9.4 RESEARCH PROGRAM MANAGEMENT

An Engineering Research Center's research program is at the core of its purpose and activities. Creating a strategic research plan is vital to the Center's success. The research plan is a central part of the ERC's overall strategic plan, which also includes education, diversity, and industrial interaction elements.

Equally as important as developing, revising, and monitoring the strategic research plan is establishing the infrastructure to select and review appropriate research projects. Integrating resources and facilities to build teams whose contributions are greater than the sum of their parts also is an important part of the research effort. The testbeds around which the ERC research thrusts are crystallized provide an important focus for research, education, industrial collaboration, and technology transfer.

Chapter 4 of the *ERC Best Practices Manual* addresses research program management for ERCs in general. This subsection of Chapter 9 focuses on research management for multi-institution ERCs.

9.4.1 The Strategic Research Plan: Development and Evolution

The plan starts with an understanding of the state-of-the-art of research in the academic disciplines that converge on the engineered systems that are the focus of the ERC. It is developed in recognition of the fact that the plan will evolve. The plan is built on established organizing principles (NSF's three-plane chart, various conventional flow charts) and several leadership levels (Center Director, an overall Research Leader, and Thrust Leaders). It is important for the academic participants to recognize the correlation between changes in the plan and its funding as well as the fact that program components may be completed or phased out.

9.4.1.1 State-of-the-Art Analysis

The first step in developing the strategic research plan is to assess the state-of-the-art in the field. This analysis should be updated continually and the Center's contributions documented, resulting in a comprehensive history of contributions in the field. The dynamic state-of-the-art analysis should cover national and international developments, and both disciplinary and interdisciplinary literature.

This initial analysis step is part of the Center's proposal development process and defines the potential contribution that a subsequent award might provide. Continuing analyses of the state-of-the-art and the impact of the ERC's work on the field must be formally coordinated and then documented through comparisons in the Annual Report submitted to NSF. Speculation about the state-of-the-art in the field and the ERC's role in its evolution is insufficient to support continued NSF funding. Sourced references and documentation are required to justify the expectation that the ERC is not operating in a vacuum toward insular goals that may have little or no application in the global environment. A multi-institution ERC may acquire information or documentation from multiple sources and perspectives, requiring joint discussions to reach a consensus about how the Center can be optimally integrated to achieve the maximum impact—and what impact it is having.

CASE STUDY: *The Mid-America Earthquake (MAE) Center, which is focused on earthquake risk only, reviews all literature in the risk arena in which tools and data may be available that apply directly to earthquake risk. Developments all over the world are reviewed continuously, even though the exposed societal systems might be different than those in the US.*

9.4.1.2 Nature of the Research Plan

The ERC strategic research plan is focused on both addressing fundamental, technical, and system-level barriers that must be overcome to advance the field—as defined by the current state-of-the-art assessment—and serving as a potential catalyst in the development of a new field and/or industry

CASE STUDY: *The state-of-the-art in power electronic systems at the inception of Virginia Tech's Center for Power Electronic Systems (CPES) was delimited by numerous disjunctions among the many components that comprise such a system. The CPES strategic plan laid out a roadmap that would provide the Center with the*

capabilities to become a world leader in power electronics through a multidisciplinary, multi-university, and multi-industrial partnership program extending over a ten-year period. The program was based on an integrated systems approach to standardize power electronics components and packaging techniques in the form of highly Integrated Power Electronics Modules (IPEM). The IPEM approach makes possible increased levels of integration in the components that encompass a power electronic system? devices, circuits, controls, sensors, and actuators. It was a new approach that took power electronics to a new level of performance.

The level of definition of the plan will vary, depending on the field and the specific Center circumstances. For example, "The primary research goals of the Center are as follows . . ." and "The baseline for progress assessment is or will be established by . . .", followed by enough detailed information to clarify the specific areas of the field to be addressed as well as the approach for achieving success in those areas utilizing the proposed Center configuration, with special attention to the advantages gained through partnering with other institutions/disciplines and industry partners. The relationship between the primary goals and the partner institutions should be articulated and future expansion and refocusing should be discussed with regard to possible changes in the makeup of the ERC where new alliances might be sought to optimize the talents needed to achieve the research goals.

