

Office of the Senior Vice President for Research
Strategic Plan FY2014-FY2019



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EXECUTIVE SUMMARY

Penn State consistently ranks among the top twenty US academic institutions in research. Annual research expenditures have nearly tripled in the last two decades to a high of \$848M in 2013. Since 1855, Penn State has developed well beyond its agricultural roots as Pennsylvania's land grant institution into a robust research enterprise with unique strengths and areas of excellence. Today, the Office of the Vice President for Research (OVPR) boasts *six strong and highly competitive interdisciplinary institutes providing globally-recognized research leadership in arts and humanities, cyberscience, energy and the environment, life science, material and social science.*

VISION

Penn State will advance its position as a world leader in research that impacts the public good. From fundamental discovery, to innovative application and sustainable implementation, our research will, more than ever before, have a transformative impact on the Pennsylvania Commonwealth, the nation, and the condition of our planet.

The research and development landscape is changing; political leaders and the many constituents we serve, most importantly our students, are looking to us for answers. Universities are expected to be – and should be – more than isolated bastions of discovery. Looking forward, the strategic actions in this plan will ensure that Penn State continues to be counted among the world's greatest research institutions, particularly in areas of established expertise and dominance. But these actions also will be transformative, molding this great university into an engine that purposely drives positive societal change, technological implementation, and economic development for the public good. It is our duty as a land grant university to respond to global events such as climate change, dwindling natural resources and lean economies by moving beyond discovery to translation and implementation. Not serendipitously, Penn State has developed the research strengths in key disciplines needed to undertake these challenges; our research future is filled with opportunity. The first five strategic goals of the OVPR align with goals established through the institutional planning process. To this we have added a sixth, reflecting the clear need to better translate our cache of bright ideas into the marketplace:

Goal 1: Advancing Precision Health in Context

Goal 2: Stewarding Natural Resources and the Environment

Goal 3: Transforming Education and Improving Access

Goal 4: Building Our Digital Future

Goal 5: Validating and Exploring Cultures

Goal 6: Advancing Entrepreneurship, Technology Transfer and Economic Development

Thus, at this critical juncture, ***the MISSION of the OVPR is to strengthen and enlarge Penn State research by providing advanced scientific resources, an informed and responsive administrative infrastructure, and an environment that facilitates cooperation and communication between and across University campuses, academic units, research institutes and external stakeholders.***

1 **Advancing Precision Health in Context**



1. Build expertise in evolutionary medicine and risk management.
2. Establish the Center for Lifespan Fitness, Performance and Health.
3. Build a deeper understanding of personalized health through integrating individual biological and behavioral data.
4. Apply understanding of bio-psycho-social processes to develop strategies that reduce the adverse effects of lifestyle choices on human health and well-being.
5. Reduce social disparities in health and healthcare.
6. Foster the convergence of biological, engineering, materials and physical science expertise to enable transformational discoveries supporting human health.

2 **Stewarding Natural Resources and the Environment**



1. Advance global water security through knowledge about water flows and systems.
2. More firmly establish Penn State leadership across all energy domains.
3. Protect and sustain natural systems through research on innovative and effective stewardship of living systems, landscapes and human-environment interactions.
4. Promote sustainability research that simultaneously supports social well-being, economic prosperity and ecological health.

3 **Transforming Education and Improving Access**



1. Promote Engaged Scholarship through research-related experiences involving advanced instrumentation and technologies, and inclusive of minorities, veterans and students at all campuses.
2. Educate faculty, students and staff to actively support technology transfer, research commercialization and work with private sponsors.
3. Create a robust postdoctoral development program to pipeline the best faculty talent.
4. Educate faculty to effectively apply and disseminate research findings beyond traditional academic forums.

4 **Building Our Digital Future**



1. Establish Penn State as the global leader in digital discovery and innovation for new insights and their translation to ensure societal well-being and economic prosperity.
2. Establish Penn State as the pioneering leader in Digital Extension for economic development through access to state-of-the-art cyberinfrastructure and personalized learning in research-intensive environments.
3. Establish Penn State as the global digital destination for science and scholarship by developing "science gateways" - hubs on the web for advancing interactive participatory modes of inquiry, learning and outreach.

5 **Valuing and Exploring Our Cultures**



1. Make integrative arts and humanities research a signature component of the research enterprise at Penn State, thereby establishing our national leadership in this emerging domain.
2. Remediate gaps in the resources available to vulnerable populations, including children, youth, elders and their families, in a global society.
3. Invigorate research and creative accomplishments across the arts and humanities.
4. Become the institution known for championing international research that develops and applies solutions for societal challenges worldwide.

6 **Invigorating Entrepreneurship, Technology Transfer and Economic Development**



1. Establish Penn State as the "go-to" academic institution for industry-sponsored research by creating a local ecosystem where Penn State researchers work hand-in-hand with industry to accelerate technology transfer.
2. Create a Penn State culture that values entrepreneurship, technology transfer and economic development.
3. Improve, streamline and clarify processes to allow for accelerating the pace at which technologies move from discovery to implementation.

PHOTO 6: Patrick Mansell/Penn State

Mission of the OVPR

The mission of the OVPR is to strengthen and enlarge Penn State research by providing advanced scientific resources, an informed and responsive administrative infrastructure, and an environment that facilitates cooperation and communication between and across University campuses, academic units, research institutes and external stakeholders. The OVPR provides strategic direction and goals for the University's research, and integrates the activities required to meet those goals.

Vision of the OVPR

Penn State will advance its position as a world leader in research that impacts the public good. From fundamental discovery to innovative application and sustainable implementation, our research will, more than ever before, have a transformative impact on the Commonwealth of Pennsylvania, the nation and the condition of our planet.

Core Values

In fulfilling its mission and vision and accomplishing the goals set forth in this strategic plan, the OVPR is informed and guided by a set of core values. These values are an integral part of who we are and help to define the agenda of the OVPR. Moreover, the values of the OVPR are actionable, with measurable evidence to confirm successful implementation.

Integrity: *We act with integrity and honesty in accordance with the highest academic, professional, and ethical standards*

It is the responsibility of all stakeholders associated with the OVPR, including individual researchers, to ensure that Penn State research is conducted in accordance with the highest ethical standards. The OVPR and its constituents are responsible for educating Penn State researchers on ethical research, for providing clear and efficient means for researchers to execute their research responsibly, and for holding researchers accountable.

Respect: *We respect and honor the dignity of each person, embrace civil discourse, and foster a diverse and inclusive community.*

We honor the dignity of each person, treat each individual accordingly, engage in civil discourse and foster a community inclusive of all cultures. The OVPR provides a welcoming research community, encouraging the success of all individuals and ensuring institutional vitality through diversity and inclusion. This respect grows from the intellectual respect for the scholarship of an individual – allowing freedom of thoughtful exploration and thoughtful expression.

Responsibility: *We act responsibly, and we are accountable for our decisions, actions, and their consequences.*

As members of the Penn State community, we in the OVPR will meet our obligations and hold ourselves accountable for our decisions and actions, and their consequences. With research as the primary directive, the OVPR will encourage Penn State research that is purposeful and valuable to today's society. With support of the OVPR, Penn State research will seek to investigate important fundamental questions, make new discoveries, and create deliverable products that will improve society through effective implementation.

Discovery: *We seek and create new knowledge and understanding, and foster creativity and innovation, for the benefit of our communities, society, and the environment.*

Penn State seeks to create new knowledge and understanding, and foster creativity for the benefit of our communities, society and the environment. The OVPR provides an infrastructure and ecosystem where fundamental research, discovery and innovation flourish within and across a variety of fields.

Excellence: *We strive for excellence in all our endeavors as individuals, an institution, and a leader in higher education*

Penn State has been a leading research university for decades. It continues to gather prestige and prominence as an institution known for a broad base of research expertise that is enhanced by synergies generated by a collaborative culture. The current strategic plan aims to continue this tradition of scientific excellence through rigorous, impactful research that leads to translational and transformative outcomes. The OVPR will strive for organizational excellence to effectively and efficiently guide the Penn State research enterprise while setting an example for universities around the world.

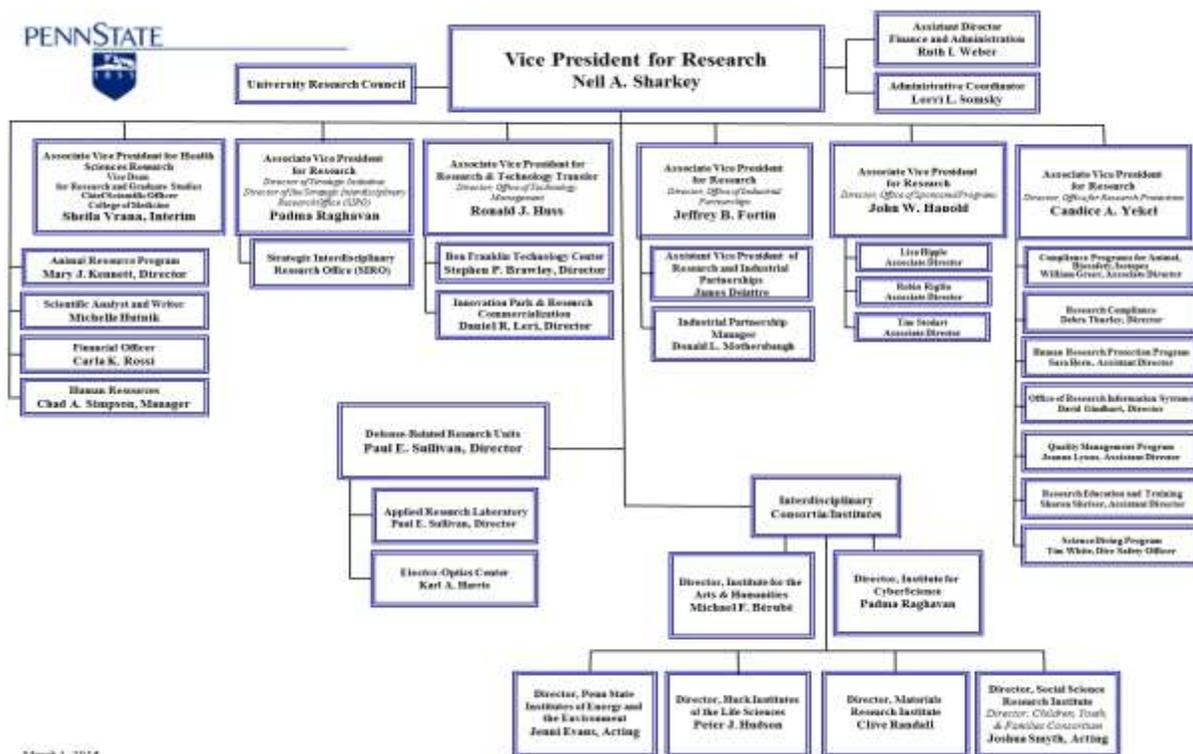
Community: *We work together for the betterment of the University, the communities we serve, and the world.*

Solutions to the most pressing needs in our world can only be obtained through cooperative transdisciplinary science. A sense of community and trust are prerequisites for transformative research. Penn State has long been at the forefront of innovative strategies aimed at breaking down traditional barriers, and fostering a sense of community and common purpose across disciplinary boundaries. The OVPR will continue to honor the unique value of each scholarly pursuit while simultaneously providing the resources and mechanisms necessary to stimulate and nurture cohesive multidisciplinary projects in which the whole is more than just the sum of the parts.

Foundational Principles

- **Sustainable:** OVPR will encourage Penn State research that is simultaneously aimed at the pursuit of human health and happiness, environmental quality, and economic prosperity for current and future generations.
- **Global:** OVPR will encourage Penn State research that is relevant, collaborative, conducted and communicated across cultures and countries around the world to form partnerships to address global intellectual challenges and ensure the greatest impact.
- **Engaged:** OVPR will encourage Penn State research that is sensitive to and connected with societal need and the context in which it is conducted.
- **Collaborative:** OVPR will encourage Penn State research that is performed through extensive internal and external collaborations and partnerships, essential elements of effective research.
- **Supporting the Land Grant Mission:** OVPR will encourage Penn State research that maximally contributes to the good of the Commonwealth, supporting the people, governments, businesses and organizations of Pennsylvania.
- **To Support Positive Societal Outcomes,** OVPR will encourage Penn State research that will impact society in meaningful ways, and researchers, colleges and support units will strive to seek the broadest possible public good in the work they undertake.

Organizational Structure of the OVPR



Where We Are: Status of Research at Penn State

Penn State is a world leader in a number of highly visible research domains with an investigational portfolio rounded out by valuable research from most – if not all – current and emerging research areas and paradigms. Examining recent research expenditures from government, industry and other sources across different performing units exemplifies Penn State’s key strengths and its broader successes in a variety of fields.

In the category of government funding, Penn State was ranked 13th in total *federal-financed* research expenditures during NSF’s most recent reporting period (Table 1). Between 2007 and 2013, Penn State reported an increase of 51% in this spending category while the top 20 institutions realized an average growth of only 38%. Most impressive was our ability to achieve 5.17% growth in the most recent difficult annual period (2012-2013) when the same top 20 institutions averaged only a 0.95% growth. This growth has been protective for our research enterprise in an era when, over the same five- period, state and local research funding decreased 29% (Table 2).

Table 1: Federally-Financed R&D Expenditures 2007-2013 for Top 20 Reporting Institutions

2013 Rank Federal	2013 Rank Overall ^a	Institution	2007 Federal government	2012 Federal government	2013* Federal government	2007-2013% Growth	2012-2013 % Growth
		All institutions	\$30,440,745	\$40,130,460	\$39,470,157	29.66%	-1.65%
		2013 Top 20	\$ 9,597,399	\$13,156,757	\$13,281,889	38.39%	0.95%
		All Others	\$20,843,346	\$26,973,703	\$26,188,268	25.64%	-2.91%
1	1	Johns Hopkins U. ^b	\$ 1,362,836	\$ 1,857,580	\$ 1,898,927	39.34%	2.23%
2	3	U. WA, Seattle	\$ 620,375	\$ 909,652	\$ 928,193	49.62%	2.04%
3	2	U. MI, Ann Arbor ^c	\$ 577,201	\$ 791,729	\$ 814,167	41.05%	2.83%
4	11	Stanford U.	\$ 534,787	\$ 636,348	\$ 652,472	22.01%	2.53%
5	18	U. PA	\$ 449,687	\$ 669,970	\$ 636,589	41.56%	-4.98%
6	13	Columbia U. , City of New York	\$ 459,748	\$ 645,573	\$ 635,987	38.33%	-1.48%
7	5	U. CA, San Diego	\$ 475,708	\$ 656,891	\$ 632,593	32.98%	-3.70%
8	9	U. NC, Chapel Hill	\$ 346,672	\$ 606,348	\$ 623,237	79.78%	2.79%
9	14	U. Pittsburgh, Pittsburgh	\$ 441,357	\$ 637,857	\$ 622,232	40.98%	-2.45%
10	7	Harvard U.	\$ 392,103	\$ 589,860	\$ 594,392	51.59%	0.77%
11	8	Duke U.	\$ 459,122	\$ 587,268	\$ 581,695	26.70%	-0.95%
12	6	U. CA, San Francisco	\$ 467,402	\$ 559,329	\$ 566,117	21.12%	1.21%
13	17	Penn State U. University Park & HMC ^c	\$ 370,789	\$ 531,421	\$ 558,871	50.72%	5.17%
14	4	U. WI, Madison	\$ 469,076	\$ 580,661	\$ 555,875	18.50%	-4.27%
15	23	GA Institute of Tech	\$ 260,230	\$ 484,212	\$ 522,134	100.64%	7.83%
16	21	Yale U.	\$ 349,027	\$ 531,421	\$ 503,227	44.18%	-5.31%
17	10	U. CA, Los Angeles	\$ 488,846	\$ 539,054	\$ 501,368	2.56%	-6.99%
18	15	U. MN, Twin Cities ^c	\$ 337,966	\$ 485,462	\$ 494,206	46.23%	1.80%
19	12	MA Institute of Technology	\$ 476,318	\$ 496,132	\$ 490,809	3.04%	-1.07%
20	22	U. IL, Urbana-Champaign	\$ 258,149	\$ 359,989	\$ 468,798	81.60%	30.23%

^aIncludes all R&D Expenditures (Federal, state, local, industry, etc.)

^bJohns Hopkins University includes Applied Physics Laboratory, with \$1,121,483 thousand in total R&D expenditures in FY 2012.

^c2007 is all campuses

Table 2: State & Local Government Financed R&D Expenditures 2007-2013

Institution	2007	2012	2013	2007-2013 % Growth	2012-2013 % Growth
	State & local government	State & local government	State & local government		
All institutions	\$ 3,145,376	\$ 3,704,365	\$ 3,657,725	16.29%	-1.26%
Penn State U., UP and Hershey	\$ 69,662	\$ 47,402	\$ 49,465	-28.99%	4.35%

Data from a National Science Foundation survey of higher education institutions illustrates that Penn State has significant strength in fields ranging from engineering and geology to psychology and sociology. As shown in Figure 1, Penn State has consistently ranked in the top five in these fields in terms of research expenditures over the past decade, and was placed in the top 10 in a dozen different research areas in 2013. Taken together, Penn State's science and engineering expenditures ranked 17th nationwide in 2013.

NSF Total S&E Research Expenditure Rankings for FY2013: Top Twenty Overall by NSF Fields and Subfields

	FY2013 Ranking	FY2012 Ranking	FY2011 Ranking	Industry	Total Engineering	Aero/Astro-Engineering	Bio-Engineering	Chemical Engineering	Civil Engineering	Eng - Electrical	Eng - Materials	Eng - Mechanical	Total Physical Sciences	Chemistry	Physics	Astronomy	Total Environmental Sci	Atmospheric	Earth Sciences	Oceanographic	Mathematical	Computer Science	Total Life Sciences	Agricultural	Biological	Medical	Psychology	Total Social Sciences	Economics	Political Science	Sociology	Number in Top Ten Fields/Subfields
Johns Hopkins	1	1	1	15	1	1	4	7	23	1	86	1	2	9	2	5	20	24	81	29	1	3	2	n/a	6	4	79	75	98	256	19	15
U. Michigan	2	2	2	14	7	14	20	17	12	8	16	10	22	12	23	21	47	n/a	16	n/a	6	61	4	49	16	9	5	1	1	2	2	11
U. Washington	3	4	3	21	18	29	5	34	21	20	35	41	27	27	22	17	5	1	40	4	30	29	5	40	15	7	46	47	166	32	14	6
U. Wisconsin	4	3	4	45	14	n/a	10	14	14	52	31	49	12	13	13	23	16	4	42	46	26	20	12	28	14	14	67	7	7	38	8	5
UC San Diego	5	5	6	8	17	n/a	6	n/a	n/a	6	139	18	15	5	12	n/a	1	10	5	2	36	10	13	n/a	91	3	8	31	43	12	30	10
UC San Francisco	6	6	7	10	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	95	46	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1	n/a	111	1	n/a	n/a	n/a	n/a	n/a	2
Harvard	7	17	27	24	50	n/a	47	72	56	79	12	57	13	3	16	14	27	86	33	n/a	15	152	18	n/a	2	40	59	4	12	1	35	4
Duke	8	7	5	2	37	n/a	11	n/a	79	18	38	70	57	75	40	n/a	44	n/a	90	36	9	81	3	n/a	7	5	6	26	32	9	22	6
UNC Chapel Hill	9	11	17	35	204	n/a	68	n/a	n/a	n/a	n/a	n/a	37	11	53	n/a	23	n/a	10	28	28	18	7	n/a	8	18	1	2	163	25	1	6
UC Los Angeles	10	8	8	12	36	n/a	59	27	71	24	24	24	16	25	8	n/a	40	25	25	n/a	12	26	9	n/a	107	2	30	9	135	70	26	4
Stanford	11	9	9	7	15	15	15	11	27	15	45	13	6	18	60	n/a	29	n/a	30	43	17	15	17	n/a	21	17	27	25	30	17	23	1
MIT	12	15	20	3	3	7	1	4	7	5	2	5	4	22	6	6	15	12	15	34	18	7	95	n/a	44	103	137	33	11	35	152	12
Columbia	13	10	12	20	43	42	16	53	92	26	141	84	30	48	21	16	4	8	4	16	50	27	15	n/a	30	16	78	65	56	20	42	3
U. Pittsburgh	14	12	10	72	88	n/a	22	48	106	98	164	56	43	31	50	36	74	n/a	91	n/a	42	60	6	n/a	18	6	33	107	102	92	156	2
U. Minnesota	15	14	13	33	27	28	12	10	19	42	147	17	26	35	19	37	49	n/a	19	n/a	8	28	16	13	29	13	3	12	14	16	5	4
Cornell	16	16	16	32	20	n/a	35	26	72	30	20	23	5	17	9	10	37	n/a	38	110	49	17	19	19	22	21	34	10	3	109	10	6
Penn State 2013	17	18	15	27	5	8	76	19	9	4	1	3	21	26	17	15	14	9	9	35	11	8	47	8	64	58	2	14	45	28	3	12
U. Penn	18	13	11	11	61	n/a	29	63	n/a	39	27	55	46	47	32	n/a	130	n/a	79	n/a	53	25	11	136	12	10	19	19	70	40	16	1
Texas A&M	19	24	23	13	6	10	28	9	1	23	32	11	25	15	24	62	3	27	39	3	7	48	40	1	106	64	90	49	41	48	44	8
Ohio State	20	19	14	4	13	61	90	22	26	16	5	6	39	43	35	32	71	n/a	27	n/a	20	12	24	22	42	23	31	27	27	21	38	2
Penn State 2012				22	4	8	76	16	11	4	1	4	18	17	13	15	13	8	8	34	10	10	48	10	65	60	3	17	32	33	3	12
Penn State 2011				8	4	10	73	11	14	4	1	4	17	18	14	14	13	8	8	35	9	9	45	8	62	62	1	17	37	29	2	12
Penn State 2010				9	3	10	55	18	24	3	2	3	17	20	17	13	11	8	7	27	7	8	45	8	62	60	1	11	34	19	2	12
Penn State 2009				4	3	11	54	7	13	4	1	3	15	11	15	13	11	9	5	29	5	6	49	9	64	63	1	14	34	11	2	12
Penn State 2008				3	3	14	46	6	17	3	1	4	15	11	13	13	11	8	6	29	6	8	51	10	69	63	1	14	43	11	2	12
Penn State 2007				3	3	12	39	3	16	4	1	4	15	16	11	15	11	10	6	33	8	8	52	11	74	62	1	14	53	16	1	11
Penn State 2006				3	3	14	35	3	13	4	1	4	9	9	12	14	12	11	7	26	7	11	51	11	73	59	2	16	47	22	1	11

Figure 1: National Science Foundation Science and Engineering Expenditure Rankings 2013

In 2012-2013 the University's total research expenditures increased to an all-time high of \$848M. As exemplified in Figure 2, the 2012-2013 total corresponds to a roughly 40% increase of \$241M over the past decade. Federal funding for Penn State research has increased by more than 50% over the same period. Penn State procures funding from a number of federal sources, with the Department of Defense (DOD) and Department of Health and Human Services (predominately the National Institutes of Health, NIH) leading the way with over \$129M of funding from each in the 2012-2013 fiscal year (see Figure 3).

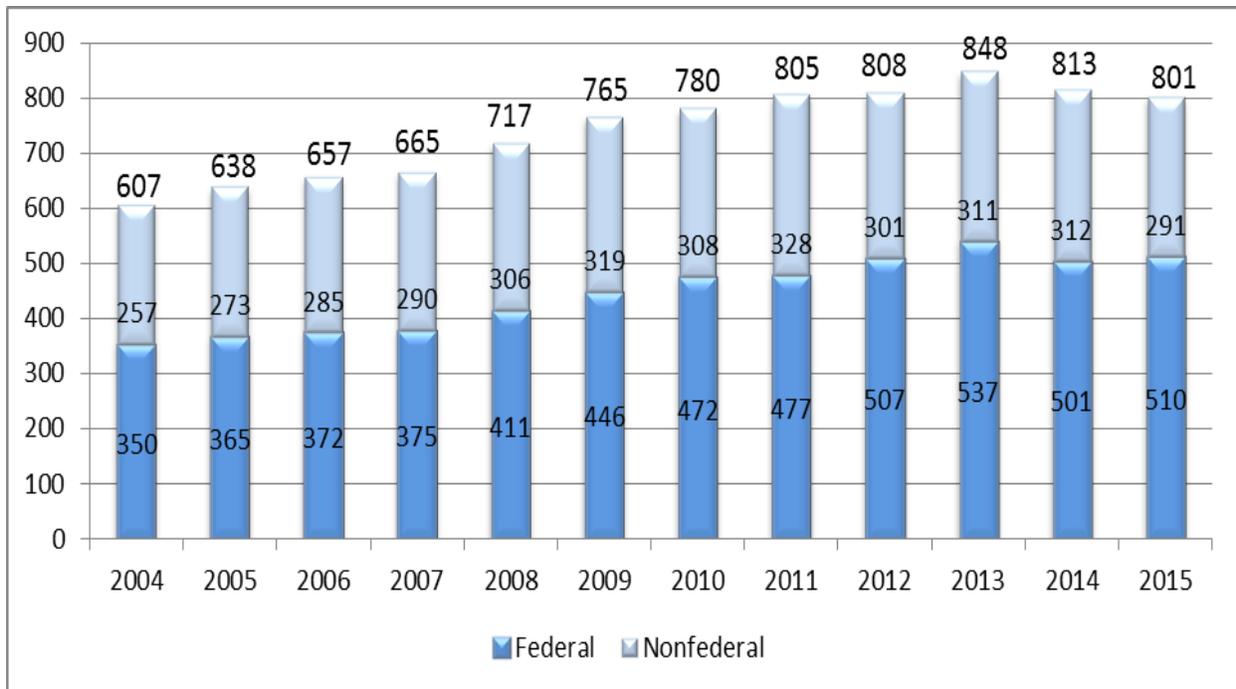


Figure 2: Total research expenditures, 2004-2015

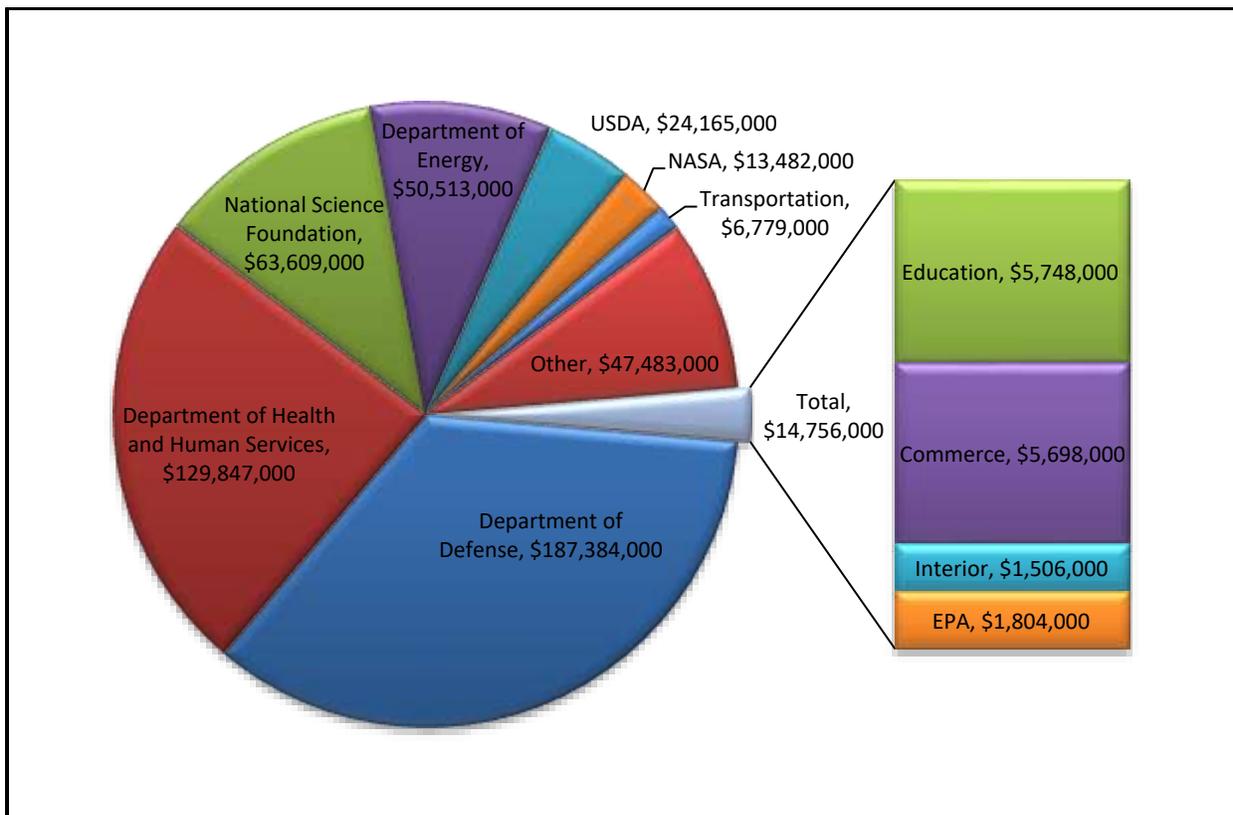


Figure 3: Expenditures by Federal Agency for FY2012-2013

Industry-sponsored research is a core institutional strength of Penn State, especially in science and engineering fields. Since 1995, 7,698 industry partners have awarded \$1.08B to support research projects involving more than 3,000 faculty members across 263 academic departments. Roughly one-half of this industry-sponsored research is in physical science and engineering fields, and approximately 20% of this funding comes from Pennsylvania based firms. While thousands of firms sponsor research at Penn State, the largest industrial research partners account for a very high proportion of this total. As shown below, Penn State's 10 largest industrial research partners alone account for 17% of total industry awards since 1995.

