

Create. Educate. Serve.

**School of Engineering and Applied
Science Strategic Planning Task
Force**

Summary Report



PRINCETON

School of
Engineering
and Applied
Science

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Executive Summary

The School of Engineering and Applied Science creates new knowledge and technologies, educates tomorrow's leaders, and serves society through discovery, design, and invention within a cross-disciplinary environment and a liberal arts setting.

– SEAS Mission Statement

This report assesses how well the School is meeting its goals (*vide infra*) and what investments and actions would most effectively advance its mission. It is the result of an 18-month process in response to a charge from the President and led by the School of Engineering and Applied Science Strategic Planning Task Force. That process included detailed assessments by six committees charged with conducting self-studies of: department structures and research priorities; the undergraduate program; the graduate program and postdoctoral experience; external relations and partnerships including internationalization; professional quality of life and diversity; and facilities and resources. Additionally, the 10 departments, centers and institutes within the School provided assessments of their own units. All constituents were engaged through surveys of faculty and alumni; focus groups of students, staff, and faculty; two retreats; visits to peer institutions; alumni forums; and an external review by prominent engineering school leaders across the country. The outcome was an extensive and comprehensive description of the state of the school, which is summarized in this report.

The task force began its work by connecting with faculty and leadership across the School to converge on a mission that is simple and direct: to create; to educate; and to serve. Engineering faculty and students cross disciplines in a creative pursuit of knowledge and inventions that have a positive impact on society. With this mission in mind, the task force established eight goals that infuse all aspects of the school and its connection to the rest of campus and which informed the rest of the planning process:

- Excel in the teaching of fundamental engineering science
- Lead through the creation and dissemination of new knowledge via research
- Serve by solving societal problems through invention
- Create an intellectual environment that embraces diversity and collaboration across all disciplines and close ties between students and faculty
- Graduate the best engineers in their fields with a mastery of design and innovation and who value life-long learning
- Foster design thinking, innovation, and entrepreneurship among our faculty and students
- Instill in all Princeton students an understanding of science, technology, and problem-based inquiry so they become technically literate citizens
- Imbue tomorrow's leaders and global citizens with a culture of service

Informed by these goals, each committee emerged from its self-study with a set of recommendations, which the task force prioritized and distilled into four categories:

- Build on Existing Strengths in Research and Teaching
- Address 21st Century Challenges
- Enhance Educational Quality and Embrace Pedagogical Innovation
- Improve the Graduate and Postdoctoral Experience and Opportunities

The highest priority recommendations include:

Construct more and better space to replace the Engineering Quadrangle and accommodate a growing computer science department. We must bring together the departments, especially those involving experimental laboratories, into modern flexible spaces that truly meet current needs, provide room to grow, and strengthen collaborations.

Maintain and enhance the excellence and diversity of the faculty, and enable strategic faculty growth, to advance the teaching and research mission of the engineering school and the University more broadly.

Create an institute of bioengineering and, over time, associated teaching programs that bring together faculty from across campus to collaborate on vital research that deepens our understanding of biology, leads to therapies with potential to improve health around the world, and provides models for engineered systems.

Revise the freshman year to include an option that more dynamically introduces students to the purpose and practice of engineering and infuses design into the curriculum at the very start of their education, thus attracting and retaining a more diverse mix of talent and better informing students about the engineering disciplines.

Increase the number of graduate students, including the creation of a pool of graduate slots that the dean of engineering can deploy in flexible ways to increase diversity of all types and support emerging research areas. Provide multi-year fellowships and improved professional development and career opportunities.

Create a mechanism for establishing nimble centers of research that draw together faculty and students around emerging fields of collaboration. Invest, through hiring and other practices, in particular, in three priority research areas that cut across departmental boundaries: resilient and smart cities, data and information, and robotics and intelligent systems.

If implemented, these and the other recommendations described in the report will allow us to achieve our vision of a diverse and inclusive community of faculty, staff, and students working together across boundaries and in state-of-the-art facilities, to create knowledge and inventions, produce tomorrow's leaders, and serve society.

SEAS Mission: Create. Educate. Serve.

In extensive discussions toward articulating a vision for the School of Engineering and Applied Science (SEAS), the core values of the school became clear. A central theme was that faculty and students should be able to cross departments and disciplines easily. SEAS departments should not be overspecialized, walled-in communities where faculty members perform research alone with their students. Rather, all Princeton engineers should be part of a larger whole in which we collaborate and interact to solve problems. SEAS should improve the educational experience for all Princeton students across all divisions, including the arts and humanities. This blurring of departmental and disciplinary boundaries – while maintaining fundamental excellence – is deep within the Princeton ethos.

Of course, a central purpose behind this cross-disciplinary culture is to create new knowledge and inventions that serve society. As Dean H. Vincent Poor has said, “engineering is a bridge between the ‘two cultures’ of science and humanities...engineers make things real, and in doing so our creations become part of human existence.” Princeton Engineering is justly proud of its accomplishments, but we can do more and we can do it better.

Engineering at Princeton is part of the core of the University’s mission of a liberal arts education. Our educational goal is more than just training our students well for future professional engineering positions. As with all of the divisions, we strive to build an educational program that produces engaged citizens and ethical leaders with a commitment to make a difference, and that contributes to the education of all Princeton students. Princeton engineers follow a wide variety of paths; SEAS' success is measured in part by the impact of our graduates in serving society within whatever career they have chosen.

Princeton’s unofficial motto, “In the Nation’s Service and the Service of Humanity,” reflects our community’s dedication to service. It is our fervent desire that engineering students leave Princeton imbued with a sense of the value of service, both for society and for their own growth. We believe we nurture that by example; our faculty and staff serve through their research, through their teaching, as well as through their professional and community service. Emphasizing service will also further our goals to increase diversity within all levels of the school.

Thus, we have agreed upon a concise **vision statement** for the school moving forward that captures these core values and is simple and direct:

The School of Engineering and Applied Science creates new knowledge and technologies, educates tomorrow’s leaders, and serves society through discovery, design, and invention within a cross-disciplinary environment and a liberal arts setting.

Or, in its shorter form: **Create. Educate. Serve.**

A Vision for SEAS: Recommendations for Excellence

“Though the E-Quad may be located at one edge of our campus, the School of Engineering and Applied Science has become central to the University’s teaching and research mission. This importance will only deepen in the years that lie ahead, and the strategic planning process presents a prime opportunity to explore and answer the following broad question: How can the University recognize and build upon the essential importance of engineering and computer science to a 21st-century liberal arts university?” – President Eisgruber in charge to task force

In this section we detail our key recommendations to answer our broad charge: How can the University recognize and build upon the essential importance of engineering and computer science to a 21st-century liberal arts university? We have categorized these recommendations into four themes:

- Build on Existing Strengths in Research and Teaching
- Address 21st Century Challenges
- Enhance Educational Quality and Embrace Pedagogical Innovation
- Improve the Graduate and Postdoctoral Experience and Opportunities

The highest priority recommendations within each theme are written in boldface, generally in prioritized order within each category. While many of these recommendations (such as curricular reform) can be accomplished with relatively modest investment of resources, our highest priority recommendations for new facilities, an increase in the size of the faculty, and a new bioengineering institute will require significant new resources. We look forward to working with the administration on this bold plan for realizing our vision and making SEAS the best it can be.

Build on Existing Strengths in Research and Teaching

As we continue to perform world-class research and provide unsurpassed education to our students, achieving all of our goals while maintaining leadership and excellence will require modern facilities and sufficient resources matched to today's research problems and student needs. It is essential that we invest in new facilities (in particular, replacing the aging Engineering Quadrangle and expanding the space for Computer Science); respond to the evolving interests and needs of our faculty and students; and provide flexible space and nimble mechanisms to continue and enhance our tradition of collaboration and interdisciplinary research.

More and Better Space

Given the extraordinary quality of our faculty and students, Princeton's engineering school is thriving despite space constraints and aging facilities. To advance the University's mission, we must provide our faculty and students with the physical infrastructure necessary to support a broad and vibrant range of teaching and research initiatives.

SEAS buildings should house state-of-the-art, versatile facilities including open maker spaces for students, cutting-edge instruments that are supported by highly skilled technical staff, and provide access to high-performance computing – all essential for outstanding teaching and research. They should function as a vibrant hub, communicating to students, faculty and visitors a palpable excitement about our current activities and the future. They should foster interdisciplinary research and innovation. Spaces in SEAS should be full of people, talking, engaging each other, and working together. Students from all across campus must feel welcome and inspired.

Facilities play a major role in recruiting faculty and students. The physical locations of SEAS buildings, facilities, and classrooms affect interactions with other parts of campus. The nature and distribution of spaces in SEAS buildings strongly influence cohesiveness of departments and opportunities for interdepartmental collaboration and innovation. New ideas on teaching and research require a broader mix of spaces to accommodate a wide variety of work modes. Old, compartmentalized office organization and style, with most work done as individuals, is giving way to new approaches symbolized by the town piazza or city square: dynamic, changing, wide-ranging interactions—large and small, with support activities around the edge. Connective spaces increase function and foster a dynamic environment. New classroom facilities must be versatile to accommodate a range of teaching styles, some teaching entirely on a computer, some following the traditional approach using a blackboard, some pursuing new methods in active learning, and others using a combination of these. And adequate space must be available to support senior independent work and co-curricular activities.

The Engineering Quadrangle (EQuad), the main building occupied by SEAS, was constructed in 1962. Its double-loaded hallway design, with separate laboratory and office

spaces, and limited flexibility, suited a strong departmental organization scheme, which was in vogue in that era. This design no longer serves the needs of our faculty and students.

More important than any other recommendation in this report is the request for new, larger, and more modern space. ***There is overwhelming consensus among all stakeholders that to realize our vision and achieve our goals our top priority need is for more and better space.*** Achieving our goal of leading through the creation and dissemination of new knowledge via basic research will only be possible if we, like almost all of our peers, invest in modern, flexible space that reflects how research is done and supports the research equipment and teaching methods in use today. The experience of our peers who have invested heavily in new facilities over the past decade (e.g., Stanford, Berkeley, MIT, Cornell, Harvard, University of Cambridge, and others) is that up-to-date buildings with open, collaborative spaces can transform the school's research and teaching environment and lead to increased scientific exchanges and communication and invigorate the school.

New, larger facilities will enable us to respond to the incredible growth of the school, especially in Computer Science (COS), and the evolving needs of our faculty and students, and to achieve our goal of creating an intellectual environment that embraces diversity and collaboration across all disciplines. The recommended facilities will include a variety of spaces, including touchdown (impromptu meeting) spaces, community spaces, instructional spaces, room for student independent work, and maker spaces.

While larger and better space is most important, there was also a preference cited by the faculty to keep the departments proximate to one another, particularly the strongly experimental fields Chemical and Biological Engineering (CBE), Mechanical and Aerospace Engineering (MAE), Civil and Environmental Engineering (CEE), and Electrical Engineering (ELE). COS and Operations Research and Financial Engineering (ORF) found this physical proximity less important. Next in priority, all departments expressed a desire to be closer to the natural sciences and mathematics. How these needs are met in a final configuration of new space is a complicated question that will continue to be addressed during the campus planning process.