9.4.1.3 Plan Organization

Deliverables take many forms and should be identified and scheduled in the research strategy development.

A PERT chart, Gantt flow chart, or equivalent schedule of planned milestones with an anticipated target date for completion can be used to summarize the plan and its deliverables. Including details for reaching the charted milestones in the strategic document is considered optional. Anticipated barriers should be identified, specifically to facilitate incremental progress, assessment and documentation. NSF has developed a "three-plane chart" that is a useful tool for organizing and visualizing the interconnections between the fundamental research, technology demonstration, and technology/system integration levels of an ERC's work. This chart can be customized to reflect the strategic research plan in detail. It is important to have the chosen organizational tool detailed at the Project, Thrust, and Center levels with clear relationships among the three levels, both top-down and bottom-up. All ERC researchers should be committed to the deliverables and have a full appreciation of where they fit within the grand plan. The effort has to be balanced among the three planes.

9.4.1.4 Research Leader

Many multi-institution Centers find that designating a single research leader whose purview spans all the research thrusts is integral to the research plan's successful realization and evolution. This optional (but recommended) position can have a variety of titles, for example, Associate Director for Research, Deputy Director, Technical Program Director, or Chief Scientist.

The administrative burden on a single-institution ERC Director is quite heavy and increases exponentially in a multi-institution ERC. Although the Center Director might be tempted to control the research program personally, it is advisable to assign another individual to the task. There are many reasons to do so, not the least of which is preservation of the Director's sanity. These include the Director's need to maintain a macroscopic view, while the research leader is immersed in the program details; the need for a single individual who is well-versed in the program to interact directly with the Thrust Leaders and facilitate research integration at a hands-on level; and the need to continually assess progress and failure, to coordinate reporting out, and to coordinate revisions to the plans in a thorough and progressive manner. Additionally, this individual may provide a higher degree of accessibility and linkage to partner university programs and Thrust Leaders, thus expediting forward progress.

9.4.1.5 Thrust Leaders

Thrust Leaders lead in planning and executing a thrust-level strategic research plan. They can provide the critical perspective that might reveal the gaps or barriers in the plan as well as its potential outcomes or shortcomings. Often Thrust Leaders can also offer preemptive solutions to perceived barriers, thus facilitating planning and implementation strategies. Thrust Leaders serve as the third level of research management, below the Research Director and the Center Director. Their role is critical in translating between researchers and research management to achieve the ERC's deliverables.

9.4.1.6 Annual Plan Review

Visit (and revisit) the strategic research plan and roadmap annually through a group effort involving all key faculty members,

Thrust Leaders, the Research Leader, selected stakeholders, advisory boards, and all partner institutions.

CASE STUDY: *At CPES, the Annual Review begins with an annual faculty Retreat. The Retreat agenda includes a review of the Center's vision, goals, technical roadmaps, barriers/challenges, expected outcomes, and a progress assessment. Retreat conclusions are subsequently presented for discussion and/or action through routine meetings of the various advisory boards.*

9.4.1.7 Changes Affect Funding

Project and thrust area funding may be directly affected by changes in the strategic research plan. It is important that all partner institutions be aware of potentially adverse effects on their anticipated future funding levels for research and be prepared to adjust their efforts accordingly.

The documentation resulting from the process of submitting a joint proposal may create expectations for funding in accordance with the original research plan. Since changes in the original research plan are a natural and expected outcome related to the nature of basic research, it is incumbent upon partner institution leaders to ensure that the administrative units within their individual institutions are aware that the dollars included in the originally proposed research plan are not to be interpreted as an entitlement to a specific dollar award in future years and that the actual institutional award will vary commensurate with the research plan's evolution. Setting this expectation requires effective communication as well as changes in the traditional culture of post-award administration. Such administration is institutionally specific because it aligns with the ways that the data included in the original proposal are used within the institution (e.g., reporting of research dollars for an individual faculty member, department, college, or for the university at large; faculty activity and tenure review; and dollars committed in cost sharing or matching support). It is also important that all Center members share responsibility for pursuing alternative funding options for any discontinued projects that have fundamental intellectual merit and/or value in the field, but are outside the scope of the strategic plan. The ERC, mainly through its Director, should spare no effort in stressing to institutional representatives that it is in the interest of all concerned that no culture of entitlement is allowed to develop, even for an institution seen as critical to a successful proposal. Only merit reviews are the basis for continuing funding, and only projects with clear deliverables germane to the Center's should receive funding.

