Keeping Ahead of the Future: A Blueprint of the Institute for the Advancement of Science and Engineering (IASE)

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A Proposal by the Provost's Advisory Committee for the Institute for the Advancement of Science and Engineering

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Executive Summary

The Institute for the Advancement of Science and Engineering will be a system-wide, premier research institute dedicated to contributing knowledge and providing solutions to great challenges that require multidisciplinary approaches across the sciences and engineering. It will establish the University of Minnesota as a leader in interdisciplinary research at the intersection of biological, chemical, physical, engineering, and computational sciences. The hallmarks of this institute are excellence, faculty engagement, and focused investments to maximize the impact of the Institute.

The advisory committee identified the following recommendations as critical to the success of the Institute.

Themes: The research at the Institute will concentrate on a small number of themes that are selected through a community process to ensure that the strength of the University is optimally leveraged. Research themes will change over time.
Membership: About twelve, extramurally funded, interdisciplinary teams of about three to four faculty each will form the core of the Institute. Membership in the Institute will be temporary to ensure a dynamic environment.
Faculty Engagement: Faculty are the key to the success of the Institute and the Institute's success will rest on faculty initiative to form teams, to develop successful themes, and to successfully compete nationally for extramural funding to support the research.
Training and Education: This Institute offers unique opportunities to train students and postdoctoral researchers in a collaborative environment across disciplines. Members of the Institute should develop training opportunities, including but not limited to training grants.
University Commitment: The Institute will only thrive if departments, colleges, and central administration embrace this concept and provide support. College and University administration need to collaborate to meet the needs of the Institute, including identifying space and removing bureaucratic barriers.
Grants Program: A Grants Program will provide a mechanism to allow new collaborative efforts to flourish and will be the main mechanism to attract new teams to the Institute. Researchers at other organizations and businesses should be engaged to broaden the reach and to increase competitiveness at the national level.
Infrastructure: The Institute will need a physical space to facilitate collaborations. This space should be designed to serve as a highly visible showcase for interdisciplinary research. Beyond physical space, the Institute will need well-equipped laboratories with state-of-the-art research equipment and permanent staff to provide technical expertise for the operation of the equipment and to meet cyberinfrastructure needs.
Administration: The Institute should be led by an internationally recognized director who should receive advice from internal and external advisory committees.
Funding: Multiple funding sources will be necessary to provide financial support. The advisory committee recommends dedicating a development officer to foster links with the private sector.
Assessment: External evaluation of research and Institute activities will ensure excellence and focus on high impact.
Disciplinary Strength: This Institute will only thrive if investments in disciplinary research remain strong for strong traditional disciplines are essential for high impact interdisciplinary research.

I. Introduction

Integrating knowledge across disciplines is necessary to make path breaking discoveries to solve the most vexing problems facing our society in energy, the environment, and human health. Funding agencies have responded by providing opportunities to address these challenges. Critical to discovery are strong connections between the biological, the physical, the computational, and the engineering sciences. Understanding complex systems requires interdisciplinary teams that integrate experiments with modeling and theory, and develop new technologies. New technologies will continue to accelerate accumulation of data across all disciplines and require novel computational approaches to understand complex systems.

As a comprehensive research institution, the University of Minnesota has a distinctive advantage of housing faculty of essentially any discipline. This collective strength provides the capacity to respond broadly to challenges and new directions. While the Graduate School has traditionally fostered education across departmental boundaries[1], the University of Minnesota as a whole has not sufficiently leveraged this strength to compete nationally for large interdisciplinary centers and research programs. As a consequence, we have seen a decline in ranking relative to our peers[2].

Strategic Task Force recommendations[3] called for an institute based on research excellence, faculty competitiveness, and focused investments that would bring together teams of researchers to leverage our strengths and to take advantage of new research opportunities. Such an institute should house interdisciplinary teams whose interests straddle biological, chemical, physical, engineering, and computational sciences. Senior Vice President and Provost Sullivan charged a faculty committee to develop a world-class interdisciplinary institute to promote advancements in the sciences, engineering, and technology. This institute will be the Institute for the Advancement of Science and Engineering (IASE). It is built on the premise that very large questions cannot be answered within a single discipline and that collaborative research across disciplines is needed to make progress.

The IASE will be a system-wide, interdisciplinary institute that will significantly enhance the research landscape at the University of Minnesota. It will foster collaborations among the biological sciences, the physical and chemical sciences, the computational sciences and mathematics, the engineering sciences, the health sciences, and the agricultural sciences. We envision that the Institute will be housed on campus in a highly visible building that brings together researchers across many disciplines and conveys its place of cutting edge research at the University.

To be successful such an institute should enhance academic synergies across disciplines, foster collaboration across institutions to meet the reality of an increasingly global academic enterprise, open new research areas, and add value to the University's research portfolio. It should both catalyze new research directions and serve as an incubator for interdisciplinary research efforts. It should bring together productive teams

[1] There are a number of interdisciplinary graduate programs, such as neuroscience, plant biological sciences, conservation biology, and scientific computation.
[2] Task Force Report on College Design: Science and Engineering, Appendix D.
[3] The following Task Force reports included a call for such an institute: College Design: Science and Engineering, Graduate Reform: Discipline Evolution, Research Infrastructure, College Design Task Force, and Collaborative Research.

of researchers across the University, and facilitate collaborations across academic institutions and the public/private sector with the goal to compete successfully for large interdisciplinary research grants that might ultimately lead to the establishment of extramurally funded centers.

Principles, Mission, and Goals

The Institute for the Advancement of Science and Engineering will establish the University of Minnesota as a leader in interdisciplinary research in the sciences and engineering. Its mission is to engage in world-class interdisciplinary research at the intersection of biological, chemical, physical, engineering, and computational sciences to promote science-based solutions to some of the biggest challenges in human health, energy, and the environment. To achieve this goal, the University must maintain and continue to promote disciplinary strength[4]. Specifically, investments in this interdisciplinary institute must not harm departments and the disciplines they represent for strong disciplines are imperative for any successful research.

The Institute will be a place of extraordinary creativity where teams of faculty engage in high risk high reward interdisciplinary research that will push the boundaries of current knowledge. It will foster new and creative approaches to research. It will transform the research landscape at the University of Minnesota towards a flexible research environment where researchers can move easily between disciplinary and interdisciplinary research. It will serve as a magnet for excellent graduate students, postdoctoral researchers, and faculty.

The Institute will be focused on a small number of themes that attract highly competitive teams of faculty. Themes will change over time. To build on faculty initiative and creativity and to encourage entrepreneurship, teams will typically be small. To ensure a dynamic environment that can respond nimbly to new opportunities, there will be no permanent membership, instead, teams of faculty will compete for temporary membership in the Institute for the duration of their research projects. Feedback from external and internal advisory committees is critical to the success. A stringent review process will ensure excellence and impact.

The Institute will serve as a catalyst and incubator for interdisciplinary initiatives and will increase our competitiveness for interdisciplinary grants. Faculty teams who successfully compete for extramurally funded, interdisciplinary research grants will form the core of the Institute. To enrich the intellectual environment and to become competitive for opportunities that require larger groups of researchers, such as center grants, teams will build connections with other teams within the Institute and with collaborators at institutions and organizations across academia and business. A Grants Program will provide critical funding for starting projects that have high potential to attract extramural funding and that fall within existing themes or initiate new themes.

Seminars and workshops will contribute to the intellectual environment and the preparation of the next generation of scientists to work collaboratively across disciplines. Establishing and fostering collaborations will allow the University of Minnesota to

[4] The importance of maintaining disciplinary strength for the success of interdisciplinary research was also emphasized in Recommendation 3 of the Science and Engineering Task Force report.

respond more nimbly to the rapidly changing research environment that requires assembly of teams to respond to challenges.

The Institute must leverage resources. Critical to the success of the Institute is a high level of extramural funding, private support in the form of endowments and donations, state government support[5], and industry support. No single source of funding can sustain the Institute on its own.

Impact and Benefits

The Institute will be a catalyst and incubator for interdisciplinary research. It will coordinate efforts of individual research teams and enhance visibility of research accomplishments. Its focus on faculty initiative and creativity will make it a trendsetter in research agendas. If successful, the Institute will become the go-to place for seeking new discoveries in areas where collaborations across collegiate boundaries are required.

The Institute will contribute to an environment that appreciates and facilitates collaboration across disciplines and will make the University of Minnesota an attractive workplace for the most creative and energetic scientists and engineers in our country and abroad. This interdisciplinary environment will be attractive to graduate students and postdoctoral associates and will allow us to recruit the best candidates of both pools.

The impact of the Institute will extend beyond its physical boundaries. The Institute will bring teams of researchers together who will not only attract new funding while members at the Institute but continue to tap opportunities for collaborative funding after they return to their home departments. Members of the research teams will become much more knowledgeable about the breadth of research at the University and can act as network nodes to bring together additional researchers. This will further enhance the collaborative research environment and more fully leverage the expertise of our faculty.

An Institute devoted to interdisciplinary research has the potential to attract additional extramural funding by facilitating formation of interdisciplinary teams prior to competitions for larger interdisciplinary grants. Improved support and infrastructure will increase the competitiveness of these teams further.

The focus on providing knowledge and solutions through science and engineering approaches to the big problems of our society will have a profound impact on the economic strength of and workforce development in the state of Minnesota. Public and private partnerships will allow the University to increase its impact on economic development, for instance through research collaborations with business partners or starting of new high-tech companies.

[5] Examples in this category include funding from state agencies or State Specials.

Our Competition

Over the past ten years[6], many public and private universities have made major investments into interdisciplinary institutes. Many of these are focused on the life sciences with the goal to foster interactions among scientists from the physical, computational, engineering, and life sciences. A few examples illustrate the depth of investments made by other institutions. Stanford BioX was begun in 1998 on the initiative of a group of faculty. Its research focuses on areas related to biology and medicine. The Cornell Life Sciences Initiative grew out of a faculty initiative focused on genomics in 1997. Its research focuses on genomic/proteomic biology and systems biology. The Michigan Life Sciences Institute that focuses on areas similar to the Cornell Life Sciences Initiative was recommended by a blue-ribbon commission and approved by the Regents in 1999. The Wisconsin Institutes for Discovery was recommended by University of Wisconsin administration, private research centers, and the Wisconsin Technology Council. It is a state and private partnership and was endorsed by the Wisconsin Governor in 2004. It focuses on research in the biological sciences in an interdisciplinary environment. The establishment of these institutes typically involves the design and construction of new research space. For instance, Stanford BioX, the Michigan Life Sciences Institute, and the Cornell Life Sciences Initiative are now housed in new 240,000 sqft buildings that each cost about $140 million. Planning and construction of these new facilities typically takes several years.