The task force also strongly recommends retaining the Forrestal site as a satellite research facility for large programs. This is a valuable resource, containing experimental facilities that are unique in the world. We suggest that the program plan also consider the types of facilities that could be constructed there, including high-bay space that does not now exist on the main campus.

The task force also recognizes the need for an interim maker space in the near term until new facilities are completed that would provide such space on a longer-term basis. There is an increasing demand from students for spaces where they can tinker and come together outside the classroom to innovate and develop ideas of their own. Co-curricular engineering activities, in particular of the maker-space and hackathon variety, are a growing trend nationwide. Many students participate in these activities, either

through the Keller Center, the E-club, or on their own. Embracing engineering outside of the classroom is an important cultural component to engineering education. These activities also provide a means of bringing people together, both among SEAS departments and between SEAS and the rest of campus.

Maker spaces at other campuses have provided means for engineers to work side-by-side with artists, designers, entrepreneurs, and novices. Such spaces are common at peer institutions and have proven to be exceptionally popular and inspiring. SEAS has an opportunity to lead in providing all students, not just engineers, opportunities to experiment with invention and manufacturing.

Faculty and Graduate Student Growth

SEAS is known for the strength of its departments and the quality of its faculty, all of whom are well regarded for performing high-quality, world-class research that makes an impact. This is demonstrated, in part, by the high number of professional awards, memberships in various national and international academies, and the high rankings in national surveys (e.g., five of the six departments are in the top 10 of the 2010 National Research Council rankings of graduate schools, with three departments in the first or second position). SEAS faculty are extremely successful in gaining sponsored research support with success rates well above the national average. SEAS is also known for the close connection between faculty, graduate students, and undergraduates. The small student-to-faculty ratio and the requirement that all students perform independent work enable SEAS to offer an unparalleled engineering education and provide opportunities for undergraduates to work closely with world-renowned faculty. Our cohesive graduate school, and our emphasis on fundamentals, provides a uniquely Princeton experience for graduate students, who begin research early as part of a supportive community under the guidance of experienced mentors. We have excelled in reaching our goal to graduate the best engineers in their field and train future leaders, prepared for whatever professional careers they choose.

To realize the vision for SEAS and advance the University's teaching and research mission, we must maintain and enhance the excellence of our faculty and graduate student population, building on and taking advantage of Princeton's distinctive strengths and approach to engineering teaching and research. The task force identified certain drivers, such as the University's commitment to be at the forefront of the most impactful areas of research and teaching in engineering and applied science, which may necessitate growth. For example, a move into a major new research area will require an increase in the number of faculty and graduate students. It is a priority for the task force that the University should make strategic adjustments in the number of graduate slots in SEAS departments and also create a new central pool of graduate slots held by the engineering school to add flexibility, aid in diversity, and advance priorities.

The leadership of SEAS looks forward to developing further the best strategy for growth to accommodate the highest priority and most impactful areas of teaching and

research. The most promising areas that we have identified are outlined in the “Address 21st Century Challenges” section of this report.

A New Collaborative Mechanism

Princeton’s organizational structure is department-centric. Almost all aspects of how we do business are based on departmental institutions and processes. Departments provide a recognized set of undergraduate concentration options and known research themes. This helps attract faculty and students at all levels. It also provides a group of experts for tenure assessment who have a vested interest in ensuring a high bar of excellence. The department structure has served the school well, but it can hamper the ability of SEAS to best handle new opportunities as they emerge. Today’s most exciting and important engineering problems do not always sit squarely in traditional departments. As a result, engineering research and associated teaching often cut across disciplines. This is a trend that is likely to continue. There are many areas of scholarship that are being actively pursued across traditional disciplines. Examples include: bioengineering, public health, personalized medicine, robotics, statistics, data analysis, optimization, materials, sensing and fabrication. That suggests that we should organize research, and in some cases teaching, in a way that also reflects these trends.

It is also to our advantage to nurture internal collaboration in research and graduate education. Our objective should be collaborating internally to achieve greater impact in solving problems and to compete more successfully with peer institutions. The chance of success in this endeavor is enhanced if we lower barriers between departments, create less siloed research efforts, and create mechanisms that foster inter-departmental research initiatives, thus creating the opportunity for greater impact and wider visibility.

Comments from a SEAS faculty survey conducted by the task force showed that there was general agreement with these principles and a view that we should move to make research and graduate education a SEAS-wide enterprise. Furthermore, there is great potential for reaching across and beyond SEAS. There has been some success in these endeavors already, primarily in education. For example, existing courses, such as CBE 440 and CEE 102, draw in large enrollments, the majority of whom are not BSE majors. The Keller Center has built bridges within and beyond engineering in its courses and entrepreneurship programs. We seek to build on these examples and extend such collaborative teaching to graduate education.

In moving to create more supportive interdepartmental structures for research there are two aspects that we need to take into account. The first is to recognize and foster the growth of existing interdepartmental research in order to give these efforts a sense of community and greater external visibility. The second is to create a new mechanism for the future, whereby emerging interdisciplinary areas can be nurtured and grown in a more natural and timely manner. ***We thus propose a new structure that allows the creation (and when warranted, the eventual promotion or retirement) of rapid response, inter-departmental, research centers.*** These will be multi-faculty driven initiatives that can respond quickly to emerging trends in research, with the potential to grow into new areas

of strength. The centers could also include participation of external groups, for example, industry advisors or participants.

These “small-c” research centers represent a structural change. Current structures (e.g. Centers and Institutes) play a crucial role on campus and function well for their purposes. However, this proposal is to create a mechanism for the growth of new research initiatives in a bottom-up, faculty-driven way. Moreover, the mechanism is universal: it is not tied to a specific research initiative or to a single point in time (five- or ten-year strategic planning, fundraising campaigns, etc.). It is available when new ideas emerge, and when trends in research create new opportunities. It allows ideas and faculty interest to coalesce and be given an opportunity to grow into something bigger. In this sense such smaller centers can seed the future evolution of research in SEAS.

We envision that centers would be established with a five-year initial term. Thereafter, there would be a five-year periodic review. After a periodic review, a successful center could be promoted (big “P” program, Institute, or Center), or reconfigured as research directions change, or retired, as appropriate. A corollary of the establishment of cross-department research centers is that SEAS needs to move to a space allocation scheme in which research space is more flexible and more recoverable. This is required to enable the timely establishment of new initiatives, and it allows us to take more risk.

Establishing these “small-c” centers will increase the flexibility within the school for the faculty to create collaborations and enter new cross-disciplinary areas. To achieve this, the new facilities described above would incorporate flexible and re-assignable research and student space and a central pool of SEAS graduate students would provide a means for bringing in students in new interdisciplinary areas without impacting existing faculty research. The recommended priority research areas described in the next section are also excellent candidates for these small centers, which could provide a structure that makes them more visible and better targets for recruiting, as well as for sponsored research (from industry and government) and fundraising required to fulfill our research and education mission.

Innovation and Entrepreneurship

We aim to foster design thinking, innovation, and entrepreneurship among our faculty and students. This reflects the growing culture of innovation and entrepreneurship that has arisen at all major research universities, particularly as invention has moved from the corporate laboratory to the academic one. It also responds to the growing demand at Princeton for courses and opportunities in entrepreneurship. At Princeton, as at many of our peer institutions, the entrepreneurial center of gravity is in the engineering school.

In May 2015, the Princeton Entrepreneurship Advisory Committee (PEAC) submitted its final report describing “the Princeton Way” to entrepreneurship. Most important is the emphasis on entrepreneurship as a “mindset” rather than an occupation; that is, as another part of the liberal education we provide and consonant with our historical emphasis on fundamentals and rigor. As stated in the report, “we think of ‘entrepreneurship’ as the

‘initiation of transformations through risk-taking actions and value-creating organizations.’” The entrepreneurial mindset has become an integral part of many of the University’s functions and is central to achieving the goals described earlier.

Different but related to entrepreneurship is "design thinking," a concept that has emerged in the last decade as an approach to creative problem solving. As opposed to the analytical perspective that dominates much of higher education, design thinking emphasizes an inductive process that encourages teamwork, empathy and rapid iteration. Modern pedagogical research has shown the importance of design thinking to engineering success, and our peers, such as Stanford and MIT, are taking the lead in innovative design education. This is a growing area on campus and one where engineering can contribute significantly to the education of all students and can support faculty interested in start-up ventures.

While entrepreneurship was studied in more detail by another task force, its future on campus is integral to the success of SEAS. The Keller Center plays the central role in coordinating courses and other activities as demand has been surging. We defer to the PEAC report and the administration response for a more detailed self-study and recommendations on entrepreneurship at Princeton, including support for undergraduates, graduate students, and faculty.

Cultivating Partnerships Across and Beyond Campus

It is essential that research innovations advance from the laboratory into the real world. Key societal concerns such as energy, water, environment, and health involve a complex matrix of end-users, providers, stakeholders, and governments. Only by engaging non-academic collaborators will Princeton’s strong liberal arts education and interdisciplinary research culture have the maximum benefit to society. Such partnerships foster a strong innovation mindset that accelerates transformational advances across society in a rapid and widespread manner. Strong collaborations outside SEAS provide internship opportunities for undergraduate and graduate students (e.g., in industry, government, or NGOs) to enhance their educations and provide them with increased employment prospects upon graduation. Exposing students to practitioners expands their training, broadens their perspective, and allows them to become more effective leaders as their careers advance. Collaborations with outside entities also provide means to continue impactful research activities even in the face of uncertain federal research support in the future.

There is a strong sense among the faculty that significant potential exists for the growth of relationships beyond the campus with non-academic partners in order to advance the University’s teaching and research missions. ***This will require building on recent progress to continue to strengthen the mechanisms that facilitate corporate- and foundation-sponsored research.*** The Office of the Dean for Research and its sub-organizations, including the Office of Corporate Engagement and Foundation Relations, the Office of Technology Licensing, and the Office of Research and Project

Administration, have important roles to play in helping to cultivate collaborations that advance Princeton's educational mission.

There are also exciting opportunities to explore for intra-University partnerships and collaborations. Currently, SEAS faculty interact as frequently across the University as within SEAS, but faculty desire to improve collaborations with other departments, particularly with the natural sciences. Faculty noted that this would be enabled by locating new buildings/departments closer to the natural sciences neighborhood on campus, as discussed earlier in this report.

There is a strong desire to increase connections across campus beyond the natural sciences, leveraging our unique liberal arts, public policy, and engineering education.

Princeton stands out among our peer institutions by its strength and the integration of liberal arts, engineering, and public policy. This cross-pollination occurs at all levels from undergraduate students to graduate students to faculty. Recommendations for the undergraduate and graduate program are detailed below. Faculty connections to the humanities and social sciences outside of the Woodrow Wilson School of Public and International Affairs (WWS) should be further nurtured and explored, capitalizing on the unique connections between the arts, humanities, and social sciences with engineering. In this area, a small investment of resources provides a large return in bringing together existing critical mass on campus. The Engineering and the Arts initiative is an excellent example to build upon and a high-profile example of making connections across the campus. We believe that some central administrative support and a small pool of funds made competitively available to faculty, similar to the 250th Fund, could pay significant dividends.

