



Center for Energy Efficient
Electronics Science

Strategic Plan

Revised March 2012

(See Revision Tracker in Appendix IV)

A National Science Foundation Science & Technology Center



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A. The Challenge

Information processing equipment, including all personal computers, consumer electronics, telephony, office equipment, network equipment, data centers and servers, and supercomputers consume a significant fraction of the total electricity production in the US, and this aggregate energy is growing dramatically with time, both on absolute basis as well as a fraction of the total. At the current time, as the total energy used for information technology constitutes a genuine, looming energy crisis, the energy used at the most fundamental level to manipulate a single bit of information is currently $\sim 10^6$ times greater than theoretical limits. Without fundamental and conceptual breakthroughs in the underlying physics, chemistry and materials science that form the foundation of information processing technologies, the inexorable growth in the role of information in our society will place an increasingly significant burden on the world energy economy.

The Center for Energy Efficient Electronics Science (E³S) was established in 2010 to respond to this challenge.

B. Vision

To open a new energy efficiency frontier in information technology by developing the science and technology that will reduce energy consumption in electronic systems by orders of magnitude. To inspire and train a diverse generation of scientists, engineers, and technicians that applies this new science and technology to benefit society.

C. Mission

Through its research, education, outreach and knowledge transfer activities, the Center for E³S will:

- Research revolutionary, out-of-the box concepts and scientific principles that would enable fundamentally new and different science for digital information processing, in order to achieve a radical reduction in energy consumption in electronic devices.
- Educate a diverse generation of scientists, engineers and technicians to be the future leaders, researchers, educators and workers of low energy consumption device science and technology;
- Foster understanding by society of the energy challenge faced in information technology; and
- Promote the application of the Center's research outcomes to be the foundation for technological solutions in low energy consumption electronic systems.

Enabling the Center's vision and mission will be:

- A leadership team that inspires and enables performance through open and timely communications and a clear norm of collaborative effort;
- A goal of conducting its transformative, integrative research in a culture that is inclusive and collaborative, and crosses disciplinary and institutional boundaries;
- Strong ethics and responsible conduct of scientific research;

- Innovative integration of multidisciplinary research, education and outreach efforts to advance training of a diverse workforce; and
- Effective knowledge translation processes that will facilitate intellectual exchange between academic institutions and industrial partners to result in beneficial application of new knowledge.

D. Integrative Research

The work of the Center for E³S will initially be organized into four distinct themes:

- I. Nanoelectronics with a focus on solid state millivolt switching
- II. Nanomechanics with a focus on zero-leakage switching
- III. Nanophotonics focused on few-photon communication
- IV. Nanomagnetism that has the potential of surpassing the Landauer Limit.

Themes I, II and IV, each pursues a different approach to low-energy electronics, each with a different mix of characteristics. One objective is to perform the research needed to evaluate how closely these characteristics might be able to approach fundamental limits. Theme III addresses the challenge that is common to all digital systems, namely high bandwidth communications both intra-chip and chip-to-chip.

In each theme, evaluations will be made on an ongoing basis, and a significant element of synergy among the projects will come from using the same set of metrics for all; metrics that will be defined as an outcome of the research on requirements from a systems perspective. This will enable future ultra-low energy information systems to be built and integrated using elements of each of these approaches. Many of the fundamental challenges and goals are common to the Themes, and the interconnected team ensures that the Center will be in a position to take advantage of common approaches and solutions.

It is anticipated that achievement of the integrative research goal will manifest itself with the following outcomes and metrics.

1. Complementary joint research addressing common problems across different projects

The metric for this goal is the number of joint projects:

- End of Reporting Period 2:
 - 30% are multi-PI projects
 - 10% are multi-institutional projects
- Reporting Period 5:
 - 30% are multi-PI projects
 - 30% are multi-institutional projects

Actions and Owners: Availability of information and sharing of ideas is key to achieving this goal.