There is no single model that can be identified as being the most successful approach. Some institutes rely on temporary faculty, others on permanent. Typically, major fund raising and gifts accompanied the establishment of the institutes. Some states, such as California and Wisconsin, provided significant funds to enable the construction of the building. Many of the recently founded interdisciplinary research institutes across the U.S. share a research focus on life sciences, and the realization that collaborations among scientists across the physical, computational, engineering, and life sciences are critical to the success of these institutes. They all share great facilities and well equipped laboratories. Investments often also include hiring of faculty. For instance, of the 25 faculty housed in the Michigan Life Sciences Institute, all but 6 were hired from the outside and 13 of the 25 are junior faculty. Cornell is planning on hiring 100 new faculty for the New Life Sciences Initiative.

Success requires commitment from faculty and administration across participating units. Highly successful faculty and themes that "show great promise for dramatic advances,"[7] rigorous review, high expectations, and advisory boards are hallmarks of these interdisciplinary institutes. Research teams often receive initial funding from internal sources before successfully competing for extramural funding.

Current Strengths at the University and Potential Research Themes

During strategic positioning, a number of areas of "big research" opportunities were identified. The Science and Engineering Taskforce report highlighted materials, energy, and environmental genomics as areas where the University of Minnesota should focus efforts, and emphasized the important role that computational biology plays in many

[6] Some, like the Beckman Institute at the University of Illinois, which was founded in 1983, are much older.
[7] Stanford BioX web page: http://biox.stanford.edu/faculty/faculty_themes_intro.html

areas of science and engineering. The Research Infrastructure Task Force report identified the following areas as significant research opportunities for the University of Minnesota: nanotechnology; infectious disease and cancer; neuroscience, cognition, and behavior; climatology, ecology, and renewable energy; and cyberinfrastructure. While this advisory committee will provide some potential themes, we wish to emphasize that faculty involvement is critical in the development and selection process of themes.

The Institute will select a limited number of research themes, perhaps three to four, which will change over time. While themes will range broadly, limited only by the faculty's creativity and capacity, the Institute will be highly focused and concentrate only on a small number of themes at any given time. Suggestions for new themes will come from the faculty and advisory boards, and will be reviewed internally and externally. The Grants Program provides an important, faculty-driven mechanism to develop a 'proof of concept' for new themes. It must be emphasized that faculty buy-in will be the key driver for establishing new themes. To be successful, a theme must receive substantial faculty support in terms of having a critical number of teams come together to submit grant applications and be successful in obtaining extramural funding.

The first two years of the Grants Program are particularly critical in identifying the first set of themes. Guidance by the Institute to identify potential themes is as important as faculty initiatives to define future themes. The ultimate selection of themes will be based on faculty responses to proposal requests. Faculty should be encouraged to form multiple teams who not only compete for grants but also develop themes that have broad faculty participation. Especially in the beginning of the Institute, it will be important to identify themes where the University already has significant strengths.

Central to scientific progress have been advances in genomics, computing, and information technologies. We expect these areas to play a key role in many of the themes of the Institute. Themes will cover the whole spectrum of interdisciplinary research in the sciences and engineering. They may range, for example, from materials to energy to climate change. They may integrate basic science research with technology development, as for instance imaging technology that has become critical in our understanding of cellular processes or nanomaterials. They may build on past successes, as for instance chemical biology[8] or nanotechnology[9]. They may cross traditional disciplines, such as geomicrobiology, which integrates across geology and microbiology. They may address significant computational challenges, such as the development of multi-scale approaches that are needed to understand how processes at one level of organization affect processes at a different level of organization, for example, how physiological responses of organisms affect and are affected by climate or how atomic level descriptions of materials affect the behavior of materials. They may lead to collaborations between engineers, chemists, physicists, computational scientists and biologists to engineer microbes, breed plants for diverse biomass utilization, and develop process technologies to produce novel chemical compounds or to design new materials or devices that are inspired by nature. We anticipate that some themes will contribute to activities in the other two newly formed institutes (Institute on the Environment and Translational Neuroscience Institute). While these institutes need to communicate to avoid too much overlap, we believe that the mission of these three institutes is different enough that there can and should be some overlap to fully utilize

[8] See http://www.pharmacy.umn.edu/cbi/home.html
[9] See http://www.nano.umn.edu/

the strengths of the University in these broad areas. For example a basic neuroscience theme might be proposed that would augment work in the Translational Neuroscience Institute. Or work on computational approaches to climate change would complement work in this broad field in the Institute on the Environment. (See Appendix A for short descriptions of themes mentioned in this paragraph.)

Education and Training

Interdisciplinary institutes provide unique opportunities to train and educate the scientific workforce of tomorrow through research experiences, seminars, and tailored programs to develop an interdisciplinary workforce. While the IASE will not be the home of undergraduate or graduate programs because of the transient nature of its research themes, it will nevertheless play an important role in the education and training of undergraduate and graduate students and their preparation for STEM careers. It should become the home for graduate training grants, and offer world-class training for postdoctoral researchers. It should provide research opportunities for undergraduate students and research achievements of the Institute must find their way into curricula. It should develop programs that facilitate working in an interdisciplinary environment, including mentoring, ethics training that specifically addresses challenges of interdisciplinary research, and overcoming language barriers when working across disciplines.

Public Engagement

As a public research university, the University of Minnesota has an obligation to educate the public beyond the degree programs it offers. This includes preparing educated and engaged citizens, participation in K-12 and adult education, and providing scientific expertise to external constituencies. The University of Minnesota's Office for Public Engagement should partner with the Institute to help disseminate university knowledge to the public and private sectors. The Institute should also consider collaborating with the other newly formed institutes[10] in this area of public engagement.

Interdisciplinary research, whether basic or applied, can provide solutions to our most pressing problems in energy, health sciences, and the environment. There is no demarcation line between basic and applied research, and, as Stokes[11] points out, research does not simply progress from basic to applied, which then leads to development and production. Instead[12], research simultaneously "seeks fundamental knowledge" and is "inspired by use." The Institute should consider lecture series that focus on this "fusion of goals"[13] to explain to the public the importance of seeking basic knowledge within a research university.

It is important for the Institute to translate its research accomplishments to the public and to become a champion for interdisciplinary research. Activities of the Institute, including

[10] Institute on the Environment, Translational Neuroscience Institute, and Institute for Advanced Study.
[11] Stokes, D. 1997. *Pasteur's Quadrant.* Washington, DC: Brookings Institution Press.
[12] Quotes are from *Rising above the Gathering Storm*. 2007. Box 3-1. National Academies Press.
[13] Ibid.

an informative web page, public lectures, and other innovative ways to engage the public, are ways to contribute to the scientific education of the general public.

Committee Process

The Advisory Committee is composed of faculty from the following colleges: CBS, CFANS, CLA, IT, Education and Human Development, Medical School, Pharmacy, and Science and Engineering at Duluth. The Advisory Committee met between November 2006 and April 2007 to prepare this preliminary report. During the preparation of the preliminary report, the committee consulted with institutes outside of the University of Minnesota to learn about the structure and organization of other institutes and what contributed to their success. In May, a Town Hall Meeting was held on the Twin Cities campus that was broadcast to coordinate campuses. In May and June, meetings with deans and the Vice President for Research were held.

Name of the Institute

We heard repeatedly during discussions that the name of the Institute should be reconsidered. Reasons are a concern that the name might cause confusion and indicate that colleges with a focus on science and engineering are not advancing the areas, and that the name lacks a contemporary image. While the Advisory Committee did not discuss the choice of name exhaustively, based on the feedback we received, we recommend reconsidering the name.

Time Line

In Appendix B, we provide a time line to chart the development of the Institute over the first seven years.

II. Organization and Structure

Overview

The Institute will be faculty-driven and competitive. It will enhance academic synergies by bringing together interdisciplinary research teams focused on a limited number of research themes. Research themes will change to promote a dynamic environment to address the most challenging big scientific questions that require interdisciplinary approaches. Themes will be chosen in consultation with faculty and advisory groups. The research capacity of the Institute will be built through the Grants Program. The Grants Program will foster new collaborations with the primary goal of positioning teams for competing for extramural funding. Smaller funds will be available for research projects that will take more time to mature and these funds provide an additional mechanism to identify new themes. A rigorous review process will ensure excellence. External and internal advisory committees will provide advice in setting research directions and will critically evaluate the Institute.

Research at any university carries the hallmark of creative and independent faculty driving research. Interdisciplinary research at a university would be unsuccessful if it diminished this role of faculty. To preserve faculty autonomy, the Institute's researchers will be organized into small research teams. This follows successful models of the Medical Research Council Laboratory of Molecular Biology (MRC LMB) in Cambridge, England, and AT&T's Bell Laboratories in Murray Hill, New Jersey, which is now emulated by the recently founded Howard Hughes Medical Institute research campus at Janelia Farm. Small research teams are "essential to promote collaboration and communication between groups, as well as excellent mentoring."[14] The small team approach where individual creativity is fostered counters a frequent concern that "big science" decreases the autonomy of faculty. The small teams will be expected to form connections along common interests to prepare for center grant competitions.

The time to maturation of the Institute will be about six to seven years. During this maturation process, common research space must become available and grow in size as the number of research teams increases. We stress that common space is very important to foster synergies within and among research groups. We strongly recommend a highly visible collaborative space where researchers across disciplines will work side-by-side in well-supported, on-campus, state-of-the-art research space.

We estimate that once the Institute is fully operational, about twelve research teams will be funded on extramural interdisciplinary grants. Each team will be led by three to four faculty who will form the core of the team. The teams will have research staff and participating faculty; they will train postdoctoral associates and graduate students. Core members of research teams will be housed in common laboratory space and will have office space in the same building; participating faculty of these teams will be able to utilize the space if needed but will not have any office space, reflecting that the time commitment on interdisciplinary grants varies from investigator to investigator and may not require physical presence in the institute. A core group, however, needs to maintain a presence.

[14] Rubin, G.M. 2006. Janelia Farm: An Experiment in Scientific Culture. Cell 125: 209-212.

In the following we will address specific aspects of the organization and structure of the Institute in detail.

We recommend that the Chief Academic Officer, the Provost, assign the oversight of the new Institute for the Advancement of Science and Engineering to the appropriate administrative office for reporting and oversight.

Director

The choice of a permanent director is critical to the success of the Institute and we recommend a national/international search. We expect the position to be filled within two years. The director must be visionary with excellent academic credentials, a broad view of science and engineering, and exceptional interpersonal skills. We expect the director to be well established with a national and international reputation and to have a proven track record in shaping research agendas. The director will have tenure in an appropriate department. Research space must be available in the home department to allow the director to continue his/her own research program. Substantial resources must be made available to make this position attractive.

