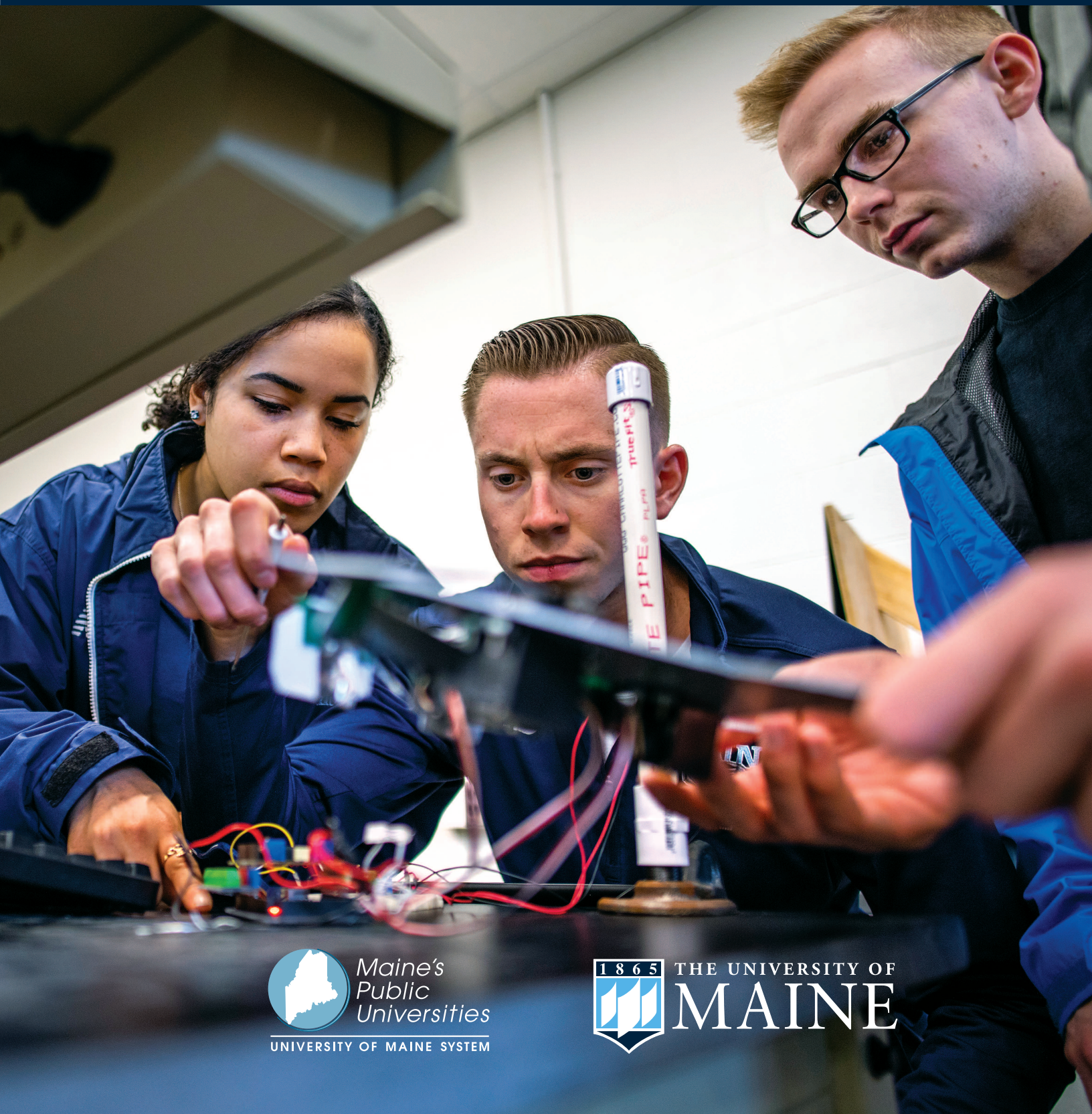




THE UNIVERSITY OF MAINE SYSTEM

Research

AND DEVELOPMENT PLAN FY20–FY24



Maine's
Public
Universities

UNIVERSITY OF MAINE SYSTEM



THE UNIVERSITY OF
MAINE

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THE UNIVERSITY OF MAINE SYSTEM

Research

AND DEVELOPMENT PLAN FY20–FY24

R&D to promote industry, business,
and community growth in Maine

FY20–FY24

Prepared by

Joan Ferrini-Mundy, President, University of Maine and University of Maine at Machias
Jason Charland, Director of Research Development, University of Maine

In consultation with

University of Maine System Vice Chancellor for Academic Affairs Robert Neely
and University of Maine System Presidents
Eric Brown, Glenn Cummings, Raymond Rice, John Short, and Rebecca Wyke

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Executive Summary

We propose that the University of Maine System advance three R&D goals for the state of Maine over the next 10 years:

- 1. Make Maine the best state in the nation in which to live, work, and learn by 2030.**
- 2. Establish an innovation-driven Maine economy for the 21st century.**
- 3. Prepare the knowledge-and-innovation workforce for Maine.**

The University of Maine System (the System), with its seven distinct campuses, its more than 5,000 employees, its 28,040 students, and its \$550 million overall budget, is a vital and vibrant asset to the state of Maine. As the heart of the state's public system of higher education, the students, faculty, and staff at the System campuses are defining the future of Maine. Our institutions provide a broad suite of educational programs designed to prepare future generations of professionals, leaders, and innovators for our state and beyond. Here, we propose a framework for research and development (R&D) for the System.

The University of Maine, the state's only public research university, has a comprehensive portfolio that addresses the most challenging problems of our time (i.e., "grand challenges") through basic and applied research, development, and commercialization, with direct impact in

Maine. We emphasize the importance of basic, foundational research in this context, knowing that the applications of the new knowledge generated from those research programs will provide as yet unimagined benefits to our state and our society in the decades to come.

The University of Southern Maine (USM) provides research leadership in economic, social, environmental, health, and workforce development policies that advance the state's economy. With its greater Portland location, USM advances workforce development and applied learning, and tackles the pressing community and state policy issues important to Maine people. The University of Maine at Augusta, the University of Maine at Farmington, the University of Maine at Fort Kent, the University of Maine at Presque Isle, and the University of Maine's regional campus, the University of Maine at Machias, all add vital and distinctive opportunities



for geographic and place-based R&D specialization, where researchers and students, in partnership with their communities, strive to find solutions to important challenges statewide.

Most critically, there are active, internationally recognized scholars and researchers who are moving society forward through their scholarship and research on all of the University of Maine System campuses.

In December 2018, the University of Maine System Board of Trustees issued a Declaration of Strategic Priorities, the first of which is Advancing Workforce Readiness and Economic Development, with a priority action item: Strengthen research and economic development efforts to support Maine industries, and to foster business formation and expansion. The President of the University of Maine and University of Maine at Machias was charged by the Chancellor to deliver a multi-year plan by March 2019 for expanding research and development across the System.

The plan we present here has been developed in consultation with faculty, professional staff, and researchers from throughout the System; the Presidents of the System universities; and the Vice Chancellor for Academic Affairs. In particular, the findings and recommendations listed below emerged through a number of open sessions with faculty and staff, through web-based inputs to the plan, and through engagement with external stakeholders.

Maine has a history of linking university-based R&D to economic needs across the state's urban and rural landscapes. The University of Maine System has a remarkable span of research, scholarship, development, commercialization, technical assistance, policy analysis, and creative contributions across disciplines, resulting from the efforts of faculty, staff, and students. That work is of significance not only to the state of Maine, but also to the nation and world. We provide examples and discuss the importance of that diversity of scholarly work and

knowledge-building, including how such work can intersect and bolster the science and technology R&D enterprise as specified in the state's seven legislated technology sectors. Because of the emphasis on economic development, this plan includes special focus on research in science and technology, using national indicators and metrics available in those areas. To achieve the three goals listed on page two and to fulfill our missions as universities, the full, broad, and comprehensive set of creative, knowledge-building, translational, and community-engaged scholarship must be sustained, supported, and celebrated across the System.

The state of Maine, the University of Maine System, and the University of Maine are underperforming in R&D activity and expenditures.¹ We clearly need to boost our R&D performance as a state, a System, and a research university in order to serve Maine and its people, and to be competitive nationally. We need to establish a research focus in Maine that will support the future economy, and to ensure that all campuses are able to participate in R&D as appropriate to their missions. There are clear steps proposed in this plan that the System universities, in partnership with other entities, can implement to improve the situation.

**Strengthen
research and
economic
development
efforts to support
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and to foster
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and expansion.**

The findings and recommendations that follow acknowledge many positive features of the current context

for R&D across the System. However, for the University of Maine System institutions to collectively move to the next level and lead in the accomplishment of the three broad goals, substantial new investment from a variety of sources, as well as realignment of current resources, will be required. In addition, re-examination and reformulation of certain policies, practices, and collaborative mechanisms will be needed to support the R&D enterprise. Data from the past 20 years, along with national benchmarking, give every indication that such investment in the research, realignments, and reformulations will yield tangible benefits and significant returns for Maine's economy, its people, and, most important, its learners, for generations to come.

Finding One:

Investment by the state of Maine and the University of Maine System in R&D has been essential to reach our current R&D capacity.

The Maine Economic Improvement Fund was established by the Maine Legislature in 1998 and the Research Reinvestment Fund was established by the System Board of Trustees in 2015. Without those resources it is quite possible that the capacity at the University of Maine to seek and obtain external funding would have been severely impeded and that R&D at the University of Southern Maine and other System campuses would have been minimal. These state funds have leveraged significant external funding and enabled hundreds of students to participate in research and to be paid for that participation. To sustain and grow university-based R&D infrastructure in Maine in the next 10 years that is properly scaled to achieve the goals will require increased investment from state and System sources. It also will require realignment over time within campus budgets. Clear metrics and accountability expectations will be necessary to track the outputs, outcomes, and impacts of these changes. Launching grand challenge initiatives will allow for focused investment in areas poised to grow and yield results in both the near and long term. Such investment stands to raise national ranking, and will increase competitiveness with similar institutions in other states for federal funds, leading world-class faculty, and excellent students to come to, and remain in, Maine. But, most important, these investments will yield benefits for the students and people of the state of Maine by enabling preparation of a knowledge-and-innovation workforce to fill key positions and attract businesses to a growing state economy.

Recommendations:

First, we recommend that the UMS Research Reinvestment Fund be renewed for five years, at a level of \$4 million per year, beginning in FY20. Additional new selection priorities should be considered, such as partnerships with private-sector entities or local communities to solve practical problems, or collaborations among researchers on different System campuses. These investments should promote strong networks of researchers, allow adequate time for faculty to conduct research, and expand opportunities for paid student

research experiences. Outcomes should include measurable return on investment (ROI), effectiveness in leveraging external funding, and quality and impact of student engagement in research.

Second, we recommend regular increases in state MEIF investment to reach a steady level of \$40 million annually by the end of FY24. This fund supports the on-campus capacity, including researchers, students, and facilities, that allows success in the intense national competition for federal research funding from the National Science Foundation, the National Institutes of Health, and other agencies. Additional MEIF resources would sustain and enhance infrastructure, and expand research capacity and expenditures in the highest-priority R&D areas for Maine's future well-being and economic success. Improving Maine's standing in national rankings of higher education expenditures in R&D will help attract R&D-intensive industry to the state. But the most important outcome of this investment will be expanded opportunity for Maine students to be educated in R&D-rich environments so they can become Maine leaders and innovators. System campuses will be asked to consistently track and report the number of students involved in R&D. In preparation for this request, by January 2020 the System should complete an analysis of ROI and impact on the Maine economy of MEIF over its 20 years of existence.

Third, the System institutions will collaboratively develop a plan for integrating R&D expenses in the educational and general (E&G) budget, parallel to the way that instructional costs are embedded. The System's appropriation allocation model encourages campuses to look closely at R&D spending in comparison to established peer institutions. In addition, universities will consider realigning resources within their E&G budgets to provide additional support, as appropriate, for their R&D goals. We strongly urge the universities to reinvest Facilities and Administration (F&A) cost recovery back into the research enterprise more substantially.

These investments will contribute to attracting students in Maine and to Maine by expanding the breadth of learning opportunities, including such options as paid internships with Maine companies interested in R&D expertise. Students with exposure to undergraduate research are likely to continue into our graduate offerings, establishing a pipeline, and improving the quality and capacity of the System graduate student body. These students will be prepared for the jobs of the 21st century and will be competitive in the national job market.

These changes would raise the profile of the University of Maine and other System campuses' ability to recruit students who are interested in undergraduate research, to attract and retain first-rate research faculty and graduate students, to compete for external federal funds, and to partner with the private sector to engage in R&D. All of these potential outcomes should be considered in designing accountability measures.

Finding Two:

Each System campus has its own unique, engaged R&D core of expertise that should be further strengthened.

Research now and in the future will have a major role in "Making Maine the most desirable state in which to learn, work, and live by 2030." Across the System, we have a rich and diverse set of research interests and capabilities, and great expertise among the faculty to continue ongoing R&D, and to undertake new lines of work in connection with their students.

Each institution has distinct identifiable strengths and emerging goals for its role in R&D, and at each university in the System the centrality and scope of the R&D enterprise differs. For the University of Maine, the state's comprehensive land and sea grant public research university, basic and applied research, development, and commercialization are core to the mission, and expenditures from externally sponsored research approach \$100 million annually. At the University of Southern Maine, the R&D strength spans many areas, and much of the work is applied. Goals for applied

learning and workforce development are important there. On the other System campuses there are excellent examples of research and scholarship fully integrated into instruction and service, though with limited externally funded research.

Recommendations:

First, each of the System campuses should develop a five-year R&D implementation plan for increasing research expenditures aligned with the goals of this plan and appropriate to each campus. Coordination and collaboration across campuses in R&D can then be considered. Existing and emerging signature R&D strengths at the University of Maine and other campuses will provide a foundation for this effort. By connecting to those established and emerging areas of strength, all campuses can design research agendas that are tailored to specific needs of their communities and geographic regions, that suit the interests and expertise of their faculty, and that will engage their students. Coordinated and public campus plans will be useful to potential new businesses and partners.

Second, the System universities, working together with Associated Faculties of the Universities of Maine and Human Resources units, should design and implement creative approaches to joint faculty appointments, including membership in the University of Maine Graduate Faculty. Such appointments will help to reduce barriers to conducting research and allow direct engagement with doctoral students. R&D faculty and student exchange and residency programs will be considered. The idea is to cultivate more cross-campus R&D collaboration that will generate tangible results for specific problems in Maine.



Third, the universities should collaborate on data governance in R&D to achieve consistency in reporting and to ensure appropriate credit for R&D expenditures. Methods to consistently include credit for a range of types of scholarly production should be explored when national surveys are not sufficient. By addressing these matters, we would support accountability and enable measurement of progress. In addition, we should assess System-wide access to research databases of interest to researchers and scholars on multiple campuses, and create cost-effective solutions.

Finding Three:

Across the University of Maine System, we have been failing to compete as well as we should for significant federal funding, and our facilities, infrastructure, and administrative support for R&D are inadequate in several fields important to Maine's future.

Between 2007 and 2016, Maine's total R&D expenditure declined nearly 40 percent — the largest decline of any state over that period. The System as a whole is underperforming in higher education R&D expenditures. There are dozens of federal competitive grant programs available across the major science agenciesⁱⁱ annually in R&D

areas of relevance to the state of Maine for which few or, in some cases, no applications are made from System universities. This unacceptable situation results from a combination of lack of faculty with expertise or interest in key areas; insufficient administrative capacity to support proposal planning and submission; inadequate faculty time to prepare proposals because of competing teaching and service loads; and lack of graduate students, postdoctoral associates and technicians. In addition, there is a critical need for improved facilities; modern and sophisticated instruments and research resources; and procedures for sharing equipment and instruments. Sometimes, faculty cannot pursue research funding opportunities because the needed equipment, facilities, and capabilities do not exist in the System, or the costs of compliance and purchasing licenses would be too great for faculty to cover from their own research budgets. Universities similar to UMaine have this research infrastructure in place, which puts our faculty at a disadvantage when competing for federal grants. And there are opportunities to engage undergraduate students in research that are not being realized because of the lack of needed equipment and personnel. Improving modernized equipment has the added benefit of enabling the training of our students to prepare for jobs of the future that would use this instrumentation. All campuses report a large need for more administrative support in R&D.