- Center Director will schedule annual retreats to discuss opportunities for collaborations. This will begin at the Kickoff Meeting that will be convened within two months after the inception of the Center.
- Theme Leaders will convene periodic Theme meetings to facilitate sharing of information and knowledge.

2. Unplanned, joint, serendipitous research efforts

The metric for this goal is the number of unplanned projects:

- Middle of Reporting Period 3: 1 project
- Middle of Reporting Period 4: 3 projects

Actions and Owners: To increase opportunities for researchers to interact,

- Executive Director will establish and support the teleseminar series on the Center's research projects that will begin within three months after the Center's inception.
- Executive Director will establish a teleseminar journal club to share relevant publications by the middle of Period 2.
- Center Director is to convene biannual discussion meetings for new ideas; to be initiated at the Kickoff Meeting.
- Center Director will establish a process for soliciting proposals of new projects and will communicate the process at the Kickoff Meeting.

3. Publications involving multiple researchers from multiple institutions

The metric for this goal is the number of submitted joint publications:

- End of Reporting Period 3: 12

Action and Owner: Executive Committee will conduct an annual review to ensure that there is proper representation of all institutions on all projects.

4. New joint research funding opportunities from other funding agencies and industry.

The metric for this goal is the number of funding proposals submitted to other funding sources, like other federal agencies and industry:

- Middle of Reporting Period 3: 1 proposal

Action Item and owner: Executive Committee will provide oversight as Center faculty continuously monitor for solicitations that could be relevant to Center members and share the relevant opportunities through Center announcements.

E. Education, Human Resources and Diversity

A major goal of the Center for E³S's goal is to be a learning environment as innovative as its research. This Center has the benefit of working toward energy efficient electronics, a global challenge tangible to most people and one that has drawn the commitment of US students as well as world-class University partners and faculty. The Center structure, with its multiple facets, allows not only for the transmission of knowledge, but also exposure to broad career paths. The Center will train engineers and scientists to work across the materials-devices-circuits-systems barriers in addressing the challenge of developing electronic systems that dramatically reduce the energy requirements of digital information processing. This training will also prepare these individuals for successful careers in research and education in the academic, public, and private sectors.

The compelling research themes and innovative educational initiatives of the Center for E³S also present unique opportunities to significantly increase the diversity of the engineering and scientific workforce engaged in solving the global scale challenges of this century. It is the Center's goal to provide an optimal context for both the recruitment of individuals from underrepresented populations, including various racial/ethnic backgrounds, women, and people with disabilities, and the development and successful maturation of a new generation of researchers and scholars that will more closely reflect the diversity of the US.

Primary elements of the education, human resource and diversity goals are:

- To train a new generation of PhD and MS-level scientists and engineers who will
 - be knowledgeable with scientific approaches to low energy digital electronics systems;
 - understand that working in diverse teams optimizes creativity; and
 - understand the process of innovation, entrepreneurship and the transition of research results to commercially-viable products.
- To increase the number of students pursuing technical disciplines, contributing to an engaged, skilled and diverse technical workforce.
- To increase the number of students from historically underrepresented groups in engineering who attends university and graduate programs in technical disciplines that will contribute to low energy electronics.
- To promote continued interest in the E³S research areas among Center participants and alumni.

Successes in these efforts will manifest themselves as follows:

1. Population of underrepresented groups associated with the Center has increased.

The metrics and targets are:

- Number of underrepresented minorities participating in the Center's research and programs
 - Period 2: Establish Baseline
 - Period 3: 5% increase
 - Period 4: 5% increase
 - Period 5: 5% increase
- Number of women participating in the Center's research and programs
 - Period 2: Establish Baseline
 - Period 3: 5% increase
 - Period 4: 5% increase
 - Period 5: 5% increase

Actions and Owners: Education and Diversity Directors, supported by the Education and Diversity Associate Directors, will develop new undergraduate programs and utilize existing pre-college programs with the goal of enhancing the feeder pools at different levels, generally targeting all students, but underrepresented minority groups in particular.