Table 3: Top Ten Penn State Industrial Research Partners, 1995-2014

General Dynamics	\$ 40,084,000
Boeing Company	\$ 21,187,000
Northrop Grumman Corporation	\$ 19,356,000
Lockheed Martin Corporation	\$ 17,609,000
Westinghouse Electric	\$ 12,692,000
United Technologies Corporation	\$ 12,078,000
Dow Chemical Company	\$ 10,341,000
Merck and Company	\$ 9,885,000
Chevron Corporation	\$ 9,790,000
Air Products and Chemicals	\$ 9,457,000
Total	\$ 166,480,000

Penn State's relationships with major industrial research sponsors are broad and deep. Penn State has executed master research agreements with more than 50 of the largest industrial research sponsors designed to simplify the management of individual awards and strengthen these relationships. For example, in 2010 Penn State executed a master agreement with Siemens and in 2013 became the first university in the US to be named a Siemens strategic partner. Similarly, in 2013 GE awarded \$10M to Penn State to support natural gas research, and Penn State named GE its Corporate Partner of the Year.

Research sponsored by industry has increased continuously over the past decades. However, at the same time, Penn State's ranking for industry sponsored research has slipped dramatically in recent years. Penn State was ranked second for industry-sponsored research in 2005 and fell to 22nd by 2012. This warrants explanation. The reason for this is that the NSF, which compiles the data and rankings on academic research, modified the guidelines concerning what may and may not be counted by universities as industry-sponsored research. The effect of these changes has been that expenditures previously counted by universities as industry sponsored research are no longer considered as such, and this has dramatically changed the rankings for this indicator. The current rankings are considered to be a more accurate reflection of the University's performance in this area.

Figure 4 shows Penn State's research expenditures by performing unit in fiscal year 2012-2013. The defense-related research units – the Applied Research Lab (ARL) and Electro-Optics Center (EOC) – continue to lead in research expenditures. A number of other academic units, campuses and groups also contribute significantly to the research enterprise at Penn State.

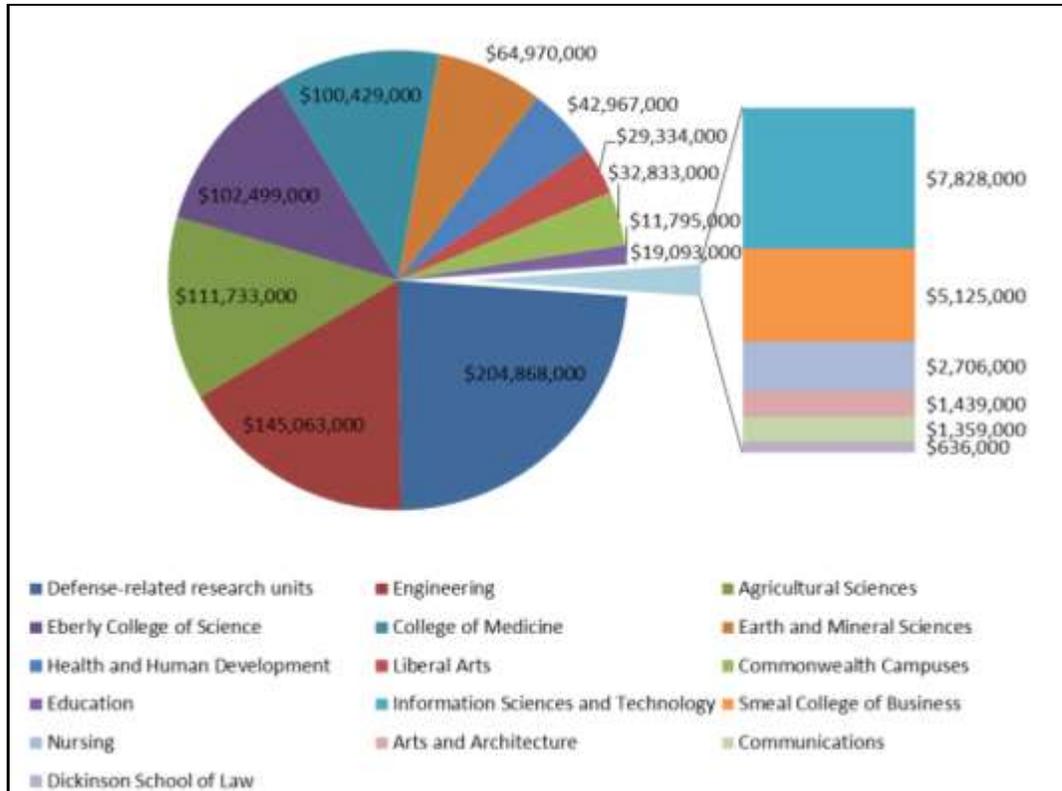


Figure 4: Expenditures by Performing Unit for FY 2012-2013

Progress toward Goals from the Previous Strategic Plan

The 2009 – 2013 strategic plan for the OVPR set out a number of key goals and objectives. Here we evaluate the degree to which the OVPR succeeded with its previous plan. The primary goals established in the previous plan were to: promote research, promote technology transfer, ensure high-quality research infrastructure and support, and enhance visibility of the Penn State research agenda. Understanding Penn State's progress toward these goals is instrumental in determining how the OVPR should direct the University's research enterprise for the next strategic planning cycle.

Promote Research:

As the primary directive of the OVPR, promotion of Penn State research is always an overarching goal for the OVPR, and in that way, this goal is never truly accomplished. However, the OVPR did make significant strides in this area over the past five years.

One valuable metric laid out in the previous plan is the number of cluster hires targeted to advance Penn State's proficiency in strategic research areas. Targeted hiring efforts coordinated and advanced by the OVPR through its institutes were indeed significant. Penn State has completed or is in the process of completing numerous hires clustered around: adolescent development (four faculty lines), child protection and well-being (12 faculty lines) cyberscience (14 faculty lines), genomics (12 faculty lines), infectious diseases (12 faculty lines), innovative methods (six faculty lines), and natural gas (12 faculty lines). These strategic cluster hires have greatly enhanced Penn State's collective expertise in these specialized areas of research, enabling new initiatives where new and existing faculty from across academic units collaborate to pursue high-value common interests.

Another target stipulated in the previous strategic plan to promote research was the continued growth of the defense-related research units (DRRUs): the Applied Research Laboratory (ARL) and Electro-Optics Center (EOC). In the 2013 fiscal year, these units were responsible for over \$204M in research expenditures, roughly a quarter of the University's total research expenditures. In the 2007 fiscal year, which was used as the benchmark for the 2009-2013 strategic plan, the defense-related units were responsible for \$168M in research expenditures. These units have shown significant increases in output, despite a significant downturn in Department of Defense spending over the last few years. Overall, the DRRUs' increase in expenditures remained on pace with the overall increases in research expenditures for the entire University.

The DRRUs' contributions to the educational mission of the University have increased considerably over the last five years. In 2012-13, ARL supported 120 graduate students through assistantships and another 29 through wage payroll, while also exposing 183 undergraduate students to research through a variety of programs. Principal among these were the Distinguished Undergraduate Research Program, Cooperative Education, Summer Manufacturing Internship Program and Diversity Stem Program.

The prior OVPR strategic plan also set out a goal to increase research funding from industry and related sponsors. This funding stream has fluctuated minimally since 2007 (see Figure 5 below), and in general we have not made very good progress. As previously mentioned, Penn State has had a few big wins with industrial sponsors but we can and should do better. University-industry research partnerships are a priority. Our strategy going forward will place renewed emphasis on expanding our footprint with private sponsors.

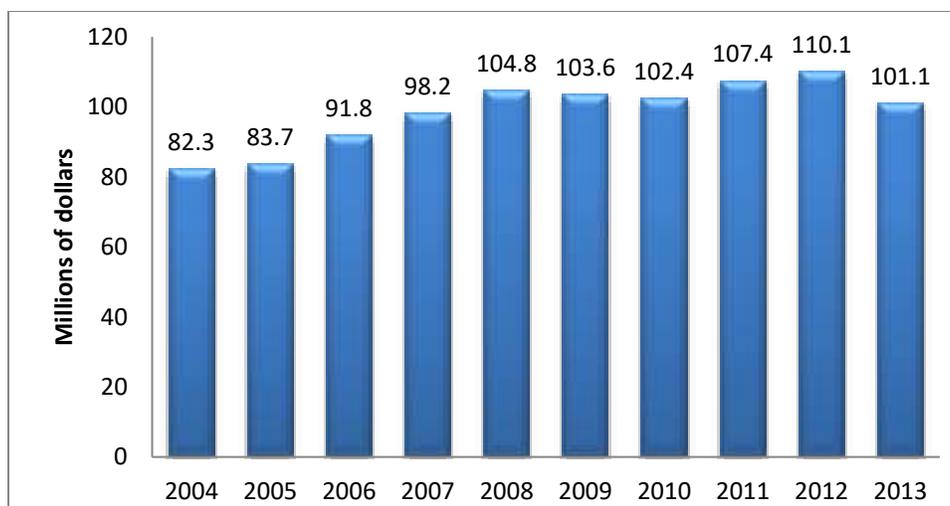


Figure 5: Research Funding from Industry, Private Foundations and Related Sources

Another strategic priority of the 2009 plan was to place greater emphasis on competing for and winning major multi-million dollar center grants. Toward this end, the OVPR established the Strategic Interdisciplinary Research Office (SIRO) in summer of July 2010. SIRO was originally constituted by combining the research administrative staff and services of the Materials Research Institute (MRI) and the Penn State Institutes of Energy and the Environment (PSIEE). Since then it has grown modestly through targeted hires. SIRO is directed by the Associate Vice President for Research and currently has 12 team members. A communications specialist/technical writer hire is currently underway to support both proposal development and communications with the broader University community.

These efforts have already translated into significant gains. In 2011 Penn State was awarded the \$120M DOE Energy Innovation Hub for Energy Efficient Building Systems Design, the largest single research award in the history of the University. Penn State has also received five DOE ARPA-E awards to date, second only to the University of California Berkeley. Still, larger gains in major awards are sought; renewed emphasis and new strategies will be employed in the forthcoming plan.

Promote Technology Transfer:

The 2009-2013 OVPR strategic plan set out the major goal of promoting technology transfer, or the translation of Penn State research to usable and impactful outcomes beyond the University. According to the prior plan, the first step in promoting technology transfer is encouraging researchers to disclose intellectual property (IP) with potential commercial value to the Intellectual Property

Penn State has been a leader in developing industry-friendly research policies and procedures

Office. Toward this goal, two well-attended town hall meetings were undertaken in the fall of 2012. The first was focused on conducting research in collaboration with private industry and the

second on entrepreneurship. These meetings achieved their intended purpose to a limited extent (i.e., to make faculty more aware of the untapped opportunity these area provide) but there is much work yet to be done. Other efforts to promote tech transfer included a complete reorganization of the former offices of industrial research and intellectual property into one office: the Office of Technology Management.

In 2012, Penn State radically changed its approach to managing intellectual property in hopes of attracting more research sponsored by the private sector. The decision about who owns the intellectual property generated from privately sponsored research is now left to Penn State researchers. If the researchers involved in the work all agree to release the IP, then any IP generated in the work will become the property of the sponsoring company. In most cases our scientists simply want to undertake the investigation at hand and have no long-term interest in the IP that might be generated. On the other hand, ownership of the resulting IP is very important to sponsoring companies. The new policy is constructed to engender this type of win-win situation. Our novel approach, unique to Penn State, has garnered considerable attention from both private industry and peer institutions. It is too early to tell what impact it will have on the volume of industry-sponsored research conducted system wide but there is no question that more private sponsors are seeking us out and exploring possibilities. Early data from the Behrend campus strongly suggests that we are on the right track. There is guarded optimism that this change, along with other follow-up strategies outlined later in this strategic plan, will lead to a boom in industry-sponsored research at Penn State.

A marker of productivity in technology transfer at Penn State is the number and quality of licenses executed by the Office of Technology Management (Table 4). Since 2009, the number of license agreements generating more than \$1M in revenue for Penn State grew to eight. In 2012, the largest single financial transaction for Penn State technology transfer was executed for an isothermal DNA amplification technology, which included an up-front license issue fee of \$1.75M. Existing license agreements also contributed to the accelerating pace of technology transfer during the previous strategic planning cycle, specifically through the success of startup companies created around Penn State research. Two Penn State startups underwent initial public offerings (IPOs) generating around \$3M in licensing revenue for Penn State. These were the first two Penn State startup companies to undergo IPOs. New startup companies are also increasingly common

Table 4: License, Equities and Startup Companies at Penn State since 1993

Year	Total Licenses	PSRF-Held Equities	Start-Up Companies
1993	7		1
1994	7		1
1995	15		3
1996	8	1	2
1997	14	1	6
1998	15	1	5
1999	21	0	2
2000	17	4	5
2001	27	8	5
2002	27	6	8
2003	16	3	2
2004	16	5	6
2005	15	0	3
2006	15	2	6
2007	11	2	3
2008	20	2	3
2009	15	1	5
2010	19	3	5
2011	18	1	5
2012	18	4	5
2013	27	7	10
TOTAL	378	51	93

at Penn State. In 2013, there were ten companies started around Penn State research, up from an average of five per year in preceding years.

The increase in startup company success at Penn State is due in part to a more favorable climate for Penn State entrepreneurship, an objective identified in the 2009 strategic plan. To promote more successful technology transfer, Ben Franklin Technology Partners in cooperation with the Office of Technology Management initiated the TechCelerator@State College program in 2012. The program is aimed at educating new entrepreneurs. Thus far it has graduated 30 teams, 18 of which are based on Penn State technology, forming 28 companies that have received over \$2.45million in startup funding. The OVPR is currently working on launching the Penn State Fund for Innovation to provide direct financial support to Penn State researchers seeking to develop their ideas into new products and startup companies.

Despite the advances described above, Penn State is ranked 62nd in the nation for licensing revenue generated with \$3,095,017 of revenue reported, 50th for invention disclosures with 132 disclosures, and 70th for licenses and options executed, with 21 such executions. Consistent with these rankings, Penn State ranks 69th for the number of full-time equivalent personnel dedicated to technology licensing, with 4.5 FTEs. Penn State is still underperforming in this domain. We can and must do better. Components of the new strategic plan being launched, including current efforts to bolster human resources in this domain, are aimed directly at making Penn State a top tier institution in technology transfer.

Ensure High-Quality Research Infrastructure and Support:

Providing effective infrastructure and support services for Penn State researchers is another constantly evolving but extremely important goal for the OVPR. In the previous strategic plan, the OVPR laid out a number of measurable outcomes to ensure progress toward this goal. For example, improving and creating support technologies for researchers was described as a priority for the OVPR. In response, new and/or improved paperless systems have been implemented for institutional review of research projects (Centralized Application Tracking System; CATS), conflict-of-interest reporting system (COINS), tracking of administrative information by researchers (myResearch Portal), and other components of the research process.

Completion of the ***Millennium Science Complex*** (MSC) was another major priority identified in the prior strategic plan for the OVPR. This \$215M complex was completed in 2011 and is designed to encourage interdisciplinary research within and across materials science and engineering and the life sciences. The MSC houses a number of highly sophisticated, state-of-the-art, shared-use research facilities. These are truly remarkable assets that enable Penn State to attract and retain the very best faculty. It is also home to two of the University's premier interdisciplinary institutes. The Huck Institutes for the Life Sciences in the south wing currently houses 36 faculty, 14 research scientists, 38 postdoctoral scholars, 21 research technicians, seven support staff, 65 graduate students and 60 undergraduates. The Materials Research Institute occupies the north wing and

accommodates 28 faculty, 40 research scientists, postdocs and visiting scholars, 48 staff and 175 grad students.

Other advancements in research infrastructure include the *Social, Life and Engineering Sciences Imaging Center (SLEIC)*, which was launched in 2009 with the arrival of the Siemens 3T scanner. To date, over 30 faculty members, as well as postdoctoral fellows and graduate students from five colleges, have led more than 50 projects using SLEIC facilities such as the Magnetic Resonance Imaging Facility and Human Electrophysiology Facility units. SLEIC projects have generated more than \$8M in external funding from the National Science Foundation (NSF), National Institutes of Health (NIH), and foundation sources for research in neuroscience, nutritional science, biomechanics, and medicine.

Last but not least, construction on the architectural award-winning *Eva J. Pell Laboratory for Advanced Biological Studies* was completed this year with final certification for use anticipated by fall semester 2014. This \$23M Level 3 biocontainment facility was funded in part by the American Reinvestment and Recovery Act and will enable advanced studies of infectious agents affecting livestock and humans. This complements our new and impressive Insectary with a series of large scale environmental chambers that mimic how climate change alters vector development and changes in transmission of vector borne infections.

The previous strategic plan also charged the OVPR with improving education for researchers to ensure that all research at Penn State is conducted in a responsible manner. Beginning in 2009, the Office for Research Protections (ORP) implemented numerous programs to improve upon its educational opportunities for Penn State researchers. New and improved programs enacted during the prior strategic planning period include *the Scholarship and Research Integrity Program (SARI@PSU)*, the *Collaborative Institutional Training Initiative (CITI)*, *conflict of interest education* and the *Laboratory and Agricultural Animal Researcher Certification Program (LARC)*. ORP also hosts a number of additional training and educational workshops and meetings that provide valuable training to Penn State faculty, staff and students.

Enhance Visibility for the Penn State Research Agenda:

Relevant to all other goals and initiatives for the OVPR, visibility of the Penn State research agenda is central to the success and impact of our work. Among other initiatives in the previous strategic plan, the OVPR aimed to improve international visibility. Since then, two examples show Penn State's recent progress to that end. The Huck Institutes of Life Sciences has made significant gains in collaborative research with universities in Africa and Asia, establishing strong links with two universities in particular: Nelson Mandela African Institute of Science and Technology in Tanzania and Fudan University in China. These initiatives have graduate students from universities located internationally undertaking matched projects with the objective of producing graduate students of equivalent training. The Global Health Center within the College of Medicine is also helping to increase Penn State's global presence and several other international partnerships are underway.

Status of Units within the OVPR

Penn State has a long productive history of interdisciplinary research and prides itself on new and innovative approaches to promote work across academic units. PSU's budget model further encourages interdisciplinary work by sharing credit and incentive funds across engaged units for sponsored research involving multiple units. Evidence of this interdisciplinary culture can be seen in the increased frequency of collaborations of faculty from multiple colleges on grant applications to support collaborative interdisciplinary projects (Figure 6). These collaborative networks clearly increased connectivity occurring during the last strategic planning cycle.

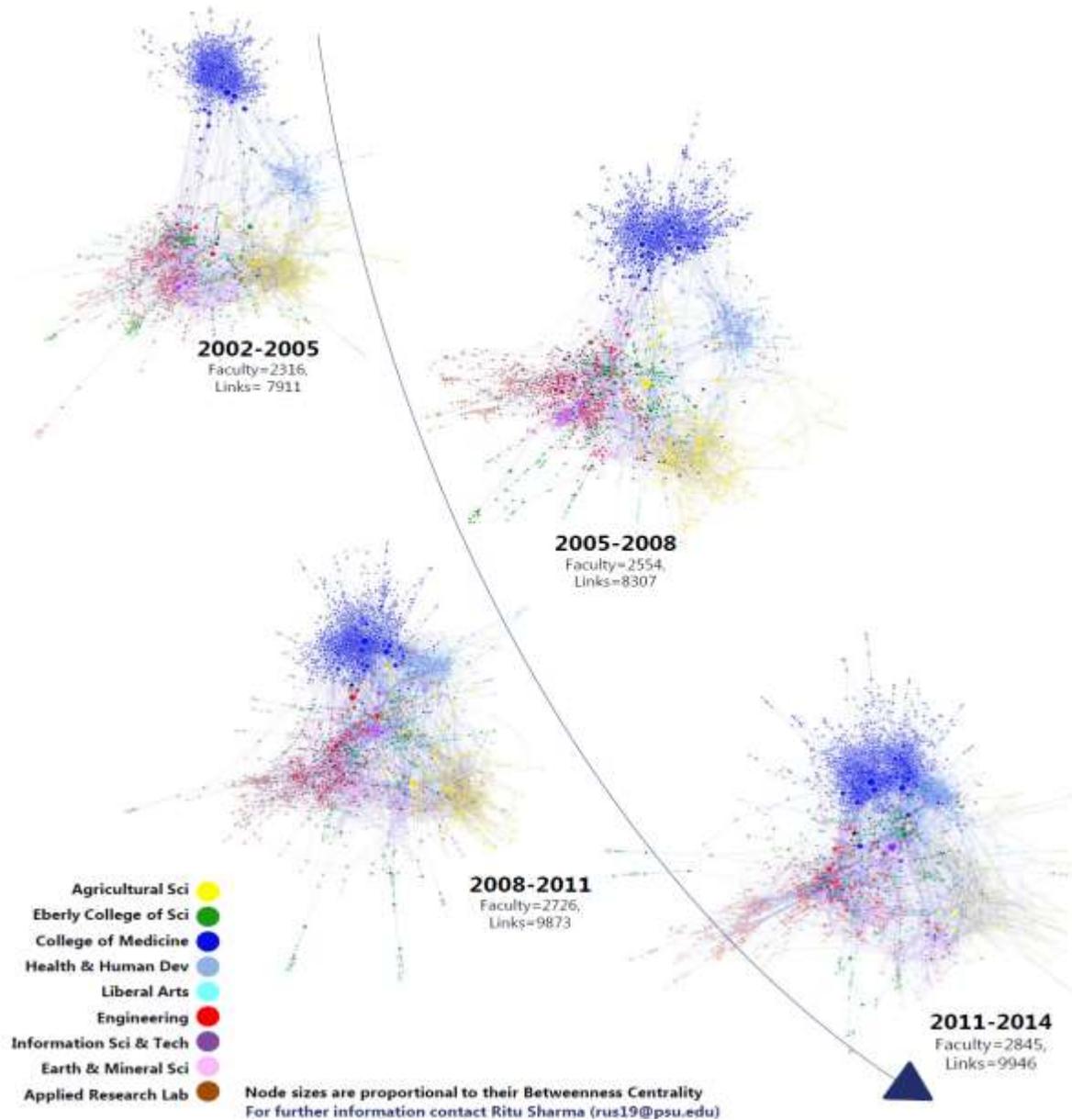


Figure 6: Networks demonstrating changes in connectivity of Penn State faculty over time. Linkages reflect co-submission of research grants.

The Institutes

The six major institutes of the OVPR (Figure 7) form an infrastructure that provides facilities and resources to support interdisciplinary research at Penn State. Each plays a specific role in leveraging existing strengths and provides bridges for collaborative efforts to advancing the Penn State research mission.

Institute for the Arts and Humanities (IAH)

In the past five years, the *Institute for the Arts and Humanities (IAH)* has supported research projects of 54 graduate students and the research and creative projects of 87 faculty members. In 2010, the IAH initiated a postdoctoral program that has emphatically put the IAH on the national and international map as a place where cutting-edge work in the arts and humanities is welcomed and fostered. The IAH also became a member of a 15-university consortium, funded by a \$3M grant from the Mellon Foundation to foster cross-institutional cooperation among humanities institutes and inaugurate a pre-doctoral fellows program.

Institute for CyberScience (ICS)

In July 2007, the *Institute for CyberScience (ICS)* was created with the specific objective of coupling computing and data sciences to specific disciplines and to the other OVPR Institutes with the aim of advancing Penn State's strategic priorities in interdisciplinary research. To test if the Institute would succeed in facilitating research and securing significant external resources for cyber-enabled research, limited funding was provided for an initial probationary period of three years. As of January 2011, ICS had provided seed funding for 19 projects in the amount of \$251,000, which resulted in 56 successful external awards totaling \$45M. Other Penn State Institutes contributed \$256,000 toward these projects for a total investment of \$507,000. In the initial three-year period, ICS faculty secured a major research instrumentation grant from NSF for a \$2M shared system known as CyberSTAR, which in 2011 provided well over half of all Penn State's shared instrumentation for computing and data. With computing rates of 20 teraops (10^{12} operations/sec) and a half petabyte (10^{15}) of storage, this system is used by 260 researchers across all institutes and colleges and in undergraduate and graduate courses in parallel computing. CyberSTAR provides new capabilities, including hosting of the data-intensive Galaxy bioinformatics gateway and the critical-zones observatory science gateway with real time sense-simulate-predict functions. The top 26 users of CyberSTAR have generated \$49,233,112 in external funding.

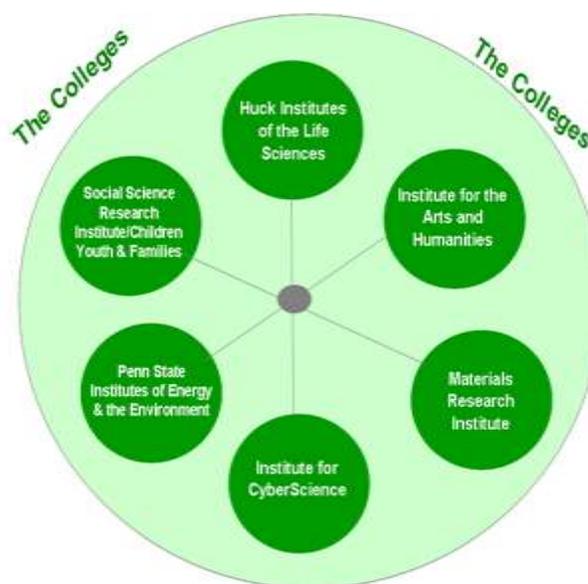


Figure 7: Six Institutes Supported by the OVPR

In 2011 an intra-University Cyberscience Task Force was charged with developing a strategic and coherent vision for cyberscience at Penn State. On the recommendations of this taskforce, the Institute for CyberScience was established in 2012 through the Office of the Vice President for Research as a peer to the Institute for Arts and Humanities, Huck Institutes of the Life Sciences, the Materials Research Institute, the Penn State Institutes of Energy and the Environment, and the Social Sciences Research Institute. In 2012-2013 ICS coordinated the Cyberscience Cluster Hiring Initiative in partnership with 16 departments in the Eberly College of Science, the College of Engineering and the College of Earth and Mineral Sciences. The response from the national community was overwhelming. The initiative received over 950 applications resulting in the co-hire of 12-14 outstanding faculty members bringing with them many new capabilities in foundational topics in cyber-enabled science and engineering. Many of these new co-hires have already led cyber-enabled advances at Penn State in topically driven areas with an abundance of experimental and theoretical expertise. ICS is currently undertaking activities to develop advanced cyberinfrastructure, defined as the effective merging of computing, networking, data technologies, services and human resources into a seamless entity to serve priorities in research. As will be seen, shepherding this effort through to completion is an important element of this strategic plan.

Huck Institutes of the Life Sciences (Huck)

The ***Huck Institutes of the Life Sciences (Huck)*** was established in 1996 to enhance and facilitate excellence in interdisciplinary research and training in life sciences across Penn State. Over the past five years the Huck has been highly successful in the recruitment of outstanding faculty in strategic areas including infectious disease, genomic sciences and plant sciences. The institute facilitated new initiatives and insights by seeding emerging fields (metabolomics), providing leadership in interdisciplinary graduate education, and ensuring that our faculty, staff and students have access to state-of-the-art workspace and instrumentation. Without question, its targeted investments in faculty co-hires, graduate education, and facilities have paid off well, and Penn State is now recognized as a world leader within fields of the life sciences. The institutes and centers that comprise the Huck are better coordinated and serve to focus the dispersed strengths across colleges and align institutional strengths with our research strategy and long-term societal needs. The Huck is unique among the University's major institutes in that it manages several interdisciplinary graduate programs in the life sciences, including some of the leading graduate programs in the country. These programs are able to recruit exceptional students dispersed across multiple colleges and departments who naturally employ interdisciplinary approaches to issues in the life sciences. Overall, the state of life sciences at Penn State is strong with an impressive array of faculty led research centers and programs supported by state-of-the-art instrumentation, facilities and exceptional graduate programs. The Huck institutes are well-positioned to take life sciences to the next level.

