Report to the Provost from the "Reimagine Systems Science at PSU" Working Group

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Introduction

In this Reimagine initiative, a faculty working group has outlined several ways that the Systems Science program could enhance PSU's responsiveness to student needs and its relevance to our increasingly complex world. Specifically, the aim of this project is to increase access to interdisciplinary education, and thus enable students to gain competencies needed for impactful careers, and to promote interdisciplinary research on challenging societal problems.

The working group first considered how best to create an Extended Systems Science Faculty, but the group soon realized that its critical task was to envision an efficient way to organize a thriving hub for complex systems teaching and research at PSU. Key questions were where to locate/host the unit and what type of unit it should be. The group came up with three ways that such a systems/complexity unit could be created. The different opportunities afforded by these alternatives are presented in this project report.

The working group included nine non-SySc faculty members, three from CLAS, three from SPH, two from MCECS and one from SW; it was supported in its efforts by the two SySc core faculty members and the interim associate dean for research and graduate programs in CLAS.

The group unanimously agreed that Systems Science is a critical and distinguishing program at PSU that needs to be supported and elevated – all the options described below attempt to do that. A viable systems science/complex systems program requires at the very least two tenure line faculty members, so all the ideas considered by the working group assumed that current faculty members will be replaced when they retire. The team notes that the two current SySc faculty have been trying to accomplish this transition for the past five years. These retirements and replacements cannot continue to be postponed.

Early options considered but rejected were moving SySc into another department in CLAS or to OAA alongside UNST and the Honors College. The group arrived at three reimagined futures for Systems Science: two relatively straightforward options, and a third option that is bolder with potentially higher returns:

1. Move SySc to MCECS with its two TT lines and budget, and merge it with the ETM department
2. Move SySc to SPH with its two TT lines and budget, as the anchor for a new institute (or equivalent) focused on systems thinking and complexity in public health.
3. Use SySc as the foundation for an interdisciplinary entity jointly sponsored by CLAS, SPH, and MCECS featuring complex systems, data fluency, and systems thinking, emphasizing areas such as STEM education, environmental & social sustainability, health & biomedicine, energy, climate.

Option 1 would strengthen ETM department and thus MCECS. Option 2 would enhance SPH. Both of these options would preserve but inevitably also narrow somewhat the current scope of Systems Science research and teaching, Option 1 emphasizing technology, Option 2 emphasizing health. Both of these options are expected to be revenue positive and to require transferring the current SySc budget to the receiving school. Considerable additional detail for Option 1 is provided in Appendix-2.

Option 3 is the most ambitious of the three options presented here and would likely require some investment. It is, however, the option that would most benefit PSU as a whole. PSU's competitive environment dictates the need for an institutional strategy that mobilizes PSU's distinctive assets to attract students and gain research funding. Flexibility is also needed to be able to adapt to a rapidly changing environment. Systems Science is a distinctive PSU asset that can help meet these needs. Option 3 would sustain the synergies that already exist between Systems Science and the three colleges and take advantage of the flexibility inherent in a unit whose foundation is the science of complex systems.

In Options 2 and 3, the two core positions in Systems Science would be augmented with an Extended Faculty of colleagues interested in systems science/complex systems; in Option 1, an Extended Faculty would be desirable but not essential.

If one or more of these options is sufficiently promising to articulate further, the next step would be a memorandum of understanding stating that after further discussions involving the PSU administration, the relevant dean(s), the Systems Science core faculty, and other interested faculty, one of these options will be adopted, and the process of implementing that option will commence as soon as possible, beginning with searches to replace retiring Systems Science faculty.

If none of the Reimagine options for SySc are strong enough to warrant adoption, the next step would be a phase-out plan for SySc that is linked to retirements of its faculty members. This plan would support current students in completing their programs and follow the prescribed shared governance procedures for program elimination. Such phase-out would likely require three years and flexibility regarding faculty FTE prior to full retirement.

The Systems Science core faculty has devoted an enormous amount of time and energy over the past five years trying to accomplish a successful transition to a future program with new hires coupled to retirements. This Reimagine effort has been extraordinarily productive and creative in coming up with three good options for moving forward. The decision about the program must not be postponed any further. Options 1-3 have a short shelf life, and will disappear if not acted upon promptly.

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Option 1: Merge SySc with the ETM Dept in MCECS

Merge the System Science Program with the Department of Engineering and Technology Management in MCECS to create an internationally distinguished department for the research and practice of managing complexity in technology-driven organizations and for educating future leaders in business, academia, governments, and nonprofits. The merged unit will be named to reflect its dual character.

As part of the merger, we will modify existing MS and PhD programs to leverage synergies and emphasize the most compelling aspects of both contributing partners: from SySc, the focus on understanding socio-technical and social-ecological systems through the lens of complexity research and the strength in data science and computational methods; from ETM, the focus on managerial foresight, leadership, and career growth, and the strength in interdisciplinary research on emerging technologies. The updated programs will enable faculty and students to tackle problems of great societal importance that are shaped by intersecting technological and societal trends and for which technology provides challenges and solutions. They include energy transformation, transportation, public health, and the future of work in the context of the ongoing digital transformation of business and government.

The merging units are interdisciplinary, have shared roots, and have collaborated on research so that there is a good cultural fit. Moreover, both departments are known for innovative education, including flexible admission, part-time degree models, work-compatible teaching schedules (including online and attend-anywhere), and stacked degrees (certificate, masters, PhD). Building on these foundations, we expect the combined unit to continue to enroll and serve students who are similar to our current students so that we can preserve successful programs. Importantly, the updated program will be nationally and internationally competitive, and able to generate enrollment growth well beyond current levels.

The new unit and its programs are expected to be cost neutral and revenue positive: cost of new hires is offset by savings when senior faculty retire, instructor costs are constant, while revenue increases due to larger class sizes in the combined program. The move into ETM office space would free up Harder House.

A precondition of the proposed merger is the ability to hire world-class junior faculty into the two tenure-track positions that will open up through retirements in System Science. The new faculty will contribute to the interdisciplinary research already occurring in both programs and expand existing collaborations with computer science, transportation, the Digital Cities Testbed Center, School of Urban and Public Affairs, School of Public Health, and community partners (industry, local government, health care). This will broaden the new unit's research base and scale it into a powerful hub for research collaborations across PSU that take advantage of emerging funding opportunities for translational, interdisciplinary research at the intersection of technology and complex systems. Importantly, the larger size of the combined faculty and its focus on synergistic programs frees up capacity to undertake innovations that ETM and SySc have planned and proposed, but never realized, due to a lack of faculty resources. They are:

A. A flexible, *remote PhD program for working professionals* that is similar in spirit to a doctorate of practice but more research-focused and positioned at the intersection of technology and systems. This program would build on the decades-long experience in both units with part-time employer-sponsored PhD students and highly interdisciplinary PhD committees. It can be achieved with modest modifications of the existing PhD programs. It would create strong connections to outside partners and ensure that research tackles emerging domains of societal relevance.

B. The creation of an innovative, nationally differentiated engineering undergraduate program (BS) focused on *engineering systems for the good of society* and tackling the implications of technology for sustainability, equity, and inclusion. The program is expected to appeal also to diverse students who are currently not attracted to engineering/computer science because they perceive as too narrow and "nerdy", as well as students who fail to complete traditional programs. It has a strong career focus and systematically fosters relationships with public employers (city, state, federal agencies). These employers tackle many technology issues of societal relevance but purchase, rather than develop the technology they use (e.g. computing, transportation infrastructure, water systems). They are committed to hiring a diverse workforce and often prefer technology generalists over deep disciplinary specializations because their employees work with vendors to integrate many different technologies to create working systems, are tasked with data analytics to manage these systems, and work with users and citizens, which requires a deep understanding of direct and indirect impacts of technology on goals such as economic prosperity, service levels, and equity and inclusion. Because public employers compete with high-paying tech companies, they are interested in early access to talent, provided by the program. They also need programs to update the skills of their existing workforce, which provides additional opportunities.

