Executive Summary

The National Science Foundation
Division of Education and Engineering Centers (EEC)
2013 Committee of Visitors (COV) Report

Executive Summary

A 2013 Committee of Visitors (COV) was assembled at NSF headquarters in Washington, DC to prepare a report on the NSF Division of Engineering Education and Centers (EEC) for the three year period from FY 2010-2012. The list of COV members, their job functions and affiliations, are provided on pages 7 & 8 of this report.

The COV met in two sessions: a preliminary one-day planning session on July 18, 2013 and a three-day session on September 18, 19 and 20, 2013 for which all COV members were present in person.

NSF CHARGE & METHODOLOGY:

The Charge to the 2010-2012 EEC COV was to address the:

- Integrity, efficacy, and quality of the processes used to solicit and review proposals and the documentation of funding decisions.
- Quality of post award oversight, monitoring, and evaluation of funded proposals and programs.
- Quality and significance of the results of the Division's programmatic investments in terms of the NSF strategic goals (See: "*Empowering the Nation Through Discovery and Innovation – NSF Strategic Plan FY 2011-2016*);
- Opportunities to more fully realize the potential of the Division's current programs and future directions for the EEC Division. (EEC Division Plan)

A representative sampling program for e-Jackets was developed by EEC staff for the various programs within the Division, broken out by group, or cluster: From the Engineering Education cluster, 38 e-Jackets were reviewed from a total of 932; from the Engineering Career Development cluster, 30 e-Jackets were reviewed from a total of 606; and from the Centers/Networks cluster 34 e-Jackets were reviewed from a total of 368. The COV believes the e-Jackets reviewed were both representative and unbiased within each Divisional cluster and across the three-year period reviewed.

The COV reviewed a broad range of materials and information including a notebook of general information and a website developed specifically for our COV, as well as public documents available on the NSF website. Management briefings and written reports were provided for the Division and for each cluster within the Division. The Committee was divided into three subcommittees, one for each cluster. Each subcommittee chair (cluster chair), working with the members of the subcommittee, prepared draft responses for each relevant COV template question prior to the meeting. COV template

questions were revised and updated by each subcommittee in breakout sessions. Draft template responses were reviewed, discussed and edited by the COV as a whole. The COV also spent significant time looking strategically at opportunities to more fully realize the potential of the Division's current programs and to address future directions and opportunities to more fully realize the potential of the Division, which was the fourth charge to the COV.

Subsequent to the meeting, additional edits and revisions were prepared by the Vice-Chair and Chair in pulling together a final report. Numerous drafts were circulated to all members for review and comment. All members were given adequate opportunity to review and comment on the final COV report, including both the COV Template and the Executive Summary. As a result of this process, the Chair and Vice-Chair believe the final report fairly represents the collective opinions of the COV as a whole and fully addresses the charge to the COV.

CONCLUSION

The COV believes that the EEC is performing its currently defined EEC budgeted activities to high standards. That is to say: (a) the integrity, efficacy, and quality of the processes used to solicit and review proposals and the documentation of funding decisions consistently met or exceeded requirements; and (b) the quality of project management, monitoring, and evaluation of funded proposals, and post award oversight, consistently met or exceeded requirements. Whatever shortcomings may have been discovered in the COV evaluation, they are not deemed material in scope and occurred infrequently relative to the number of proposals under consideration.

EEC programmatic outcomes for proposals funded in the 2010-2012 time frames were not reported by NSF nor reviewed by the COV. It was thus not possible to fully assess the quality and significance of the results of the Division's programmatic investments in terms of the NSF strategic goals. Emphasis of the COV review was mostly on processes, not outcomes. The COV believes the programs funded by EEC fall within the goals of the *NSF Strategic Plan FY 2011-2016* and will contribute to meeting the Strategic Plan goal outcomes over time.

Opportunities to more fully realize the potential of the Division's current programs and future directions for the EEC Division are addressed in "Recommendations," below and in the last section of the COV Template, **Other Topics**.

RECOMMENDATIONS

As quoted from the most recently issued NSF Strategic Plan for 2014-2018, on Page 4, **Strategic Planning In a Dynamic, Global Context**:

> *"NSF has the responsibility to be a steward of the Nation's research and education enterprise in the midst of changing conditions that materially affect its success. ... New opportunities are emerging and technologies are arising across*

all disciplines. … NSF maintains a strong focus on carrying out our mission in a way that is sufficiently flexible to meet the changing requirements of the research and education enterprise as well as to address emerging and pressing societal challenges. At stake is the competitive strength of the Nation in the coming decades. NSF is not alone in this view."

Among Key Strategic Goals in the 2014 NSF Strategic Plan:

"Investing in the development of the next generation of researchers, scholars, and knowledge workers is one of NSF's most important approaches to transforming the frontiers of science and engineering…. NSF supports research and development on STEM education and learning to prepare a diverse, globally competent STEM workforce and a STEM-literate citizenry."

There are many recommendations and opportunities for improvement embodied within the full COV report, all of which we believe are consistent with the NSF's and EEC's Strategic Plans and stated Goals. For emphasis, we have restated our COV's three strongest recommendations in this executive summary:

1. The COV strongly recommends that the EEC take a leadership role in engineering education, notwithstanding the fact that many aspects of engineering education activities within EEC may overlap with STEM education activities performed by the Education and Human Resources Directorate. We further recommend that EEC remain independent from EHR. The reason for this is that the COV believes strongly that Engineering is *practice-based and innovation-based* to a far greater degree than other scientific disciplines within STEM. As such, the education of engineers is distinctly different from the education for the basic sciences such as biology, chemistry, physics, and mathematics. The COV fears that if engineering education is considered only as a part of STEM education, some of its distinct issues and needs may not be addressed adequately. This could be a detriment to engineering education, which is so necessary to our national priorities and to NSF goals in the Strategic Plan, in particular problem solving and innovation.

2. EEC should conduct a "Gap Analysis" (in cooperation with EHR and other Engineering Divisions) to assess what needs to be done in engineering education, where and how engineering education and research needs are being accomplished today, and what gaps and overlaps exist that either leave critical needs unsatisfied, or alternatively result in overlap and thus inefficiency and waste. We recommend that the current engineering education research leadership role continue within EEC. That said, the COV encourages intimate two-way cooperation and coordination between EEC and EHR on engineering education activities to minimize overlap and avoid gaps. The EEC Division should engage with EHR regarding the "E" of STEM. Both should work as a team where each contributes what it does best, with a shared responsibility to advance engineering education together.

3. EEC needs to do more on innovative engineering education program development and evaluation by developing its own programs focused on implementation of test sites for evaluation of novel engineering educational concepts. In addition, EEC should further conduct a greater level of engineering education research to see how well these transformative approaches to teaching and learning engineering are really working in order to better assess the strengths and weaknesses of new methods and practices. Doing something new will require EEC to redirect funds from other research programs or would require additional funds from the Engineering Directorate to be allocated to EEC. To reduce internal funding requirements and leverage its own resources, EEC should pursue cooperative relationships with other internal NSF organizations and external resources such as industry groups and engineering professional societies, among others. The COV also strongly recommends that EEC develop from within its own Engineering Research Center (ERC) organization at least one and up to five programs in the engineering education space ($4-5 Million per year each for 5 years and renewable for up to 10 years) focusing on engineering education and engineering education innovation to find fundamental ways to do more/better engineering education with fewer dollars and to discover ways to excite and to attract more minority students and women into engineering.