Materials Research Institute (MRI)

Since the previous strategic planning cycle, the ***Materials Research Institute (MRI)*** has leveraged the Millennium Science Complex, key faculty talent, federal programs, industry collaborations and

a bevy of other resources to significantly advance the development and application of novel cutting-edge materials. MRI's Materials Characterization Laboratory (MCL) and Nanofabrication Facility (Nanofab) are key components of this success and provide exemplary models for additional shared core facilities. In each of the past three years, the MRI has identified nearly \$145M worth of awards and industrial projects that were enabled by the analytical capabilities of the MCL or by the materials processing and electronic device fabrication capabilities of the Nanofab. MRI-supported research has led to significant advances in fields such as: nanoscale science, nanoelectronics, flexible and low-cost electronics, infrared materials and technologies, and others. The MRI is also aggressively transferring this advanced research to industry and the public via industry collaborations, startup companies, and other means of effectively using intellectual property connected to Penn State materials research.

The Penn State Institutes of Energy and the Environment (PSIEE)

During the past five years, **The Penn State Institutes of Energy and the Environment (PSIEE)** have been involved in hiring 35 new faculty. Strategic hires were made based on the needs of the University in key areas of environmental and energy research. Three new faculty were hired in collaboration with the Huck and MRI. The most dramatic advances during the 2008 – 2013 strategic planning cycle were fueled by successful major interdisciplinary research awards. These multi-million dollar awards were highly competitive, and in several cases there were just one or two projects funded nationally. Penn State has been recognized as a model for the NSF's critical zone observatory and sustainable research network programs. Penn State is one of only two universities to lead a DOE Energy Innovation Hub (CBEI) and is second only to MIT in the number of awards in the DOE's prestigious Advanced Research Projects – Energy (ARPA-E) program. Penn State is increasingly recognized nationally and internationally for our effective leadership of innovative interdisciplinary research. The Institute's largest award was from the Department of Energy to support the establishment of the \$21M Center for Lignocellulose Structure and Formation headed by Dr. Daniel Cosgrove. International awards included a \$10M award to Dr. Bruce Logan for research on Energy for a Sustainable Water Infrastructure and Agriculture.

During the previous five year strategic plan, over \$400,000 was spent to upgrade the Water Quality Laboratory with remodeled facilities and new instrumentation. PSIEE also supported the creation and continued funding of the LIME (Laboratory for Metals and Isotopes in the Environment). Most recently, Penn State made a commitment to purchase a significant amount of equipment and expand these core facilities to support energy and environmental research. In association with the Earth and Environmental Systems Institute, the LIME lab will be transformed into the Energy and Environment Sustainability Laboratory (EESL), while additional instrumentation will be co-managed with the Materials Characterization Laboratory in the Materials Research Institute.

Social Science Research Institute (SSRI)

The **Social Science Research Institute (SSRI)**, in addition to continuing its existing work, significantly expanded its reach during the previous strategic plan. In 2009 the SSRI, in collaboration with relevant college and institutes, established the Social, Life and Engineering

Sciences Imaging Center (SLEIC) with the installation of a Siemens 3T scanner for advanced human imaging research. Another new entity under the SSRI umbrella, the Clearinghouse for Military Family Readiness, was launched in 2010 and has already grown to almost 40 full-time employees. The Clearinghouse works closely with the Department of Defense and the military services to conduct research and outreach projects supporting military members and families. In 2011, the Survey Research Center initiated the Dynamic, Real-time, Ecological, Ambulatory Methodologies (DREAM) project to aid research on behavior, experiences, physiology and environmental factors in people's natural settings and during their daily lives. Established in 2012, the Network on Child Protection and Well-Being is expanding via an ongoing cluster hire of faculty who will work together to design and evaluate novel approaches to the prevention, detection, and treatment of child abuse and neglect. Most recently, in early 2014, the Population Research Institute created the Census Research Data Center (RDC) to provide approved researcher access to economic, census, and health data that are currently restricted and difficult to obtain, thus greatly expanding opportunities for demographic, economic, and health related research among all faculty at Penn State.

Defense-Related Research Units

Two major units within the OVPR are responsible for the more than \$200M in defense-related research expenditures reported by Penn State in 2012-2013 (Figure 4). The Applied Research Laboratory (ARL) was established at University Park by the US Navy in 1945. The Electro Optics Center (EOC) was founded in Freeport, PA in 1999 as an enabler of electro-optics manufacturing technology from a staff comprised primarily of former industry and Department of Defense personnel. Together these two units host five major high-profile initiatives.

Undersea Technology – Ship Self Defense System: For the past several years ARL has been supporting the US Navy as the technology developer and design agent for an Anti-Torpedo Torpedo capability to defend ships from an attacking torpedo. The research and technology development is sponsored by the Office of Naval Research and ARL's role as the engineering design agent is in support of the Naval Sea Systems Command, Surface Ship Torpedo Defense (SSTD) Program. This multi-year development was recently commended by the Navy's Chief of Naval Operations, Admiral Jonathon Greenert during a visit to the laboratory to signify the system's deployment to the fleet.

Advanced Materials and Manufacturing Technology: In support of the Navy's Manufacturing Technology Program, ARL has developed advanced materials applications and implemented leading edge manufacturing technologies that have been transitioned to the Navy to support new systems under development as well as sustain current fleet systems. The net effect of this effort has been a return of investment for the Navy in terms of savings of several \$100M, both on existing and emerging fleet platforms. Recently, the ARL has joined with the College of Engineering and the College of Earth and Mineral Sciences to establish a new, major center at Penn State for

research on additive manufacturing as applied to high-performance metal components. The Center is sponsored by the Defense Advanced Research Projects Agency, the Office of Naval Research and Army Research with 27 participating industrial partners. The Center for Innovative Materials Processing is also a part of the National Initiative for Additive Manufacturing.

Unmanned Undersea Vehicles (UUV): ARL has forged a critical role in the Navy's program to develop and deploy large displacement unmanned undersea vehicles for a variety of potential missions. The pioneering work accomplished by the laboratory through critical experimentation and demonstrations has provided a firm foundation and acceptance of large UUVs as a necessity for the future Navy with an official Program of Record established. One of the ARL vehicles is being tested with the goal of identifying and tracking narcotics trafficking at sea.

Navy Laser Weapon System (LaWS): A Navy program has begun that fields a laser based defensive system called LaWS aboard Navy ships. The concept is based upon research performed at the EOC over the previous decade that combines incoherent beams to achieve high power on a target with moderate beam quality. The approach has proven highly successful in engaging targets at tactically significant ranges in maritime environments.

This aggressive program is in response to current threats that the LaWS system is uniquely qualified to address and defeat. The EOC is providing engineering support to the Naval Surface Warfare Center in several technical areas including the optical system which includes upgrades to the coatings, collimating optics, turning mirrors, output window, and primary and secondary mirrors. The EOC is also providing software and associated hardware upgrades to allow the system to be operated by a single individual. A directive from the Chief of Naval Operations called for an upgraded LaWS system to be installed for deployment on the USS Ponce in 2014.

Fluid Dynamics Research Consortium: The Applied Research Laboratory has teamed with the Departments of Mechanical and Nuclear Engineering, and Aerospace Engineering to establish the Fluid Dynamics Research Consortium (FDRC) at Penn State under the auspices of the Office of the Vice President of Research. The FRDC is a forum for coordinating the extensive fluid dynamics expertise across the University and currently has 146 members. The consortium fosters collaboration between researchers, hosts a regular seminar series and facilitates the submission of University wide proposals. Applications of this ongoing research are depicted in Figure 8 below.

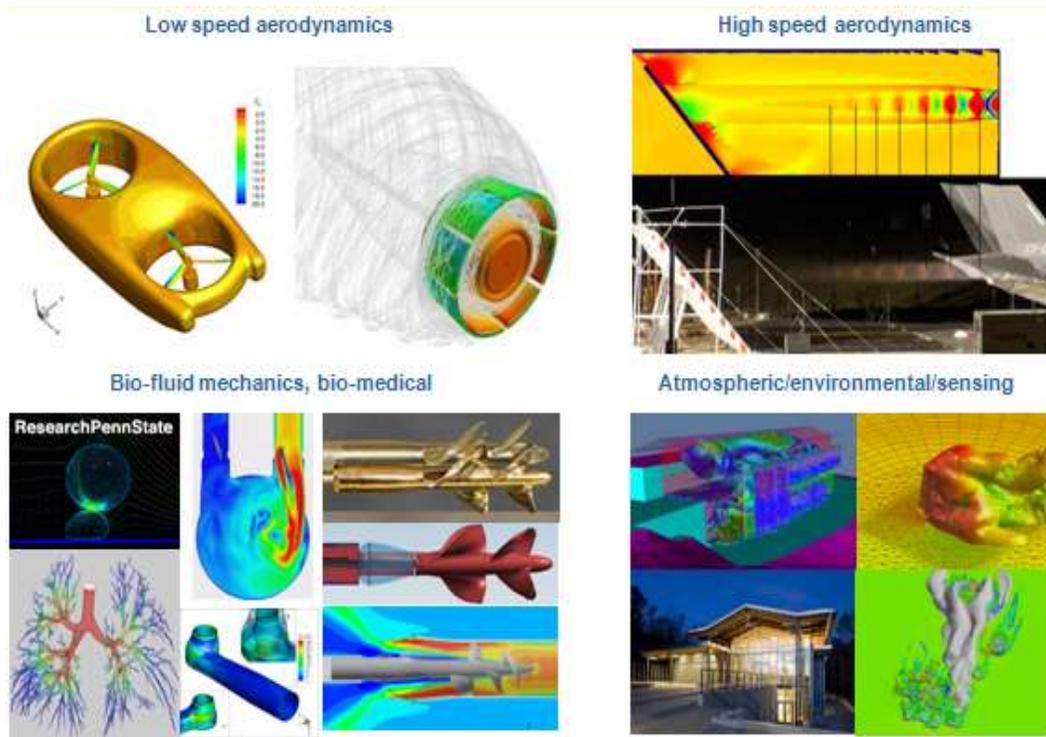


Figure 8: Fluid Dynamics Research Consortium (FDRC) Aerodynamics Research Applications in Bio-fluid Mechanics and in Atmospheric and Environmental Sensing

OVPR Supporting Units

The ***Animal Resource Program (ARP)*** has continued to improve infrastructural support for research. In the past five years, the ARP has helped to establish and maintain laboratories across the University, including those in the Millennium Science Complex, the recently completed Eva J. Pell Laboratory for Advanced Biological Research, and the Centralized Biological Laboratory. In response to faculty requests and research needs, the ARP developed and opened a gnotobiotic facility in 2013, which is already being used to enhance the work of several investigators.

The ***Office of Sponsored Programs (OSP)***, which provides central coordination and oversight of all research awards that come into Penn State, has taken a number of steps in the previous five years to increase the efficiency and effectiveness of processes associated with management of research awards. Many of the forms and procedures that previously required hard-copy print-outs and in-person signatures have been converted to allow for electronic submissions. The OSP was also extensively involved in the implementation of Penn State's new policies regarding intellectual property, which are designed to encourage additional research funding and partnerships that were previously not appealing to external partners. Finally, the OSP has streamlined and improved a number of internal processes, such as training and reporting procedures.

The **Office of Technology Management (OTM)** oversaw the first and second initial public offerings (IPOs) for Penn State startup companies, Anacor Pharmaceuticals Inc. and REVA Medical. In 2012, the Office of Technology Management signed a license agreement with Life Technologies (now Thermo Fisher) for \$1.75M, the largest single financial transaction for Penn State technology transfer. The Office of Technology Management also streamlined, clarified, and generally improved a number of processes and policies related to technology transfer, intellectual property, and entrepreneurship at Penn State.

The **Strategic Interdisciplinary Research Office (SIRO)** was established in 2010 to enhance our ability to secure and manage large awards. The office is currently organized into two functional areas. The pre-award unit with seven team members supports the full suite of proposal development and submission activities. The post-award unit has five team members who support activities after extramural funding has been awarded to a principal investigator (PI). Activities in both units are performed with appropriate levels of coordination with other research support units. SIRO has shepherded the development of an average of 30 larger interdisciplinary proposals annually for the past three years. As of March 2014, these efforts reflect a 20% success rate through contributions to the success of 18 strategic awards across seven colleges/campuses and five agencies. These proposals totaled \$53M and averaged \$5M each. Additionally, SIRO has managed the MRI and PSIEE submissions for approved single investigator grants; this additional activity averages 160 submissions annually.

The **Office of Research Program Development (ORPD)** led coordination between Penn State and the I-99 Corridor Alliance aimed at leveraging research conducted in the Millennium Science Complex (MSC) for regional economic development, providing an additional \$40M in Commonwealth funding for the MSC. This office also secured \$110M of federal (Department of Energy) and state funding for the Energy Efficient Buildings (EEB) Hub at the Navy Yard in Philadelphia, now named the Consortium for Building Energy Innovation. Research Program Development also facilitated collaboration across seven of the Commonwealth's leading engineering research universities to promote state and federal funding support for industry-university manufacturing research partnerships.

The **Office for Research Protections (ORP)** has implemented a number of policy and infrastructure changes to improve the efficiency of processes related to review of research using human participants and animal subjects, conflict-of-interest, research-misconduct reporting and education in the responsible conduct of research since 2009. One of the largest and most impactful changes is the shift from an existing software system to a state-of-the-art system, the Computerized Application Tracking System (CATS) for reviewing research proposals that use human subjects. This shift will increase the efficiency by which proposals will be reviewed by Penn State's Institutional Review Board (IRB) and brings all reviews, including those originating from the College of Medicine, under a single system. In 2009, ORP also implemented an ethics training program, called Scholarship and Research Integrity at Penn State (SARI@PSU) that has since gained national recognition for its scope and effectiveness. To better manage conflict-of-interest

reporting, ORP implemented the Conflict of Interest System (COINS) in 2010 as a computerized method for researchers to report any potential conflicts of interest to ensure that research is conducted responsibly. These major endeavors by ORP have also been supplemented by myriad other improvements in Penn State's policies and procedures for ensuring research is conducted consistently, efficiently and responsibly.

The **Office for Research Information Systems (ORIS)** has worked with a number of other support groups to create and improve a number of computerized systems to expedite administrative work necessary for the execution of Penn State research. Key projects that ORIS has worked on include: a proposal budgeting system, a proposal submission system, a conflict-of-interest management system (COINS), a research review system (CATS), the OVPR website, and others.

Innovation Park is a 118-acre research and business campus under development by Penn State to create an environment where University and business partners collaborate to convert knowledge to societal impact. In partnership with the Office of Finance & Business, the OVPR is charged with oversight of the enterprise. Between 2009 and 2013, an additional 94,500 square feet of space was constructed and leased. The current build out is 1,013,682 square feet, fully leased, with a total build out target of 1,443,858 square feet. During 2011-12 the Innovation Park Office worked with the Park developer, the College Township Planning Commission and the Research Park Management Corporation Board to update the master plan for the Park. WRT Architects of Philadelphia, PA and Sweetland Engineering of State College, PA were engaged to assist in a major modification of the governing Planned Research and Business District (PRBD) zoning ordinance. In addition to the ordinance update, building massing was calculated for the remaining acreage, a new storm water management concept was proposed and accepted, and various setbacks adjusted to increase build-out efficiency. In 2012-13, a buyout of the majority owner in the developer partnership was facilitated. The transaction resulted in a \$38M sale of the 328, 329 and 330 buildings. In turn, the Partnership is in a strengthened capital structure for future build programs, requiring less pre-lease commitments for the commencement of new projects. The Park is at 100% occupancy, with a new 87,000 square feet build program commencing in 2014. Innovation Park Office anticipates an additional 120,000 square feet of new net space to be constructed during the period 2014-19 period.

The **Ben Franklin Technology PARTners of Central and Northern Pennsylvania (BFTP/CNP)** is one of four regional, non-profit corporations funded by the Commonwealth's Ben Franklin Technology Development Authority that provide financial support, technology and management experience to early-stage Pennsylvania companies, as well as linkages to public, private, and education resources to strengthen the high-technology components of the state's economy. The BFTP/CNP is operated by Penn State for the Commonwealth of Pennsylvania, and the OVPR is charged with oversight of the organization. The BFTP/CNP has recently launched a series of TechCelerator entrepreneurial support programs to increase the local commercialization of Penn State and community innovations. At University Park alone, this effort has dramatically increased the number of University-based startups in the last two years. Over the past five years, BFTP/CNP

programs have aided formation of 48 new companies, 228 new products, 58 new processes, 84 new patents or copyrights and 1260 new jobs.

STRATEGIC GOALS

The OVPR will advance six strategic research goals aligned with institutional goals and the major strategic thrusts of Penn State’s colleges and institutes. The first five strategic goals correspond directly with the University’s thematic priorities. An additional goal reflects a vitally important thrust intended to significantly advance Penn State’s contributions to regional, national and global economic growth. Each goal will be achieved through multiple objectives lead by an OVPR signature objective. The six strategic goals are:

Goal 1: Advancing Precision Health in Context

Goal 2: Stewarding Natural Resources and the Environment

Goal 3: Transforming Education and Improving Access

Goal 4: Building Our Digital Future

Goal 5: Validating and Exploring Cultures

Goal 6: Advancing Entrepreneurship, Technology Transfer and Economic Development

Collaboration is a foundational principle central to the research that undergirds our strategic priorities, all of which are influenced by a myriad of efforts falling under the purview of dozens of supporting units, colleges and campuses. A convergence of the biological, social, engineering, agricultural, material and other sciences jointly support each objective. Each objective is presented with a primary affiliation to a specific goal, but simultaneously contributes to other goals to integrate and solidify the proposed platform to advance Penn State research.

The institutes and service units of the OVPR will support the work of collaborative teams of researchers across the University to achieve these goals. Key supporting strategies include: encouraging collaboration among researchers, improving internal and external communication, facilitating technology transfer, providing support for large, multi-investigator proposals, and expanding computational and IT resources. The OVPR and will work closely with relevant deans, institute directors and advisory committees of collaborating units (Table 5) to pursue and attain these goals.

Table 5: Penn State Colleges, Institutes and Units Contributing to OVPR Goals

Applied Research Laboratory (ARL)	Eberly College of Science (ECOS)
Behrend College (BC)	Electro Optics Center (EOC)
Clinical & Translational Sciences Institute (CTSI)	Huck Institutes of the Life Sciences (HUCK)
College of Agricultural Sciences (CAS)	Institute for CyberScience (ICS)
College of Arts and Architecture (CAA)	Institute for the Humanities (IAH)
College of Earth and Mineral Sciences (EMS)	Materials Research Institute (MRI)
College of Engineering (COE)	Pennsylvania College of Technology (PCT)
College of Health & Human Development (CHHD)	Penn State Harrisburg (PSH)
College of Information Sciences & Technology (IST)	Penn State Institute for Environment & Ecology (PSIEE)
College of the Liberal Arts (CLA)	Smeal College of Business (SCOB)
College of Medicine (COM)	Social Sciences Research Institute (SSRI)
College of Nursing (CON)	Sustainability Institute (SI)

While facilitating cross-unit collaborative efforts, the OVPR will ensure strong supporting infrastructure. State-of-the-art information technologies will enable researchers to address multi-scale and complex questions by challenging Big Data. Under the auspices of ICS, Research Computing will ensure shared network, computer and storage infrastructure; advanced technical support, programming and services; and Big Data and Big Simulation capabilities will lead to the identification of critical experiments. Geographically dispersed campuses and facilities from Philadelphia to Pittsburgh will provide access to both urban and rural settings with diverse populations and industries. The Office of Sponsored Programs (OSP) will strive to streamline research administration to minimize faculty administrative burdens. The Office for Research Protections (ORP), Animal Resources Program (ARP) and other units will provide Penn State researchers with the knowledge and resources necessary to conduct research safely and responsibly. The Strategic Interdisciplinary Research Office (SIRO) will provide coordinated pre-award and post-award research administration services supporting large projects that involve multiple colleges and units to support new transformative and translational projects. The Office of Human Resources (HR) will be vital to the recruitment of the best talents in new initiatives. Penn State marketing and communications departments and others will regularly publicize landmark findings and significant grant awards. Communication about Penn State research is crucial for both increased visibility of our research and public recognition of its impact on society. The Office of Technology Management (OTM) will ensure that any meaningful technologies created by Penn State researchers are transferred to government, businesses and individuals so these discoveries can have the greatest impact.

GOAL 1: Advancing Precision Health in Context

Penn State OVPR will promote precision healthcare and health resiliency in populations and individuals by melding University research expertise in the life sciences, social and behavioral sciences, medicine, engineering and informatics for translation to clinical practice, service and education.

As a major part of Penn State's focus on human health, the OVPR will encourage and support research enhancing societal understanding of health from multiple perspectives. Through research we will integrate basic and advanced knowledge about the human system; technological and computational advances that ensure better understanding and management of health and healthcare practices; social factors influencing the well-being of different groups and cultures; infectious diseases and environmental disruptions that might threaten human welfare, and more. Through research expertise being combined across the University, six specific objectives will converge on a common goal of improving the health and well-being of humans and of society by connecting these many informed avenues.

SIGNATURE OBJECTIVE 1.1 *Build expertise in evolutionary medicine and risk management*

Modern medicine and public health are focused on directly attacking the life forms that harm us. Yet biology and experience have shown us many of these pathogens and pests are extremely good at evolving protective responses. Pathogens rapidly evolve drug resistance, vectors evolve against insecticides and target antigens can even evolve to make vaccines worthless. Cancer is also an evolutionary process: tumor cell lines evolve against drugs and are a major cause of death. The global estimated burden imposed by the counter-adaptation against antibiotic resistance is believed to reach a global mortality rate of 10 million deaths per annum by 2050. However, cancer rates are actually falling slowly. But the deaths due to infections are rising rapidly as antimicrobial resistance spreads. In short, evolution matters to human health and well-being, and is going to become a serious problem over the next 10-20 years.

Penn State is uniquely placed to lead the world in evolutionary risk assessment and management. Not only do we have substantial existing expertise in infectious disease, cancer, evolutionary biology, ecology, insecticide resistance and resistance in plant pathogens, but we have an institute structure that breaks down discipline boundaries and builds trans-disciplinary research teams. Moreover, there are no other institutions with the vision to bring such a diverse group of clinical, life science, agricultural and social science areas together. The potential is largely untapped since most clinical, oncology and infectious disease workers have little or no formal training in evolutionary biology, and they have a lack of understanding about the selection processes and the ways these can be avoided. This means there are intellectual opportunities at the interface of

evolutionary biology and public health and medicine, which have the potential to generate novel approaches to evolution-proofing existing and new therapeutics.

Specific questions to be addressed include the following: (1) Can the evolution of resistance be best retarded by using drugs (insecticides, etc.) sequentially, in rotations, at random or in combinations? (2) Under what circumstances should drugs be used aggressively? Standard practice is to hit hard, yet that approach kills semi-resistant mutants at the price of providing maximum selective advantage to organisms with high-level resistance – the very organisms that cause the problems. (3) What properties of chemicals best retard evolution? (E.g., short or long half-lives, mode of action, etc.) (4) What non-chemical technologies can best retard the evolution of resistance? Almost certainly the answers to these questions are context-specific but the intellectual challenge is to identify the general principles, determine the details that matter and use these to solve real world health problems.

Signature Objective 1.1	<i>Build expertise in evolutionary medicine and risk management</i>
Supporting Strategies	Make strategic hires, promote collaboration and innovation among researchers, improve internal and external communication, support larger proposal development and preparation, provide seed funding opportunities, and expand and improve supporting resources and state-of-the art instrumentation
Assessment	<ul style="list-style-type: none"> • Faculty hires with expertise and interest in the computational approaches to the life sciences, especially genomics and personalized healthcare • Successful collaborations (grants and publications) between researchers with varied skills crossing the spectrum of biology in terms of scale and species
Involved Units	CAS, COE, COM, CON, ECOS, CHHD, CLA, CTSI, HUCK, SSRI, ICS PSIEE, MRI

OBJECTIVE 1.2 Establish the Center for Lifespan Fitness, Performance and Health

Penn State has a strong culture that recognizes the importance of balance between academics and athletics in our student population, as well as the proven benefits of activity and physical fitness on mental health and well-being across the age spectrum. This awareness is a unifying culture for Penn Staters everywhere – students, faculty, staff and alumni. Medicine and athletics are now at a critical juncture where the health benefits of personal fitness are now clearly evident, while at the same time significant long-term health risks are associated with common types of athletic injury such as concussions or ACL injuries. Likewise, childhood conditions such as malnourishment and obesity and conditions of the aging such as osteoporosis are well-known to impact both the quality and length of life. Against this backdrop, Penn State researchers in several different units work to improve health and performance while minimizing personal injury.

The Center for Lifespan Fitness, Performance and Health will capitalize on the combined strengths and visibility of Penn State research and athletics. Foundational activities will include establishing a donor base and recruiting a director. The proposed institute will be administered under the Huck and ideally will be physically located within or close to facilities managed by Athletics, with foundational support from University Athletics, the College of Medicine and the College of Health and Human Development.

The Center for Lifespan Fitness, Performance and Health will connect researches, clinicians, coaches and resources across existing Penn State centers and laboratories in the Colleges of Medicine, Engineering, (Eberly College of) Science, Health and Human Development, Sports Medicine, the Penn State Center for Sport Concussion Research and Service, the Center for Healthy Aging, and the Microvascular Research Laboratory, Human Thermoregulation Laboratory. The NIH-funded Clinical and Translational Sciences Institute (CTSI) and Penn State Social Sciences Research Institute (SSRI) will provide key expertise and resources. Supporting dissemination activities will involve World Campus and Ag Extension.

As this center grows and develops, the College of Engineering, College of Liberal Arts and Eberly College of Science will become critical contributors to the expertise supporting the associated research endeavors. Ultimately, translation to practice will be facilitated through outreach and education programs supported by Athletics, Extension and World Campus. This will be initiated through a cluster hire for 12 new positions in animal mechanics and seeking to make appointments in diverse departments including Kinesiology, Physics, Bioengineering and Sports medicine.

Objective 1.2	<i>Establish the Center for Lifespan, Fitness, Performance and Health</i>
Supporting Strategies	Attracting a director with national and international recognition and allocate space, make strategic hires, promote collaboration and innovation among researchers, improve internal and external communication, support larger proposal development and preparation, expand and improve computational and IT resources, and maintain state-of-the art instrumentation.
Assessment	<ul style="list-style-type: none"> • Size of donor base • Accomplishments of the founding director • Shared grants and publications among member faculty
Involved Units	CAS, COE, COM, CON, ECOS, CHHD, CTSI, HUCK, SSRI, ICS PSIEE, MRI

OBJECTIVE 1.3 *Build a deeper understanding of personalized health through integrating individual biological and behavioral data*

The last 10 years have brought rapid advances in instrumentation and technologies supporting health and medicine. With these advances have come new capabilities to store and interrogate an

individual's health data originating from gene expression through to behavioral responses to predict how interventions may alter these responses. Thus the fundamentals of healthcare are rapidly changing. What is the optimal treatment for each individual at each time point? How does the environment shape our responses to intervention? How can we map the future healthcare landscape so people are resilient to the trials of life?

Personalized medicine is now possible based on the fusion of data sets that link the genome to behavior to healthcare. The Penn State expertise to gather and fuse the data to answer these questions spans all domains and is distributed across a variety of research units including the College of Engineering, College of Health and Human Development, College of the Liberal Arts, College of Medicine, Eberly College of Science, Huck Institutes of Life Sciences, Social Science Research Institute and others. Integration and analyses of connected datasets is already being accomplished at Penn State where the silo walls have been removed between disciplines. A new Cyberhealth initiative in the Millennium Science Complex is combining the skills of the Institute for Cyberscience with those from Life and Social Sciences by facilitating the application of innovative computational techniques to diverse datasets. Through the application of innovative computational techniques to diverse datasets, our vision is to obtain novel medical insights into how to develop devices, vaccine interventions and other actions.

The OVPR will support the Huck Institutes plan to strategically hire research and tenure-line faculty who have expertise and skills in biological informatics relating to genomics, metabolomics, infectious disease and biological image analysis. These new faculty hires will work with existing faculty to turn data to insight and innovation in the life sciences. The OVPR will also facilitate continued and enhanced collaboration between the Huck Institutes' Center for Medical Genomics and the College of Medicine's genomics team focused on personalized medicine and healthcare. Moreover, the 2013 completion of the award-winning Eva J. Pell Laboratory for Advanced Biological Research will improve Penn State researchers' ability to investigate infectious diseases in the immediate and long-term future and attract world-leading researchers focused on combating infectious disease.