C. The creation of a BS in Complex Systems that builds on the existing Systems Minor and draws heavily on existing UG curriculum in SYSC, ETM, UNST, ECE, CS, MTH & STAT, GEOG, BIO, ESM, SB, SPH, SB and CUPA. Initial discussions with the CLAS dean's office have been encouraging. New courses would include systems ideas and complex systems modeling & data analysis, leveraging SFI's Complexity Explorer curriculum. Specialty areas could include systems thinking, data analysis, computer modeling, and systems intervention. Such a new major would appeal to a broad spectrum of students seeking a more general inter/trans-disciplinary education leading to employment as the "go to" problem solvers who are well prepared to sort out complex situations. Employers are eager to hire people with these skills, compensate them well, and provide highly rewarding career paths.

Additional analysis of Option 1 includes a side-by-side comparison of the two units which shows a high degree of compatibility: both are highly flexible, attract a broad fraction of mid-career learners and part time students, offer a stackable curriculum with certificates and MS and PhD degrees, generate many graduates for their small size, and encourage students to take full advantage the curriculum across PSU. Details are provided in Appendix-2.2.

A detailed SWOT (strength-weaknesses-opportunities-threats) is shown in Appendix-2.3, which underscores the compatibility of the units in terms of relevance to PSU's mission, focus on accessible STEM methods, proven research productivity, and leadership. However, both units are small with an aging faculty structure, and have limited undergraduate presence. Opportunities include enrollment growth, contributing to PSU's need for differentiation, new programs to meet needs of future students, and increased research funding.

Appendix-2.1 provides the dashboard view of ETM, which can be compared with Appendix-1.1 which provides this for SySc; these show the steady contributions of these units and their ability to manage well their limited resources. Appendix-2.4 provides a list of the recent ETM dissertations which can be compared with Appendix-1.2 which provides this for SySc; these lists show the high interdisciplinarity of both units. Overall, these appendices illustrate the synergy that exists in the curriculum and research of the two units, which provides a strong basis for future expansion.

Option 2: Integrate Systems Science with the OHSU-PSU SPH

We envision the transformation of the current system science program into an institute (or institute-like structure) housed within the OHSU-PSU School of Public Health (SPH). The new System Science institute would be generally based on a similar approach to the PSU Institute for Aging (IOA) which has both an educational mission and programs and a vital research component. While "merging" with an SPH 'faculty unit' (e.g., Biostatistics; caveat: the SPH does not have a departmental structure for faculty) may provide a short-term or developmental role, an institute would provide greater opportunities for development and relative independence and breadth of the System Science program. Consistent with the IOA model, a combined teaching and research portfolio would take maximal advantage of growth opportunities in both domains that could support infrastructural needs (e.g. admin support, additional faculty), and new teaching, learning and research opportunities for existing System Science students and faculty, as well as students and faculty throughout the SPH, PSU and OHSU.

The Systems Science Program at PSU represents a well-developed asset that has substantial professional and historical value. This asset should not be squandered thoughtlessly and would be a tremendous asset to the SPH. This program was among the "first in the market" for these ideas (1970) and therefore has the legitimacy of foresight. Systems thinking and methods of systems analysis are now required (2016) for accreditation of Schools of Public Health (and are quickly developing topics in medical professional training) providing natural opportunities for expanded and re-imagined systems science coursework. Similarly, demands for and interest in systems science thinking and methods applications in public health, health systems, and general medical research have increased significantly including interdisciplinary topics such as social justice, equity and anti-racism, developmental origins of health and disease, social determinants of health, climate and environmental change, and systems and policy simulation. A strong systems science program – one with established degree-conferring and research *bona fides* – would distinguish the OHSU PSU SPH nationally and internationally, while enhancing the reputations of PSU and OHSU as well. Likewise, the Systems Science program would benefit tremendously from this new home.

The idea of bringing the Systems Science program into the SPH as an independent teaching and research entity has been well received by the SPH Dean and Associate Dean (both of whom were involved in and supportive of prior negotiations to integrate Sys Sci into the SPH). A brief survey of faculty interest indicated strong support across the sub-disciplinary areas of the SPH including both research and teaching.

We see the integration of the System Science program with the SPH as an opportunity to expand its general curricular and research presence by leveraging the growth opportunities at the intersection of public health and system science. Significant opportunities exist for expanding the student audience of existing or developed Systems Science coursework and degrees by integrating the Systems Science identity and access into the SPH's community of more than 100 graduate students (and thousands of undergraduates). Similarly, significant opportunities exist to develop public health and related coursework that is system science focused. The SPH's accrediting body, the Council on Education in Public Health (CEPH), has incorporated a foundational competency in systems thinking that will require more development and integration of systems science-based coursework throughout the doctoral, master and undergraduate curriculum. This systems science focus is also now appearing in medical education (e.g. physician, nursing) opening additional avenues for curricular expansion through OHSU.

This type of cross-fertilization has already been evident at the doctoral level where SPH doctoral students have increasingly taken Systems Science courses while at the same time several System's doctoral students

have focused in public health, taking SPH courses and pursuing dissertations with a public health focus. There is untapped potential at the master and undergraduate level that could be realized through integration of new and existing degree programs. This could include joint Systems Science/Public Health master degrees, or Systems Science or Public Health master degrees with the alternative specialization. This opportunity exists at the undergraduate level where the existing BA in Health Sciences could develop a systems science concentration and/or system science minor/majors (if developed) might incorporate public health courses as optional focal application areas.

Similarly, there are significant untapped opportunities to expand systems science-based research both bringing Systems Science expertise and perspectives into public health research, and bringing public health expertise and perspectives into Systems Science research. Dr. Wakeland's successful NIH grant work, with Drs. McCarty and Wallace of the SPH, modeling prescription opioid diversion and policy options to reduce it is a key example. Complex systems generally, climate/environment, and justice-oriented areas such as anti-racism and population health equity are all areas that offer significant opportunities for either public health focused research or generalized systems science research with public health implications. An example of Systems Science research in these areas is the PhD work of Amanuel Zimam Melekin, a student of Dr. Zwick, who used systems data analytical techniques to study disparities in health outcomes by race and ethnicity, and who now is working at the CDC. Potential connections with medical research (e.g. genomics, bio-informatics) are also evident. In addition, these are potential areas that can attract or be outlets for potential philanthropic funding. The SPH, for example, has been successful raising money to support anti-racism efforts, one area (e.g. institutionalized and systemic racism) where system science approaches could elevate existing research approaches.

The envisioned systems science institute would continue to provide a focal unit for dedicated and existing affiliated faculty, while providing a "home" for the variety of SPH faculty - several trained in systems science or related fields – who have expressed interest in collaborating with a systems science unit to help support its new mission. An institute with a focal systems science mission and a broad portfolio would continue to attract multi-disciplinary faculty and students from across PSU, while adding in OHSU in addition. This would include potential opportunities to hire dedicated system science faculty through traditional PSU TT or NTTF lines as well as more research focused OHSU positions.

Overall, there is a tremendous opportunity to "reimagine" system science in a way that supports and enhances PSU – and OHSU - priorities and reputation, while maintaining the system science programs broad focus through alignment and support in the specific area of public health. The alignment of system science thinking and methods with areas addressing critical social issues and needs, and with educational, research and philanthropic goals that are particularly evident in the public health and medical fields, is central to its attraction to students and faculty and to its clear potential as area of significant growth.

Implementation

This vision will require a dedicated core of tenure track lines, leadership, mentoring and P&T processes. Specifically, the existing funding for the systems science program would have to be transferred to the SPH. This was the sticking point in previous SPH merger discussions. The existing systems science faculty could "float" within the non-departmental SPH structure initially. We envision the subsequent hiring of a senior system science faculty member who would be the "founding" institute director and at least one additional dedicated TT junior faculty. The senior hire would require vision to take the reins of the Systems Science degree programs and develop the SPH institute. The long term should aim at two more System Science tenure track lines to ensure the robustness of dedicated faculty.

