**NSF’s ERC Post-award Review System: Strengths and Weaknesses**

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As was discussed in Chapter 3 of the ERC Program History, “ERC Generations -1 to -3: How They Evolved,” it was decided at the outset that the ERC program would include post-award oversight as a management tool. There would be on-site annual reviews by a team of scientists and engineers along with NSF staff. The first two site visits are particularly important, as necessary corrections in the ERC’s programs need to be made as early as possible to ensure a successful first renewal and to set the stage for the ultimate success of the ERC. Since the awards are made for three-year periods, the third-year and sixth-year reviews are pivotal for awards of the subsequent three-year periods.

Once the ERC award is made, it is in the interest of all stakeholders that the individual ERC be successful. It is therefore important for the annual reviews to provide as much constructive support to the ERC as possible. It is also important for all parts of the ERC, including the industrial partners, to come together annually to work as a team and self-review the progress made.

A delicate balance in the makeup of the ERC is important, as research leaders in the fields that the ERC is addressing need to play key roles in the ERC. However, often such leaders are not accustomed to playing a supporting role with their research and often they are not used to reporting to a research director in a program as complex as an ERC. When such faculty object to playing such a role, the burden of replacing the faculty member is placed upon the center director. An ERC site visit team can greatly lesson such a burden by identifying the problem in the site visit report and recommending actions to correct such problems.

For many faculty members, being part of an ERC is their first experience in team research in support of a common goal. This can also be true for their departments and colleges/universities. In some cases, the established process for evaluating faculty for tenure and promotion may need adjustment to ensure that the ERC faculty members and their students are institutionally motivated to participate in team research. Such interdisciplinary team-based research has been a goal of the ERC Program since its inception; however, it has taken time for the academic world to adjust to this new way of operating—although it has become much more the norm than it was in the early days of the program, in no small measure due to the influence of the program itself.

At first, the research teams with common goals were confined to the home institution of the ERC. With Gen-2 and then Gen-3 ERCs, the participating institutions were expanded to partner universities and then to global institutions, to the great benefit of the ERCs’ students and their research. More recently, an added emphasis has been placed by NSF and the participating universities on innovation and entrepreneurship. The annual site visits have therefore moved beyond focusing on the quality of the research and the progress being made to consider impacts on society and the economy being achieved through technology transfer to start-up companies as well as to larger and more established companies. This is particularly important as ownership and locations of larger companies are now more internationally distributed than ever. Direct benefits to the U.S. economy can therefore be shown most directly through technology transfer to smaller, domestic companies.

There are many important benefits of the annual site visit, including bringing together the entire ERC team for communal review of progress made, involvement of the IAB partners to help evaluate the center’s research and research directions, determinations of appropriate midcourse corrections, identifications of dead ends in the research program, and identification of new opportunities. The annual review has also been proven to be of great importance as a neutral forum for IAB members to establish a dialogue among themselves and discuss common industry issues and opportunities. Many IAB members have remarked that this benefit alone justifies their membership.

One risk of the annual site visit is possible over-enthusiasm of the site visit team for the ERC in its report and a lack of critical review, particularly in the first year or two. This can lead to a false sense of success by the ERC and subsequently lead to problems in the critical third-year review. It can also miss the opportunity to make corrections early, before students have invested their time on a topic that would subsequently be dropped.

Another point of growing importance at the annual site visit is the preparation of the ERC for “graduation” from NSF support after the tenth year. In the early years of the ERC Program the impacts of graduation from ERC support were not fully comprehended by the ERC or at NSF. It was quickly learned, however, that the importance of preparation for this event must be fully understood by the ERC. While a great majority of ERCs (more than 80 percent) end up continuing beyond the tenth year of NSF support, successful transition to “beyond NSF” requires a great deal of planning to minimize disruptions to students and research programs. The site visit team nowadays begins to press the ERC for that kind of initial planning beginning at the sixth annual site visit. If changes in the ERC’s direction are contemplated after the tenth year, it is particularly important that the planning start early. While the site visit team is constructed to review the programs of the ERC, it is in less of a position to judge the post-NSF planning, which must come from the ERC, including its IAB. Going forward, NSF will likely find ways through the annual site visit to be more proactive in guiding the ERC towards its graduation.

A key measure of success of an ERC is the steady progress towards its research goals and the achievement of its vision. This may or may not be completed in the ten-year timeframe of NSF funding. However, the overriding goal of the ERC Program to create a new type of engineer able to function and organize team-based multidisciplinary research can and must be achieved in all ERCs. The annual site visit teams place a great deal of emphasis on evidence of such progress.

Overall, the success of the ERC depends upon its leadership, followed by the support of the host institutions. Particularly at the first two years of sites visits, it is important to identify problems at the management level. This allows NSF staff to work with the ERC to make necessary changes. When such changes are not forthcoming, the ERC may be terminated, as has happened in several instances.