9.4.1.8 Phasing-Out Mechanism

It is advisable to include a phasing-out mechanism as part of an evolving research plan. This will help ensure that the impact on both students and related research projects that results from discontinuing a project or a thrust area is minimized. Phasing out a research area is more complicated in a multi-university Center and requires thorough advance coordination with Campus Directors at partner institutions.

9.4.1.9 Serendipitous Discoveries

As research program assessment occurs, it is likely that some discovery merits further examination and yet does not fall under the strategic plan, even as the strategic plan evolves to encompass changes pertinent to the core research undertaking. In an integrated multi-university environment, the decision to discontinue a particular project or thrust is generally achieved through consensus. Some alternative paths for continuing or using the discovery may be identified in advance so that expectations are limited to realistic possibilities and group harmony is not threatened by the natural evolution of basic research. For example, there may be "seed" or "bridging" funds set aside as part of the industry consortium to temporarily continue research, or the Center may submit a proposal to industry or a government funding agency seeking support for supplemental study in a particular area. Projects that are of a highly fundamental nature should be good candidates for NSF support while those that are of a high application value should be attractive to industrial partners. If such a project falls in neither category, and is not integral to the Center's strategic plan, it is clear that it should not be continued under the aegis of the ERC.

9.4.2 Project Selection and Review

Creating a program, thrusts within a program, and projects within thrusts is fundamental to the research effort. As the program progresses, new barriers and challenges appear, changing the scope and resource allocation. The Center Director is central to the continuous refinement or redefinition of the research program and to determining project approval and funding allocation.

9.4.2.1 Process

As the research program progresses, changes in scope, resource reallocation, and expertise shift will occur. A general process for project selection and review should be established and included in the Center's policies and procedures manual for reference.

The plan and scope of the research are fluid for much of the life of a successful multi-institution ERC, requiring regular review and interactive discussion among various groups of participant institutions. The review process should be balanced to include various Center stakeholders and adequate time for information gathering. Implementing checks and balances to preserve the integrity of the process and minimize stakeholder bias is necessary, yet the process must be simple enough to be practical in terms of time, implementation, and procedural requirements. As the ERC reaches maturity and approaches graduation, less fluidity will be required; hence even the review process itself is not set in stone and should be adapted to the phases an ERC goes through during its life cycle. It is essential that at all stages institutional representatives should act and advise in a Center mode with no bias and no parochialism. Within the established review procedure, the Director's role as the ultimate arbiter is crucial, and therefore her objectivity and judgment should be beyond reproach.

9.4.2.2 Research Program Refinement or Redefinition

The Center Director is crucial to continuous refinement or redefinition of the research program's scope in consultation with research thrust leaders and the Scientific and Industrial Advisory Boards (SAB and IAB). It works best if the selection process is neither entirely bottom-up nor top-down but is highly consultative, with the Center Director as the ultimate decision maker.

Technical leadership and researchers among all partner universities first prioritize research needs and review available program resources in consultation with the IAB and thrust leaders. Although advisory groups provide input to the selection process, Center Directors must be careful to moderate the advisory roles so that special interests do not dictate the Center's research plan to the point that core research becomes fragmented or loses its systems focus. Pressure to support projects that are needed by industry or purported to be needed by industry, within the Center's core research program, should be resisted. Core research is generic in nature and applicable to a wide range of stakeholders, and should not be in service to narrow stakeholder interests. The outcomes of all group discussions regarding research directions should be communicated to the Director in a concise form. The Director may selectively use or disseminate the information in accordance with ongoing consultation with advisory boards or research leaders. In the case of a substantial change in scope, the Center's Governing Board or Leadership Team (if one exists and is different from the IAB) should be involved, offering assistance in composing a revised plan. Failure to keep the Governing Board involved in these processes may result in a lack of commitment from partner institutions, a result that carries a substantial threat to the potential 10-year life of a successful multi-institution Center.

9.4.2.3 Revised Thrust-Level Program

The Center Director approves a revised thrust-level research program plan developed by the Research Director and the Thrust Leaders. This plan includes consideration of related Center objectives (such as education, industrial collaboration, and inter-institutional interactions).