2. Number of the Center's students from underrepresented minority groups pursuing bachelor and advanced degrees has increased.

The indicator of success and the Center's targets are:

- Number of pre-college students who pursue a bachelor degree in science and engineering
 - End of Reporting Period 2: Establish baseline
 - Period 3: 5%
 - Period 4: 10%
 - Period 5: 15%
- Number of community college students who transfer from 2-year community colleges to 4-year universities to pursue a B.S. in science and engineering
 - End of Reporting Period 2: Establish baseline
 - Period 3: 5%
 - Period 4: 10%
 - Period 5: 15%
- Number of undergraduates who pursue an advanced degree in science and engineering
 - End of Reporting Period 2: Establish baseline
 - Period 3: 5%
 - Period 4: 10%
 - Period 5: 15%

Actions and Owners: Education and Diversity Directors, supported by the Education and Diversity Associate Directors, will develop new undergraduate programs and utilize existing pre-college programs with the goal of enhancing the feeder pools at different levels, generally targeting all students, but underrepresented minority groups in particular.

3. Graduate students and postdoctoral fellows have been trained in a broad cross-section of topics related to E³S.

The success metrics and targets are:

- Number of graduates
 - End of Reporting Period 3: 50% trained
 - End of Reporting Period 5: 100% trained
- Number of publications where at least one student or postdoc author has prior publications in one or more other theme(s).
 - Reporting Period 3: 9 publications
 - Reporting Period 5: 12 publications

Actions and Owners: Education Director will develop programs for graduate students and postdocs that will enable community building, promote leadership and support professional development.

Specific actions include:

- Work with Center Director and Theme Leaders to develop a new course on the topics of E³S and establish a training process;
- Establish an incentive process for students and postdocs to co-author multi-theme publications; and

- Establish incentives to encourage faculty to host graduate student rotation.

4. All students and postdoctoral fellows demonstrate leadership skills.

Students and postdoctoral fellows will have opportunities to demonstrate their leadership skills by participating in education and leadership programs, including formal mentorship in undergraduate and precollege education programs, participation in the Graduate Student and Postdoc Council, and workshop organizing.

The metrics and targets for this goal are:

- Number of students and postdocs participating in education and diversity programs
 - Reporting Period 2: 5%
 - Reporting Period 3: 60%
 - Reporting Period 5: 75%
- Number of students and postdocs serving in leadership roles in the Center
 - Reporting Period 2: Baseline
 - Reporting Period 3: 15%
 - Reporting Period 5: 20%

Action and Owners: Education Director will facilitate the development and implementation of the leadership programs by the end of Period 2.

5. Center is viewed positively in the news.

The metric for this goal is defined as the number of events that lead to articles and publications in the news with targets at:

- End of Period 2: Establish baseline
- Period 3: 100% increase
- Period 5: 50% increase

Action and Owner: Executive Director is responsible for capturing newsworthy results for press release. Recognizing that the campuses' public affairs departments typically have limited resources, Executive Director will hire external resources to fill resource gaps, if it is necessary. The Center will organize public lecture series to highlight the Center's pursuits and the general topic of energy efficiency.

F. Knowledge Transfer

The knowledge transfer goal of the Center for E³S is to establish an industry/education partnership to introduce new more efficient electronics technologies, while preparing workers at all levels to participate in the new opportunities. Cross-fertilization would go in both directions, up and down the food chain, for device researchers at the leading electronics companies, circuit designers, CAD software writers, all the way to manufacturing workers in the semiconductor equipment industry. Thus opportunities will be created at all levels, including Community College students up to Ph.D. graduates from research

Universities. Knowledge transfer is the means by which research results are conveyed from the Center's faculty and students to society. Knowledge transfer is envisioned to be through the following channels:

- Strong liaisons with the concerns of industry to make certain that the academic technical directions will be practical, and lead to real success;
- Advice to policy makers at all levels of government on the implications for various device systems;
- Demonstration projects that test the devices and materials resulting from the Center's research projects;
- Meetings, summits, and workshops where results and knowledge gained through Center research activities are shared; and
- Knowledgeable students skilled in research as well as entrepreneurship.