Internationalization

SEAS is strongly supportive of the University's efforts at internationalization. Providing opportunities for international collaboration and research to our faculty and significant international experiences for our students advances our vision of engineers who are nimble at crossing cultures and implementing their technical expertise in a human context. Encounters with the peoples, cultures, and contemporary concerns of other regions of the world prepare undergraduate and graduate students for leadership and lives of service in an increasingly interdependent and culturally diverse world. Engineering as a field of practice and research is exceptionally international in scope, so studying or working abroad enables Princeton students to appreciate the diversity of engineering experience that they will encounter in their professional lives. Providing international opportunities is a key part of achieving our goal of imbuing tomorrow's leaders and global citizens with a culture of service.

SEAS faculty collaborations outside of Princeton are roughly evenly divided between domestic and international universities and research centers. Over 75% of the faculty respondents considered their level of interactions with international partners as "just right." Some faculty noted that significant, long-term visits to international partners can

be difficult (such as for sabbatical), particularly for experimentalists who need to supervise their laboratories. This creates a barrier for certain faculty in increasing international exposure. Mechanisms for short-term visits, both for our faculty and visiting faculty, would be valued. SEAS involvement in revisions to the Global Scholars and Global Networks programs is important.

There is also a strong desire to provide substantial international experiences as part of graduate student training. The primary impediment here seems to be faculty resistance to long-term absences as this interrupts research progress and can impact an entire laboratory. Cost is also cited as a barrier as international trips can be expensive and frequently disallowed from sponsored research grants. A common refrain has been that international experiences tend to be ad hoc and fortuitous, driven largely by personal relationships among scholars rather than institutional opportunities.

In the survey of undergraduate alumni, roughly 30% reported that they had an international experience during their time at Princeton. One-quarter of those spent a year or a semester abroad, half had a four-week or longer experience (typically over the summer), and the remainder had short-term exposure. Over 70% of these students felt that their experience was of at least some help in their career after Princeton. Significantly, over half of the survey respondents expressed a wish that they had the opportunity to study abroad, signifying the need to provide more opportunities and facilitate different kinds of international experiences.

During AY 2014-15, 33 BSE students studied abroad for a semester or academic year, a major change from 25 years ago when the annual number was zero to two. The scheduling of the study abroad experience is determined by the requirements of the student's department and desired destination. The principal obstacles to academic-year study abroad are usually not curricular, except when a student wants to pursue multiple certificate programs. Major barriers to studying abroad are usually extracurricular activities and friends, as well as the perception that a semester is a long time to be away from Princeton. Most engineering departments are comfortable with allowing students to study abroad, with CEE, COS, and MAE students most represented cumulatively over the last five years. Some, like CEE, explicitly stress the desirability of international study.

While SEAS has a strong international program, there are several steps that could create more opportunities for faculty, graduate students, and undergraduates. The consensus within the task force is that a broader portfolio of international experiences would provide the highest likelihood of increasing participation. While some initiatives can be implemented by the school, others, as noted by other task forces and the *Accreditation Report*, require renewed efforts by the University and the Council on International Teaching and Research to provide a framework for overall strategic planning and support of internationalization. ***We recommend enhancing the opportunities for internationalization by creating more short-term opportunities for undergraduate international experiences, providing support for faculty and graduate student international visits and collaborations, and providing incentives for faculty to create courses with more international content.***

Enhance Diversity and Inclusion

SEAS is committed to increasing the diversity of its students, research staff and faculty and to make working and studying here a rewarding and supportive experience for all regardless of racial, ethnic or socioeconomic background or gender. To credibly tap into the entire STEM talent pool within this country and abroad as well as develop the next generation of engineering and technology leaders, various proposals (both existing and new) must be implemented to meet this goal.

To increase diversity among the faculty, we will aim to improve recruitment and hiring practices to increase the number of female and minority faculty candidates in our applicant pools. Several practices in the search process can be implemented to address the need to increase faculty diversity in SEAS: 1) advertising positions as open searches to attract the strongest possible candidates; this is critical to maximizing success with the smaller pool of women and minority candidates, where their research areas in a given year may not be synchronized with the search focus; 2) engaging outstanding candidates earlier in their Ph.D. and post-doctoral careers, before they have entered the job market; 3) participating in and recruiting candidates from mentoring workshops (e.g., MIT/UC Berkeley's "Rising Stars in EECS" which is organized for women entering the academic job market in electrical engineering and computer science) and/or forming a Princeton/SEAS "Rising Stars in Engineering" conference; 4) forming a SEAS target-of-opportunity committee to identify strong candidates to refer to dean of the faculty; 5) providing central oversight of the search process in departments to ensure consistency and that an adequately diverse pool of candidates is considered. The latter is already being done by the Office of the Dean of the Faculty, but support from the SEAS Office of the Dean could also contribute. Some departments within SEAS have already implemented some of these practices, but they need to be made systematic across the school.

A high priority is to implement a SEAS-wide competitive, named postdoctoral fellowship program to recruit recent high-quality Ph.D. 's, with a particular emphasis on securing a large and diverse applicant pool. At SEAS we often seek to hire assistant professors who have a given track record, requiring some postdoctoral experience. This puts the candidate on a stronger track and makes promotion at Princeton more likely. This postdoctoral program will allow us to provide these candidates with an experience for further growth, offering an important service to them, and will allow us to recruit the top individuals from this program into our faculty. We will also be performing an important service to the academic community.

To increase diversity among Ph.D. students we plan to expand on programs that have been successful but need further refinement to gain traction and yield results. Several SEAS faculty members are involved with the Princeton Engineering Graduate Symposium (PEGS) – a recruiting and summer research program within SEAS targeted at undergraduate students across the U.S. Furthermore, we have in place the Princeton–CUNY/CCNY Strategic Partnership, a recruiting and summer research program for

undergraduate students at City University of New York. We need to make a more concerted effort to recruit the top students from these programs as well as expand these programs via symposia and additional summer internships for minority undergraduate students. ***We recommend creation of a number of multi-year SEAS Graduate Fellowships and graduate admission slots to aid in the recruitment of top graduate students,*** with a focus on securing a large and diverse applicant pool. To facilitate their recruitment, these students should be awarded at least two years of full support for use after their first year. Like the “open searches” for faculty, this will decouple graduate admissions offers from specific projects SEAS faculty members might have funding for and that might not be within the interest/background of these students. ***We also recommend the creation of a pool of Master of Science in Engineering fellowships that would support students looking to gain better preparation for the Ph.D.***

Engaging with various institutions - including those that have traditionally served minority groups - on a regular basis, and constantly monitoring talented undergraduates from these institutions, is a task that is extremely time-intensive, yet it does require faculty expertise and involvement. ***Hence, we propose creating the position of an associate dean for diversity within SEAS.*** This individual should be a SEAS faculty member with a strong research and teaching track record as well as a record of active engagement with diverse communities. The associate dean would be responsible for undergraduate and graduate recruitment as well as coordinating, tracking and supervising faculty searches as described above. The dean would also work with the associate deans for the undergraduate and graduate programs to ensure that adequate support and programming is available for our students, particularly minority students, to enable their success in SEAS.

SEAS is proud of the positive work environment we have created and of the high satisfaction among the faculty, staff and students. ***Nevertheless, three priority areas arose that are clearly in need of improvement: junior faculty mentoring, research and instructional staff support and communication, and spousal support in recruitment.*** We recommend that SEAS develop school-wide programs for junior faculty mentoring to ensure quality and consistency, sharing best practices among departments, providing formal and informal gatherings of junior faculty across the school, ensuring follow-up with individual mentors, and developing a standard set of mentoring practices to help train and guide mentors, including regular follow-up by the administration. We recognize that the dean of the faculty has been making efforts to strengthen the programs for providing spousal support in hiring; these will be critical for improving and diversifying recruitment, especially of women. The University and the engineering school need to also provide clarity on the use of lecturers, strengthen their career path, and provide professional development so they feel they are welcome members of the community with a positive future. Likewise, the University needs to improve support and communication among and with the research staff, clarifying their career paths and providing opportunities for professional growth.

Address 21st Century Challenges

A key outcome of our planning process is the identification of the need to build strength in new cross-disciplinary areas that represent some of the emerging technological challenges of the 21st century, allowing us to achieve our goals of leading through the creation and dissemination of new knowledge via basic research and serving by solving societal problems through invention. Of particular importance is the evolution of biological engineering research into a field of its own with critical implications for understanding life, advancing human health, and addressing environmental challenges. ***A priority outcome from the task force is the recommendation to create an interdepartmental institute of bioengineering.*** While many faculty across the school are engaged in bioengineering-related research, the time has come to bring them together into a unified, collaborative effort, using shared infrastructure, and creating a community that will amplify efforts and attract students. Princeton is the only school among our peer institutions without a bioengineering department; the creation of the institute will help close that gap, allowing us to address the important problems of today and to attract the best faculty and graduate students. We also encourage planning to start early for a graduate degree and eventual undergraduate program. We are convinced that by drawing on Princeton's fundamental strengths in biology, ecology, chemistry, chemical engineering, and environmental engineering, among others, we can, within five years, become one of the country's leading centers of bioengineering.

In addition to bioengineering we recommend that the school emphasize three new priority research areas, ***resilient and smart cities, data and information, and robotics and cyber-physical systems.*** These interdisciplinary areas represent opportunities where Princeton is well positioned to provide tremendous benefits to society, but that require SEAS and the University to make a more conscious effort to put them on a path to success. Departments have already begun to conduct searches in these areas and progress will involve even more collaboration and interactions with the whole of campus. These priority areas can guide cluster hiring among departments, be candidates for the small centers described earlier, inform the campus planning effort, and be targets of fund-raising, particularly for innovation seed grants.

An Institute of Bioengineering

Biomedical engineering and biological engineering are the latest additions to engineering disciplines. Historically, biomedical engineering evolved out of engineering applications in medicine, which has a long history but is still largely empirical. This status persisted until the middle of the 20th century, when the molecular basis of life was discovered. In the 1970s and 1980s, recombinant DNA technology gave rise to a large and rapidly developing biotech industry, which uses living organisms for mass production of complex chemicals, such as antibiotics and protein therapeutics. The biological matter that is being manipulated here is a bacterial or animal cell within a bioreactor.

As our understanding of the molecular and physical substance of living systems becomes increasingly resolved and quantitative, we can think of manipulating increasingly complex biological systems. Doing so in a reproducible and responsible manner calls for the foundation of a rigorous engineering discipline. Conversely, understanding biological systems and communities can lead to advances in traditional engineering via what is often termed “bio-inspired design”. Bioengineering is at the center of several of the National Academy of Engineering’s “Grand Challenges for Engineering.” Payoffs to society are emerging from this field in pharmaceuticals, energy, biomaterials, the environment, and numerous other areas.