Despite all this, we are confident that System faculty and staff are resourceful and deeply committed to their students,



their research, and to Maine, and that we can remedy much of this situation with relatively modest resources, and increased coordination and communication.

Recommendations:

First, assuming availability of additional resources from combined sources, the universities will review and address needs for coordinated hiring of faculty in key areas of importance to the state as determined, for instance, by System Board of Trustee goals, or recommended in the reports of the Maine Economic Growth Council or the economic growth plan currently under development through the Office of the Governor. Similar coordination or information-sharing should be applied to the hiring of postdoctoral associates, technicians, and graduate students.

Second, a System-wide inventory of R&D instruments and facilities should be assembled and made available to all new faculty. The Coordinated Operating Research Entities, or CORE, pioneered at the University of Maine, provides a model and could be expanded System-wide. Campus master plans should address needs for expanded and renovated R&D facilities.

Third, the comprehensive research administration and development capacity currently in place at the University of Maine should be made available to support faculty research needs across the System. Inter-campus research administration collaborations between the University of Maine and other System campuses have been established (e.g., with the University of Maine at Machias and the University of Maine at Fort Kent). Research administration services also exist at the University of Southern Maine. Both the University of Maine and the University of Southern Maine house expertise for research compliance, which could become shared resources with other System campuses.

Finding Four:

Across the System undergraduate students are engaging in authentic research experiences and community-engaged research initiatives that are benefitting the region and the state.

The opportunity to participate in research, development, and commercialization activities is highly attractive to

undergraduate and graduate students, and many faculty across the System are effectively integrating research with instruction, including community-engaged research on problems of specific local interest. In the various listening sessions conducted during the development of this plan, faculty shared many examples of such student experiences. However, this student involvement is not as widespread or systematic as would be necessary to attract many more students to System institutions, and help retain them.

Recommendations:

First, the System must provide leadership in incentivizing and enabling every undergraduate student in the University of Maine System to have a meaningful/authentic experience in research, scholarship, development, creative production, policy analysis, translation, or commercialization. System Program Innovation Funds should be considered as a resource.

Second, Course-based Undergraduate Research Experiences and other similar evidence-based courses should be piloted and evaluated across the System according to campus capacity and interest, and supported with campus resources. Impact on recruitment, enrollment, and retention will be assessed, as well as the ability of students to obtain paid summer internships and employment after graduation, and whether students remain in, or return to Maine.

Finding Five:

The private and nonprofit sectors and the Maine state government are eager for expanded R&D interactions with higher education.

Private-sector entities already partner in R&D relationships with several System universities, with a large number at the University of Maine. External companies considering moving to Maine also have expressed great interest in partnering with the University of Maine System to extend their R&D capabilities for those interested entities. However, sometimes locating the best System research experts and gaining access to R&D capabilities are challenging. If UMaine and other System institutions were more easily able to partner with private-sector industries and businesses, we could tap a great source of economic stimulus in the state and provide opportunity for student interaction.

In the context of a dispersed and locally driven ecosystem in Maine for economic development, University of Maine System faculty and staff are deeply engaged in efforts to support commercialization, business development, incubation, and private-sector needs in R&D. The System has ample capacity to grow research partnerships with the private sector, as well as commercialization outputs of university research (e.g., spin-offs, revenue, and intellectual property.) As with research expenditures, the System has room to grow industrial contract income, licensing revenue, invention disclosure, and patent production, as well as the number and types of startup companies spun off from university research. Those efforts could be expanded with potential impact statewide. And, in areas of policy and business that are key to the state, including ecosystem health, health care, education, aquaculture, marine resources, and biomedical and biotechnology applications, the System institutions already are positioned, because of the breadth of their research expertise, to more systematically provide background information and analyses to the state and to the members of our federal delegation.

Recommendations:

The universities should continue to work closely with the private and government sectors to establish productive collaborations. Approaches to consider should include the creation of a Maine R&D Fellows program designed to connect System faculty, state government, Maine's federal delegation, and potential private/nonprofit partners to work collaboratively.

Second, the University of Maine should undertake a high-level review of existing doctoral programs in the STEM fields. The review should consider how program emphases align with current and projected state economic and R&D needs: whether basic, discovery research is sufficiently supported, and whether new directions in science and technology, including convergence, machine learning, and shared data sets, are being incorporated. Program consolidations, examination of how new programs are developed, and other realignments should be undertaken to lead to increased

production of doctoral degrees — an important part of building R&D capacity.

Third, research commercialization outputs as measured by revenue, intellectual property production, and university spin-off companies, business incubation and acceleration, and formal partnerships with industry should grow significantly during the plan's implementation phase. Revenue targets should be set to grow significantly and the number of formal partnerships and spin-off outputs should double by 2025.

Finally, System institutions will engage in more robust communication of System R&D accomplishments statewide and nationally. As the Governor's economic development plan is completed, System universities should seek the best ways of providing capacity to that plan through strategic interactions with the Governor and the Maine Legislature in identifying and responding to changing priorities needing R&D inputs.

Conclusion

The University of Maine System is committed to the improvement of quality of life and economic success of the state of Maine. Strategic expansion of research and development across the institutions of the System will have a direct impact on that quality of life and economic success. The success of the research and development enterprise across the University of Maine System depends, ultimately, on the creativity, innovation, and productivity of the individuals and groups engaged in R&D. Their successes are essential in helping Maine's learners have access to the best research-based education possible; obtaining external funding for research that will impact Maine and the world; sustaining the quality of research facilities, instruments, and technical staff; and fully integrating research and instruction. We must make shifts in policies, practices, and resource allocations in the System, and partner strategically with the Maine Legislature, the Office of the Governor, education systems in Maine, and the private sector. This will enhance the abilities of our faculty, students, and staff to be the regional, state, national, and international leaders in research that they are qualified to be, to benefit the learners and all people in Maine.



Introduction

Consider the following:

- **The state of Maine ranks 51st among U.S. states, Puerto Rico, and the District of Columbia in higher education research and development expenditures, at \$100 million.ⁱⁱⁱ**
- **The state of Maine ranks 45th among U.S. states, Puerto Rico, and the District of Columbia in total research and development performance with a total expenditure of \$508 million.^{iv}**

Research and development (R&D) expenditures are directly tied to leading indicators of a state's economic health — employment, wages, prices, and productivity. To address the University of Maine System (the System) Board of Trustees' priority to advance workforce readiness and economic development, it is imperative to develop and implement sound strategies to increase higher education research and development expenditures in Maine, and to support business and federal R&D performance increases in the state.

The context is complex, and the plan proposed here is multi-faceted and long-term. The proposed goals to guide this strategy are:

- Make Maine the most desirable state in the nation in which to live, work, and learn by 2030.
- Establish an innovation-driven Maine economy for the 21st century.
- Prepare the knowledge-and-innovation workforce for Maine.

Background

The University of Maine System, with its seven distinct campuses, its more than 5,000 employees, its 28,040 students, and its \$550 million overall budget, is a vital and vibrant asset to the state of Maine. As the heart of the state's public system of higher education, the students, faculty, and staff at the System campuses are defining the future of Maine. Our institutions provide a broad suite of educational programs designed to prepare future generations of professionals, leaders, and innovators for our state and beyond. Here, we propose a framework for research and development for the System.

The University of Maine, the state's only public research university, has a comprehensive portfolio that addresses the most challenging problems of our time (i.e., "grand challenges") through basic and applied research, development, and commercialization, with direct impact in Maine. We emphasize the importance of basic, foundational research in this context, knowing that the applications of the new knowledge generated from those research programs will provide as yet unimagined benefits to our state and our society in the decades to come.

The University of Southern Maine (USM) provides research leadership in economic, social, environmental, health, and workforce development policies that advance the state's economy. With its greater Portland location, USM advances workforce development and applied learning, and tackles the pressing community and state policy issues important to Maine people. The University of Maine at Augusta, the University of Maine at Farmington, the University of Maine at Fort Kent, the University of Maine at Presque Isle, and the University of Maine's regional campus, the University of Maine at Machias, all add vital and distinctive opportunities for geographic and place-based R&D specialization, where researchers and students, in partnership with their communities, strive to find solutions to important challenges statewide.

Charge

On December 18, 2018, the UMS Board of Trustees endorsed a "Declaration of Strategic Priorities to Address Critical State Needs." The first of its four goals for the System is:

Goal One: Advancing Workforce Readiness and Economic Development

The state of Maine's declared higher education public policy requires UMS universities to cooperate among themselves and with Maine businesses to develop educational programs that produce critical thinkers with adaptable, transferable skills who will advance the Maine economy. Given Maine's demographic and economic challenges, and workforce needs, UMS must strategically manage a collaborative, student-centered public higher education system that maximizes learner employability, and economic opportunity and development. It is characterized by flexible, 21st-century lifelong learning opportunities, business and economic development, and research that drive economic innovation, all derived from effective partnerships and continuous feedback among students, parents, public education systems, policy makers, and employers."

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The Board further specified the action to: "Strengthen research and economic development efforts to support Maine industries, and to foster business formation and expansion," with a deliverable of a "multi-year plan for prioritizing expanded research and development across the University of Maine System."^{vi}

This document is the deliverable specified by the Board. The process of its development is described in Appendix A.



Historical highlights: Research and development in the University of Maine System

University of Maine

The University of Maine (UMaine), founded as the Maine State College of Agriculture and the Mechanic Arts in 1865, carries the charge to “promote the liberal and practical education of the industrial classes.”^{vii} UMaine was established as the state of Maine’s land grant institution, maintaining this status into the modern System era. This mandate was historically focused on agriculture and engineering, an orientation strengthened by the 1887 Hatch Act that directed land grant institutions to share “information gleaned from the experiment station’s research to the state.”^{viii} Experiment stations were an expansion of the traditional educational mission into the domain of research. As noted in a 1995 report on agricultural colleges prepared for the National Academies Press, “the 1862 Morrill Act had tasked land grant colleges with the education of future generations. The 1887 Hatch Act formally introduced research to their suite of activities.”^{ix}

Research and education naturally led to arenas beyond the agriculture and mechanic arts first envisioned at the institutions’ founding nationwide. Arthur Andrew Hauck, president of UMaine from 1934 through 1958, also was one of the foremost historians of the early era of the university’s history. In his 1954 work “Maine’s University and the Land-Grant Tradition,” Hauck describes how the university evolved to “maintain strength in those courses which seem best adapted to the resources and needs of the State. [This led to the] establishment of a department of Forestry, in 1903, and of a course in Pulp and Paper Technology in 1913.”^x Under Hauck’s leadership, the university developed a Department of Industrial Cooperation, intended to make “research staff and facilities available to Maine industry.”

Collaboration with industry in the service of the state has continued ever since. The ongoing role of the University of Maine in linking educational and economic development pursuits can be seen in the recent, well-received report *Forest Opportunity Roadmap/Maine*.^{xii} This is a framework for a public-private partnership, designed to ensure the economic future of Maine’s forest industry. Research is at the core of this plan and statewide implementation is underway.

The time is right to consider similar initiatives, in such areas as aquaculture, agriculture, and the biomedical fields in order to expand partnerships to enhance the Maine economy through R&D.

Land grant universities have unique responsibilities. Educators at these institutions also must drive research efforts, and researchers must be engaged as teachers. The knowledge generated in these twinned pursuits is of practical use to the state. Today, the University of Maine is a land grant and sea grant university, maintaining the mission of educating our state's learners in the context of internationally recognized research serving Maine. Additionally, University of Maine Cooperative Extension's local engagement with communities, farmers, small businesses, and youth catalyzes community-driven research and development in Maine statewide.

Today, UMaine's R&D strengths are in engineering; marine sciences; science, technology, engineering and mathematics (STEM) education; climate change; advanced materials for infrastructure and energy; forestry and the environment; data science; sustainability solutions and technologies; finance; Northeastern Americas humanities; and aging.^{xiii}

The University of Maine at Machias (UMM) was founded in 1909 as a normal school to prepare teachers, as advocated for by the citizens of

Machias.^{xiv} UMM became a degree-granting institution in 1952 and joined the University of Maine System in 1968, where continued public advocacy transformed the school into a four-year degree-granting institution, with strengths in biology and science, as well as education. UMM became a regional campus of UMaine on July 1, 2017. Research interests include aquaculture, geospatial sciences, biology, and psychology and community studies.

University of Southern Maine

The University of Southern Maine provides leadership to enhance Maine's future through innovative economic, social, environmental, health, and cultural research, and workforce

development policies and initiatives to help drive the state's economic prosperity. The university was founded as a teachers college in Gorham in 1878. At the end of 1918, Portland University was established as a school for accountants. From these two institutions, the modern University of Southern Maine was born. Billing itself as "northern New England's outstanding public, regional, comprehensive university," the University of Southern Maine is "dedicated to providing students with a high-quality,

accessible, affordable education.

Through its undergraduate, graduate, and professional programs, faculty members educate future leaders in the liberal arts and sciences, engineering and technology, health and social services, education, business, law, and public service."^{xv} With a research legacy that stretches back to its time as the University of Maine Portland-Gorham, the University of Southern Maine has long distinguished itself in multiple fields. Current research activities "promote knowledge, discovery, and creative solutions that advance Maine's economy, communities, and the quality of life for all Maine citizens; strengthen classroom education and transform the lives of students through real-world learning opportunities; and support faculty and staff commitment to excellence in scholarly accomplishments regionally, nationally, and internationally."^{xvi}

Research interests at the University of Southern Maine include domestic violence, children in danger, the opioid crisis, strategic tourism and hospitality, elder health policy, research compliance, marine science, education, environmental entomology, survivability of Maine rural hospitals, and the economic development of Maine cities and towns.

University of Maine at Augusta University of Maine at Farmington University of Maine at Fort Kent University of Maine at Presque Isle

The University of Maine at Augusta, founded in 1965 by the Maine Legislature, was intended as a community-based,

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two-year degree program for the University of Maine. It quickly developed into an institution offering two- and four-year degrees in the University of Maine System, and today operates at campuses in Augusta and Bangor, as well as online.^{xvii} Research interests of the faculty include sociology, aging, psychology, criminal justice, community-based participatory research, mental health and human services, biology, and bioethics.

The University of Maine at Farmington (UMF) was founded in 1864 as the first public normal school in the state of Maine, with a mission to train educators. Joining the University of Maine System in 1968, UMF retained its public liberal arts orientation (it is a founding member of the Council of Public Liberal Arts Colleges) and added a graduate program in education in the first decade of the 21st century.^{xviii} Research interests of faculty include early childhood education, instructional technology, experiential learning, literacy, biology, aquaculture, and K–12 education.

The University of Maine at Presque Isle was founded as the Aroostook State Normal School in 1903 and joined the University of Maine System in 1968, assuming its current name in 1971. From its early mission of educating teachers,

the institution has evolved to offer a suite of undergraduate degrees, both in-person and online.^{xix} Current research areas of the faculty include agriculture, biology, forestry, predictive analytics, geology, earth and environmental sciences, and STEM education.

The University of Maine at Fort Kent (UMFK) was founded in 1878 as the Madawaska Training School. Operating from several locations, it landed in its permanent home in 1888. As the school evolved into a four-year degree-granting institution, it joined the University of Maine System under its current name in 1970 and added an array of liberal arts majors to its traditional strengths in education.^{xx} Research interests at UMFK include forestry, biology, and rural development.

A wealth of examples demonstrates the growth and evolution of the System institutions in synergy with the needs of the state of Maine. In the writing of this plan, it became clear that development of new knowledge and understanding across fields, research-based partnerships with communities and the private sector, and commitment to solving problems for Maine resonate throughout the System.





The Role of Research Universities

U.S. research universities emerged in the post-Civil War years, and much has been written about their role.^{xxi} A key development was the recommendation of Vannevar Bush (1945) that the United States government should provide federal funding to support science in the nation's research universities. He wrote: "First, we must have plenty of men and women trained in science, for upon them depends both the creation of new knowledge and its application to practical purposes. Second, we must strengthen the centers of basic research which are principally the colleges, universities, and research institutes. These institutions provide the environment which is most conducive to the creation of new scientific knowledge and least under pressure for immediate, tangible results. ... It is only the colleges, universities, and a few research institutes [in contrast to research in industry and government] that devote most of their efforts to expanding the frontiers of knowledge. ... Basic scientific research is scientific capital."^{xxii}

U.S. universities and the U.S. system of graduate education in research are regarded as the best in the world. Jason Owen-Smith provides an argument for these

universities as a public good: "Universities contribute to our quality of life because they are sources of key inputs for the many other sectors. They use public investments to support work that generates knowledge and people who know how to use it."^{xxiii} Public land grant universities comprise a major component of that system, and are the places where, in addition to basic research, a large proportion of more applied work is conducted to solve immediate problems in their states and regions.