The issue of insufficient funding for engineering education was stressed in the 2010 COV report and in the 2007 COV report before it. Much of the current EEC $125 million budget is expended on cross-functional research to support other divisions within the Engineering Directorate such as ERC, NCN, REU, RET, among others. This leaves very little funding available for engineering education and engineering education research. Only about $10-15 million is expended on engineering education and research per se, plus funds transferred in from other organizations, which could not be identified from budget information provided. Past COV reports have stressed the extremely low funding levels at EEC for achieving a mission recognized as critical in the NSF Strategic Plan. The COV believes the budget at EEC is woefully inadequate to meet the NSF's Strategic Goals in the area of engineering education. More staffing and more reliance on full time NSF employees would be appropriate with reduced reliance on AAAS and Einstein Fellows. EEC must staff and organize to efficiently manage a larger level of activities. EEC staff will need to allocate and expend resources (including travel budgets) to stay current with the cutting edge of engineering education. It will also take significant staffing effort to take on a much needed leadership role among consortia of industry, academia, government and engineering professional societies. This will not happen without significant travel for relationship building and development of cooperative agreements, but building the potential funding leverage should provide a good return on that investment of personnel time and travel.

Engineering education is facing significant challenges. These challenges can be viewed as problems, or they can be viewed as exciting opportunities for transformational change. Transformational change will require leadership, which can be

a great opportunity for NSF, in particular EEC, to bring its talents and abilities to address these needs for the public good and for the Nation.

Our Nation is now experiencing an upsurge of interest in engineering education, in large measure due to the substantial impact engineering education will have on the innovation ecosystem so critical to the competitive strength of our Nation. Public interest in engineering education is focusing on many issues that need attention and leadership. These are now being addressed sporadically by many disparate organizations, but should be addressed at a national level, and EEC could lead this effort. Some of these issues include: implementation of "Common Core" education standards which for the first time will introduce engineering in our secondary schools (which several States are now opposing); doing something to help lower the cost for an engineering education and reduce the disincentives for a college degree; opportunities to address the shortage of engineering faculty at the undergraduate level and also the shortage of secondary school teachers with adequate training in science and engineering (S&E); developing innovative methods for teaching students about engineering and getting them excited about the field; assessing and taking advantage of the unknown impacts of Massive Open On-Line Courses (MOOCs); creation of student centered high tech methods and the Internet sites for learning and teaching science and engineering; developing more relevant teaching methods, mentoring and curricula for education targeted to attracting and retaining underrepresented ethnic minorities, racial minorities, and women to engineering. Today's minorities will be tomorrows majority, and we need to do all we can to get them excited about engineering and its potential to maximize their professional contributions to society.

In conclusion, The COV felt that the messages of the past COVs – the need for more engineers, the need for a more diverse and better prepared workforce, and the opportunities associated with innovation in engineering education – are coming to fruition today in a dramatic, fast, and furious way -- requiring changes within the engineering education community, and requiring leadership from EEC. U.S. industry, States/Commonwealths, professional societies, government agencies, foundations, parents/students, and universities are all investing their own resources, because they see the value in engineering education. Up until now, the NSF EEC has been reaching out to these groups, leveraging their investments, and collaborating to meet these needs, but only to a very limited degree. Not enough is being done. A sense of urgency is required. And there is a need for greater leadership. NSF EEC could provide a great service to our Nation by taking that leadership role and addressing these critical needs that are core to the NSF Strategic Plan. The NSF EEC can be a key player in all of this, but will need sufficient funding, manpower, and support to fully leverage the investments of the past that have provided an excellent basis for guiding engineering education today and innovating for the future.

FY 2013 REPORT TEMPLATE FOR NSF COMMITTEES OF VISITORS (COVs)

Date of COV: July 18, 2013 and Sept 18, 19, 20, 2013
Program/Cluster/Section: **Engineering Education, Engineering Career Development, Centers & Networks**
Division: Engineering Education and Centers
Directorate: Engineering
Number of actions reviewed: ***Please see COV Sampling Method document*** **Awards:** **Declinations:** **Other:**
Total number of actions within Program/Cluster/Division during period under review: ***Please see COV Sampling Method document*** **Awards:** **Declinations:** **Other:**
Manner in which reviewed actions were selected: ***Please see COV Sampling Method document***

MEMBERS OF THE 2013 ENGINEERING EDUCATION & CENTERS DIVISION COMMITTEE OF VISITORS (COV)

	Name	Affiliation
	Dr. David B. Spencer COV Chair	Chairman of the Board & Founder, wTe Corporation, Bedford, MA; Member, Engineering Advisory Committee
	Dr. Cynthia Furse, Co-Chair:	Associate Vice President for Research, University of Utah
COV Members & Sub-team Chairs:	Dr. Leigh Abts	Professor University of Maryland, College of Education, College Park; *Engineering Career Development Sub-team Chair*
	Dr. Tim Anderson	Dean, College of Engineering, University of Massachusetts Amherst; (Also served on EEC COV for 2010)
	Dr. Diana Bauer	Director, Office of Economic Analysis, Office of Policy and International Affairs, U.S. Department of Energy
	Dr. Louis Burton	Consultant, Retired: DuPont, Cisco Systems; *Centers & Networks Sub-team Chair*
	Dr. Mun Y. Choi	Provost & Executive Vice President for Academic Affairs, University of Connecticut
	Dr. Barry Horowitz	Professor & Department Chair, Systems and Information Engineering, University of Virginia; Retired President and CEO, Mitre Corporation, Bedford MA.
	Dr. Tracey Jacksier	Analytical Sciences Core Global Lab Director & Sr. International Expert, Air Liquide America Corporation
	Dr. Adrianna Kezar	Professor of Education, University of Southern California & Co-Director of the Pullias Center for Higher Education
	Dr. Michael Loui	Professor and former Associate Dean, University of Illinois at Urbana-Champaign and Editor of Journal of Engineering Education
	Dr. Scott Midkiff	Vice President, Information Technology & CIO, Virginia Tech
	Dr. Janet Rutledge	Vice Provost and Dean of Graduate School, University of Maryland, Baltimore County; *Engineering Education Sub-team Chair*

	Dr. Elba Serrano	**Regents Professor of Biology, New Mexico State University**
	Dr. Frances Williams	**Interim Director, Center for Materials Research, Norfolk State University**
	Dr. Gregory Washington	**Dean, Henry Samueli School of Engineering, University of California, Irvine**
	Dr. Sandra Woods	**Dean, College of Engineering, Oregon State University**

INTEGRITY AND EFFICIENCY OF THE PROGRAM'S PROCESSES AND MANAGEMENT

Briefly discuss and provide comments for *each* relevant aspect of the program's review process and management. Comments should be based on a review of proposal actions (awards, declinations, and withdrawals) that were *completed within the past three fiscal years*. Provide comments for *each* program being reviewed and for those questions that are relevant to the program(s) under review. Quantitative information may be required for some questions. Constructive comments noting areas in need of improvement are encouraged.

MANDATORY QUESTION I about the quality and effectiveness of the program's use of merit review process. Please answer the following questions and provide comments or concerns in the space below the question. ***Please consult your assigned jackets, program summaries and plotted data for your particular sub-team***