While the Huck Institutes develop and provide access to tools and technologies that assist in the management, analysis and dissemination of life sciences data, the Social Sciences Research Institute (SSRI) will focus on cyberhealth to optimize healthcare and healthcare delivery using evidence-based practices and policies that encourage a sustainable health system. Health and mental health promotion and disease prevention and treatment will be investigated using novel methodologies (e.g., electronic devices, social media, and human-technology hybrids), Big Data analytics and other innovations for enhancing health and health behavior.

Objective 1.3	<i>Build a deeper understanding of personalized health through integrating individual biological and behavioral data</i>
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Supporting Strategies	Strategic hires, promote collaboration and innovation among researchers, improve internal and external communication; support larger proposal development and preparation, expand and improve computational and IT resources, maintain state-of-the-art instrumentation, renew focus on data analysis across graduate related curricula
Assessment	<ul style="list-style-type: none"> • Data and network capabilities • Faculty hires with expertise and interest in the computational approaches to the life sciences, especially genomics and personalized healthcare • Successful collaborations (grants and publications) between researchers with varied skills, including data analysis and visualization • Use of the College of Medicine’s Genome Sciences Facility • More cross-campus COM-UP initiatives • Training on data analysis for health-focused faculty and researchers • Resources saved by addressing research questions via efficient computational methodologies in lieu of more resource-intensive options
Involved Units	CAS, CHHD, COM, ECOS, HUCK, ICS, IST, SSRI

OBJECTIVE 1.4 *Apply understanding of bio-psycho-social processes to develop strategies that reduce the adverse effects of environment and lifestyle on human health and well-being*

The SSRI is investigating how environments and experiences “get under the skin” to affect stress and immune functions, social, cognitive, and affective neural processes, and gene-related mechanisms, and the ways in which these bio-psycho-social processes shape and are shaped by human behavior, health and development. Research on health-focused behavioral interventions is extremely important given that approximately 40% of premature deaths in the US are associated with behavioral patterns such as smoking and poor nutrition (Figure 9).¹ The OVPR will champion these pursuits and provide the resources and infrastructure necessary to enable measurable progress in the development and implementation of sustainable practices aimed at reducing the morbidity and mortality associated with exposures that can be controlled with changes to environments and lifestyles.

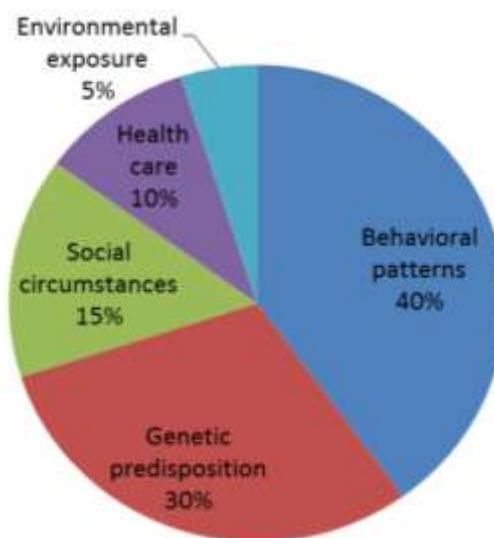


Figure 9: Proportional Contribution to Premature Death in the US¹

¹ Schroeder, S. A. (2007). We can do better – improving the health of the American people. *The New England Journal of Medicine*, 357, 1221-1228.

Objective 1.4	<i>Apply understanding of bio-psycho-social processes to reduce the adverse effects of environment and lifestyle on human health and well-being</i>
Supporting Strategies	Make strategic hires. Promote collaboration and innovation among researchers, improve internal and external communication, support larger proposal development and preparation, expand and improve computational and IT resources, maintain state-of-the art instrumentation
Assessment	<ul style="list-style-type: none"> • Number of faculty hired with expertise and interest in health-related behaviors • Successful collaborations (grants and publications) between researchers in psychology, sociology, education, communications and life sciences
Involved Units	COE, CHHD, CLA, COM, CON, CHHD, LA, COC HUCK, SSRI,

OBJECTIVE 1.5 *Reduce social disparities in health and healthcare*

A key focus of research in the social and behavioral sciences at Penn State is on the health and development of children, youth and families from diverse socio-cultural backgrounds. Penn State's faculty includes many internationally renowned experts in this field and several SSRI units – including the Population Research Institute with its focus on immigrant families, the Clearinghouse for Military Family Readiness, and the Network for Child Protection and Well-Being – are focused on translational research on vulnerable populations. Faculty from CE, CAS and EMS are working on supporting strategies for communities to improve nutrition through food availability with breeding programs for drought-resistant crops and eliminating food deserts. Building on this foundation, a priority area for SSRI's investments during the upcoming strategic planning cycle is identifying the causes and consequences of growing social disparities in health, education and other kinds of resources within the US and around the world. Thus, investments in social science translational research will ultimately promote the health and well-being of diverse populations of children, youth and families and aid in the development of evidence-based policies and practices for remediating widening gaps in the health, education, and community resources – all toward sustaining a diverse and changing population in a global society. The College of Health and Human Development is also dedicated to this goal and plans to hire faculty with expertise in health and healthcare disparities and in global health.

Objective 1.5	<i>Reduce social disparities in health and healthcare</i>
Supporting Strategies	Collaboration among researchers, improving internal and external communication, assisting proposals for external funding, expanding computational and IT resources, and improving and maintaining buildings, lab and user facilities
Assessment	<ul style="list-style-type: none"> • Number of faculty hired with expertise and interest in health-related social disparities • Successful collaborations between researchers in sociology, life sciences and diverse cultures • Policy suggestions and improvements that will lessen disparities in access to health-related resources, such as nutritious food and healthcare • Increased funding from supporting agencies and foundations such as NIH, USDA, USAID, RWJF and Gates
Involved Units	CHHD, CLA, COM, COE, HUCK, ICS, SSRI

OBJECTIVE 1.6 *Foster the convergence of biological, engineering, materials and physical science expertise to enable transformational discoveries supporting human health*

Convergence –the integration of the biological, engineering and physical sciences – is leading to what is considered to be the “third revolution” in the life sciences and follows in the footsteps of molecular biology and genomics. Science is seeing a paradigm shift in how research is organized and conducted through interdisciplinary collaborations. Through the connections between institutes, Penn State has a unique opportunity to be a leader in this revolution with a Center for Convergence of Biological, Engineering and Material Sciences (CoBEAM). The integration of these distinctive disciplines and cultures helps to drive innovation and create entirely new approaches to address some of society’s most pressing problems.

The primary aim is to build success in the Millennium Science Complex and establish precedence in key strategic areas through targeted hires and seed funding. Specifically, institutes (HUCK, MRI and ICS) will work closely with colleges (notably COE, ECOS and EMS) to stimulate the development of novel devices, imaging tools and biologically inspired materials that will help transform life, engineering and physical science research, and spur innovation. The development of a Center for Convergence Science and Engineering will help bring together flexible and dynamic teams and research scientists to build capacity and develop a critical mass of faculty aligned along a translational pathway.

Objective 1.6	<i>Foster the convergence of biological, engineering, materials and physical science expertise to enable transformational discoveries supporting human health</i>
Supporting Strategies	Plan for a Center for Convergence Science and Engineering that sits at the interface between the Huck, MRI and the COE; identify, develop and support high-impact interdisciplinary and transformative projects that will advance the science and spur innovation through the development of novel materials and devices for improving disease diagnosis, biomedical imaging and the development of novel bio-inspired materials; target faculty hires in strategic and cross-cutting thematic areas such as magnetic resonance imaging, tissue engineering and biologically-inspired materials; develop a pipeline of potentially transformative convergence projects that could lead to the submission and winning of ERCs and large NIH center grants; support curricular innovations that will promote for graduate and undergraduate education in Convergence Sciences for training the future workforce.
Assessment	<ul style="list-style-type: none"> • Increased competitiveness for extramural research funding • Increased collaborations of the life science disciplines with those in the materials and engineering sciences • Increased opportunities for collaboration with industry and global engagement • Enhanced reputation and visibility of Penn State as a leader and go-to place for convergence research by key stakeholders including funding agencies, academic and industrial partners, and policy makers
Involved Units	CAS, CHHD, COM, ECOS, ENG, EMS, HUCK, MRI, PSIEE

GOAL 2: Stewarding Natural Resources and the Environment

Penn State will further advance its established leadership in environmental stewardship with specific foci on water, agricultural, energy, climate and human resources.

To strengthen Penn State’s position as a world leader in the stewardship of natural resources and the environment, the OVPR will promote and facilitate research that focuses on pressing and timely questions of natural resource management, energy and the environment. This research will investigate how humans connect to the world around them by exploring new ways to sustain, conserve and optimize the use of water, food, energy and the environment through global connections, cyber resources, and organizational, political, and social sciences.

Accomplishing this overarching goal will require creative collaborations across many disciplines. The willingness of Penn State researchers to gather around these research challenges is demonstrated in the development of the strategic plans for each of the OVPR-related institutes. For example, the PSIEE strategic planning process actively involved 62 faculty from seven different colleges and 31 departments, actively engaged in identifying five unifying PSIEE research themes:

1. Smart Energy Systems
2. Future Energy Supply
3. Climate and Ecosystem Change
4. Health and the Environment
5. Water and Biogeochemical Cycles

The major research themes from all the OVPR-related institutes are similarly interdisciplinary with research programs crossing multiple colleges and disciplines, and all of them will benefit from a major new unifying initiative connecting *data to knowledge to impact* on the environment, economy and society (Figure 10).

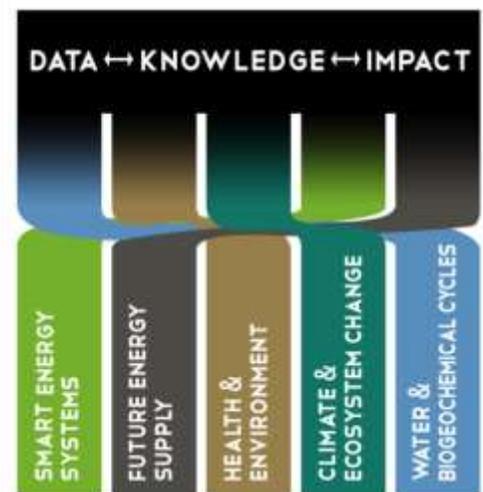


Figure 10: Unifying Themes Supporting Improved Management of Natural Resources

SIGNATURE OBJECTIVE 2.1 *Advance global water security through knowledge about water flows and systems*

Water is an essential resource for biological, ecological, industrial and practically every other system on Earth. Thus, it is a societal imperative that regional and temporal variations in water availability and maintenance of sufficient quantities and quality of water for these myriad systems are understood. Many units at Penn State have expertise and investments in water-related research due to its broad importance. These programs and people already enjoy very strong regional, national and international reputations. For example, the College of Earth and Mineral Sciences is

renowned for its expertise in climate dynamics and climate change; the College of Engineering for its expertise in water treatment and water infrastructure; the College of Agricultural Sciences for its expertise in natural resource assessment, policy, economics and management of natural resources; the Eberly College of Sciences for its expertise in marine science and water chemistry; and the College of Arts and Architecture for its work on sustainable stormwater management design. Penn State has a number of research and analytical facilities, centers and institutes (listed below). Further, there is substantial water expertise in applied and outreach units at University Park and the Commonwealth campuses, including Pennsylvania Sea Grant at Behrend and the Environmental Training Center in Harrisburg.

Despite this infrastructure, the current widely-distributed water-related efforts on campus occasionally result in duplication, unnecessary competition for internal and external resources, and missed opportunities. Though the University is highly productive with regard to the awards of grants and contracts in water-related fields, there is a substantial opportunity-cost to the University in large research proposals that are not being generated, and in losing some of our best applicants for faculty, postdoctoral and graduate student positions and opportunities to other institutions with attractive water programs. There is also the potential to lose some of the current expertise that substantially contributes to the breadth, depth and richness of Penn State, as water programs at many other universities are growing.

Creation of the *Penn State Water Institute* will facilitate better integration of existing resources. Leveraging these resources can help catapult Penn State to world leadership in water research and education and provide pathways for Penn State research to have real world impacts in the Commonwealth and beyond.

Penn State is already working toward assuring the availability of quality water, with over 180 involved faculty and staff involved with this topic. Penn State also has 19 undergraduate majors and six minors in fields related to water research. Because of its location within the Great Lakes Watershed, Chesapeake Basin and Marcellus Shale areas, Penn State can directly engage in nationally relevant water quality issues. The *Penn State Water Institute* will build on this strong base of expertise to advance global knowledge and disseminate best practices to promote responsible and effective water resources management. This institute will rise to the challenge of ever-changing needs for water resource management in a complex world.

The *Penn State Water Institute* will be inclusive of many Penn State units currently addressing water-related issues and will provide the opportunity to expand Penn State scholarship further into the realm of water law and policy. For some, the focus is direct and water is the primary interest. For others, the focus is indirect, addressing broader issues which either include water or have implications for water. The following list of existing capabilities at Penn State reflects the vast expertise on water-related topics that will be leveraged through this institute.

College of Agricultural Sciences

- Agriculture and Environment Center (AEC), <http://extension.psu.edu/aec>
- Biomass Energy Center, <http://www.bioenergy.psu.edu/>
- Center for Watershed Stewardship (operated jointly with College of Arts and Architecture), <http://water.psu.edu/cws/>
- Environment and Natural Resources Institute (ENRI), <http://agsci.psu.edu/enri>
- Water Extension Portal, <http://extension.psu.edu/water>

College of Earth and Mineral Sciences

- Center for Climate Risk Management (CLIMA), <http://www.clima.psu.edu/index.php>
- Center for Environmental Informatics (CEI), http://apps.cei.psu.edu/cei_wp/
- Center for Geomechanics, Geofluids and Geohazards (G3), <http://g3.ems.psu.edu/>
- Earth and Environmental Systems Institute (EESI), <http://www.eesi.psu.edu/>
- Earth System Science Center (ESSC), <http://www.essc.psu.edu/>
- Institute for Natural Gas Research (INGaR) (also supported by the College of Engineering) <http://ingar.psu.edu>
- Marcellus Center for Outreach and Research (MCOR) (also supported by the College of Agricultural Sciences), <http://www.marcellus.psu.edu/>
- Penn State Ice and Climate Research Center (PSICE), <http://www.psice.psu.edu/>
- Riparia (Wetlands Center), <http://www.wetlands.psu.edu/>

College of Engineering

- Engineering Energy and Environmental Institute (E3I), <http://www.engr.psu.edu/e3i/>

College of Liberal Arts

- Rock Ethics Institute, <http://rockethics.psu.edu/>

Eberly College of Science

- Center for Statistical Ecology and Environmental Statistics, <http://sites.stat.psu.edu/~gpp/>
- The Polar Center, <http://polar.psu.edu/>

Commonwealth Campuses

- Behrend – Pennsylvania Sea Grant, <http://www.paseagrant.org/>
- Harrisburg – Environmental Training Center, <http://hbg.psu.edu/etc/>

Office of the Vice President for Research

- Huck Institutes of the Life Sciences <http://www.huck.psu.edu/>
- Penn State Institutes of Energy and the Environment (PSIEE), <http://www.psiee.psu.edu/>
 - Ecology Institute (jointly between PSIEE and Huck)
<https://www.huck.psu.edu/content/research/ecology-institute>
- Pennsylvania Water Resources Research Center (PA-WRRC)
<http://www.pawatercenter.psu.edu/>
- Sustainability Institute <http://sustainability.psu.edu/>

Signature Objective 2.1	<i>Advance global water security through knowledge about water flows and systems</i>
Supporting Strategies	Encouraging collaboration among researchers, improving internal and external communication; assisting proposals for external funding; facilitating technology transfer; expanding our research capabilities to include human dynamics as well as water law and policy; improving and maintaining buildings, labs and user facilities
Assessment	<ul style="list-style-type: none"> • Creation of Penn State Water Institute • Number of faculty hired with varied expertise and interest in water research • Successful collaborations between researchers from diverse research fields • Large projects and grants with interdisciplinary teams • Establishment of a water graduate degree program • Demonstrated impacts on water policy and management strategies • Outreach impact (e.g. published and online materials, presentations, workshops, stakeholder engagement)
Involved Units	CAA, CAS, COE, COM, COS, ECOS, EMS, HUCK, PSIEE and Associated Units

OBJECTIVE 2.2 *More firmly establish Penn State leadership across all energy domains*

As society continues to increase its energy consumption needs, improvements in **energy sources, efficiency, infrastructure and management** will become increasingly important to the process of stewarding natural resources. Penn State has recognized expertise and leadership across all energy sources and systems from fossil fuels to renewables, transmission to energy economics, impacts and policy. The Department of Energy (DOE) ranks Penn State 9th nationally in energy research, and the Science Citation Index ranked Penn State second in publications and citations.

Despite this expertise, Penn State has yet to achieve the desired level of global recognition for “all things energy.” Over the next five years, expanding, coordinating and leveraging our energy expertise are key requirements for integrating and marketing the University’s collective energy expertise. In addition, research at the nexus of energy and the environment is critical to the future of energy science and to supporting policy development in the Commonwealth and beyond.

With the support of the OVPR, Penn State researchers will investigate existing and innovative methods for energy production, infrastructure and utilization, carbon sequestration, energy storage and management, related environmental questions, energy efficiency of buildings, transportation, businesses and other modes of consumption. Opportunities for innovations and entrepreneurship abound in the environment of energy expertise envisioned in this plan. Penn State already has the research capacity to be the recognized leader in the energy field, broadly defined. International recognition of this capacity is now dependent primarily upon organizational management. The following list of existing capabilities reflects the vast expertise on energy-related research at Penn State; descriptions of illustrative areas of focus or programs are given below.

College of Agricultural Sciences

- Center for Green Roof Research, <http://plantscience.psu.edu/research/centers/green-roof>
- Environment and Natural Resources Institute, <http://agsci.psu.edu/enri>
- Northeast Regional Center for Rural Development, <http://aeese.psu.edu/nercrd>

College of Earth and Mineral Sciences

- Earth and Environmental Systems Institute, <http://www.eesi.psu.edu/>
- Institute for Natural Gas Research at Penn State, <https://ingar.vhostname.psu.edu/psu/>
- Center for Geomechanics, Geofluids and Geohazards, <http://www.geosc.psu.edu/node/1009>
- Resources Energy and Environmental Economics and Policy, <http://www.ecoecon.psu.edu/>
- EMS Energy Institute, <http://www.energy.psu.edu/>
 - Gas Flooding Joint Industry Project, <http://www.energy.psu.edu/gf/>
 - Penn State and Dalian University of Technology Joint Center for Energy Research, <http://www.energy.psu.edu/jcer/>
 - Stripper Well Consortium, <http://www.energy.psu.edu/swc/>
 - Unconventional Natural Resources Consortium, <http://www.energy.psu.edu/unrc/>
 - West Penn Power Sustainable Energy Fund, <http://www.energy.psu.edu/se/index.html>

College of Engineering

- Electrochemical Engine Center, <http://ecec.mne.psu.edu/>
- Engineering Energy and Environmental Institute, <http://www.engr.psu.edu/e3i/>
- Hydrogen Energy Center, <http://www.engr.psu.edu/h2e/>
- Indoor Environment Center, <http://www.engr.psu.edu/iec/index.htm>
- Mid-Atlantic Clean Energy Application Center, <http://maceac.psu.edu/>
- Mid-Atlantic Solar Resource and Training Center, <http://www.research.psu.edu/capabilities/centers/solar-energy-innovation-center>

Office of the Vice President for Research

- **Penn State Institutes of Energy and the Environment**, <http://www.psiee.psu.edu/>
 - Batteries and Energy Storage, <http://www.best.psu.edu/>
 - Biomass Energy Center, <http://www.bioenergy.psu.edu/>

Intercollege Research Institutes and Centers

- Institute for Natural Gas Research at Penn State, <https://ingar.vhostname.psu.edu/psu/>
- Center for Watershed Stewardship, <http://www.water.psu.edu/cws/>
- Marcellus Center for Outreach and Research, <http://www.marcellus.psu.edu/about/organization.php>

Interdisciplinary Energy Research

National Energy Technology Laboratory (NETL) Regional University Alliance (RUA)

For the past five years, Penn State and four other research universities have provided a range of research and engineering services to the National Energy Technology Laboratory (NETL). NETL, part of the US Department of Energy (DOE) national laboratory system, conducts research in coal, natural gas and oil technologies. Through this partnership, Penn State faculty and graduate students collaborate on carbon capture and sequestration, unconventional fossil fuel sources, highly efficient energy conversion technologies, environmental and economic impacts and similar areas that figure prominently in the nation's quest for cleaner sources of energy and energy security. NETL is in the midst of selecting a new prime contractor to execute its R&D mission. Penn State and its RUA partners are competing for this contract with the aim of continuing and expanding work with NETL. In addition to Penn State, university partners in the NETL-RUA are: *University of Pittsburgh, Carnegie Mellon University, West Virginia University, Virginia Polytechnic Institute and Oregon State.*

Biomass

Center for Lignocellulose Structure and Function

The Center for Lignocellulose Structure and Function is a DOE Energy Frontiers Research Center focused on developing a detailed understanding of lignocellulose – the main structural materials in plants – from cellulose synthesis and fibril formation to a mature plant cell wall, forming a foundation for significant advancement in sustainable energy and materials.

Natural Gas

Natural gas is a growing source of supply that is abundant in Pennsylvania due the Marcellus Shale formation, and in other formations elsewhere in the US. Exploring ways to better extract, manage and use natural gas is helping Pennsylvania and the US become more energy efficient and independent. Recent technology advances have redefined the natural gas resource map globally, with impact likely to continue over the next 50 years. Penn State has research expertise committed to advancing research related to natural gas.

Institute for Natural Gas Research (INGaR)

The College of Earth and Mineral Sciences and the College of Engineering have teamed up to create a new Institute for Natural Gas Research (INGaR). INGaR will bring together faculty, researchers and students, working closely with industry, who recognize the importance of developing interdisciplinary approaches to the study of complex innovative processes

Institute for Natural Gas Research -INGaR

Mission: *To conduct independent and impartial scientific research in the broad area of natural gas, ranging from exploration to production to utilization, working closely with industry and government partners to support the ongoing development of a natural gas-based economy.*

involved in natural gas exploration, production, transmission, storage, processing, combustion, infrastructure, water and environmental issues. To facilitate this initiative, expanded office space, laboratory space, and computing facilities will be jointly pursued by the colleges and central administration.

Marcellus Center for Outreach and Research (MCOR)

The Marcellus Center for Outreach and Research (MCOR) is Penn State's education and research initiative on unconventional gas plays. Funded by Penn State's College of Agricultural Sciences, College of Earth and Mineral Sciences, Penn State Institutes of Energy and the Environment, and Penn State Outreach, MCOR serves state agencies, elected and appointed officials, communities, landowners, industry, environmental groups and other stakeholders. MCOR is committed to expanding research capabilities on technical aspects of developing this resource and to providing science-based programming while protecting the Commonwealth's water resources, forests and transportation infrastructure.

Center for Collaborative Research on Intelligent Natural Gas Supply Systems (CCRINGSS)

Penn State is working over the next five years with General Electric as a founding partner to create a multidisciplinary center: the Center for Collaborative Research on Intelligent Natural Gas Supply Systems (CCRINGSS). CCRINGSS will leverage the combined expertise of faculty across four academic colleges (the Smeal College of Business, the College of the Earth and Mineral Sciences, the College of Engineering, and the College of Information Sciences and Technology) and engage a variety of stakeholders to develop a deep understanding of shale gas supply chain systems, including technical innovations, design, investments and operations (Figure 11).



Figure 11: CCRINGSS Collaboration Model

Further undergirding this effort will be activities aligned with Penn State's educational mission, which contributes to the development of tomorrow's workforce. Penn State's leadership in research and education in these domains positions the University to undertake this effort, offering significant opportunities to develop technologies, strategies and workforce expertise. The center could also support the creation of new educational and outreach programs, such as a graduate certificate program that would link supply chain and data analytics with technical aspects of the energy industry.

Energy Efficiency

Consortium for Building Energy Innovation (CBEI)

The Consortium for Building Energy Innovation (CBEI) is focused on generating impact in the small- and medium-sized commercial buildings (SMSCB) retrofit market. Located at The Navy Yard in Philadelphia, CBEI develops and demonstrates systems solutions in a real-world regional context for national deployment in the future. As 95% of commercial buildings in the US are small- or medium-sized, CBEI's research into and deployment of energy efficiency solutions for SMSCB is critical.

Bringing together 14 organizations including major research universities, global industrial firms and national laboratories from across the US, CBEI is dedicated to creating pathways to 50% energy reduction in existing buildings by 2030. Numerous senior investigators and graduate students are actively engaged in CBEI research projects.

Energy Storage

Penn State is home to several pockets of expertise focused on energy storage, most notably the Battery Energy Storage Technology (BEST) Center which focuses on innovative new materials, cells and systems. Other contributors to this effort include the Battery Application Technology Testing and Energy Research Laboratory within the Larson Transportation Institute, The Center for Dielectrics and Piezoelectrics, the Applied Research Laboratory, and the Electro-optics Center.

Objective 2.2	<i>Strengthen Penn State leadership across all energy domains</i>
Supporting Strategies	Co-funded faculty hires, facilities, core support; encouraging collaboration among researchers; improving internal and external communication; assisting proposals for external funding; facilitating technology transfer; improving and maintaining buildings, labs and user facilities
Assessment	<ul style="list-style-type: none"> • Establishment of Institute for Natural Gas Research (INGaR) and Center for Collaborative Research on Intelligent Natural Gas Supply Systems (CCRINGSS) • Number of faculty hired with varied expertise and interest in energy research • Successful collaborations between researchers from diverse research fields • Large projects and grants with interdisciplinary teams • Demonstrated impacts on energy policy and industry strategies
Involved Units	CAS, COE, ECOS, EMS, ICS, MRI, PSIEE, SCOB

OBJECTIVE 2.3 *Protect and sustain natural systems through research on innovative and effective stewardship of living systems, landscapes, and human-environment interactions*

To help Penn State maintain its position as a world leader in the stewardship of natural resources, the OVPR will encourage and facilitate research that focuses on timely and important questions of natural resource management and environmental stewardship. This research will investigate how humans connect to the world around them by exploring new ways to sustain, conserve and optimize the use of water, food, energy and the environment, through global connections, cyber resources, and organizational, political, and social sciences. This objective extends the exploration of natural systems beyond water and energy to include research on climate and ecosystem change, health and the environment, and other cross-cutting areas.

Climate Science and Ecosystem Change

Climate science is fundamental both to understanding how the Earth System operates, and to assessing the broad potential impacts of climate change and the relative merits of adaption and mitigation responses to climate change. Penn State has a history of strength in both the basic science and in related areas such as water security (variability, quality and management), infectious disease, ecosystem dynamics, food security and societal vulnerability/adaptation, including relevant areas of policy, law, economics and ethics. Penn State has an exceptional cadre of scientists working in all of these areas, but the cumulative impact of this talent is under-recognized. Given modest additional resources, Penn State can secure its role as a leading institution both nationally and internationally in the science of climate and natural systems.

In recognition of the need for future leaders who can lead communities through highly interdisciplinary challenges and address the impacts of a changing climate, there has been a proliferation of climate research and education programs at major US universities, including Penn State. PSIEE will work to leverage Penn State's expertise in climate and environmental change by building research networks addressing challenges at the human-environment interface, such as food and water security in the face of climate change. These networks will enhance the translation of Penn State research to societal impacts in this important realm. Centers already working at the forefront of interdisciplinary science of climate change, including food security, health impacts and natural systems include:

College of Agricultural Sciences

- Agriculture and Environment Center, <http://agsci.psu.edu/aec>
- Center for Chemical Ecology, <http://ento.psu.edu/chemical-ecology>
- Center for Pollinator Research, <http://ento.psu.edu/pollinators>
- Center for Private Forests, <http://ecosystems.psu.edu/research/centers/private-forests>
- Environment and Natural Resources Institute, <http://agsci.psu.edu/enri>
- Northeast Regional Center for Rural Development, <http://aese.psu.edu/nercrd>
- The Schatz Center for Tree Molecular Genetics, <http://ecosystems.psu.edu/research/centers/schatz>

College of Earth and Mineral Sciences

- GeoVISTA Center, <http://www.geovista.psu.edu/>
- Astrobiology Research Center, <http://psarc.weebly.com/>
- Center for Geomechanics, Geofluids and Geohazards, <http://www.geosc.psu.edu/node/1009>
- Center for Solutions to Weather and Climate Risk, <http://solutions2wxrisk.psu.edu/>
- Earth and Environmental Systems Institute, <http://www.eesi.psu.edu/>
 - Center for Climate Risk Management, <http://www.clima.psu.edu/>
 - Center for Environmental geoChemistry and Genomics, <http://www.essc.psu.edu/CECG/>
 - Center for Environmental Informatics, http://apps.cei.psu.edu/cei_wp/
 - Resources Energy and Environmental Economics and Policy, <http://www.ecoecon.psu.edu/>
 - Earth System Science Center, <http://www.essc.psu.edu/>
 - Penn State Ice and Climate Research Center, <http://www.psice.psu.edu/>
 - NE Regional Center, <http://www.niccr.psu.edu/>

College of Engineering

- Engineering Energy and Environmental Institute, <http://www.engr.psu.edu/e3i/>

Eberly College of Science

- Center for Statistical Ecology and Environmental Statistics, <http://sites.stat.psu.edu/~gpp/>

Office of the Vice President for Research

- **Huck Institutes of Life Sciences**, <http://www.huck.psu.edu/>
- **Penn State Institutes of Energy and the Environment**, <http://www.psiee.psu.edu/>
 - The Polar Center, <http://polar.psu.edu/>
 - The Ecology Institute, <http://www.huck.psu.edu/content/research/ecology-institute>

Health and the Environment

The National Academy lists climate change, emerging infections and pollutant impacts as three of the six most important environmental challenges of this century. Environmental change and gene-environment interactions are impacting human and animal health. Exposure is increasing with climate change as vector life cycles shorten and opportunities for contact with hosts increases. Susceptibility to infectious agents and the evolution of new infections are determined by environmental contaminants, secondary infections, population dislocation and nutrition. Toxic elements within water systems and food sources provide additional stressors to the action of both infectious and noninfectious diseases.