A thriving university-based research and development enterprise is distinguished by, and requires, a number of elements: substantial university investment to enable a comprehensive research enterprise; research and scholarship in broad and diverse areas — from science and engineering to social sciences, arts, and humanities; an extensive portfolio of research-oriented graduate programs, including doctoral programs in a wide variety of fields; state-of-the-art research facilities, including large centers and institutes; faculty research performance counted as a major factor in their evaluation; and faculty, staff, and students from across the levels and units at the university, engaged in significant

research.^{xixiv} Research universities typically include clusters of nationally and internationally known faculty working across their disciplines on discovery, on grand challenges, and on science and engineering solutions to pressing problems; cohorts of excellent graduate students at the Ph.D. level to expand the faculty reach, become expert in needed new techniques, and bring innovative thinking to discovery and problem solution; industry partners to enable translation of research for economic impact, and to frame new research questions driven by practice; and state-of-the-art facilities to allow experiments, technique design, testing, and development. This collection of attributes is essential to the federal funding that is necessary for research universities to thrive.

In a comprehensive research university, social scientists, humanities professors, and leaders in the arts all have crucial roles in contributing to the development of the knowledge and understanding that will move our state and our society forward. Often research in those fields is supported by the institution and other sources, both private and public.

The state of Maine is home to a single public research university, the University of Maine. UMaine is the only public university in Maine categorized as a doctoral university by the Carnegie Classification; it is an “R2: High research activity university.” For comparison purposes, of the other New England land grant universities — the University of Massachusetts at Amherst, the University of Connecticut, and (as of January 2019) the University of New Hampshire — are categorized as “R1: Very high research activity” universities.

The University of New England also is classified as R2 after recent methodological changes allowed professional doctorate degrees to be counted in the Carnegie classification.

UMaine faculty and staff have convened to address needed steps that would lead to R1 designation, a result that is important for the entire state relative to increasing R&D expenditures, and to all universities in the System in terms of collaboration through faculty, students, infrastructure, and support for research on the campuses.

Research, Development and Commercialization

Because of the history in Maine of connecting university-based R&D to state economic needs, and the charge for this

plan, there will be special focus on science and technology R&D, using the national indicators and metrics available in that area.

Definition and Context

This plan is focused on research and development to propel the economy, and train the workforce for Maine and beyond. In the interest of clarity, we provide a definition of research and development that is employed by the National Center for Science and Engineering Statistics (NCSES) of the National Science Foundation (NSF), the federal statistical agency that tracks national and state indicators of R&D in science and engineering, and provides national rankings and benchmarking data. The NCSES definition reads: “R&D is creative and systematic work undertaken in order to increase the stock of knowledge, including knowledge of humankind, culture, and society, and to devise new applications of available knowledge. R&D covers three activities defined below — basic research, applied research, and experimental development.”

- Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view.
- Applied research is original investigation undertaken in order to acquire new knowledge. It is directed primarily toward a specific, practical aim or objective.
- Experimental development is systematic work, drawing on knowledge gained from research and practical experience, and producing additional knowledge, which is directed to producing new products or processes, or to improving existing products or processes.^{xxv}

Throughout the University of Maine System, there is excellent work underway in all of these categories and beyond. The University of Maine, which has achieved extensive results in all three areas, has distinctive strength in basic and applied research. The University of Southern Maine has prioritized and built strength in experimental development, policy analysis, and technical assistance. Campuses across the System are engaged in geographically situated work, much of it in the applied research category.

Research Expenditures

The most common indicator used to assess the research health of an institution of higher education is total research expenditures, which include both federal and non-federal funds. These “dollars spent” in a given fiscal year are categorized by source of funds (i.e., federal government, state and local government, business, nonprofit, institutional, and other) in a survey of institutions conducted by NSF’s NCSES, with clear definitions and conditions for what can be reported to ensure consistency across institutions. NCSES also gathers and reports data on state and private-sector research expenditures.

The top-ranked research institutions in the country in 2003 accounted for 25 percent of the research expenditures nationally; in 2015, that dropped to 18 percent. Less research-intensive universities typically have had more state and local support to drive up their research expenditures and, thus, their capacity to contribute.^{xxvi}

Today, the University of Maine research and development enterprise, as measured by the standard NCSES Higher Education Research and Development (HERD) Survey on total R&D expenditures in 2017, is ranked 155th among 902 academic institutions surveyed. UMaine ranks lowest of all of the New England land grant universities in total R&D expenditures. The most recent HERD Survey results for Universities of Maine System institutions are in Table 1. These are important because they allow for national benchmarking in the science and technology areas that are most central to economic growth.

Research and development expenditures in a university are derived from spending on basic and applied research, and development, as defined earlier in this document. Commercialization expenditures also are critical to university research impact, but are not tracked in the HERD survey. Those activities as enacted in the System are described next.

**NSF Higher Education Research and Development (HERD) Survey Results,
University of Maine System institution research and development
expenditures in thousands**

	2013	2014	2015	2016	2017
UMaine 2017 Ranking*=155	77,583	101,247	79,500	79,222	99,502
USM 2017 Ranking*=364	11,725	9,408	7,091	4,773	7,147
UMM 2017 Ranking*=696	379	384	Not reported	Not reported	737
System total**	89,687	111,039	86,591	83,995	107,386

*Out of 902 total institutions. By comparison, UNH, 133; UVM, 144; URI, 152; UNE, 350; Bowdoin College, 494; Colby College, 512; Bates College, 534; MMA, 547.

**UMA, UMF, UMFK, and UMPI did not report research and development expenditures to HERD. This plan recommends that improved data governance practices be implemented in order for UMS to more accurately and completely report research expenditures to NSF HERD.

Table 1. NSF Higher Education Research and Development (HERD) Survey Results, University of Maine System institution R&D expenditures in thousands ^{xxvii}

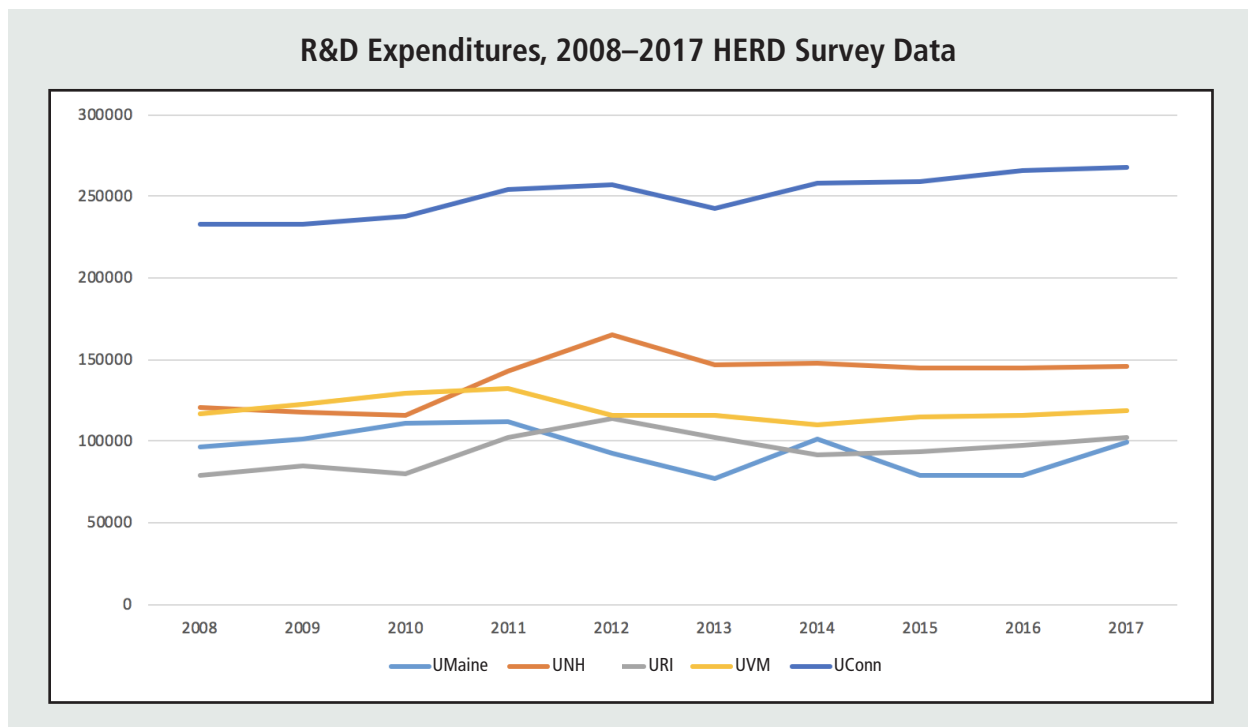


Figure 1: Research and development expenditures for select New England institutions according to HERD data

For comparison purposes, we display HERD research expenditures for select New England institutions in Figure 1.

Basic and Applied Research

For additional framing of the research enterprise and how work can be categorized, we recommend the formulation in Stokes' Pasteur's Quadrant,^{xxviii} which introduces the notion of "use-inspired basic research" (see Figure 2). This includes "basic research that seeks to extend the frontiers of understanding but is also inspired by considerations of use."^{xxviii} He also describes this as "strategic" research.

Stokes provides a historical perspective that draws on the formulation of basic, applied, development, and production research offered by Bush, the engineer whose thinking inspired the founding of NSF. Debates and philosophical discussions endure about whether pure and applied research are distinct. Bush notes "... new products and new processes do not appear full-grown. They are founded on new principles and new conceptions, which in turn are painstakingly developed by research in the purest realms of science."^{xxix} In this discussion of research and development

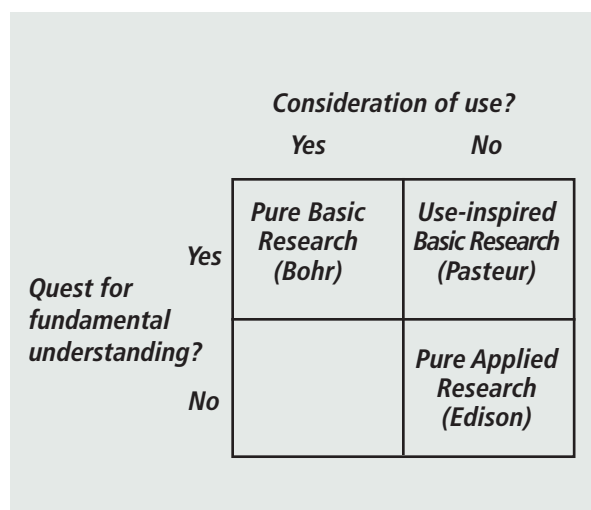


Figure 2: Quadrant Model of Scientific Research^{xxx}

that will be useful to the state of Maine, we also strongly support the importance of basic (pure) research, both as the foundation for new applications and as needed when new questions arise in applications.

Development

In the research enterprise, development incorporates the translational efforts to bring research findings and discoveries to implementation in the form of processes and

products. In the biomedical field, this is referred to as “bench to bedside,” and an important analogue exists for much of the research conducted in the state. Ongoing development is necessary to transform material science into material products, biogenetics laboratory breakthroughs into cures for disease, engineering insights into engineering practices, and chemical discoveries into chemical products. In experimental development, research knowledge is “directed to producing new products or processes or to improving existing products or processes.”^{xxxii}

More broadly, development supports the growth and vitality of the state’s economy. Research and experimental development within research universities play a central role in the growth of the economy.

Commercialization

The state of Maine ranks 40th in Milken Institute’s State Technology and Science Index ranking,^{xxxiii} a measure of states’ capacity in technology and science, and the state commercialization ecosystem. Commercialization is about the conversion of university-developed intellectual property to private-sector application. Channels for that conversion include technology transfer, patenting and licensing, consulting, new spin-offs, and other approaches to bringing

to market knowledge and solutions that have emerged in research, and have been tested and refined in experimental development across the “valley of death” — the gulf between viable science and viable commercial development. One kind of return on investment from basic and applied research is that which can be realized in new products and services brought to market, commercial revenue, academic spin-off companies, externally formed entrepreneurial activities, and licensing revenue.^{xxxiii}

In Figure 3, we indicate productivity in this area over time at UMaine, the primary producer of intellectual property outcomes in the System.

All major research universities have well-developed infrastructure to support scientists in preparing invention disclosures, filing patents, developing license agreements, and offering access to incubators and business accelerators. Such capacity is being developed at the University of Maine, and as it grows it will link the research activities at UMaine and elsewhere in the System to the economic development of Maine. The primary emphasis of UMaine’s commercialization activity has been developing partnerships for contracted research and commercialization, and providing entrepreneurial support to encourage spin-off and startup activity. A 2017 UMaine commercialization report^{xxxiv}

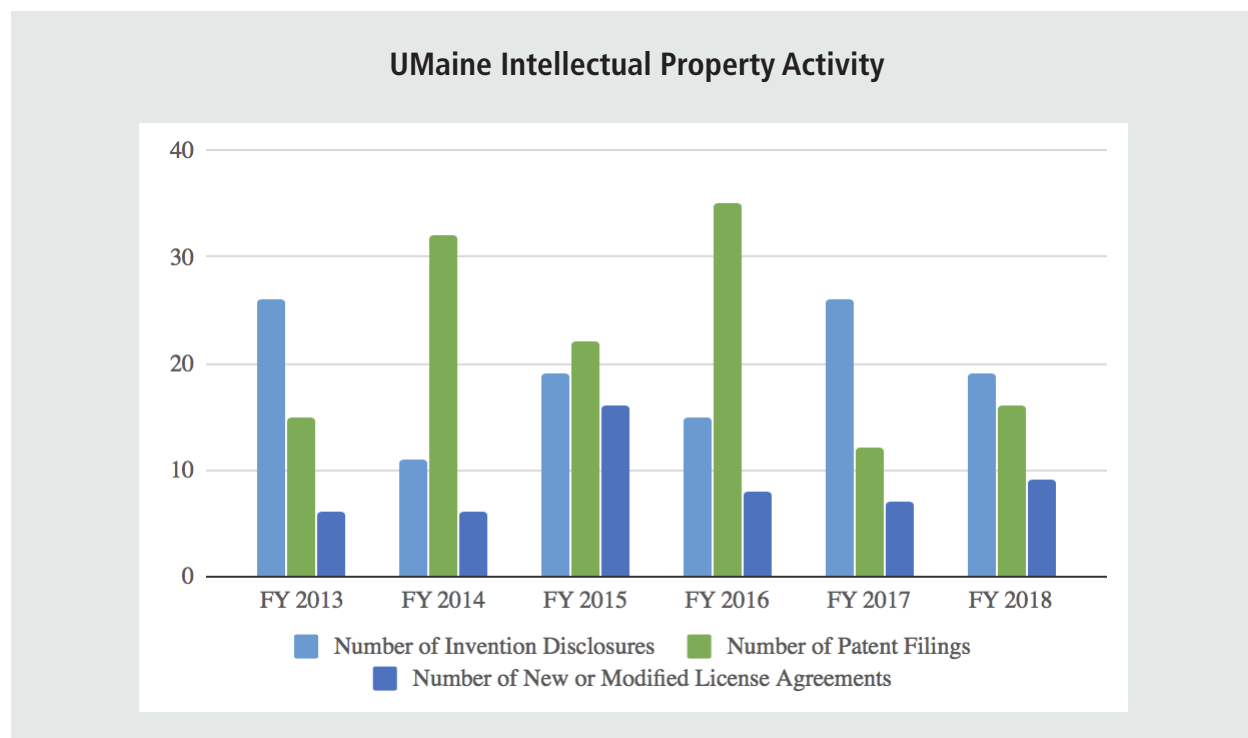
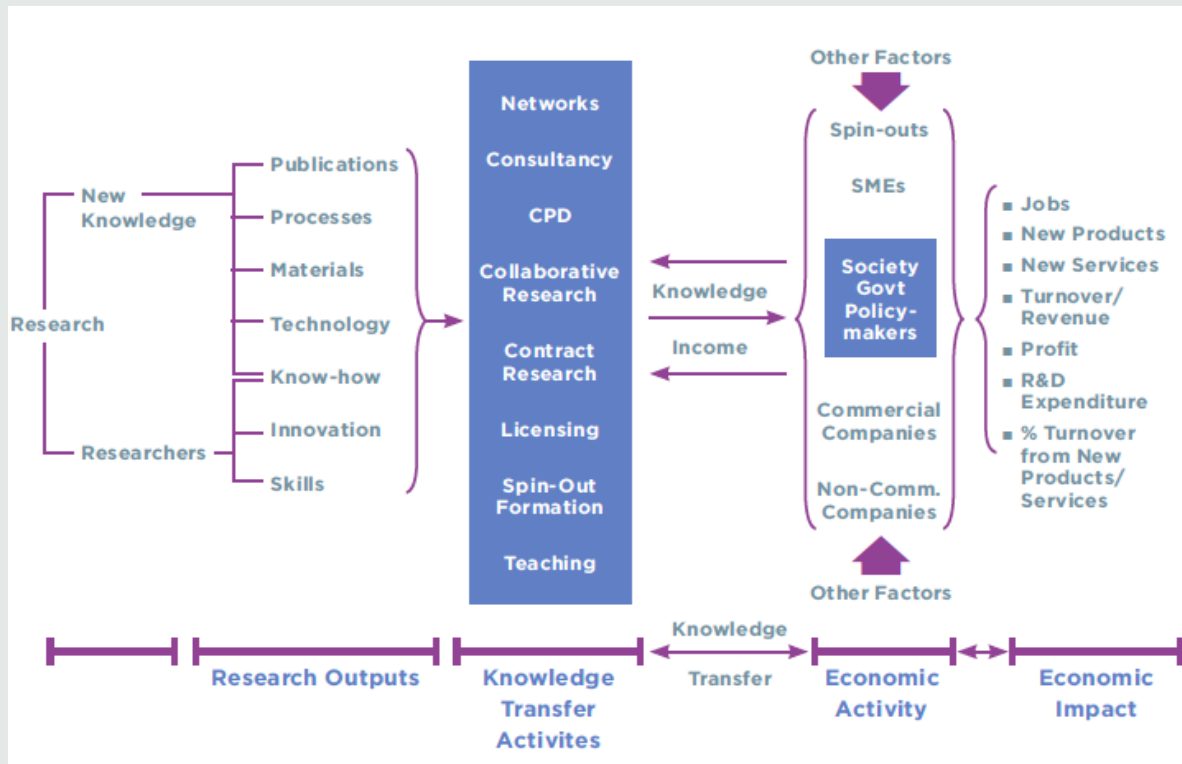