The Center Director can use the input received from the thrust leaders and advisory boards to formulate a proposed preliminary plan and allocation of funds by thrust/program area. This proposal should include consideration for promoting interdisciplinary and intra-institutional collaboration. The Director's thrust/program allocation proposal may then be submitted to the Center Executive Committee, Governing Board, or Leadership Team for evaluation and recommendation. The Center Director is ultimately responsible for defining the research priorities.

9.4.2.4 Project Proposals

Once the scope is defined for an annual funding period, a request for project proposals may be issued, setting forth timetables and deliverables schedules. Potential awardees may then submit project proposals to the respective thrust/program leaders. The thrust leaders may then enlist assistance from industry champions from the IAB in the review, prioritization, and recommendations for project funding, using the approved research plan and preliminary allocation proposal as a basis for discussions. (This is one common procedure. Other mechanisms may be followed.)

9.4.2.5 Project Approval

The Center Director makes the final determination regarding project approval and distribution of resources. In the procedure described above, the Director considers the recommendations of the thrust/program leaders and renders a recommended

allocation for incorporation in the final funding allocations. Individual partner institutions may receive more or less than the initial proposal plan sets forth, depending on annual review of assessed progress, future needs, available funds, and the state-of-the-art in the field. Indeed, termination of all projects at a partner institution, if done for clear and identifiable reasons, is legitimate; this allows for new alliances to be established that serve the evolving Center mission. The Director may tap into any or all of the resources available to him/her to facilitate funding decisions.

Partner institutions should be reminded regularly that evolution of the research plan and assessed progress on core initiatives as part of that plan determine continued funding through the Center, which therefore may or may not correspond to the initial multi-year proposal plan. An inwardly focused approach to research challenges and related allocation of resources can threaten an otherwise productive intellectual collaboration. Acknowledgment of this fundamental axiom is necessary to maintain cohesiveness in a multi-institution Center.

9.4.2.6 Continuing Funding

Continued funding for each project is reviewed each year, based on the prior year's progress and the merit of the proposal for the next year.

The Director's top priority in funding decisions is the overall Center health and progress toward long-term goals. Individual institutions are assured of financial support only to the degree that it will be commensurate with the contribution of its Center participants to the overall success of the core program. All communications, calls for proposals, and effort evaluations should reinforce this approach so that administrations for individual partner institutions do not lose sight of the competitive approach to the dissemination of core funds and the continuing need for innovative thinking and approaches to the research.

9.4.3 Research Team Integration

To obtain the benefits derived from an ERC, it is important to integrate the research throughout the organization and achieve collaboration. The collective capabilities and facilities of the Center are more powerful than the individual partners but there must be an organizing principle to achieve the greater capability. A framework to guide the research, points of contact for each activity, good communication within the collaboration, measurable and deliverable objectives, and a certain flexibility to accommodate differences in style are required.

9.4.3.1 Research Integration

Identifying a specific need/purpose for research integration is essential.

Simply obtaining agreement that collaboration is a good idea is not sufficient to bring collaborators from multiple institutions and industries together to actually accomplish the integration of technology. A specific technological advantage to be gained through multi-institutional involvement must be identified in advance of establishing a multi-institution Center. The same principle applies to a renewed Center, where new alliances replace existing ones in the service of the evolving systems vision. Specific methods for achieving integration should be written, along with role assignment for each of the participating institutions. Projects and their integration should be viewed as Center-wide activities, not as institutional activities.

9.4.3.2 Research Program Structure

Structuring a research program that is interdisciplinary in nature and focused on one or more engineered systems is an effective way to promote ERC culture and is necessary to achieve its goals.

As a matter of course, research faculty focus on their chosen discipline. But the expansion of knowledge in ERC systems-based fields requires reaching beyond the chosen discipline, seeking potentials to link and discover beyond known and established boundaries. Connections are made through communication, and initiation is the key. All ERC participants share responsibility for initiating and cultivating interdisciplinary partnerships. A suggested approach is to engage related disciplines in the proposed ERC undertaking early, possibly through a symposium or information gathering that provides an opportunity for other disciplines to be briefed at a summary level and to offer feedback related to the potential for interaction with the ERC plan.