Additional "core" faculty could be supported through research roles (e.g. OHSU research faculty), or through additional teaching/program development in combination with research (e.g. PSU tenure track) given successful expansion of the institute's portfolio. These new faculty would be also be tasked with integrating existing System Science program activities into the new institute while identifying and supporting affiliated faculty interested in System Science teaching and research. PSU faculty could take a sabbatical to teach within the Systems Science institute, with Systems Science picking up the additional 25% of the faculty's salary.

A variety of fiscal aspects would need to be worked out. Growth in SCH, research or philanthropic revenues would need to be rewarded with additional core faculty lines. Some initial incremental investments may be required to launch the project. Administrative support for system science has been generally limited or non-existent, largely due to its small scale. While one aspect of this vision is that a combination of research and SCH growth could provide this, such supports are likely needed in the interim.

Challenges

There are several challenges that would need to be considered in moving the Systems Science program within the OHSU-PSU SPH.

- While an institute structure should allow the new System Science program leeway to pursue a diverse portfolio of activities, its placement in SPH would require greater alignment with and to public health related teaching and research to justify its placement there. This would likely require the initial new faculty hires to have interest and alignment with public health related areas.
- As a CEPH accredited school, Systems Science programs (e.g. PhD), or at least some part of them, would likely have to find a way to align with CEPH accreditation standards – again pulling the new program "towards" a public health focus.
- As a joint university program (but with OHSU as the lead), development of the Systems Science "Institute" would need to negotiate OHSU based policies related to research, educational and organizational structure.

Option 3: CoSys, a transformative complex systems unit

Systems Science can be a formative component of a transdisciplinary academic unit hosted by CLAS with strong linkages to SPH and MCECS. This transformative and futuristic program, with a working name of CoSys (short for Complex Systems) featuring core system scientists and their collaborators from both social and biophysical departments across the colleges, will focus on a wide range of pressing and complex grand challenges such as climate change and adaptation, environmental equity, social transformation, technological change, and public health. The program will provide a truly transdisciplinary environment in an institution of higher education to integrate domain knowledge, particularly in the areas with existing strength in PSU such as computation and data science, environmental research (especially climate and resilience), and social justice, and therefore enable PSU to better prepare our increasingly diverse students for a future rife with uncertainty and complexity.

Rationale:

1. PSU's student demography is changing towards higher diversity. For instance, more than 50% of 2021 incoming freshmen are non-white. Our students demand more transdisciplinary training to prepare for a future with deep uncertainty.
2. Under current budget and structural constraints, including SCH and P&T considerations, existing departments are not encouraged to foster a strongly interdisciplinary environment on campus. CoSys, as a transdisciplinary program, would be able to bridge departmental/disciplinary silos, help to reduce curriculum redundancy, allow transdisciplinary-minded faculty to freely collaborate in both teaching and research, and, most importantly, better prepare our students for an increasingly complex and chaotic future.
3. As an integral part of CoSys, the current SySc unit will use system science approaches and methods to help fuse diverse applied academic domains and strengthen the usage of complex systems science and methods in both graduate and undergraduate education within participating colleges, and eventually at the university level; thereby attracting more funding in support of complex systems research and education. CLAS includes a wide range of disciplinary academic units including both social and natural sciences as well as interdisciplinary programs such as Geography and ESM, providing an ideal academic home for CoSys. The current SySc unit has been a part of the School of the Environment (with Geography, ESM, and Geology) and loosely affiliated recently with Geography, which lays a solid foundation for SySc to play a significant role in reimagining a transdisciplinary program that could include these units and much more.

Phase One: The SySc unit would participate along with other units in CLAS in a curriculum redesign to support the transformative CoSys doctoral degree. Some classes in CoSys would be cross-listed from other departments whose curriculum either addresses complex systems or has a strong interdisciplinary component. CoSys classes would also be cross-listed with other departments, increasing the feasibility of interdisciplinary courses whose appeal is distributed across multiple units (e.g., SOE's EES doctoral program).

The futuristic CoSys program will need new talent, particularly those with formal training in transdisciplinary complex systems research and education. With potential funding from the Provost, a future cluster hire (in Phase Two) led by CoSys would help to address this need. In parallel, Geography and ESM have initiated a conversation to consolidate their own undergraduate degree programs into one

integrated interdisciplinary program. Existing SySc courses and new CoSys concepts and methods courses would be included in the curriculum for the consolidated undergraduate program, some as required, some as electives. And, likewise, the CoSys curriculum would draw on the consolidated interdisciplinary curriculum in GEOG and ESM. The consolidated and streamlined curriculum will help attract and retain a diverse and highly motivated student population, and prepare them for impactful and rewarding careers.

Given its scope and ambition, CoSys will need cohesive and dedicated leadership. Initially, there will be many challenges as CoSys earns its place with the PSU community. While it is possible that interim leadership could potentially bring CoSys to fruition, we strongly recommend that an early or mid-career complex systems educator be recruited during FY22 to replace one of the senior retiring SySc faculty members. Ideally, this new hire would be mentored during FY23 by the other retiring senior SySc faculty member to become a co-lead of CoSys. Extensive outreach to potential early partners in the CoSys endeavor will be essential and it should be augmented by outreach university-wide and beyond.

The current SySc MS degree and graduate certificate programs would be retained and improved. The Complex Systems PhD may incorporate or supplant the current SySc PhD, or the current degree will be retained as complementary to the CoSys degree.

The CoSys structure and curriculum will also be designed to strengthen trans/interdisciplinary research at PSU through a well-designed mentoring program for faculty and doctoral students. It seems likely that the mentoring program would also extend to post-doctoral students as an integral part of a healthy interdisciplinary research unit.

The CoSys mission will include fomenting and executing interdisciplinary research involving faculty from departments across the university. During FY23, an early to mid-career complex systems researcher would be recruited to lead the research aspects of the new unit. A novel idea could be for this new hire to be the other co-lead for the new unit to maximize its dual role in the college as an educational and research unit. The research arm of CoSys would secure federal funding for transdisciplinary projects, and also develop relationships with other research entities in the Pacific Northwest (Intel, BPA, PNNL, OSU, UO, WSU, UW, etc.). Early efforts would likely include developing a database of interdisciplinary researchers and projects at PSU

Phase Two The curriculum redesign process would culminate in FY23 with the definition of an exciting cluster hire proposal to be carried out in FY24 with active involvement of the recently hired education and research CoSys co-leads.

The new unit would also feature a well-designed and funded extended faculty model whereby current faculty members across PSU could join the unit in a tangible fashion. For example, an extended faculty member could be funded at .1 FTE by the new unit. This would allow for a course buyout to allow the extended faculty member to teach a course in the new unit, advise doctoral students, and/or prepare collaborative interdisciplinary grant proposals. Another intriguing idea could be an “internal sabbatical” program funded so as to allow a faculty member in another unit to be co-located for a year in the new unit, at full pay, doing teaching, research, and preparing proposals for externally funded collaborative interdisciplinary research.

If CoSys was funded to cover the .25 FTE salary loss during a sabbatical, it would be possible to gain a full FTE for a year at less than 25% of the cost. To take advantage of the synergies of faculty with diverse backgrounds, several such arrangements could be funded. The call for participation would be open to

faculty across PSU as well as externally. This idea resonates well with faculty members, several of whom indicated they would be very interested. Defining and initiating these creative and tangible extended faculty ideas will be a priority, if not in Phase One, then very early in Phase Two.

Internal funding or possibly external grant-related funding associated with CoSys could also potentially help to attract external (visiting/sabbatical) faculty to PSU and thereby enrich intellectual life at the university.

To encourage interdisciplinary/transdisciplinary research and teaching, effort may need to be focused on the development of an "accounting" system that recognizes the values of interdisciplinary/transdisciplinary research and teaching in the academic system (e.g., unit budget allocation, individual faculty P&T, etc.).

The curriculum and learning opportunities around system thinking and confronting complexity will strengthen the preparation of both undergraduate and graduate students to meet societal challenges and propel their careers in business, academia, and government.