A Princeton Bioengineering Institute would draw on a variety of engineering fields, including CBE, MAE, ELE, CEE, and COS as well as the natural sciences such as molecular biology, physics, chemistry, ecology and evolutionary biology, and neuroscience. The engineering departments alone currently have more than 10 groups with specific strengths in biostatistics, biomaterials, lab-on-a-chip, bio-sensing, biological systems modeling, environmental bioengineering, bioremediation, biofuels, and implantable medical devices. Creating the institute would allow this work to shift from siloed efforts into a combined strength with a focal point and critical mass, shared infrastructure, and a sense of community and shared purpose. We expect this would have an amplifying effect on existing and emerging efforts in bioengineering research. Bioengineering is still a young field. By drawing on expertise from across the campus and leveraging our traditional strengths in fundamentals and rigor, we would have an opportunity to make transformational contributions to this nascent field of engineering.

The establishment of a bioengineering institute would enhance the education of our graduate students through interactions with other communities of researchers and eventually through a formal Program in Bioengineering. The establishment of an undergraduate major would attract students from across the campus and provide a more cohesive program and training than the current certificate. Both programs would attract a strong pool of prospective students.

This new institute would provide an administrative home for bioengineering efforts, a home for shared equipment, and facilitate applications for large center and training grants. The space needs of the institute would need to be incorporated into the program plan for replacing the Engineering Quadrangle. The institute would also facilitate cross-SEAS and University-wide collaborations, building on a number of notable successes in the past. The Neuroscience Institute and the Andlinger Center could serve as models for the initiation and growth of the institute.

If established, we recommend that the bioengineering institute begin planning for both a graduate degree program and an undergraduate major at the outset, moving quickly to offer Ph.D.s and evolving to develop an undergraduate degree gradually. We note that the existence of a graduate program will also aid in the recruitment and retention of faculty. As new faculty members would be hired in both the institute and the departments, the graduate student allotment in both would need to increase accordingly.

One of the immediate priorities of the new institute would be to plan the courses that would eventually be required for an undergraduate degree in bioengineering and to start offering these courses as electives, building a base of faculty members to sustainably teach these courses. The popularity of the current Program in Engineering Biology attests to the strong interest among Princeton undergraduates and to the viability of an eventual degree program. Over the last 10 years, an average of about 30 certificates have been granted each year.

Resilient and Smart Cities

Over 70% of the world's population is expected to inhabit cities by the year 2050. This is only one of the major challenges that our cities are facing today. In addition to increasing population densities, other challenges include limited water supplies, limited natural resources, climate change (e.g., rising sea levels and extreme weather), aging infrastructure, increase in load demands (intense and heavy traffic), and disruptive hazards (e.g., earthquakes, tsunamis, terrorist acts). These challenges amplify the risk and threaten not only to degrade or destroy our public infrastructure, but also to impose societally disruptive consequences.

This vast array of complex technological and societal challenges presents enormous opportunities, both for synergistic activities and for sharing of human, civil, and natural resources. It is critical for engineering research to take on these challenges, as even modest improvements in how resources are used can map to unprecedented economic and societal ramifications. “Resilient cities” refers to the ability of a city’s physical infrastructure, and economic and social structure, to respond to and recover from slow and/or abrupt changes and loading conditions. “Smart city” is a subset of “resilient city” since “smart” is one approach for achieving resilience. Broadly, “smart city” refers to the concept of using information technologies to achieve improvements in the efficiency with which resources are developed, used, and maintained.

Technological solutions for resilient and smart cities, even in concept, are in their infancy. Princeton is poised for leadership in this domain, because of (1) its interdisciplinary approach to science and engineering; (2) its leadership and skill in critical engineering areas of civil, electrical, mechanical, and environmental engineering; and (3) its strength in social sciences and policy. The solutions will require innovations in: building, from materials to urban planning; sensing, from transducers and electronics to data analytics; deployment, from economics to policy; and utilization, from operations research to sustainability.

Data and Information

Today we collect, store, transmit and analyze data at unprecedented scale in many aspects of society, commerce, and science. Cheap ubiquitous sensors are leading to a cascade of new data sources. We have mapped the human genome, and genetic data are leading advances from drug discovery to our understanding of fundamental biological processes. For many machine learning problems, neural networks are suddenly outperforming all other approaches, simply because the datasets on which training is based have reached a sufficient size to enable effective generalization to new data.

The data explosion has raised new intellectual challenges ranging from processes involving capture, transmission and storage of data at massive scale, to new methods for data analysis involving high-performance computing, parallel and distributed programming, statistics, machine learning, and the mathematics and science of the digital world. Moreover, the collection and storage of data impinges on issues such as the privacy and security of data, privacy of the individual citizen, and government policy.

Advances in the analysis and management of data and information hold enormous promise for many areas including: better and more efficient healthcare, progress in drug discovery, robotics, human learning, understanding human cognition, social networks, ecological networks, and so on. Princeton is poised to lead in research and teaching related to data and information. We think of this initiative as having several thrusts:

Engineering of Information. We have expertise in sensors across SEAS and in data storage, computer architecture, high-performance computing and networking in both COS and electrical engineering. Many elements of a core effort are in place, but the effort lacks overall visibility, a coordinated plan for growth and renewal, and a sense of community and shared purpose.

Statistics and Machine Learning. Princeton is now establishing a strong effort across campus, coordinated through the Center for Statistics and Machine Learning (CSML), with participation from SEAS and other entities such as Genomics and Neuroscience. It is critical that this effort be nurtured into a center of strength.

Mathematics of Algorithms and Information. We have some strong groups of traditional excellence in algorithms and the theory of computation and information in the departments of: COS (algorithms and fundamental limits of computation), Electrical Engineering (information sciences, estimation, information security), and ORF (optimization, probabilistic analysis) as well as departments outside of SEAS -- Mathematics, Economics and the Program in Applied and Computational Mathematics. While peer institutions are beginning to establish interdisciplinary centers, Princeton has a unique opportunity to leapfrog our peers to become a leader in this area. Fundamental mathematical advances will drive our understanding of information, network and computational elements in a host of sciences, which is complementary to the data-driven insights sought at Princeton's CSML.

Robotics and Cyberphysical Systems

There is a groundswell of interest from undergraduate and graduate students in next generation robotics. Partly this can be explained by recent success stories such as IBM Watson's win over humans at the game of Jeopardy (IBM's DeepQA project), the rise of the self-driven car (Google, et al.), by ambitious plans for drone delivery of purchases and supplies (Amazon, Google), and partly by the maker movement and the readily accessible market for robotic components (e.g. quadcopters, Arduinos, and wireless communication), as well as the entrepreneurial lure of moving robotics out of the factory into a broader spectrum of the economy.

The incredible advances and successes of machine learning over the past 20 years have brought us to the threshold of a new level of robotic intelligence. In addition, one should no longer think of robotics only in anthropomorphic terms, but also in terms of smart personal assistants, smart cars, smart buildings, and smart infrastructure. The smartphone is just the tip of the iceberg.

Larger than the field of robotics itself is the concept of networked intelligence interacting with the physical world - this is an emerging field known as cyberphysical systems. Example applications include computer-controlled road networks, electric grids, interconnected electricity generation platforms (wind, solar, nuclear, hydro, gas, coal), citywide traffic flows, citywide automated water and waste management, energy management and even microclimate management. This has impacts on future cities and urban environments and on the way we manage our energy resources and our energy delivery infrastructure -- a natural tie-in to the "smart cities" priority area above. It also raises major concerns about safety, liability, privacy, and fair, ethical application.

As things stand today, SEAS has strong but isolated teaching and research efforts in certain aspects of robotics and machine intelligence (MAE, ELE, COS, and ORF). For example, a team of Princeton students made it to the semi-finals in the 2007 DARPA Grand Challenge for a self-driving car, in serious competition with much more deeply-established programs like those at Stanford and Carnegie Mellon. More broadly, there exist a number of potential robotics-related connections across campus, for example with the appointment of Monica Ponce de Leon, who has a strong track record in this area, as the new dean of Architecture. We recommend that the University explore and facilitate collaboration across campus in this area.

Enhance Educational Quality and Embrace Pedagogical Innovation

Over the past few decades, engineering schools have been at the forefront of educational innovation and reform. While we are and should be justly proud of the education we provide and the high quality of our graduates, it is time to examine our academic program to ensure we continue to meet our goals of graduating the best engineers in their fields with a mastery of design and innovation, of fostering design thinking, innovation, and entrepreneurship, and of instilling in all Princeton students an understanding of science, technology, and problem-based inquiry while maintaining our known excellence in the teaching of fundamental engineering science. Engineering as a profession has changed and evolved (in particular with the renewed emphasis on design and innovation) as have our students. It is important that our educational programs evolve as well and that we embrace continuous quality improvement.

As the University looks to new modes of pedagogy and new teaching spaces, we must continue to lead. Our vision is of a culture where innovation and scholarship in education are valued so that we best prepare our students for a future in leadership and service and that we become welcoming to a more diverse population. We see a future of increasing school-wide collaboration on our undergraduate and graduate programs to ensure quality throughout the curriculum. We envision an increasing number of students from outside engineering taking courses from a growing menu of classes that reach the broader undergraduate community as part of an expanded view of a liberal education. We are encouraged by the recent efforts at the McGraw Center and the Council on Science and Technology to assess modern pedagogical research and engage with faculty and departments on evidence-based teaching. This needs to increase and become more widespread; these ideas form the foundation of our recommendations on the undergraduate program.

A Revised Freshman Year Option

The need for reform and new modes of teaching is most keenly felt in our freshman year. It is clear both from survey data and focus groups that the freshman year is the single largest area for potential improvement in the SEAS undergraduate program. The current freshman year has seven required courses: two math, two physics, one chemistry, one computer science, and one writing seminar. Students also typically take one non-technical course in each semester, thus completing their freshman curriculum. There is no exposure to biology in freshman year, despite its growing importance to many fields of engineering, and almost no engineering or design. Students are left having to declare a major with almost no exposure to the engineering fields and no interaction with the engineering faculty. ***Our top academic recommendation is to create a revised freshman year option that will improve the engineering experience, better introduce students to the engineering faculty and disciplines, and make engineering more accessible and more attractive to a broader range of students.***

We have identified four strategies to enhance the freshman year curriculum, which we describe below.

Strategy #1: Students should experience engineering and design in the freshman year in a hands-on way.

Strategy #2: Students need more exposure to SEAS faculty and disciplines to make informed choices about majors.

Strategy #3: The freshman year curriculum should “raise all boats” and provide a strong foundation to a diverse group of students.

Strategy #4: Students should be taught by faculty members who have a vested interest in strong foundational courses.