In addition to day-to-day administration of the Institute, the role of the director includes raising the visibility of the Institute, attracting faculty, facilitating collaborations, building external partnerships, and being active in fund raising. In the initial years, the director will play an important role in identifying space needs, securing interim research space, and overseeing the design and construction of permanent research space.

The first two years will be critical in establishing the Institute. To bridge the time until a permanent director is found, we propose that an interim director is chosen early Fall 2007 to oversee the establishment of the Institute. The main initial responsibility of the interim director is to attract research teams, establish the Grants Program (described below), and work with the University administration to identify and secure interim research space. In addition, the interim director is responsible for raising the profile of the Institute within the University and externally through symposia, web presence, and promoting the achievements of research teams.

The (interim) director must be supported by administrative staff. Staff needs will expand as the Institute grows.

Staffing

Administrative Staff

Minimal administrative staffing needs to be available during Years 1 and 2 to facilitate the logistics of establishing the Institute, to help research groups to successfully establish their research programs, and to compete for interdisciplinary, extramural grants. Staff function during the first two years must include administrative assistance to the Interim Director, developing and maintaining a web page, and organizing meetings and seminars. The Institute should utilize the services of the Collaborative Research Services (CRS) of the Office of the Vice President for Research until the activities in the

Institute justify hiring staff to meet administrative needs and to facilitate submission of interdisciplinary grants.

Technical Staff

As the activities in the Institute increase, the need for technical and administrative staff will grow. The Institute will house shared equipment and instrumentation that will require trained staff to operate. There is also need to develop cyberinfrastructure for the Institute, which will require technical staff (see Section III for more detail). It is important that these staff members are permanent and not hired on grants of individual teams in order to provide continuity and access. The technical staff members will not replace technicians of individual teams but provide services that are shared among teams. In addition to technical staff, support to prepare large interdisciplinary grants should be available. This may include, grant writers, budget preparation, and support staff for logistic support. The exact needs for all technical and administrative staff are difficult to predict at this stage and should be revisited as the Institute develops.

Development Staff

To ensure long-term financial stability, the Institute must be the target of significant fundraising efforts. To succeed in these efforts, the University needs to devote substantial amount of time to development. The Institute's interdisciplinary research has the potential to attract funding outside of federal and state agencies and beyond what individual colleges could achieve. To fully take advantage of these opportunities, the Institute's fundraising and development activities should be supported by a development officer who devotes a substantial amount of time to this activity. The Institute on the Environment and the Translational Neuroscience Institute face similar challenges and the University should consider sharing such a position among the institutes, at least during the initial years. As the institutes mature, each institute might warrant a full time development officer. Since the Institute does not report to a single college, the reporting structure should be reviewed to ensure effectiveness of this position. In addition, it is very important that the development officer coordinates his/her efforts with fundraising efforts in participating colleges.

Advisory Committees

External and internal advisory committees are essential to achieving the goals of the Institute. The external advisory committee consists of top scientists and industry representatives. We recommend considering the inclusion of international scientists and scientists from industry. The primary role of the external advisory committee is to advise the Institute on new directions and themes, identify opportunities for development and fund raising, and to critically assess the impact of the Institute on science and the public. The internal advisory committee should include representatives of the administration of participating colleges, the Office of the Senior Vice President for Academic Affairs & Provost, the Office of the Vice President of Research, and the Graduate School to ensure communication and buy-in.

The external advisory committee will grow as the Institute grows and membership will change over time. The selection process of committee members is important to ensure diversity and broad representation of research areas. Nominations of new members

should come from different sources, including the director, faculty, the advisory boards, and University administration. To ensure diversity and breadth, we recommend that the committee members are appointed by the Provost.

The internal advisory committee will provide critical expertise in identifying strengths and weaknesses in research expertise. The committee will critically review efficient and effective use of resources. It is inevitable that the Institute will encounter barriers during its operation, including space issues, identifying resources, or filling gaps in expertise through cluster hires at the college level. The internal advisory committee will provide needed links to other administrative and management units of the University to help overcome these barriers.

Faculty

Membership in the Institute carries significant benefits. Members will be immersed daily in a thriving intellectual community. The research facility with its research space, instrumentation and staff support will optimally support interdisciplinary research. The Institute will serve as a magnet for recruiting excellent graduate students and postdoctoral researchers.

The Institute must become a temporary home to our most successful interdisciplinary leaders. Faculty will become core members of the Institute if their team is supported by extramural grants and their research is central to the Institute's mission. We envision that most teams will initially be funded through internal grants but we also expect that some teams will become members without having been supported through the internal grants program. Faculty will be members of the Institute for the duration of the interdisciplinary grant or until the theme is terminated. There will be no permanent membership. We do not suggest term limits but continued membership requires extraordinary achievements. A rigorous review process must be in place to ensure highest quality, and continuation of membership must be contingent on positive reviews. The importance of temporary membership cannot be stressed enough—this is the only way to ensure a dynamic research environment.

<u>Responsibilities</u>

The privilege of being a member of the Institute must carry responsibilities. Foremost, faculty must strive to engage in high-profile research that raises the visibility of the Institute and the University of Minnesota. They must actively build a larger research community, both within the University of Minnesota and with external academic, public, and private partners. Seminars, workshops, and conferences are some means to achieve this broader reach. In addition, symposia and lectures to inform the public should be part of the Institute's activities that are initiated by members of the Institute.

The interdisciplinary research environment of the Institute provides unique training opportunities to prepare students and postdoctoral associates for a collaborative workplace in which researchers communicate across disciplines. While the Institute will not offer its own degrees, it should actively participate in education and training. Graduate and postdoctoral training will be the primary educational focus but undergraduate education will be part of the Institute in the form of research experiences

for undergraduate students. Research teams in the Institute should seek graduate training grants that support the Institute's themes.

Extramural funding will be the primary mechanism that will sustain the research in the Institute. Funding should be sought from sources that include federal and state funding agencies, industry, donations, and State Specials. Endowments will be critical to sustain the Institute long-term. Teams who are supported through the Grants Program will seek funding opportunities outside of the University to continue the research. Faculty who have been successful in getting extramural funding will continue to seek outside funding, in particular for center grants when appropriate.

Relationship with Home Department

Mechanisms should be developed for faculty to maintain a strong presence in their home departments. This is particularly important for new hires so that they feel well integrated into their home departments while at the Institute and when they leave the Institute and return to their home departments.

Faculty should keep their departmental space and maintain their own, individual research programs. They will continue their teaching and service obligations to their departments. The space assigned to carry out the interdisciplinary research will be dedicated to the research funded on the interdisciplinary grants and is considered temporary space. The main advantage of common space is that research groups, including their graduate students and postdoctoral researchers, will be able to interact more readily with each other across disciplines. The collaborative space cannot replace a faculty's member space in the home department.

We do not endorse buy-out from teaching for every faculty member participating in the Institute. This should be reserved for those who lead proposal preparation for large interdisciplinary grants that require a significant time commitment of the lead-PI. Time should also be made available to the lead-PI during the initial six months of funding for a large interdisciplinary research grant. When a faculty member receives a teaching release, funds need to be made available to their home departments for temporary replacement hires.

Provisions should also be considered for aiding system-wide collaboration. Although virtual or teleconnected collaboration may help stimulate initiation of new projects, or provide a means for collaborators in different locations to touch base on a regular basis during the course of an existing project, it is vital that provisions be made to facilitate the temporary relocation or researchers from the coordinate campuses to the Twin Cities campus. This may include, but is not limited to, allocation of research space at the Institute for researchers from the coordinate campuses, residential and travel support, and granting of short-term leaves and/or teaching appointments in order to allow a researcher a block of full-time collaboration in the Institute. For example, it would be advantageous to the goals of the Institute for a researcher at one of the coordinate campuses to take up residence for a half- or full-year period at the Institute in order to collaborate full-time on an interdisciplinary research project; like a counterpart at UMTC, this person would maintain their academic ties to their home department, but could transfer teaching during that time to UMTC in order to fulfill their academic responsibility to the University while participating in Institute collaboration.

Junior Faculty

Junior faculty must be encouraged to participate in interdisciplinary research. As explained in more detail in Section III, interdisciplinary research may carry risks for junior faculty with respect to tenure. Any untenured faculty therefore should receive regular feedback on their progress, and special arrangements should be made to ensure that participation in the Institute does not jeopardize the standing of the faculty in the home department. Means to accomplish this could be semi-annual meetings of the junior faculty with both the department head/chair of the home department and the Institute's director to review progress.

Grants Programs

A well funded grants program will be critical to the Institute's success in its role as catalyst and incubator both during the initial establishment phase and once the Institute is running at full capacity. We propose two levels of funding, a theme development grant program and a future theme grant program. It is important that all grants are awarded to interdisciplinary teams of researchers, not individuals. While the funding must primarily benefit University of Minnesota faculty, the Grants Program must recognize the globalization of research by allowing teams to include researchers from other institutions. Since requests for large interdisciplinary proposals often include components beyond research, such as education or public involvement, the Grants Program should dedicate some funds to these activities when appropriate. Teams supported by this Grants Program must actively increase the visibility of the Institute. Grant proposals for either program will be evaluated by committees of peers.

Theme Development Grant Program

The Theme Development Grant Program will provide substantial grants to interdisciplinary teams of researchers who do not already have an established track record of extramural funding in the proposed area in order to prepare for competing for major interdisciplinary initiatives two or three years later. Funding could be used for research activities and for support of graduate students and postdoctoral researchers. This program will be competitive and evaluation of proposals must assess the quality of the team members and the proposed research and the long-term potential pay-off. These grants will provide the time needed to not only form competitive teams but also to demonstrate feasibility of the proposed project. They will be the main mechanism to grow the Institute to its full size and to provide a steady supply of new research teams once the Institute is fully established. Teams who receive these grants agree to compete for extramural funds, and continued funding for the second year of the grant must be contingent on their readiness to compete for extramural funds. We recommend that the home colleges of the team members pay back the awarded amount to the Theme Development Grant Program if a team does not apply for extramural funds.

The sizes of these grants will vary depending on the project. Most grants will be of the order of $200-400K per year per team for typically two years. Some grants will be substantially less, whereas others might be much higher[15]. The duration may also vary and may be as long as 3-4 years in exceptional circumstances. Continued funding must

[15] Grants in the AHC Competitive Grants Program range from $200K to $1 million.

depend on the outcome of a rigorous review process and a demonstrated effort to compete for extramural funding after the first year. It is important to fund teams well and to fund fewer teams than spreading the funds among a larger number of teams.

During the first two years, semi-annual competitions for the Theme Development Grant Program should be held to phase in research groups. Each competition should result in funding for about two research teams. The grants must be focused on the themes of the Institute. After the first two years, we expect that some of the teams supported on these grants will have successfully competed for extramural grants. These teams will form the core of the Institute. After the first two years, competitions are held annually with the goal of having up to eight research teams funded on these grants at any time.