Recruiting several new faculty members over the next few years and attracting a new generation of students to PSU will foster the university's diversity, equity and inclusion priorities. CoSys could foster the formation of diverse research teams including social scientists, statisticians, economists, and other interdisciplinary scientists (health, environmental, ecological, geographical, complex systems, computation, etc.)

Synergies

CoSys will collaborate not only with other disciplines, but also with interdisciplinary units already at the university. The possibilities are practically endless. For example, the new data science program in Math/Stats is about data. But the power of data lies, of course, in applying this knowledge to specific domains such as climate science. There are many climate scientists across PSU, in Geography, Geology, Physics, Engineering, Math, Chemistry, etc. CoSys would be in a tremendous position to unite faculty from across these different areas to pursue ambitious externally funded research.

Public health is interdisciplinary by its very nature. It draws on sociology, psychology, biology, medicine, transportation, economics, finance, logistics, data science, etc. It is extremely unlikely that faculty members in these units have time to track down and interact with all the specialties involved. Enter CoSys. This could perhaps be the greatest *gain* for the university.

Summary and recommendation

Three very promising reimagined futures for Systems Science at PSU have been provided with varying levels of detail. The first option is perhaps the simplest and easiest to implement: merge SySc with a compatible department: the ETM department in MCECS. Considerable detail is provided in the appendices to demonstrate the compatibility and the potential synergies.

The second option is to move Systems Science to the joint OHSU PSU School of Public Health (SPH) and create a complex systems institute with a combined educational and research mission. The school sees many potential benefits, with details regarding Implementation yet to be determined.

The third option is to create a transdisciplinary complex systems unit hosted by CLAS and designed in collaboration with and supported by MCECS and SPH. This is the most ambitious option with arguably the largest potential benefit to PSU. While the vision is exciting and tangible, implementation details are yet to be determined.

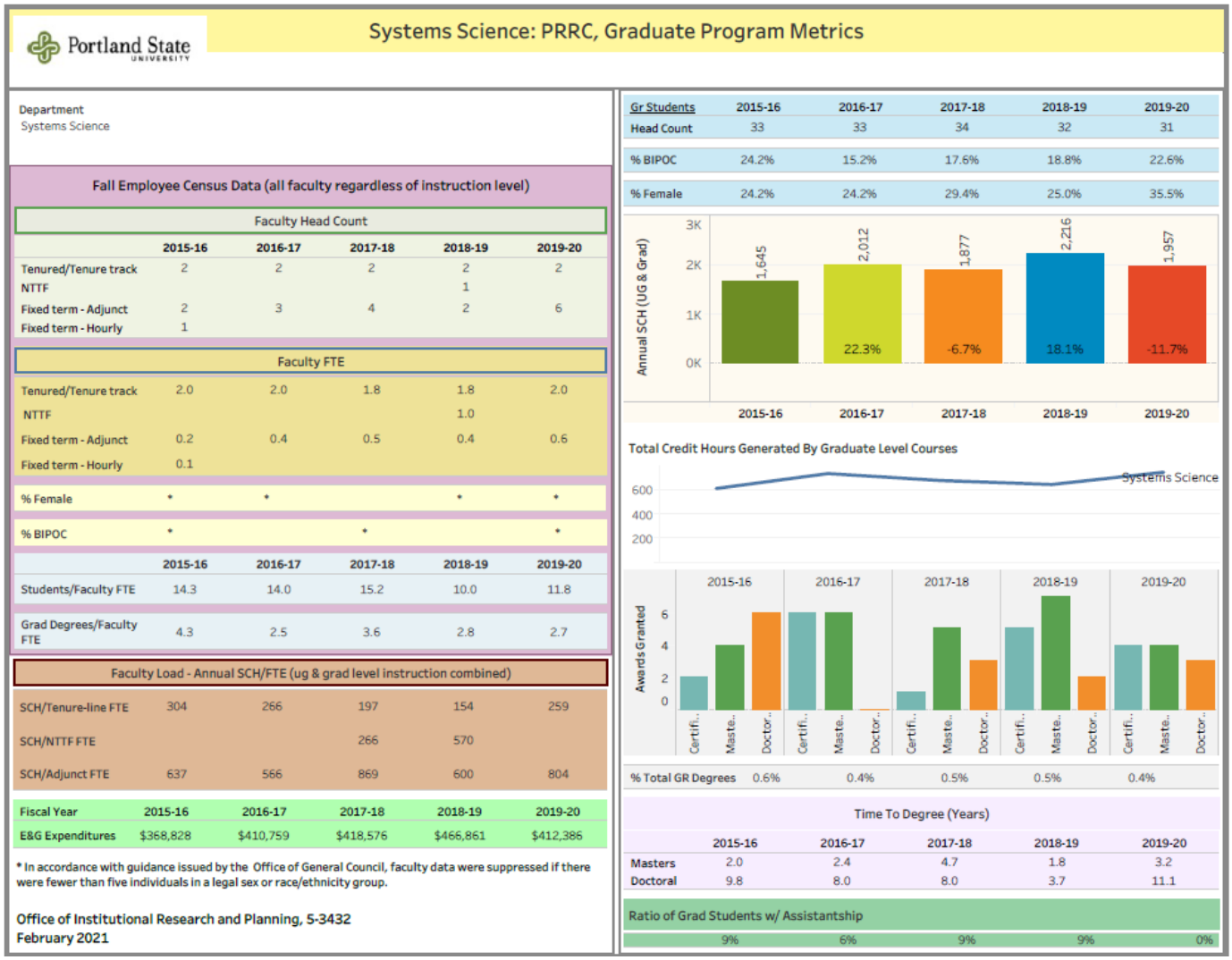
The first two options are expected to be roughly cost neutral initially, and revenue positive in the relatively near future. Option three is anticipated to require some investment by PSU over time, and an appreciable return on that investment would accrue over time. The first stage would be cost and revenue neutral, with the two senior SySc faculty members being replaced by a mid-career complex systems educator and a mid-career complex systems researcher. The investment would come in the second phase in the form of a cluster hire leading to significant growth in students and research funding.

The alternative to these options is the phasing out of Systems Science when its current senior faculty members retire. It is the consensus of the working group that such an outcome would be shortsighted and damaging to PSU. Instead, the working group unanimously and enthusiastically urges the implementation of one of the options outlined. This Reimagine initiative has presented PSU with a strategic opportunity that should be seized, and quickly since decisions on this matter have been postponed far too long. To reiterate the point made in the Introduction: these options have a short shelf life. To initiate the process of selecting the best option and planning its implementation, the concrete step needed now is a memorandum of understanding affirming that (a) the replacement of the two senior SySc faculty will be coordinated with their retirement and that (b) these two TT lines will transfer to MCECS if Option 1 is selected, to SPH if Option 2 is selected, or remain in CLAS if Option 3 is selected.

Appendices

Appendix-1 Some information on Systems Science

Appendix-1.1 Dashboard



Portland State UNIVERSITY

Systems Science: PRRC, Graduate Program Metrics

Department
Systems Science

Fall Employee Census Data (all faculty regardless of instruction level)

Faculty Head Count

	2015-16	2016-17	2017-18	2018-19	2019-20
Tenured/Tenure track	2	2	2	2	2
NTTF				1	
Fixed term - Adjunct	2	3	4	2	6
Fixed term - Hourly	1				

Faculty FTE

Tenured/Tenure track	2.0	2.0	1.8	1.8	2.0
NTTF				1.0	
Fixed term - Adjunct	0.2	0.4	0.5	0.4	0.6
Fixed term - Hourly	0.1				
% Female	*	*		*	*
% BIPOC	*		*		*

	2015-16	2016-17	2017-18	2018-19	2019-20
Students/Faculty FTE	14.3	14.0	15.2	10.0	11.8
Grad Degrees/Faculty FTE	4.3	2.5	3.6	2.8	2.7

Faculty Load - Annual SCH/FTE (ug & grad level instruction combined)

SCH/Tenure-line FTE	304	266	197	154	259
SCH/NTTF FTE			266	570	
SCH/Adjunct FTE	637	566	869	600	804

Fiscal Year	2015-16	2016-17	2017-18	2018-19	2019-20
E&G Expenditures	$368,828	$410,759	$418,576	$466,861	$412,386

* In accordance with guidance issued by the Office of General Council, faculty data were suppressed if there were fewer than five individuals in a legal sex or race/ethnicity group.