These strategies lead us to propose two alternate pathways to satisfying freshman year requirements (similar to how MAT 201/PHY103 or EGR 191/192 can both satisfy requirements). One path would consist of the traditional requirements, taught by the traditional departments, with the possible expansion to include a biology option. While these courses do not themselves address our goals, they are suitable for students on the fence between engineering and natural sciences. In addition, we would also offer an alternate set of courses that satisfy the freshman year requirements, housed within SEAS and taught by engineering faculty members. These courses would teach the foundational knowledge (math, physics, chem/bio, computer science) in the context of engineering and design, rather than as separate disciplines. We would thus expose students in a hands-on way to modeling and simulation, data processing, circuits, and mechanics, for instance, while still providing a firm scientific and mathematical grounding. This would also provide an opportunity to introduce students to all SEAS disciplines and SEAS faculty in a meaningful way. Projects would provide a mechanism to teach technical writing and team-based collaboration. A service component would introduce students to using design thinking and engineering innovation for public service, emphasizing the importance of service at the start of their Princeton careers.

Improving the freshman year experience will have ancillary benefits, such as making significant progress towards attaining our goals in access and inclusion. We thus recommend the formation of a committee to study a revised set of courses for the freshman year and to develop the course content for a potential first offering in fall 2017. The committee will examine best practices at a range of institutions and develop a first-year curriculum appropriate for SEAS that is project-based and student-centered and emphasizes design, teamwork, service, and interdisciplinarity.

Engineering as Part of a Liberal Education

The School of Engineering and Applied Science successfully contributes to the education of non-engineering students by providing courses that attract students from across campus, with over three-quarters of Princeton students taking at least one engineering

course during their four years. Introductory computer science is now the most popular course on campus and a computer science distribution requirement is being discussed to recognize the foundational role computer science now plays. The Keller center offers a suite of courses in design, innovation, and entrepreneurship that attract students from all divisions. ***We recommend that SEAS should offer additional courses on technology targeted to A.B. students outside of engineering.*** This will be made easier as the faculty and graduate student size grows, making resources available for additional non-departmental courses. It can also be aided through funds, such as those available through the Keller Center and the 250th Fund, to give faculty incentives for developing such courses. The McGraw Center and the Council on Science and Technology can provide essential support to faculty looking to innovate new courses for non-engineers. The University and SEAS should also be committed to maintaining successful courses beyond the initial start-up funding. This recommendation will allow us to achieve our goal of instilling in all Princeton students an understanding of science, technology, and problem-based inquiry so they become technically literate citizens.

Service and Civic Engagement

Part of the task force charge from President Eisgruber is to examine “how best. . . the School of Engineering and Applied Science [can] contribute to and enhance the University’s culture of service by helping students use their education for the common good” as well as determining “how. . . the school can help prepare leaders and engaged citizens who will make significant contributions in our technology driven society.” First and foremost, these questions are answered by pointing to engineering as a discipline itself. Engineering can be defined as the application of the tools of math and science to solving problems that affect humankind. Thus, the very choice by a student to study engineering reflects a desire to be of service to others. Indeed, many students report that they are drawn to engineering by the desire to do something of benefit to society. The integration between engineering and the liberal arts at Princeton underscores the fundamental human dimension in engineering scholarship and practice. Fostering greater understanding of engineering science and design in the freshman year would advance students’ understanding of the role of engineering in society to address significant human challenges. ***We expect that part of the freshman year reform will be embedding in the curriculum the use of design thinking and innovation in service to society.*** Additionally, many BSE students engage in service through student organizations and activities within and beyond the School of Engineering and Applied Science. We recommend that SEAS should continue to engage with partners and stakeholders across campus to help advance the University’s broader efforts to make service and civic engagement more central to the mission of the University.

Additional Opportunities

We share the administration’s commitment to increasing opportunities for undergraduates to have international experiences and for more international content in courses, as described earlier. The office of the associate dean for undergraduate affairs in SEAS and

the Keller Center should work with the Council for International Teaching and Research and the vice-provost for international affairs to develop more short-term international opportunities for engineering students. *We strongly endorse calendar reform that will align the Princeton calendar more closely with other institutions and provide a “January Term” or “J-term” that could be used for enriching academic experiences as well as international ones.* We also encourage expansion of the role of the standing curriculum committee to address commonalities in coursework across departments and to share best practices in teaching innovations and pedagogy.

Improve the Graduate and Postdoctoral Experience and Opportunities

SEAS attracts excellent graduate students and postdoctoral research associates who conduct outstanding research, contribute in an essential and exemplary manner to our teaching mission, and – after leaving Princeton – form an irreplaceable network of industry and academic leaders who are eager and willing to support our institution and its graduates. The success of SEAS departments within the National Research Council rankings is a testament to the high quality of our graduate and postdoctoral colleagues. In the survey sent to all graduate alumni, 93% of SEAS graduate alumni said their overall academic experience at Princeton was excellent or very good and 87% indicated that they were either very well or quite well prepared for their chosen careers.

SEAS recognizes the critical role that graduate students and postdoctoral researchers play in our mission. Below we outline a set of recommendations to improve and enhance the graduate student and postdoctoral experience.

Mentoring and Professional Support

In surveys and focus groups, graduate students, postdocs, and faculty all expressed a need for enhanced professional development and placement support, including opportunities for industry internships and non-academic opportunities both during and immediately following a graduate student's program of study. Some departments have developed successful – but largely *ad hoc* – internship programs, which could provide a useful model for future initiatives (currently, these programs tend to be largely dependent on individual faculty members' connections to industry). In almost all cases, advice and information related to career services and professional development has been transmitted by departmental graduate representatives. The committee found that such administrative support is crucial to the success of graduate students; we cannot overstate the influence and impact professional support has on graduate students within departments. Postdoctoral research associates would similarly benefit from enhanced professional development and placement support.

Recent input from graduate surveys has emphasized the importance to recent graduates of experience with entrepreneurship and team-based, collaborative, and multi-disciplinary activities in their professional lives. ***We recommend that SEAS directors of graduate studies work with the associate dean for graduate affairs and Career Services to explore more centralized efforts to improve professional development of graduate students and postdocs and increase opportunities for internships, interaction with industry, and entrepreneurship.***

Recruiting and Multi-Year Graduate Fellowships

During discussions with current graduate students, it became apparent that the reputation of the University and that of individual faculty were critically important to their decisions

to apply to and attend Princeton. Students highly value working with the very best faculty, and there was broad consensus that the quality of faculty advising and mentoring is high.

We recommend enhancing communications with prospective students regarding the balance between independent and directed research, the balance between applied and basic science, and the process by which advisors and mentors would be assigned, in order to advance Princeton's recruitment efforts and ensure that applicants are fully informed as they make decisions about graduate study. It is particularly important that we remain competitive in our effort to attract students from diverse backgrounds, including women and people of color. *We recommend that the school work with departments to improve our visibility and messaging about graduate study in SEAS. To aid in recruiting and improve our yield, we strongly recommend the introduction of multi-year graduate fellowships to be offered to top candidates.* This will increase the appeal of Princeton, enabling us to better compete for the very best; increase diversity; and provide flexibility to work within the admission caps. This, combined with more aggressive recruiting, will make us more competitive with our peer institutions and will help the faculty navigate fluctuations in funding and new research directions.

Connecting Across Campus

At the graduate level, there is high demand for Princeton Environmental Institute-Science, Technology and Environmental Policy (PEI-STEP) fellowships/seminars to link the policy and technology worlds. To this end, SEAS should leverage Princeton's strength in public policy through additional joint WWS-SEAS initiatives, such as CITP. More joint faculty appointments in WWS/SEAS could be supported, and a joint WWS/SEAS Ph.D. program could be considered. Through SEAS and WWS, Princeton can be an ideal neutral party to bring industry, government, NGOs and academic scientists together on contentious technology/policy issues. *Additional connections in the graduate program to other campus divisions and entities should be explored and encouraged.*

New Graduate Programs in Materials Science and Applied Physics

One of the most important aspects of any leading university-based research activity is a vibrant and top-ranked Ph.D. program that attracts the best students from around the world. PRISM no doubt has one of the strongest collections of faculty and researchers in materials science and engineering in the country, and **the task force recommends the establishment of a graduate degree-granting Program in Materials Science and Engineering to leverage these extraordinary strengths (a goal to create such a program was identified when PRISM was first established in 2003).** Such a program would also attract top students from materials science undergraduate programs and others who aspire to work across numerous disciplinary boundaries, including CEE, ELE, CBE, MAE, as well as biology, chemistry, physics, and geosciences.

A parallel need that has been identified through our strategic planning process is for a graduate degree-granting Program in Applied Physics. Princeton has a long history of strength in applied physics, spread across multiple departments (including ELE, MAE, Physics and Chemistry) and centralized under the PRISM umbrella. However, these research activities have been primarily within small isolated groups, reducing the experience of graduate students and faculty (particular junior faculty) and negatively affecting recruiting. Further success is limited by two organizational constraints. First, Princeton does not offer a graduate degree in applied physics; as a result, there is a group of strong students who are not applying to any department at Princeton because they are specifically interested in that degree and are reluctant to join a department outside their primary field. Second, students who do apply to an existing department to study applied physics only see a small fraction of the applied physics faculty on campus, hampering recruitment and narrowing their educational experience. Thus, *we recommend establishing a graduate degree Program in Applied Physics*, also under the auspices of PRISM.

Appendix A: Acknowledgments

This report, the result of an 18-month self-study and planning process, was only possible because of the dedication, commitment, and support of a large number of people, both within the School of Engineering and Applied Science and outside of it. The chair of the Strategic Planning Task Force particularly thanks the task force members for their time and energy devoted to the self-study. There couldn't possibly have been a better group of faculty to work with on this important task. It is due to their efforts that the future of engineering at Princeton looks bright.

The task force also thanks the committee chairs, Professors Kelly Caylor, Mark Zondlo, Bruce Koel, Andrew Houck, Adam Finkelstein, and Peter Ramadge. The insights and honest self-assessments from each committee were invaluable. The chair and task force members are grateful for the committees' time and commitment. We also express our thanks to the support staff who supported the task force and committee efforts, particularly Jennifer Poacelli.

Of course the entire process would not have happened without the direction of President Christopher L. Eisgruber and our executive sponsor, Provost David S. Lee. Provost Lee met with us frequently and gave helpful guidance, as did Assistant Vice President Hilary Parker. Vice Provost Paul LaMarche was an invaluable member of the task force, providing insights, and constructive criticism when necessary, and helping to guide us to this document.

University Architect Ron McCoy and Associate University Architect for Planning Natalie Shivers gave us their time and important input on the many issues we discussed regarding buildings and space needs. The team at ZGF Architects joined us on multiple trips to peer institutions and met frequently with us to help develop our recommendations on space. Vice Provost Jed Marsh also helped guide us through questions about space and data gathering and was instrumental in helping us develop our alumni and faculty surveys. We are grateful to all of them.

We are also grateful to the many faculty and staff across campus who gave of their time and resources to meet with committees or the task force or who helped to gather critical information. In particular, we thank Michele Minter, Sarah-Jane Leslie, Jim Stone, and Mary Baum.