Evaluation of these grants should involve both internal and external evaluators. External evaluators should be paid an honorarium for evaluating proposals. The evaluation committee should make funding recommendations to the director. Because of the importance of this program, the recommendations should be reviewed by both the internal and external advisory committees.

Future Theme Grant Program

The Grants Program should include a component that is targeted towards high-risk, high-reward projects that are in the very preliminary stages and therefore not suitable for the Theme Development Grant Program. These projects should have the potential to become competitive for the Theme Development Grant Program within two years. Risks must be taken and it is expected that some of the research funded by the Future Theme Grant Program will simply fail. This grant program will also serve to identify new themes that are proposed by faculty or to prepare for competing for graduate training grants. Funding could be used, for instance, for workshops, symposia, preliminary data collection, graduate seminars, or other activities that bring together potential teams or inform groups of researchers of novel directions.

The level of funding of this program is substantially less than that of the Theme Development Grants Program and individual grants are funded at a much lower level, consistent with the goal of catalyzing new areas. We recommend that about 10-20% of the total funds are allocated to the Future Theme Grant Program. The schedule for competition in this program is the same as in the Theme Development Grant Program.

An internal committee should review proposals to this program and make a recommendation to the director of the Institute, which should also be reviewed by the internal and external advisory boards.

Graduate Fellowship Program

Graduate training will be an integral part of the Institute. To attract the best graduate students to the Institute, we propose the establishment of a graduate fellowship program that would fund up to twelve graduate students per year on two-year fellowships. These fellowships are intended to support graduate students who participate in the research of extramurally funded core teams and will likely have the most impact if they are used for support during the first two years when funding on extramural research grants is more difficult.

Sabbatical Program

The Institute will serve as a magnet for researchers outside of the University of Minnesota. To facilitate longer visits, we propose to provide partial funding to sabbatical visitors.

Review and Assessment

Rigorous and regular review and assessment of the research themes, grants program, research program, management, and financial plan by an external review committee composed of internationally recognized scientists is essential to the success of the Institute. It is particularly important to develop decision points when a theme should be terminated, for instance, if it no longer yields the expected benefits or teams were successful in competing for a center that would focus on the theme. The University is currently developing a plan for reviewing all centers and institutes at the University. The Institute must follow this review process. As part of the assessment plan, the Institute should establish benchmarks and a sunset clause.

The Institute will be judged successful if (i) its activities result in measurable positive effects on the overall quality and impact of the University, including achieving national and international prominence; (ii) participating colleges endorse its continued operation and recognize its value; and (iii) its financial model is sustainable. The Institute's role in the University will change as the Institute matures and this must be reflected in a management style that allows the Institute to adapt to changing demands. The review will play a critical role in identifying areas where changes are warranted.

The Institute must develop decision points at which the continuation of the Institute is critically evaluated by internal and external evaluators to ensure that the concept is only continued to be pursued if the Institute is still judged successful. These decision points should be more frequent in the beginning of the Institute, e.g. every two years. Criteria for success will change as the Institute matures but should include the ones mentioned above tailored to the stage of the Institute. While we do not recommend setting an end date for the Institute at this point, we do re commend that the Institute's continuation should be discussed in regular time intervals, e.g., every five years, once it is fully established and more frequently in the beginning, especially before major investments are made.

The Task Force for Collaborative Research developed a set of criteria to evaluate themes and projects (see Appendix C). These criteria are well suited for assessment of activities in the Institute and we recommend that the Institute adopts this set of criteria. In addition, the Institute must consult with and be regularly reviewed by the external and internal advisory committees mentioned above.

Grants Program

The Grants Program is critically important to the long-term success of the Institute. We stress the importance of applicants including benchmarks and assessment criteria in grant proposals as explained in Appendix C. Impact and feasibility of proposed benchmarks must be a criterion in the evaluation process. All teams must provide annual

reports[16] that explicitly address the benchmarks and criteria each team set for themselves and continued funding must be based on successfully achieving these goals. Additional criteria must address the ability of a team to integrate itself into the Institute and form connections with other teams, the degree to which a team participates in Institute activities, and a team's contributions to the mission and goal of the Institute.

Themes and Research Program

The review of the themes and research program must make explicit the added value of the Institute to the University of Minnesota. The themes must be regularly evaluated to assess whether they continue to meet the expected benefit. The review of themes should include explicit recommendations on continuation or termination. The assessment of the research program must include standard research metrics that measure activities by its members, such as success in attracting extramural funding, number of publications and citations, invited lectures presented by Institute's members, number of graduate students and postdoctoral associates participating in Institute's research, and awards to Institute's members. The review must address the Institute's impact on activities that integrate research and education, as measured by its success in obtaining graduate training grants, training graduate students, the quality and frequency of research seminars, influence on graduate and undergraduate curricula, and number of undergraduate research activities. In addition, the Institute's efforts to increase scientific literacy of the public, as measured, for instance, by public lectures or panel discussions, should be assessed.

As the Institute matures, its mission and goals may change and the relative importance of the various activities may shift. The review criteria must therefore be regularly evaluated to ensure appropriateness and must be changed if needed.

Financial Plan

The long-term success of the Institute hinges on its ability to become financially sustainable. The Institute will create synergies that will allow it to attract untapped funding sources. The review process must include an assessment of the Institute's ability to attract funding to achieve the goal of financial sustainability. Initially, the Institute cannot be expected to be financially sustainable but it must demonstrate that it is on track towards a financially sustainable operation. During the first four years, successful fundraising for endowments and success in obtaining grants for research activities will become increasingly important. The review process must also assess the effective and appropriate use of resources.

Infrastructure

Once the Institute reaches full capacity, it will need its own physical space with laboratories and office space to house the core teams together with their research staff, graduate students and postdoctoral associates, and flexible research space for teams that are supported on the Grants Program, computational capabilities, shared

[16] The review mechanisms of federal agencies, such as the National Science Foundation, could provide models for evaluating grants.

instrumentation and equipment[17]. There are many examples of architectural designs[18] for flexible, interdisciplinary research space that include both wetlabs and computational space. These designs include common space to foster creative exchanges and lower the language barrier that is inherent to interdisciplinary research. The Institute must also provide space for visitors and have face-to-face video conferencing capability that is free of charge for members of the Institute. The permanent space should be designed to accommodate future needs.

Research during the first two years will be conducted in existing lab space. If additional lab space is needed, participating colleges should make a serious effort to provide interim space. During the first two years of operation, temporary research laboratory space should be identified and made available to research groups that successfully competed for interdisciplinary, extramural grants. Some space might also be needed by teams that are supported by the Grants Program. The research space should grow as the number of teams on extramural funding grows.

During the establishment of the Institute, equipment and instrumentation must be identified that is appropriate for the research themes. The (Interim) Director together with research teams must identify opportunities to compete for funding to purchase such equipment. In addition, colleges and central administration need to partner to identify resources to purchase equipment. Duplication, however, needs to be avoided, and we expect there to be situations when investments in existing facilities are preferable over investing in new equipment or instrumentation that would be housed in the Institute.

External Partnerships

Successful interdisciplinary grant applications are often put forward by multi-institutional research groups from academia and, depending on the topic, may include businesses from the private sector. The Institute must facilitate the formation of such groups. While the Grants Program must benefit primarily investigators from the University of Minnesota, it must allow the support of collaborators outside of the University to prepare for multi-institutional grants[19]. To facilitate multi-institutional collaborations, access to video conferencing facility, travel funds to convene groups, and organization of workshops to initiate collaborations are needed.

As a land grant institution and the only public research institution in the state of Minnesota, the University of Minnesota carries a responsibility to be a major driver of the state's economy. The Institute's themes will provide opportunities to establish partnerships with the state of Minnesota and leading businesses and to foster the establishment of start-up companies. These partnerships may range from an advisory role to funding projects at the Institute to facilitate collaborations between scientists from academia and business. Mechanisms therefore must be developed to facilitate partnering with industry and to help scientists when starting their own companies[20].

[17] Details on the building are described in Section IV.
[18] Examples of innovative architectural design include the HHMI Janelia Farm or the James H. Clark Center of Stanford's BioX.
[19] In cases where support for external collaborators is requested, teams should demonstrate that funds for collaborating institutions cannot be secured from partner institutions before requesting funds through the Grants Program.
[20] The Institute should partner with the Office of the Vice President of Research on this.

The Institute can learn from other successful models of public/private partnerships. For instance, the California Institutes for Science and Innovation now include four institutes, which are the outcome of a partnership among the state of California, the University of California, and hundreds of businesses. These institutes focus on research areas that are "critical to sustaining California's economic growth and its competitiveness in the global marketplace."[21] One of the Institutes, the California Nanosystems Institute (CNSI), was established with $100 million from the State of California and an additional $250 million in federal and industry funding. It is administered jointly by UCLA and UCSB. Collaborations with industry are encouraged and a Business Advisory Board serves as a link to industry to encourage collaborations. CNSI has served as the incubator for several start-up companies. Another example is the MIT Media Lab[22] that was established in 1985 and that "pioneered collaborations between academia and industry, and provides a unique environment to explore basic research and applications, without regard to traditional divisions among disciplines." The highest level of partnership is the Corporate Research Partner membership level that supports larger research projects. Corporate Research Partners provide $750,000 per year for a minimum of three years per partner to research activities. The lowest level of sponsor support is the Graduate Fellows Program for $75,000 per student per year.

[21] http://www.ucop.edu/california-isntitues/about/about.htm
[22] http://www.media.mit.edu/ and http://www.media.mit.edu/about/index.html

III. Facilitating Interdisciplinary Research

The Institute can only succeed if there is strong commitment at all levels of the University, from departments to the central administration. Budgetary and cultural barriers must be overcome for interdisciplinary research has become a *sine qua non* at any research university. Investments in interdisciplinary research must not harm the disciplines for strong disciplines are imperative for successful disciplinary research. The Institute must facilitate building teams across institutions for interdisciplinary research grants are increasingly awarded to inter-institutional teams of researchers. Faculty and administrators must exercise patience for it will take years before the Institute will reach its full potential.

A successful institute will have measurable impact on the research enterprise of the University. It will attract excellent graduate students and postdoctoral associates and serve as a magnet for faculty recruitment. It will make faculty more productive by providing a stimulating intellectual environment. It will allow faculty to engage in new research directions. State-of-the-art research infrastructure and shared research space will increase the University's competitiveness for interdisciplinary grants and will be attractive to faculty.