9.4.3.3 Research Capabilities and Facilities

Institutional partner capabilities and facilities pertinent to achievement of the vision, mission, and goals of the Center must be clearly identified and recognized.

As individuals come together to form a Center, participating faculty usually have or gain a general knowledge of the capabilities and facilities of each of the individuals involved. It is important to expand that knowledge to include the specific facilities and capabilities available to the Center and to include potentially related areas as well, as the idea is to broaden the involvement of disciplines, individuals, and technologies in order to explore new paradigms, thus achieving what could not have been achieved without the Center. Education is closely related to research; hence the research plan also provides the basis for the Center's education plan from which uniquely trained individuals emerge.

9.4.3.4 Framework to Guide the Research Process

Roadmaps, testbeds, and benchmarking are essential management tools for integrating faculty research and assessing progress.

Routine communication can be bogged down in individual preferences for certain research aspects, constraining productive use of time and minimizing overall progress. It is advisable to establish a framework to guide the process and assess progress toward meeting Center goals. One of the most effective means of integrating research and determining the criticality of individual projects is capstone projects or testbed applications. Testbeds should be end-to-end applications that bring together many or even all of the tools and knowledge, not *in* a thrust but *across* the thrusts. Planning for testbed applications exposes projects that are not germane to the Center mission.

9.4.3.5 Point of Contact

A central contact should be established for each area of activity.

Communication with the individual best suited to respond is as important as communicating regularly and effectively. Individuals responsible for specific roles and or target areas should be identified and contact information centrally distributed so that communications are direct and channeled appropriately. This is part of the complete management plan of the Center, which should be agreed upon and available to all involved. No activity should be left without a responsible contact individual.

9.4.3.6 Communication is Essential

Frequent and direct group communication is essential to success.

Because there is a growing emphasis on outreach in all Centers, this demands an increased awareness of the need for continuous and effective communication. Communication provides the basis for all actions, interactions, and decision-making in the Center environment. A suggested approach is to establish (as a minimum) a schedule for regular interaction/collaboration of each thrust group, project group, the industry board, the Executive Committee, and each of the advisory boards. Additionally, each partner institution should establish a regular on-site meeting devoted solely to ERC business. This is desirable because Center activities are often a subset of the activities of individual participants. A scheduled meeting forces focus on the activities specifically related to the ERC. Many other opportunities will evolve with the needs of the Center and should be encouraged by senior management. In addition to project, thrust and board integration, it is essential that cross-cutting interactions are instituted in the ERC, whereby 'horizontal groups' cutting across the thrusts meet face-to-face or virtually, and focus on threads that link across thrusts toward Center objectives.

9.4.3.7 Program Measurables: Statement of Work and Period of Performance

Specific task assignments such as Statements of Work (SOWs) and Periods of Performance (POPs) should be established.

Regular monitoring, reporting, and sharing of project progress is especially important in a multi-institution Center due to the geographic dispersion of the participants and the consequently limited ability to observe progress directly. The annual call for proposals, where used, will be most effective in an atmosphere where effort assignments and SOWs for the review period are clearly defined, disseminated, and reinforced through discussion. All projects should have project sheets that articulate milestones and deliverables that are further linked and integrated at the thrust and system levels. Annual coordination of meetings and meetings prior to or after site visits are ideal forums for assessing progress and re-charting the Center's path.

9.4.3.8 Opportunities for New Faculty

Opportunities for new/junior faculty should be apparent.

The expanded opportunity inherent in on-site Center management support is often diluted by the geographic dispersion of the partners and the Center profile may differ among partner institutions. Extra effort may be necessary to ensure that a new/junior faculty member is fully aware of the research underway and the ways in which he may become involved. It is important to train at all levels, including junior faculty, so that the Center will have a lasting influence on the research culture, away from unsolicited proposals and towards the Center's ethos.

9.4.3.9 Industry Research Champions

Engage industry partners to serve as research champions and testbed partners as well as mentors and technology transfer participants.

