can be leveraged in terms of resources and in other ways as well.

We heard indications that while changes in the local industry have benefited Rutgers by bringing some outstanding faculty, there is also the possibility of faculty defections to local industry and startups. Based on our own experience, our suggestion is to flow with the industry/startup trend rather than fight it. Recognizing that startups and industry development are sometimes the best way to increase the impact of academic research, a culture can be created in which temporary moves to industry to commercialize research and then returning to the university is natural, expected, and nurtured. This includes:

- Faculty should be made to feel that they are not being disloyal, but rather acting in the university's best interests in the long run.
- Industrial experience should be valued for its contribution to teaching (bringing more real-world engineering and management to bear) and to research (motivating important new research initiatives).
- Faculty should be rewarded in the academic promotion process for contributions made in industry, particularly in the degree to which their research’s impact is enhanced. Faculty should not be penalized in terms of university salary or tenure decisions for leaves of absence within reasonable bounds.
- Research conducted by groups of faculty, whether interdisciplinary or not, should be the norm so that continuity of teaching and graduate student supervision is maintained while some faculty are on leave of absence.
- In order to support the flow to and from industry, it would be best to formulate and disseminate guidelines rather than dealing with cases in an ad hoc manner.
• Finally, any steps that make Rutgers a more attractive place, such as improved academic excellence, more interdisciplinary work, and improved facilities will serve to attract faculty back to the university.

Resources
We have mentioned elsewhere a general lack of faculty hiring in the Computer Cluster disciplines, with a resulting stagnation in areas of research and to some extent a loss of energy and vitality. Major improvements in quality and reputation will require stepped-up faculty hiring. The University can choose to devote more resources to this area. There is a trend at public universities toward funding of growth in faculty positions in areas of high demand through non-traditional sources like endowed professorships and differential tuition revenue, and possibilities like these can be considered. Encouragement of and incentives for retirements are another route.

Also mentioned elsewhere are some shortcomings in academic space, particularly as to its fragmentation and a shortage of research space in some areas. Consolidation of the Computer Cluster activities would have major benefits, perhaps even beyond organizational shifts. Expansion of a current building or a major new “computing cluster” building would be a welcome step.

We found the resources available to the computer engineering effort within the ECE Department to be especially inadequate when evaluated in relation to the research opportunities, student interest, and teaching loads. Regarding teaching, CE appears to have significantly higher loads than CS Department. To some extent this could be addressed by shifting some teaching responsibilities for the CE students to CS, possibly in conjunction with organizational changes described later. There is a substantial overlap of courses between CE and CS at the more elementary levels, and we found the programmatic justification for this to be somewhat weak. (Two of the reviewers reside in EECS departments where there are a single set of such courses without apparent problems.) More joint appointments, more collaborative research across departments, and more team teaching of large enrollment courses would all help in developing a single unified perspective. To the extent it is impossible to dispense with different courses (e.g. to teach programming languages needed for other core courses early in a student's experience) there could be separate tracks, but most basic courses could, we believe, be common.

It would also be appropriate to allocate more faculty lines to CE. The research opportunities in CE also seem to exceed the resources, particularly with respect to the faculty, which is smaller in relation to CS than is common at other universities. But it is important to not neglect CS and LIS when it comes to faculty hiring, as new hiring (particularly at the junior level) is key to revitalizing their research activities.

3. Learning from Others
Can you identify other universities that have recently made major improvements in the excellence and stature of their computer and information science and engineering programs?

As of 1995, the following programs in computer science were deemed "most improved":

• Oregon Graduate Institute of Science & Technology
• University of Maryland - Baltimore County
• University of Florida
• University of California - San Diego
• University of Virginia
• University of Washington
• University of Illinois at Chicago
• University of Colorado
• University of North Texas
• Georgia Institute of Technology


Computer engineering was not ranked separately, but in electrical engineering, the following programs were deemed most improved.

• University of Central Florida
• North Carolina State University
• University of California - Santa Barbara
• Texas A&M University
• University of California - Davis
• University of California - San Diego
• University of Texas at Austin
• Washington State University
• University of Maryland College Park
• University of Arizona

The improvement rankings are nine years out of date, and will be updated in the new NRC rankings in 2007. We recommend that Rutgers study these rankings and the factors behind them when the new rankings become available. For example, it would be worthwhile to initiate a conversation with deans or chairs associated with programs at some of these universities.