Office of Institutional Research and Planning, 5-3432
February 2021

Gr Students	2015-16	2016-17	2017-18	2018-19	2019-20
Head Count	33	33	34	32	31
% BIPOC	24.2%	15.2%	17.6%	18.8%	22.6%
% Female	24.2%	24.2%	29.4%	25.0%	35.5%

Total Credit Hours Generated By Graduate Level Courses

% Total GR Degrees	0.6%	0.4%	0.5%	0.5%	0.4%

Time To Degree (Years)

	2015-16	2016-17	2017-18	2018-19	2019-20
Masters	2.0	2.4	4.7	1.8	3.2
Doctoral	9.8	8.0	8.0	3.7	11.1

Ratio of Grad Students w/ Assistantship					
	9%	6%	9%	9%	0%

Appendix-1.2 SySc Dissertations and Theses from 2015 to 2021

This is background information for all three options. A comparable list for Option 1 is provided in Appendix-2.4.

PhD Dissertations 2021

Get Your Model Out There: Advancing Methods for Developing and Using Causal-Loop Diagrams (https://pdxscholar.library.pdx.edu/open_access_etds/6737), Erin Suzanne Kenzie

PhD Dissertations 2020

Systems Isomorphisms in Stochastic Dynamic Systems (http://pdxscholar.library.pdx.edu/open_access_etds/5410), Rajesh Venkatachalapathy

PhD Dissertations 2019

Fractals as Basis for Design and Critique (http://pdxscholar.library.pdx.edu/open_access_etds/5183), John Charles Driscoll

Closing the Loop: the Capacities and Constraints of Information and Communication Technologies for Development (ICT4D) (http://pdxscholar.library.pdx.edu/open_access_etds/5003), Phillip Nicholas Turman-Bryant

Statistical Analysis of Social Network Change (http://pdxscholar.library.pdx.edu/open_access_etds/5415), Teresa Danielle Schmidt

Quantifying Spatial Potential Access Equity in an Agent-Based Simulation Model of Buprenorphine Treatment Policy in the United States (http://pdxscholar.library.pdx.edu/open_access_etds/4516), Alexandra Elizabeth Nielsen

PhD Dissertations 2018

SOSIEL: a Cognitive, Multi-Agent, and Knowledge-Based Platform for Modeling Boundedly-Rational Decision-Making (http://pdxscholar.library.pdx.edu/open_access_etds/4239), Garry Sotnik

Enhancing Value-Based Healthcare with Reconstructability Analysis: Predicting Risk for Hip and Knee Replacements (http://pdxscholar.library.pdx.edu/open_access_etds/3772), Cecily Corrine Froemke

MS Theses and PhD Dissertations 2017

Socioeconomic Determinants of Health Disparities by Race and Ethnicity: the Mediating Role of Social, Psychological and Behavioral Factors (http://pdxscholar.library.pdx.edu/open_access_etds/3765), Amanuel Zimam Melekin

Systems Thinking in the Forest Service: a Framework to Guide Practical Application for Social-Ecological Management in the Enterprise Program (http://pdxscholar.library.pdx.edu/open_access_etds/3312), Megan Kathleen Kmon (MS thesis)

PhD Dissertations 2016

Introducing Complex Systems Analysis in High School Mathematics Using System Dynamics Modeling: A Potential Game-Changer for Mathematics Instruction (http://pdxscholar.library.pdx.edu/open_access_etds/2950), Diana Marie Fisher

The Peer Network as a Context for the Socialization of Academic Engagement (http://pdxscholar.library.pdx.edu/open_access_etds/2652), Linda Mary Newton-Curtis

A Systems Approach to Stress and Resilience in Humans: Mindfulness Meditation, Aging, and Cognitive Function (http://pdxscholar.library.pdx.edu/open_access_etds/2700), Barry S. Oken

The Development of Personal Resources in the Academic Domain: Age Differences in the Evolution of Coping and Perceived Control and the Process Structures that Facilitate Academic Engagement
(http://pdxscholar.library.pdx.edu/open_access_etds/2632),Teresa Marie Greene

MS Theses and PhD Dissertations 2015

Assessing Unique Core Values with the Competing Values Framework: The CCVI Technique for Guiding Organizational Culture Change (http://pdxscholar.library.pdx.edu/open_access_etds/2315), Anthony John Santoriello

Combining Systems Methodologies to Reduce Allergen-Related Food Recalls
(http://pdxscholar.library.pdx.edu/open_access_etds/2373), Jill Marie Sweney (MS thesis)

A Combined Energy and Geoengineering Optimization Model (CEAGOM) for Climate Policy Analysis
(http://pdxscholar.library.pdx.edu/open_access_etds/2620), John George Anasis

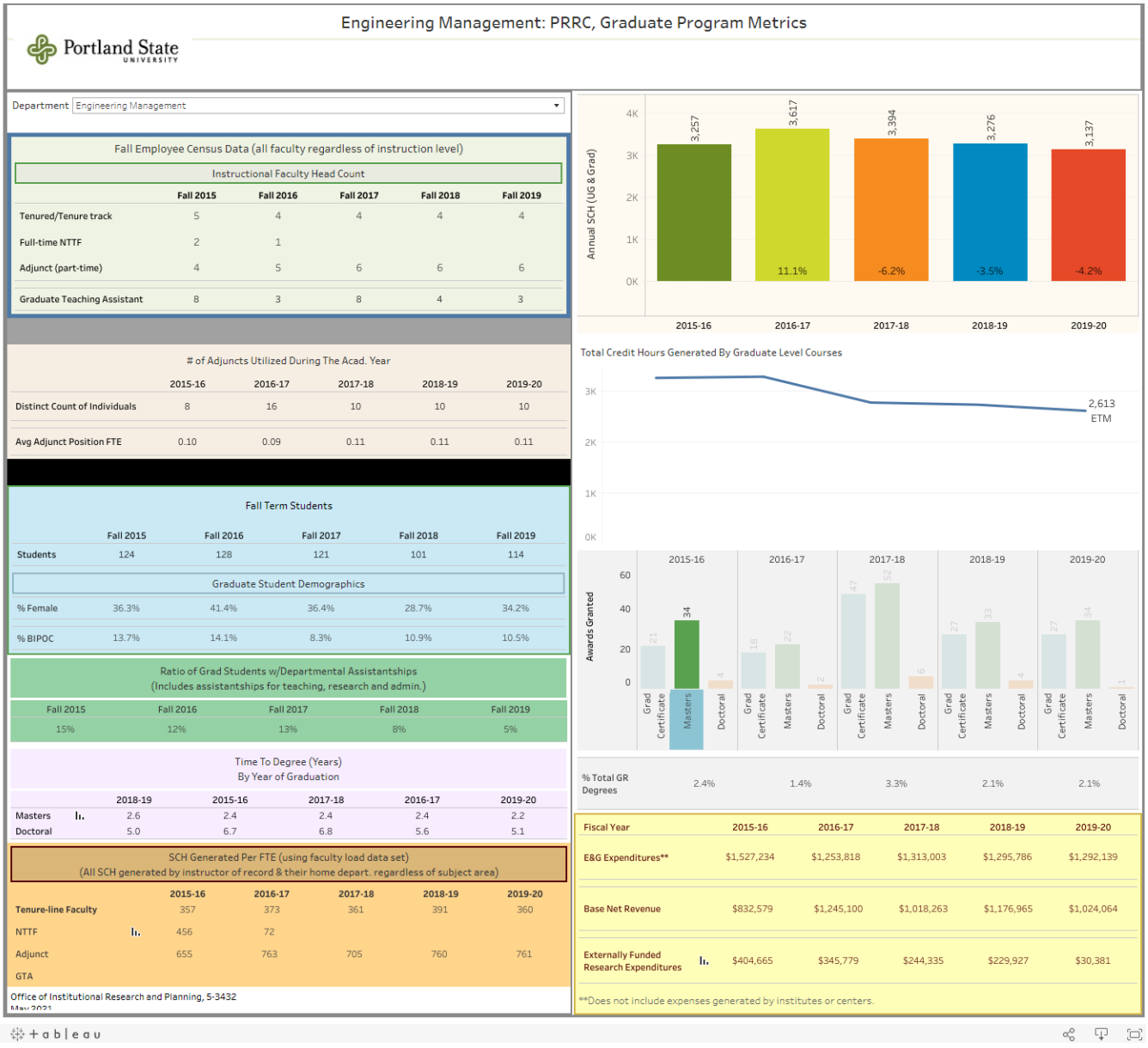
Global Time-Independent Agent-Based Simulation for Transactive Energy System Dispatch and Schedule Forecasting
(http://pdxscholar.library.pdx.edu/open_access_etds/2212), Shawn Aaron Chandler (MS thesis)