If the Institute is at the cutting edge of new directions, inevitably gaps in faculty expertise will arise. It will not be enough to rely on individual departments to foresee these needs in their individual hiring plans and fill the gaps as positions become open due to faculty leaving. The vision for future needs must come collectively from the faculty and the leadership of the Institute, the colleges, and central administration. The Institute must envision promising research directions and identify gaps in faculty expertise. The Institute must work with colleges and central administration on hiring plans for cluster hires in promising areas. It is important that colleges support the hiring plans and that departments are actively engaged in the process since departmental homes of faculty hired through this process will often only be determined once the top candidates are identified.

Budgetary Barriers

Cluster hires to have faculty expertise in place when new areas emerge require substantial investments, typically $20-30 million in set-up and additional recurring funds for annual compensation. These funds cannot come from the Institute since a faculty's home will be in a department, a faculty hire is a long-term investment and goes beyond the five to seven year of the tenure of a faculty in the Institute, and not every faculty member hired through this process will become a member of the Institute. Funding must be part of presidential or other University-wide initiatives to demonstrate the support of the entire University for the Institute.

Budgetary concerns will be raised by departments and colleges. Long-term financial health of the Institute is important. If the Institute is successful, it will attract large, collaborative grants that provide a steady stream of resources in the form of research funds and indirect cost recovery (ICR). Participating colleges must work out agreements ahead of time on how to distribute ICR to the benefit of the University without

jeopardizing the disciplines[23]. ICR must enhance the capacity of our faculty to engage in interdisciplinary research through investments in infrastructure to keep up with changing technology and hiring of new faculty to fill gaps in expertise. While ICR is a major revenue stream, the ICR generated by research in the Institute will not suffice to sustain the Institute. To avoid that the Institute is seen as a drain on college resources, other streams of revenue must therefore be identified. Fund raising to endow fellowships and seed grants and contributions by industrial partners will be needed beyond income from extramural grants. In addition, recurrent funds to cover cost of administrative and scientific staff must be available.

Cultural Barriers

Cultural differences across colleges can generate dissonance[24]. A flexible structure that accommodates differences can avoid problems, in particular in the initial stages of the Institute. As the Institute matures, a different model might emerge, but regardless of the model, it is important to ensure that faculty do not feel disadvantaged when joining the Institute. This flexibility is also important for interdisciplinary projects funded through the Grants Program that will only later attract extramural funding. Funding through the Grants Program should allow faculty to recover salary that they would normally be able to obtain from extramural grants, such as summer salary for those who are on 9-month appointments or academic year salary for those who are required to generate academic salary from grants. Salaries of graduate students should be at least at the level of research assistants in their graduate programs. Likewise, postdoctoral researchers should be paid salaries that are competitive with equivalent positions in their affiliated home departments rather than equalizing salaries across all members of the Institute.

Departments will be sensitive about the impact of the Institute on disciplinary research. It cannot be overemphasized that interdisciplinary research will only flourish if the University maintains excellence in disciplinary research. Departments and colleges must anticipate needs at the level of the discipline years before the particular expertise becomes essential for interdisciplinary research, and fill gaps in expertise in order for the Institute to be competitive. This will require a substantially increased level of cooperation among departments and colleges to understand future needs and to coordinate hiring plans to optimally position the University to be at the forefront of research.

Allocation of a faculty member's effort will be of departmental concern. Institute members are expected to maintain a presence in their home department while spending a considerable fraction of their research time in the Institute. They are expected to continue their disciplinary research (albeit at a reduced effort), their contributions to education and training according to departmental expectations, and service. It is very important that a member of the Institute will retain their departmental research and office space to ensure continuation of departmental activities and a smooth transition when membership ends. However, because of the temporary nature of the membership of faculty in the Institute, the impact of a member's effort spent outside of the department

[23] Since ICR supports departmental infrastructure, colleges must be sensitive to department needs and must keep disciplines supported. Faculty receiving grants through IASE activities will likely generate fewer ICR dollars through their departments, yet department needs will not necessarily decrease by this shift in activities.

[24] These differences include types of appointment (A versus B), college-specific requirement to raise salary through grants (common in the AHC), and different funding levels for graduate students and postdoctoral associates.

will be of relative short duration (typically less than five to seven years), which should lessen this concern.

Junior faculty are among the most creative and energetic members of our faculty and are poised to make important contributions to interdisciplinary research. The Institute therefore should include junior faculty, which raises concerns about tenure and promotion. Junior faculty need to recognize the importance of maintaining a presence in their home departments and building a reputation for their contributions within their respective disciplines while participating in interdisciplinary research. They need to ensure that their contributions to interdisciplinary projects are clearly discernable.

Being a member of the Institute as a junior faculty should be considered favorably by tenure and promotion committees. Playing a major role in jointly authored papers and grants should be viewed as an accomplishment, regardless of the position of the author on the paper and whether the faculty member is listed as PI or co-PI. It cannot be expected of a junior faculty member to be lead-PI on a large interdisciplinary grant (in fact, this should be discouraged). Likewise, not every author on a multi-authored paper can be senior author. It should also be acknowledged that multi-authored papers may take longer to be completed than single-authored papers.

The Advisory Committee recommends that departments provide additional mentoring to junior faculty who are members of the Institute to ensure that junior faculty receive guidance on how to fulfill expectations. The departmental promotion and tenure committees must receive feed-back on performance by the director of the Institute. A standing committee of faculty members should be appointed by and report to the Provost to observe the tenure process of junior faculty who are involved in interdisciplinary research across the University. This committee should make recommendations on appropriate measures to ensure fair evaluation and whether tenure clock extensions should be considered to account for the potential increase in time needed to engage in new directions and to complete projects with multiple investigators.

The Advisory Committee emphasizes that disciplinary research is integral to every research university and that not every faculty member will engage in interdisciplinary research. The University will continue to rely on single-investigator grants or disciplinary collaborative grants as major drivers to push the frontiers of knowledge. However, in order to maximize its impact and to fully utilize opportunities, the University must significantly increase its engagement in collaborative interdisciplinary research in order to establish itself among the top ranked universities in the U.S.

Towards Collaborative Research

An analysis of data on sponsored research in science and engineering at the University emphasizes the urgency to increase our engagement in collaborative research. In Appendix D, we present data of grants submitted by CBS, CFANS[25] (formerly COAFES and CNR), IT and the Medical School[26] during the period between July 1, 1999 and June

[25] The College of Food, Agricultural and Natural Resource Sciences (CFANS) was founded in 2006. For simplicity, we will refer to CNR and COAFES collectively as CFANS for the entire period under consideration.
[26] See Appendix D for details on the findings.

20, 2006. Over the past several years, the University of Minnesota has shown a relative decline in its ability to attract extramural funding[27] compared to peer institutions. In addition, the University of Minnesota is often perceived as an R01 institution, meaning that the institution relies overly on single-investigator grants.

Our analysis confirms a strong reliance on single-investigator grants. Single-investigator grants comprise 66% of submitted and 71% of awarded grants. The number of grants (submitted or awarded) declines exponentially with the number of investigators. Moreover, much effort is expended on smaller grants[28]: 52% of awarded grants requested less than $100K, which contribute 4.4% of the total requested award amounts. Whereas slightly less than 1% of awarded grants requested more than $5M, which generated 21% of the total requested award amounts. During the period between July 1, 1999, and June 20, 2006, 67 grant proposal were submitted requesting more than $10,000,000, of these 27 were funded. Among these funded projects, we find 13 distinct projects.

Because of lack of data from other institutions, it is difficult to compare our efforts with other universities. However, over the past several years, other research universities have increased their research and development funding at a much greater rate than the University of Minnesota[29], largely due to their ability to successfully compete for large interdisciplinary grants. The steep exponential decline in grants as the number of investigators increases points to a culture where collaborations are still relatively rare, and the faculty at the University of Minnesota appear to spend a disproportionate effort on small, single-investigator grants. We recognize the importance of single-investigator grants and emphasize that they will always be a major funding source for academic research. However, there are increasingly research opportunities that require the formation of interdisciplinary teams, which has been recognized by funding agencies. In a funding environment where agencies promote larger, interdisciplinary efforts and where a significant fraction of sponsored research funds go to team efforts, institutes, like the IASE, must allow faculty at the University of Minnesota to compete successfully for these opportunities and to open new areas of research, without diminishing the role of disciplinary research. The new opportunities and benefits afforded by the Institute must outweigh the challenges and barriers that accompany this cultural change.

Critical Needs

Computing Needs

Computing and information technology are now essential components for advances in sciences and engineering. The infrastructure enabling these advances has been termed cyberinfrastructure. The importance of developing cyberinfrastructure was highlighted in a report by the National Science Foundation, *A Cyberinfrastructure Vision for the 21st Century*[30]. While hardware and software for high-performance computing are an important component of cyberinfrastructure, the needs go far beyond this. The aforementioned report addresses needs for high performance computing; data, data

[27] The Science and Engineering Task Force report provides a detailed analysis in Appendix D.
[28] The amounts listed are the amounts requested over the entire funding period in both categories (submitted and awarded) to allow for comparisons between the two categories.
[29] See for instance the analysis in Appendix D of the Science and Engineering Task Force report.
[30] National Science Foundation 2006 http://www.nsf.gov/od/oci/ci_v5.pdf

analysis and visualization; observatories and virtual organizations; and education and workforce. The Minnesota Supercomputing Institute (MSI) has played a leading role for many years to provide much of the needed services and the Institute will need to establish a strong collaboration with MSI. To be on the leading edge in science, the Institute must take a leadership role, in collaboration with MSI, in identifying and providing solutions for needs in this area.

To develop the cyberinfrastructure, permanent scientific staff in the Institute will be necessary. Date must not only be collected for specific purposes of a project but must be considered a valuable resource and curated, just like specimens that have been brought back from scientific journeys around the world for centuries and that have remained valuable resources for scientific inquiries, stored permanently in museums. Data we collect today will be used for different purposes tomorrow and data across studies will be combined. Data curation must go beyond the funding period of a single grant and must be available in an accessible form to other researchers. Technicians hired on a grant cannot fulfill this function. Permanent staff is needed for this.

It is also important to identify computational needs that are similar across teams to avoid duplication. In particular, the Institute will need to collaborate with the MSI and the Digital Technology Center (DTC) to develop the increased need in infrastructure. Needs will include staff that cannot be hired on grants where the focus is on a single project and time cannot be allocated for integrating needs across different projects. In addition, the Institute must have funds to accommodate computer hardware and software needs. Permanent staff must be available to provide the necessary support. The MSI and the DTC must play an important role in the Institute but without expanding its current capacity will likely not be able to accommodate the increased need.

Instrumentation

New technologies have become drivers of discovery and the Institute should strive to play a leading role in the development of new technologies. Examples of technology developments that had major impacts include the human genome project that would not have been possible without significant technological advances in sequencing. New imaging technologies continue to open windows to previously unknown details from the scale of single atoms to the scale of galaxies. The Institute should make available centralized facilities with state-of-the art equipment and instrumentation that meet research needs specific to the research themes. These facilities should provide high quality service and be staffed by permanent staff to ensure consistent quality. This facility should be open on a user-fee basis to University employees outside of the Institute.