QUALITY AND EFFECTIVENESS OF MERIT REVIEW PROCESS	YES, NO, DATA NOT AVAILABLE, or NOT APPLICABLE
1. Are the review methods (for example, panel, ad hoc, site visits) appropriate? **Comments:** In summary, for all program clusters and sections, the review methods were appropriate. Different review mechanisms were used for different types of proposals and programs. The COV supports this targeted approach. Internal policies have been established in writing for proposal solicitation, review and award based on sector, program scope and program size. Quite appropriately, the extent of review methods and processes increase as program size increases, as program duration increases, and as the level of complexity increases. Program supplements were reviewed internally by NSF staff according to customary policy Budget constraints are leading to more virtual panels and fewer face to face reviews. The COV believes virtual panels are not as effective as face-to-face. The COV recommends that EEC develop a policy for when to allow virtual panels. Face-to-face panels are strongly encouraged for more complex, or larger awards, particularly in the Centers & Networks cluster where the size and complexity of programs consistently warrant full panel reviews. Some inconsistencies were observed for the Broadening Participation Research Initiation Grants in Engineering Program (BRIGE). Similar inconsistencies were noted in prior COVs and the EEC Division is addressing this matter. Such inconsistencies may in part be attributed to the fact that this program is	**YES**

managed under rotators rather than NSF full time staff, which we presume was, at least in part, driven by EEC budget constraints.	
2. Are both merit review criteria addressed **a) In individual reviews?** **b) In panel summaries?** **c) In Program Officer review analyses?** **Comments:** Reviews were appropriate for a) individual reviews, b) panel summaries, and c) program officer reviews and analyses. Overall the reviews were both broad in perspective and specific regarding proposal details. The review summaries were complete and addressed both the Intellectual Merit and Broader Impact Criteria. Panel reviews were much better documented than Ad Hoc reviews. There were no material inconsistencies uncovered during our review. The long standing confusion regarding how to best interpret and implement the intent of Criterion 2, Broader Impact, remains an issue, as it was in both the 2007 and 2010 COV reports. It is our belief this issue should be addressed at the Engineering Directorate and the NSF Director level since it appears to be a wide spread issue of concern throughout many parts of the agency. This 2013 COV did believe that the review process would benefit from more specific guidelines for both Criteria. There was a general consensus that the Broader Impact statements in proposals were often "open-ended," highly qualitative and indefinite with little quantitative data. Thus they did not appear to have the rigor that is seen in the intellectual merit sections of the proposals.	**YES**
3. Do the individual reviewers giving written reviews provide substantive comments to explain their assessment of the proposals? **Comments**: Panel sizes and work load appear to be appropriate. Individual written reviews, for the most part and with few exceptions, were substantive and provided strengths and weaknesses for each proposal. Reviewer's opinions of each proposal provided an overall evaluation of both criteria: 1) Intellectual Merit and 2) Broader Impact Criteria.	**YES**
4. Do the panel summaries provide the rationale for the panel consensus (or reasons consensus was not reached)? **Comments**: Panel summaries were, as might be expected, stronger and more convincing than individual written reviews. Overall panel summaries addressed the reasons	**YES**

the panelists felt the proposal was strong or weak, and their recommendations were reflected in the content of the summary. Panel reviews provided the rationale behind their recommendation in a manner that would be valuable to the Program Officer and to the Principal Investigator. They reflected a reasonable balance between individual reviewer inputs and panel inputs. The use of a lead person for each proposal plus a scribe to record the content of the panel discussion as a whole is a good approach and should be continued.	
5. Does the documentation in the jacket provide the rationale for the award/decline decision? **[Note: Documentation in the jacket usually includes a context statement, individual reviews, panel summary (if applicable), site visit reports (if applicable), program officer review analysis, and staff diary notes.]** **Comments**: The COV found that, almost without exception, the jackets included all the items set forth in the "Note" just above in this Paragraph 5. The thoroughness of the review process for ERC awards and subsequent monitoring through site visits and reports is commendable and demonstrates strong stewardship of this large and important program at the NSF. NSF has managed the program very effectively, including planning, direction, and review to ensure progress against objectives. Generally speaking for all programs, the Program Officer review and analysis were often the most complete summary of the panel deliberations. The jackets contained a balanced rationale for the award/decline decision. In a few cases diary notes and correspondence with the PI were also contained within the jackets. These provided further support for decisions giving evidence that the Program Officer followed through in addressing concerns raised by the panel. Those concerns were routinely conveyed by the Program Managers to the PIs. We recommend that the program managers prepare a document (an internal program evaluation) assessing each panel's performance after each panel cycle. This could be treated as a "context statement" for internal NSF use and institutional memory regarding reviewers, problems, challenges and opportunities for improvement regarding future panels and reviewers.	**YES**
6. Does the documentation to the PI provide the rationale for the award/decline decision? **[Note: Documentation to PI usually includes context statement, individual reviews, panel summary (if applicable), site visit reports (if applicable), and, if not otherwise provided in the panel summary, an explanation from the program officer (written in the PO Comments field or emailed with a copy in the jacket, or telephoned with a diary note in the jacket) of the**	**YES**

basis for a declination.] **Comments**: By and large, PI documentation included the elements set forth in the "Note" above. According to the COV, the information in the reviewer comments, panel summary and context statement were sufficient for the PI to understand the rationale for the award/decline decision. However, there were several cases where the most important information was in the Program Officer review analysis. Based on the documentation in the jackets It was not clear how much of this information was shared with the PI. Opportunities for improvement should be conveyed to the PI when possible and practical. Declined proposals could include more guidance regarding how to improve the proposal itself or how it was written. Some sort of "check-off" list might be of help to be sure all the necessary activities and communications with a declined proposal have been carried out, so a declined proposal will at least provide a learning experience for the PI.	

7. Additional comments on the quality and effectiveness of the program's use of the merit review process. **Comments**: Management of the merit review and award process appears to be effective. The diversity of awards, such as gender/ethnicity/career level of PIs, geographic and institutional setting, and department/discipline, was provided and appeared to be appropriate. **Centers & Networks:** The merit review process used is effective, even if budget and time constraints must be applied at times. Each Jacket includes at least 3 written individual reviews, most of which were discussed in a panel meeting at NSF. Although some proposals receive one or more ad hoc reviews, other Jackets include four to six regular reviews. In some cases, the program could do a better job of following through threads of site visit review comments from year-to-year. It is particularly important to discuss the resolution of negative comments. **Engineering Education:** In several cases the reviewer comments suggested an expansion of the scope of work in the proposal. It is not clear from the documentation in the Jackets whether the PIs were asked (either directly or indirectly) to incorporate this additional work into the project. There was no evidence of a budget getting increased to accommodate additional work scope.	**YES**

Documentation of Supplemental Awards was well done in some cases and in other cases the only information was an amendment to the award letter.

Review guidelines state that reviewers should address both strengths and weaknesses. However in several cases "Strengths" and "Weaknesses" were not explicitly stated but rather part of a broader general discussion. NSF may consider making separate boxes for strengths and weaknesses within each criterion if a breakdown of each within the evaluation is truly expected.

Career Development:
Overall the RET and REU program review processes were consistent and information provided was complete.

The staff clarified that effective 2013, the BRIGE program is no longer an entirely Ad Hoc reviewed program. BRIGE grants having a Scientific thrust are reviewed by a disciplinary panel, and BRIGE grants having an Education thrust are reviewed in an Ad Hoc process. The current program officer will be stepping down in 2013 after serving for a year. The staff is taking steps that the new program officer is aware of all the concerns. The COV analysis would have benefited from the inclusion of more of the e-mail exchanges between the Program Director and the PI. Overall the RET and REU programs appear to be well-managed.

Overall:
The COV still remains concerned about succession plans and ultimate management rehiring and management training for the BRIGE program.

The processes and documentation provided for panel reviews were more detailed than those provided by the Ad Hoc reviews. We recommend panel review for all programs, as a case in point, BRIGE.

A detailed checklist could be provided as a management follow-up tool to ensure process consistency.

Detailed guidelines for the review of Broader Impact statements could be developed and disseminated.

MANDATORY QUESTION II concerning the selection of reviewers. Please answer the following questions and provide comments or concerns in the space below the question. ***Please consult your assigned jackets, program summaries and plotted data for your particular sub-team.***

SELECTION OF REVIEWERS	YES , NO, DATA NOT AVAILABLE, or NOT APPLICABLE
1. Did the program make use of reviewers having appropriate expertise and/or qualifications?	**DATA NOT AVAILABLE**

Comments:

Insufficient information was contained within the jackets to ascertain the reviewers' backgrounds and to determine each reviewer's qualifications for proposal review. To the extent we were able to quiz the Program Managers; their selection of the reviewers seemed to be very strategic and thoughtful given the many topic areas covered by the jackets. Diversity was a key factor in selection – e.g. geographic diversity, race / gender, type of institution, and different technical disciplines. While we did not know the educational background of the reviewers, the review selection did seem to honor the need for diverse expertise. Reviewer comments demonstrate technical expertise in the area of interest.