Programs in information sciences were not ranked, although information science programs will be listed under the category of developing areas in the next NRC ranking. In our estimation, some particularly strong programs include: The School of Information, University of Michigan; Information School, University of Washington; The School of
a. What factors were most important to the ability of the universities to make major improvements?

First, we should acknowledge that members of this Committee feel they do not have good visibility into how these specific programs improved. However, we can make some general comments:

- The most important factor is clearly hiring faculty with strong potential and intellectual quality. Generally the programs that achieve the highest eminence focus on hiring and developing junior faculty, rather than trying to achieve a short-term hit by focusing on senior faculty. In addition, there is a danger in hiring solely into individual units that a “pureness” test is applied, closing off important cross-cutting opportunities. This can be overcome by encouraging (or even forcing) hires into joint appointments.

- The faculty hiring process is all important. Members of the Committee would be glad to share experiences (good and bad) in this area.

- Improving programs leverage their local environment. High quality of life is important, but also improving campus facilities and the presence of a relevant local industry and community of higher educational opportunities are very helpful.

- The improving programs as represented by reputation surveys also focus their efforts on improving their research, through various actions such as placing greater emphasis on research outcomes in their hiring and promotion practices, encouraging interdisciplinary research, setting up appropriate mechanisms for attracting extramural funding, etc

b. Does Rutgers have the key factors needed to make major improvements?

**Faculty renewal**

Ways should be found to increase the faculty hiring rate, as this is a critical mechanism for renewal and for extending the reach into new and exciting areas. There may be a temptation to increase the short-term impact by hiring senior established researchers, but the committee believes that a longer-term focus should be emphasized by focusing on junior faculty, nurture and support them, and allow them to “grow up” within the Rutgers culture. This is good advice for any program, but especially at Rutgers where the current experience distribution is more heavily weighted toward seniority than at most universities.

**Allocation of resources**

Resource constraints are an inhibitor (state funding, sagging industry in NJ); thus in the near term it is clearly essential to focus on the efficient and effective deployment of existing resources.
**Acquiring new resources**

It would be prudent to develop a compelling plan for the future of computing cluster efforts at Rutgers that could be used to seek new funding, whether from the state, local industries, foundations, alumni, or wealthy individuals. Such a plan should be coordinated across the cluster; otherwise, it will be unclear who is doing the proposing, and if funding were forthcoming, it would not be clear how it should be divided and administered. It might be possible for a cross-departmental, cross-school group (e.g. the Computing Coordination Council -- CCC) or the VP of Research VP to put forward such a plan, and then be responsible for dividing resources. If such a plan were to come from a new “school of computing” (as discussed later) we believe it would have a better chance of attracting support as funders are more likely to want to be part of something new, as opposed to contributing to the status quo. Even if there were a prior agreement about the sharing of new resources, it's possible that such an agreement could be undercut by a donor with a specific interest in some part of the overall group, and without a unified management resources would have to be steered to some subgroup.

Does Rutgers have what it will take to form a unified front in creating a compelling vision of the future of computing at Rutgers, and carrying out the vision if funds are forthcoming? The existence of the CCC is encouraging, and the CCC could possibly become the basis of a governing group for a unified computing effort. Alternatively a new “school of computing” (as discussed later) could provide vision, focus, commitment and energy.

**4. Interdisciplinary Research Activities**

One difficulty with a discipline-centered cluster review is delimiting the cluster. The cluster for computer and information science and engineering focuses on units of the University with significant concentrations of scientists involved in computer science research (rather than on research which makes use of computing). However, computer science is an interdisciplinary science, and it is important for the departments/units involved in this review to develop appropriate connections to the rest of the university and exploit the opportunities arising from these connections.

a. **Would enhanced relationships with other units help computer and information science and engineering attain greater excellence?**

First, the committee would like to make clear that it appreciates this question, because in our view scholarship and teaching that bridges traditional academic disciplines is increasing in importance, and rapidly becoming critical to academic excellence. The traditional approach of partitioning human knowledge into compartments corresponding to traditional academic disciplines is becoming less and less effective at addressing real-world challenges and opportunities. Many of today's challenges and opportunities are intrinsically cross-disciplinary, and many of the major discoveries and advances will surely arise from interdisciplinary activities. So we believe that Rutgers should place a high priority on this issue.