Communication

Collaborations across institutions, national and international, are becoming the norm. Many large collaborative awards now go to groups of investigators from multiple institutions. Rapid and effective communication capability is needed to facilitate such collaborations.

As we move towards a virtual workspace, it will be increasingly important to provide easy access to communication tools that facilitate collaborations across institutions and organizations that are in different geographic locations. Provisions for inter-campus

collaborations between the Twin Cities campus and the coordinate campuses are critical for further development of the broadest possible University-wide research integration. Tools to facilitate communication include, for instance, video conferencing facilities and instrumentation that can be accessed remotely.

IV. Funding

Business and Financial Plan

Budget

All figures are in 2007 dollars. Inflationary increases should be added accordingly. It should be noted that all estimates below are preliminary since much depends on the initial success of attracting teams who are successful in competing for extramural funding. The needs also depend much on the themes that will emerge competitively through the Grants Program. The Business and Financial Plan must be revisited as the Institute matures to ensure that it still appropriately reflects the needs 3-6 years from today.

The Advisory Committee recommends a two-stage approach to establish the Institute for the Advancement of Science and Engineering. During the initial six years, the Institute will build its research capacity through the Grants Program. Teams funded under the Theme Development Grant Program will compete for extramural funding, which will be the primary funding mechanisms for research activities. (We expect some teams to become core members without first receiving grants through the Grants Program.) By the end of Year 6, we expect the Institute to have reached its steady-state research capacity with about twelve extramurally funded research groups, about five to seven research groups funded through the Theme Development Grant Program, and about three to four teams through the Future Theme Grant Program.

We propose a model where researchers are organized into smaller teams of three to four core faculty. Most of these teams will be initially funded through the Grants Program and will become core teams of the Institute if they are successful to attract extramural funding. The teams are organized around themes and teams within each of the themes will interact and form larger groups that will ultimately compete for large center grants. Each research group will have postdoctoral associates, graduate students, and technicians, and may collaborate with other scientists from the University or other institutions and organizations, including industry.

To house the approximately twelve research groups[31] and provide flexible research space as hotel space for teams supported through the Grants Program, we estimate the need for a building with about 80,000 to 90,000 sqft of usable space[32]: 40,000 to 50,000 sqft in flexible laboratory space; 10,000 sqft to house shared instrumentation; 3,500 sqft for computational space; 6,000 sqft of faculty office space; 10,000 sqft for office space for graduate students and postdoctoral researchers; 2,000 sqft of administrative office space; 3,000 sqft in combined space for seminar rooms; 3,000 sqft for an auditorium; and 4,000 sqft for common space, which includes gathering space and video conferencing facilities. The laboratory space includes about 30,000 to 40,000 sqft of open space for research teams and 10,000 sqft of hotel space for teams that are supported through the Grants Program and are in need of shared laboratory space. The

[31] We estimate that each team will have about 3-4 principal investigators, and each investigator about 3-4 graduate students and postdoctoral associates.

[32] For comparison, Stanford BioX is housed in a 240,000 sqft building, the Michigan Life Sciences Institute moved into a 230,000 sqft building, and the Cornell Life Sciences Initiative provided a 240,000 sqft building. Each of these buildings cost about $140 million.

estimated cost for the building is $60 to $80 million. The building must be equipped with shared instrumentation that will need to be replaced and updated regularly. We estimate that an additional $10 million are needed for initial set up of infrastructure, including instrumentation and equipment. During the initial phase of establishing the Institute, much of the research will likely be done in existing space of participating faculty. However, space needs to be available for projects that require common laboratory space. We estimate that by the end of Year 2, the need for such space will be about 6,000 sqft. Space needs will likely increase by about 2,000-3,000 sqft per year as the number of teams increases and the first teams successfully compete for extramural funding. For renovation of interim space, we estimate $225 per sqft. By the end of Year 2, renovation costs are estimated to be 6,000sqft x $225=$1,350,000. In each of Years 3-5, additional space might need to be renovated and we estimate this to be between 2,000sqft x $225=$450,000 to 3,000sqft x $225=$675,000 per year.

After the second year, a permanent director will oversee the Institute. Substantial resources must be made available to make this position attractive. The Institute will need to be supported by permanent technical and administrative staff. We expect the need for technicians to run specialized and shared equipment and the need for staff to support cyberinfrastructure and computational needs. Administrative staff will include an administrative director, accounting and budget staff, web and public relations staff, and office assistants. By the end of the sixth year, this permanent staff needs to be in place to support the research. The staff needs to be built up during the six years as the Institute grows to its full size. Estimates for scientific staff are preliminary and staff numbers and expertise will depend much on what kind of instrumentation and computational needs emerge. Total cost once the Institute is fully established is estimated to be about $1,600,000. Figure is based on the following estimates:

	Expected Salary	Expected Fringe	Total
Director	$ 250,000	$ 81,000	$ 331,000
Administrative Staff			
Administrative Director	$ 85,000	$ 28,000	$ 113,000
Accounting	$ 52,000	$ 19,000	$ 71,000
Web/Public Relation	$ 70,000	$ 23,000	$ 93,000
Office Assistant (2)	$ 70,000	$ 25,000	$ 95,000
Proposal Support	$ 52,000	$ 19,000	$ 71,000
Scientific Staff			
Computer Support			
IT	$ 100,000	$ 32,000	$ 132,000
IT	$ 100,000	$ 32,000	$ 132,000
Computer Staff Support	$ 60,000	$ 19,000	$ 79,000
Computer Staff Support	$ 60,000	$ 19,000	$ 79,000
Technicians (5)	$ 300,000	$ 108,000	$ 408,000
TOTAL	$ 1,199,000	$ 406,000	$ 1,605,000

The Grants Program will award grants to interdisciplinary groups of researchers and play an important role in increasing the competitiveness of faculty for extramural interdisciplinary grants. Theme Development Grants should allow faculty to recover summer or academic salary (depending on the culture in their home departments), and to support graduate students and postdoctoral researchers. We propose to award three to four two- to four-year seed grants per year, each grant will average about $200,000 to $400,000 per year: total per year: $2.7 million. The longer duration will be for grants that are initially smaller but might need more lead time to yield successful grant applications. In addition, the Future Theme Grant Program will provide two to three smaller two-year grants for up to $100,000 per year: total per year: $500,000. (Figure is based on an average of nine Theme Development Grants supported in any given year: 9 x $300,000=$2,700,000 and on an average of five Future Theme Grants supported in a given year: 5 x $100,000=$500,000)

While we expect faculty to continue their regular teaching and service duties, we recognize the time demands on faculty who lead major proposals. We expect that each year, faculty in the center will apply for a combined total of four to six major interdisciplinary grants. Of these, about two to three are expected be successful[33]. We propose to provide release time to the lead PI during proposal preparation and during the first semester of a new interdisciplinary grant. These funds may also be used to provide partial reimbursement to coordinate campuses for faculty who visit the Institute (tuition recovery from courses these faculty teach on the UMTC campus provide another source for reimbursement). Total estimated cost: $396,000. (Figure is based on six 50% FTEs with an average salary of $100,000 and 32.1% fringe rate: 6 x $50,000 x 1.321=$396,300)

To attract graduate students, we propose to offer twelve two-year graduate fellowships per year: total per year: $960,000. (Figure is based on 12-month stipend of $28,000 and $12,000 fringe.)

Collaborations with other institutions are becoming increasingly important. We propose to provide sabbatical supplements to sabbatical visitors from outside the University of Minnesota in the form of two sabbatical supplement fellowships, each $50,000. Total cost: $100,000.

The Institute needs to run an active seminar series, public lectures, and workshops/conferences. The seminar series needs to attract high-profile speakers from other institutions and organizations. A public lecture series with two lectures per year should inform the public about important research areas. Workshops/conferences that are held at the University of Minnesota will help establish the University of Minnesota as a leader in interdisciplinary areas. Total cost: $49,000. (Figures are based on 20 seminar speakers per year, $1,200 per speaker; $5,000 for public lectures; $10,000 per workshop as a match for extramural funding[34]: 20 x $1,200+ $5,000 + 2 x $10,000=$49,000)

In addition, to fund office supplies and equipment, $115,000 is budgeted annually.

[33] The probability of success is based on the average success probability of larger UMTC grants in the sciences and engineering.

[34] Partial workshop funding should be obtained from granting agencies. A typical workshop costs about $20,000.

Summary of expected recurrent cost (in 2007 dollars):

Recurrent Cost w/o Building Maintenance	
Personnel	$1,605,000
Office	$ 115,000
Grants Program	$3,200,000
Buy-out	$ 396,000
Fellowships	$ 960,000
Seminars	$ 49,000
Sabbaticals	$ 100,000
TOTAL	**$6,425,000**

Because the Institute will not belong to a single college, a budget for maintaining and operating the building must be available. Attention, however, must be paid to several management issues in order to be functional. These include on the personnel side a building manager to maintain space and equipment, and interact with vendors and facilities management, and a Research Safety Officer to maintain safety records, train personnel, and insure compliance with regulations. In addition, funding must be available for shared equipment, service contracts, and maintenance and repair costs. The costs for these expenses cannot be determined at this point.

Funding

Funding for the Institute must come from a variety of sources. An endowment will be needed to cover fellowships and part of the Grants Program. We propose that a $40 million endowment should be raised to fully fund the graduate fellowship program and to partially fund the Grants program. A combination of recurrent funds from the University and donations from industry partners should cover the remaining cost of the Grants Program. We propose that the Institute's personnel, office, and seminar expenses are covered by O&M funds and ICR return. Sabbatical funding and buy-out of faculty should be covered by recurrent funds from the University. State funding should be sought to enable the University to cover the cost of University's share of running this Institute.

Research activities beyond those funded on the Grants Program must be entirely funded from extramural sources. The primary federal funding sources will be the NIH, NSF, and DOE. State funding and funding from industry must be sought in addition. Foundations may provide additional sources of funding depending on themes. The Director of the Institute must play an active role in identifying and securing funding from outside the University.

Long-term Performance

It is instructive to model the long-term performance of the Institute to assess the budgetary implications. For this purpose a simple stochastic model was developed to determine when the Institute will reach steady-state and how funding success rates affect the number of internal grants.

In the first scenario, we assume that the Institute funds 3-4 new seed grants every year (30% of the time, three will be awarded; 70% of the time, four will be awarded). Internal interdisciplinary grants are awarded for two years each. Each group that receives an internal grant will make up to two attempts to apply for an interdisciplinary grant with a success rate of 40% each time the team applies. We assume that the interdisciplinary grants last for five years. We assume that each group competes up to twice for a center grant with 10% success probability per attempt and per group. Center grants are for five-years and about half of them are renewed on average.