Note: COV 2007 and 2010 made similar observations regarding the fact that reviewer data is either not available or cannot be reasonably obtained on a uniform basis.

NSF should consider how it could appropriately obtain reviewer background and experience information which would be provided as a confidential part of the e-Jackets and which could be provided to COVs to address this question using reported data. Can reviewers be asked to provide this data? Otherwise, should this question be eliminated? It would seem this is a process issue that should be addressed by NSF at a higher level than by EEC, since it is an agency wide COV issue.

2. Did the program recognize and resolve conflicts of interest when appropriate?	**YES**

Comments:

All programs state that they follow the NSF Conflicts of Interests (COI) policy. No conflicts were observed in sample jackets. There is insufficient information on the reviewers' backgrounds for us to ascertain if there were unstated COI issues. The COV believes Program Managers take NSF COI policy seriously

and implement the policy effectively.	
Additional comments on reviewer selection: The use of full merit review panels is expensive, but is a good mechanism for assuring fair and informed reviews allowing interchange between reviewers and face to face nuanced listening. It is particularly useful for multidisciplinary proposals. Reviewers from academia, government, and business participated. Although more reviewers were from the eastern US, this may be influenced less by selection than by cost and travel time required for availability. Virtual panels do help to address this disparity. Recruiting reviewers is challenging for the set of large, multidisciplinary projects that are typically considered by the ERC program. The EEC Division is to be commended for successfully forming highly qualified panels and site visit teams. We strongly recommend that reviewers for all programs have expertise in Broader Impacts on a par with Intellectual Merit. Broader Impact evaluations should be of such quality that this criterion is judged with consistent competency with that of Intellectual Merit evaluations. This is especially important with respect to the emphasis in the 2013 NSF program guidelines. Due to the interdisciplinary nature of engineering education, it was sometimes clear that not all reviewers had expertise with social science language. We hope, but could not confirm, that reviewers with sufficiently broad skills were selected for these panels. We note that NSF does not provide an easy way for someone to volunteer to be a reviewer and may not have in place adequate systems to collect information on prospective reviewers. Program managers rely on people they know, meet, or find via awarded NSF grants, or people who specifically contact them asking to be reviewers. We recommend that NSF seek methods to make volunteering for a panel easier, maintain an electronic data base of potential reviewers, collect expertise information (including experience with education, outreach, diversity), perhaps team with other agencies or professional societies to gain access to their data bases on reviewers used for other grants and/or society publications.etc. – and add a button to the front page of Proposal submissions to 'volunteer for a review panel'.	

*NSF does not have the legal authority to require principal investigators or reviewers to provide demographic data. Since provision of such data is voluntary, the demographic data available are incomplete. This may make it difficult to answer this question for small programs. However, experience suggests that even with the limited data available, COVs are able to provide a meaningful response to this question for most programs.

MANDATORY QUESTION III concerning the management of the program under review. Please comment on the following questions. ***Please consult your assigned jackets, program summaries and plotted data for your particular sub-team.***

MANAGEMENT OF THE PROGRAM UNDER REVIEW

1. Management of the program.

Comments:

Overall:
The vast majority of the e-jackets are complete, containing the required documentation. The management of the proposal review process and the selection process appears fair, transparent and justified. Programs are managed professionally. Management of the review and award process appears to be effective. The diversity of awards, such as gender/ethnicity/career level of PIs, geographic and institutional setting, and department/discipline, was provided and appears to be appropriate. Awards appeared to meet the timing requirements of NSF. At the e-jacket stage, it is difficult to assess outcomes that at such an early stage are mainly intuitive judgments rather than historically outcomes supportable with facts and data. Accordingly the COV did not address program outcomes as part of its review. However, It is important for NSF to measure the programmatic outcomes of the portfolio based on the overall goals. From the sample of jackets reviewed it was not possible to determine the impact on an individual program basis or for a sub-group within the Division.

The thoroughness of the review process for ERC awards and subsequent monitoring through site visits and reports is commendable and demonstrates strong stewardship of this large and important program at the NSF. NSF has managed the program very effectively, including planning, direction, and review to ensure progress against objectives. Overall the RET and REU programs appear to be well-managed programs. The BRIGE program management and processes appear to be problematic. One question is whether the BRIGE program is negatively impacted due to the use of NSF Rotators versus the full time staff assigned to the RET and REU programs.

Looking at the organizational charts for EEC, particularly for Engineering Education, it is obvious that there are a large number of rotators and temporary personnel as compared to full time NSF employees. For example, for Engineering Education, Donna Riley is the only full time NSF employee. Her entire support team is made up of just five AAAS Fellows and one Einstein Fellow. While these Fellows are talented individuals, and do not consume much budget, it takes time and management to bring them up to speed, and at the end of a short term, they leave and must be replaced. While they bring fresh ideas and excitement, they may lack experience, bring with them the challenges of substantial staff turnover, training and re-training, and they may lack NSF agency experience. A balanced team approach would enlist a larger proportion of full time regular NSF program managers supported by both "Fellows" and full time NSF Staff.

2. Responsiveness of the program to emerging research and education opportunities.

Comments:

Overall:
The EEC Overview and Strategic Directions document is responsive to emerging issues in engineering education. The COV feels strongly that the EEC must proactively take a leadership role within NSF on developing discipline-based education research (DBER). We are cognizant of the fact that EEC has supported the DBER community through past research funding and the COV feels that such funding must continue and preferably be increased. Engineering education is changing -- very rapidly. NSF appears to be aware of these recent and impending changes, but funding levels in EEC are insufficient to address these needs in other than a cursory manner or with depth in a narrow area of investigation. As one of the primary federal agencies with a mandate to attract, prepare, and retain a STEM workforce to meet the needs of our nation, NSF should be taking a leadership role. And EEC should rightly be leading that charge, or at least leading the development of the NSF Vision with respect to the particular issues that are critical to the Engineering Profession. For engineering, there are many more challenges and opportunities than are being met, and the EEC budget is insufficient to address what are serious education research and education leadership needs for the engineering community. For example, what is EEC's involvement in MOOC's and how is it assessing the potential of MOOC's to change engineering education? What is EEC doing to act as a catalyst to pull together (and even leverage) the diverse activities of industry, academia, and professional engineering societies? These disparate resources and their various activities require some leadership and coordination to avoid unnecessary overlap and avoid gaps, and NSF could play an important role in guiding these widely diverse attempts to make a positive impact on engineering education. Moreover, research on assessment of best methods, or alternative approaches, will be needed. Is there a leadership role that EEC could play? If NSF EEC plays little or no role, who will? Are there unique issues that must be addressed for engineering that are different than how those needs might be addressed for STEM in general by the Education and Human Resources Directorate (EHR)? How much coordination is currently occurring between EHR and EEC and how well are they working as a team in this effort? Are critical activities falling through the cracks? Should some sort of management analysis or gap analysis be conducted to be sure what needs to be done? Is there a clear vision of the entire transformative program to advance engineering best practices? Is there a clear vision on the table that informs what needs to be done to lead this effort and by whom to meet the strategic goals of NSF for engineering? And are those programs indeed happening? (This issue is discussed in more depth in Section V of this report with clear actionable examples.)

Centers & Networks:
The ERC program is a very powerful and impactful program. In the Centers and Networks programs NSF has placed emphasis on emerging research areas, e.g. nanotechnology. Data indicates good progress on diversity, including specialties and geography. Gen-3 ERC criteria are noted in several Jackets with favorable comments by reviewers and NSF. The SECO solicitation promotes licensing and commercialization of ERC inventions and developments by small businesses. The ERC program has found flexible ways to respond to emerging opportunities and to increase impact of existing awards. This is demonstrated through the use of a supplement to increase access for small and medium size enterprises, and to allow others to access software and computational resources. This is also demonstrated through the creation of the Small-Business ERC Collaborative Opportunity (SECO) program to facilitate transition of research results into innovative products through collaborative work. But has the ERC program ever considered an ERC focused on Engineering Education as a topic? The COV believes this could lead to very important contributions to engineering education using the funding of the ERCs to drive collaborative research efforts by

academia, industry and federal agencies to meet critical engineering education needs for the nation.