To this end, the committee appreciates the cluster review approach, which recognizes the opportunity to increase the scope and quality of Rutgers teaching and research in the computing fields through greater coordination among academic units and possibly
through reorganization. In this direction, we applaud the Computing Coordination Council (CCC), which we found has taken excellent first steps. All participants in the CCC display a positive and constructive attitude, an important precursor to success. There is opportunity in taking a holistic approach, recognizing current strengths and weaknesses and addressing what institutional initiatives can build on the strengths and bring Rutgers to the next level. We recommend that the CCC be expanded to include, at minimum, Statistics and Business. As we learned, statistics already has expressed its interest in being included. Business may require more convincing, and we encourage the administration to do what's needed to persuade Business to participate.

To answer the question specifically, yes definitely. This is elaborated below.

b. What are the most important interdisciplinary clusters of computer and information science and engineering activity that the units involved in this review should focus on?

There are many possibilities that we can think of:

- There is a natural affinity between the signal processing expertise in CE and the video and graphics efforts in CS, and all these activities could be focused more toward human-centered and social computing.
- In the context of mobile and pervasive computing, there are many opportunities for collaboration between CE, CS, and LIS.
- The boundary between hardware and software has always been blurred, and the increasing focus on massive parallelism (likely to occur even in commodity microprocessors in the near future) places great stress on software engineering technologies and methodologies, numerical analysis techniques in the physical sciences, etc. This could be the focus of collaboration between CE and CS.
- There is an increasing affinity between statistics (Statistics) and artificial intelligence (CS) in machine learning and its applications.
- Oftentimes efforts in business and organizational computing (reflected to some degree in Business and LIS) consider the IT infrastructure to be a black box and fail to explore opportunities for new technologies better matched to needs. Hence there is an opportunity to collaborate with CS and CE.
- The new NSF Office of Cyberinfrastructure is focused on improving and expanding the infrastructure supporting computing in various scientific disciplines, and this would be a natural affinity between CS, CE, and the physical and social sciences.
- Social computing offers an opportunity for collaboration between the humanistic fields and LIS and CS.

We intend this list to be representative rather than exhaustive.

c. What barriers currently restrict or interfere with Rutgers computer and information science and engineering interdisciplinary activities, if any? What are some realistic approaches to dealing with these barriers?
Complex and fragmented organization

While there are areas of real individual strength, overall we found the organization of computing efforts to be complex and fragmented to the detriment of collaborative and interdisciplinary research. There are several areas of real dysfunction that can and should be addressed. Particularly the level of collaboration, both interdisciplinary and intra-disciplinary can and should be greatly improved, both within academic units and across academic units.

Overhead return

A topic that came up repeatedly was overhead return. The current system seems to engender gaming to maximize overhead return, placing a barrier to some joint grant activity that would otherwise make sense. The Committee members come from systems where either there is no overhead return, or some overhead return goes to units administering research but that return is not influenced by individual grants. One Committee member comes from a university with a strict "responsibility centered management" budget system where dollars go to the schools that generate them, and has seen first-hand the problems that this causes for inter-school collaboration and the need to have mechanisms in place (perhaps MOU's) to direct the flow of indirect costs to match the faculty on the grant. We understand that Rutgers is already addressing this issue, which we believe is important.

Fragmentation of office space

Separation into different buildings as well as the more serious geographic separation of LIS and Winlab are an obstacle to collaboration. Consolidation into a more unified space would be a great help. A less radical alternative would be the creation of space specifically devoted to interdisciplinary research activities.

Incentives for collaborative research

The academic personnel system does not appear to sufficiently encourage and provide positive incentives for collaborative research and joint authorship. Although we did not explore this in depth, the reviewers encountered some indication that the academic personnel review processes at Rutgers inadvertently discourages collaborative research through excessive attention to separating and partitioning credit where researchers have joint authorship. If so, the committee believes this should be addressed, because the strong results often arise from a collaboration itself and are not easily attributed to one participant, and because such a process often contributes to acrimony. The review processes should exalt and reward collaborative research, especially for non-tenured faculty (this sets the tone for an entire career). At most of the top-ranked universities, joint authorship is treated similarly to single authorship, with little or no attention paid to microscopic examination of individual contributions in such works. It is recognized that collaboration can result in intellectually sound outcomes even where significant ground is not broken in the constituent disciplines. Considerable attention is taken to aligning peer review processes with the disciplinary (or interdisciplinary) nature of the research. A strong message is also sent to junior faculty that collaborative work is appreciated, and that it is likely to result in higher quality outcomes and actually strengthen their tenure case. It is fair to expect faculty to make strong individual contributions as well. A lot of
opportunity for interdisciplinary and collaborative research and teaching arises from the
culture of an institution and the attitudes of administrators and individual faculty.