Figure 3. UMaine Intellectual Property Metrics

Logic Model of University Knowledge Transfer



Source: University of Glasgow. In Holi, M., Wickramasinghe, R., van Leeuwen, M. (2008). *Metrics for the Evaluation of Knowledge Transfer Activities at Universities*. Cambridge Library House.

Figure 4. Logic Model of University Knowledge Transfer

offers recommendations for the campus that are being implemented now to enhance capacity in this area. The UMaine President's Innovation and Economic Development Council (IEDC) was formed to actively address policy, practice, culture, and outreach issues to advance commercialization in the University of Maine System.

Figure 4 represents a logic model that the University of Maine is examining in an effort to further articulate the economic impact of university research.

Summary: Research, Development, and Commercialization

In the next Figure, we provide a graphic to convey the complexity of the cyclical innovation continuum for research,

development, and commercialization. Often this is rendered a linear pathway, as in the classic characterization credited to Bush in 1945. However, in the rich environment of the System and the state, the feedback and feedforward loops are in place, and we have developed some capacity in development and demonstration, as well as commercialization. Especially important to this are the programs and capacity of UMaine's Office of Innovation and Economic Development, the University of Southern Maine Small Business Development Center and Center for Entrepreneurship, and, going forward, the System's Maine Center Ventures.

Funding for Research, Development, and Commercialization in System Institutions

The U.S. National Science Board reports in its *Science and Engineering Indicators 2018* that “academic institutions conduct just under half of the nation’s basic research and, importantly, train young researchers in the process.”^{xxxix}

In Maine, universities are responsible for about 25 percent of research expenditures in the state. The remainder comes from the private sector and state government. In this section we focus on higher education R&D.^{lxvii}

Funding and investment in R&D in higher education come from multiple sources, and the investment from those combined sources leads to research expenditures. Externally sponsored research awards fund specific work on particular studies, topics, or defined activities in universities. Across the

System, externally funded sponsored research is most heavily concentrated at UMaine, then at the University of Southern Maine, and then in smaller amounts across the other System campuses.

Over the past two decades, the state of Maine R&D appropriation has provided critical support to the University of Maine System, most significantly through the Maine Economic Improvement Fund, debt service and bonds for System research and development facilities, and the Maine Technology Institute^{xxxv} to catalyze commercialization. The System provides essential investment through the Research Reinvestment Fund (RRF). The universities themselves, primarily UMaine, invest educational and general fund (E&G) resources in their research enterprises. And two key federal

Cyclical Innovation Continuum

Research, Development, and Commercialization

Lack of adequate funding in the “valley of death” can potentially kill a project before it makes it to production and public access.

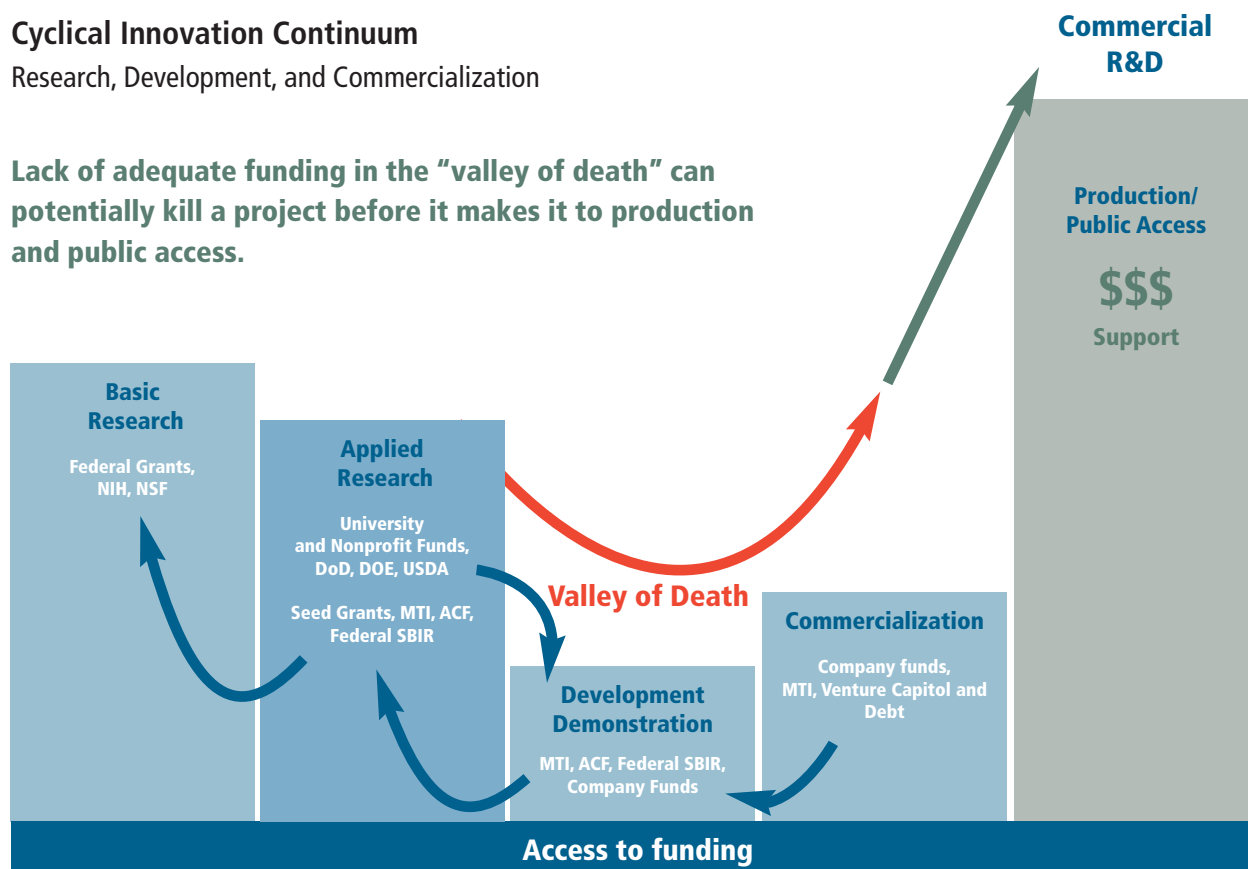


Figure 5. Cyclical Innovation Continuum for Research, Development, and Commercialization

sources — The Established Program to Stimulate Competitive Research (EPSCoR) and the Institutional Development Award (IDeA) Network of Biomedical Research Excellence (INBRE) — are mentioned here because of their importance in building research capacity across System institutions and at other research institutions, colleges, and universities in Maine.

Maine Economic Improvement Fund

The state created the Maine Economic Improvement Fund in 1998 to “administer investments in targeted research and development and product innovation and to provide the basic investment necessary to obtain matching funds and competitive grants from private and federal sources. ... Research and development means applied scientific research and related commercial development conducted by the University of Maine System, its member institutions and its employees and students in the target areas.”^{xxxvi} The intention was to ensure the future vitality of the state’s economy by investing in the research capacity of the University of Maine

System within the Legislature’s seven targeted technology sectors: aquaculture and marine sciences, biotechnology, composites and advanced materials technologies, environmental technologies, information technologies, advanced technologies for forestry and agriculture, and precision manufacturing. Initial appropriations were for \$4 million from the 1998 budget surplus.

The investments expected to produce such outcomes as the attraction of world-class researchers and increased external funding, leading to new statewide economic opportunities spurred by research innovations in partnership with Maine’s private sector. In FY18, the state’s \$17.35 million MEIF investment was leveraged at a rate of 3.6:1 by System campuses for an additional \$62.35 million in federal and private-sector grants and contracts in the seven sectors. UMaine and the University of Southern Maine are the two universities with established research and graduate programs in the seven targeted research sectors. UMaine has received 76.4 percent of the MEIF funds; USM 19.1 percent. Of the remaining MEIF funds, 1.4 percent are distributed to the University of Maine at Machias and 3 percent go to the other System campuses and Maine Maritime Academy.^{xxxvii}



The MEIF investment has been absolutely critical to building System capacity to support state economic development over the past 20 years. Through the MEIF investment in research capacity, the System enabled cluster faculty hires, and supported the design of new programs and associated facilities with the goal of maximizing economic impact in Maine. These programs are competitive for the federal funding that enables the universities to develop and support their science and technology research, as well as their broader scholarly missions. These resources also provide critical laboratories, facilities, and capacity that Maine businesses do not have, and help fill a gap in Maine's R&D landscape that has few corporate headquarters where industry R&D typically takes place. Furthermore, these programs attract and involve students in real research applications as part of their education. MEIF increasingly fosters university partnerships with business and industry through economic development collaborations, entrepreneur training programs, business incubators, technology accelerators, business research, educational partnerships, and other programs. These efforts lead to new Maine-based products, technologies, patents, and spin-off businesses, in addition to enhanced workforce development.

Specific outcomes of MEIF funding include:

- Increased by 60 percent the number of industry contracts with the System for R&D and innovation assistance in the last 10 years, with more than 850 Maine companies and organizations served since MEIF began.
- Created more than 20 new businesses specifically to commercialize university technologies since 1999.
- Supported approximately 500 full-time System faculty and staff with R&D expenditures in FY18.
- Filed more than 250 U.S. and international patents in the last 15 years.
- Trained undergraduate and graduate students for jobs in Maine, with 268 graduate students and 610 undergraduate students receiving more than \$6 million in student wages, tuition, and health insurance covered by research funding, grants, and contracts in FY18.

The MEIF investment tracks in parallel with the HERD R&D expenditures (see Figure 6).

In summary, the wisdom and foresight of the Maine Legislature in creating MEIF has paid dividends for economic development in the state of Maine.

Growth of R&D Activity in Maine

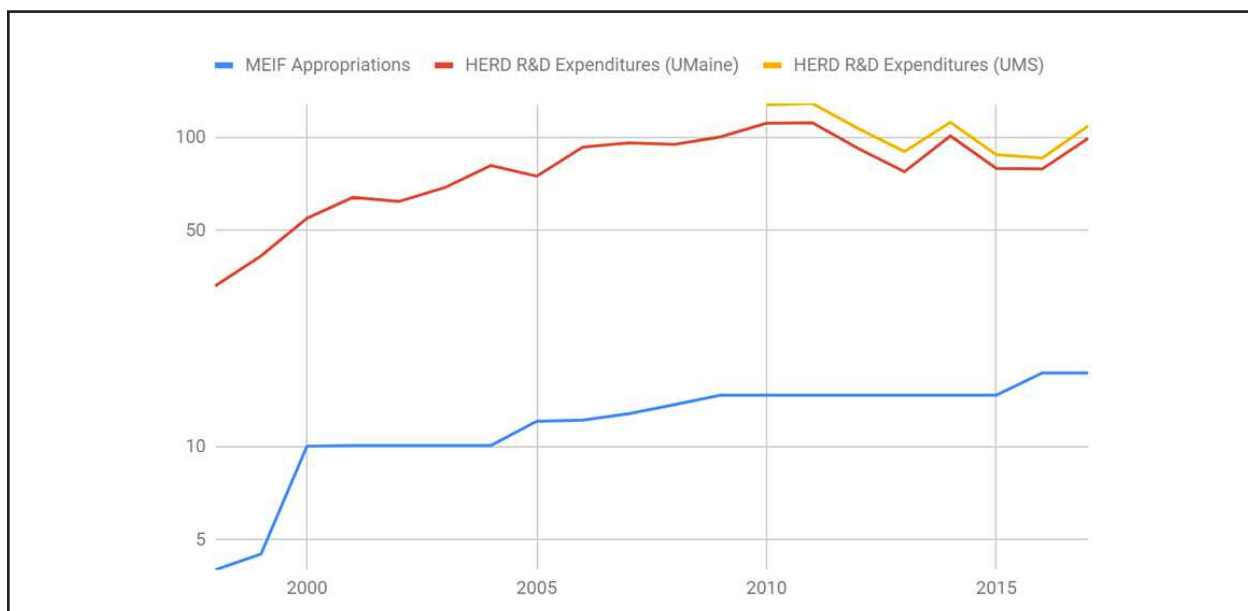


Figure 6. Growth of R&D Activity in Maine

University of Maine System Research Reinvestment Fund

Complementary to MEIF is the System-initiated Research Reinvestment Fund. The Board of Trustees committed \$10.5 million for this initiative, \$2.1 million per year for FY15–FY19. RRF objectives are strengthening research, development, and commercialization activities that are tied to Maine businesses and to industries that are critical to the future of Maine. RRF has provided important resources to establish campus capacity to seek and manage external funding through the following initiatives.

Competitive/Seed Grant Funding to System Researchers

Since its inception in June 2015, RRF has received 454 proposals from researchers spanning all campuses. Of these applications, a total of 161 projects have been competitively selected by the RRF Advisory Board for awards totaling \$5,830,914 in grant funding. UMaine faculty have spearheaded 141 of these projects, with researchers on other campuses taking the lead on 20 projects and being actively involved as co-investigators on an additional 38 projects. This seed funding has led to \$18,188,442 in external grant dollars for a return on investment of 3.1 to 1. A total of 185 external entities were included as project partners, many of which are in the private sector and are Maine-based businesses. RRF-funded projects are aligned with various economic sectors, with the greatest investments made in aquaculture and marine sciences, education, biotechnology, environmental technologies, and advanced technologies for forestry and agriculture. The breadth of RRF funding reflects the sectors highlighted by the Maine Legislature, as well as signature strengths within the System. Sector representation includes MEIF-designated sectors, as well as sectors beyond MEIF that are of significant relevance to Maine's economy, such as education and healthcare.