Intersections of Critical Systems Thinking and Community Based Participatory Research in Developing a Web Site for Autistic Adults (http://pdxscholar.library.pdx.edu/open_access_etds/2215), Dora Madeline Raymaker

The Role of Environmental Dynamics in the Emergence of Autocatalytic Networks
(http://pdxscholar.library.pdx.edu/open_access_etds/2458), Joe Fusion

Appendix-2 Further detail on the ETM option

Appendix-2.1 Dashboard Engineering and Technology Management



Engineering Management: PRRC, Graduate Program Metrics

Portland State UNIVERSITY

Department: Engineering Management

Fall Employee Census Data (all faculty regardless of instruction level)

Instructional Faculty Head Count

	Fall 2015	Fall 2016	Fall 2017	Fall 2018	Fall 2019
Tenured/Tenure track	5	4	4	4	4
Full-time NTTF	2	1			
Adjunct (part-time)	4	5	6	6	6
Graduate Teaching Assistant	8	3	8	4	3

# of Adjuncts Utilized During The Acad. Year

	2015-16	2016-17	2017-18	2018-19	2019-20
Distinct Count of Individuals	8	16	10	10	10
Avg Adjunct Position FTE	0.10	0.09	0.11	0.11	0.11

Fall Term Students

	Fall 2015	Fall 2016	Fall 2017	Fall 2018	Fall 2019
Students	124	128	121	101	114

Graduate Student Demographics

% Female	36.3%	41.4%	36.4%	28.7%	34.2%
% BIPOC	13.7%	14.1%	8.3%	10.9%	10.5%

Ratio of Grad Students w/Departmental Assistantships
(Includes assistantships for teaching, research and admin.)

Fall 2015	Fall 2016	Fall 2017	Fall 2018	Fall 2019
15%	12%	13%	8%	5%

Time To Degree (Years)
By Year of Graduation

	2018-19	2015-16	2017-18	2016-17	2019-20
Masters	2.6	2.4	2.4	2.4	2.2
Doctoral	5.0	6.7	6.8	5.6	5.1

SCH Generated Per FTE (using faculty load data set)
(All SCH generated by instructor of record & their home depart. regardless of subject area)

	2015-16	2016-17	2017-18	2018-19	2019-20
Tenure-line Faculty	357	373	361	391	360
NTTF	456	72			
Adjunct	655	763	705	760	761
GTA					

Office of Institutional Research and Planning, S-3432
May 2021

% Total GR Degrees	2015-16	2016-17	2017-18	2018-19	2019-20
	2.4%	1.4%	3.3%	2.1%	2.1%

Fiscal Year	2015-16	2016-17	2017-18	2018-19	2019-20
E&G Expenditures**	$1,527,234	$1,253,818	$1,313,003	$1,295,786	$1,292,139
Base Net Revenue	$832,579	$1,245,100	$1,018,263	$1,176,965	$1,024,064
Externally Funded Research Expenditures	$404,665	$345,779	$244,335	$229,927	$30,381

**Does not include expenses generated by institutes or centers.

tableau

Appendix-2.2 A side-by-side examination of the merging units

System Science (CLAS) →	**Engineering and Technology Management (MCECS) - new home, the new unit to be renamed**
Foundations	
Study of general principles governing complex systems and the use of systems ideas and methods in interdisciplinary research, investigating social-ecological and socio-technical systems, and their structure, function, and temporal development. Draws on the natural and social sciences, mathematics, computer science, and engineering to address complex problems in the public and private sectors.	Research to provide a link between engineering, science, and management disciplines, resulting in theory, methods, and actionable recommendations that help organizations (business, government, non-profits) achieve strategic and operational objectives through existing and emerging technology. Emphasizes approaches to manage uncertainty and complexity of today's interconnected technology and business environments
Credentials offered	
PhD in System Science MS in System Science Graduate Certificate (GC) in Computational Intelligence GC in Computer Modeling and Simulation Systems Minor for Undergraduates No full-blown undergraduate program but offers eight UNST courses and a Systems Minor based on the UNST courses plus 10 4xx sections of our graduate courses	PhD in Technology Management MS in Engineering and Technology Management Graduate Certificate (GC) in Strategic Management of Technology GC in Technology Management GC in Project Management GC in New Product Development (Product Management) GC in Technological Entrepreneurship No undergraduate program but offering two UNST courses in the DTIE cluster
Credential offered through School of Business	
GC in Business Intelligence and Analytics (the two units offer a total of 12 out of 21 required credits)	

<table>
<tr><th colspan="2">Number of Degrees granted</th></tr>
<tr><td>Grad Certs., MS and PhD programs with a 50-year track record, graduating 65 students between 2015/16 and 2019/20 (10 PhD, 29 MS, 26 Certs).</td><td>MS and PhD program with a 30-year track record, granting 175 MS, 140 Cert, and 17 Ph.D degrees between 2015/16 and 2019/20.
(Data for 2020/21 is not fully tabulated but the department granted 13 PhD degrees).</td></tr>
<tr><th colspan="2">Teaching Philosophy and Student Profile</th></tr>
<tr><td>Focused on general system principles and techniques, agnostic to the application domain

The PhD and MS programs mainly attract applicants who are generalists seeking methods for research and problem-solving that enable them to understand and address complexity in their professional domains.

Many have considerable work experience and are preparing for a career change. Many work part-time or full time while earning systems credentials focusing on computer simulation and/or data-driven modeling and analysis. Some PhD graduates pursue academic careers though many work in private industry or governmental agencies.</td><td>Focused on technology management principles and techniques with a focus on fostering the careers of graduate students with a technology background, agnostic to any particular technology

Graduate programs mainly serve “career enhancers” - early- and mid-career working professionals, who which to acquire skills for their next career move. Students (including PhD) self-fund their studies (many employers pay tuition, many international students have scholarships). These students have an engineering background and seek more breadth of knowledge by adding leadership, data science, decision making under dynamic complexity, project management, and insights into current technology trends, such as digital transformation. After graduation, many remain with their current employer while others change companies.

PhD program additionally attracts people who wish to become academics and about 50% of the graduates join academia.</td></tr>
<tr><td colspan="2">Both programs are highly flexible, permitting and encouraging electives from other programs. They are designed to be taken part-time: many classes are taught once a week, in the late afternoon or (at ETM) in the evening. Pre-pandemic, SySc has had many online options and ETM has used hybrid formats with a flipped classroom. Both units are committed to expanding the availability of “attend anywhere” where this is practical.</td></tr>
</table>

Appendix-2.3 SWOT Analysis

S. Strengths

Relevance Both programs admit students with a similar profile: mid-career professionals, often employer-funded, who do not want to further deepen their already existing disciplinary knowledge but are looking for additional breadth, which will allow them to "connect the dots" and move into new and/or leadership positions. The two units offer different content to this student population: SySc addresses the frequent call for system-thinking and complexity-relevant methods, including data science. ETM fulfills the need for leadership education in technology-driven organizations (including government, academia, and non-profits) and emphasizes the ability to think, plan, decide and act with strategic foresight in light of rapid technological change and its social, economic, environmental, and other impacts. This makes both programs highly relevant in an *increasingly complex and rapidly changing world* and differentiates them from other programs for working professionals, such as MBAs.