Career Development:
Other than those associated with an ERC, there is no clear indication that the REU, RET and BRIGE programs have a strategic focus. On the educational component, linking the activities of the RET teachers to state standards could be very important. Longitudinal evaluation of the students taught by the teachers and other measures for the impact of RET participants will be valuable. Similar evaluations of REU and BRIGE participants will be useful in determining the success of these programs.

3. Program planning and prioritization process (internal and external) that guided the development of the portfolio.

Overall:

Career Development:
We recommend a strategic effort to garner more successful community college proposals. Community colleges typically have limited grant and contract infrastructure, less internal training programs and fewer mentors for grant and proposal writing tutorship. Community college faculty are often unable to leave their more extensive teaching loads in order to travel to regional NSF training meetings. Additional training by NSF via webinars, online templates and examples of high quality proposals is recommended. We also suggest NSF staff bring in more community colleges as reviewers to better understand the proposal and award processes, while at the same time helping other reviewers and program managers understand the value and the expertise within community colleges.

During our COV meetings, the RET and REU staff explained how their programs are encouraging and funding proposals from community colleges, and we encourage continuing NSF efforts to enhance partnerships between two and four year colleges on joint proposals.

Specialized programs, such as BRIGE, might suffer from both the management and process perspective due to lack of alignment to the research and education mission of NSF. The relative amount of the EEC portfolio dedicated to these programs should align with the national emphasis on STEM workshop development. A baseline dollars/student participant metric might be a useful tool in portfolio development.

RET – With the information provided seems to be acceptable.

BRIGE – Not enough information provided to make an adequate assessment.

REU – With the information provided seems to be acceptable.

Note: COV 2007 and 2010 made a similar observation of the importance of partnering with community colleges.

Note: Additional discussion of portfolio opportunities is presented under OTHER at the end of Section IV.

4. Responsiveness of program to previous COV comments and recommendations.

Comments:

Centers & Networks:
NSF has made significant progress in addressing the comments / recommendations from the 2010 COV. However, some points either have not been addressed or can still be improved upon:

1. There are still some questions as to whether an adequately higher percentage of industry reviewers has been achieved for proposal reviews.

2. It is not clear if diversity data gathering issues have been resolved; specifically for women or underrepresented minorities. To make further progress specific problem areas should be defined and data collected with enough detail to measure status and progress versus goals.

3. The 2010 COV report commented on the need for a Succession Plan, which is part of strategic planning. This has not been thoroughly addressed and should be considered for all mission critical positions.

Engineering Education:
Review of the engineering education research e-Jackets suggests that the awarded proposals were prepared with high standard. The research methodologies were appropriate and advanced, the relevant literature was identified and synthesized, the research question was well posed, the dissemination plan was sensible. They were of the same standard as one expects in the discipline proposals. The reviewer's comments for the declined proposals, however, suggest that the same standards of rigor are not applied. The engineering education research community is relatively small and suffers from acceptance by the broader engineering research community. Thus the recommendation that EEC continue to take a leadership role in maintaining and communicating the best practices for engineering education research.

Apparent Lack of Responsiveness:

2010: [The COV strongly encourages the Foundation, the Engineering Directorate, and the EEC Division ***to elevate engineering education alongside the core engineering scientific disciplines*** *given its strategic importance in maintaining the United States' pre-eminence in the world.]*

*2010: [****The Engineering Education Program is severely underfunded, as suggested in the previous (i.e. 2007) COV report. To increase the impact of the program, NSF must increase the funding. EEC is the only program that funds engineering education research. This positions EEC in a critical national role.*** *This program can address major needs for workforce preparation.]*

Neither of these recommendations has been addressed. The engineering education program continues to be severely underfunded as suggested in the past two COV reports. There continues to be a need to maintain a distinguishing critical role for the engineering education programs in EEC. For almost a decade, each of the three COVs has made essentially these same comments

regarding the inadequacy of EEC's program portfolio and budget (and we are adding staffing as well). Each successive COV has expressed the same viewpoint more strongly than the last.
Repeated Past COV Recommendations Needing a Stronger, Actionable Response:

2010: [Given EEC's unique role in engineering education research the division must continue to drive the community to increase research rigor, similar to discipline research, including potential for transformative results, sound assessment and evaluation methods, concise review of the literature, and knowledge transfer and dissemination.]

2010: [Sustained programs in engineering education are needed to establish and implement best practices, including programs that specifically address recruitment, retention, and advancement of women and URMs.] We note that this is a tough issue and will require significant time and effort to accomplish and further that this subject is being addressed in part through the broadening participation program. However more work is needed.

2010: [There is a need for a major program (collaborative, multi-PI, multi-university) effort to allow faculty to try high-risk ideas with the potential for high national impact.]

The REE program is flexible with regard to size and duration of award and thus allows larger, multi-institutional proposals to try high-risk ideas. This also allows for smaller exploratory projects. The typical award is now $100k/ year for 3 years. However, the budget for this program is not sufficient to fund more than one larger project every few years and certainly not a center-like award. Therefore, the main intent of this recommendation has not been addressed. The COV would recommend that the EEC consider funding a large scale, new ERC award to address this potential opportunity.

2010: [The division should return to the practice of accepting unsolicited proposals to better encourage innovative research and collaboration. The target date for these unsolicited proposals needs to be on a perennial predictable schedule.]

The REE program allows unsolicited proposals that must be submitted during the two annual deadline periods.

2010: [NUE has run 8 years and should be evaluated for continuation.]

NUE was evaluated. It is continuing as part of NNI.

Career Development:
Both the 2007 and 2010 COV reports identify several areas that require continued attention: implementation of broader impacts, inconsistent reviews, BRIGE program management consistency and outcomes, and community college participation. We think it is important to consider some monitoring process or annual progress reporting on these items, so progress can be made to improve them.

IV. Questions about Portfolio. Please answer the following about the portfolio of awards made by the program under review.

RESULTING PORTFOLIO OF AWARDS	APPROPRIATE, NOT APPROPRIATE, OR DATA NOT AVAILABLE
1. Overall quality of the research and/or education projects supported by the program. **Comments:** **Centers & Networks:** The quality of the centers and projects supported is very high. The centers integrate high quality research having substantial intellectual merit and innovation potential with EEC's education objectives. EEC is a model for industrial, government and academic collaboration leading to innovation in an educational environment. The review process has ensured that awards are to high-quality proposals that also meet specific program goals. For ERC awards, the review process allows for feedback to the proposers who then have the opportunity to improve their proposed centers by responding to identified weaknesses and threats. This appears to be particularly effective in addressing problems while still preserving the valued aspects of the proposed center. The FY11, Solicitation NSF 09-545 produced four new ERC's awards, the ERC Class of 2011, including two jointly funded and jointly reviewed by DOE and NSF. During FY10 and FY12, no new ERC proposals were awarded, but 33 supplements were awarded to existing centers. Although no NERC awards were made in FY"10 and FY11, three new NERCs were funded from NSF 12-537 as the NERC Class of 2012 focused on nanotechnology. In addition, the Small-Business ERC Collaborative Opportunity (SECO) program provides seed money to innovate in small firms and speed the translation of ERC research into the marketplace. The COV believes the topics of proposals and quality of research associated with these large awards were appropriate. During our Strategic Discussions, the COV also strongly recommended that EEC issue a new ERC award focused solely on engineering education, which should be a large scale multi-university Center for Educational Innovation (comparable to the level of funding of the ERCs in general) that addresses the broad engineering educational challenges set forth in the Foundation's Strategic Plan and also set forth in the Strategic Planning for EEC. **Engineering Education:** Overall quality for engineering education research was very good. The awards were collaborative, engaging experts from other related fields and	**APPROPRIATE**