Collaboration with industry should and will occur in many different ways, especially in the multi-institution environment. It is essential to engage industry in such a way that the flow of ideas, information, and results is continuous and timely. One way to be sure that the Center is receiving and responding to industry interests is to engage industry members as research champions. A research champion serves as a mentor in a particular aspect of development and works closely with Center Thrust Leaders to ensure industry relevance and facilitate direct knowledge transfer. Industrial participants also greatly enhance the educational experience by serving as mentors to young faculty and students; the guidance they provide encompasses research, career choices, and industrial interaction. This model has been very effective at many Centers, enhancing the level, continuity, and quality of industry involvement.

9.4.3.10 Failures Can Occur—Know When to Cut Losses

There is no failsafe mechanism to ensure that all actions, decisions, plans, and policy implementations will result in a model, integrated, multi-institution, productive research undertaking. Incremental failures will almost certainly occur. A plan for acknowledging failure and moving forward in spite of it, while addressing the shortcoming, should be in place. The Center Director and its leadership should not shy away from taking bold decisions.

9.4.4 Role of Testbeds

The boundaries of the knowledge fields addressed by ERCs are virtually unknown. Testbeds provide a means of demonstrating potential and inspiring intellectual exploration beyond the knowledge proven through demonstration.

As the product of the Center's collaboration, testbeds provide a basis for the assessment of research outcomes, a means for integration of research, and a way to demonstrate systems' impact. They are the focal point for collaboration and guide the investigations by offering greater understanding of the issues. They drive modifications to the strategic plan and are the basis for knowledge transfer.

9.4.4.1 Focus for Integration

Testbeds provide a focal point for researchers to rally around and pursue common goals.

A testbed provides a conceptual framework and a tangible way to demonstrate the integration feasibility of a particular tool set. It can be a catalyst for excitement among researchers as well as provide a shared vision for continuing exploration. It also yields results of interest to those supporting the Center; so it is useful—not just a showcase.

CASE STUDY: *At the MAECenter, testbeds apply the various tools to a system (transportation networks), a region (city or state) or an organization (national or state emergency management agency). They integrate all products of the projects and thrusts to provide a scenario of the possible consequences of an earthquake on the testbed system, region, or organization.*

9.4.4.2 Improved Understanding

Testbeds provide a basis for better understanding of system requirements and barriers.

The visual realization provided by a testbed demonstration may serve as a teaching device for researchers not previously immersed in the concept demonstrated. Concept edification through proof is an effective and powerful tool. In a multi-institution, multi-disciplinary, multi-sponsor environment, demonstration can be the difference between discovery and incremental advances.

9.4.4.3 Driver for Continuing Research

The “proof of concept” achieved through testbeds nearly always serves as a driver for continuing research. The exploration of true knowledge synergy or the compatibility of traditionally separate application areas is enhanced through testbed applications in the context of multidisciplinary cooperation.

The revelations resulting from testbed demonstrations have the potential to turn a skeptic into an advocate or, conversely, terminate exploration along a less-than-promising course. In either case, knowledge is gained and further exploration is seeded. Integration of subsystems, disciplines, and concepts tends to have a unifying effect on the individual researchers involved, spurring broader contemplation and intellectual discussions.

CASE STUDY: *Currently, there is relatively limited understanding of the dynamic behavior of power electronics systems or of how the systems may be modeled and controlled. Testbed demonstration of the fundamental nature of system-level issues at CPES is expected to open new opportunities for expanded use of advanced electronic power distribution systems.*

9.4.4.4 Driver of Modifications to Research Plan

Ultimately, testbeds may drive modifications to the strategic research plan based on the learning achieved through systems analysis and test results.

One of the bonuses of unplanned discovery is the alternative path(s) presented to the researcher. In the case of a multi-institutional, multidisciplinary Center, the intellectual consideration spurred by an unplanned discovery is often exponentially increased. This may lead to a stronger strategic plan or a modification to the original plan that strengthens the original concept. Many centers set aside “seed” funds to nurture such discoveries.

9.4.4.5 Industry Knowledge Transfer

Testbeds provide a strong basis for the continuing exchanges and knowledge transfers with industry. Through this vehicle, Center research remains pertinent to industry and provides a platform for it to create products or develop technologies.

Historically, testbed demonstrations are well-received by industry; industry representatives typically provide useful feedback stemming from testbed demonstrations. The Center can use this feedback to enhance research and produce additional useful results for industry application. This sharing also complements the dissemination of information that is the common mission for universities and ERC.