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We are indebted to our outstanding external review committee, chaired by Lance Collins, dean of engineering at Cornell University. We thank Dean Collins, Dean Mary Boyce of Columbia, Dean Andreas Cangellaris of Illinois, Urbana-Champaign, Dean Bernd Girod of Stanford, Dean Marc Parlange of British Columbia, Dean Kathleen Stebe of Penn, and Dean Lynn Stein of Olin for their extremely helpful insights and suggestions on our self-study and for Princeton Engineering in general. Because of their efforts we have a much better strategic plan.

This report would also not have been possible without the administrative and thoughtful support of Amy Lewis. Her dedication to this effort was essential as she kept the process running smoothly, made critical contributions, and ensured a successful outcome. We also thank our communications director, Steve Schultz, for his critical help in producing this final document, and the dean's administrative assistant, Andrea Mameniskis, for her continued support throughout the process.

Appendix B: Background and Charge

“The quality of a liberal arts university today depends greatly on the strength of its engineering programs, which serve as windows upon human experience and as models of problem-driven, rigorous inquiry in addressing some of the world’s most pressing challenges” – President Christopher L. Eisgruber in the PAW, Dec. 2014

By all measures, engineering at Princeton is thriving. In particular, its importance to the University’s mission and its societal impact are significant and growing. Our undergraduate enrollment is up 80% since 2003 (the year of our last strategic plan). Research income has increased by 57%, graduate enrollment has expanded by 18%, and the faculty has grown by 12%. A quarter of all Princeton undergraduates now major in engineering. Our faculty members are well recognized for their scholarly excellence, their research impact, and their quality of instruction. The school is ranked fourth in the world by Times Higher Education, largely on the basis of our outsized impact and exceptional faculty. Our department chairs uniformly cite the largest and most recognized engineering schools – MIT, Stanford, and Berkeley – as their direct competitors. The growth of the School of Engineering and Applied Science (SEAS) reflects national trends while also defining a special story about Princeton and how it harnesses its diverse strengths in the service of society.

Indeed the school's most visible areas of growth over the last decade have focused on combining technical excellence and the strengths of a liberal arts university to solve societal problems and prepare leaders who make wise use of technology. The Andlinger Center for Energy and the Environment and the Center for Information Technology Policy – both emerging from the school's strategic thinking a decade ago – exemplify this approach. The Keller Center, a product of the same process, brings students across the engineering school and the University together in innovative classes, service initiatives and entrepreneurial teams – weaving together societal and technological themes. These initiatives have helped stoke student interest and have integrated engineering as a vital part of the University much more fully than at any point in the school's history. Over three-quarters of Princeton undergraduates take at least one course in the School of Engineering during their careers, and several engineering courses are known throughout the University for their accessibility and educational impact.

A key measure of the school's success is the range and impact of societal contributions by our alumni. In addition to founding and leading companies such as Amazon, Google, Lockheed Martin, and SanDisk, engineering alumni serve as university presidents and deans, hold public office at all levels of government, lead in the military, medicine and the arts, and populate outstanding academic and corporate research labs around the world. In a survey conducted as part of this planning effort, engineering alumni were overwhelmingly positive about their undergraduate experience and their level of preparation. In responses from over 700 alumni who graduated in the last 25 years, over 81% described their overall experience and career preparation as either excellent or very good. Over 93% described their background and preparation as better than or equal to

their colleagues. Many respondents described the high quality of instruction and cited the importance of the liberal arts component.

The success and growth of engineering at Princeton coincides with an increasing sense of urgency among leaders nationally who are investing in engineering as a vehicle for driving economic growth and solving societal problems. As succinctly stated in the landmark 2005 report, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* and its update in 2010, *Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5*, “. . . a primary driver of the future economy and concomitant creation of jobs will be innovation, largely derived from advances in science and engineering. While only four percent of the nation’s work force is composed of scientists and engineers, this group disproportionately creates jobs for the other 96 percent.”¹ Since those reports were published, the number of degrees awarded in engineering fields nationwide has shifted dramatically upward. This renewed emphasis on science, technology, engineering and math (STEM) education along with the impact of the digital revolution has driven a surge in enrollment, particularly in computer science departments, across the country. This shift also has sparked explosive interest *outside* of the engineering school as students and faculty in all fields observe how technology touches our lives in ways unimaginable only a generation ago. Students across the University especially see the need to become literate in information technology and data sciences.

In addition, nations around the world are turning increasingly to their universities as engines of innovation and as the training grounds of technically literate citizens. The *Gathering Storm* report notes “. . . the very real pressures of today’s financial markets make it difficult for corporations to invest in fundamental research In this environment the great United States corporate research laboratories are increasingly becoming a thing of the past. . . . In such a scenario the nation’s research universities will have to assume even greater responsibility for performing much of the nation’s research. . . .”² Universities are responding by investing in and enhancing their engineering schools, including forming international and industrial collaborations and building new facilities. Engineering schools are also placing a growing emphasis on entrepreneurship and design thinking, providing education and resources not only to their students but to their universities as a whole. Today’s students have come of age in an entrepreneurial culture, believing they can make the world better through innovation and entrepreneurship. Entrepreneurial opportunities bring diverse communities of students together who are interested in service and leadership. The center of gravity of these activities is the engineering school.

Our core strength derives from our students, alumni and faculty who embrace the combination of fundamental strengths, nimble collaboration, and culture of service that Princeton Engineering has come to embody and who are eager to leverage those strengths

¹ *Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5*, The National Academies Press, Washington, DC, 2010.

² *Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5*, The National Academies Press, Washington, DC, 2010.

to benefit society. Princeton engineering can play a vital role not only in reinforcing the importance of arts, humanities, social science and government to the education and functioning of a modern engineer, but also in articulating the essential role engineering can play in advancing the educational mission of the University across all disciplines. Engineering can contribute to the liberal education of all students by showing how it uses rigorous, science-based inquiry to solve problems and connect value to innovation, how engineers see possibilities, and how design and invention are approached and utilized to create without losing the sense of aesthetics, empathy and societal importance that arts, humanities, and social sciences can provide. Having a world-class engineering school in the midst of a great liberal arts institution creates extraordinary opportunities for engineers to do what they do best: putting science to use for society. At the same time, it draws in non-engineers to experience engineering and technology and to develop an appreciation for their role in society and public policy and how they can be put in service to humanity.

Given these national and Princeton-specific trends, and with the University engaged in a campus-wide strategic planning process, the time is right to assess the state of the engineering school and create a plan for its future. Our year-long self-assessment and strategic planning process has made clear that while we have been successful in promoting our top research priorities, the societal needs that have driven so much of our growth in the last decade remain as urgent as ever. In addition, the growth of the school has outstripped its physical spaces and revealed compelling needs to grow and restructure aspects of its research and teaching. In the face of these challenges, our planning process revealed myriad opportunities to flourish. Our task was guided by the following charge:

The School of Engineering and Applied Science Strategic Planning Task Force is asked to begin by conducting a self-study and external review. It is expected that this self-study will mirror the well-established process for departmental self-studies, including internal examination of the school's strengths, weaknesses, internal structures, academic programs and facilities. Additionally, the task force is asked to identify current and future challenges as well as potential opportunities. An external review committee will then be invited to comment on the internal examination and make further recommendations.

In the course of its work, the task force is asked to consider the following questions:

- Which academic fields or educational programs are of highest priority for significant new investment now and in the future? Are there areas where we should scale back to allow us to dedicate resources more fully to the most relevant and critical issues of today and the future?
- How best can the School of Engineering and Applied Science leverage and enhance collaboration among departments and disciplines, both within the school and across the University? How can the School of Engineering and Applied Science's facilities and its physical connection with the rest of campus most effectively form bridges among engineering, the natural and social sciences, and the humanities?

- To what extent and how should questions about the school's physical compactness and proximity to other disciplines inform that campus planning process that will guide the campus' physical development for the next 10 years and beyond?
- How should the school's academic departments be structured to best accomplish our teaching and research goals?
- How best can the School of Engineering and Applied Science contribute to and enhance the University's culture of service by helping students use their educations for the common good? How can the school help prepare leaders and engaged citizens who will make significant contributions in our technology-driven society?

Taken together, our self-study and strategic recommendations provide a blueprint for ensuring that SEAS remains one of the top engineering schools in the world and that we contribute the maximum benefit to society through our research and graduates.

Appendix C: SEAS Self-Study

The School of Engineering and Applied Science (SEAS) task force was one of six created across the University to examine specific areas of teaching and research. From July 2014 to July 2015, the task force combined a self-study of the school with a discussion of strategic future directions (see Figure 1 for a summary timeline of the process). Upon endorsement of the SEAS strategic planning charge by the president and provost (see Appendix A), the task force began by conducting an in-depth self-study, mirroring the process for departmental self-studies, encompassing an internal examination of the school's strengths, weaknesses, opportunities and threats (SWOT). This was followed by the development of strategic priorities for the school. To execute this study, the task force established six cross-cutting committees to perform a thorough “state of the school” in their respective areas and report back with prioritized recommendations. Committee membership was comprised of faculty from each of the six departments with an assigned liaison from the SEAS task force (see Appendix B for a list of committees, membership, and their specific charges). Overall, one-third of faculty within SEAS actively participated in the strategic planning process. In addition, each department held a retreat in fall of 2014 and prepared an individual SWOT and strategic plan that was then provided to the task force. The four SEAS centers and institutes prepared SWOT analyses and strategic plans for the task force as well.

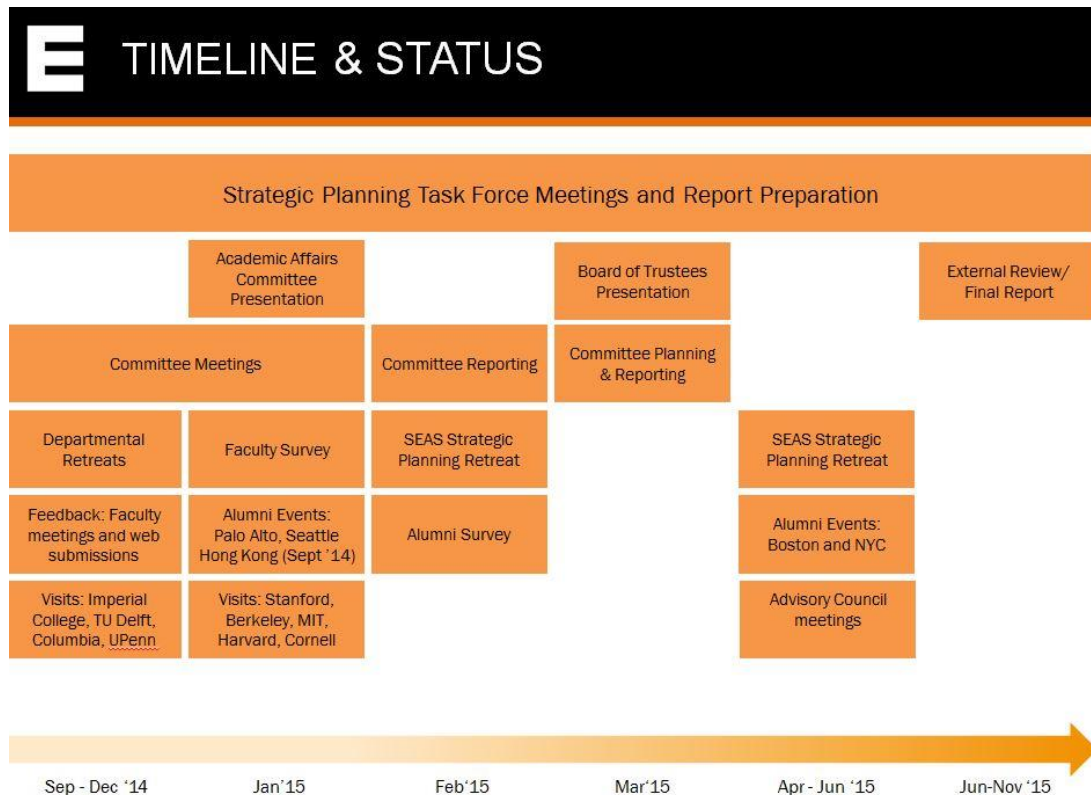


Figure 1: Summary timeline of the SEAS task force self-study and strategic planning process.