disciplines as appropriate. As stated previously, for the most part, accepted engineering education research methodologies were employed. **Career Development:** The BRIGE, RET, and REU programs supported quality research and facilitate the participation of students and teachers into the research of the research mentors.	
2. Does the program portfolio promote the integration of research and education? **Comments:** **Centers & Networks:** The integration of research and education is present in awarded proposals in a manner that is appropriate for the particular award. For ERC awards, there is strong integration of research and education, including at the middle school, high school, undergraduate, and graduate levels. For supplements and the Small-Business ERC Collaborative Opportunity (SECO) program, awards support the integration of research and education to a much lesser extent, but to the degree appropriate for the award. Data indicates a favorable impact of ERC's on curriculum and outreach across disciplines. Participants include community college faculty and students. During 2012 ERCs (17) produced a total of 266 academic degrees (BS, MS, PhD) including a high percentage (149/266) of Ph.D. graduates across a wide range of disciplines. **Engineering Education:** The program integrates research and education through research on engineering education. The program should encourage more translational projects that investigate how the results of research on engineering education can be implemented in the practice of engineering education. **Career Development:** Yes, the program portfolio promotes the integration of research and education, especially for the REU and RET programs which rely on the integration of the research of the PIs and research mentors with academic/educational experiences for students and teachers.	**APPROPRIATE**

3. Are awards appropriate in size and duration for the scope of the projects? **Comments:** **Centers & Networks:** Award sizes and duration are appropriate for the various awards. In particular ERC awards are large and durations are for up to 10 years, but these are large-scale, complex projects with a broad set of activities. Annual funding increases then decreases sharply in the final years. Thus, the award size and duration are appropriate and encourage ERCs to secure revenue and in-kind support from members, investors, and other non-government sources. Despite the large size of one ERC award, the funding allocated within the ERC to individual projects was too small. The amount allocated to thrust areas was also modest, at best. This observation can be made from the annual report. It is commendable that the site visit team also noted this issue and that it was addressed in the PI's response to the site visit team's report. **Engineering Education:** The budgets seemed reasonably aligned with the scope of work and the durations varied but in general were deemed appropriate for the scope of work. One possible exception was a planning grant with a 9 month duration where reviewers were concerned about the short duration but the success would have to be measured against the outcomes and performance which were not yet measurable. **Career Development:** The COV concurs with previous COVs that said there was not enough money for RET or REUs, and they should be larger in size and duration. The COV did not indicate if this recommendation would still be valid if it meant fewer grants would be issued as a result of maintaining the same total budget for RET and REU awards.	**Generally, YES. See comments.**
4. Does the program portfolio have an appropriate balance of innovative / potentially transformative projects? **Comments:** **Centers & Networks:** ERC proposals are closely scrutinized for their potential to provide transformative and innovative outcomes. Awards have strength in this regard, as appropriate for the particular award. Some projects that were potentially highly innovative and transformative were declined, but only in cases where the goals appeared overly risky and a credible work plan was	**APPROPRIATE**

not presented in the proposal. **Engineering Education:** Most proposals contained timely research topics and employed appropriate assessment methods by professionals well acquainted with topics. There seemed to be an expert in assessment and evaluation on each panel. The initial proposals did not always have well thought out assessment and evaluation plans, but in those cases the Program Officer worked with Principal Investigator to improve the plan.	
5. Does the program portfolio include inter- and multi-disciplinary projects? **Comments:** Large-scale awards are clearly multi-disciplinary. Smaller awards are not necessarily multi-disciplinary, but meet other goals and/or leverage multi-disciplinary research elsewhere. Multi-disciplinary projects are facilitated through the REU/RET programs which usually have multiple research mentors from various disciplines involved in the programs.	**APPROPRIATE**
6. Does the program portfolio have an appropriate balance considering, for example, award size, single and multiple investigator awards, or other characteristics as appropriate for the program? **Comments:** **Overall:** The COV recommends that the EEC investigate some larger scale education projects that might help transform the academy. Earlier COVs have asked the Directorate to consider larger programs to broadly impact engineering education such as regional centers devoted to engineering education, national and regional networks or coalitions, and regional centers with wide geographic distribution and connections to underserved populations. **Centers & Networks:** The ERC program focuses on center-scale awards that, appropriately, are large in size, have multiple investigators, and are relatively long in duration. Multi-PI projects enable collaboration and inter/multi-disciplinary projects. The program also leverages supplements and special programs, such as the Small-Business ERC Collaborative Opportunity (SECO) program, to be flexible in meeting needs where lower funding amounts, shorter durations, and smaller teams are appropriate.	**ADDITIONAL LARGER PROJECTS ARE RECOMMENDED**

7. Does the program portfolio have an appropriate balance of awards to new investigators? **NOTE: A new investigator is an investigator who has not been a PI on a previously funded NSF grant.** **Comments:** EEC has a variety of very large programs (ERCs, low % of new investigators serving as PIs) and smaller programs (BRIGE, all new investigators). For each type of grant, the number of new investigators is appropriate. The COV recommends that additional resources be routed to the BRIGE program. Staff concerns about BRIGE management and their efforts to improve efficacy of this program are laudable.	**APPROPRIATE**
8. Does the program portfolio have an appropriate geographical distribution of Principal Investigators? **Comments:** The awards reviewed are not well distributed geographically with 10-12 states receiving most awards while the majority of states received no award. However, not enough data is available to assess the overall portfolio and determine if this distribution is appropriate.	**INSUFFICIENT DATA**
9. Did the reviewers for EEC proposals represent an appropriate balance of: geographical distribution, gender and ethnicity? **Comments:** The geographic distribution was generally appropriate. There is, however, some overrepresentation of panelists from the eastern United States and an underrepresentation of panelists from the western United States. While it is perceived that women were less represented than men as panelists, data indicates women averaged 52% (48-56%) of ERC panelists in 2010-12. Given the gender imbalance in science and engineering, women are likely better represented as panelists than in the disciplines at large. Ethnicity data on reviewers was not available.	**INSUFFICIENT DATA**

10. Does the program portfolio have an appropriate balance of awards to different types of institutions? **Comments :** Most awards made have been to Research Institutions whose student and faculty demographics are not representative of the broader population. While diversity is always a goal and part of Broader Impacts criteria, there is a need to put some clear consequences for non-performance into this requirement. A stronger NSF-wide effort should be made to improve diversity of research participants (students, PIs, types of institutions, etc.). We recommend NSF require a diversity plan (at the university, college, and/or department level), and information on how the proposed research fits in with this diversity plan, as a supplementary document *required* for all proposals. Those submitted without such diversity plans would be returned without review. **Centers & Networks:** Most of the awards for Centers and Networks were to universities (95%). The program's awards are predominately to "research universities" with "very high" research activity (Carnegie Classification of Universities designation "RU/VH"). This is not surprising given the scale of center-level awards and the capabilities necessary to execute on such an award. Research Universities defined as having "high" activity and some other different types of institutions are, appropriately, involved in larger awards. There could be opportunities to include more different types of institutions, particularly in large awards. However, dilution of funds and loss of critical mass for major projects and facilities would be a concern.	**YES, IN GENERAL, WITH THE EXCEPTION OF DIVERSITY CONSIDERATIONS**
11. Does the program portfolio have appropriate representation of PIs from underrepresented groups[1] in its awards? **Centers & Networks:** There is gender and racial diversity among the investigators to some degree. This could improve, as could gender and racial diversity among science and engineering faculty. However, the awards to female PIs are double the percentage of women in engineering programs. The same appears to hold true for PIs from underrepresented racial minorities, except the percentage is even higher (3 times the percentage of racial minorities in science and engineering).	**YES**

[1] NSF does not have the legal authority to require principal investigators or reviewers to provide demographic data. Since provision of such data is voluntary, the demographic data available are incomplete. This may make it difficult to answer this question for small programs. However, experience suggests that even with the limited data available, COVs are able to provide a meaningful response to this question for most programs.