Infrastructure Support to the Business Development Enterprise

RRF has provided funding to increase System capacity to meet strategic outcomes in the areas of business partnerships, technology transfer, and commercialization leading to economic development. The UMaine Office of Innovation and Economic Development, working with the

UMaine Office of the Vice President for Research and Dean of the Graduate School, piloted formal professional development and training for faculty and staff at UMaine, to be extended to universities across the System. UMaine also created the Maine Innovation, Research and Technology Accelerator to move RRF-funded and selected other projects closer to commercialization outcomes. In addition, UMaine secured funding from the National Science Foundation to establish Maine's first I-Corps site,^{xxxviii} to help faculty and graduate student teams identify market opportunities for their innovations. In addition, RRF allowed the Office of Innovation and Economic Development at UMaine to expand commercialization capacity within UMS, facilitating industry engagement and partnerships. This enables regular, systematic intercampus collaboration on economic development initiatives.

Infrastructure Support to the Research Enterprise

RRF investment enhances the research infrastructure System-wide through staff positions in the UMaine Office of Research Administration (ORA) and the Office of Research Development (ORD). ORA manages and administers extramural grants and contracts for UMaine, UMM, and UMFK, with discussions underway about providing similar services to UMA. ORD provides grant-writing services to faculty, primarily at UMaine, with a particular emphasis on interdisciplinary and large dollar-value grants. In addition, ORD staff conduct outreach to early-career faculty and support new researchers' ability to compete for extramural funds. In FY18, ORD staff conducted 38 separate training sessions, providing professional development opportunities to 330 faculty, staff, and students. In FY19, ORD organized the proposal development process of the \$20 million NSF EPSCoR RII – Track 1 submission, in collaboration with Bigelow Laboratory for Ocean Sciences, the University of Southern Maine, the University of Maine at Machias, and others. ORD staff also supported 12 NSF Early Career Development (CAREER) submissions and were key contributors to UMaine's first NSF National Research Traineeship (NRT) award that will train cohorts of graduate students to become the next generation of environmental conservation leaders.

Through our listening sessions on all System campuses in the preparation of this report, we learned that awareness of external funding opportunities, identification of and connections to R&D collaborators within the System, and professional staff support for research administration and



research development services are desired and needed to expand R&D. Because of these limitations, the System institutions are unable to compete each year for what we estimate to be many millions of dollars of external funding from primarily federal, but also state and private-sector sponsors. There are opportunities for multimillion-dollar interdisciplinary grants, equipment and infrastructure funding, early-career faculty research support, and training grants for undergraduate and graduate students for which System faculty could be actively and, we believe, successfully, competing. Additional grants produce facilities and administration dollars that can support infrastructure and operating expenses at the universities, and could provide employment and learning opportunities for students, faculty, and staff.

University Investment

The cost of having a thriving R&D enterprise on a campus is not fully supported by external funding and, thus, research expenditures for a university comprise more than dollars coming in from external grants. R&D enterprises require many other supports, including faculty salary; undergraduate and graduate student support for engaging in research; research facilities upkeep; startup research and laboratory funds for new faculty; cost-sharing and matches for grant proposals; compliance expertise and expenses; research administration; laboratory facilities; maintenance of field sites; instruments; deployment of data collection and sensors; post-award reporting; fiscal management of externally funded awards; and research support personnel.

Outcomes of Maine EPSCoR Awards










1980-1987	1990-1993	1993-1996	1996-1999	2000-2003	2003-2006	2006-2009	2009-2014	2014-2019
\$4.3M	\$5.5M	\$8.8M	\$9.4M	\$6M	\$6M	\$12.7M	\$24M	\$24M
								
Earth and Marine Science	Global Environmental Change	Wood Science and Marine Molecular Biology	Adv. Eng. Wood Composites and Aquaculture	Biosensors, Intel./ Spatial	Institute for Molecular Biophysics	Forrest Bioproducts	Sustainability Solutions Initiative	Sustainable Ecological Aquaculture Network
Ar-dating and Heat Flow Lab	Stable Isotope Lab	DNA-sequencing facility Timber Bridge/FRP Hybrids Project	Advanced Structures and Composites Center (formerly AEWCC) Aquaculture Research Institute (formerly Center for Coop. Aquaculture Research)	Intelligent Spatial Design Technology Institute (ISTI) housed at LASST	Institute for Molecular Biophysics	Forest Bioproducts Research Institute	Sen George J. Mitchell Center for Sustainability Solutions	Capacity of Aquaculture Research Institute strengthened with new Ocean Acidification Lab

Figure 7. Outcomes of Maine EPSCoR Awards

This requires direct investment of institutional E&G dollars. Because of its mission and scale, UMaine provides the largest relative commitment of institutional funds for R&D among the System institutions.

Maine Established Program to Stimulate Competitive Research (EPSCoR) and the Maine IDeA Network of Biomedical Research Excellence (INBRE)

In the development of this plan, EPSCoR and INBRE funding, in addition to MEIF and RRF, were referenced repeatedly by faculty across the System as being essential to their research programs and ability to support students.

Maine is one of 26 federally designated EPSCoR states/jurisdictions, meaning that “0.75 percent or less of total NSF research funds go to recipients within a jurisdiction, averaged over the preceding three-year period.” Among this cohort, Maine ranks 15th in terms of NSF funding.^{xi} Through the EPSCoR program, partnerships are developed in states among their higher education institutions, industry, government, and others to effect lasting improvements in their R&D infrastructure, capacity, and national competitiveness for research funding. Since 1980, Maine has received NSF EPSCoR funding totaling \$125 million, with oversight and coordination provided by UMaine. Highlights of accomplishments over these years

include \$117 million in follow-on grants for NSF-funded research; 36 patents, products, companies created; 43 faculty and 28 postdocs hired; 353 graduate students supported; and internships provided to 920 undergraduate and 239 high school students. Additionally, EPSCoR has facilitated the establishment of four research centers and three institutes. The infographic above illustrates the outcomes resulting from major EPSCoR awards over the last 39 years in Maine.

A second key source of research support has been INBRE, a collaborative network of Maine educational and research institutions led by MDI Biological Laboratory and sponsored by the National Institute of General Medical Sciences of the National Institutes of Health. Since 2004, INBRE has provided approximately \$7 million for System faculty and students, as well as collaborative activities in the life, biomedical, and health sciences fields. Currently, INBRE funds are supporting genetic and bacteriological research conducted by faculty from the University of Maine at Farmington and University of Maine. Past support has gone to researchers in genomics at the University of Maine at Machias and the University of Maine. Undergraduate research experiences are funded through the summer research fellowship program, open to students from across the System and other institutions of higher education in Maine.^{xii}



Goals to Drive the Expansion of System Research and Development

We propose the following goals for Maine, to serve as a focus expanded R&D across the System and in Maine, as well as to catalyze collaboration statewide:

- Make Maine the best state in the nation in which to live, work, and learn by 2030.
- Establish an innovation-driven Maine economy for the 21st century.
- Prepare the knowledge-and-innovation workforce for Maine.

These goals have a 10- to 20-year, long-term horizon, with expected near- and mid-term milestones and outcomes. Achieving these goals will require collaborative engagement

across the University of Maine System, with the Office of the Governor, the Maine Legislature, higher education and K–12 education, business and industry across the state, tribal governments, and communities and municipalities, as well as greatly enhanced and wider interaction with federal and private-sector funders.

Milestones included here focus primarily on initial efforts to be undertaken by the University of Maine System and its partners, and assume clear definition of individual campus roles, missions, and expectations within the R&D environment. For each goal we propose a metric and some key milestones as a basis for implementation efforts. Strategies and emphases will evolve as milestones are completed and as context changes.

Goal One:

Make Maine the best state in the nation in which to live, work, and learn by 2030.

We propose this goal as an aspiration to unify efforts across the System and beyond because of its breadth and importance for Maine, and its alignment to focused investment in R&D along several dimensions. Achieving this goal would require addressing several related “grand challenges” that focus on solutions to problems that affect people both locally and around the globe, such as energy, food production, and health and wellness. Many research universities across the country have organized grand challenge initiatives, allowing the integration of research, student learning, and public engagement to identify solutions that inherently require innovative and interdisciplinary approaches.^{xliii}

Maine can address its own grand challenges by cultivating a quality of life so compelling that people are drawn to move to, and remain in, Maine, contributing to its workforce, diversity, and communities. Maine has the opportunity to build a robust, inclusive infrastructure for livability, including autonomous and public transit, high-quality education and health systems, digital connectivity, cultural diversity and experiences, and abundant recreation. This goal also directly addresses the demographic challenges articulated in the Board of Trustees’ Declaration of Strategic Priorities. By investing in and elevating the status of the public higher education R&D enterprise, Maine will increase its ability to attract new and highly skilled talent for the innovation economy, as well as retain existing talent, of all ages, who currently choose to leave the state to pursue their careers.

One ranking of states’ “livability” is provided by *U.S. News and World Report*. The “Best States” rankings are based on metrics across categories of health care, education, economy,

opportunity, infrastructure, crime and corrections, fiscal stability, and quality of life. Maine currently ranks 22nd.

System institutions can address this goal and the related grand challenges through research and development that could lead to new jobs in biomedicine, renewable energy, and data science/artificial intelligence. Researchers and scholars can build models for inclusion to enrich Maine through diversity; develop strategies to reduce poverty;

expand recreation and tourism; provide cultural enrichment through the arts and humanities; and create media strategies to inspire young workers and families to move to Maine. We have researchers and students who would be very committed to these directions, but we currently lack resources to pursue them in a concentrated and strategic way.

We propose an initial list of grand challenges in support of this goal that align with current and needed research and development capacity. In the implementation of this plan, we hope that other grand challenges will be formulated and advanced.

Grand Challenge: Build a healthier Maine

Maine could become the healthiest state in the nation by squarely facing the many challenges arising from its aging population, stressed health care system, and lack of sufficient awareness of healthy choices. Strategies developed in Maine could be national models to transform how we address health challenges, especially in rural settings.

System institutions can contribute through research into new opioid addiction therapies, a cure for dementia, new biopharma solutions, precision health methods, models for delivering high-quality low-cost preventative health care, data discovery to support improved health, methods for creating transportation networks embedded within the healthcare system, models for understanding human and animal health and their connections, technologies for helping control vector-borne diseases, collaborative networks that

We have researchers and students who would be very committed to these directions, but we currently lack resources to pursue them in a concentrated and strategic way.

assist with healthy aging, sociological approaches to addressing mental and behavioral health issues, and media strategies for raising health awareness and encouraging healthy life choices. These directions fit within the current technology sectors of biotechnology, environmental technologies, and information technologies.

Grand Challenge: Strengthen education to increase opportunity

Maine deserves the best possible educational system in order to provide the most opportunity to its citizens, and it has a great foundation on which to build. In order to maximize opportunity for all in Maine, we must face substantial challenges, including a lack of resources, difficulty implementing the most effective educational methods at scale, the rural nature of our state, and teacher shortages in key areas. Ultimately, improvement in this area links directly to the preparation of a workforce for Maine, one that capitalizes on the multiple forms of diversity (socioeconomic status, race/national origin, ethnicity, gender, experience, family) for innovation and creative problem-solving. And it involves working closely with all education systems in the state to build on the many strengths of teachers and faculty, and to expand effective innovations and improvements that are underway.

System institutions can contribute to achieving these goals through research on learning and pedagogy to enrich education, from preK to seniors — research that must be done collaboratively with educators across the state. That research would help us better understand effective approaches to teacher preparation, including continuing professional development; the knowledge and skills needed by teachers to successfully enable all of their diverse students to reach their full potential, including those who come from poverty or are new to this country; models for reducing gender disparities in educational opportunities and completion rates; data-science-based approaches to improving learner success and graduation rates; techniques for increasing the integration between the arts and STEM education; impactful and innovative distance and online education; and professional development programs for teachers, counselors, and community educators. Education is a key area for community-engaged and action research, working with outstanding teachers across Maine on these challenges. Our institutions can enhance their engagement in the continuing development and support of educators; provide information on research-based best practices for effective education; promote integration across disciplines; collaboration networks that cross geographic and institutional boundaries; and develop enrichment opportunities through departments, colleges, research labs,



field sites, centers, and institutes. Research and development should be a resource in continued efforts to partner with school districts, across System campuses, with other Maine higher education partners, and with the Maine Department of Education to expand innovative strategies to improve schools. It might be advisable in the first phases to focus this work in the STEM disciplines, including computer science. Some of these initiatives would fit within the information technologies sector.

Grand Challenge: Empower rural sustainability

Maine's rural nature is both a challenge and an opportunity, necessitating the availability of education, employment, and community services, regardless of location. Expanded broadband and transportation infrastructure are critical to enabling Maine people to study and work anywhere, helping to close the income and opportunity gap between urban and rural Maine through access to expanding high-tech jobs.

System institutions can contribute to achieving these objectives through research on broadband technology, autonomous transportation, new technologies for effective distance education and collaboration, rural health care, aging in place, and the social dynamics of thriving rural communities. Additionally, such assets as Maine's quality of place, arts and cultural breadth, and our annual attraction of visitors through tourism, outdoor recreation, and seasonal residencies could be further studied in the context of economic development and rural sustainability. Many of these initiatives fit in the information technologies, biotechnology, aquaculture and marine sciences, and composites and advanced materials technologies sectors.

Grand Challenge: Address climate change and protect our natural resources

Maine is already a leader in developing new ways to reduce the progress and impact of climate change, understand the potential and vulnerabilities of our ecosystem, and protect our natural resources. We can continue to build on that leadership.

System institutions can contribute to achieving these goals through research and development about clean energy; carbon emission reduction technology; cost-effective electric vehicles; technology and policy solutions to changing

Arctic challenges; sustainable agriculture technology and practices; aquaculture; effects of ocean acidification on fisheries industries; economic models for balancing competing interests; approaches to help governments and schools be more green; and stewardship models for water, air, and marine environments. This work is encompassed in the environmental technologies, composites and advanced materials technologies, precision manufacturing, and advanced technologies for forestry and agriculture sectors.

Grand Challenge: Make Maine the Northeast's premier food basket

Maine's food production capability could be expanded by increases in aquaculture and extension of the growing season, providing both economic opportunity and a mechanism for eliminating hunger in Maine. System institutions can contribute to achieving these goals through research on effective hydroponics, low-cost solar technology, greenhouses, sustainable farming methods, diversified fishery management, and innovative forest products. System institutions have long-standing strengths in many of these fields and are poised to continue their significant contributions. The sectors addressed are aquaculture and marine sciences, and advanced technologies for forestry and agriculture.

The proposed grand challenges set the System on course to continue advancing the needs of the people of Maine. Each of these grand challenges has associated milestones that provide assessment tools for the System and the state.

Metric and key milestones for Goal One: Make Maine the best state in the nation in which to live, work, and learn by 2030

Metric for Goal One

Each grand challenge component will have clear metrics and public dashboards in place by the end of FY20, and multiple efforts across Maine are aimed at achieving number one status in an appropriate ranking system, such as *U.S. News and World Report*.

Key Milestones for Goal One

- System leadership generates statewide conversation about the Goal One-related grand challenges, and announces research and development emphases for the next five years beginning in fall 2019.

- Within the System, R&D and instructional resources are directed as appropriate toward the goal and related grand challenges, beginning with implementation of the FY20 budget.
- Grand challenge initiatives are evaluated on an annual basis to optimize impact and implement needed changes on a continual basis.
- The System supports state leaders with data and research evidence in discussion of reconsideration/expansion of the current set of technology sectors to ensure a focus on growth industries for Maine, and advancement in small communities and the rural parts of our state.

Goal Two:

Establish an innovation-driven Maine economy for the 21st century

Through R&D, Maine's universities have a direct role in improving the economy. A strong R&D base can help attract new industry, support the expansion of businesses and industries that are here, spin off new startup companies, and enable the education of an innovative workforce. The Board of Trustees has identified this as a key role of the System in Maine's economy: "The state of Maine has charged its higher education institutions to work together cooperatively with Maine businesses to advance the Maine economy."^{xliii} The Board also acknowledges the role of R&D: "And the System must continue to grow the research and knowledge base that will support those emerging workforce and business needs to enable and even catalyze innovation in Maine." Growing the knowledge base, and expanding capacity in the state for business-related R&D through the System, are critical catalysts for the economy.