For example, a Huck institutes initiative seeks to understand and prevent the consequences of selective pressures, specifically evolutionary change, that arise through anthropogenic-induced insults and to mitigate against such issues as spread of infectious disease, antimicrobial resistance

and adaptation to climate change. Specifically, this initiative aims to facilitate the development of novel approaches for the adaptation of plants, animals and humans to climate change, and mitigation against the impacts on health associated with environmental disruptions including pollutants, toxins and antimicrobial agents. Together, the Huck and PSIEE have created the Ecology Institute to leverage new investments in key areas of strategic interest, including plant sciences, infectious diseases and toxicology, bringing together Penn State's strengths in these areas.

College of Agricultural Sciences

- Center for Infectious Disease Dynamics, <http://www.cidid.psu.edu/>
- Center for Molecular Immunology and Infectious Disease, <http://vbs.psu.edu/research/centers/cmiid>
- Center for Molecular Toxicology and Carcinogenesis, <http://www.cmtc.psu.edu/>
- Center for Reproductive Biology and Health, <http://www.huck.psu.edu/content/research/independent-centers-excellence/center-for-reproductive-biology-and-health>
- Center for Sports Service Research, <http://plantscience.psu.edu/research/centers/ssrc/research>
- *E. Coli* Reference Center, <http://vbs.psu.edu/research/centers/ecoli>

College of Engineering

- Indoor Environment Center, <http://www.engr.psu.edu/iec/index.htm>

College of Medicine

- Penn State Hershey Cancer Institute, <http://www.pennstatehershey.org/web/cancer/home>

Sustainable Chemistry and Materials

As a major research university with a complex infrastructure spread across many campuses, Penn State has many opportunities to implement and evaluate new technologies and best management practices. One example is an initiative in sustainable chemistry and materials. This effort includes departments in four colleges (Engineering, Earth and Mineral Sciences, Agricultural Sciences and the Eberly College of Science) that are rethinking chemistry and materials science to include considerations of toxicity and sustainability in discovery, design and education. Several new research programs have been initiated with support from Dow Chemical and other companies as well as federal grants. PSIEE and the Sustainability Institute have also partnered to fund several new courses and curriculum renovation. To complement this research and education program, three departments (Chemistry, Chemical Engineering, and Materials Science and Engineering) have been piloting best practices for chemical management and safety at a scale that is virtually unknown at research universities today.

Objective 2.3	<i>Protect and sustain natural resources through innovative and effective stewardship of living systems, landscapes and human-environment interactions</i>
Supporting Strategies	Encouraging collaboration among researchers; improving internal and external communication; assisting proposals for external funding; improving and maintaining buildings, lab and user facilities
Assessment	<ul style="list-style-type: none"> • Outreach impacts through published and online materials, presentations and stakeholder engagement • Number of faculty hired with expertise in environmental and natural resources research • Successful collaborations between researchers from diverse research fields • Large projects and grants with interdisciplinary teams
Involved Units	AA, CAS, ECOS, EMS, HUCK, ICS, MRI, SSRI, PSIEE

OBJECTIVE 2.4 *Promote sustainability research that simultaneously supports social well-being, economic prosperity and ecological health*

Anthropogenic and environmental changes are having a profound impact on the health and sustainability of humans, agriculture and natural ecosystems. Research addressing these potential changes will come from individual and collaborative work from the Huck, the Penn State Institutes of Energy and the Environment (PSIEE), the Eberly College of Science, the College of Agricultural Sciences, College of the Liberal Arts, College of Earth and Mineral Sciences and others. In addition, Penn State's Sustainability Institute is working on comprehensively integrating sustainability into the University's operations, teaching and outreach to prepare students, faculty, staff and members of the wider community to be sustainability leaders across all facets of their lives.

The OVPR, its institutes and its service units will provide support for various projects to facilitate expansion of Penn State's expertise in developing compelling programs designed for responsible stewardship of natural resources. Key OVPR supporting strategies for promoting applied research on natural resources include, but are not limited to, integrating, exploring and communicating about energy and environment opportunities; promoting interdisciplinary faculty and leadership development for resource research; managing, coordinating and improving buildings, labs, and user facilities necessary for this research; and measuring effort, success, and outcomes to show Penn State's progress toward responsible stewardship of resources.

To take advantage of local opportunities for practical application of energy and environment research, the OVPR will assist individuals and teams of researchers with identifying, applying for and acquiring large grants targeted at applications of natural resources research. The OVPR will also work with University communication units to publicize Penn State researchers' successes with grant funding and to communicate important findings of grant-funded research and other projects. The OVPR will facilitate creation of interdisciplinary research teams with expertise and interest in energy

and environmental issues. PSIEE, for example, will provide opportunities for training and mentoring in project management, science communication, stakeholder engagement and conflict management to ensure successful collaborations between diverse groups of Penn State researchers.

OVPR's institutes and service units will also maintain and improve the resources necessary for Penn State researchers to conduct cutting-edge research in these areas. The interdisciplinary research envisioned requires integration and coordination of Penn State's institutes, academic units and support units.

Objective 2.4	<i>Promote sustainability research that simultaneously supports social well-being, economic prosperity and ecological health</i>
Supporting Strategies	Collaboration among researchers; improving internal and external communication; assisting with proposals for external funding; facilitating technology transfer; improving and maintaining buildings, lab and facilities
Assessment	<ul style="list-style-type: none"> • Number of faculty hired with varied expertise and interest in energy and environmental issues • Successful collaborations between faculty, industry, government and other practitioners • Large projects and grants with interdisciplinary teams • Use of the Consortium for Building Energy Innovation • Policy suggestions and improvements that will have an effect on energy and/or environmentally related topics
Involved Units	CAS, ECOS, EMS, MRI, PSIEE, SCOB, SI

GOAL 3: Transforming Education and Improving Access

The Penn State OVPR will transform education through research-based opportunities for engaged scholarship and learning.

Penn State President Eric Barron has identified six imperatives for successful institutions of higher education: excellence; student engagement; demographics and diversity; student career success and economic development; accessibility; and technology. Research provides essential and integral contributions to meeting these imperatives. It both helps us discover how to better achieve these goals *and* is in itself a best practice for education through the engaged scholarship of students and learners of all types. The OVPR will advance four specific objectives to support to President Barron's six imperatives for Penn State to excel in higher education and to advance the education mission of the institution.

SIGNATURE OBJECTIVE 3.1 *Promote Engaged Scholarship through research-related experiences involving advanced instrumentation and technologies, and inclusive of minorities, veterans and students at all campuses*

Engaged scholarship encompasses a wide variety of out-of-classroom academic learning experiences to complement in-classroom learning and reach a broad spectrum of learners. The OVPR will support Penn State's growing emphasis on engaged scholarship with a robust **Engaged Research Scholars Program** featuring opportunities for learners at all levels to actively engage in the research process. The program will be designed to attract and accommodate students studying at Penn State Commonwealth Campuses, enabling them to work in research-intensive environments at University Park and Behrend campuses for exposure to state-of-the-art equipment and techniques. Attention will focus on the inclusion of veteran, underrepresented and disadvantaged populations in activities supporting career development through internships and applied learning. These programs will also support external recruitment activities supporting diversity enhancement by modeling after the successful ARL Diversity Outreach Opportunities Research (Open D.O.O.R.) Program: https://www.arl.psu.edu/documents/doors_brochure.pdf .

The OVPR **Engaged Research Scholars Program** will support diverse student interests and needs through both paid and for-credit internship opportunities in affiliated laboratories and offices that both perform and support research functions. Where appropriate and feasible, this program will use the Penn State Learning Factory model and create transdisciplinary teams of interns to solve major challenges, creating teams of students with broad skill sets to tackle tough challenges. Internship challenges and opportunities will be identified by all six of the major VPR institutes, creating mutually-beneficial experiences encompassing disciplines ranging from materials engineering to social science to medicine. Internships within the support units of the VPR will

provide experiences in commercialization, technology transfer, resource management, intellectual property, applied ethics, grant development and project leadership.

The OVPR will work to make these and other opportunities known to interested undergraduate, graduate and postdoctoral scholars by leveraging an exemplary model from the College of Engineering for undergrad “internship in research” placement and creating a University-wide website for matchmaking. This website will advertise opportunities for engaged scholarship in new venues as well as serve to match-make across colleges to complement the needs of existing internship programs such as The Learning Factory, Humanitarian Engineering and Social Entrepreneurship, Alliance for Arts in Research Universities, Center for Research in Design and Innovation, the DigiFab network, and the Immersive Environmental Laboratory. This network will bring together the most creative student minds from disciplines as diverse as engineering and theater.

Funding to expand such student opportunities will be pursued through the inclusion of student researcher roles in large grant proposals and supplemental applications to agency programs such as NSF REUs and similar opportunities to fund veteran, underrepresented minority and other disadvantaged populations. SIRO will promote funding for these opportunities in large proposals. Promoting “research for credit” at graduate and undergrad levels will also expand these opportunities University-wide. Related information will be actively disseminated to students' advisors.

Signature Objective 3.1	<i>Promote Engaged Scholarship through research-related experiences involving advanced instrumentation and technologies, and inclusive of minorities, veterans and students at all campuses</i>
Supporting Strategies	Engaged scholarship; cross-campus match-making and recruitment, team science, participation in research retreats and forums
Assessment	<ul style="list-style-type: none"> • Internships supporting engaged scholarship: offered and filled • Veterans and minority participation • Cross-campus participation
Involved Units	All campuses, colleges, institutes and units

OBJECTIVE 3.2 *Educate faculty, students and staff to actively support technology transfer, research commercialization and work with private sponsors*

The competitiveness of the global economy is changing the culture of higher education. The need for a highly skilled workforce to support commercialization is now recognized well beyond the business and industry sectors. Penn State’s mission in education, research and service is not complete until Penn State research is fully translated into beneficial applications supporting the

well-being of our society. Federal agencies funding research are calling for institutions of higher education to produce a workforce to advance research through employment outside the walls of academia.

In response, the OVPR will guide a series of educational programs, including seminars, town halls and online resources, to provide a workforce trained to support research translation, implementation and commercialization efforts. These programs will include educational opportunities on topics including entrepreneurship, intellectual property management, business management, regulatory compliance, investment practices and communications.

Objective 3.2	<i>Educate faculty, students and staff to actively support technology transfer, research commercialization and work with private sponsors</i>
Supporting Strategies	Develop seminars, workshops and online training support for faculty, staff and students on resources, communication strategies and awareness of related practices, policies and procedures
Assessment	<ul style="list-style-type: none"> • Communications to faculty, staff and students encouraging engagement • Sponsored speakers and events promoting engagement • Training opportunities offered and attendance
Involved Units	All campuses, colleges, institutes and units

OBJECTIVE 3.3 *Create a robust postdoctoral development program to pipeline the best faculty talent*

Recruiting and mentoring the next generation of science leadership is a major challenge facing all institutions as Baby Boomer retirements are rapidly depleting the population of active senior researchers. To maintain its competitive ranking as a research institution and to meet its mission as an educational institution, Penn State must establish a reputation for excellence in training the next cohort of senior scientists. In this development pipeline, postdoctoral researchers are now one of our most valuable assets. In short, both Penn State's and indeed the nation's futures are highly dependent on recruiting, training, retaining and advancing a strong pool of postdoctoral researchers.

Until now, postdoctoral researchers have had no common support base within the University for professional and career development support. Yet training postdoctoral scientists presents unique needs and challenges inherent not only to this career stage but to the changing demographics as well. A robust ***Postdoctoral Development Program*** needs to provide training in advanced research, team and project management skills, scientific and lay communication strategies, teaching and more. Training must support future positions not only in academia but in industry, government and policy as well. Strong institutional programs must be plugged into strong

networks that allow leading peer institutions to exchange and retain the best of these trainees to cross-fertilize science across the most advanced research programs.

In addition to addressing career growth, these programs also need to address issues of work-life balance. Individual development planning should provide mentors able to discuss diverse career aspirations and personal resource management. Moreover, this rising generation of scientific leadership looks very different in terms of demographics. Today's postdoctoral scientists need very different types of personal and family support than those of the last generation.

The OVPR will respond to this programmatic need and challenge by establishing a strong Office for Postdoctoral Development that solidly supports individuals at this critical career stage. This program will be led by a Director of Postdoctoral Programs with support from a full-time administrative assistant. The leadership of this office will study successful programs at other CIC and peer-ranked institutions (e.g., Berkeley Chancellor's Postdoctoral Fellowship Program) and work to create networks with other highly-ranked research institutions to exchange best practices and create match/placement systems. The institution will look inward across its diverse system to Commonwealth Campuses to ensure that talent within our own system is fully supported and promoted. Incentives will be established to both attract and promote the best postdoctoral talent into faculty positions. Special attention will be given to ensure fair and equitable consideration is given to the advancement of veterans, women and minorities within this population.

The OVPR Postdoctoral Development Program will pursue these strategies for success:

- Support functions and retreats to educate postdocs on topics essential to career advancement such as lab management, publication, teaching, grant writing and personal finance.
- Pursue postdoctoral training grants and support individuals in aggressively pursuing awards through programs such as the NIH Early Investigator Awards and NSF Career programs.
- Reach out to CIC and peer institutions to form a network for placement and sharing of resources.
- Ensure that every postdoctoral scholar has an active mentor and Individual Development Plan (IDP).
- Work to establish hiring incentives and create postdoctoral opportunities in traditionally underfunded areas of research such as the humanities.
- Support minorities and special populations in identifying special training and funding opportunities available to them.
- Work with Corporate and Foundation Relations to establish endowments supporting postdoctoral scholar positions.

Objective 3.3	<i>Create a robust postdoctoral development program to pipeline the best faculty talent</i>
Supporting Strategies	Postdoctoral training workshops and retreats, mentoring programs; increase funding sources for postdoctoral hires; identifying programs supporting postdoctoral position; forming a network of highly-ranked peer research institutions to support postdoctoral advancement and exchange; encourage IDP development with support from the AAAS program (http://myidp.sciencecareers.org/) where appropriate
Assessment	<ul style="list-style-type: none"> • Numbers of postdoctoral scholars applied, interviewed, hired and retained • Postdoctoral scholarly productivity in numbers of publications, patents, programs and major datasets • Extramural funding awarded to postdoctoral scholars • Extramural funding awarded to support postdoctoral scholars • Job placement success
Involved Units	All colleges and institutes

OBJECTIVE 3.4 *Educate faculty to effectively apply and disseminate research findings beyond traditional academic forums*

Penn State must effectively communicate with the public and community we serve. The University needs to deliberately build knowledge dissemination systems (e.g., cyber “Science Gateways, Goal 4, Objective 3) connecting stakeholders to data, models and theory for decision-making, uptake of new technologies, and implementation of evidence-based policies and practices. This dissemination is our obligate mission as a land grant university and recipient of federal funding for research. Penn State clearly has the scholarly expertise needed to make a positive difference.

This objective can be effectively accomplished through better utilization and communication across existing resources. Penn State has tremendous outreach capacity through Cooperative Extension, WPSU, industry partners, clinical practices, educational activities and our alumni network. These will be augmented by faculty development opportunities targeting communication skills and pedagogical approaches for translating “data implementation to impact” into outreach and education activities, whether through active learning, public seminars or popular press. Funding for much of this outreach is included in major federal grants, especially those from the National Science Foundation (NSF). Grant agencies often include supplemental opportunities for dissemination.

A specific area of faculty training required for meeting this objective is in communicating with lay audiences via the popular press and electronic social networking. These forms of communication are often neglected by faculty in many areas of research-intensive science, but they can no longer be ignored. The current economy is driving close public scrutiny of governmental budgeting practices, making public support of research essential to the continued health of research funding.

Providing the tools for improved communication will be only half the battle. Incentives will be needed for faculty engagement. This must include promotion and tenure practices that reward faculty participation in informal education activities such as hosted by Penn State’s Center for Science and The Schools, Science-U, 4-H, Cooperative Extension, Ollie and “Plugged In.”

Objective 3.4	<i>Educate faculty to effectively apply and disseminate research findings beyond traditional academic forums</i>
Supporting Strategies	Educational opportunities for faculty on dissemination strategies; faculty reward systems for participation and engagement in this objective; inclusion of funding for such efforts in grant and other sponsorship requests.
Assessment	<ul style="list-style-type: none"> • Faculty-written popular press articles and presentations • Faculty oral presentations to lay audiences and in informal settings
Involved Units	All colleges and institutes

GOAL 4: Building our Digital Future

New insights and discoveries across the arts, engineering, humanities, and the sciences are being increasingly driven by our ability to analyze, integrate, construct and simulate computational models from observational and experimental data. Recent advances in areas such as imaging, gene

While we all live and use digital assets from computer to cell phones in our everyday lives, Penn State intends to create and advance the next generation of breakthrough technologies via digital discovery, innovation and extension.



sequencing, remote sensing, electronic health records, social media and internet-based technologies have transformed the world around us, and simultaneously have generated exponential increases in the volume, velocity, and variety of scientific and scholarly data – that is, “**big data**”. Our ability to gather digital data now outstrips our ability to utilize data. In order to ensure our well-being and economic prosperity, we

must gain insights, drive innovation and inform policies by advancing and applying scientifically rigorous approaches for data analysis and computational modeling.

Penn State is decisively responding to this challenge with leadership from the *Institute for CyberScience (ICS)*. ICS will drive digital discovery, innovation, extension and learning to develop the next generation of digital assets to advance our academic priorities. Our objectives are to establish Penn State as: 1) the global leader in digital discovery and innovation to ensure societal well-being and economic prosperity, 2) the pioneer in digital extension for economic development, and 3) the global digital destination for participatory inquiry, learning and outreach through science gateways. Each of these objectives will be accomplished through synergistic and coordinated activities that are advanced by the ICS to rapidly accomplish measurable milestones.

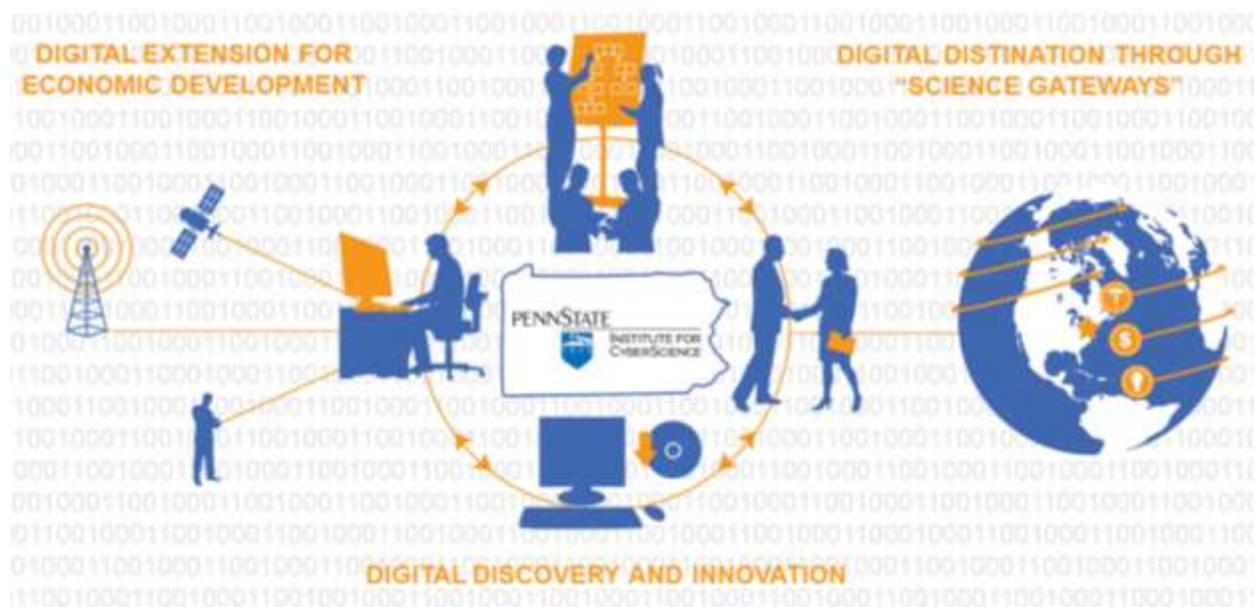


Figure 12: Building our digital future with the Institute for CyberScience (ICS).

SIGNATURE OBJECTIVE 4.1 *Establish Penn State as the global leader in digital discovery and innovation for new insights and their translation to ensure societal well-being and economic prosperity*

In 2012, the Obama administration unveiled the “big data” initiative to advance state-of-the-art core technologies and our ability to harness them “to accelerate the pace of discovery in science and engineering, strengthen our national security, and transform teaching and learning”². Federal investments are huge and continue to increase as shown in Figures 13 A and B of “cyber”-coded Federal contracts and grants³. Concurrently, there are questions about how best to provide the advanced computing resources required for driving this growth. For example, the National Science Foundation (NSF) has tasked a study committee of the National Research Council to consider⁴ how NSF can “*provide the advanced computing resources needed to advance its science and engineering ... best provide advanced computing for integrated discovery involving experiments, observations, analysis, theory, and simulation?...coordinate and set overall strategy for advanced computing activities?*”

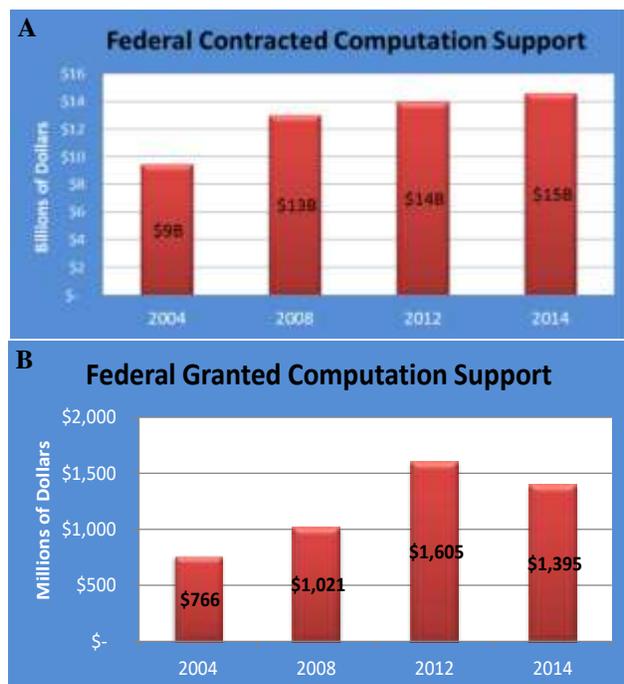


Figure 13: US federal dollars awarded for cyber contracts (A) and grants (B).

In this environment of growth for digitally-enabled research, peer institutions are rapidly investing in strategic initiatives to gain competitive advantages. For example, University of Washington’s multi-year data science initiative at its eScience Institute⁵, the University of Illinois Big Data - Grainger Engineering Breakthroughs Initiative⁶, the University of Rochester’s \$100M commitment to the Institute for Data Science⁷ and the recent \$60M investment by RPI in its Institute for Data Exploration and Applications⁸ all involve aggressive plans for hiring faculty who specialize in advancing research through digital means. Additionally, many of our peers including

² See: http://www.whitehouse.gov/sites/default/files/microsites/ostp/big_data_press_release.pdf, 2012.

³ Data Source: www.usaspending.gov

⁴ See the Future of NSF Advanced Computing at http://sites.nationalacademies.org/cstb/cstb_152352, 2015

⁵ See <http://escience.washington.edu/what-we-do/data-science-research-positions-university-washington>, 2013.

⁶ See <http://graingerinitiative.engineering.illinois.edu/bigdata/>, 2013.

⁷ See <http://wxnews.org/post/university-rochester-makes-big-commitment-big-data>, 2013

⁸ See <http://news.rpi.edu/content/2013/06/13/rensselaer-idea-harnessing-power-data-change-world>, 2013

the University of Illinois at Urbana Champaign⁹ and the University of Wisconsin at Madison¹⁰ are enhancing the sustainable delivery and governance the range of computing and data services, i.e., advanced cyberinfrastructure services, to support and drive these initiatives.

Penn State has also embarked on developing our capabilities to lead through research in this digital age. Starting with the Report of CyberScience Task Force¹¹ and more recent task forces to determine

*The Penn State Institute for CyberScience (ICS) will lead through **digital discovery and innovation** to drive insights and solutions for societal well-being and economic prosperity.*

how ACI should be enhanced and reorganized¹² and indeed all research IT should be governed¹³. ***We must make continued investments along both these fronts to build the digital future in which we can lead.*** Penn State will gain the capacity to lead through “***digital discovery and innovation***” by embarking on:

- ***a bold and coordinated faculty co-hiring initiative to build capacity to advance foundations and applications of “Big Data”, “Big Simulations” and “Big Systems” to promote scientific advances, societal well-being and economic prosperity; and,***
- ***an Advanced CyberInfrastructure (ACI) services initiative to bring computational modeling, simulation, and data analysis to bear around our strengths in theory, experiments, and observations.***

Taken together, these two initiatives will drive new research collaborations and the scaling-up of smaller projects into centers of excellence. Additionally, they will drive ***digital extension*** for economic development through “virtual” prototyping options, and “digitally assisted” business incubation approaches (Objective 4.2) and will enable the development of sustainable ***science gateways*** on the web to make Penn State the global digital destination for participatory inquiry, learning and outreach (Objective 4.3).

The increases in cyber-coded federal funding shown in Figure 13 are typically being achieved through reprogramming of funds that are currently directed at theory and experiment and not through the influx of new funds. This is a reflection of how the digital revolution has transformed the research landscape and with projections of flat Federal R&D investments, these trends are likely to accelerate now and into the future. Thus, our competitiveness as a university will increasingly depend on cohesive approach to co-hiring faculty and developing ACI services to

⁹ See <http://itgov.illinois.edu/>

¹⁰ See <http://aci.wisc.edu/>

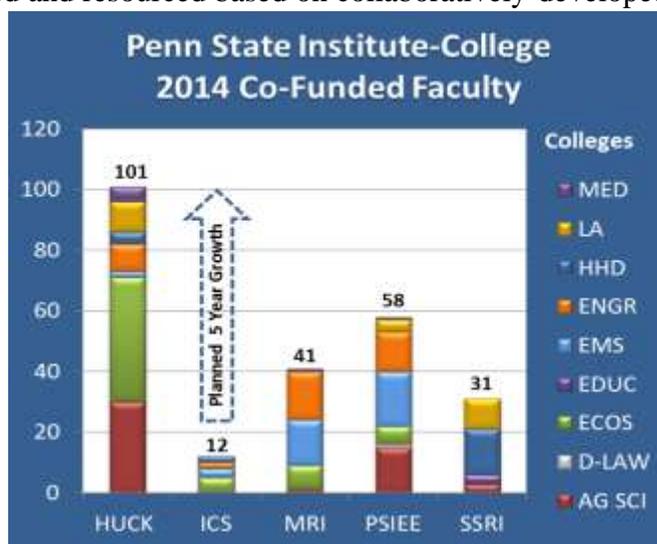
¹¹ See Report of the 2011 CyberScience Task Force, the Pennsylvania State University <http://ics.psu.edu/wp-content/uploads/2014/08/ctfreptlores.pdf>

¹² See Faculty Recommendations for Research Computing Statement from the Research Faculty Members of the Research IT Strategic Planning Committee, see <http://sites.psu.edu/researchitcommittee/wp-content/uploads/sites/3088/2013/03/Research-IT-report-7-May-2013.pdf>

¹³ See Research CI Governance Task Force Report <http://ics.psu.edu/research-ci-governance-taskforce/>, 2014

catalyze discovery and innovation by leveraging our experiments in theory and experiment at the colleges and other OVPR institutes.