12. Additional comments on the quality of the projects or the balance of the portfolio: **Comments:** **Overall:** It would be helpful for NSF to articulate their goals for the balance of the portfolios. It would also be useful for NSF to develop a repository for publications generated from an award and to have a registry of participants. **Centers & Networks:** It is clear that the program works to ensure quality and balance in its portfolio through both the review process and management of awards. Data indicates a high number (44%) of Center and Network awards in 2010-2012 went to Electrical Engineering PI awardees. Other major fields are about 10% each, only a quarter of the awards to Electrical Engineers. For balance, consideration should be given to increasing participation by other fields. With the increasing importance of multi-national business and the global economy, consideration should be given to increased international collaboration and joint research.	

OTHER TOPICS

1. **Please comment on any program areas in need of improvement or gaps (if any) within program areas.**

The COV believes that the EEC is performing its currently defined EEC budgeted activities to high standards. That is to say: (a) the integrity, efficacy, and quality of the processes used to solicit and review proposals and the documentation of funding decisions consistently met or exceeded requirements; and (b) the quality of project management, monitoring, and evaluation of funded proposals consistently met or exceeded requirements. Whatever shortcomings may have been discovered in the COV evaluation, they are not deemed material in scope and occurred infrequently relative to the number of proposals under consideration.

The COV strongly recommends that the EEC take a leadership role in engineering education, notwithstanding the fact that many aspects of engineering education activities within EEC may overlap with STEM education activities performed by the Education and Human Resources Directorate. The reason for this is that the COV believes strongly that Engineering is *practice-based and innovation-based* to a far greater degree than other scientific disciplines within STEM. As such, the education of engineers is distinctly different from the education for the basic sciences such as biology, chemistry, physics, and mathematics. The COV fears if engineering education is considered only as a part of STEM education, some of its distinct issues and needs may not be addressed adequately. This could be a detriment to engineering education, which is so necessary to our national priorities.

That said, the COV encourages intimate two-way cooperation and coordination between EEC and EHR on engineering education activities to minimize overlap and avoid gaps. The EEC Division should engage with EHR regarding the "E" of STEM. Both should work as a team where each contributes what it does best, with a shared responsibility to advance engineering education.

We recommend that the current engineering education research leadership role continue within EEC.

We also believe that EEC should conduct a "Gap Analysis" (perhaps in cooperation with EHR and other Engineering Divisions) to assess what needs to be done in engineering education, where and how it is being accomplished, and what gaps and overlaps exist that either leave critical needs unsatisfied, or alternatively result in overlap and thus inefficiency and waste.

The COV sees a shortage of technical, financial and human resources within EEC to lead the work efforts for all the engineering areas that need attention. For example, the Engineering Education sector (cluster or group) within EEC expends only about $10-15 Million of the Division's total $125 Million budget. These funds appear to be expended mostly on engineering education research. So far as we could tell from budget

information, the balance of the $125 Million goes to Centers (ERCs and NCNs), REU's, RET's, and BRIGE (which were the only other EEC activities the COV evaluated in its 2013 assessment). These activities surely have an engineering education component, but generally speaking, they are not aimed at engineering education per se. Rather, they are focused on research and innovation.

Based upon supplementary documentation made available by EEC, to the COV's best knowledge and belief, none of the EEC Engineering Research Centers has as its goal the development of best practices for engineering education. The EEC ERC drives wonderful innovation research, but these are in the areas of biotechnology, manufacturing, energy, and optoelectronics. None of these centers is aimed at addressing innovation in education methodology.

The COV believes that EEC needs to do more on innovative engineering education program development and evaluations – novel programs focused on implementation of test sites for novel educational concepts. In addition, EEC could further conduct engineering education research to see how well these transformative approaches to teaching engineering and engineering education are working and assess their strengths and weaknesses. Doing something new will require EEC to allocate a larger fraction of funds from other ERC programs or would require additional funds from the Engineering Directorate. Alternatively, or in addition, cooperative relationships can be employed which leverage the talents and funds of other organizations both inside and outside NSF.

Regarding EEC's investments in Engineering Career Development, we reviewed only the BRIGE, REU and RET programs. These do train and produce better students and teachers though the practice of conducting research, but do they necessarily generate better ways of advancing engineering education except for those directly involved in the awards and in the research performed? In a sense, it could be said these programs are warehoused within EEC, but they really serve the other divisions within the Engineering Directorate. They educate, but neither transform nor advance the practice of education and/or development and testing of new educational processes.

The bottom line is that there are various opportunities and needs in engineering education where NSF EEC could play a greater leadership role. Is this within their charter? That was unclear based on our assessment of the combination of the EEC strategic plan presented by the Division Director combined with the e-Jackets. If these opportunities are already being addressed elsewhere in NSF, such as in the Education and Human Resources Directorate or in the Engineering Directorate, we were not fully aware of it from our COV review and certainly not from the review of e-Jackets within EEC.

Based upon review of the document, *Inspiring STEM Learning*, Report (NSF 13-800, Sept. 2013): https://www.nsf.gov/about/congress/reports/ehr_research.pdf, it is clear that Education & Human Resources expends more than $800 million annually developing knowledge about and evidence for "what works" in STEM education. The "E" in STEM is part of

that effort and rightly so. But then what is the role of EEC and how does it relate and work with EHR? How should the organizational charter for each organization divide up the activities associated with engineering education? This is an NSF issue that should be addressed from an organizational and mission standpoint as well as from a division of labor and activities standpoint.

It seems that EEC is the warehouse for many Engineering Directorate programs that serve the Engineering Directorate and its subordinate divisions. In that sense, it is somewhat of a cross functional support organization much like the Industrial Innovation and Partnerships Division (with the exception of the SBIR/STTR program) that houses and manages programs that support other divisions within the Directorate and NSF as a whole. Perhaps EEC should house cross functional programs for the Engineering Directorate and conduct engineering education *research*, but not focus on the other aspects of engineering education which would be left to the other divisions and directorates within NSF. It seems this management and organizational decision remains to be fully addressed, but should be addressed in the near term so it is understood not only by the COV, but more importantly by others who work within EEC and at NSF.

The COV recommends that a Gap Analysis be conducted for Engineering Education. We would further recommend that such an analysis be conducted in conjunction with EHR, other divisions within the Engineering Directorate, supported by other agencies and professional society organizations that could contribute both technically and financially to a first rate assessment and analysis.

During our COV, we conducted our own EEC Strategic *mini-gap analysis*, at least in part to set forth typical examples of activities we would like to see happening and which we presumed EEC should be leading.

At the highest level, we suggest the following:

- Treat Engineering Education as a Grand Challenge
- Define Best Practices (or put in place a program to define Best Practices) by bringing together the larger engineering community to review the existing body of literature, evaluate what is presently being done within NSF (EEC and elsewhere) and conduct a "Gap Analysis." EEC could be the catalyst and should have the ability and credibility to lead this.
- Strategically integrate EEC & EHR activities, plus tie in technical disciplines to education creating integration with CBET, CMMI, ECCS, IP, CISE, etc. This may require support at the Assistant Director or Director level within NSF.
- Leverage national and international investments including those from engineering societies, industry, and other federal agencies -- where NSF could play a catalytic and leadership role without the need to provide investment funds directly.
- Establish a program for dissemination, integration and implementation of best practices within the engineering education community.

The education trends that need to be addressed include diversity, the high cost of an engineering education, the rapid changes in technology that need to be part of an effective long term education/career, rapid education technology changes such as MOOCs, engagement of K-12 students to excite them about engineering, and the need for engineers -- and how this need will be met in our education systems including consideration of new certification approaches. (EEC provided data on how many engineers are produced each year, but did not assess the expected shortfall and how it would be met.)