Grant administration
Extramural grants with joint PI’s seem to be a particular problem because of the large
number of places where grants are administered. The fragmentation of grant
administration within the Computer Cluster could easily result in a single faculty member
with grants administered by several organizations. This in itself is a disincentive, as it
introduces an unnecessary level of complexity and coordination overhead when a PI is
balancing resources and obligations.

To illustrate the possibilities, one of the committee members is from MIT, where there is
a single computing department and a single research laboratory associated with that
department. Another is from Berkeley, where there is a single department associated with
a single larger organized research unit at the college level which administers all grants in
a single organization. In fairness, neither of these two cases includes an information
sciences component, which is not explicitly recognized at MIT and resides in a different
college at Berkeley.

This committee does not want to be overly prescriptive, but we can state a few simple
guiding principles that should be kept in mind in considering institutional factors that
relate to collaborative and interdisciplinary research. These are utopian ideals, and we
recognize that compromises will always have to be made:

• Where faculty interest overlaps academic units, this should be associated with a joint
appointment so that this faculty member has influence and interaction in both places.
Often collaboration comes out of joint service on administrative committees.

• There should be no financial impact up or down for either faculty or units that
participate in joint research.

• There should be no hint of devaluation of research outcomes for jointly authored
research, and when collaboration results in new insights these should not be evaluated
solely from the parochial perspective of each constituent field.

• All grants for a given PI should be administered in the same organization, includin
cases where there are two or more PI’s.

Concrete ways in which these principles can be moved to practice are possible in the
Rutgers context. First, we believe that the number and scope of the centers can be
addressed, and there are possibilities for reorganizing the academic departments as well.
This is elaborated below.

Joint appointments
We recommend that the number of joint appointments be increased. First, the existing
faculty should be afforded an opportunity to seek a joint appointment in another unit,
even if it is a 0% or "courtesy" appointment. Of course, it should be at the discretion of
the "receiving" unit to make such appointments, but institutional incentives and the local
culture should encourage this. Second, opportunities should be identified to create new
joint appointments and hiring processes that seek outstanding candidates for such
appointments. Obvious opportunities for this exist between statistics and computer science, between information sciences and computer sciences, between computer science and computer engineering, between biology or bioengineering and computer science and computer engineering, and between information sciences and business. (We don't mean to exclude other possibilities.) The committee recognizes that there are issues with junior appointments where two or more units will need to evaluate tenure, but there are creative ways to deal with this. For example, joint appointments between computer science and electrical engineering are very common at Stanford, and the candidate is allowed to specify (at the final hour) which department is solely responsible for the tenure decision.

Leadership
The academic leadership at all levels can do much to shift this culture. It just takes vision, priority, and effort.

5. Teaching

What are the issues to consider when deciding how much to invest in and grow the undergraduate, masters, and doctoral programs?

a. How should graduate education in computing and information sciences and engineering be structured? b. How well are the educational needs of truly interdisciplinary areas (e.g. bioinformatics) served?

The Committee did not interact with graduate students in sufficient depth to offer much specific advice about what may be in need of improvement. We can offer some general comments:

- Generally we believe that the education at the graduate level should be broader than in the past. For example, many students should combine an expertise in computing and communications with another, like biology, statistics, economics, business, etc.
- If there were more collaborative research efforts focused around problem domains, rather than disciplines (for example bioinformatics or social computing) then this would spill over naturally into curriculum and graduate education.
- A fruitful mode of graduate student supervision is joint supervision by faculty in different disciplines, in addition to taking courses across disciplinary boundaries. Students can gain a strong expertise that transcends disciplines, and also in the process contribute to the education of their faculty advisors.
- An important factor in collaboration across disciplinary boundaries is the configuration of research space. It is therefore valuable to do space planning with desired or expected collaborations in mind, and not structure research space strictly according to departmental and center boundaries.

C. To what extent should the "service" needs for computing and information fluency be addressed?

The computing disciplines are of increasing importance to students across the university, including the humanities but especially in the physical and social sciences and professional schools. The computing cluster academic units could and should be teaching
service courses for these students. For example, we heard that the Physics Department teaches a service course in scientific computing. Why not Computer Science, or why not a team teaching approach? The usual problem with having Physics independently teach such a course is that this tends to perpetuate antiquated tools and methodologies, and the advantage of having computer science participation is that it can expose these students to new and fresh approaches as well as exposing computer scientists to the computing challenges faced by physicists.