Serving non-traditional students transitioning into STEM Both programs attract students with diverse educational backgrounds and graduate them into high-paying STEM jobs: System Science admits many students with non-STEM degrees, such as Architecture, Art, Business, Education, and Social Work. ETM admits students with undergraduate degrees in STEM but also those with other degrees, who have acquired knowledge of technology on the job. The percentage of female graduates is between 25 and 40% in both programs (trending slightly higher for ETM than for SySc), which is higher than for other STEM degrees. Thus, both units are well-positioned to contribute to PSU's commitment to serving non-traditional students and increasing access to graduate education in STEM.

Global Alumni Networks System Science has a 50+ year history, ETM is over 30 years old. Together, they have graduated well over 1100 PSU graduate students and created global networks of loyal and engaged alumni who care about the future of their programs and come back for presentations, to teach classes, and for collaborations. For example, ETM is in regular contact with over 50% of its alumni through a LinkedIn ETM Alumni group. Through this network, we know that 18% of ETM alumni are at the highest leadership levels (i.e., President, Director, Vice President, CEO). Existing alumni networks constitute an ongoing resource for knowledge, advice, student placement, and collaboration.

ETM's International footprint ETM is the editorial home of a leading IEEE journal. Since 1987, ETM also organizes an annual global conference, PICMET, which takes place in Portland and in international locations. This, in addition to ETM research, results in high international visibility and a high percentage of international students, including Fulbright and Royal Thai scholars.

Proven Research Productivity despite limited resources Despite consisting of only two tenured faculty, System Science publishes an average of five peer-reviewed journal articles per year, plus many conference publications. The four full-time faculty members at ETM (all tenured) and ETM students have published over 100 peer-reviewed journal articles and conference papers since 2018.

Both units have acquired external funding for interdisciplinary research: In the past five years, research expenditures in System Science have exceeded 600K. In ETM, they have exceeded 1.2 Million. ETM faculty Dr. Daim is Co-PI on a recently awarded 2 Million grant by the National Centers of Academics in Cybersecurity, located within the National Security Agency. This work focuses on security in smart grid systems, an emerging technology, and occurs in collaboration and under the leadership of CUPA. ETM faculty Dr. Jetter is PI on a 660K grant from the National Academy on Sciences, Engineering, and Medicine

that uses system modeling to train workforce for culture change. Funded research in both units occurs in collaboration with other research institutions. For System Science, they include, among others, OHSU, Stanford, and Harvard/Mass General Hospital. For ETM, they include OHSU, OSU, Michigan State University, Vanderbilt, Bonneville Power Administration, and others. Both units engage in campus-wide interdisciplinary research with partners in Social Work, Public Health, Anthropology, Computer Science, Civil Engineering, and others.

Leadership Both units have committed faculty who deeply care about the future of their units and programs. At ETM, Dr. Antonie Jetter has volunteered to lead a "merger team" and to do the hands-on work necessary to integrate the units, to synergistically update their graduate programs, and to outline - together with partners - research and hiring strategy. Dr. Jetter's research uses participatory system modeling to understand and improve complex systems, ranging from wildfire dynamics to safety on offshore rigs, and to create scenarios of alternative (technology) futures to improve strategic planning. Dr. Wayne Wakeland (SySc) has agreed to help shepherd SySc through the transition. He and Dr. Jetter have collaborated on multiple PhD projects, serving on committees for each other's PhD students.

W. Weaknesses

For System Science, the **most salient weakness is the size and age structure of the faculty**: the entire program consists of only two faculty (both planning to retire shortly), has not seen a new hire in 20 years, and has no staff support. Given the age and support structure, replacement hires within the existing organizational structure are unrealistic - junior faculty need colleagues and mentorship. ETM has similar challenges, though with a lower level of urgency: the department consists of four tenured faculty, down from seven. One faculty member is likely to retire within the next 3-5 years. The last three open tenure lines were not replaced so that there has not been a new faculty hire in 16 years.

The lack of new faculty in both programs **reduces the ability to respond to emerging research and educational trends:** ETM students need (1) more courses that apply data science and computing (taught in some System Science classes) to technology management, (2) courses that are focused on generally applicable methods for analysis and decision-making (i.e., "how to do things", such as many of the system modeling techniques taught in System Science), and (3) more exposure to emerging technologies such as IoT, smart energy technologies, and health care innovation (which have been subject of collaborative research in ETM and SySc). System Science teaches several popular "timeless" courses and some current topical courses but is limited in overall breadth. The focus on "domain agnostic", general courses makes it somewhat difficult for students to envision their future career path. This is a barrier to recruiting and leaves SySc students relatively on their own to find their desired employment opportunities. Fortunately, they are often very distinctive applicants so they get the jobs they are seeking. Access to courses with more clearly articulated, in-demand job skills (e.g. project management, product management, strategic planning), which exist in ETM, would improve the attractiveness of the SySc program to students.

Both programs have only **limited presence in undergraduate education**. This hampers recruiting into graduate programs because students cannot simply continue with or return to what is familiar to them. It also makes it difficult to maintain a sufficiently large and diverse group of faculty, which is needed to do exciting research and ensure the breadth and vibrancy of graduate programs. Both units have recognized this weakness and have taken the initiative to offer undergraduate classes under University Studies. System Science offers eight courses and a Systems Minor. ETM offers two courses. Both programs have engaged in only **minimal systematic outreach and student recruiting and no advertising**, due to lack of staff support and faculty capacity.

O. Opportunities

Immediate Opportunities: **Enrollment growth:** Both programs have managed to more-or-less maintain graduate enrollment at a current level of over 30 for System Science and between 110-120 in ETM. This has occurred despite minimal systematic outreach and student recruiting and only minor updates to the curriculum, due to lack of capacity. By joining forces and leveraging the synergies between both units, we can a) forcefully reverse the slow erosion of attractiveness of the current ETM program as a result of its limited ability to offer a full range of updated courses and b) preserve and strengthen the enrollment currently produced by SySc. Such an updated curriculum, if clearly articulated and well-marketed, will drive enrollment growth.

Differentiation for PSU: There is limited competition for both programs: Locally, OSU offers an MEng (not MS) and a Graduate Certificate, yet no PhD program, in Engineering Management. Both programs strongly resemble traditional industrial engineering, lacking the unique leadership and system focus ETM and SySc offer. George Fox offers a Doctorate of Business as an option for part-time doctoral students, however, it is not a PhD (does not align with careers in academia) and has no technology focus. System Science or complexity programs exist (and new ones are being created) in many universities across the nation, however, they are domain-specific and, for example, exclusively address climate systems, social networks, or energy systems. Accordingly, they accept students with a narrow set of prior qualifications and prepare them for much narrower careers. The merged program has the opportunity to be more broadly positioned, attractive, and nationally/internationally competitive.

Short-term Opportunities: Two new faculty hires (to replace retiring SySc faculty) will allow the newly merged department to reach critical mass and a balanced faculty structure (2 assistant, 2 associate, 2 full professors). New faculty will open novel possibilities for research collaborations and funding and increase the scale of our research ability. Moreover, they will add research-informed courses, further raising the relevance and attractiveness of our programs. In particular, they can contribute to the creation of a flexible (remote) PhD program for working professionals, outlined above. Such a program will create strong connections to outside partners and ensure that research tackles emerging domains of societal relevance.

Medium-term Opportunities: With expanded resources through new faculty hires and increased enrollment, we could tackle new undergraduate engineering and complex systems programs, as discussed above. With its focus on engineering for societal good, it is targeted at students who do not usually seek STEM education and is differentiated from general engineering or systems programs that are offered at other universities. This makes it possible to recruit students from beyond local and regional boundaries. In addition to undergraduate degrees, we could investigate certificate programs for (re-)training public employees in foresight, systems thinking, and data/complexity science.