These channels will be enabled when the Center achieves the following outcomes:

1. Easy access to the knowledge, information and technology by the Center community and the outside world.

The success metrics are:

- Number of website hits
- Number of unique visitors

with targets at:

- Summer of Reporting Period 2: Baseline established
- End of Reporting Period 3: 20% increase

Actions and Owner:

- Executive Director will establish a website to ensure the content will be current.
 - internet capability by the end of 1Q2011
 - intranet capability by the end of 2Q2011.
 - The Center recognizes cyber security is a key issue and must be addressed as part of the website design and implementation. Executive Director will present a cyber-security plan before implementation of the website; due to Executive Committee by February of 2011.

2. Two way knowledge, information and technology exchange (outside work →in, as well as Center → out)

The metrics of success are:

- Number of contacts with industry; and
- Number of presentations about industrial technologies

with targets at:

- Reporting Period 2: 18 contacts with industry
- Reporting Period 3: 36 contacts with industry
- Yearly: 2 industrial technology presentations

Action Items and Owners:

- Executive Director will facilitate interactions between PI's and industrial partners and publish a status report of the interactions as part of each center-wide newsletter.
- Executive Director and Faculty Members organize a speaker series on industrial technologies. The first schedule will be released in middle of Reporting Period 2.
- Executive Director will distribute one email newsletters per year on Center highlights beginning six months after the inception of the Center to promote the Center with industrial partners.
- Eugene Fitzgerald will offer a patent workshop to the Center's faculty by the end of the Reporting Period 2, in recognition that a common understanding of the protection of ideas will promote interactions among the Center's co-PIs; see also Knowledge Transfer 4.

3. Center is recognized to be an important source of relevant, innovative and far-reaching research.

The success metrics and targets are:

- Number of publications per year: 18
- Number of citations
 - Reporting Period 3: 10
 - Reporting Period 5: 100

Actions and Owners:

- Executive Director will establish a process to track all publications on the Center's website by the end of Reporting Period 2.
- Executive Director will establish a process to track citation statistics of the Center's publications and publish the data annually.

4. Center is recognized to be a key source of technologies with beneficial impacts on society.

The success metrics and targets are:

- Number of patent disclosures:
 - Reporting Period 3: 3
 - Reporting Period 5: 8
- Number of technology development attributable to Center's research:
 - Reporting Period 10: 1

Actions and Owners:

- Executive Director, supported by E. Fitzgerald, will organize seminars on technology commercialization in the beginning of Reporting Period 3.
- Executive Director and Center Director will jointly establish a process to encourage, support and track patent disclosures by 2Q2011.

5. Center's students are hired by relevant industries.

The success metric and targets are:

- % of students hired by relevant industries
 - End of Reporting Period 5: 50%

- Reporting Period 10: 50%

Action and Owner:

- Executive Director will create a process to track student post-graduate job statistics in Reporting Period 2.

G. Center Leadership

The leadership team is dedicated to inspiring and leading the Center for E³S based on the following values:

- Inclusiveness
- Teamwork
- Open and timely communications
- Agility
- Focus on Performance

The leadership team will be recognized as being successful when:

- The Center's members recognize that Executive Committee is effective, agile and courageous in decision making.
- Center members are well informed as there is clear and timely communication on all center activities.
- The Center's research portfolio is well recognized within and outside the Center to be well-integrated, complementary and comprehensive.
- There is a culture permeating the Center's relationships, processes, and activities that recognizes and values performance, and avoids possessiveness.