A list of opportunities developed by our COV team below is neither complete, nor necessarily in any order of priority. But it includes several concrete suggestions of things we think NSF should consider doing to play a leadership role in engineering education. While suggestions may already be, or are being, addressed elsewhere in the agency, for the most part, we could not see that they were being addressed within EEC.

- Develop at least one and up to five ERC level programs in the engineering education space ($4-5 Million per year each for 5 years and renewable for up to 10 years) focusing on engineering education innovation. Innovate to find fundamental ways to do more/better engineering education with fewer dollars, and experiment to find better ways to excite underrepresented groups and women to pursue educations and careers in engineering.
- Focus on developing educational methods that are targeted specifically to underrepresented groups who will be tomorrow's majority (today's majority with an inflection point having already occurred in birth rates.)
- Evaluate removal of unnecessary curricular barriers and technical requirements and pre-requisites which are known to discourage people from entering engineering, especially women and minorities who may have broader interests and opportunities.
- Design learning programs and interactive teaching methods that will excite early age students (K-6, K-12) about engineering, as differentiated from science and mathematics.
- Establish collaborations with K-12 schools to actually implement the engineering focused learning programs that have been designed.
- Distill/disseminate best practices beyond the Engineering Education Research community, through a network of regional centers, workshops, online and in person training materials (faculty/teacher development).
- Form a stronger partnership with EHR without being absorbed into EHR.
- Assess engineering education methods and certifications for Massively Open On-line Courses (MOOCs) and other novel engineering education alternatives to a customary undergraduate degree program.
- Catalyze change at the broader level by funding projects at the department or college level as opposed to single investigator funding.
- Set a "design experience" for teachers (DET) and undergraduate students (DEU) looking at new courses and practices aimed at the engineering education of the future.

- Support engineering educators working directly with minority communities to identify and solve engineering problems specific to those communities.
- Broaden diversity and reduce under-representation gaps by establishing a gatekeeper who is capable of trimming overall NSF funding, not just EEC funding, to research universities with high activity or very high activity (RU/VH) that do not meet diversity thresholds OR give priority to schools who have currently been achieving progress toward diversity.
- Include small, agile education funding for individual or small group experiments.
- Study diffusion of innovation in education
- Design or drive a one-week curriculum aimed at geographic or underrepresented minorities to expose them to engineering and get them excited about engineering.
- Support translational research on how results from engineering education research can be implemented in practice.
- Catalyze the strong integration of design, problem solving and innovation practice into NSF's EHR STEM programs to ensure that these programs extend beyond basic research and also address the "E" in STEM.
- Provide international research experiences for socio-economically disadvantaged students.
- Develop a program that focuses on the transition points in the engineering pipeline to increase the attraction and retention of students to both study and practice engineering.
- Pilot novel engineering curricula in grades 8-12 aimed at exciting students about engineering.
- Improve the training for graduating engineers in the softer skills of people management, group performance and teams, project management, presentations clear and effective writing and communication skills.
- Support and encourage STEM mentorship programs for engineering at the grade K-6 level.
- Lead a discussion about roles of key organizations such as NAE, ABET, etc. working together for engineering education reform.
- Facilitate building professional/personal relationships across the whole career spectrum, particularly for minority students. (Example: Replicate the Carl Sagan and Neil deGrasse Tyson mentor relationship.)
- Commission a comprehensive longitudinal study to answer the question of how many engineers of which disciplines are needed and when – looking out 5-10 years. Assess the current academic capacity of the US to meet the needs either with US Citizens or with Green card status and determine if there is a shortfall. What is needed to do something about it? Could this study be done in consortia with NAE, industry, engineering societies but with NSF leadership and oversight?
- Work with the colleges of education and engineering schools to develop a course work and certification program for pre-college teachers in engineering helping them improve teaching of engineering and science at the grade 8-12 level using best practices.

- Develop/promote programs that facilitate re-entry of people later in life who seek to become engineers.
- Investigate methods of engineering education to lower its cost at least by half.
- Develop regional education centers that have as their responsibility the task of disseminating best practices to schools in their region (K to Grey).
- Drive development of a website that is "cool" to kids, interactive and capable of being used by small groups of children to self-teach engineering in a fun way. (Example: TED talk, "Hole in the Wall").
- Drive the development of a website that teaches teachers how to teach engineering principles (particularly teachers without an engineering or technical background) with practical experiments and exercises that would excite students about STEM and the world of science and engineering.
- Develop at least one website (preferably more) that is targeted to underrepresented groups (African-Americans, Hispanics, Native Americans, Women, etc.) and implement web-based volunteer coaching methods to help the students learn and become more excited about STEM and engineering in particular.

Develop the above websites in conjunction with kids who help pick the topics and also test the site out. Hire the right team to develop these websites, and include at least a panel of kids (including paying them if need be) to manage the processes and content. Continue involvement in the maintenance and evolution of the above websites to keep them current and insure that they continually engage latest web teaching technology and best engineering education practices.

The above bulleted examples of potential opportunities to drive the engineering education program are examples of the types of things that could be done by EEC, not examples of things that our COV necessarily recommends. However, what we do recommend is that the EEC commission an outside team of engineering education thought leaders, similar to those who served on this COV, to conduct a Gap Analysis to identify concrete and definitive actions that would be part of an implementation program for taking a leading role in driving the nation's engineering education agenda.

2. **Please provide comments as appropriate on the program's performance in meeting program specific goals and objectives that are not covered by the above questions**

The following verbatim quotation was from Part C, OTHER TOPICS contained in the **2010 COV** evaluation of EEC.

> "*The following section provides the observation and recommendations for the engineering education program.*
>
> ***NSF is encouraged to address all the recommendations; however, the COV believe that the following three must be addressed:***

- *Given EEC's unique role in engineering education research, the division must continue to drive the community to increase research rigor, similar to discipline research, including potential for transformative results, sound assessment and evaluation methods, concise review of the literature, and knowledge transfer and dissemination*
- *Sustained programs in engineering education are needed to establish and implement best practices, including programs that specifically address recruitment, retention, and advancement of women and URMs.*
- *There is a need for a major program (collaborative, multi-PI, multi-university) effort to allow faculty to try high-risk ideas with the potential for high national impact.*"

These same issues were raised by the 2007 COV. While the 2013 COV would not say "no progress has been made" on these key issues, they have now been repeatedly raised for almost a decade of COV reports. We would say that these three recommendations have not been driven to the level we would have expected. It is our view that the budget and complement of human resources in EEC is woefully inadequate to accomplish what we believe is the full intent of these 2010 recommendations. These recommendations by the 2010 COV closely parallel the independent recommendations of this COV in this report in Sections I-IV.

3. Please identify agency-wide issues that should be addressed by NSF to help improve the program's performance.

The Broader Impact policy issue described in Section I, Question 2 is an agency wide issue that needs to be addressed more fully from a policy and implementation strategy standpoint on an agency wide basis.

In Section II, Question 2, an electronic data base within NSF for reviewers should probably be agency wide, or at least such a data base should be developed for the agency as a whole and implemented on a directorate or divisional basis.

Under Section IV, Question 10, we suggest an NSF-wide effort be made to improve diversity of research participants by requiring a "diversity development plan" as a supplementary plan required to be submitted by all university proposers as a condition to NSF proposal review. Such strong action would in all likelihood have to be supported at the Director level to be implemented.

The International Collaboration in Section IV, Question 12 and the increased use of face-to-face reviews and reduced reliance on virtual panels would in all probability impact travel budgets which would have an agency wide impact in terms of compliance with budget directives.

4. **Please provide comments on any other issues the COV feels are relevant.**

None

5. **NSF would appreciate your comments on how to improve the COV review process, format and report template.**

None.

SIGNATURE BLOCK:

For the Division of Engineering Education and Centers 2013
David B. Spencer, Sc.D.
EEC COV Chair