Long-term Opportunities: With the structural and curricular changes and the hires described above, we can build a vibrant, funded research program, consisting of six research-active faculty members and mature doctoral students with diverse skills and networks. They will do interdisciplinary research at the intersection of **complexity and technology** - topics that are also relevant for other groups on campus, such as Digital Cities Testbed Center and the Futures Collaboratory. Much of the work will occur in collaboration with other PSU units and with external partners. As the newly merged unit - and our partners at PSU - gain experience with interdisciplinary research practice the new department is poised to become an important resource for other PSU researchers, leading the way towards large interdisciplinary grants, such as center grants.

T. Threats

The threat for System Science is existential in that there is **no ability to continue existing programs if the remaining faculty retire without replacement.**

For ETM, there is a threat of a **slowly eroding attractiveness of course offerings:** as a result of budget cuts, the department had to cancel electives that were taught by adjunct instructors and reduced the number of sections of courses. This results in a less diverse program and reduced schedule flexibility - both are essential for the type of students that are being served by the program. A lack of clear future perspectives might lead faculty to leave.

Appendix-2.4 ETM Dissertations from 2015 to 2021

With few exceptions, all dissertations deal with complex systems. Many use system modeling or data analytics techniques or contribute to the foresight literature.

PhD Dissertations 2021

Assessment of the Blockchain Technology Adoption for the Management of the Electronic Health Record Systems (https://pdxscholar.library.pdx.edu/open_access_etds/5655) , Saeed Mohammed Alzahrani

Information Security Maturity Model for Healthcare Organizations in the United States (https://pdxscholar.library.pdx.edu/open_access_etds/5758) , Bridget Joan Barnes Page

Perceived Value of Technology Product Features by Crowdfunding Backers: The Case of 3D Printing Technology on Kickstarter Platform (https://pdxscholar.library.pdx.edu/open_access_etds/5708) , Nina Chaichi

Technology Management Maturity Assessment Model in Healthcare (https://pdxscholar.library.pdx.edu/open_access_etds/5696) , Amir Shaygan

PhD Dissertations 2020

Exploring Policies and Strategies for the Diffusion of Remote Patient Monitoring (RPM) for the Care of Senior Population (https://pdxscholar.library.pdx.edu/open_access_etds/5505) , Hamad Asri Alanazi

Achieving High Reliability Organizations Using Fuzzy Cognitive Maps - the Case of Offshore Oil and Gas (https://pdxscholar.library.pdx.edu/open_access_etds/5606) , Ahmed A. Alibage

An Assessment of the Decision-Making Units' Efficiency in Service Systems (https://pdxscholar.library.pdx.edu/open_access_etds/5490) , Maoloud Yakhlif Dabab

Evaluating R&D Projects in Regulated Utilities: the Case of Power Transmission Utilities (https://pdxscholar.library.pdx.edu/open_access_etds/5513) , Edwin Garces

A Scoring Model to Evaluate Offshore Oil Projects: Case of Eni and Mellitah Oil & Gas (https://pdxscholar.library.pdx.edu/open_access_etds/5601) , Abdulhakim Giadedi

Determinants of Green Purchase Intentions of Saudi Consumers (https://pdxscholar.library.pdx.edu/open_access_etds/5613) , Amani Mohammed Kaadoor

A Market Diffusion Potential (MDP) Assessment Model for Residential Energy Efficient (EE) Technologies in the U.S. (https://pdxscholar.library.pdx.edu/open_access_etds/5512), Momtaj Khanam

Exploring the Factors Influencing Big Data Technology Acceptance (https://pdxscholar.library.pdx.edu/open_access_etds/5515), Mohammad Nayemur Rahman

Determinants of Student Information Technology Adoption
(https://pdxscholar.library.pdx.edu/open_access_etds/5503), Hans P. VanDerSchaaf

Narrowing the Cognitive Distance Between Engineers and Customers: a Novel Approach, Based on Fuzzy Cognitive Mapping
(https://pdxscholar.library.pdx.edu/open_access_etds/5412), Byung Sung Yoon

PhD Dissertations 2019

Development of a Readiness Assessment Model for Evaluating Big Data Projects: Case Study of Smart City in Oregon, USA (https://pdxscholar.library.pdx.edu/open_access_etds/4996) , Husam Ahmad Barham

Evaluating Project Assessment Techniques for High-Profile Transportation Projects Development and Delivery: Case of State Departments of Transportation (DOTs) in the United States
(https://pdxscholar.library.pdx.edu/open_access_etds/5109) , Rafaa Ibrahim Khalifa

A Scoring Model to Assess Organizations' Technology Transfer Capabilities: the Case of a Power Utility in the Northwest USA (https://pdxscholar.library.pdx.edu/open_access_etds/4995) , João Ricardo Lavoie

PhD Dissertations 2018

Achieving Organizational Ambidexterity: An Exploratory Model, Using Fuzzy Cognitive Maps
(https://pdxscholar.library.pdx.edu/open_access_etds/4374), Yasser Alizadeh

Exploring Technology Forecasting and its Implications for Strategic Technology Planning
(https://pdxscholar.library.pdx.edu/open_access_etds/4224), Yonghee Cho

Assessment of Technology Adoption Potential of Medical Devices: Case of Wearable Sensor Products for Pervasive Care in Neurosurgery and Orthopedics (https://pdxscholar.library.pdx.edu/open_access_etds/4205), Liliya Stepanivna Hogaboam

Opportunity Identification for New Product Planning: Ontological Semantic Patent Classification
(https://pdxscholar.library.pdx.edu/open_access_etds/4232), Farshad Madani

Developing a Mixed-Methods Method to Model Elderly Health Technology Adoption with Fuzzy Cognitive Map, and its Application in Adoption of Remote Health Monitoring Technologies by Elderly Women
(https://pdxscholar.library.pdx.edu/open_access_etds/4511), Noshad Rahimi

Assessment of Policy Alternatives for Mitigation of Barriers to EV Adoption
(https://pdxscholar.library.pdx.edu/open_access_etds/4376), Bilgehan Yildiz

PhD Dissertations 2017

Technology Assessment Model of Developing Geothermal Energy Resources for Supporting Electrical System: the Case for Oregon

(https://pdxscholar.library.pdx.edu/open_access_etds/3515), Ahmed Shehab Alshareef

Technology Planning for Aligning Emerging Business Models and Regulatory Structures: the Case of Electric Vehicle Charging and the Smart Grid

(https://pdxscholar.library.pdx.edu/open_access_etds/4031), Kelly R. Cowan

Development of a Technology Transfer Score for Evaluating Research Proposals: Case Study of Demand Response Technologies in the Pacific Northwest (https://pdxscholar.library.pdx.edu/open_access_etds/3479), Judith Estep

PhD Dissertations 2016

Consistency Analysis for Judgment Quantification in Hierarchical Decision Model (https://pdxscholar.library.pdx.edu/open_access_etds/2699), Mustafa Sulaiman Abbas

Exploratory Study of the Adoption and Use of the Smartphone Technology in Emerging Regions: Case of Saudi Arabia (https://pdxscholar.library.pdx.edu/open_access_etds/2651), Fahad Abdulaziz Aldhaban

A Measurement System for Science and Engineering Research Center Performance Evaluation (https://pdxscholar.library.pdx.edu/open_access_etds/3285), Elizabeth Carole Gibson

Developing a Hierarchical Decision Model to Evaluate Nuclear Power Plant Alternative Siting Technologies (https://pdxscholar.library.pdx.edu/open_access_etds/2943), Marwan Mossa Lingga

PhD Dissertations 2015

Technological Forecasting Based on Segmented Rate of Change (https://pdxscholar.library.pdx.edu/open_access_etds/2220), Dong-Joon Lim

Network Structure, Network Flows and the Phenomenon of Influence in Online Social Networks: An Exploratory Empirical Study of Twitter Conversations about YouTube Product Categories (https://pdxscholar.library.pdx.edu/open_access_etds/2465), Nitin Venkat Mayande