Faculty co-hiring. The ICS faculty co-hiring initiated in 2012-2013 will continue to support our goals of digital discovery and innovation through interdisciplinary team science to recruit candidates recognized for their strengths in “*Big Data*”, “*Big Simulations*” and “*Big Systems*”, and for their ability to develop and apply these to promote scientific advances, societal well-being and economic prosperity. In each year of ICS co-hiring to date, opportunities for partnering with departments and colleges have been routinely oversubscribed by factors of two or more, reflecting very strong demands and unmet needs. This University-wide need to attract the next generation of faculty cohorts who can advance digital approaches to research, education and outreach is indeed a reflection of how the academic landscape is being transformed by the digital revolution. Further, many of the new initiatives around digital discovery and innovation, such as the Materials Genome¹⁴, the Brain Initiative¹⁵, Precision Medicine¹⁶, and Big Data¹⁷ will likely expand into a landscape of flat Federal funding at the expense of more traditional areas of inquiry such as theory, observation and experiment. These trends call for a significant expansion of the ICS co-hiring initiative to develop our capacity to lead. Thus, we plan to continue ICS co-hiring along emergent thematic areas of increasing opportunity that can leverage openings and priorities at departments/colleges. The exact departments and institutes who will partner for each year’s “cluster” of faculty co-hires will be developed and resourced based on collaboratively-developed proposals. By marshalling resources along multiple fronts including opportunities for development, it may well be within our reach to expand our co-hiring program to a total of a 100 appointments over a 5 year period. This is not surprising because, while multiple disciplines have been advanced by the co-hiring programs at the other four OVPR institutes (Figure 14), digital methodologies are increasingly becoming the approach for creating valuable linkages within and across *every* discipline. Thus,



¹⁴ See details of the foundational \$25M in federal awards for *Materials Genome* research at <https://www.whitehouse.gov/blog/2012/11/29/25m-research-awards-advance-administration-s-materials-genome-initiative>, and a complete description of the ongoing *Materials Genome Initiative* <https://www.whitehouse.gov/mgi>.

¹⁵ See President Obama’s *Brain Initiative* announcement at <https://www.whitehouse.gov/the-press-office/2013/04/02/remarks-president-brain-initiative-and-american-innovation>, and details the \$46M investment made in 2014 and links to the blueprint for planned research at <http://www.braininitiative.nih.gov/index.htm>.

¹⁶ See details of the 2016 presidential commitment of \$215M for the NIH Precision Medicine Initiative at <http://www.nih.gov/precisionmedicine/>.

¹⁷ See the 2012 announcement of the \$200M initiative with links to specific agency plans at https://www.whitehouse.gov/sites/default/files/microsites/ostp/big_data_press_release.pdf.

ICS co-hires involving more than one college or in collaboration with other institutes are readily envisioned.

Advanced CyberInfrastructure (ACI). The effective merging of computing, networking, data technologies, services and human resources into a seamless entity will enable researchers to answer complex questions through “*cyber-scopes*” – novel cyber instruments that are the equivalent of the astronomical telescopes or the biological microscopes. ICS will enable the targeted application of ACI to drive scientific research, and to redefine research of the future can take place in an integrated manner around digital, experimental, observational and theoretical modes of inquiry. ICS will also leverage synergies in the ACI (the pipeline from scientific software and data to hardware) to realize enhanced returns on investments from the consolidation of resources and open and transparent processes for planning and access that link effectively to University-wide governance structures for research information technologies that are in the process of being implemented. Major investments in Penn State’s ACI in 2014-2015 now set the stage for this progress.

Areas of Priority. The following are some key areas of priority in the near term for the cohesive development of our faculty co-hiring and ACI initiatives around our existing strengths.

- 1) **Complex Networks and Systems** – Most of our activities take place in environments with interconnected natural, engineered, information and human networks that leave massive streams of data that require scientifically rigorous approaches to extract knowledge and solutions. The ultimate goal is to safeguard and manage risks, bring predictive capability, develop and leverage our networks, such as those for energy, environment, finance, food, healthcare, information, learning and socio-political contexts, to promote our health, well-being, security and economic competitiveness. Our objective is to establish Penn State as leader in quantifying, predicting and managing risk around our critical infrastructure, information and socio-political networks. Commonalities across different kinds of large-scale networks hint at the possibility of capturing the underlying general principles that we seek to characterize by bringing new capacity to bear around our existing strengths including those at the
 - **Big Data Social Sciences Program** (NSF IGERT; <http://bdss.psu.edu/people/blm24>)
 - **Center for Infectious Disease Dynamics** (<http://www.cidid.psu.edu/>)
 - **Cyber-Security Collaborative Research Alliance** (<http://cra.psu.edu/>)
 - **Earth and Environmental Systems Institute** (<http://www.eesi.psu.edu/>)
 - **Sustainable Climate Risk Management NSF Research Network** (<http://scrimhub.org/>)
- 2) **Big Data Science for Precision Health in Context** – Over the last few decades, rapid advances in imaging, genomics, electronic health records, and information and communication technologies have led to exponential increases in the volume, velocity, and variety of data, i.e., “big data” in biomedical and health sciences. New discoveries in

general, and in biomedical and health sciences in particular are increasingly being driven by our ability to integrate and analyze, construct and simulate predictive models from data that range from individual to population scales. Our goal is to position Penn State as a leader in successfully responding to the NIH BD2K initiative. We will seek to advance health informatics for life-long personalized healthcare by learning predictive patterns and, ultimately, causal effects for applications around ageing, cardiovascular diseases, obesity, cognition and behavior, around our existing strengths represented by the

- **Center for Big Data Analytics and Discovery Informatics** (<http://ist.psu.edu/directory/vuh14>)
- **Center for Brain, Behavior, and Cognition** (CBBC; <http://cbbc.psu.edu/>)
- **Center for Comparative Genomics and Bioinformatics**, <http://www.bx.psu.edu/>, and
- **Center for Medical Genomics**, <http://www.huck.psu.edu/content/research/independent-centers-excellence/center-for-medical-genomics>
- **Clinical and Translational Sciences Institute** (<http://ctsi.psu.edu/>)
- **Population Research Institute** (PRI; <http://www.pop.psu.edu/>)
- **Social, Life and Engineering Sciences Imaging Center** (SLEIC; <https://www.imaging.psu.edu/>), and the
- NSF Expeditions in Computing **Visual Cortex on Silicon** (<http://www.cse.psu.edu/research/visualcortexonsilicon.expedition/>)

3) **Digital Manufacturing and Materials by Design** – Just as the assembly line revolutionized manufacturing at the turn of the last century, digital manufacturing is leading the industrial revolution of today. The integration of digital modeling and simulation to produce materials with tailored properties and optimized processes for manufacturing, product design and testing can bring about enormous benefits in costs savings and shorter time to market. We plan to advance breakthrough digital technologies for manufacturing around our strengths in computational materials design at the

- **Center for Innovative Metal Processing by Direct Digital Deposition (CIMP-3D)**, <http://www.cimp-3d.org/>
- **Direct Digital Manufacturing (DDM)**, https://www.arl.psu.edu/mm_lp_cimp3d.php, with Technology for Metallic Systems (or Additive Manufacturing)
- **Materials Characterization Lab (MCL)**, <http://www.mri.psu.edu/facilities/mcl/>
- **Materials Computation Center (MCC)**, <http://www.mri.psu.edu/facilities/mcc>
- **Nanofabrication Laboratory (PSU-Nanofab)**, <http://www.mri.psu.edu/facilities/nanofab>

The following supporting strategies, assessment metrics and units will lead to achieving this objective.

Signature Objective 4.1	<i>Establish Penn State as the global leader in digital discovery and innovation for new insights and their translation to ensure societal well-being and economic prosperity</i>
Supporting Strategies	Co-hiring faculty and developing ACI services to bring computational modeling, simulation, and data analysis to bear around institutional strengths in theory, experiments, and observations. Major themes include but are not limited to: complex networks and systems, big data science for precision health and digital manufacturing and materials.
Assessment	<ul style="list-style-type: none"> • Quality and quantity of faculty co-hires. • Success within 3 years in 1-3 “ultra-scale” (\$10M+) grants • Increases in cyberscience funding at rates that match or exceed the increase in “cyber” coded funding opportunities nationally and at our peers • Recognition as a leader in cyber-enabled approaches for complex networks and systems that advance security, health and economic prosperity • Growth of user base, extramural funding, research projects and publications that are supported by the ICS-ACI • Indicators for computation and storage capacities and space for “collaboratories” • Student enrollment in coursework, education and training programs of faculty co-hires
Involved Units	ICS in partnership with all OVPR institutes units and colleges

OBJECTIVE 4.2 *Establish Penn State as the pioneering leader in **Digital Extension** for economic development through access to state-of-the-art cyberinfrastructure and personalized learning in research-intensive environments*

Penn State is a land-grant university founded around the concept of agricultural “extension” to develop and deliver technologies, and educational programs for economic development. By serving in this role, we have developed into an international leader in education, research and outreach. And to ensure that we continue this leadership, we intend to provide leadership in “*digital extension*” to invigorate the economy – both locally and globally – through entrepreneurship and with the launch of startups for economic development (Figure 15).

We will accomplish our goals for Digital Extension by providing access to our state-

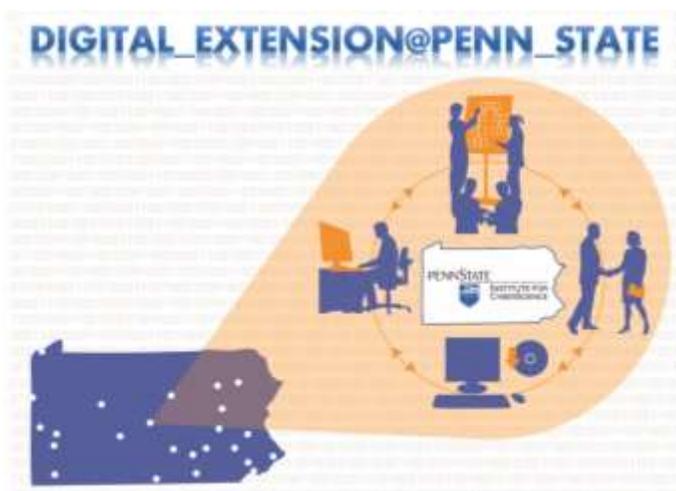


Figure 15: Digital extension will invigorate the local economy through access to state-of-the-art cyberinfrastructure, technical training, personalized learning and pathways from discovery to product design and prototyping.

of-the-art cyberinfrastructure, technical training and personalized learning in research-intensive environments, thereby supporting pathways from discovery to product design and prototyping through cyber-enabled creativity. Key innovations by faculty and students hold the potential for success in new startups and industry partnerships such as the hugely-successful New Leaf Initiative¹⁸. Through the virtualization of business incubation, cyber-enabled entrepreneurship can overcome the challenges of successful business startups in rural Pennsylvania¹⁹.

DIGITAL EXTENSION will open pathways from discovery to cyber-enabled product design and prototyping. Knowledge networks and data streams will enable fluid access to intellectual capital for the translation of research to applications supporting societal advancements and economic development.

Knowledge networks and data streams can be mined to identify “open spaces” and allow intellectual capital to be accessed and applied in a fluid manner by tapping into strengths embedded in our research enterprise.

Cross-disciplinary collaboration networks supporting diverse communities will be fostered by cyber-enabled spaces supported by customized ACI; a suite of accessible computing, data and programming services; and “professors of practice” for catalyzing the development of bold, new ideas. Fully-developed “core facilities” on shared hardware will bring new capabilities by customizing software, data, and services to empower Penn State researchers, entrepreneurs, and industry partners to engage in ground breaking research and its successful translating for economic development.

A diverse cadre of next generation scientists and engineers will be produced by developing new curricula and interdisciplinary degree programs that integrate digital discovery and innovation and its translation into technologies for economic development. ICS, in partnership with World Campus, will seek to advance digital personalized learning and training technologies to develop Pennsylvania’s manufacturing and knowledge-based industries, and to revolutionize learning and transform delivery models. In particular, we will develop digital certificate-granting short courses/workshops, and promote active learning through collaborative problem solving with the use of: (i) hybrid classroom/online learning modules including personalized components for K-16 and beyond, (ii) creativity-fostering internships within cyberscience research projects and “collaboratories”, and (iii) an intra-Penn State “cyber-learning factory” where students digitally design products, do virtual prototyping or test virtual-models for business incubation.

Major online degree programs are gaining momentum and scale and the World Campus is a recognized success that ICS will partner with for substantial investments in technology to improve the student and classroom experience that can associate with and support growing Ed Tech

¹⁸ The New Leaf Initiative was founded in to “... nurtur[e] the best community of innovators, changemakers, entrepreneurs, and visionaries in the region”, <http://newleafinitiative.org/>.

¹⁹ See Report of the 2011 CyberScience Task Force, the Pennsylvania State University, <http://ics.psu.edu/wp-content/uploads/2014/08/ctfreptlores.pdf>.

companies through beta testing partnerships, workforce and economic development programs and internship/co-op programs.

Now is the time to capitalize on this alignment of opportunity and institutional strengths to create the *Penn State Digital Extension* system that simultaneously leverages World Campus²⁰ and the Agriculture Extension network with ICS capabilities in digital discovery and innovation, and ACI. In this way, we will fulfill our vision to lead through “Digital Extension” both in Pennsylvania, and nationally as a land grant institution, by developing and distributing global cyber-solutions for business, community, family and personal needs.

These supporting strategies, assessment metrics and units will lead to achieving this objective.

Objective 4.2	<i>Establish Penn State as the pioneering leader in Digital Extension for economic development through access to state-of-the-art cyberinfrastructure and personalized learning in research-intensive environments</i>
Supporting Strategies	Develop an expansive web-based presence for Digital Extension as a resource for business, professional and personal solutions; Identify funding streams for collaboration on enhanced course delivery methods, personalized learning and Digital Extension to develop manufacturing and knowledge-based industries; Strategic proposal development support for economic and community development and partnerships with institutions, businesses and industries
Assessment	<ul style="list-style-type: none"> • Technical training and consultation for advancing knowledge-based startups and entrepreneurship • Use and access of ICS ACI by local industry and business • Use and advancement of Penn State online education delivery services and products • SBIR and STTR research funding • Large industry-sponsored enrollments in distance and hybrid learning programs
Involved Units	ICS, World Campus, CAS, and all academic units

²⁰ World Campus goals are 45,000 enrollments with a net cash flow of more than \$50M per year.

OBJECTIVE 4.3 *Establish Penn State as the global digital destination for science and scholarship by developing robust “science gateways” – hubs on the web for advancing interactive, participatory modes of inquiry, learning and outreach*

Digital discovery and innovation by Penn State researchers often leads to the development of scientific software, tools and data collections that can be leveraged to establish our academic pre-eminence in the digital age. Quite simply, by building cyber “science gateways”²¹ or hubs on the web that host digital tools and data, we can become the digital destination for participatory modes of inquiry, learning and outreach (Figure 16). Multiple Penn State projects are making advances in simulation software, data analysis tools and digital collections. These projects will be leveraged to advance our visibility through science gateways, while responding flexibly to the infusion of new knowledge in the form of new data and software tools.

Penn State Science Gateways
will host tools, applications, and data collections offered through web-portals for participatory inquiry by broad global communities.



Figure 16: Penn State as the global digital destination for advancing participatory inquiry, learning and outreach by developing cyber “science gateways”.

There are gaps in the connecting infrastructure for supporting the digital lifecycle of scientific and scholarly digital. Multiple institutional resources and solutions have simultaneously evolved. Thus, the time is now ripe for a managed convergence of these resources into a cohesive PSU-HUB of science gateways that are internally leveraged and optimized.



Figure 17: New Penn State ACI hardware will support robust science gateways

²¹ See <http://sciencegateways.org/what-is-a-science-gateway/>, 2015.

With the recent establishment of the ACI within ICS (Figure 17), the organizational framework is now in place to advance this process.

The first steps in this process will be to 1) identify and optimize existing independent systems, and 2) integrate independent digital access and archiving systems into a supportive connected network. This will include working with the University Libraries and networking cyber resources found across every Penn State research institute including but not limited to:

- *Astrophysical Multimessenger Observatory Network* (<http://amon.gravity.psu.edu/>)
- *Big Data Social Sciences Program* (NSF IGERT; <http://bdss.psu.edu/people/blm24>)
- *Center for Big Data Analytics & Discovery Informatics* (<http://ist.psu.edu/directory/vuh14>)
- *Center for Brain, Behavior, and Cognition* (CBBC; <http://cbbc.psu.edu/>)
- *Center for Comparative Genomics and Bioinformatics* (<http://www.bx.psu.edu/>)
- *Center for Environmental Informatics*, (http://apps.cei.psu.edu/cei_wp/)
- *Center for Medical Genomics* (<http://www.huck.psu.edu/content/research/independent-centers-excellence/center-for-medical-genomics>)
- *CiteSeerX*, <http://citeseerx.ist.psu.edu/index>
- *Galaxy*, <https://toolshed.g2.bx.psu.edu/>
- *Penn State Data Commons* (<http://www.datacommons.psu.edu/>)
- *Pennsylvania Spatial Data Access* (PASDA; <http://www.pasda.psu.edu/>),
- *ScholarSphere* (University Libraries <https://scholarsphere.psu.edu/>)
- *Visual Cortex on Silicon*
(<http://www.cse.psu.edu/research/visualcortexonsilicon.expedition/>)
- *Sustainable Climate Risk Management, SCRIM*, <http://scrimhub.org/about.php>
- *Security CRA*, <http://www.cra-usa.net/>

ICS will partner with the University Libraries and Colleges and other OVPR institutes to develop and host a PSU-CYBERHUB service which will provide a directory to existing web-science gateways for research, learning and outreach. Further, it will provide seed-funds and ACI-services to partner with research centers to expand science gateways that are in early stages of development. Even preliminary forms of such science gateways will provide a competitive edge to attract large-scale funding²² from federal agencies for the creation of and access to cyber tools.

The supporting strategies, assessment metrics and units leading to achieving this objective are described in the table below.

Objective 4.3	<i>Establish Penn State as the global digital destination for science and scholarship by developing robust “science gateways” – hubs on the web for advancing interactive participatory modes of inquiry, learning and outreach</i>
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²² See for example the Iplant (<http://www.iplantcollaborative.org/>), and nanohub (<http://nanohub.org/>) projects among others.

Supporting Strategies	Create communities of participatory research by developing PSU-CYBERHUB, a directory with access to an array of science gateways that showcase Penn State-created digital assets for research, learning, industry partnerships and entrepreneurship; Foster the development of digital repositories where researchers may search for the products of scholarship as well as contribute their own research output centered about key research centers; In partnership with University libraries, coordinate collections and develop shared technology infrastructure with peer institutions to support the global reach and impact of Penn State research
Assessment	<ul style="list-style-type: none"> • Number and use metrics across science gateways from external accesses • Number of researchers and research projects using systems from Penn State • Data use/access metrics and citations of PSU science gateways • Storage space available in separate systems and data and software inventories
Involved Units	ICS, OVPR Institutes, Colleges, University Libraries

GOAL 5: Valuing and Exploring our Cultures

The Penn State OVPR will expand its role in building stronger interdisciplinary communication and collaborations to foster and disseminate outcomes of research undertaken to enhance understanding and valuation of diverse cultures.

Valuing and exploring our cultures is a challenging goal given the complexities of human beings as both individuals and as collective communities. Penn State researchers are engaged in virtually every aspect of the many ways that culture affects, structures and enriches our lives. Preeminent life scientists are collaborating across colleges and institutes to better understand how our genes and environment define us as individuals and distinguish us from others. Penn State is a leader in the fields of anthropology, sociology and psychology where researchers are looking at how individuals have come together to form modern societies with diverse cultural beliefs and practices. Engineers and architects design much of the physical and cyber infrastructure supporting our cultures. Faculty in the humanities have studied the history, variety, and significance of human expression since the invention of writing. Faculty in communications and the arts study, develop, and practice forms of human expression ranging from the Pyramids to the Internet. Lastly, international research and collaborations advance the understanding of diverse cultures. Clearly, research in all these areas has a role to play in supporting related institutional priorities.

SIGNATURE OBJECTIVE 5.1 *Make integrative arts and humanities research a signature component of the research enterprise at Penn State, thereby establishing our national leadership in this emerging domain*

As a founding member of the Alliance for Arts in Research Universities (a2ru), Penn State has over the past several years taken a leading role in defining and promoting the nascent field of

interdisciplinary arts research. This transdisciplinary approach to tackling complex problems entails integrating arts methodologies and practitioners into the traditional research enterprise. Visual artists, poets, musicians, designers, and others become integral partners in the formulation and exploration of research questions, rather than mere handmaidens who might have a useful role in the dissemination of findings. Similarly, humanists can, and must, be similarly integrated into the University's research enterprise.

Establishing Penn State as a national and international leader in interdisciplinary arts and humanities research is a fundamental goal during this planning cycle. To this end, the OVPR will make available additional resources to build on and expand the substantial connections that already have been established across colleges, institutes and departments. The OVPR will charge the Associate Deans for Research in Arts & Architecture, Communications and Liberal Arts, and the Director of the Institute for Arts and Humanities with formulating strategies for realizing this ambitious goal. This will entail developing key intellectual thrusts by facilitating regular executive committee meetings, promoting collaboration across colleges and institutes, improving internal and external communication, better supporting proposal preparation and submission, and making recommendations for facility needs. They also will assist in formulating strategies to ensure the timely internal and external dissemination of important research news to all University stakeholders and audiences.

Several nascent and developing centers and laboratories will provide additional infrastructure to support this developing initiative.

Arts and Design Research Incubator (ADRI)

Operating within the A&A Research Office, this new initiative provides seed funding, technical support and workspace to high-impact interdisciplinary arts and design research projects that, although often in their initial stages, have a strong probability of attracting future external funding. (More information is available at sites.psu.edu/adri.) Drawing on and creating collaborative partnerships across the PSU research landscape, ADRI projects engage with University-wide research initiatives and priorities, push methodological and disciplinary boundaries, make innovative use of technology, often link research and teaching, and have the potential to garner national and international recognition. ADRI project teams are collocated within a 2,000-square-foot workspace that encourages cross-fertilization and boundary crossing. ADRI also coordinates and hosts a range of programming designed to foster, support and disseminate innovative interdisciplinary arts research.

Borland Project Space

Effective Spring Semester 2015, the Borland Gallery (125 Borland Building) has been repurposed as the "Borland Project Space." This initiative showcases the vibrant research culture in arts and design disciplines at Penn State, with the term "research" intended to encompass the full range of practices in which faculty and students engage to create new knowledge in these fields. By

deploying a residency model, the aim of this initiative is to move beyond traditional notions of exhibition, performance and scholarly programming in an effort to reveal the processes and procedures of arts research, which are customarily hidden from view. Programming will interrogate the materials, methods and strategies deployed by artists, designers, theorists and historians; foreground the kinds of questions they pose and the way they frame them; and display the kinds of evidence they collect and ways they marshal it. The underlying belief is that in doing so, faculty in the arts and design disciplines will better understand themselves and each other as practitioners and teachers, and we will significantly raise the visibility of such work as integral to the research culture and mission of the University. It is expected that the significance of the projects in the Borland Project Space will attract national and international attention and interest.

From the perspective of the goal of promoting interdisciplinary arts and humanities research, the Borland Project Space provides a site and framework for researchers from other domains to better understand points of intersection across disciplines and ways of integrating arts and design research into basic and applied research. Over time, the interdisciplinary research that results will be a central component of programming in the Borland Project Space.

Center for Imaging Innovation (CI2)

A picture is worth a thousand words, and individuals with the talent to produce eye-catching, effective and informative illustrations of scientific data and concepts are rare and highly valuable. High quality images are essential to success in today's rapid communications landscape, and image needs are changing rapidly across disciplines, communications platforms and technologies. Thus, it is often difficult for researchers to find the expertise needed to capture and optimize images of varying scale, resolution, subject matter and sources for varied analytical and aesthetic needs. *The Center for Imaging Innovation* is being founded to meet the highly varied demands for images of for research projects.

The mission of the Center for Imaging Innovation is to provide an exhaustive menu of image services from generation to publication to archiving. The center will be a place where science and art come together to optimize the use of imagery for both data generation and communications. Services and opportunities to be supported will include:

- Imaging with new modalities from illustrative to photography
- 3D and time/motion illustrations
- Image authentication
- Images for journals, grants and publications
- Collaborative products with WPSU, University Libraries and other institutional resources
- Hyper-saturated visual imagery to communicate complex, detailed information
- Student internships with Media Commons

Signature Objective 5.1	<i>Make integrative arts and humanities research a signature component of the research enterprise at Penn State, thereby establishing our national leadership in this emerging domain.</i>
Supporting Strategies	Support the Associate Deans for Research in Arts & Architecture, Communications, and Liberal Arts, and the Director of the IAH in identifying and carrying out strategies to achieve this object. Provide funding to ADRI, CI2, and other centers and initiatives that will be integral to success in this area.
Assessment	<ul style="list-style-type: none"> • Creation of interdisciplinary research teams including representation from the arts humanities (possibly to include a specific number as a target). • Funded research including faculty from the arts humanities • Funding for research in the arts and humanities
Involved Units	Every Penn State college and unit

OBJECTIVE 5.2 *Remediate gaps in the resources available to vulnerable populations, including children, youth, elders and their families, in a global society*

Vulnerable populations include minorities, persons with disabilities, and those living in poverty. Gaps in the resources supporting vulnerable populations occur in every human service sector from education to medicine to social services. These gaps have many different direct causes across urban and rural settings where race, culture and ethnicity create vastly different challenges for accessing and receiving jobs, goods and services. Penn State has a long and growing list of researchers who are expanding knowledge and developing interventions to support the many different vulnerable members of our society, including children, elders, persons with disabilities and the socially and economically disadvantaged. Current researchers working in this landscape cross many colleges and institutes (Table 7). With this objective, the OVPR will create a platform upon which these diverse groups can come together to share knowledge and create synergies.

Table 7: Penn State Research on Vulnerable Populations and Supporting Units

Vulnerable Populations	Research Topics (including disparities among)
Children and Youth	Addiction & Substance Abuse
Displaced and Recently Immigrated	Affordable Housing & Shelter
Individuals & Families	Child Maltreatment
Economically Disadvantaged Individuals & Families	Chronic Disease/Disease Management
Elderly	Community Resources
Gay, Lesbian, Bisexual & Transgendered	Education Access
Individuals	Employment
Persons with Disabilities	Food Access and Safety; Malnutrition
Military Families and Veterans	Healthcare Access
Racial and Ethnic Minorities	Health Risk Behaviors
Rural and Inner City Residents	Infectious Disease
War and Conflict Zone Residents	Natural Resources
Women and Female Youth	Physical Environment
	Safety and security
	Social Services Access

Stress Management	
Supporting Penn State Research Units	
Colleges College of Agricultural Sciences College of Communications College of Earth and Mineral Sciences College of Engineering College of Health and Human Development College of the Liberal Arts College of Medicine College of Nursing Eberly College of Science College of Education	Research Units Center for Rural Pennsylvania Child Study Center Clearinghouse for Military Family Readiness Clinical and Translational Sciences Institute (CTSI) Huck Institutes of the Life Sciences (Huck) Institute for CyberScience (ICS) Institute for Personalized Medicine Materials Research Institute (MRI) Penn State Institutes of Energy and the Environment (PSIEE) Population Research Institute Prevention Research Center Social Sciences Research Institute/Children, Families and Youth Consortium (SSRI)

The Social Science Research Institute (SSRI) will serve as the coordinating unit to develop and bring together interdisciplinary faculty expertise to focus on this objective. SSRI faculty includes many internationally renowned experts across many related fields, and several SSRI units (including the Population Research Institute with its focus on immigrant families, the Clearinghouse for Military Family Readiness, and the Network on Child Protection and Well-Being) are focused on translational research for the betterment of vulnerable populations with disproportionately low socioeconomic and ethnic minority backgrounds. Building on this foundation, a priority area for SSRI's investments during the upcoming strategic planning cycle will be to identify the causes and consequences of growing social disparities in health, education and other kinds of resources within the US and around the world as a step toward the development of programs and policies that remediate these inequalities. Investments in social science translational research will ultimately promote the health and development of diverse populations of children, youth and families, and remove vulnerabilities. Notably, by virtue of a focus on diverse populations, the social science units have a unique capacity to attract students and scholars who have specialized interests in these topics.