The key features of a site visit are: presentation of the vision, goals, and strategic plan by the center director, presentations of the research by thrust leaders complemented by a student poster session, presentation of the industry program by the industry liaison officer (ILO), and presentations of the education and diversity plans by the education and diversity directors. This is followed by private site visit team meetings with the IAB and with the students. For ERCs in the sixth year onward, there is also a presentation on the ERC’s self-sufficiency plans. Such presentations, meetings, and interactions provide direct support for the site visit team’s preparation of the site visit report and recommendations to NSF. Prior to departure of the site visit team, NSF staff debrief the ERC leadership on the conclusions and recommendations of the site visit team.

Generally, the ERC director’s presentations are well done and do not contain major surprises. However, if substantial changes have been made in the vision and goals of the ERC without prior agreement by NSF, this can lead and has led to serious problems with continued support by NSF.

The strategic plan includes a discussion of testbeds and must evidence a strong interrelationship among the research thrusts. If this is not the case and the research is seen to be consist more of non-interacting “silos,” that is a cause for serious concern, as team-based research across the entire ERC is expected. When it is found that a research program or thrust is non-interacting, site visit teams in the past have called for correction up and including to the elimination of that research thrust.

One of the more challenging features of the strategic plan can be the definition and roles of testbeds. This difficulty is due to the variability of the ERCs, with some being able to incorporate a proof-of-principle testbed early in the life of the ERC and others having to depend upon significant progress being made at the more fundamental research plane before an appropriate testbed can be identified. As the role of the testbed is both to bring the research closer to application and to tie together the research programs, appropriate testbeds must be identified and implemented early in the life of the ERC. The IAB should play a role in defining the testbeds and actively support them as progress is made. When this does not occur, strong involvement of the IAB becomes difficult and the future success of the ERC becomes jeopardized. When well executed, the testbeds serve to identify barriers and feed back to the ERC ideas for new research projects, sometimes including new fundamental understanding.

Most often, though, the focus of the site visit team is upon the research programs and progress. It is expected that the ERC will be at the forefront in its research programs and will exert global leadership in its primary areas. Site visit team members are selected for their expertise in these fields of research. Site visit team members provide valuable guidance to the ERC and can be particularly useful in helping to identify new opportunities and directions as well as identify dead ends. This provides valuable feedback to the ERC leadership during its annual decisions about which projects to continue to support as well as what new projects to include in the research program. Since the decisions regarding which projects to support can be difficult and contentious for the ERC, the site visit team here again provides valuable independent guidance.

The IAB is an important part of the ERC and receives careful attention by the site visit team. It is expected that the IAB will be stable and growing, particularly as the research programs of the ERC mature. Generally, the IAB starts with a cadre of members intrigued by the prospects of the ERC, and then there may be some turnover as IAB members find the research not sufficiently close to application to be of direct interest and as individual members’ situations change (key member advocates leave, companies are reorganized, companies merge or are bought out, companies directions change, etc.). IAB membership then grows with continued recruitment by the ILO and with the support of existing IAB members, as research progress is made.

When the overall membership declines and particularly when IAB involvement in the ERC declines, it is deemed a negative indicator by the site visit team and is likely to compromise the overall success of the ERC. It also makes it more difficult for the ERC to transition to self-sustainability. When the ERC is mired at the fundamental research plane without good testbeds potentially leading to applications, it can become difficult to sustain a viable IAB. If the IAB falls below a “critical mass” of membership, it can lead to a recommendation by the site visit team to withhold continued NSF support pending corrective action taken by the ERC. Because the site visit teams often focus most on the research programs, sometimes this important feature may not be fully appreciated by all site visit team members. Consequently, it is important that the NSF’s charge to the site visit team concerning the importance of the IAB be clearly presented. While pre-site visit team briefings cover all the key features in the review of an ERC, the emphasis on different features of the ERC can be inconsistent. I believe that the performance of the site visit team would be enhanced by a more carefully executed team briefing.

The importance of the education and diversity programs of the ERCs has grown greatly since the early years of the ERC program. There is now significant emphasis placed on these programs, with major portions of the site visit devoted to these programs.

The education program now extends beyond the universities to include outreach to K-12 in the local communities. Education outreach beyond schools to society is also encouraged. The ERCs have focused on creating new courses and modules for existing courses, as well as new textbooks, to achieve its educational goals. Advances in new approaches to education outreach have progressed more slowly and have often lacked creativity. Typically, the ERC will reach out to local schools and provide materials and training for the schools’ science programs. While this is effective, particularly when coupled with teacher training through the Research Experiences for Teachers (RET) program, it does not create a new paradigms that can easily be replicated in other schools. The ERCs, with encouragement by NSF, need to take more of a research approach and test hypotheses of what can make a self-sustaining difference in STEM education in K-12 schools. A successful example of this is the Science For Life (SFL) education outreach program established by the graduated Biomimetic Microelectronic Systems (BMES) ERC at USC, which engages the entire family. SFL hosts a “Family Discovery Day,” with the objectives of demonstrating to the parents what their children have been learning, directly engaging the entire family in STEM discovery activities, and reinforcing the idea that learning is a family matter. By directly engaging the family, students are much more likely to have ongoing support at home for STEM education.