To help meet its promise to the Center's members, the leadership team has defined the following metrics to track its own performance:

- New Projects:
 - Reporting Period 2: 1
 - Reporting Period 3: 3
- Number of center wide communications:
 - 1 newsletter
 - Annual retreat
 - Annual NSF review
 - Updated website
- Number of disputes: annual decrease in incidences requiring intervention by the Executive Committee
 - Period 2: Established baseline. Set yearly quantitative goal for yearly decrease for subsequent years.
- Evaluation: earning 3 or higher on Likert scale

- Annual rating of the Center by External Advisory Board;
- Annual rating by internal co-PI's; and
- Annual recognition survey of Center members on perception of recognition

Action Items and Owners:

- Executive Director will:
 - Establish and implement a process to publish a newsletter to the Center's members thrice yearly by the beginning of 2011.
 - Organize an annual retreat for the Center with the first retreat being the Kickoff Meeting.
 - Develop and implement the process for recognition survey by the middle of Reporting 2.
 - Develop the processes for internal and external rating of the Executive Committee. The Executive Committee will implement the processes by before the end of Reporting Period 2.
- Center Director will
 - Communicate a proposal process for new research ideas by the Kickoff Meeting; see also unplanned joint research projects on page 5.

H. Ethics Code

The legacy of the Center for E³S rests on the integrity and credibility of its research results and the role models the co-PI's provide for the next generation of scientists and engineers. All members must commit themselves to ensuring that all aspects of the Center's life will be based on the strongest ethics. To ensure responsible conduct of research, the Center will implement a Center wide program that will inform and guide all members on the ethical and responsible conduct of scientific research. This program will include:

- All members' written commitment to a defined code of ethics after completing an ethics awareness training course.
- Implementation of annual ethics awareness training that will include:
 - Guidelines for authorship, acknowledgement of material source, prior art and intellectual contributions;
 - Laboratory notebook documentation, and data acquisition and validation protocols; and
 - The elements constituting plagiarism and the consequences of plagiarism.

Actions and Owners: Executive Committee will:

1. Establish a written code of ethics; 6 months after the Center's Kickoff Meeting
2. Develop and implement an annual offering of an ethics course;
 - Completed by the middle of Reporting Period 2 and annually refresher course, thereafter, for existing members;
 - Training to be completed within 6 months for new members joining the Center after joining the initial course offering.
3. Establish and conduct a confidential survey of members regarding fairness in authorship; by the middle of Reporting Period 2 and annually thereafter; and
4. Establish and conduct a confidential survey of members on incidents of plagiarism; by the middle of Reporting Period 2 and annually thereafter.

The success metrics and targets for these actions items are:

- Authorship: Baseline of complaints established before the end of Period 2; Decrease in number of authorship complaints by 20% annually thereafter.
- Incidences of Plagiarism: Baseline of complaints established before the end of Reporting Period 2; Decrease in number of incidences by 20% annually thereafter.

I. Responsibility for the Strategic Plan

The Executive Committee is responsible for the Strategic Plan of the Center for E³S. As part of its leadership responsibility, the Executive Council will conduct an annual review of the progress towards fulfilling the Center's goals, identify corrective actions, and revise the Plan, if deemed necessary.