Gross domestic spending on R&D as a percentage of gross domestic product (GDP) for a country or a state is considered to be a leading indicator of economic success. Fortunately, for the past two decades Maine has steadily increased its investment in R&D, recognizing the importance of this to growing the economy.^{xlv} However, according to the Maine Development Foundation in the 2018 *Measures of Growth* update, "Maine has historically devoted less than one percent of our total gross domestic product to Research and Development Expenditures, below the U.S. average and well below the New England average." The report authors continue, "R&D spending supports innovation, the ultimate

driver of most economic growth," and note that "Maine's total spending on research and development was approximately 0.9 percent in 2015. The [Maine Economic Growth] Council's benchmark is 3 percent by 2020."^{xlvi}

Nationally, almost two-thirds of academic R&D spending goes to basic research, largely through federal grants and awards. Applied research constitutes 28 percent and development 9 percent. In Maine's case, MEIF funds are directed by statute to support applied research and development. At the same time, any overall increase in R&D expenditure that preserves the important university role in basic research will require the universities to increase their capacity for external funding, largely from the federal government.

With additional resources and capacity from the state and the System, and from within the universities, our productivity in seeking and receiving external grants can increase. In terms of real-dollar federal funding obligations for science and engineering R&D, Maine ranks 47th among states in external funding from federal agencies (compared to New Hampshire at 34th). Of particular concern are the state's rankings with U.S. Department of Agriculture and National Science Foundation at 48th.^{xlviii} Additional external support also would provide funding for more graduate students. According to the same federal data, among states and localities, including Washington, D.C. and Puerto Rico, Maine ranks 51st in total number of sciences, engineering, and health graduate students, and 52nd in science, engineering and health postdoctoral appointees.^{xlix} There are few appropriate placements for postdoctoral scholars across the System and, at present, opportunities are limited to UMaine. For Maine, increased federal funding allows for support of more undergraduates in paid internships and lab experiences, tuition support for graduate students, expertise, and facilities to be shared with current and potential academic, business and industry partners.

Nationally, distribution of academic R&D expenditures is shifting, with life sciences receiving the largest share (57 percent) in 2016, followed by engineering at 16 percent.ⁱ Within engineering, the growth areas are bioengineering and biomedical engineering, and both fields are currently very strong in Maine. Other non-science and engineering fields, such as education, business, and the humanities, accounted for just under 6 percent of total academic R&D spending.ⁱⁱ Those fields are critical to enhancing the quality of Maine as a place to live, work, and learn, and, thus, will need more state and institutional support.

Increasing R&D-intensive business industry in Maine

In comparison to other states, Maine is still building its industry-led R&D. Historically, the focus in this state has been on agriculture, forestry and timber, fisheries, and manufacturing. Although many of our industries are R&D-dependent, often that R&D is occurring at national and international headquarters, rather than in Maine. Yet at UMaine and across the System, research and development are underway that support growing and emerging business here, ranging from aquaculture, to repurposing of forest biomass, to renewable energy, to cellulose nanomaterials, to biomedical engineering, to aging. One way that universities can help draw business to Maine is to have the students, faculty, and facilities available to support targeted applied research, development, and incubation activity customized to industry needs and expectations. University-private sector partnerships can be developed to support research and development of interest to Maine industry. These types of partnerships can further build R&D connections, expand

specialized capacity for development, and help establish workforce pathways. The UMaine University Research Council produced a plan in 2012ⁱⁱⁱ that included a goal to “increase industry-funded research projects from the FY10 level of \$4.5 million to \$9.0 million by FY17.” UMaine has not achieved that goal; in FY18, partnerships are at about \$5 million. We can help to grow jobs and new business by having an attractive R&D ecosystem for Maine, with System institutions playing a central role.

In 2014, Richert advocated for increased R&D spending by businesses in the state of Maine in the frequently cited *30 and 1000* report.ⁱⁱⁱ The report projected that “if 30 percent of the state’s adults had at least four-year degrees, and if businesses, academia, and government were spending \$1,000 per employed worker on research and development, Maine’s per capita income would reach the national average.”^{liv} This would rest on a combination of higher education, state, and industry R&D investment. Richert recommended two pathways to enhance industrial investments in R&D in Maine: First, “retool sectors in which Maine has been traditionally strong [...] but that are



typically low R&D performers” (e.g., the wood products sector, as it shifts to engineered wood composites and forest bioproducts); second, to work with sectors that are “high R&D performers [...] in which new technologies and applications provide new options for Maine businesses to penetrate the sectors,” (e.g., pharmaceuticals, or chemical, biological, and particle-detection and analytical instruments).^{lv} System institutions already have been instrumental in the first, and are well poised, in partnership with the state and the private sector, to advance the second.

Essential to enhancing statewide R&D expenditures and impact on the economy is a robust, coordinated approach to innovation derived from all forms of research activity, and engaging students in that activity as preparation to be future leaders in Maine. This means cultivating innovators and entrepreneurs, supporting the identification and disclosure of intellectual property, enabling spin-off and spin-out companies growing out of university-based research, developing product development collaborations, and facilitating licensing agreements with commercial partners. In addition, partnership with the outstanding Maine research laboratories and private universities can expand the impact of work based in the public university system.

There is federal support for promoting growth of small businesses through the Small Business Innovation Research program (SBIR) and the Small Business Technology Transfer program (STTR). In 2014–16, Maine ranked 35th of 52 states and territories nationally in SBIR/STTR receipts, up from 38th in the 2012–14 data. This is encouraging and is an area on which to build. At other points in time, Maine has been significantly higher in the table (13th in 2004–06, 15th in 2006–08; above the national average in both instances).^{lxviii} This suggests that, relative to the overall economy of Maine, federal funding for commercialization and small business expansion represents a meaningful opportunity for growth. The universities can be very helpful partners in these ventures, and can provide pathways for student engagement that could lead to new and expanded business in Maine.

In Maine, patent activity has increased dramatically over a 50-year span. Between 1963 and 2015, patent filings in Maine per capita increased 215 percent, an increase in

keeping with growth in the top third of all states with increased filings. There is still ample growth potential in Maine. Although this increase outstripped Connecticut and Rhode Island, it still substantially lagged New Hampshire and Vermont.^{lxix} Promoting further activity would involve increased patent applications coming through the System, and also through companies whose corporate headquarters are in Maine. In recent years, UMaine has been the source for the majority of patent disclosures and new companies launched on the basis of university research. Today, UMaine, Maine Center Ventures, and the University of Southern Maine all are engaged in supporting business incubation, acceleration, and commercialization that impact Maine’s businesses in critical ways. There is great demand from students and private-sector entities for expansion and statewide access to these opportunities.

Metric and key milestones for Goal Two: Establish an innovation-driven Maine economy for the 21st century

Metric for Goal Two

Increase total R&D expenditures across all sources in Maine to 3 percent of Maine’s gross domestic product by FY30.

Key Milestones for Goal Two

- Resources and expertise in System laboratories and research groups in the state’s seven priority technology sectors are strategically developed and deployed to help attract R&D-intensive industry to Maine, and to expand the R&D capacity of current Maine industry by fall 2020.
- All System campuses have increased five-year R&D expenditure goals, consistent with institutional strengths and mission, in response to System incentives, partnerships, shared personnel (in collaboration with the AFUM and Human Resources), common infrastructure and other approaches by fall 2021, and consider agreeing to a goal of doubling current expenditures from external (federal and private) sources by FY25.
- State of Maine base investment in System R&D is increasing to support the personnel, facilities, and infrastructure essential to a public university system R&D enterprise that substantially engages Maine students.

Goal Three:

Prepare the knowledge-and-innovation workforce for Maine

Key to the growth of R&D in a state or nation is the presence of educational systems and institutions that prepare the learners who will work in the emerging industries; who will invent the ideas, techniques, and technologies of those industries for the future; and who are prepared to collaborate across disciplines, with diverse teams, to solve yet-unimagined problems through convergence approaches. For Maine, this means ensuring that our public research university and all public education institutions prepare students to work with — and to become — the discoverers, inventors, innovators, and business leaders of tomorrow in Maine, and that the universities are adequately resourced to provide that preparation. The impact of thousands of graduates of System universities ready to enter the Maine workforce, equipped with state-of-the-art knowledge about technologies, data science, innovation and problem-solving in fields and sectors key to Maine's future, will be enormous.

A fundamental aspect of the environment for this kind of preparation is having active researchers working directly and extensively with undergraduate and graduate students. This engagement occurs in university classrooms, in course-related labs, in research labs, in field sites, in community-engaged partnerships, and in connection with internship and external work experiences.

U.S. News and World Report posted “10 reasons to go to a research university” that apply to Maine. Several of its points are particularly pertinent: “Courses at research universities often incorporate the latest research.” The article continues, “Faculty can be more energized/Faculty at research universities are often making genuine discoveries; there are state-of-the-art facilities; you could get an advantage for admission to graduate and professional schools; you can network with distinguished and well-placed people in the field.”^{lvi} This kind of outstanding educational opportunity is present in Maine, not only at UMaine, but in specific areas in other parts of the System, as well. Those include, for example, health policy at the University of Southern Maine, education at the University of Maine at Farmington, biology at the University of Maine at Augusta, marine sciences at the University of Maine at Machias, agriculture at the University of Maine at Presque Isle, and forestry at the University of Maine at Fort Kent.

Uniquely powerful learning experiences through research for all students

Perhaps most important for Maine, the universities provide uniquely powerful learning experiences for the students who will graduate from their programs and become Maine's workforce, particularly for those whose professors are active researchers and scholars. Those faculty are working daily in their labs, generating new knowledge that is helping to solve challenges in Maine that range from the effective use of nanocellulose from forest biomass, to diagnosing and seeking cures for disease, to engineering structures that will revolutionize the production of renewable energy, to creative works that sustain our culture and enrich our quality of life. And they also are working daily in their classrooms, engaging with students who have a front-row seat to the discovery, creation, and innovation their professors are providing. At UMaine, many students have the opportunity to have a research experience in their classroom, a lab, or a field site. Across the System, students are working in communities, alongside their professors, to bring research to bear on local challenges and problems. Because their education in a research university centers on the development of these skills, students learn how to be creative problem solvers, how to apply principles of science and engineering in unexpected contexts, and how to collaborate and work across disciplines.

In describing the need for “knowledge workers” in Maine, Richert (2014)^{lviii} argues “their common denominator is the discovery, generation, use, management, or distribution of knowledge and information, often including intellectual property.” That very description characterizes what researchers do every day in their work, and clarifies the distinctive role of a research university. Having those researchers as teachers uniquely shapes the development of students at a research university.

Expanding opportunities for doctoral research and research in graduate education

Graduate students are essential to expansion of the R&D enterprise across the System and, thus, the improvement of the Maine economy. They extend the reach of researchers, playing key roles in all aspects of the research process, from problem formulation through data collection to specialized knowledge of use of tools and instruments, to analysis and

interpretation, to engagement with the community, to career opportunities through spin-offs. They are interested in becoming experts in data science, instrument operation, community-engaged research to solve real problems in Maine, and interpretation and communication of research.

An important factor in national rankings of universities (i.e., Carnegie Classification) is the number of doctoral degrees conferred by an institution. In addition to increasing research expenditures System-wide, we will increase the number of doctoral students to support the robust R&D enterprise. As part of the doctoral experience, our students are guided by world-class faculty, they mentor master's and undergraduate students, they provide expert undergraduate instruction, and they aim for careers in academia and beyond, bolstering the scientific workforce in Maine. These graduate students often seek employment within the System and help expand expertise. Projections about job openings in Maine indicate that over the next 10 years there will be need for people with graduate degrees in education administration, statistics, mental health/substance abuse, advanced nursing, and speech pathology. Universities in Maine can gear up to ensure that programs are available to fill that state need.

Figure 8 displays trends in enrollment by graduate degree type at UMaine. We would need to see an increase in enrollment in research master's and doctoral programs to help realize both the increased R&D expenditures for the state and the enhanced workforce.

Figure 9 compares UMaine to New England peers in doctoral production. Our trend line is declining and lags behind a key peer, UNH. Doctoral students are essential not only for the new ideas and diversity that they bring to research and scholarship, but also for the role they play in expanding the capacity of faculty researchers. They enable engagement with more undergraduate students, along with increased time for faculty partnerships across the System and with the private sector, and capacity to respond to funding opportunities. Thus, doctoral students are an important part of a healthy state R&D ecosystem and benefit Maine.

National trends in STEM graduate education indicate the need for more interdisciplinary programs that provide experiences in convergent research, that prepare students for data-intensive science, and that enable students to consider careers outside of academia. UMaine recently convened a Graduate Education Summit of campus leaders to plan for