The diversity programs emphasize the engagement of women and underrepresented minorities, with the goal of achieving a more diverse faculty and student body. Early on it was recognized that the pipeline of underrepresented minorities into engineering needed to be addressed. This required reaching back into K-12 schools and bringing Caucasian girls as well as girls and boys from underrepresented minorities into STEM programs. As new STEM initiatives have been implemented, ERCs have been able to partner with these schools and directly support their programs in the middle school and high school classrooms.

In Gen-2, ERCs have also engaged universities with large populations of underrepresented minorities as partner institutions. ERCs have recruited students into the Research Experiences for Undergraduates (REU) programs from these institutions as well as from other institutions with high proportions of underrepresented minorities. While the efforts have often looked good on paper, at times it has been difficult in practice to fully engage students from these institutions and integrate them into the ERC research teams. One example where this is working particularly well is the Advanced Self-powered Systems of Integrated Sensors and Technologies (ASSIST) ERC, headquartered at North Carolina State University. The Center’s Florida International University partner, with its large Hispanic population, brings a strong research program in textiles to directly support the ERC’s wearable sensor testbeds.

Starting with Gen-2 ERCs, a student Strengths-Weaknesses-Opportunities-Threats (SWOT) analysis has been required and presented at a private meeting with the site visit team. Generally, students are quite open about their experiences in the center. The students are usually able to relate their interactions with other ERC researchers at their institution and across partner institutions. The most common difficulty in their inclusion tends to occur when the partner institution has few students involved in ERC-supported research. This also occurs when students with ERC-funded research do not realize they are an integral part of the ERC and the SLC does not know their identities. When this occurs, the site visit team flags this deficiency and expects it to be corrected. On one occasion I asked the students if they could explain their center’s vision. None of the students were able to respond. Clearly, the center leadership had some work to do.

The site visit team also probes the involvement of the IAB members with the students. Well-functioning ERCs provide opportunities for IAB members to support students in their research. In some cases, IAB members are identified with specific research projects and are readily available to support the students. This has helped lead to student internships and to funding of associated projects. The SLC will often work with the IAB to foster such interactions, including arranging IAB member seminars. But in site visit after site visit, it has become clear that there are even more students who would like an internship in industry; usually the fault lies with the students’ lead professors, who don’t want to lose them for a summer or semester, or don’t want them lured into an industrial job before they complete their degrees.

Prior to completion of the site visit, a breakfast meeting including members of the administration across all partner institutions is held with the site visit team. In particular, the deans of engineering attend this meeting. This allows the site visit team to learn how the ERC is being supported at the institutional level. Often there is a discussion of what the institution is doing to support the cross-disciplinary research, education, and inclusion programs of the ERC. This is particularly relevant to the hiring of new faculty. Increasingly, it has become the norm for the institutions to have active programs in place to reach out and encourage women and underrepresented minorities to join the engineering school faculty.

The Gen-3 emphasis on innovation has not only spurred the ERCs to specifically target innovation in the education programs, but has also prompted an increased emphasis on entrepreneurship and innovation across the partner institutions, as described by the administrators. Start-up companies are being actively supported by institutional investments and facilities at research parks. The emphasis on start-ups, however, does pose a risk. Faculty and students may not fully understand their responsibilities concerning conflict of interest when it comes to the use of equipment, supplies, and facilities in direct support of the start-up. It is not clear that all institutions have mandatory conflict-of-interest training programs in place for faculty and students involved in such start-ups. I understand that NSF has recently prepared a detailed flow-chart to guide the faculty and start-up personnel through this process—a necessary and useful tool.

After the meeting with the lead and partner institution’s administrations, the site visit team adjourns for a private meeting and to write up the site visit report. There is a vote taken on what rating to give the ERC: renewal of support, a conditional renewal pending approval of strategy to address significant weaknesses, and a recommendation against continued support. The site visit team also prepares a SWOT report. If a conditional renewal is recommended, problem areas must be satisfactorily responded to and corrected by the ERC as determined by the NSF staff. There is a delay in funding the new year of support until this requirement is satisfied. On the rare occasion that the site visit team recommends cessation of support and the NSF staff agree, continued support is phased out over the subsequent two years to protect existing students’ funded research.

Even with a recommendation of renewal of support, any threats to the success of the ERC as identified in the site visit team’s SWOT are communicated to the ERC by NSF staff and must subsequently be satisfactorily addressed. Upon completion of the report, further review of the report occurs at NSF prior to release to the ERC.

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