There are a number of other possible topics for service courses, with the goal of student understanding of computing, its context and its applications, that enhance the students ability to exploit computing in their professional and student lives. Examples include the fundamental ideas of computer and communication science, information architecture, information retrieval, information authenticity, business computing, social computing, computing ethics and policy, especially with respect to privacy and security. In many of these cases there is an opportunity for a team teaching approach leveraging Rutgers strength in the humanistic disciplines, business, public policy, etc. Not only will this be to the students’ great benefit, but it will also expose the computing cluster faculty to a number of related issues, disciplines, and faculty with overlapping interests. This may ultimately pay benefits in terms of interdisciplinary research opportunities. In pragmatic terms, service courses are a substantial and stable source of student enrollment, which can help justify faculty resources. The new broad course offered by Michael Littman seems very promising.

d. How well are the needs of students within the computing cluster for an education outside computing-specific topics being addressed?

We have taken the liberty of adding this question to your original “charge”, because we believe it is important. To what extent should students in the computing cluster departments be exposed to other disciplines, and what disciplines? Our answer to this would be “much more than in the past”, for a couple of reasons. First, the applications of computing disciplines are becoming much broader and deeper, spanning virtually all fields. Computing cluster students will be presented with many opportunities to contribute to a variety of fields, working with domain specialists. While deeply technical skills will always be in demand, many students will benefit from a broader education.

Second, several decades of technology advance have resulted in a relative shift in importance from cost and performance issues toward what do we do with the amazingly capable technologies we possess. These questions apply to a much richer and diverse set of applications and products, are integrally related with design decisions, and involve issues like what do users want and need and how does the marketplace work. Many areas of study such as human and organizational interfaces to information systems, intellectual property, economics, standardization, and sociology and psychology have become more important. Some of these are areas where information sciences, business, and law can and should be offering interdisciplinary courses that are routinely taken by computing students. Better yet, Rutgers could be setting up interdisciplinary majors or certificate programs that bring engineering, computer science, information science, law, and business students together in the same classroom, most appropriately at the masters level.
6. Computing Infrastructure

By the nature of the discipline, computer and information science and engineering have a special relationship to the computing and communications infrastructure of the University.

a. What role should computer and information science and engineering units play in institutional decision-making about computing and communications infrastructure?

There seem to be two specific roles:

- Since faculty and graduate students have special expertise in advanced forms of computer and communication infrastructure, it is valuable to incorporate their advice into planning of advanced facilities. This is particularly true in support of the physical sciences, which are deploying ever-advancing forms of high-performance cyberinfrastructure for computation and acquisition and management of scientific data.

- The Computing Cluster disciplines are often early adopters of new technologies, offering an opportunity to define and refine approaches in a sympathetic environment.

b. Is the computing and communications infrastructure in the University appropriate to support the research activities of the computer and information science and engineering units?

Everybody runs their own facilities, and while we didn’t have a chance to explore this in depth, users seem to be satisfied with the infrastructure. The few faculty we met outside of the computing cluster seemed dissatisfied with the computing educational opportunities for their non-computing-discipline students.

There may be opportunities for sharing resources, especially systems support personnel, and for eliminating waste via unused cycles. As a basic principle, each researcher needs to have access to equipment, software, networking and databases that will allow him or her to perform at the leading edge of his or her specialty. If the researcher needs only cycles and space of a kind that is considered "standard" -- e.g. MACs or PCs with Linux or Windows -- it would make sense for the university to arrange and/or encourage sharing of facilities (e.g. machine rooms, network access) and support staff. It is inefficient for small groups to do or arrange all their own support. To the extent that researchers need exotic or very large facilities (e.g. supercomputers, very large clusters, unusual hardware or software) much of the impetus for obtaining facilities must come from the researchers. Nonetheless the university will have to provide space. And in order to attract (and retain) the best faculty, the university could arrange start-up packages. These will be especially important to quickly get new faculty with special needs to the point where they can do productive research and take more responsibility for funding their own research programs.

The fact that there are many organizations in separate and geographically distributed schools means that sensible, efficient planning and sharing is inherently difficult. Streamlining the organizational structure could help avoid inefficient and unfair resource allocation.
7. Administrative Structures

In light of your answers to questions 1-6:

a. What are the most appropriate roles for centers and institutes in achieving excellence?