The long-term pattern that develops under this scenario (based on averaging 25 runs) is that on average 7.4 seed grants need to be supported each year. They will result on average in 11.9 extramural interdisciplinary grants and 3.4 center grants that are active in any given year. It is important to realize that it will take years before the Institute will reach its full capacity. The internal funding reaches its steady state after the first year, the extramural interdisciplinary funds after about six years, and center grants after about 13 years. Successful center grants that are the result of collaborations within the Institute cannot be expected until 8-9 years into its operation.

If the success rate for an interdisciplinary grant is 60% instead, a steady state of on average 5.4 internal grants would suffice to reach a steady state of 11.5 interdisciplinary research grants. A steady-state of 5.4 internal grants with a 40% success rate of obtaining an extramural interdisciplinary grant would only result in about 8.6 such grants. Assuming that success probability of obtaining an extramural interdisciplinary grant is positively correlated to the size of the internal grant that brought the team together, it becomes important to track data on grant size versus success probability to determine the optimal number and size of individual awards under the constraint of a fixed pool of funding.

Appendix A

Materials

This is a multidisciplinary theme that was proposed by the Science and Engineering Taskforce (Appendix J). Innovative materials have important applications in every area of technology development, including electronic devices, biomedical devices, drug delivery, biodegradable materials, energy production and storage devices, or environmental engineering. The University of Minnesota is highly competitive in this area and research initiatives could promote economic development of new industries.

Energy

This theme was also proposed by the Science and Engineering Taskforce (Appendix J). The University has already made significant investments in this area through the Initiative for Renewable Energy and the Environment with over $19 million of seed grant funding. A recent submission of a $125 million to the DOE for a Midwest Bioenergy Research Center that involved about 70 faculty from the University of Minnesota demonstrates the strength of the University in this area.

Chemical biology

Chemical biology at the University of Minnesota grew out of graduate training grants. "The *Chemical Biology Initiative (CBI)* is designed to stimulate and encourage interdisciplinary biomedical/biotechnology research, technological development, and education at the cross roads of chemistry, physics, biology, and engineering at the University of Minnesota. Our central goal is to enable the development of a deeper understanding of biology that can be applied to the improvement of health."[35]

Biological Engineering

Advances in our understanding of cell function open the door to rationally engineering biological systems to synthesize therapeutic drug or cost-effective enzymes for industrial applications. About thirty years ago, recombinant DNA technology provided the first tools to move genes from one organism to another. It is now possible to synthesize DNA *de novo*, which enables the engineering of novel organisms for specific functions. This field, also known as synthetic biology, is developing into a new technology with very broad applications. It cuts across biotechnology and nanotechnology, and relies heavily on information science

Multi-scale cell-to-organ biology

Modeling of physiological systems from the gene level to the behavior of a full system, for instance, an organ or a tissue requires multi-scale models that integrate information at different levels of resolution. A deep understanding of biology and mathematical and engineering approaches are needed to develop models of complex biological systems across different scales that accurately describe the functioning of the whole system.

[35] Description is from the home page of the Chemical Biology Initiative at http://www.pharmacy.umn.edu/cbi/home.html

Fundamental research in this area could lead to novel biomedical devices, prosthesis, and artificial organs.

Imaging

Recent technology developments in high-throughput imaging open new research directions for cell and developmental biologists. Three-dimensional time-lapse movies of living cells will allow localization of proteins during different physiological stages of a cell. These new technologies are also used to understand the development of multi-cellular organisms. This theme could draw in researchers from the physical, biological, and medical sciences to push the research boundaries in cell and developmental biology with advancements in imaging technologies.

Nanobiology

This is a fast growing area that will have profound impact on many fields, including biomimetic materials, molecular motors, targeted drug delivery, therapeutics, diagnostics, or biosensors. Advances in this area require collaborations among physicists, chemists, biochemists, chemical engineers, and computational scientists.

Bio-inspired Design

Technological advances enable the design of innovative materials and devices that are inspired by nature. For instance, sensor systems are being developed based on the same principles that biological organisms use to sense the environment. Electroactive polymers have been developed that mimic behavior of muscles. Advances in this area require a mechanistic understanding of biological processes and translating this knowledge into engineering solutions.

Multi-scale approaches to climate change

Climate change will have profound effects on the world's populations and economies. While models to predict future climate have greatly improved over the years, the vastly different scales in these complex interactions between the physical and biological world still pose significant challenges and require multi-disciplinary teams to provide solutions. Multi-scale modeling of the effects of climate change across various scales, from physiological responses of individuals to large-scale climatic changes, is needed for improving the predictive capabilities of these models. Likewise, interdisciplinary approaches to understanding the periodicity and magnitude of past global climate change captured in geological and glacial ice-core records is essential for developing robust forward models. This theme would also lend itself to collaborative efforts with the Institute on the Environment, especially with its focus on integrating policy and science.

Geomicrobiology

Geomicrobiology studies the interaction of microbes with the physical environment. Understanding these interactions is of practical importance, for instance, in the context of clean water from aquifers for human consumption. Interactions between microorganisms and the inorganic environment are important in the formation of structural parts of animals, such as sea shells or bones, or mineral deposits by bacteria. Fundamental insights into the origin and evolution of life can be gained by studying

microbes that live in extreme environments, for instance high temperature, high pressure, high salinity, high concentrations of dissolved heavy metals. This area would bring together a wide variety of fields and continues to receive funding from federal agencies, such as NSF and DOE.

Neuroscience

The University of Minnesota has considerable strength in this broad area. Aspects of this area will be addressed by the newly formed Institute for Translational Neuroscience, which will bridge the research between basic and translational science in areas such as neurodegenerative and neuromuscular diseases, mental health, neuroengineering, and memory research. Because of the breadth of neuroscience, there will be many areas, such as computational neuroscience or human-machine interactions that might not be addressed by the Institute for Translational Neuroscience but would fit well into the IASE.

Biomass Utilization

Biomass as a sustainable resource is a resource for renewable energy, fuels, and chemicals that are traditionally produced from non-renewable resources like coal and petroleum. Products go far beyond the traditional wood and paper products and include ethanol from starch and cellulose, bioplastics, and industrial solvents. Development of this field will require collaborations among plant biologists, microbiologists, chemists, engineers, and computational scientists.

Appendix B

Time Line

The Institute will build up to full capacity over the first six to seven years. Development in the form of fund raising and building bridges to the public and private sector are critical to the long-term success and should be initiated from the start. During the first two years, the Grants Program will be established and the initial set of themes will be chosen. During this period, the Institute must gain a web presence and reach out through symposia and public lectures to attract attention. In the following years, the number of extramurally funded teams will reach steady-state. Research grants and partnerships with the private and public sector will then become the primary source of research funding. Graduate training grants will further support the educational activities of the Institute. The following table provides a time line of the number of activities in each of the major categories.

Year	Themes	Grants Program Competitions	Development Grants	Core Teams	Training Grants	Symposia & Workshops	Public Lectures
1	1-2	2	4	0	0	1	1
2	2-3	2	8	1	0	1	1
3	3-4	1	8	2	0	2	2
4	4	1	8	4	1	2	2
5	4	1	8	6	1	2	2
6	4	1	8	9	2	2	2
7	4	1	8	12	2	2	2

Appendix C

The Task Force on Collaborative Research put forth a set of questions, listed below, "to help guide the selection of potentially productive collaborative proposals, whether large or small scale and from all areas including science, engineering, social sciences, health sciences and humanities. These criteria can be applied to intercollegiate and to interinstitutional collaborations."

1) What is the nature of the proposed opportunity?
   a. What is the potential scientific or scholarly impact?
   b. Is the impact dependent on, or at least enhanced through, the collaborative nature of the proposed activity?
   c. How will the University's reputation be affected (enhanced)?
   d. What are the specific possibilities for future outside funding?
   e. Does it hold the potential for becoming a new disciplinary focal point/new discipline?

2) How well does the proposed project fit within the University of Minnesota?
   a. Is there substantial faculty commitment?
   b. Does the University have appropriate expertise? Who will be the core members of the new team and what will be their roles?
   c. Does the project have appropriate leadership and a leadership plan that addresses intellectual, educational, and managerial leadership?
   d. What is the strategic fit of the proposed project?
   e. Does the proposal align with Presidential Initiatives or compact priorities?
   f. What other resources and considerations are relevant?
   g. What are the expectations and plans for continued funding of the effort? Does it open up new funding opportunities?

3) How will the project be evaluated after it is initiated? The applicants should define these evaluation criteria as part of the application process. The plan for evaluation should consider criteria such as:
   a. Milestones
   b. Reputation
   c. Impact
   d. Identification and engagement of stakeholders and end users
   e. Ability to attract outside funding (return on investment)
   f. Plans for continuous evaluation
   g. Criteria for termination of the project

Appendix D

Funding History

To survey the sponsored research in science and engineering, the Advisory Committee analyzed the grant history at the University of Minnesota during the period between July 1, 1999 and June 20, 2006, focusing on grants submitted by CBS, CFANS[36] (formerly COAFES and CNR), IT and the Medical School. The recent track record of the University shows a relative decline compared to peer institutions in its ability to attract extramural funding[37]. In addition, the University of Minnesota is often perceived as an R01 institution, that is, an institution that relies overly on single-investigator grants. We focused our analysis on award amounts and number of investigators.

During the period between July 1, 1999, and June 20, 2006, a total of 19,113 grants were submitted by CBS, CFANS, IT, and the Medical School. Of these grants, 9,688 were funded, totaling over $4.2 billion. The overall success rate is over 50%. The likelihood of successfully competing for a grant varies with the number of investigators, and is highest for single investigator grants (54%) and falls to about 35% for grants with four or more investigators (see Figure 1).