Data gathering

The task force spearheaded a variety of methods for gathering information to inform the current state of the school and strategic plan. Outreach included:

- All SEAS faculty had the opportunity to provide feedback via the SEAS Faculty Survey during the winter of 2015;
- All undergraduate alumni within 25 years post-graduation were invited to participate in a survey about their experience in SEAS and career preparation;
- The Graduate School launched an alumni survey with a subset of data provided to SEAS;
- Several committees held focus groups with undergraduate and graduate students, faculty, and staff;
- Task force members and engineering school administration made several visits to peer institutions and held alumni events around the world;
- A comprehensive review of various peer comparisons included mission and vision statements, buildings, facilities, personnel, and curriculum structure(s).

Strategic planning retreats

Connecting the work of the six committees was a crucial part of the task force objective; to do so, two strategic planning retreats were held in February and April of 2015, respectively. The initial retreat over the winter was primarily a venue for committee chairs, department chairs and center directors to present their SWOT analyses and allowed for feedback and discussion among attendees, as well as to begin brainstorming new initiatives. In April, the group reconvened for presentations of key findings and recommendations from each committee in anticipation of their final reports to the SEAS task force. The retreats successfully identified synergies and issues that crossed committee boundaries, ascertained departmental themes, and prioritized future needs and directions. Both gatherings were imperative to providing feedback and building consensus among stakeholders as the final report began to take shape.

Reporting

The reporting process was primarily conducted in stages, to allow the task force to deliberate each committee recommendation independently and prior to the creation of the final prioritized recommendations. The task force invited committee chairs to attend at least one meeting between June and July upon submission of their respective reports. Further, various campus partners were invited to the final series of task force meetings to identify important ideas that may be missing from the report and to further inform the overall plan prior to prioritization by the task force and review by SEAS executive sponsors.

TASK FORCE MEMBERS

H. Vincent Poor, Dean, School of Engineering and Applied Science

N. Jeremy Kasdin (MAE, Vice-Dean of SEAS, Chair)

Claire Gmachl (ELE)

Peter Jaffe (CEE)

Jennifer Rexford (COS)

Clancy Rowley (MAE)

Sunkaran Sundaresan (CBE)

Robert Vanderbei (ORF)

Ex-Officio

Emily Carter (ACEE Director)

Mung Chiang (Keller Center Director)

Ed Felten (CITP Director)

James Sturm (PRISM Director)

Administrative Support

Amy Lewis

Jennifer Poacelli

COMMITTEE MEMBERS

Undergraduate BSE Program

Chair: Andrew Houck (ELE); Task Force Liaison: Clancy Rowley (MAE)

Dan Steingart (MAE)

Sigrid Adriaenssens (CEE)

Andrea LaPaugh (COS)

Jamie Link (CBE)

Steve Lyon (ELE)

Bill Massey (ORF)

Ex-officio

Peter Bogucki

Cornelia Huellstrunk (Keller Center)

Representatives of Certificate Programs (not on committee, but invited to a meeting)

Evelyn Laffey (Council on Science and Technology)

Undergrad administrative representative

Career Services

Select undergraduate students

Clayton Marsh (Dean of College Office)

Faculty, Research Staff and Diversity

Chair: Claire Gmachl (ELE)

Erhan Cinlar (ORF)
Ignacio Rodriguez-Iturbe (CEE)
Mona Singh (COS)
Rod Priestley (CBE)
Julia Mikhailova (MAE)
Sharad Malik (ELE)

Ex-officio

Mary Baum (Office of Dean of Faculty)

Department Structures and Research Priorities

Chairs: Adam Finkelstein (COS) and Peter Ramadge (ELE); Task Force Liaison:
Bob Vanderbei (ORF)

René Carmona (ORF)
Sanjeev Arora (COS)
Naveen Verma (ELE)
Stanislav Shvartsman (CBE) (bio)
Maria Garlock (CEE)
Marcus Hultmark (MAE)
Eric Wood (CEE)

Ex-officio

Celeste Nelson (CBE)
Mung Chiang (Keller Center)
Department Chairs

Rick Register (CBE)
James Smith (CEE)
Sharad Malik (ELE)
Howard Stone (MAE)
Andrew Appel (COS)
Jianqing Fan (ORF)

Graduate Program and Postdoctoral Experiences

Chair: Kelly Caylor (CEE); Task Force Liaison: Jen Rexford (COS)

Tom Funkhouser (COS)

Thanos Panagiotopoulos (CBE)
Ronnie Sircar (ORF)
Mike Mueller (MAE)

Ex-officio:

Mikko Haataja (MAE)
Brandi Jones (SEAS)
Sarah McGovern (former graduate administrator in ELE)
Select grad students
Select post-docs
Career Services

Facilities and Resources

Chair: Bruce Koel (CBE); Task Force Liaison: Sankaran Sundaresan (CBE)

Barry Rand (ELE)
Claire White (CEE)
Lex Smits (MAE)
Ramon von Handel (ORF)
Kai Li (COS)
Rick Register (CBE)

Ex-Officio:

Nan Yao (Research Staff, PRISM)
Bob Kennedy (SEAS)
David Magier (associate librarian)
Shana Weber (Office of Sustainability)
Mark Wilson (Office of Design and Construction)
Tom Nyquist (Facilities; waiting for Mike McKay to confirm)
Jay Dominick (OIT)
Natalie Shivers (University Architect)

Relationship with External Entities

Chair: Mark Zondlo (CEE), Task Force Liaison: Peter Jaffe (CEE)

Warren Powell (ORF)
Bob Prud'homme (CBE)
Lynn Loo (CBE)
JP Singh (COS)
Ed Law (MAE)
Ruby Lee (ELE)
Michael Oppenheimer (WWS)
Forrest Meggers (ACEE/SoA)

Ex-officio:

John Ritter (Technology Licensing and Intellectual Property)

Jane Maggard (SEAS Development)

David Langiulli (Corporate and Foundations Relations)

Tony Novembre (PRISM)

Steve Schultz (SEAS Communications)

Appendix D: Princeton Engineering Past and Present

“Revolutions in information technology and other fields have made engineering schools pivotal to the success of research universities . . . it is hard to imagine where we would be without [SEAS]. It has produced some of our most successful and generous graduates, and it is the epicenter of innovations—in computer science, energy and the environment, and entrepreneurship—that are of general interest to our student body.” – President Eisgruber to the Board of Trustees, 2014

Engineering at Princeton, with roots in the 19th century, has always been a story about harnessing and expanding scientific knowledge to design solutions to problems – and doing so in the context of a liberal arts university. The University created the School of Science in 1875 and hired its first engineering professor – civil engineer Charles McMillan – who quickly began attracting students, adding faculty and building a department. Physicist Cyrus Fogg Brackett started the same year and founded the School of Electrical Engineering in 1889. These threads came together in 1921 with the founding of the School of Engineering. Arthur Greene, the founding dean, was attracted to Princeton's emphasis on liberal arts courses as integral to an engineering education. He wrote:

"The imagination of the engineer should be equal to that of the novelist, the artist, the poet, or the preacher, for in many respects the work of all these creators is the same."

Half a century later, in 1971, former dean of engineering Robert Jahn continued that sentiment and added emphasis on engineers as problem solvers whose positive impact derives in large part from the breadth of their liberal arts education:

"We have a small engineering school which must flourish in the framework of a small, liberal, excellent university. That I regard as an advantage, especially in an era which favors individually tailored, liberal engineering education for its students. . . . We must respond to the needs of society for solutions to some very pressing problems. What better place to do it than at a university which has well-developed programs in the humanities, social sciences, and natural sciences; and which has a heritage of engineering education that has always emphasized the development of the mind of the student more than the simple transfer of technical facts and techniques?"

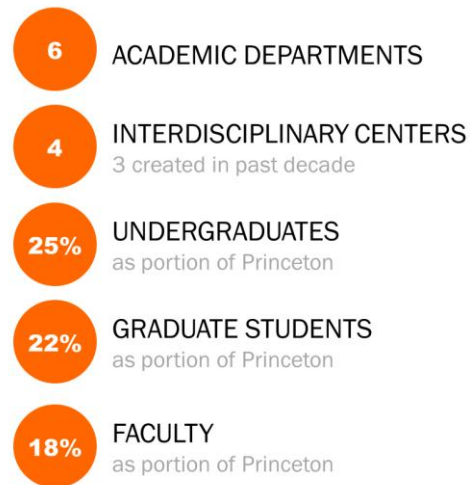
The approach also served the school's research enterprise well. With the University's deep strength in math and physics, and its emphasis on fundamental inquiry, the engineering departments grew and became highly ranked.³ Departments such as Mechanical and

³ The most recent National Research Council rankings (<http://sites.nationalacademies.org/PGA/Resdoc/index.htm>) give median scores in top 10 for all Princeton departments included in NRC categories. Princeton CS, EE and CEE ranked

Aerospace Engineering, while having robust experimental groups, developed strong programs in theory and computational science. The Department of Computer Science, formed in 1985, also built on Princeton's mathematical roots and quickly became top ranked. True to Princeton's small liberal arts ethic, research and teaching went hand-in-hand, with faculty engaging undergraduates in important problems and preparing graduate students to be a next generation of leaders in their fields.

Over the decades, the names and number of departments have evolved to reflect long-term shifts in disciplines. Computer science was originally added with an "and" to electrical engineering, and eventually became a stand-alone department. Similarly, operations research split from civil engineering in 1999. "Biological" was added to the chemical engineering name in 2010. Today the school is home to six departments: Chemical and Biological Engineering; Civil and Environmental Engineering; Electrical Engineering; Computer Science; Mechanical and Aerospace Engineering; and Operations Research and Financial Engineering. The school also hosts four interdisciplinary centers: the Andlinger Center for Energy and the Environment, the Center for Information Technology Policy, the Keller Center, and the Princeton Institute for the Science and Technology of Materials. The school also supports 11 undergraduate certificate programs.