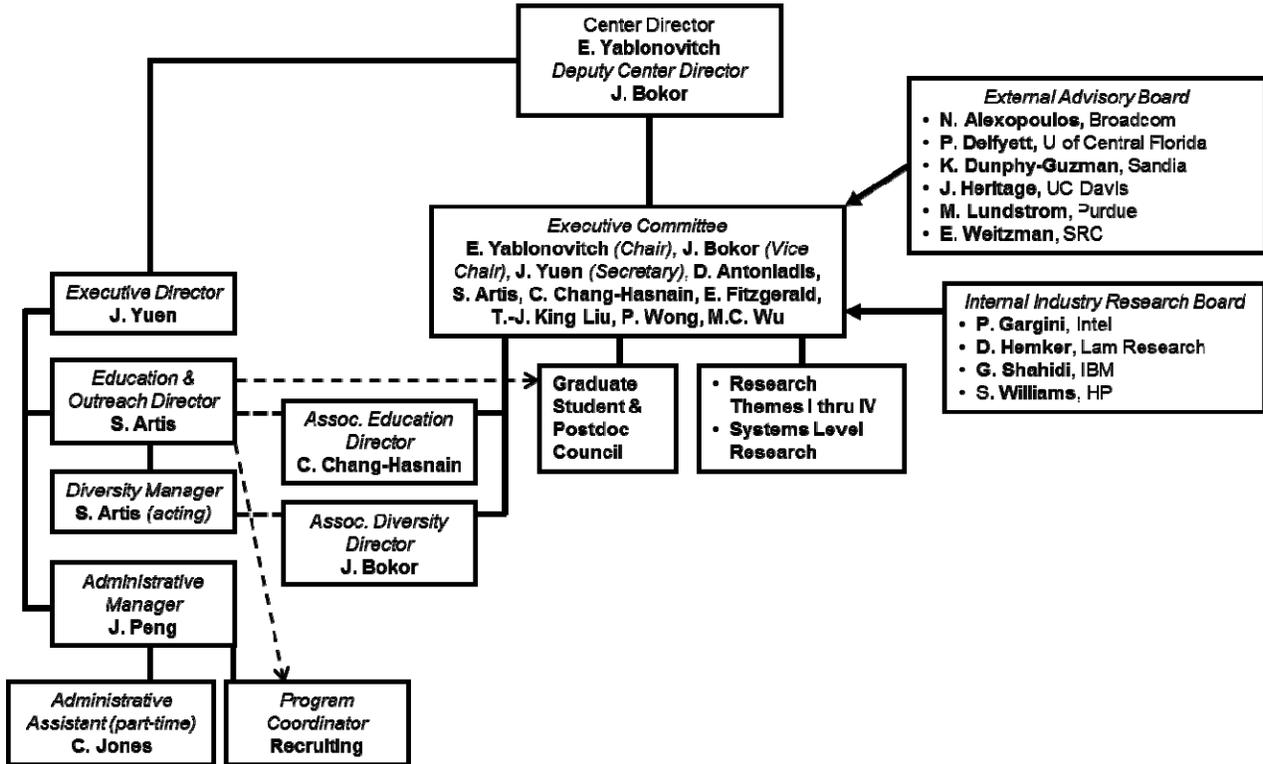
The Center Director has the responsibility to communicate the progress of the Center to its members at the Center's annual retreat.

The Executive Committee will from time to time seek outside experts to provide advice and counsel, and to aid in the development and implementation of assessments. Advising the Executive Committee is an independently functioning External Advisory Committee. Assessment of the Center's education programs will be conducted guided by education assessment experts. If appropriate, the Strategic Plan will be updated with the goals and action plans defined in response to external input, and assessment and evaluation results.

APPENDIX I

Management Structure – Center for E³S

(updated March 1, 2012)



APPENDIX II

Summary of Key Metrics

| In Support of | Metric | Targets | Owner |
|----------------------|--|---|--|
| Leadership | New projects | Period 2: 1 Period 3: 3 | Executive Committee |
| | Centerwide Communications | 1 newsletter Annual Retreat Annual NSF Review Updated website | Executive Director |
| | Number of disputes | Period 2: Baseline Annual decrease | Executive Committee |
| | Annual Surveys <ul style="list-style-type: none"> • perception of recognition – Students / Postdocs • perception of recognition – Co-PIs • external advisory board survey | 3 or higher on Likert Scale | Executive Committee |
| Ethical Conduct | Authorship disputes | Period 2: Baseline 20% decrease annually | Executive Committee |
| | Plagiarism | | |
| Integrative Research | Multi-PI projects | Period 2: 30% Period 5: 30% | Center Director Theme Leaders |
| | Multi-Institutional projects | Period 2: 10% Period 5: 30% | |
| | Unplanned research projects | Mid Period 3: 1 Mid Period 4: 3 | Center Director |
| | New joint research funding opportunities | Mid Period 3: 1 proposal | Executive Committee |
| | Publications with authors from multiple institutions | Period 3: 12 | Executive Committee |
| Education | Number of Center graduates who have completed E ³ S training | Period 2: Baseline Period 3: 50% Period 5: 100% | Education Director Center Director Theme Leaders |
| | Number of publications with student and postdoc authors who have published previously in other themes | Period 3: 9 Period 5: 12 | Center Director Theme Leaders |
| | Number of students and postdocs participating in education and diversity programs | Period 2: 5% Period 3: 60%* Period 5: 75%* | Education Director |
| | Number of students and postdocs serving in leadership roles in the Center* | Period 2: Baseline Period 3: 15% Period 5: 20% | |
| | Number of events leading to external articles on Center | Period 2: Baseline Period 3: 100% increase* Period 5: 50% increase* | |