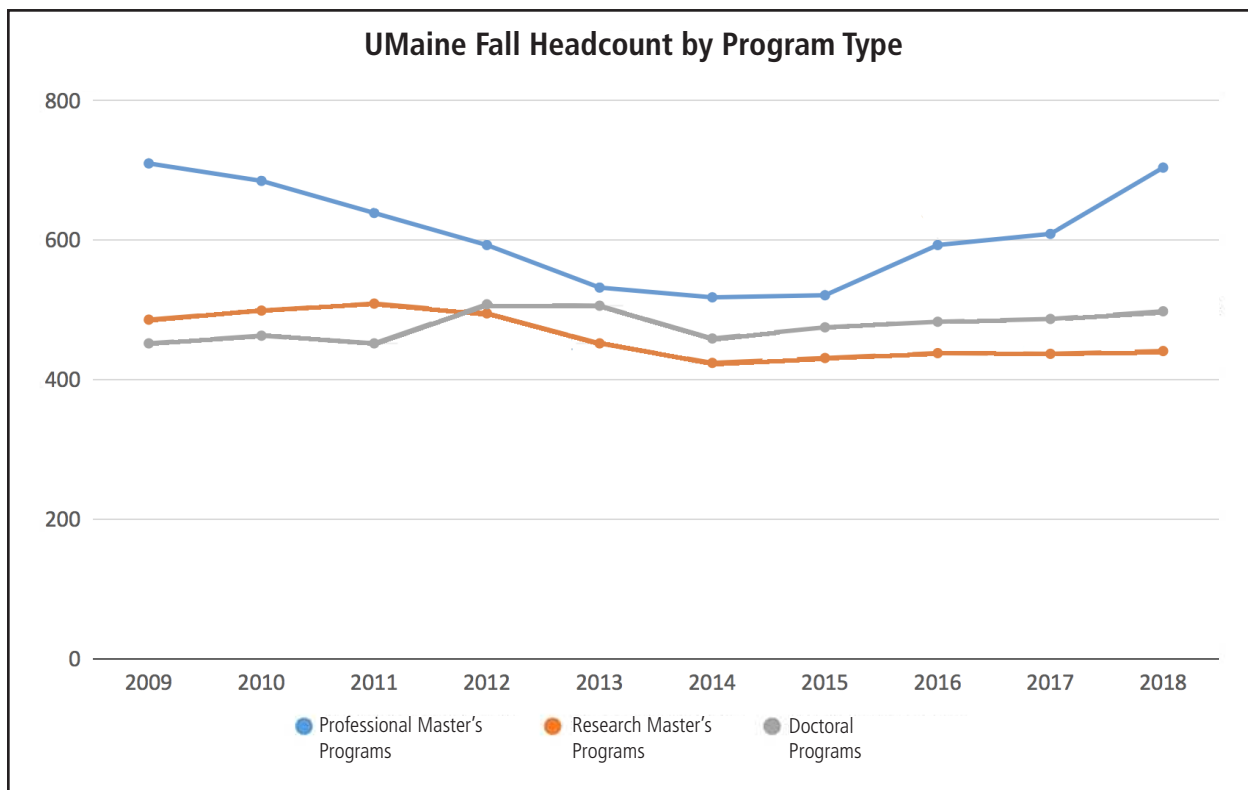


Figure 8. UMaine Fall Headcount by Graduate Degree Type, 2009–2018

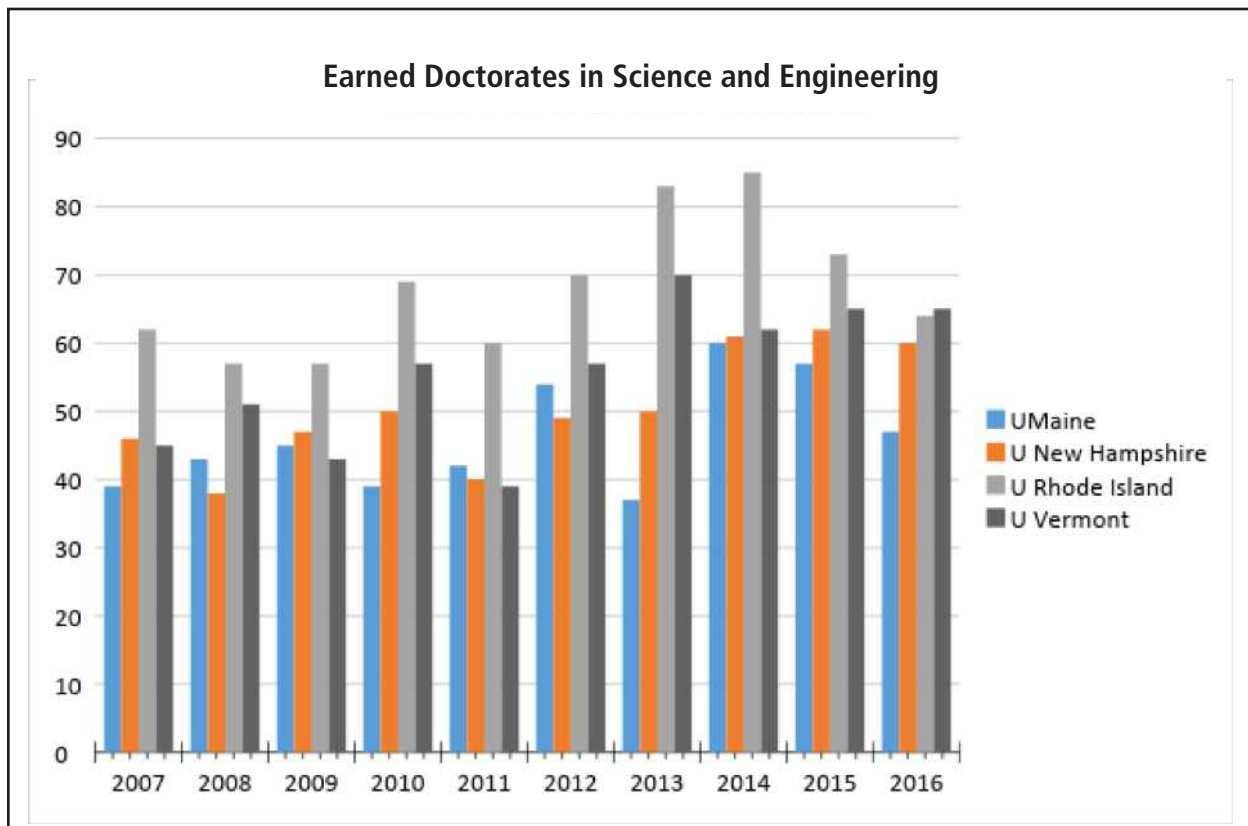


Figure 9. Earned Doctorates in Science and Engineering, UMaine and other New England Institutions, 2007–2016

such future directions. Given trends in science and research, approaches such as hiring cluster groups of faculties around interdisciplinary themes, as UMaine already is doing, and enabling more “free-standing” Ph.D. programs so that such faculty can provide cutting-edge preparation, may be worthwhile and could be expanded.

Establishing pathways to Maine careers for System students

Based on conversations in the development of this plan, we aspire to guarantee that every student in the University of Maine System has opportunities to engage significantly in research, innovation, and/or creation of knowledge experiences beginning in fall 2020.

UMaine will initiate a pilot program and provide support for faculty to work toward grand challenge or theme-based courses, modules, or combinations that enable the introduction of “core” standards and foundational disciplinary knowledge within a problem or theme-based structure. This type of education, often called problem-based

learning or project-based learning, requires students to be active in the educational process, and promotes collaborative work. Several educational institutions have begun to adopt or promote this model of learning. In a recent report on educating Gen Z students, Selingo (2018)^{lxii} suggests that attending to students’ top reasons for going to college, and their learning preferences, is critical for higher education. The most common reason these students decide to attend college is “to get a better job.” Instruction should include a blend of “independent and group work and experiential opportunities.”^{lxiv} Experience with faculty who are directly engaged in research and scholarship can be arranged in that mode.

There is support across the System institutions for further development of workforce training and recruitment pathway programs, including student internships, co-ops, and fellowships statewide and with geographic relevance. This can occur through partnerships with Maine businesses and industries to address their workforce needs.



At the University of Maine, students in each college have the option to participate in internships, and most of them will do so in Maine-based organizations, such as state government, health care providers, private nonprofits, and private corporations. Other campuses also have extensive internship opportunities. Throughout the System, several academic programs require capstone projects that challenge students to produce original ideas, engage in research, solve real problems, and present their findings. Research activity also is incorporated into regular coursework, and there is a growing interest and emphasis on campuses to promote interdisciplinary research experiences for students. Students have many opportunities to develop and refine their research skills and professional capacities. On several campuses, undergraduates have the opportunity to engage in community-based research activity. There is great interest overall in expanding these options and making them possible for more students in the System.

Community-engaged research connected to undergraduate learning

Community-engaged research involves direct collaboration with local partners beyond the university to take up questions that are of interest and concern to the community. Such R&D is conducted with and for state government, business and industry, nonprofits, and community leaders, alongside faculty, staff, and students. The retraining of workers, including offering certifications, micro-credentialing, and degree completion partnerships with Maine businesses and industries, can be explored through such collaborations.

In addition, there are examples where community-engaged research is incorporated into classroom-based research across the System. For instance, the University of Maine routinely involves students in classroom-based research in such areas as aquaponics, water quality, ecology, and analytical chemistry. Many programs at the Cutler Institute/Muskie School of Public Service at USM involve students as graduate or research assistants in research. An example is the Public Health Program, which over the last five years has supported 105 graduate or research assistantship opportunities that have benefited 46 graduate students. Based on accreditation documentation, approximately 67 percent of the University of Southern Maine's health-related research projects included graduate students, and approximately 33 percent were classified as community-based. Similarly, the Maine Education Policy Research Institute,^{lv} jointly led by USM and UMaine, undertakes studies and data collection to support state government policy leaders in their decision-making. There is expertise and interest across the System in expanding these opportunities, which would lead to an increasingly prepared workforce and citizenry, ready to make a difference in Maine communities.

Metric and key milestones for Goal Three: Prepare the knowledge-and-innovation workforce for Maine

Metric for Goal Three

Sixty percent of adults in Maine have postsecondary education credentials that enable their participation in the future R&D workplace by 2025.

Key Milestones for Goal Three

- Every student in System institutions has opportunities to engage significantly in research, innovation, and/or creation of knowledge experiences beginning in fall 2020.
- The number of funded doctoral students in the System to enhance the scientific workforce in Maine and beyond will increase by 20 percent by fall 2025.
- Workforce training and recruitment pathway programs, including student internships, co-ops, and fellowships, are in place statewide, involving all System institutions, and with geographic relevance, through partnerships with Maine businesses and industries to address their workforce needs, by fall 2022.

Findings and Recommendations

The process of preparing this plan, which included review of relevant reports and documents both about Maine and the national R&D endeavor, and input sessions and discussions with System faculty, staff, students, administrators, and stakeholders from the Legislature, the Governor's Office, and the business sector, has led to some key findings and associated recommendations.

Finding One:

Investment by the state of Maine and the University of Maine System in R&D has been essential to reach our current R&D capacity.

The Maine Economic Improvement Fund was established by the Maine Legislature in 1998 and the Research Reinvestment Fund was established by the System Board of Trustees in 2015. Without those resources it is quite possible that the capacity at the University of Maine to seek and obtain external funding would have been severely impeded, and that R&D at the University of Southern Maine and other System campuses would have been minimal. These state funds have leveraged significant external funding and enabled hundreds of students to participate in research and to be paid for that participation. To sustain and grow university-based R&D infrastructure in Maine in the next 10 years that is properly scaled to achieve the goals will require increased investment from state and System sources. It also will require realignment over time within campus budgets. Clear metrics and accountability expectations will be necessary to track the outputs, outcomes, and impacts of these changes. Launching grand challenge initiatives will allow for focused investment in areas poised to grow and yield results in both the near and long term. Such investment stands to raise national ranking, and will increase competitiveness with similar institutions in other states for federal funds, leading world-class faculty, and excellent students to come to, and remain in, Maine. But, most important, these investments will yield benefits for the students and people of the state of Maine by enabling preparation of a knowledge-and-innovation workforce to fill

key positions and attract businesses to a growing state economy.

Recommendations:

First, we recommend that the UMS Research Reinvestment Fund be renewed for five years, at a level of \$4 million per year, beginning in FY20. Additional new selection priorities should be considered, such as partnerships with private-sector entities or local communities to solve practical problems, or collaborations among researchers on different System campuses. These investments should promote strong networks of researchers, allow adequate time for faculty to conduct research, and expand opportunities for paid student research experiences. Outcomes should include measurable return on investment, effectiveness in leveraging external funding, and quality and impact of student engagement in research.

Second, we recommend regular increases in state MEIF investment to reach a steady level of \$40 million annually by the end of FY24. This fund supports the on-campus capacity, including researchers, students, and facilities, that allows success in the intense national competition for federal research funding from the National Science Foundation, the National Institutes of Health, and other agencies. Additional MEIF resources would sustain and enhance infrastructure, and expand research capacity and expenditures in the highest-priority R&D areas for Maine's future well-being and economic success. Improving Maine's standing in national rankings of higher education expenditures in R&D will help attract R&D-intensive industry to the state. But the most important outcome of this investment will be expanded opportunity for Maine students to be educated in R&D-rich environments so they can become Maine leaders and innovators. System campuses will be asked to consistently track and report the number of students involved in R&D. In preparation for this request, by January 2020 the System should complete an analysis of ROI and impact on the Maine economy of MEIF over its 20 years of existence.

Third, the System institutions will collaboratively develop a plan for integrating R&D expenses in the E&G budget, parallel to the way that instructional costs are embedded. The System's appropriation allocation model already encourages campuses to look closely at R&D spending in

comparison to established peer institutions. In addition, universities will consider realigning resources within their E&G budgets to provide additional support, as appropriate, for their R&D goals. We strongly urge the universities to reinvest F&A cost recovery back into the research enterprise more substantially.

These investments will contribute to attracting students in Maine and to Maine by expanding the breadth of learning opportunities, including such options as paid internships with Maine companies interested in R&D expertise. Students with exposure to undergraduate research are likely to continue into our graduate offerings, establishing a pipeline, and improving the quality and capacity of the System graduate student body. These students will be prepared for the jobs of the 21st century and will be competitive in the national job market.

These changes would raise the profile of the University of Maine and other System campuses in ability to recruit students who are interested in undergraduate research, to attract and retain first-rate research faculty and graduate students, to compete for external federal funds, and to partner with the private sector to engage in R&D. All of these potential outcomes should be considered in designing accountability measures.

Finding Two:

Each System campus has its own unique, engaged R&D core of expertise that should be further strengthened.

Research now and in the future will have a major role in “Making Maine the most desirable state in which to learn, work, and live by 2030.” Across the System, we have a rich and diverse set of research interests and capabilities, and great expertise among the faculty to continue ongoing R&D, and to undertake new lines of work in connection with their students.

Each institution has distinct identifiable strengths and emerging goals for its role in R&D, and at each university in the System the centrality and scope of the R&D enterprise differs. For the University of Maine, the state’s comprehensive land and sea grant public research university, basic and applied research, development, and commercialization are core to the mission, with \$100 million annually in research expenditures from external sponsors.

At the University of Southern Maine, the R&D strength spans many areas, and much of the work is applied. Goals for applied learning and workforce development are important there. On the other System campuses there are excellent examples of research and scholarship fully integrated into instruction and service, though with limited externally funded research.

Recommendations:

First, each of the System campuses should develop a five-year R&D implementation plan for increasing research expenditures aligned with the goals of this plan and appropriate to each campus. Coordination and collaboration across campuses in R&D can then be considered. Existing and emerging signature R&D strengths at the University of Maine and other campuses will provide a foundation for this effort. By connecting to those established and emerging areas of strength, all campuses can design research agendas that are tailored to specific needs of their communities and geographic regions, that suit the interests and expertise of their faculty, and that will engage their students. Coordinated and public campus plans will be useful to potential new businesses and partners.

Second, the System universities, working together with Associated Faculties of the Universities of Maine and Human Resources units, should design and implement creative approaches to joint faculty appointments, including membership in the University of Maine Graduate Faculty. Such appointments will help to reduce barriers to conducting research and allow direct engagement with doctoral students. R&D faculty and student exchange and residency programs will be considered. The idea is to cultivate more cross-campus R&D collaboration that will generate tangible results for specific problems in Maine.

Third, the universities should collaborate on data governance in R&D to achieve consistency in reporting and to ensure appropriate credit for R&D expenditures. Methods to consistently include credit for a range of types of scholarly production should be explored when national surveys are not sufficient. By addressing these matters, we would support accountability and enable measurement of progress. In addition, we should assess System-wide access to research databases of interest to researchers and scholars on multiple campuses and create cost-effective solutions.

Finding Three:

Across the University of Maine System, we have been failing to compete as well as we should for significant federal funding, and our facilities, infrastructure, and administrative support for R&D are inadequate in several fields important to Maine's future.

Between 2007 and 2016, Maine's total R&D expenditure declined nearly 40 percent — the largest decline of any state over that period.ⁱ The System as a whole is underperforming in higher education R&D expenditures. There are dozens of federal competitive grant programs available across the major science agenciesⁱⁱ annually in R&D areas of relevance to the state of Maine for which few or, in some cases, no applications are made from System universities. This unacceptable situation results from a combination of lack of faculty with expertise or interest in key areas; insufficient administrative capacity to support proposal planning and submission; inadequate faculty time to prepare proposals because of competing teaching and service loads; and lack of graduate students, postdoctoral associates, and technicians. In addition, there is a critical need for improved facilities; modern and sophisticated instruments and research resources; and procedures for sharing equipment and instruments. Sometimes, faculty cannot pursue research funding opportunities because the needed equipment, facilities, and capabilities do not exist in the System, or the costs of compliance and purchasing licenses would be too great for faculty to cover from their own research budgets. Universities similar to UMaine have this research infrastructure in place, which puts our faculty at a disadvantage when competing for federal grants. And

there are opportunities to engage undergraduate students in research that are not being realized because of the lack of needed equipment and personnel. Improving modernized equipment has the added benefit of enabling the training of our students to prepare for jobs of the future that would use this instrumentation. All campuses report a large need for more administrative support in R&D.

Despite all this, we are confident that System faculty and staff are resourceful and deeply committed to their students, their research, and to Maine, and that we can remedy much of this situation with relatively modest resources, and increased coordination and communication..

To sustain and grow university-based R&D infrastructure in Maine in the next 10 years that is properly scaled to achieve the goals will require increased investment from state and System sources.

Recommendations:

First, assuming availability of additional resources from combined sources, the universities will review and address needs for coordinated hiring of faculty in key areas of importance to the state as determined, for instance, by System Board of Trustee goals, or recommended in the reports of the Maine Economic Growth Council or the economic growth plan currently under development through the Office of the Governor. Similar coordination or information-sharing should be applied to the hiring of postdoctoral associates, technicians, and graduate students.

Second, a System-wide inventory of R&D instruments and facilities should be assembled and made available to all new faculty. The Coordinated Operating Research

Entities, or CORE, pioneered at the University of Maine, provides a model and could be expanded system-wide. Campus master plans should address needs for expanded and renovated R&D facilities.

Third, the comprehensive research administration and development capacity currently in place at the University of Maine should be made available to support faculty research

needs across the System. Intercampus research administration collaborations between the University of Maine and other System campuses have been established (e.g., with the University of Maine at Machias and the University of Maine at Fort Kent). Research administration services also exist at the University of Southern Maine. Both the University of Maine and the University of Southern Maine house expertise for research compliance, which could become shared resources with other System campuses.

Finding Four:

Across the System, undergraduate students are engaging in authentic research experiences and community-engaged research initiatives that are benefitting the region and the state.