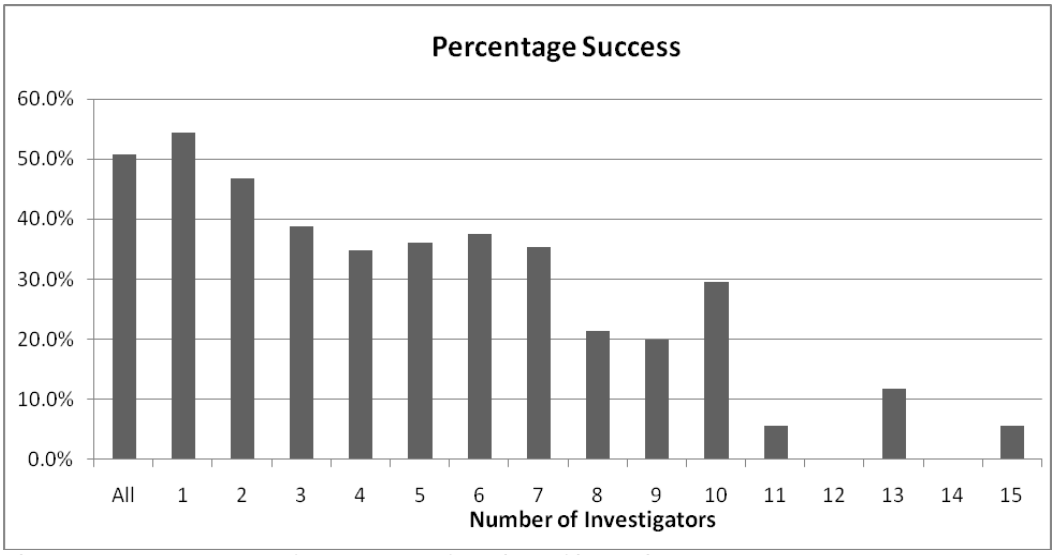

Figure 1. Success rate of grants as a function of investigators

The next two graphs summarize the number of grants as a function of requested/awarded amounts. The mode of the distribution of requested grants is in the interval from $100K to $1 million. The mode of the distribution of awarded grants is in the interval from $10K to $100K. This indicates that our success rate is higher for smaller grants.

[36] The College of Food, Agricultural and Natural Resource Sciences (CFANS) was founded in 2006. For simplicity, we will refer to CNR and COAFES collectively as CFANS for the entire period under consideration.

[37] The Science and Engineering Task Force report in Appendix D provides a detailed analysis.

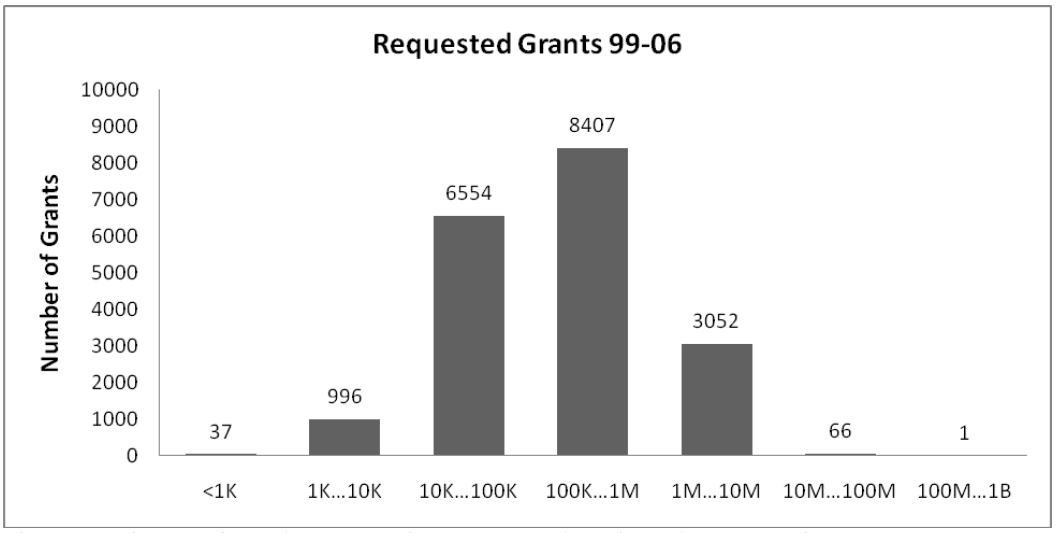

Figure 2: The number of requested grants as a function of requested amounts.

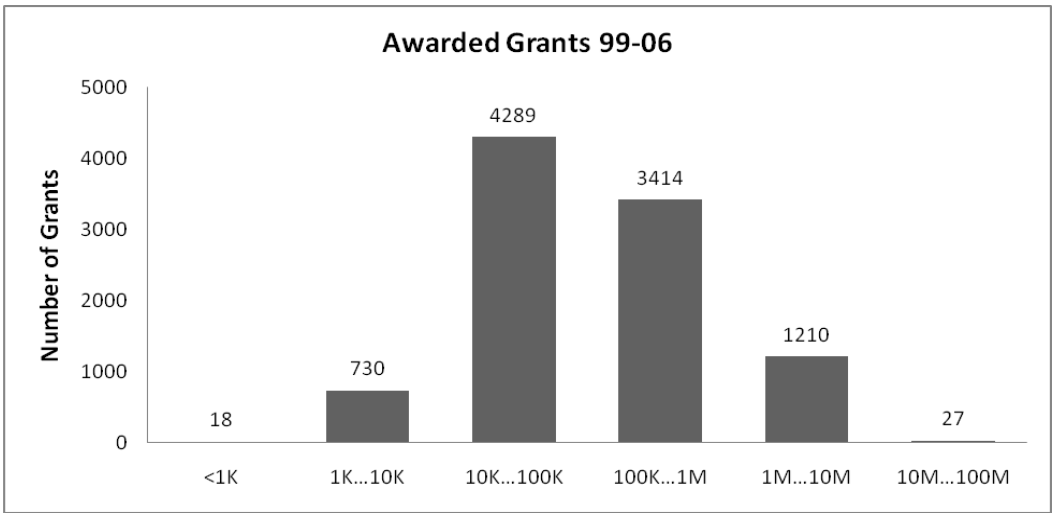

Figure 3: The number of awarded grants as a function of requested amounts.

Single-investigator grants comprise 66% of submitted and 71% of awarded grants. The number of grants (submitted or awarded) declines exponentially with the number of investigators. Specifically, for every investigator added between one and eight investigators, the number of submitted grants declines by a factor of 0.41 (R^2=0.99) and the number of awarded grants by a factor of 0.38 (R^2=0.99). For more than eight investigators, the number of awards (submitted or awarded) levels off and shows no discernable pattern. (See Figures 4 and 5.)

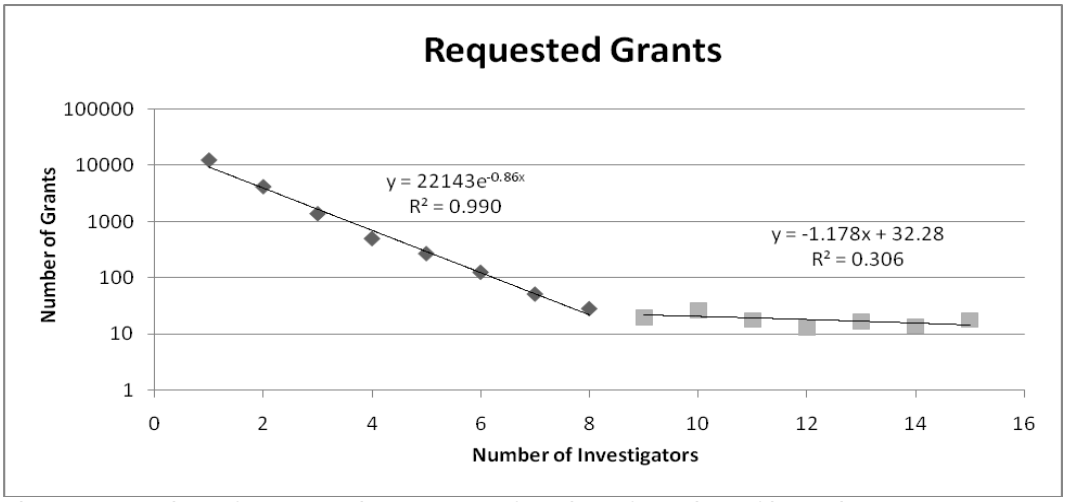

Figure 4. Number of requested grants as a function of number of investigators

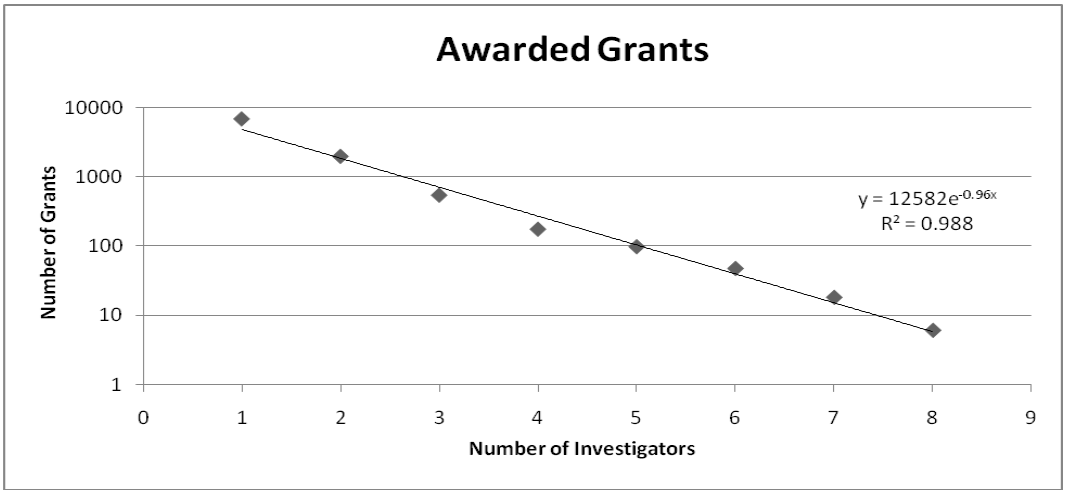

Figure 5. Number of awarded grants as a function of number of investigators for eight or fewer investigators.

Not only are most grants submitted by and awarded to single investigators, much effort is expended on smaller grants[38]. Of all submitted grants, 34% requested between $10K and $100K, 44% between $100K and $1M, and 16% between $1M and $10M. Of all awarded grants, 44% requested between $10K and $100K, 35% between $100K and $1M, and 12% between $1M and $10M. To appreciate the effort expended relative to the award amounts, we contrast the number of awards to the requests relative to the total requests: The 52% of awarded grants that requested less than $100K made up 4.4% of the total requested award amounts, whereas the slightly less than 1% of awarded grants that requested more than $5M generated 21% of the total requested award amounts. During the period between July 1, 1999, and June 20, 2006, 67 grant proposal were submitted requesting more than $10,000,000 of these 27 were funded. Among these funded projects, we find 13 distinct projects.

[38] The amounts listed are the amounts requested over the entire funding period in both categories (submitted and awarded) to allow for comparisons between the two categories.

Single-investigator grants deserve special attention. 66% of submitted and 71% of awarded grants listed a single investigator[39]. Among submitted single-investigator grants, 31% requested less than $50K and 45% less than $100K. Among awarded single-investigator grants, 40% requested less than $50K and 57% less than $100K.

[39] Since only 70 out of the 12,538 submitted single-investigator grants and only 33 out of the 6,827 awarded single-investigator grants requested over $5M, almost all of the single-investigator grants listed appear to be true single-investigator grants and not center grants that list only one principle investigator.