We have expressed the view elsewhere that centers focused on narrow topical areas are a mistake unless it is understood from the beginning that they are to have a limited lifetime. In our view the best approach is centers with broad and flexible and changing mandates, and we would characterize DIMACS and WinLab in this category. (The term “laboratory” may fit this concept better.) All centers should be subject to periodic external review, with the expectation of eventual sunset. Two of the reviewers come from universities (MIT and Berkeley) where the term “center” has a limited meaning as a collaborative research group focused around some topic, with the expectation that the center is dissolved (and often a new one constituted with an overlapping group of faculty) as the researchers move on to a new topic.

b. What on-going mechanisms could increase success in collaborative work?

It can be extremely valuable to have administrators who are knowledgeable about faculty expertise and interests, and the state-of-the-art in a number of areas. Such administrators can introduce potential collaborators, convene brainstorming sessions, and offer incentives to initiate collaborations in especially promising areas (see discussion in section 2.c.) The VP of Research can fill this role in many areas; where the administrators don't know certain areas, outside committees or special symposia could provide ideas.

c. Do the administrative structures now in place help (how?) or hinder (how?) Rutgers ability to leverage its strengths and make significant advances in computer and information science and engineering? What alternative organizational structures should be considered, if any?*

As mentioned elsewhere the current organizational structure seems overly complex and introduces concrete disincentives in areas such as collaboration and interdisciplinary research. Rather than being prescriptive, allow us to summarize three general directions that Rutgers could follow.

**Incremental change**

Working within the current organizational framework, there are opportunities for organizational changes that would reduce some artificial barriers. Generally these should move in the direction of simplification, and would focus on both the structure of research centers and on the academic departments.

Regarding the centers, we suggest specifically renaming and repurposing CAIP as the designated location for all computer cluster research that crosses departmental boundaries. CAIP's space is highly desirable, and could be offered as an incentive for those who can generate the best ideas for its use, although its basic premise of catalyzing university-industry applications-oriented projects remains viable. The status of WinLab could be increased by changing its reporting to the VP of Research, and simultaneously expanding its scope to be responsible for the more ambitious pervasive computing
initiative. Some consolidation of research centers, making them fewer in number and broader and more generic in their research mission would be desirable. As mentioned before, we believe that research centers focused around narrow topics can be problematic in the institutionalization of activities that lose interest over time, and deterring the movement into new and more exciting areas of research.

Regarding departmental structure, it would be desirable to reduce the number of colleges overlapping the computer cluster, for example by moving CS and CE into the same college or even a common department. (However, there could be negative impacts of this on EE that should be carefully considered.)

The advantage of this “incremental change” approach is that less radical changes can be made more quickly and will require less consensus-building effort. A disadvantage is that by not forcing disruptive change, the potential benefits are lessened: it is inherently difficult to institute an environment with continual changes. Fatigue will set in, and in addition as things improve there will be less and less pressure for further change.

**Single research center**

Some universities try to achieve a sense of unity by creating a single “research center” or “laboratory”, a physical facility with offices for students and faculty as well as lab space. This arrangement can physically bring together people from different departments, without having to solve the problem of merging different departments or establishing a new school.

Rutgers could adopt this sort of model by consolidating into a single “computing cluster center” without boundaries where all faculty and students could locate their research grants. This results in a type of “matrix” structure where research is managed in one place, and other academic activities (curriculum, teaching, academic personnel, etc.) are managed in the disciplinary based departments.

As an example, MIT has had an integrated laboratory for CS research since the early 1960's (although for a time the AI lab was administratively separated from the Lab for Computer Science). In this structure, departments are still responsible for teaching and for tenure and promotion decisions, but the research center is responsible for research facilities, grant administration, and space. With this structure, it is possible to reach further afield for collaborators (the MIT research center has faculty from math and biology) since the collaborators don't have to "leave" their own academic department.

An alternative is the “organized research unit” as at Berkeley, which provides a single focus of grant administration and management of special facilities, leaving generic office and laboratory space the responsibility of academic departments.