Objective 5.2	<i>Remediate gaps in the resources available to vulnerable populations, including children, youth, elders and their families, in a global society</i>
Supporting Strategies	Research to identify and develop alternative support strategies; education opportunities; protective services; automated assistive and self-help technologies; remote service delivery through technology
Assessment	<ul style="list-style-type: none"> • Reduced healthcare needs • Reduced violence-related injuries • Lower assault rates • Improved quality of life indicators
Involved Units	CAS, CHHD, COC, COE, COM, CON, ECOS, EMS, HUCK, ICS, IST, PRC, PRI, PSIEE, MRI, SSRI

OBJECTIVE 5.3 *Invigorate research and creative accomplishments across the arts and humanities*

Research within the humanities is an important component of the Penn State research enterprise, but there are clear opportunities to expand this role across the humanities and to more frequently engage with scientists and engineers in translational research. Since 2010, the *Institute for the Arts and Humanities* (IAH) has taken decisive steps to become more prominent in the international world of humanities centers and institutes while continuing to serve its various local constituencies at Penn State and in the surrounding community. Residencies and fellowships have made major contributions to the intellectual life of Penn State, supporting faculty and graduate students across the disciplines. Under the heading of the “Being Humans” framework, the IAH has tried to foster even more ambitious interdisciplinary work that acknowledges the expanding terrain of common interest with the social and physical sciences. The postdoctoral program, started in 2010, and drew 45 applications in its first year and more than 200 in each of the past two years. Applicants come from all over the world, as announcements spread awareness that the IAH offers postdocs a vibrant intellectual community and time to work.

In 2014, the IAH won an unprecedented grant from the Andrew W. Mellon Foundation to undertake a two-year project titled “The Boundaries of the Human in the Age of the Life Sciences.” The project asks how we are to think of ourselves *as humans* as a species (rather than as a cluster of clans, tribes, religions or nations) – a species that now has the power to affect the physical composition of the biosphere, even as new developments in genetics and evolutionary theory compel us to acknowledge that our interactions with the biophysical world are far more fluid and complex than we had thought. Expanding the inquiries of the arts and the humanities well beyond the traditional disciplines associated with them, and incorporating the work of biologists, anthropologists and historians of science, “The Boundaries of the Human in the Age of the Life Sciences” is precisely the kind of interdisciplinary undertaking that will make Penn State a leader in humanities research.

In 2016, the IAH will celebrate the fiftieth anniversary of its founding. The time is right for additional investments in the Institute. An investment in infrastructure would be transformative, as it would allow the IAH to better host its own meetings, lectures, performances and receptions. An investment in programming would be equally important, insofar as it would allow the Institute’s national and international aspirations to be realized. Investments in the future of the Institute should be made with the goal of creating better conditions for Penn State faculty and graduate students to advance their research and creative projects, and in so doing elevate IAH to a more prominent place among its peers at major public research universities.

In many ways, the IAH is in the strongest position in its 48-year history. For the first time, its director is a member of the International Advisory Board of the Consortium of Humanities Centers and Institutes, and is well-positioned to enhance the national and international reputation of the

IAH while expanding programs for Penn State faculty and graduate students. To this end, the OVPR will support the IAH in its efforts to:

- Remain active in the projects of the Consortium of Humanities Centers and Institutes;
- Participate energetically in Mellon Foundation initiatives, taking the lead on new programs when possible (as we did with the Humanities Without Walls pre-doctoral internships, coordinated by 15 institutions organized loosely around the CIC);
- Expand the postdoctoral program to two-year fellowships;
- Expand residencies and grants that serve Penn State faculty and graduate students;
- Leverage “The Boundaries of the Human” in order to build permanent programmatic links among the arts, humanities, social sciences, and life sciences; and
- Find ways to bring visiting scholars and artists to campus for semester-long residencies.

Objective 5.3	<i>Invigorate research and creative accomplishments across the arts and humanities</i>
Supporting Strategies	Remain active in the projects of the Consortium of Humanities Centers and Institutes; participate energetically in Mellon Foundation initiatives, taking the lead on new programs; when possible (e.g., Humanities Without Walls pre-doctoral internships); expand the postdoctoral program to two years (possibly around the theme of “Being Humans”); expand residencies and grants that serve Penn State faculty and graduate students; and, find ways to bring visiting scholars and artists to campus for semester-long residencies
Assessment	<ul style="list-style-type: none"> • Endowment levels benchmarked against CIC peers • Numbers of resident scholars and postdoctoral positions supported • Numbers and quality of applications for Penn State scholars, residents and postdoctoral programs • National and international recognition events for Penn State scholars from the Arts and Humanities • Extramural funding for projects and scholars for Arts and Humanities
Involved Units	AA, CLA, COC, IAH

OBJECTIVE 5.4 *Become the institution known for championing international research that develops and applies solutions for societal challenges worldwide*

Penn State boasts an expansive network of international research connecting with every continent on the globe (Figure 18). Faculty, students, scholars and outreach specialists from virtually every discipline are engaged worldwide, providing expertise in agriculture, anthropology, art, climate, communications, computing, ecology, energy, engineering environment, geography, health, humanities, medicine, psychology and sociology. The breadth of our diverse international student base also contributes to the reach and impact of Penn State research, and helps remind our community of our societal obligation to consider not only the value of specific research productivity for the US and other G20 countries, but also for reducing disparities in access to resources and improving the human condition among societies less like our own.



Figure 18: Geographic distribution of Penn State international collaborators as reflected by co-authorship on peer-reviewed publications [Source: scival.com/trends/].



Figure 19: Interdisciplinary partnerships such as one involving materials scientists and the College of Arts and Architecture and in projects in the Art and Design Incubator will lead to novel solutions such as this ceramic water filter (Credit: B. Stephen Carpenter II).

Penn State's leadership believes a concerted effort to bring together researchers from different disciplines and with experience working in different cultures will stimulate a cross-fertilization of skills and expertise that will enable new discoveries and new solutions such as the recently-developed simple ceramic water filter (Figure 19). These discoveries and solutions will happen more rapidly if administrators from the corresponding colleges and units supporting international researchers form a supporting network to develop and share best practices for meeting the many additional requirements associated these endeavors.

With these purposes in mind, this objective will be supported by three major initiatives:

1. Creating an *international researchers' network* and host supporting activities to stimulate the exchange of ideas and practices and support networking that brings together international researchers with complementary skills and expertise needed for transformative and translational research in specific geographical locations.
2. Launching new *interdisciplinary research initiatives targeting solutions for the world's most pressing challenges* through a collaborative relationship with the Global Engagement Network.
3. Creating an *administrative best practices network for international research* to streamline administrative processes and share best practices to minimize delays and remove barriers associated with the many regulations specific to international collaboration, research and associated travel.

International Researcher Network

Activities designed to support networking among the international research community will include specific events such as seminar series, research forums and retreats. It will include the creation of a map-based social networking platform to allow faculty to find experienced collaborators in specific disciplines and locations. It will start with the development of an international research expertise database. Such a database will be created and updated periodically using data from the Penn State Strategic Information Management System (SIMS), publication databases and Global Programs. Table 8 provides a small sample list of some prominent Penn State international researchers with the types of key data elements that will be used to begin to populate this database. Researchers identified using specific SIMS target fields (Table 9, next page) and publication databases will be contacted and invited to correct and approve information prior to adding it to the database. The database will be accessible for expertise searches by individuals both within and external to Penn State.

Table 8: Sample Penn State faculty engaged in international research presence by topic, and collaborating institutions

Faculty	Expertise and Topic	Country/ Region Institutions	Department	College/ Unit	Sponsors
Airhihenbuwa, Collins	HIV/AIDS	Ghana	Biobehav Health	CHHD	NIH
Caldwell, Linda	HIV/AIDS	South Africa	Rec, Parks & Tourism	CHHD	NIH
Crane, Robert	Climate	South Africa/ Univ of Capetown	Geography	EMS/ ASEADA	NSF
Hudson, Peter	Infect Disease, Climate Change, Genomics	Australia, Botswana, Finland, Italy, Scotland, Tanzania, UK	Biology	ECOS/ Huck	Nelson Mandela Afri Inst; Gates
Kroll, Judith	Bilingualism, Learning	Brazil, China, Columbia,	Psychology	CLA	NSF/ PIRE

		Germany, Mexico, Netherlands, Spain			
Lynch, Jonathan	Drought Resistant Crops	Africa, Latin America, Puerto Rico	Plant Science	CAS	USAID, USDA
Mehta, Khanjan	Technology-based Solutions	Kenya, Tanzania, India, China	Eng Design	ENG/MRI	Alliances
Monroe, Burt	Opposition, Rhetoric, and Democratic Style	Middle East, North Africa	Political Science	CLA	NSF
Nyblade, Andrew	Climate Change	Ethiopia, Cameroon, Kenya, Tanzania, Zambia, Zimbabwe, University of Withwaters	Geosciences	EMS	NSF
Staffer, Jay	Technology, Evol & Ecology	Malawi/Bunda College	Eco System Sci & Mgmt	CAS	NSF
Trinitapoli, Jennifer	Demography, HIV/AIDS	Ghana, Malawi	Sociology	CLA	NIH

Table 9. SIMS fields and sorting logic to populate an international research database.

SIMS Field	Sorting Logic Example
Foreign Sponsor	A PI is receiving funding from Toshiba headquarters in Japan but the PI might be working entirely with personnel from Westinghouse, the Pittsburgh subsidiary of Toshiba. The PI may opt out of the database.
Foreign Subcontractor	A PI is sending assays to a lab in Germany for characterization and may not consider himself/herself an "international" researcher. The PI may opt out of the database.
Foreign Shipments	A PI is shipping samples to a lab in Germany for characterization and may not consider himself/herself an "international" researcher. The PI may opt out of the database.
Foreign Travel	A researcher is traveling to a conference at a location outside the US, but the topic of the conference is not international research and the researcher's presentation does not involve international collaborations. The researcher may not consider himself/herself an "international" researcher. The PI may opt out of the database.
Foreign Visitors	A foreign visitor may come to visit a Penn State researcher as part of a site visit team or to provide technical expertise on operating a new piece of equipment. The traveler may not be tied to any ongoing "international" research collaboration.

Global Engagement Network Research Initiatives

The OVPR will advance efforts to promote international research through collaborative support for a new research initiative led by the Penn State **Global Engagement Network (GEN)**²³ – a network of strategic partnerships around the world with peer institutions that share Penn State's commitment to solving the most pressing global challenges through a multi-layered engagement of research, faculty and student collaboration.

The Global Engagement Network will advance strategic partnerships around the world with peer institutions that share Penn State's commitment to solving the most pressing global challenges through a multi-layered engagement of research, faculty and student collaboration.

The GEN offers expanded access to regional networks of intellectual capital, resources, and funding, while capitalizing on the strengths, benefits and opportunities that arise from multidisciplinary and multicultural approaches to problem solving. The GEN leverages Penn State intellectual resources with those of other major research universities worldwide. At the same time, it integrates research into our educational programs and provides student engagement opportunities that build global citizenship and leadership. These strategic partnerships also provide a mechanism for diversifying the regions from which we attract international students and scholars and broaden opportunities for Penn State students studying abroad.

Over the next five years, the OVPR will provide funding for four seed grants to be awarded annually to interdisciplinary teams of Penn State investigators proposing new research initiatives that jointly support the institution's strategic goals for research and GEN goals for building global citizenship and leadership. These seed grants will be awarded following a review process that engages faculty leaders in international research and scholarship to project teams demonstrating both clear plans for impactful interdisciplinary research with global impact and a collective commitment to a long-term, sustainable collaborative research relationship.

International Research Administrator Best Practices Network

Members of the Administrative Committee on Research (ACOR) with international research administration experience will be invited to join a focused subcommittee on international research. The purpose of this subcommittee will be to share knowledge of procedures and best practices for navigating the complicated regulations that apply to international research. This administrative network will invite participation broadly from administrative areas of the University including pre-award support services, post-award spending, accounting, travel and human resources. The subcommittee will work to centralize expertise and best practices for topics such as:

- Data sharing
- Insurance coverage
- ITAR compliance

²³ Additional information on the Global Engagement Network is available at <https://global.psu.edu/gen>.

- Laws applying to travel and conducting research in specific countries
- Travel safety issues, e.g., knowing traveler locations

Objective 5.4	<i>Become the institution known for championing international research that develops and applies solutions for societal challenges worldwide</i>
Supporting Strategies	A Penn State International Research website hosting news, an expertise database and administrative best practices; seed grants offered by the GEN; a series of international research seminars, forums and retreats, and electronic social networking platforms; ACOR subcommittee/network on international research administration
Assessment	<ul style="list-style-type: none"> ● Research seminars, forums and retreat attendance and communications ● Number of entries and assess/queries of International Research Database ● Number of faculty, staff and students involved in international research ● Extramural funding for international research and seeded by GEN grants ● PSU faculty co-publications with international scholars ● Time for processing specific documents associated with international research, ranging from visas to purchasing ● Website access, use of database and best practice documents
Involved Units	All institutes, colleges and units in collaboration with Global Programs with support units including Human Resources, OSP, SIRO and Research Accounting

GOAL 6: Invigorating Entrepreneurship, Technology Transfer, and Economic Development

Penn State will continue to translate its scientific research and leverage its resources to invigorate entrepreneurship, technology transfer and economic development in Pennsylvania, the United States and the world.

The newly created *Office of Industrial Partnerships* (OIP) will lead advancement of three major objectives over the next five years to significantly change the culture of Penn State and the way we work in this playing field, and by brokering new relations across the academia-industry divide.

SIGNATURE OBJECTIVE 6.1 *Establish Penn State as the "go-to" academic institution for industry-sponsored research by creating a local ecosystem where Penn State researchers work hand-in-hand with industry to accelerate technology transfer*

Based on analysis of intellectual property (IP) costs and revenues, Penn State and the OVPR recently shifted their perspective on how to manage IP created through its research agreements with industry sponsors. Specifically, the University has taken a stance of flexibility toward negotiating ownership of IP created via collaboration between Penn State researchers and industry.

In the past, Penn State required that it maintain ownership of this IP, but that stance has proven to cost the University more money than the IP generated. The new more flexible stance on IP ownership allows for more efficient IP management and related technology transfer, thereby ensuring Penn State's research has the greatest benefit to the University and to society.

Penn State's new position on IP is but one step toward a more progressive approach to industry collaboration. Yet it provides a major signal to those within and without that the University is serious in establishing a leadership position in industry-sponsored research and development. The next steps toward this goal include major education and outreach efforts for both internal and external stakeholders. For example, Penn State negotiators and technology officers will be encouraged to form joint working groups with their industry counterparts to develop and disseminate best practices for facilitating industry collaborations while protecting Penn State's mission and the interests of its researchers.

The new Associate Vice President for Research and Director of Industrial Partnerships (AVPR & DIP) will lead the OIP in advancing this objective through a major marketing and match-making effort. The aim will be to match industry need with University expertise in win-win relationships that lead to sustained partnerships. The AVPR & DIP will interface with similar existing positions in the Materials Research Institute and the Applied Research Laboratory and with new positions being established in the Eberly College of Science, the College of Engineering and elsewhere to form a cohesive industry-friendly network that understands their needs and creates the necessary synergies to meet them. Long-term, we intend to attract businesses of all sizes to locate in the State College vicinity (capitalizing on the infrastructure available at **Innovation Park**), the I-9 corridor and vicinities surrounding relevant campuses, ultimately working alongside faculty and students in symbiotic relationships. These partnerships will in turn promote local innovation, job creation and student experiences leading to long-term career opportunities. The economic benefits to the UP and Campus communities are obvious.

The University will strive to integrate our academic priorities with the priorities of our industry partners by working cooperatively with the Chamber of Business & Industry of Centre County (CCBIC), local partners at the Commonwealth Campuses and partners in Philadelphia (e.g. PIDC at the Navy Yard) and Pittsburgh (see Support Strategies). We envision an environment where academic scientists, professors of practice, postdoctoral scholars and students at all levels work alongside personnel employed by our industrial partners to develop new technologies and practices – environments similar to the Learning Factory model in the College of Engineering and recent successful initiatives at the Behrend campus. These shared translational research and development experiences will be aimed at bringing new products and processes to market while training and creating opportunities for students across the spectrum of Penn State majors. Company internships for faculty and students will be reciprocated through recruitment and deployment of **Professors of Practice** who will provide the practical knowhow and business experience needed to effectively

guide our participation and prepare our students. These positions will be supported by institutional, federal and state funding, and industry sponsorship.

Signature Objective 6.1	<i>Establish Penn State as the "go-to" academic institution for industry-sponsored research by creating A local ecosystem where Penn State researchers work hand-in-hand with industry to accelerate technology transfer</i>
Supporting Strategies	Firmly establish an internal network coordinated by the new AVPR & DIP; identify new potential partners whose needs match Penn State expertise; enhance processes to make Penn State even more user-friendly; educate faculty in how to better interface with private sponsors; recruit and deploy new Professors of Practice as needed; develop user friendly processes to create mutually beneficial "in-residence" experiences for our students
Assessment	<ul style="list-style-type: none"> • Number, scope, and value of new partnerships formed • Enhancements (jobs, products and partners) among existing partnerships • Number of faculty, staff and students engaged • Feedback from faculty and industry partners • Number of partners locating facilities at and near UP and campus communities • Number and quality of graduates working in affiliated domains after graduation
Involved Units	OIP with all institutes, colleges and campuses, OSP, OTM, BFTP/CNP, Innovation Park, community partners

OBJECTIVE 6.2 *Create a Penn State culture that values entrepreneurship, technology transfer and economic development*

Our aim is to become a truly entrepreneurial University whereby we effectively promote the transition from invention and creativity to implementation in the marketplace. Creating a Penn State culture that values entrepreneurship, technology transfer and economic development means changing how traditional academics think and operate. This is a formidable challenge. To be successful, the importance and value of entrepreneurship in its many forms needs to be effectively communicated by central leadership as well as the leaders of every campus, academic unit and institute at Penn State. A change agent is needed to break down barriers embedded in tradition and culture. Thus, this initiative will begin with a series of meetings between academic and research deans and directors to more fully engage and educate them about the desired cultural change and importance of this change to the health of the Penn State research enterprise and its academic mission.

The new OIP, led by the AVPR & DIP will be charged with assessment of the current culture and establishment of a set of recommendations and assessment metrics for change. Subsequently, the OIP will lead efforts to disseminate information, organize unit educational activities, and monitor progress toward this change. Items on the table include: developing and publicizing reward structures for faculty and staff entrepreneurial successes; opening the College of Business to other majors; hiring more professors of practice throughout the University to help develop products, build companies and create new educational opportunities for students; creating partnerships

between inventors and potential entrepreneurs within the University; creating more inexpensive off-campus space for entrepreneurial activity and expanding student entrepreneurship programs.

Coordinating and adjusting existing resources will contribute to our success. These include marketing resources and opportunities already created through the *Fund for Innovation*, the *Ben Franklin Technology Partners for Central and Northern Pennsylvania (BFTP/CNP)*, *Innovation Park*, the **Undergraduate Entrepreneurship Minor** and several student organizations.

Fund for Innovation

The Fund for Innovation (FFI) is organized under The Penn State Research Foundation to greatly enhance the culture of research commercialization at the University. The mission of the Penn State FFI is to provide funding to jump-start new companies based on Penn State intellectual property, demonstrate commitment to the commercialization of results of government grants, and impact Pennsylvania's economy through job creation. Three key FFI programs will advance this mission: Proof-of-Relevance Program, Proof-of-Concept Award, and Jump-Start Funding (Figure 20 below).

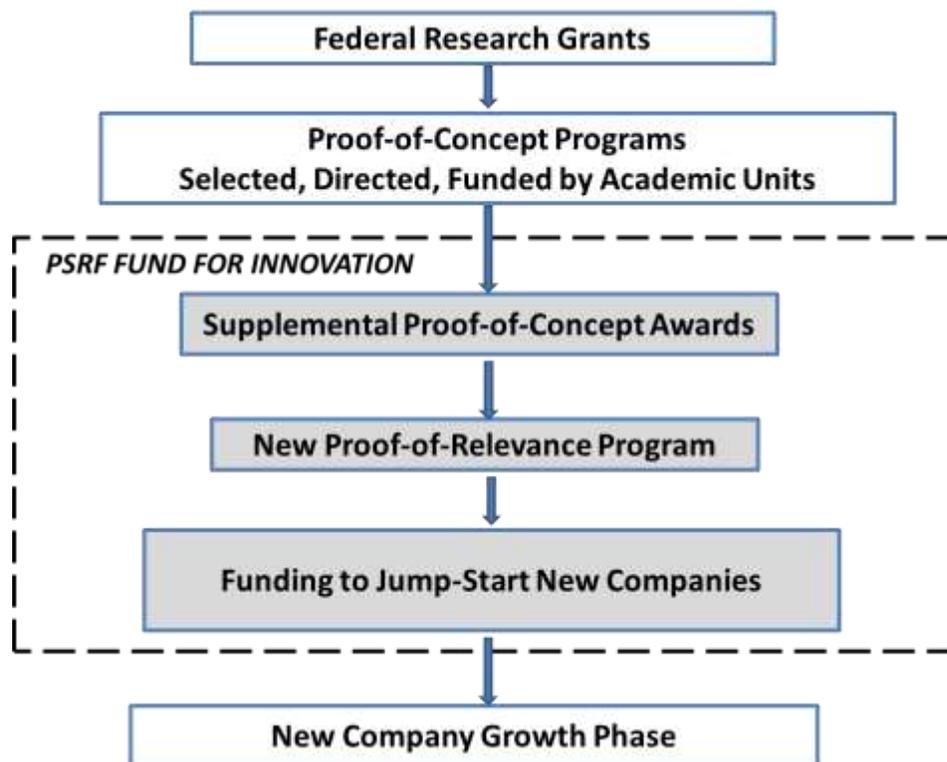


Figure 20: Model for Company Development under the Penn State Fund for Innovation

First year goals for the FFI include supporting 12 to 16 college proof-of-concept programs, conducting 10 proof-of-relevance studies, and providing funding for five to six new companies.

This will be jointly accomplished by the Penn State Research Foundation with support from the Office of the Provost.

Ben Franklin Technology PArtners for Central and Northern Pennsylvania (BFTP/CNP)

The BFTP/CNP is operated by Penn State for the Commonwealth of Pennsylvania, and the OVPR is charged with oversight of the organization. The BFTP/CNP has recently launched a series of TechCelerator entrepreneurial support programs to increase the local commercialization of Penn State and community innovations. This effort at University Park alone has dramatically increased the number of University-based startups in the last two years.

The strategy of the BFTP/CNP over the next few years will be to grow successful businesses and create new wealth and jobs in Central and Northern Pennsylvania. Specific activities will include:

- Increase the number of individuals exploring entrepreneurship and, as a result, increase the number of new companies started across the region and across the University
- Create more local funding opportunities for both follow-on and proof-of-concept stage companies
- Facilitate angel and venture investment in Central Pennsylvania startup companies
- Increase the visibility and sponsorship of our Innovation and Business Plan contests to reward and support entrepreneurship across the 32-county Ben Franklin service territory
- Promote the Ben Franklin Innovation Adoption program for existing small Pennsylvania companies to link with University expertise
- Leverage at least \$1M per year in additional external support to Ben Franklin and Penn State economic and technology development programs

Innovation Park

Innovation Park is a 118-acre research and business campus under development by Penn State to create an environment where University and business partners collaborate to convert knowledge to societal impact. In partnership with the Office of Finance & Business, the OVPR is charged with oversight of the enterprise. Between 2009 and 2013, an additional 94,500 square feet of space was constructed and leased. The current build out is approximately 1 million square feet, fully leased with a total build out target of nearly 1.5 million square feet.

Related Opportunities

The OVPR will facilitate aggressive pursuit of federal funding opportunities supporting entrepreneurial efforts including **Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) grants** as well as **NSF Engineering Research Centers (ERC) and Industry & University Cooperative Research Program (I/UCRC) grants**.

Penn State research produces an abundance of technology and knowledge ripe for transfer to the commercial sector. The six institutes administered by the OVPR will provide low-hanging fruit ready for transfer.

Objective 6.2	<i>Create a Penn State culture that values entrepreneurship, technology transfer and economic development</i>
Supporting Strategies	Establish senior leadership buy-in and cohesion; establish the council for entrepreneurship; technology transfer and economic development; better coordinate existing resources; create more inexpensive space for entrepreneurial activity; develop reward structures for faculty and staff success; open the College of Business to other majors; hire more professors of practice throughout the University; expand student entrepreneurship programs.
Assessment	<ul style="list-style-type: none"> • Number of patent and license filings • Number of new startup companies • Numbers of students engaged in entrepreneurial minor and related activities • Number of SBIR/STTR and ERC, I/UCRC awards • Increase in startup funding availability from Angel, venture or other
Involved Units	All campuses, colleges and institutes, senior leadership, OIP, OSP, OTM, BFTP/CNP, Innovation Park, community partners

OBJECTIVE 6.3 *Improve, streamline and clarify processes to accelerate the pace at which technologies move from discovery to implementation*

Penn State ranks 62nd in technology licensing income, 41st in number of patents filed, and 35th in number of patents among academic institutions. Given its top-20 ranking in research expenditures, these statistics are just one indicator of the systemic change needed to facilitate the transformation of ideas to products. The recent decision to increase the number of technology licensing officers in the Office of Technology Management (OTM) is a very positive move and sends a message to the Penn State research community that Penn State is serious about technology transfer. But researchers can be further encouraged and enticed to participate in transformative practices through more visible recognition and reward for participation and successes by faculty and staff in the tech transfer process.

To accomplish this objective, leadership will be encouraged to study the licensing revenue structure of the University to optimize resources and to study other institutional approaches to identify best practices in this domain. Outreach and education activities to engage and connect faculty with key resources will be extended collaboratively by OIP, the AVPR & DIP and regional organizations such as BFTP/CNP and CCBIC. An easy-to-follow step-by-step pathway will be defined to enhance the ease at which ideas can be transferred to the marketplace. We also aim to increase the quality and availability of our educational resources about the operational aspects of starting new a business, provide more options and better advice about incubator space, and forge more connections with venture capitalist and mentors – particularly alumni – willing to invest in and guide young entrepreneurs and mange new startup companies.

Other attractive ideas for advancing this goal, some of which are already underway, include: IP fairs to attract investors and partners, competitions with financial rewards for new startup companies and a Penn State branded platform to attract investors and venture capital.

Objective 6.3	<i>Improve, streamline and clarify processes to accelerate the pace at which technologies move from discovery to implementation</i>
Supporting Strategies	Support unit policy self-assessments and analysis; faculty and staff education and training; two new licensing technology officers; engage alumni; new competitions and marketing platforms
Assessment	<ul style="list-style-type: none"> • Number of patent and license filings • Number of new startup companies • Attendance at training and informational sessions • Number of industry funded programs • Contracting process time
Involved Units	All campuses, colleges and institutes, senior leadership, OIP, OSP, OTM, BFTP/CNP, Innovation Park, alumni and community partners

SUPPORTING STRATEGIES

1: Meeting the Imperatives for Higher Education and Fostering Diversity

Research is inseparable from teaching and service as Penn State endeavors to fulfill its tripartite mission as a land grant institution of higher education. President Barron has identified six Imperatives that will be core to our success in this mission: ***1) excellence; 2) student engagement; 3) demographics and diversity; 4) student career success and economic development; 5) accessibility; and 6) technology.*** From among these imperatives, “demographics and diversity” touches all the others and is one for which a framework for success has been clearly defined. “Accessibility” for all populations is also integral to all other imperatives. Thus, to ensure an environment reflecting its core diversity values, the OVPR has considered these two diversity-focused Imperatives in the design and implementation of this strategic plan. This is illustrated in Table 10 below where specific objectives of the OVPR Strategic Plan are mapped to the seven Challenges identified by the Penn State Framework to Foster Diversity and the two diversity-focused Imperatives described above.

The OVPR believes that interdisciplinary research, which by definition is a core thrust of OVPR institutes, brings together disparate disciplines that often include varying participation of underrepresented groups. Therefore, by its nature, interdisciplinary research promotes a teamwork environment that includes exposure to and promotes respect for differing perspectives.

Moving forward, the first phase of the OVPR plan implementation will involve designated leaders implementing and assessing progress toward each objective of the plan. With support from the OVPR Office of Human Resources and other OVPR supporting units, and in collaboration with

The Graduate School and the Office of the Vice Provost for Educational Equity, each leader will provide guidance on appropriate targets for the metrics associated with each diversity-related objective. Specific attention will be given to the two diversity-focused Imperatives of higher education, with special attention given to the seven Challenges for diversity. Active participation of OVPR staff members on commissions within the Office of the Vice Provost for Educational Equity will further facilitate communications and the sharing of resources for meeting these objectives while concurrently fostering diversity within the unit.