Quick Facts



These trends, coupled with the dawn of the Internet age and waves of high-tech booms near the turn of the 21st century, led to a general broadening of the school's role and vision. That is, it became increasingly clear that engineering is as integral to a liberal arts education as the liberal arts are to a well-rounded engineering education.

This increased integration led to significant growth in size and recognition of the school. The current complement of 1,300 undergraduates (across all four years), more than 580 graduate students, 109 post-doctoral researchers, and 145 faculty members represents substantial growth in every area, as illustrated in the following figure. Perhaps even more significantly, in line with our goals of broader engagement, enrollment in engineering courses has grown in the last decade by 115 percent, which far exceeds the 60 percent growth in engineering majors. While one in four Princeton undergraduates is majoring in engineering today, the great majority of the remaining students also take at least one course in engineering during their four years. Increasingly, courses are not just simplified

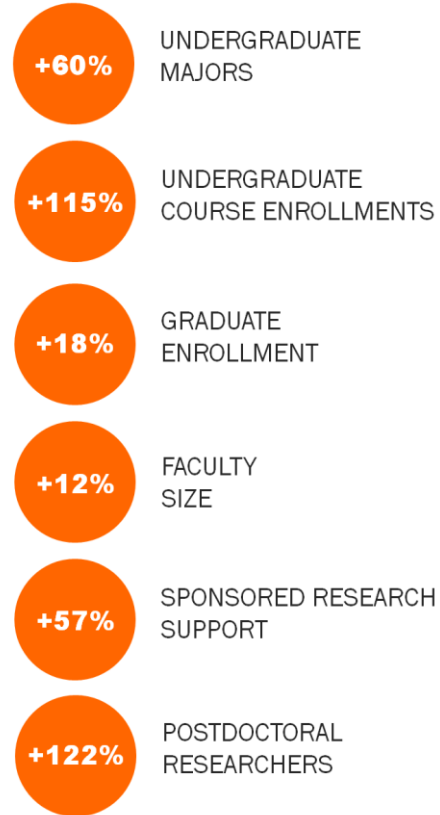
#1 in at least one of the two NRC methodologies. The Times Higher Education ranking (<https://www.timeshighereducation.co.uk/world-university-rankings/2015/subject-ranking/engineering-and-IT#/>) places Princeton School of Engineering and Applied Science at #4 globally.

versions of technical material targeted toward humanities majors, but are full intellectual integrations that draw A.B. and BSE students in equal numbers.

Beyond course enrollments, the school has become a catalyst for student activity in entrepreneurship and service and for faculty and graduate student collaborations. The Keller Center, founded in 2005, created programs such as the eLab summer accelerator program, which engages students from across campus, while its annual Innovation Forum engages faculty and graduate students from many departments. The Engineers Without Borders student service organization also is highly interdisciplinary. Engineering faculty members have joint appointments at the Woodrow Wilson School of Public and International Affairs and at the Lewis-Sigler Institute for Integrative Genomics, the Bendheim Center for Finance, the Department of Mathematics, the Program in Applied and Computational Mathematics, and the School of Architecture. Faculty have current or recent collaborations in many areas across the University, including neuroscience, dance, music, visual arts, architecture, molecular biology, chemistry, physics, astrophysics, ecology, sociology and philosophy.

This spirit of collaboration has led to new centers to foster interdisciplinary research and teaching in specific areas of societal need. Since the 1990s, the engineering school has been home to an interdisciplinary institute for materials science, the Princeton Institute for the Science and Technology of Materials. Known as PRISM, this institute brings together engineers, physicists, geoscientists, and chemists and has longstanding strengths in nanotechnology and atomic-scale imaging. More recently, supported by the Aspire campaign, the school added the Andlinger Center for Energy and the Environment and the Center for Information Technology Policy (joint with the Wilson School). Opened for occupation in fall 2015, The Andlinger Center occupies its new 129,000 square-foot building. Among the many state-of-the-art laboratories designed to enhance collaborations on energy and environmental research are an Imaging Analysis Center and a 28,000 sq. ft. cleanroom housing an expanded Micro- and Nano- Fabrication Lab and instructional space. These new Andlinger/PRISM central facilities will serve the entire campus, greatly expanding current capacity and capability and enhancing this already significant research area, making Princeton the premier nanofabrication center in the tri-state area.

GROWTH: 2004-15



The Center for Information Technology Policy addresses critical emerging issues of privacy, security and the social impacts of digital technologies. The center, located in Sherrerd Hall between the Engineering Quadrangle and the Wilson School, brings strong technical expertise to issues that are typically addressed through law schools or other non-technical programs.

As part of its growth, the school has also expanded its sponsored research by nearly 60 percent, brought in 18 percent more graduate students, and more than doubled the number of post-doctoral researchers. The physical space available to engineering departments and centers also has increased significantly in the last 10 years in large part due to the Aspire campaign, including the addition of Sherrerd Hall, the renovation of Hoyt Lab and the Andlinger Center complex, though it has not kept pace with the needs of the growing research base and increasing faculty and student populations.

Sustaining and building on this growth and on the school's overall opportunities to achieve a positive impact are driving goals as we move through a new phase of strategic planning.

Appendix E: Measuring Success – Benchmarks and Metrics

This report describes our priority recommendations which, if implemented, will enable us to succeed in our mission, reach our goals, and achieve our vision for the future. However, it is not enough to simply articulate a vision; benchmarks are needed to define success along with metrics for measuring whether we are meeting them. In this appendix we present the **five benchmarks of success** for SEAS and suggested metrics we will use going forward to ensure that our plan is succeeding.

SEAS has a diverse, world-class faculty whose research is well recognized and impactful.

Achieving our mission in many ways lies on the shoulders of our faculty. Attracting and retaining a diverse, talented and dedicated faculty is essential to our success. Measuring the demographics and the impact of our faculty and how their work contributes to and enhances the SEAS and University missions will require annual data gathering on various metrics in conjunction with campus partners such as the dean of the faculty and dean for research. Key areas will include the tracking, analyzing and trending of:

- Retention and recruitment success (including exit interviews)
- Faculty diversity
- School rankings (particularly those that focus on scholarly quality and impact)
- Sponsored research income as an indicator of the innovative, cutting-edge nature of their scholarship
- Academy memberships
- Awards and honorary degrees
- Faculty leadership in professional societies, journal editorships, board positions, and other leadership roles
- Publications of textbooks and other learning and research tools
- Scholarly publications and collaborations

SEAS undergraduate students acquire technical and leadership skills and a liberal arts sensibility needed to succeed in graduate school or careers and move on to become leaders in their chosen fields.

As the survey of SEAS undergraduate alumni from the winter of 2015 revealed, engineering alumni are highly satisfied with both their overall experience at SEAS and their career preparation. To build upon the strong connection alumni have with their *alma mater* and SEAS specifically, a variety of measures will be captured on an ongoing basis with the goal of connecting SEAS undergraduates with mentors across a variety of fields, and showcasing engineering alumni successes and connections across a variety of disciplines:

- Career placement
- Graduate school placement
- Alumni awards and accomplishments

- Alumni in corporate and government leadership
- Alumni entrepreneurial successes
- Recognized alumni service
- BSE attrition rates

SEAS graduate students and postdoctoral fellows are valued members of the University community who become leaders in academia, industry, or the public sector.

Building a stronger community of graduate students and postdoctoral fellows is an essential outcome of our plan. By gathering key data points each academic year with the support of colleagues at the Graduate School, SEAS will have the tools to ascertain and communicate the effectiveness of our graduate and postdoctoral programs and to quickly find weaknesses and address them. Key metrics include:

- Graduate student yield
- Size and diversity of applicant pool
- Time to degree
- External fellowships
- Honors and awards
- Alumni accomplishments and leadership roles (both graduate students and post-docs)
- Alumni and postdoctoral placement (academic positions, corporate and government leadership, service)

All Princeton students graduate with an appreciation of science and technology and their roles in society.

The steady growth in the number of Princeton students majoring in an engineering field, coupled with the interest of the entire student body in exploring engineering courses, demonstrates the extensive reach of SEAS. Likewise, as described in this report, the ubiquity of technology speaks to the need for technically literate graduates no matter their major. One of our most important goals is to provide all students with a sense of the social and policy implications of what they do and the role of technology in their lives. Success here will be measured by several key metrics:

- Alumni service
- Alumni surveys
- Course evaluations
- Enrollments (number of A.B. students taking SEAS classes)
- Collaborations with other divisions
- Senior exit survey data

SEAS has state-of-the-art facilities and outstanding staff to enable breakthrough research.

To continue the world-class research and high-quality teaching at SEAS, it is imperative we improve our facilities and maintain excellent staff. We must then continually measure

how well the school's needs are being met and how well we compare to our peers. This will be done through the following key metrics:

- Faculty recruitment and retention
- Faculty surveys and focus groups
- Industrial collaboration
- Advisory councils and peer visits
- Use of excess and overflow space and flexibility

Appendix F: References

Miller, Richard K., “Rethinking Engineering Education: Richard K. Miller”, *Research-Technology Management*, Nov-Dec, 2013.

Constable, George and Bob Somerville, *A Century of Innovation*, Joseph Henry Press, Washington, DC, an Imprint of the National Academies Press, 2003.

Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future, The National Academies Press, Washington, DC, 2007.

Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5, The National Academies Press, Washington, DC, 2010.

The Engineer of 2020: Visions of Engineering in the New Century, The National Academies Press, Washington, DC, 2004.

Educating the Engineer of 2020: Engineering Education to the New Century, The National Academies Press, Washington, DC, 2005.

Creating a Culture for Scholarly and Systematic Innovation in Engineering Education, American Society for Engineering Education, Washington, DC, 2009.

Innovation with Impact, American Society of Engineering Education (ASEE), Washington, DC, 2012.

Yoder, Brian L., *Engineering by the Numbers*, American Society of Engineering Education, Washington, DC, 2014.

Educating Engineers for the 21st Century, The Royal Academy of Engineering, London, UK, 2007.

Olson, Steve, *The Importance of Engineering Talent to the Prosperity and Security of the Nation*, Summary of a Forum sponsored by the National Academy of Engineering, The National Academies Press, Washington, DC, 2014.

Designing a Digital Future: Federally Funded Research and Development in Networking and Information Technology, Report to the President and Congress, President's Council of Advisors on Science and Technology, December 2010.

Continuing Innovation in Information Technology, National Academies Press, Washington, D.C., 2012.

Wolf, Michael and C. Brett Lockard, “Occupational employment projections to 2020”, *Monthly Labor Review*, January, 2012.

Roth, Michael S., *Beyond the University: Why Liberal Education Matters*, Yale University Press, New Haven, CT, 2014.

Grand Challenges for Engineering, National Academy of Engineering, Washington, DC, 2008.

Miller, Richard K., “Rethinking Higher Education: Olin College of Engineering”, *Civic Engagement, Civic Development, and Higher Education*, Jill N. Reich, Ed., Bringing Theory to Practice, Washington, DC, 2014.