One of the issues that has to be addressed in this structure is the scope of the research center. It is relatively easier to get funding to start a focused center (such as Winlab), because the funder can see what the vision and relevance is. But with a focused center, the focus can seem exclusionary, the topic can grow stale, and the center can lose its sense of direction. A set of focused centers result in a proliferation of centers, with a fragmentation of responsibility and discouraging faculty from pursuing broader interests or shifting their interest. The MIT lab has succeeded over time to some extent because it has no specific vision, but tries to be broad and to accommodate any new aspect of CS
that emerges. But this lack of focus, while actually beneficial for stability and interaction, may make initial funding harder. Finally, the selection of a director must be done carefully, since any director will have his or her own priorities, which must not be seen as narrowly defining or limiting the future of the center. It requires attention and care (from the top) to keep such a center from splintering into fragments.

One of the issues to be sorted out is whether the faculty see benefits (promotion, funding, autonomy) from founding and leading their own center. If the administration sends this signal, then a unified research center will have trouble surviving, even if it nominally controls the space. Again, using MIT as an example, there are parts of the Institute (CS) where the faculty are happy with the sense of cooperation and collaboration (and the strong administrative support) that comes from the large research center. In other parts of the Institute (like the Sloan Business School), where a number of the faculty members have founded their own centers (currently about 20), for reasons of prestige and fund-raising. At Berkeley, centers are commonly set up by groups of faculty around joint research projects, but they are lightweight, short-lived, and they do not administer grants or space.

**A school or college of computing and informatics**

We use this title because several universities (Arizona State, UNC-Charlotte) have recently adopted this name. But it could be "school of computing and information sciences," just plain "school of informatics" (Indiana University and University of Northern Kentucky use this for schools that include both computing and information science) or any of a number of subtle variants.

The pros for this are rather straightforward and include breaking up the current "silo structure" to remove artificial barriers to collaboration in both research and teaching. In principle this would also create a more efficient structure, not just for teaching and research, but also for administration. Hopefully it would also create new synergies, cause a "splash" in the world of academic information technology, raise rankings and increase external funding. This might also be an occasion to go to the state or a large donor for extra funding to create the new school. The cons are somewhat more subtle and have largely to do with the problems of merging existing cultures. It is not easy to bring together cultures growing historically out of engineering, arts and science, and library science. Invariably some group will feel threatened or underappreciated. Also the efficiencies and synergies can be over-exaggerated if the new structure is only a "paper umbrella" over existing structures, and in fact can become a distraction from the missions of the original units.

Rutgers may in fact be very well-positioned to create such a school. One key factor is that the Department of Library and Information Science faculty tend to be more technical that their colleagues in corresponding units at other universities, and the department already has an undergraduate program in Information Technology and Informatics. There is the issue that it is embedded in a school that also includes a Department of Communication and a Department of Journalism and Media Studies. It would be critical to carefully think through all the implications of removing Library and Information Science and what this would mean to the current School of Communication, Information, and Library Studies. An alternative might be for all of these to join a new school of computing and
informatics. There is in fact a precedent (the new School of Informatics at the University of Northern Kentucky) for a school that includes Informatics, Library Science, Computer Science, "Media Informatics" and Communications. Indeed at the technical infrastructure level, computation, information, digital media, and communication are all entangled and there are good intellectual and practical reasons to support this by an academic administrative structure.

We know of no precedents for a school containing these, and also including computer engineering, though there are plenty of precedents for schools that join computer science and computer engineering. The main issue of moving computer engineering is its current entanglement with electrical engineering, particularly in the curriculum at the first two years of the undergraduate programs but also in mutual support of research programs. But the computer engineering faculty is quite small, and inferior in resources to both the computer science faculty and quite possibly to their electrical engineering colleagues in the same department (we did not have adequate opportunity to review this). They could benefit by being with the computer science faculty, and continued curriculum support and collaborative research would certainly be feasible. It will take someone nearer to the ground to properly assess these alternatives, though we urge that ultimately a point of view be taken that is high enough off the ground to be able to see the forest for the trees.

**Other comments**

We have several suggestions regarding the cluster review process:

- Please recognize the tradeoff between a cluster review and in-depth review of individual units. We have not been as thorough in the latter as we would hope.

- It would be helpful to disclose the full process of the review in advance, prior to soliciting committee members. In particular, we were not informed about the written report until arrival.

- The committee was probably not afforded sufficient time to meet in executive session while still on site (although we recognize the tensions of meeting with so many units).

- The self-assessment material was more voluminous and detailed than necessary for a review of this type. We recommend that the reviewed units be given a tight page limit associated with a focused set of questions to answer.