The opportunity to participate in research, development, and commercialization activities is highly attractive to undergraduate and graduate students, and many faculty across the System are effectively integrating research with instruction, including community-engaged research on problems of specific local interest. In the various listening sessions conducted during the development of this plan, faculty shared many examples of such student experiences. However, this student involvement is not as widespread or systematic as would be necessary to attract many more students to System institutions, and help retain them.

Recommendations:

First, the System must provide leadership in incentivizing and enabling every undergraduate student in the University of Maine System to have a meaningful/authentic experience in research, scholarship, development, creative production, policy analysis, translation, or commercialization. System Program Innovation Funds should be considered as a resource.

Second, Course-based Undergraduate Research Experiences and other similar evidence-based courses should be piloted and evaluated across the System according to campus capacity and interest, and supported with campus resources. Impact on recruitment, enrollment, and retention will be assessed, as well as the ability of students to obtain paid summer internships and employment after graduation, and whether students remain in, or return to Maine.

Finding Five:

The private and nonprofit sectors and the Maine state government are eager for expanded R&D interactions with higher education.

Private-sector entities already partner in R&D relationships with several System universities, with a large number at the University of Maine. External companies considering moving to Maine also have expressed great interest in partnering with the University of Maine System to extend their R&D capabilities for those interested entities. However, sometimes locating the best System research experts and gaining access to R&D capabilities are challenging. If UMaine and other System institutions were more easily able to partner with private-sector industries and businesses, we could tap a great source of economic stimulus in the state and provide opportunity for student interaction.

In the context of a dispersed and locally driven ecosystem in Maine for economic development, University of Maine System faculty and staff are deeply engaged in efforts to support commercialization, business development, incubation, and private-sector needs in R&D. The System has ample capacity to grow research partnerships with the private sector as well as commercialization outputs of university research (e.g., spin-offs, revenue, and intellectual property.) As with research expenditures, the System has room to grow industrial contract income, licensing revenue, invention disclosure, and patent production, as well as the number and types of startup companies spun off from university research. Those efforts could be expanded with potential impact statewide. And, in areas of policy and business that are key to the state, including ecosystem health, health care, education, aquaculture, marine resources, and biomedical and biotechnology applications, the System institutions already are positioned, because of the breadth of their research expertise, to more systematically provide background information and analyses to the state and to the members of our federal delegation.

Recommendations:

The universities should continue to work closely with the private and government sectors to establish productive collaborations. Approaches to consider should include the creation of a Maine R&D Fellows program designed to

connect System faculty, state government, Maine's federal delegation, and potential private/nonprofit partners to work collaboratively.

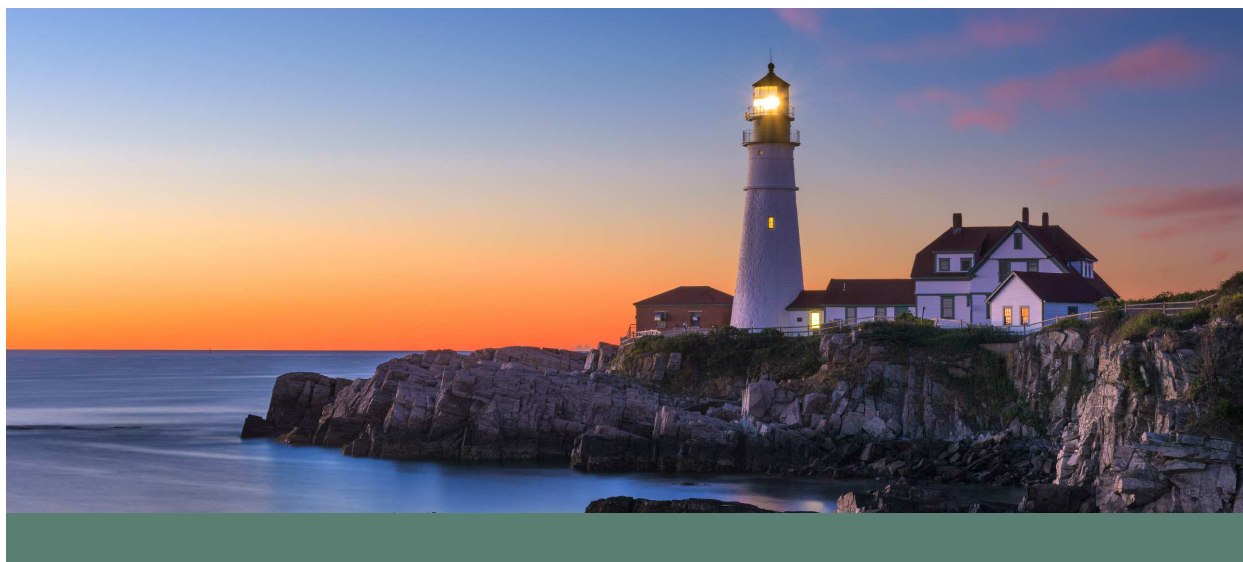
Second, the University of Maine should undertake a high-level review of existing doctoral programs in the STEM fields. The review should consider how program emphases align with current and projected state economic and R&D needs, whether basic, discovery research is sufficiently supported, and whether new directions in science and technology, including convergence, machine learning, and shared datasets, are being incorporated. Program consolidations, examination of how new programs are developed, and other realignments should be undertaken to lead to increased production of doctoral degrees, an important part of building R&D capacity.

Third, research commercialization outputs as measured by revenue, intellectual property production, and university spin-off companies, business incubation and acceleration, and formal partnerships with industry should grow significantly during the plan's implementation phase. Revenue targets should be set to grow significantly and the number of formal partnerships and spin-off outputs should double by 2025.

Finally, System institutions will engage in more robust communication of System R&D accomplishments statewide and nationally. As the Governor's economic development plan is completed, System universities should seek the best ways of providing capacity to that plan, through strategic interactions with the Governor and the Maine Legislature in identifying and responding to changing priorities needing R&D inputs.

Conclusion

The University of Maine System is committed to the improvement of quality of life and economic success of the state of Maine. Strategic expansion of research and development across the institutions of the System will have a direct impact on that quality of life and economic success. The success of the research and development enterprise across the University of Maine System depends, ultimately, on the creativity, innovation, and productivity of the individuals and groups engaged in R&D. Their successes are essential in helping Maine's learners have access to the best research-based education possible; obtaining external funding for research that will impact Maine and the world; sustaining the quality of research facilities, instruments, and technical staff; and fully integrating research and instruction. We must make shifts in policies, practices, and resource allocations in the System, and partner strategically with the Maine Legislature, the Office of the Governor, education systems in Maine, and the private sector. This will enhance the abilities of our faculty, students, and staff to be the regional, state, national, and international leaders in research that they are qualified to be, to benefit the learners and all people in Maine.



Appendix A

Process for Developing the UMS R&D Plan

Work commenced on the UMS R&D Plan shortly after the UMS Board of Trustees published its Declaration of Strategic Priorities document in December 2018. A steering committee (see next page for roster) was formed to serve in an advisory capacity, UMS presidents were provided regular updates, and engagement fora were set up for each UMS campus via Zoom. Draft goals and milestones were communicated as part of the outreach meetings, and participants had the opportunity to comment directly, as well as submit written comments via an online survey tool and through email. The majority of outreach sessions occurred in spring 2019. A total of over 400 people were reached in the 19 sessions held. Such outreach and listening sessions will continue as part of the implementation process.

Outreach Events

UMaine Faculty Forum, Memorial Union	11/30/2018
UMS Faculty Fellows AY18–19 Cohort, Wells Conference Center	1/25/2019
UMaine Early Career Faculty, Memorial Union	1/25/2019
UMS Board of Trustees and UMaine Board of Visitors, Wells Conference Center	1/27/2019
UMaine Deans Council, President’s Conference Room, Alumni Hall	2/6/2019
UMaine Council of Associate Deans, Alumni Hall	2/7/2019
University Research Council, Stodder Hall	2/7/2019
UMaine Board of Visitors, Portland, Maine	2/8/2019
Cooperative Extension Leadership Team Zoom Meeting	2/20/2019
UMaine and UMM Town Hall, Wells Conference Center and via Zoom	2/25/2019
UMaine Graduate Board, Stodder Hall	2/28/2019
University of Maine at Presque Isle Zoom meeting	3/4/2019
University of Maine at Fort Kent Zoom meeting	3/4/2019
University of Maine at Farmington Zoom meeting	3/7/2019
UMaine Graduate Education Summit, Buchanan Alumni House	3/8/2019
University of Southern Maine Zoom meeting	3/8/2019
University of Maine at Machias Zoom meeting	3/8/2019
University of Maine at Augusta Zoom meeting	3/15/2019
Bioscience Association of Maine (BioME), University of Maine	3/20/2019

Written input

University of Maine at Augusta, Office of the Vice President for Academic Affairs and Provost
 University of Southern Maine, Office of the President
 UMaine Academic Deans
 UMaine Cooperative Extension
 UMaine School of Earth and Climate Sciences, and Climate Change Institute
 University of Maine Board of Visitors
 UMaine Faculty Senate Research and Scholarship Committee
 University of Maine College of Education and Human Development
 University of Southern Maine Department of Environmental Science and Policy
 University of Maine at Farmington Division of Early Childhood and Elementary Education
 University of Southern Maine Center for Education Policy, Applied Research, and Evaluation
 University of Maine Coordinated Operating Research Entities (CORE)

Consultations

2/25/2019	UMS President's Council Meeting
2/28/2019	Consultation with Vice Chancellor for Academic Affairs Robert Neely
3/6/2019	Meetings with Maine's Congressional Delegation
Various dates:	Meetings with members of the Governor's staff, Commissioners, and members of the Maine Legislature

Steering Committee Meetings

1/24/2019	Kickoff
2/7/2019	Task teams formed
2/22/2019	Task team report out and work session on goals
3/7/2019	Discussion of what added investment does for the state

Steering Committee Members

Pankaj Agrrawal, *Professor of Finance, UMaine*

Brian Beal, *Professor of Marine Ecology, UMM*

Lucille Benedict, *Associate Professor of Chemistry, Director of Quality Control Collaboratory, USM*

Habib Dagher, *Executive Director, Advanced Structures and Composites Center, UMaine*

Sandra De Urioste-Stone, *Associate Professor of Nature-based Tourism, UMaine*

Caitlin Howell, *Assistant Professor of Chemical and Biomedical Engineering, UMaine*

Brenda Joly, *Associate Professor, Muskie School of Public Service, USM*

Benjamin King, *Assistant Professor of Bioinformatics, UMaine*

Paul Mayewski, *Director, Climate Change Institute, UMaine*

Penny Rheingans, *Director, School of Computing and Information Science, UMaine*

Kris Sahonchik, *Director, USM Research and Cutler Institute*

Kristy Townsend, *Associate Professor of Neurobiology, UMaine*

Karen Wilson, *Associate Research Professor, Department of Environmental Science and Policy, USM*

Other Participants in Steering Committee Meetings

Jason Charland, *Director of Research Development and R&D Plan Project Coordinator, UMaine*

Jeff Hecker, *Executive Vice President for Academic Affairs and Provost, UMaine*

Ross Hickey, *Assistant Provost for Research Integrity, USM*

George Jacobson, *Professor Emeritus, UMaine*

Jason Johnston, *Dean, College of Arts and Sciences, Associate Professor of Wildlife Ecology, UMPI*

Renee Kelly, *Assistant Vice President for Innovation and Economic Development, UMaine*

David Townsend, *Professor of Oceanography and Faculty Senate President, UMaine*

Kody Varahramyan, *Vice President for Research and Dean of the Graduate School, UMaine*

Jake Ward, *Vice President for Innovation and Economic Development, UMaine*

Samantha Warren, *Director of Government and Community Relations, UMS*

Appendix B

Key Stakeholder Interview Summary

Members of the UMS R&D plan steering committee interviewed several key stakeholders^{lxvi} with unique perspectives in the development of R&D initiatives in Maine, as well as other parts of the country. Discussion questions with interviewees covered goals and deliverables of statewide R&D initiatives; partnership models that have proven effective in rural states; thoughts on grand challenge initiatives; and what it takes for stakeholders and research universities to work together to advance prosperity. A summary of key idea responses is found in the table below, with the most frequent responses highlighted in bold.

Question	Category	Key Ideas
1. What advice can you provide us related to establishing goals and deliverables for our proposed R&D plan?	Strategic Planning	<ul style="list-style-type: none"> • Jointly determine needs with stakeholders (including needs of potential students) • Cross-sector collaborations • Immediate deliverables; quick turnaround and follow up with stakeholders • Long-term goals
	Focus	<ul style="list-style-type: none"> • Applied research and basic research
2. Are you aware of any R&D partnership models/initiatives between universities and the private sector that have worked particularly well in rural states?	Characteristics	<ul style="list-style-type: none"> • Create a network of collaborators • Basic and applied research • Talk to stakeholders to identify needs • Meet unmet needs • Support commercialization
	Examples in Maine	<ul style="list-style-type: none"> • Cooperative Forestry Research Unit (UMaine) • ASCC/FBRI (UMaine) • FOR/Maine
3. Are you aware of any grand challenge initiatives that research universities are tackling in your state?	Rural Economic Development	<ul style="list-style-type: none"> • Winning strategy for sustainable economic development • Focus on next generation of forest products • Support regional planning and economic development strategies for rural areas
	Community viability	<ul style="list-style-type: none"> • Engage in community development • Invest in broadband
	Quality of place	<ul style="list-style-type: none"> • Develop clean energy • Work on multisector, multiagency, multi-disciplinary efforts to address sustainability
4. What does it take for states and research institutions to work together to advance prosperity?	Investment of time and resources	<ul style="list-style-type: none"> • Shared commitment (time, resources) and intention (willingness) • Investment (from state, industry, universities)
	Engagement, shared decision making, and empowered human capital	<ul style="list-style-type: none"> • Shared planning, vision and clear understanding of how different pieces should be integrated • Balance applied with basic research to respond to needs of Maine stakeholders • Build functional communities — engage multiple stakeholders, collaborate in grants • Leadership

Appendix C

Acknowledgments

Office of the President



5703 Alumni Hall
Orono, Maine 04469-5703
Tel: 207.581.1512
Fax: 207.581.1517
umaine.edu

Development and creation of this plan was a team effort, and I will start by thanking all of the faculty, staff, students, and administrators who attended the outreach events and provided creative ideas, shared critiques, offered solutions and strategies for implementation, and shared observations of strengths, weaknesses, and opportunities related to R&D within the System. The R&D plan steering committee and administrators within the System served as insightful advisors and constructive critics, and also provided compelling examples of faculty, staff, students, and external collaborators working together to advance R&D in Maine and beyond. Special thanks go to members of the UMaine's President's Office staff and Cabinet; the UMaine Board of Visitors; the UMM Board of Visitors; Presidents Brown, Cummings, Rice, Short, and Wyke; Vice President and Head of Campus Egan; and the System Board of Trustees. Consultation with Chancellor Page and Vice Chancellor Neely was invaluable in the development of this plan's recommendations, and I am grateful for their support through this process. Additional thanks to UMaine Vice President for Research and Dean of the Graduate School Kody Varahramyan for providing staffing support to coordinate this project through the able assistance of Jason Charland, UMaine Director of Research Development, along with his colleagues Saul Allen and Allyson Hammond in the Office of Research Development. Thanks also to Val Ireland for help with designing this document. And, thanks to Sharon Buchanan, UMaine Finance Communications Specialist, for her assistance with preparing presentation materials.

Through the initiation of this process, I am invigorated by the passion and enthusiasm that exists within the System that will allow us, collectively, as One University, to advance R&D in the state of Maine and reach our three unifying goals:

- Make Maine the best state in the nation in which to live, work, and learn by 2030.
- Establish an innovation-driven Maine economy for the 21st century.
- Prepare the knowledge-and-innovation workforce for Maine.

I look forward to the next steps of implementation that will include additional engagement with internal and external stakeholders, and taking action swiftly and boldly to produce results that will have lasting and resounding impact on the System's R&D enterprise, our students, our communities, and the economic health and prosperity of the state of Maine.

Sincerely,

Joan Ferrini-Mundy

President, University of Maine and University of Maine at Machias

MAINE'S LAND GRANT AND SEA GRANT UNIVERSITY

Endnotes

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Office of the Chancellor • 15 Estabrooke Drive • Orono, ME 04469 • maine.edu

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