Table 10: Directory: OVPR Objectives Supporting Penn State’s Framework to Foster Diversity

Framework For Diversity Challenges	OVPR Objective Number & Impact on Diversity Challenge	Impact on Diversity-focused Imperatives
1: Developing a Shared and Inclusive Understanding of Diversity	<p>1.5; 5.2 – Research on disparities will foster awareness and offer solutions for inequities within our own institution and beyond.</p> <p>5.1 – Interdisciplinary research teams will help build bridges to cultural understanding across diverse disciplines and cultures – within the microcosm of the team and more broadly through outcomes.</p>	<p>Diversity & Demographics – Cultural understanding builds a stronger and more inclusive campus environment through broadening of understanding and perspectives.</p>
2: Creating a Welcoming Campus Climate	<p>3.3 – The Postdoctoral Development Program will strive to recruit, support, train and mentor diverse populations.</p>	<p>Diversity & Demographics – Interdisciplinary research offers ripe opportunities for postdoctoral scholars from diverse populations and OVPR will promote their success.</p>
3: Recruiting and Retaining a Diverse Student Body	<p>3.1 – Engaged scholarship activities will be actively promoted to diverse populations. The ARL D.O.O.R.S. program will provide but one model approach.</p>	<p>Diversity & Demographics – Underrepresented and disadvantaged populations will be able to engage in activities supporting career development through internships and applied learning.</p> <p>Accessibility – Competitive compensation will help to support education affordability.</p>
4: Recruiting and Retaining a Diverse Workforce	<p>1.2; 1.3; 2.1; 2.2; 2.3; 2.4 – Strategic hires present opportunities for increasing diversity of the faculty.</p> <p>5.3 – Newly-created scholars and postdoctoral positions will offer opportunities for expanded diversity at these levels.</p> <p>6.1, 6.2, 6.3 – New industrial partnerships locating in the University Park area provide jobs and hiring opportunities to attract a more diverse workforce to the community surrounding the University.</p>	<p>Diversity & Demographics –The Penn State faculty and staff demographics need to reflect those of our state, our nation and our world to provide a richer learning environment.</p>
5: Developing a Curriculum That Fosters United States and International Cultural	<p>3.1 – Engaged scholarship activities will be actively promoted to diverse populations. The ARL D.O.O.R.S. program will provide but one model approach.</p> <p>3.3 – The Postdoctoral Development program will provide support, training and mentoring for diverse populations.</p>	<p>Diversity & Demographics – Well-supported and inclusive educational experiences ensure that all populations receive the broadest exposure to differing perspectives.</p>

Competencies (through broad curriculum activities)	3.4 – Training for communications beyond traditional academic forums will include training for communications across diverse cultures. 4.2 – Distance education services will foster international collaborations and the development of cultural competencies.	Accessibility – See description in Challenge 3 related to D.O.O.R.S. Objective 4.2 ensures that broadest socio-economic representation will have access.
6: Diversifying University Leadership and Management	1.2; 1.3; 2.1; 2.2; 2.3; 2.4 – Strategic hires present opportunities for increasing diversity at the senior faculty and center director levels, providing a pipeline for recruitment to more senior positions. The Human Resource staff of the OVPR will provide guidance on best practices for recruiting well in all hiring opportunities.	Diversity & Demographics – Diversity among our leadership is critical to ensuring success in fostering a diverse campus climate.
7: Coordinating Organizational Change to Support Our Diversity Goals	The Human Resource staff of the OVPR will monitor all hiring opportunities. OVPR staff members are represented as appointed members on two University equity commissions (including participation in commission leadership) and, in these capacities, are well positioned to communicate needs and contribute to best practices within the unit and among external partners.	Diversity & Demographics Accessibility – The President’s Equity Commissions address issues of diversity and demographics and accessibility among many other concerns of underrepresented groups among students, faculty and staff across the campuses.

2: Improving strategic proposal development and post-award management

Penn State’s portfolio of funded extramural research has nearly tripled over a period of twenty years (1994-2013) with expenditures increasing from \$317 to \$848M in 2013 (Figure 21). This growth has been fueled in part by multi-year coordinated efforts by the OVPR Institutes and Colleges to develop strategic areas of priority in interdisciplinary research. To better leverage funding in these established areas of research strength, the Strategic Interdisciplinary Research Office (SIRO) was founded in 2010 to advance the research mission of the University by supporting proposal development and project administration for complex research projects.

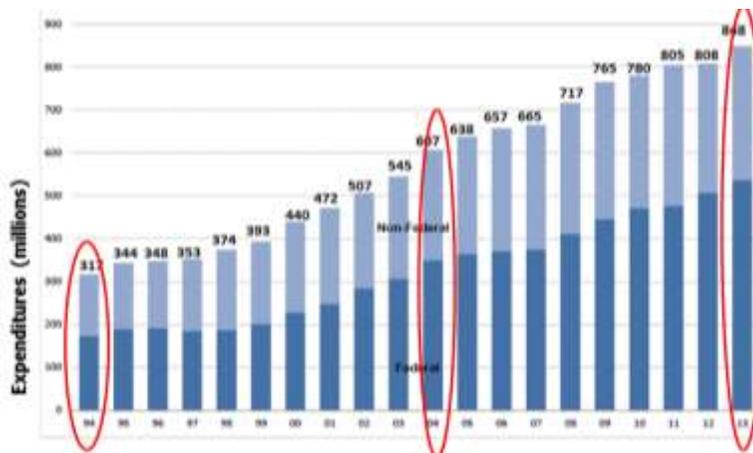


Figure 21: Penn State research expenditures nearly tripled over the most recent 20 Year Period (1994-2013).

Looking to the future, Penn State will face ever-growing levels of peer competition in an increasingly constrained funding environment. The competition is extremely intense for large “center-scale” awards that can establish our preeminence in leading-edge interdisciplinary research. Proposals that are successful at these scales typically require significant development beyond the technical content, including original and credible plans for education, outreach, project management and risk mitigation. *We can gain a competitive advantage by continuing to development SIRO services to effectively enhance the quality of large, strategic proposal.* Additionally, once awarded, such projects impose considerable administrative burdens on the principle investigator and project leadership team. By alleviating some of these burdens through higher levels of support services and by providing development services that leverage strengths around the project team, we could enhance our chances for success in upcoming opportunities. A more fully developed SIRO should result in improved pre- and post-award experiences for our faculty that will encourage greater levels of interest in developing large proposals. Additionally, it is expected to yield greater consistency of pre-award budgeting and post-award management practices across the University to reduce audit risks. Thus, we plan to provide a comprehensive suite of services through SIRO to enable Penn State faculty to develop, win and manage large-scale extramurally funded interdisciplinary projects along areas of strategic priority²⁴.

²⁴ The creation of support offices to enable the development of large proposals is now a national trend as documented by the National Organization of Research Development Professionals and the National Council of University Research Administrators.

VISION: SIRO will provide the highest levels of service to enable the success of Penn State researchers in extramural funding opportunities

GOALS

SIRO aims to achieve its vision through thrust focused on three goals:

- Increase Penn State competitiveness in strategic interdisciplinary sponsored research.
- Enhance researcher productivity by facilitating the development of proposals and reducing the administrative burdens of extramurally funded research.
- Promote best practices related to the lifecycle of large interdisciplinary research activities by serving as an effective communication hub to the Penn State community.

SIRO aims to achieve these goals through three major thrusts, with guidance by an Internal Advisory Board (IAB) representing our stakeholder community at the Colleges and Institutes.

1. *SIRO will engage in a targeted set of ongoing capacity building activities, i.e., advanced planning and team building before or between the releases of major solicitations.*
2. *SIRO will develop a coherent suite of pre-award and post-award services to enhance researcher productivity and leverage opportunities that arise during the lifecycle of large extramurally-funded interdisciplinary projects.*
3. *SIRO will streamline its operations for the effective and sustainable delivery of an expanded suite of services.*



Figure 22: Lifecycle strategic project support services offered by SIRO.

To optimize Penn State’s competitiveness in securing, and success in executing, projects funded by large extramural awards, the OVPR will continue development of the SIRO to provide the highest level of support for strategic, extramurally-funded projects. This support will be extended across the lifecycles of strategic research projects through an approach that fully integrates pre-award, post-award, and long-term strategic research project development and support services (Figure 22). SIRO development and improvement will be accomplished through expanded activities under three ongoing thrusts:

1. Engaging in a targeted set of ongoing capacity building activities, e.g., advanced planning and team building before or between the releases of major solicitations.
2. Developing a coherent suite of pre-award and post-award services to enhance researcher productivity and leverage opportunities across the lifecycle of large extramurally-funded interdisciplinary projects.
3. Streamlining operations for the effective and sustainable delivery of an expanded suite of services.

Rewards and Risks

An analysis of Penn State’s success relative to peer institutions in terms of research expenditures shows that we have potential for growth in winning larger awards across many major agencies (see Figure 23). Even with our current success in DOD funding, this preliminary analysis suggests that we have proportionally fewer DOD awards above the \$5M threshold than many with comparable or lower levels of total expenditures including the U. Illinois, U. Maryland CP, Georgia Tech and Carnegie Mellon. The same is true for awards from NIH (see Johns Hopkins, U. Washington and Columbia) and NSF (U. Washington and Columbia).

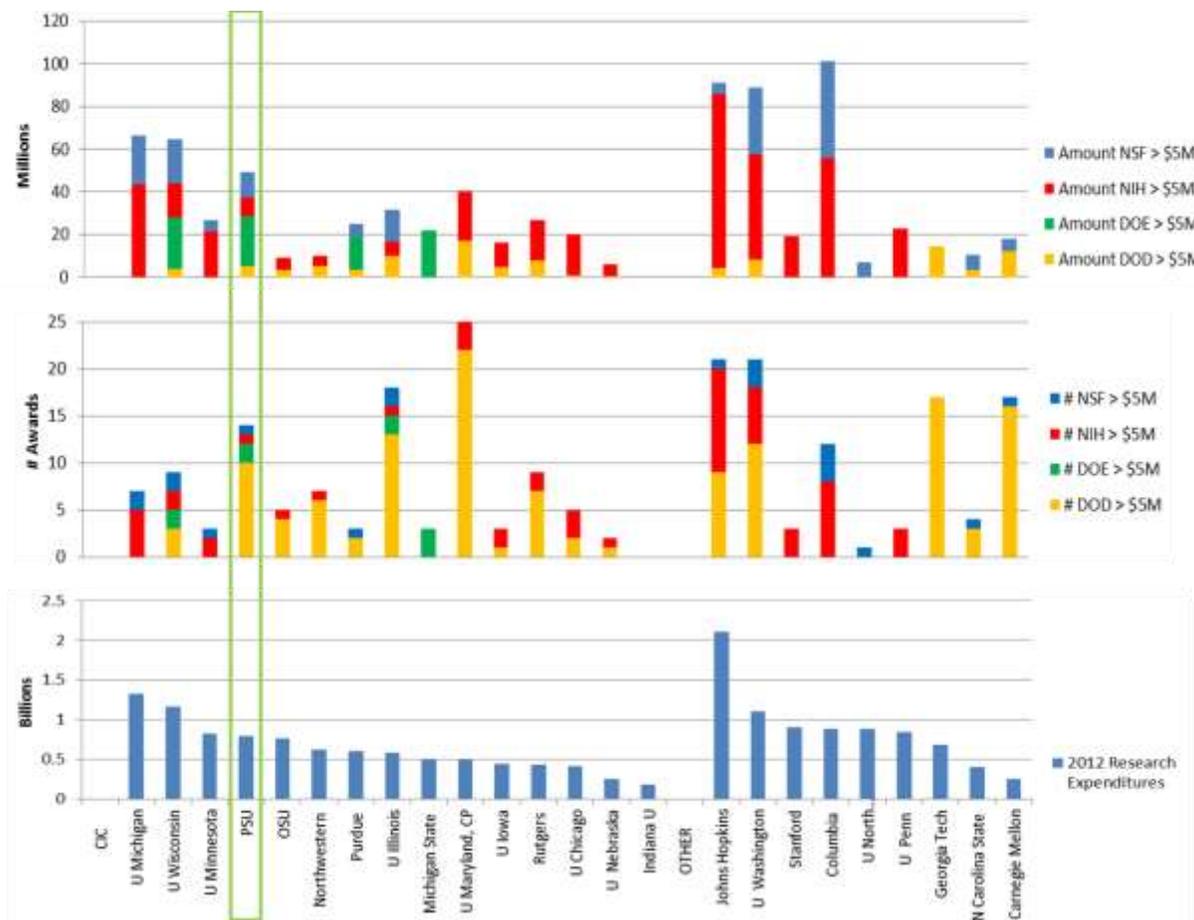


Figure 23: 2012 Research Expenditures & Major Agency Awards and Amounts at CIC and Top Rank US Institutions by 1) Total Expenditures (Bottom), 2) Total Number of Major Agency Awards over \$5M (Middle), and 3) Total Amount of Major Agency Awards over \$5M (Top).

Our research portfolio is indeed very resilient as it is currently made up of many smaller awards because the loss of a few awards would have limited impact. Imagine now our growth and gains in recognition if we could only improve the rates at which we win large awards! This is the future that we should seek to realize through an orderly development of SIRO. The risks of not doing so are simply too high – we cannot afford to fall further behind in securing large awards with the attendant risks of lost reputation and lower rankings.

3: Enhancing services, efficiencies and resources across OVPR units

Office of Sponsored Programs (OSP)

The Office of Sponsored Programs (OSP) will play a key role in the over-arching OVPR goal of streamlining research administration, including work with for-profit sponsors (Goal 6, Objective 4). A permanent director of this unit was appointed at the beginning of 2015, and we are now solidly positioned to advance the goals for this unit. Presently, the OSP has identified the following ways of improving systems and procedures in the following key areas:

Proposal Preparation

One of the challenges associated with the pursuit of large awards is the difficulty of coordinating efforts across multiple colleges. This will be addressed through multiple initiatives. 1) OSP will work with The Administrative Committee on Research (ACOR) to identify best practices across colleges in order to make sure resources are being shared (e.g., proposal checklists, deliverable tracking systems, etc.). 2) Better mechanisms will be developed for allocating cost-sharing responsibilities among multiple colleges. 3) OSP will work with the Office of Research Information Systems (ORIS) to create searchable databases of award information and abstracts, making it easier for researchers working in disparate colleges and departments to identify areas of common interest. OSP also plans to work with ORIS to develop budget-building tools that will allow faculty members to generate their own budgets

Award Negotiation

OSP devotes the majority of its effort to reviewing and negotiating grants, contracts, and non-financial agreements. OSP's twin imperatives are 1) to identify any significant problems in sponsored research agreements, and 2) to resolve those problems as quickly as possible so research can move forward. Training and streamlining efforts are complicated by the fact that Penn State maintains funding from approximately 1,200 sponsors at any given time. This portfolio is actually much more diverse than many of our peers. (For example, only 25% of Penn State's awards are from NSF or DHHS, whereas the University of Michigan receives over 60% of its support from those two sponsors.) A training plan has been developed by OSP for keeping up with this complex responsibility.

Award Administration

OSP plays a limited role in supporting award administration, since most post-award functions are managed by the Controller's office and the college Financial Officers. However, OSP continues to play a role in disseminating award information, issuing and closing out subawards, and educating the research administration community and will be active in sharing information and developing procedures for more seamlessly bridging the pre-award to post-award transition.

Communication and Faculty Education

OSP's most significant accomplishment in communicating with the faculty is the development of the MyResearch Portal. This system provides faculty with comprehensive, web-based access to all of their proposals, awards, expenditures, non-financial agreements, subawards, and protocols. Plans for the next several years include integrating this information so investigators can review their information by project. A second area of need is in facilitating effort monitoring. OSP is not responsible for Penn State's effort certification system; however, OSP will contribute to efforts to ensure that faculty members understand and correctly report on effort certifications. OSP also can contribute to faculty training programs associated with property management, subrecipient monitoring, and cost-sharing. These are areas of significant audit.

Office of Research Protections (ORP)

The mission of the Office of Research Protections (ORP) is to: 1) Promote and maintain compliance, 2) Reduce regulatory burden for researchers, 3) Provide leadership; 4) Protect research data; and 5) Enhance partnership. The ORP supports and provides oversight in eight areas of research compliance. These areas are identified below along with the most broadly-impacting goals for the next planning period.

Conflict of Interest (COI)

1. Successfully complete a one year cycle with institutional COI in order understand volume, complexity, etc.
2. Improve faculty orientation/training for committee membership; stress importance of regular attendance; discuss time release with members in order to encourage membership and attendance.
3. Integrate CATS and COINS functionality through ancillary review, ePIAF and possibly other ways.
4. Provide ongoing training and professional development to staff
5. Implement electronic disclosure form for the institution that is integrated with individual disclosure form on COINS.

Research Misconduct

1. Increase education and outreach efforts on new policy and research misconduct in general.
2. Establish a relationship with Media relations/Public information to manage time-sensitive news.
3. Develop templates and SOPs for new policy that meets federal regulatory requirements.
4. Develop checklists to ensure that all required steps and processes are used for each case.
5. Implement use of box.com for research misconduct document and data handling.

Centralized Application Tracking System (CATS)

1. Reassess staffing organization, competency requirements and needs.
2. Integrate CATS with other current research administrative systems (e.g., myResearch portal, SIMS)
3. Include COINS, IACUC eSub and other future research administrative systems under the same project team so that all projects are handled consistently and efficiently.

Human Participants

1. Fully implement the HRPP Toolkit policies and procedures.
2. Fully implement the use of CATS-IRB
3. Increase visibility of the IRB program.
4. Continue to reduce the amount of protocol review time used with the IRB or IRB staff.

Responsible Conduct of Research (RCR) Education Program

1. Establish a partnership with the director of University ethics and compliance to assist with establishment of ethics training, education, and certification opportunities that complement and are supported by existing University programs.
2. Work with graduate programs to ensure their students are receiving the SARI@PSU training specified by their program's plan.
3. Continue working with ORIS to ensure the SARI@PSU faculty portal continues to function as designed.
4. Work with Penn State's Survey Research Center, assess the climate of integrity among the graduate student population who participate in SARI@PSU and compare with previous climate studies.
5. Identify and secure additional facilities to host our workshops and presentations.
6. Explore additional/alternative themes for our workshops and presentations such as RCR themes targeted to specific audiences, and topics to address current issues important at Penn State and nationally, such as Data Management and Protection.

Quality Management (QM) Program

1. Work to align Standard Operating Procedures with the College of Medicine's Research Quality Assurance Program.
2. Secure approval of a Research Quality Policy.
3. Orient and train the new Quality Management Compliance Coordinator for interactions with the IRB Program, other programs, and investigators with attention to FDA-related regulations and Good Clinical Practice
4. Develop a more robust tracking system for programmatic changes implemented as a result of the annual Customer Service Survey feedback
5. Develop a smooth and clear process for investigators and compliance personnel to identify and establish contact with the QM Program and to use it regularly as a resource for FDA-related and other human participant research.
6. Develop post-approval review activities within the Animal Care and Use Program.

Science Diving Program

1. Develop a RA policy and a culture of concern within the PSU diving community
2. Consider alternative training pathways especially for new graduate students
3. Incorporate scientific diving into general education
4. Become a leading mid-size program at AAUS

Animals, Biosafety, and Isotopes (ABI)

Huron Consulting is in the process of evaluating the animal care and use program and goals for these programs will be determined following receipt of their recommendations.

Office of Resource Information Systems (ORIS)

ORIS provides three main services to the Vice President for Research and the research enterprise: 1) system and network support to the Vice President for Research and support office; 2) non-financial research compliance and administration systems; 3) leadership within the Information Technology (IT) and enterprise systems communities at Penn State. ORIS has strategic objectives in all three areas.

1) ORIS will complete adoption of virtual server technologies to leverage central Information Technology Services (ITS) investment in hardware, software, and facilities and completely eliminate the need for local servers and server rooms. In addition, ORIS will be an early adopter of ITS's virtual desktop platform, providing common desktop services to all its customers, regardless of device or location. Virtual desktops will enable ORIS's customers to re-think the office environment by enabling robust telecommuting. Both virtual server and desktop technologies are important sustainability initiatives. These two initiatives will also enable ORIS to re-focus its support resources from administering local services to enabling customers to embrace new devices and IT services and to transform their service delivery models.

2) ORIS will continue to enable the transformation of its customers' business processes, specifically in non-financial research compliance and research administration through system improvements to SIMSreports, SIMSbudgets, IAF, CATS, and PRAMS and through new systems or modules. ORIS will enable research administration units (not just in VPR) to provide better data and new functions through the myResearch Portal. ORIS will facilitate improved analysis and decision-making related to research administration at both departmental and college levels through a SIMSreports overhaul. ORIS will replace aging technology and continue to investigate commercial alternatives to home-grown systems. ORIS will improve its customers' capability to deliver information to their customers through an improved web presence.

3) ORIS will continue to provide leadership within the IT community to ensure that research interests are addressed in enterprise IT planning and governance. ORIS will actively participate in enterprise system planning and governance, specifically in the HR and Financial system

replacement projects. ORIS will work with OSP, ORP, ITS Security and Privacy offices to develop policies and guidance on the protection of sensitive research data.

Animal Resource Program (ARP)

The Animal Resource Program (ARP) looks forward to continued growth in support and development of biomedical and interdisciplinary research by **meeting the need for healthy animals for research and education at the lowest practical cost**; and, in partnership with Penn State Colleges and Institutes, promoting a dynamic animal research environment. The ARP has established four goals to advance this mission.

ARP Goal 1: Assure adequate facilities and equipment to support all animal use activities.

Several Penn State animal facilities (Henning, Research D, and Noll) are aging and will need major renovation and maintenance over the next 5-10 years to meet required standards. Unfortunately these small facilities do not allow for future expansion of animal research programs. Given the cost associated with major renovations and maintenance, it may be more cost effective to build a large new animal facility and close some of the smaller aging facilities. The small older animal facilities could be converted to valuable classroom or research space, while a larger new animal facility could be sized to allow for program growth and would be more cost effective to operate. On the West/Central Campus, several new animal researchers have come from engineering, physics, ARL and kinesiology, yet there are no animal facilities on the west side of campus to support them. A moderately sized 8,000 -12,000 GSF animal facility should be planned for the next major research building on West/Central Campus.

ARP Goal 2: Provide low cost animal resources by maintaining operational and program efficiency, infrastructure support, and information transfer and responsiveness.

The primary goal is to maximize the efficiency of operation and minimize the need for increased staffing and other resources. A further goal is to assist investigators in working more effectively by making information and services readily available. To stimulate and enhance life science research at Penn State, it will be important to subsidize animal research costs to minimize future per diem increases in support of competitive grant budgets. It is also critical to maintain per diems within reasonable ranges for recruitment and retention of top quality animal researchers.

ARP Goal 3: Maintain AAALAC accreditation and compliance with all applicable regulations.

MISSION

The mission of the ARP is to provide Penn State with high quality animal care services and facilities to improve animal research and ensure the health, well-being and humane treatment of animals used in research and teaching at the University.

Recent accreditation of the animal care program by the Association for the Assessment and Accreditation of Laboratory Animal Care (AAALAC) was a major accomplishment. Maintaining the program and its facilities, especially the farm facilities and other related programs such as occupational health and safety in a manner consistent with these standards will be an ongoing challenge. As AAALAC accreditation is an important benchmark indicating the quality of our animal care program, administrative support and cooperation from units across campus will be essential in maintaining it.

ARP Goal 4: Refine veterinary care and enhance veterinary education.

ARP veterinarians are currently exploring opportunities to provide increased veterinary services, particularly for large animal veterinary care. Clinical veterinary care for farm animals is currently handled at the departmental level; in the case of the Department of Dairy and Animal Science it is contracted out to a local practice. Dr. Jake Werner of the ARP currently handles oversight of large animal veterinary care but does not manage the contracts. Due to increasing costs and awareness for tighter biosecurity (clinical veterinarians who travel from farm to farm constitute a risk to our herds and flocks), the need for better follow-up care, and the need for more training for large animal investigators, the feasibility of managing all veterinary care internally should be considered. Basing veterinary care for all PSU animals out of the ARP rather than individual departments would provide consistent veterinary care and oversight. It would also potentially serve as an opportunity to further veterinary medical education by supplying veterinary medical student or internship opportunities.

The ARP is also partnering with the Veterinary and Biomedical Sciences Department to explore submitting a proposal to establish a Veterinary Research and Technology master's degree program. This program would produce highly trained veterinary technicians for work in research arenas. The ARP would benefit by gaining access to additional diagnostic equipment as well as serving as a resource for this program.

4: Leveraging the Philadelphia Navy Yard for increased partnerships

The historic Philadelphia Navy Yard is a 1,200-acre centrally located waterfront business campus committed to smart energy innovation and sustainability. The Navy Yard location provides access to the city's workforce of more than 3 million people and over 100 colleges and universities. In addition, Philadelphia is at the heart of the bustling Northeast corridor, midway between New York City and Washington, D.C. This accessible location is minutes from I-95, I-76, the PA and NJ Turnpikes, and links easily to outlying destinations via Amtrak's 30th Street Station and a world-class international airport, providing extensive connectivity to business industry and research institutions along the mid-Atlantic region of the US east coast (See Figure 24).



Figure 24: Penn State buildings at the Navy Yard.

The Navy Yard is home to more than 11,000 employees and 143 companies in the office, industrial/manufacturing, and research and development sectors, occupying 6.5 million square feet of real estate in a mix of historic buildings and new high-performance and LEED® certified construction. Industrial partners in this space include Urban Outfitters, Glaxo SmithKline, Aker Philadelphia, Revzilla, and Ben Franklin Technology Partners. Amenities include five parks, seven dining options, a hotel, on-site intramural sports and fitness, charity and cultural activities, with much more under development.

After the naval shipyard closed in 1992, Penn State became highly engaged in redevelopment efforts. The site continued to host joint research by ARL and the Naval Ship Systems Engineering Station (NAVSESS). Since 2006, the OVPR and COE have jointly pursued extending opportunities at this campus to provide a platform for engagement in the Philadelphia region. This resource has leveraged over \$130M in external funding from the PA Keystone Innovation Zone, PA Distributed Power Management Project, and multiple Department of Energy initiatives relating to clean energy and building energy innovation. Penn State occupies four buildings on the Navy Yard campus with renovations of Building 661 (37,000 square feet and 4,000 square feet of shell

space available) and new Building 7R (25,000 square feet) under way. Building 7R was completed in Fall 2014 to house The Building Energy Education and Innovation Center and offer a 170-seat auditorium, three to four breakout rooms, four to six classrooms and laboratory space.

In addition to providing research resources, engaged scholarship opportunities for students are available through industry leaders and related-research units studying urban redevelopment and metropolitan sustainability issues including transportation, business, energy, health, welfare, housing, education, crime and justice.

5: Increasing Penn State's Pittsburgh presence through partnerships with the University of Pittsburgh and Carnegie Mellon University

The University understands that the Commonwealth's urban centers play a vital role in the health of the state and that it has an obligation to them. These urban areas can also serve to help in the education of students as well as the engagement of the public in the delivery of its mission. In addition to the connectivity provided to Philadelphia via the Navy Yard (above), networking with the Pittsburgh region enables University researchers to have access to a second regional urban center of business and industry. The OVPR has initiated talks with leading research institutions in the Pittsburgh area, e.g., Carnegie Mellon University and the University of Pittsburgh, to develop collaborative efforts toward technology transfer and economic development around specific areas of research for meeting the needs of urban communities. A prominent initiative for this group will be the *Consortium for the Built Environment*.

Two important University resources for networking with the research infrastructure in the Pittsburgh area: the *National Energy Technology Laboratory (NETL)* and the *Penn State Center Pittsburgh*.

Penn State Center Pittsburgh (PSCP)

Penn State currently has a strong presence in the Pittsburgh and Allegheny County urban core with The *Penn State Center Pittsburgh (PSCP)* through collaboration among Penn State's Outreach and Online Education Office, Extension Office, and the College of Agricultural Sciences. PSCP places significant emphasis on the engagement of Pittsburgh community organizations, non-profits, public officials, local universities, and area corporations.

This internal collaboration, and its focus on Pittsburgh's metro center, is unique among land grant universities and is nationally recognized as an innovation in the movement of state Extension offices to embed in metropolitan regions.

In its current formation, PSCP offers Pittsburgh-based programming and technical assistance in:

Architecture	Landscape Architecture
Community & Economic Development	Storm Water Mitigation
Energy	The Arts
Food Security and Entrepreneurship	Urban Agriculture/Food Production
Green Space and Community Design	Urban Forestry
Health and Nutrition	Vacant Lot Rejuvenation
K-12 STEM	Youth Development

PLAN IMPLEMENTATION

The first draft of the OVPR plan was circulated widely among members of the University Research Council and University leadership between August 2014 and February 2015. Edits were completed to address weaknesses noted in the October 2014 review by the Office of the Planning and Institutional Assessment (OPIA). A roadmap for implementation has now been created to include an OVPR leader who will champion each objective by monitoring progress toward our goals. These individuals will monitor progress using defined metrics and milestones using a planning chart provided as an Appendix to this document. Progress will be documented and assessed each six months during the five-year cycle and discussed in biannual collaborative planning meetings that will include OVPR leaders.