| | | | |
|--------------------|---|--|--|
| Diversity | Number of underrepresented minorities participating in the Center's research and programs | Period 2: Baseline Period 3: 15% increase* Period 4: 10% increase* Period 5: 5% increase* | Education Director Diversity Director Assoc. Education Director Assoc. Diversity Director |
| | Number of women participating in the Center's research and programs* | Period 2: Baseline Period 3: 5% increase Period 4: 5% increase Period 5: 5% increase | |
| | Number of pre-college students who pursue a bachelor degree in science and engineering** | Period 2: Baseline Period 3: 5% Period 4: 10% Period 5: 15% | |
| | Number of community college students who transfer from 2-year community colleges to 4-year universities to pursue a B.S. in science and engineering** | Period 2: Baseline Period 3: 5% Period 4: 10% Period 5: 15% | |
| | Number of undergraduates who pursue an advanced degree in science and engineering** | Period 2: Baseline Period 3: 5% Period 4: 10% Period 5: 15% | |
| Knowledge Transfer | Website hits & unique visitors | Period 2: Baseline Period 3: 20% increase | Executive Director |
| | Number of contacts with industry | Period 2: 18 Period 3: 36 | Executive Director |
| | Presentations by industry | Yearly: 2 | Executive Director |
| | Center publications | Yearly: 18 | Executive Director |
| | External citations of publications | Period 3: 10 Period 5: 100 | Executive Director |
| | Patent disclosures | Period 3: 3 Period 5: 8 | Executive Director Center Director |
| | Students hired into relevant industries | Period 5: 50% Period 10: 50% | Executive Director |
| | Technology development attributable to Center's research | Period 10: 1 | Center Director |

**New metric added or targets updated in Period 2*

***New metric added or targets updated in Period 3*

APPENDIX IV

Revision Tracker

| Revision Date | Changes |
|----------------------|---|
| March 2011 | <p>[1] Revised dates for actions and metrics to align with NSF Grant Reporting Periods.</p> <ul style="list-style-type: none">• Reporting Period 1: Sep 15, 2010 to Feb 28, 2011• Reporting Period 2: Mar 1, 2011 to Feb 29, 2012• Reporting Period 3: Mar 1, 2012 to Feb 28, 2013• Reporting Period 4: Mar 1, 2013 to Feb 28, 2014• Reporting Period 5: Mar 1, 2014 to Feb 28, 2015 <p>[2] Appendix II – Added Targets & Owner for Ethical Conduct</p> |
| December 2011 | <p>Added new metrics and targets developed in Period 2 for Research, Education and Diversity goals and updated targets that were previously marked TBD. Metrics and targets were revised in Period 2 to provide a more detailed set of performance indicators that the Center can utilize to track the Center’s progress. No substantive changes were made to the Strategic Plan.</p> |
| March 2012 | <p>[1] Major revision with the main purpose to streamline metrics and provide greater clarity .</p> <p>[2] Revised actions to ensure effectiveness.</p> <p>[3] Removed Appendix III, Summary of Key Actions.</p> |