Preparing for the next 50 years
Our educational program for computer sciences (CS) majors has been the envy of many of our peers.
Executive Summary

The University of Wisconsin–Madison Computer Sciences Department was founded in July 1964. On the occasion of our 50th anniversary, we look to the past with pride, and also take the opportunity to assess the present and chart a course for the future. In this document we outline our vision to embark upon the next 50 years with an expanded depth and breadth of contributions to the university, the state, and the world. Our plans include three important changes in the ways we execute our core mission.

- **We will educate more majors, more non-majors, and more non-traditional students.** Our educational program for computer sciences (CS) majors has been the envy of many of our peers. We will continue to develop and enhance this program to meet the tremendous growth in demand for CS majors, and extend it to meet the exploding demand for computational thinking among non-CS majors and professional students.

- **We will expand our excellence in technology-focused computer science research with enhanced emphasis on research motivated by problems outside of CS.** Our research in technology-focused CS is renowned globally. Building on this foundation, we will develop a research program that gives equal weight to CS research motivated by problems external to CS, and promote the fruitful interchange of ideas between technology-focused research and externally-motivated research.

- **We will reach out to local industry and provide education and technical innovation to catalyze the growth of Madison into the high-tech hub of Wisconsin and the upper Midwest.** Since the 1970s, our department has seeded key enterprises that have become the foundation of the Madison area’s high-tech community. We will build on these successes by conducting innovative research ripe for spinning off to industry, by fostering close ties with local high-tech businesses, and by producing a stream of first-rate UW–Madison graduates to be the employees and entrepreneurs that fuel the growth of this sector.

These changes, boldly implemented, will vault our department into a leadership role in changing the world. Our students will be prepared fully for roles as educators, researchers, and industry leaders—creating and implementing the future. Our enhanced mission in research will foster the creation of new inventions and paradigms that will change the world radically in ways that we cannot predict or envision today, but that will have a profound impact on all our lives.
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Introduction

Fifty years ago, the University of Wisconsin–Madison created the Computer Sciences Department. This visionary move anticipated both the lasting importance of computer science education and the rapid development of computer science as an academic discipline that would soon attract some of the top minds in science and engineering research. The initiative was bold; in July 1964, there was only one other CS department in the United States. Fifty years later, the department’s founders and their supporters in the university administration have proved to be prescient beyond their wildest imagining.

The discipline of computer science has grown enormously. Originating as a fledgling offshoot of mathematics and electrical engineering, it has become a mature field whose influence spreads throughout education, science, commerce, government, and the daily lives of billions. During this period, Wisconsin’s CS department has enjoyed an international reputation as a leader in research and education.

We have trained over 6,000 graduates with a “Wisconsin” CS education, with its core of challenging, project-based courses that teach students fundamentals that transcend ephemeral changes in technology. Alumni have helped build and run companies in the Madison area and beyond, including AOL, Autodesk, Epic, Microsoft, Oracle, Palo Alto Networks, Rocket Fuel, WebMD, and Yahoo!. Others have become faculty members at top-ten schools including Berkeley, Carnegie Mellon, Cornell, Georgia Tech, Illinois, Texas, and Washington. Still others have applied their CS training to positions of leadership in non-tech industries.

Our research contributions include pioneering systems that were instrumental in the early development of the Internet; innovations in microprocessor design that are currently used in hundreds of millions of processors in smartphones, tablets, laptops, desktops, and data centers; systems that provide millions of CPU-hours to scientists and that have played a central role in the discovery of the Higgs boson; fundamental advances in graphics and approximation theory; and principles of data management that are used by the “big data” systems that power corporations large and small.

Our department stands at a critical juncture. We must enter the next 50 years with a leap that expands our footprint as a leader in CS research, that provides a larger community of UW students with the CS skills that are critical to success in 21st-century jobs, and that places us firmly at the center of Wisconsin’s burgeoning high-tech industry. Maintaining the status quo is not an option, as competition is fierce among top CS departments, and our peers are innovative, larger than we are, and still growing. To continue to be a leading CS department, we must adopt new strategies and execute them decisively. Through this document, we aim to crystallize our vision for the future of the department.
We will expand and broaden our educational program.

Our plan for the future includes a fresh vision for our educational program. We propose an expansion and broadening of our program, educating a larger number of CS majors together with a more diverse set of students, including those whose primary passion lies beyond CS.

Historically, we have focused on the education of CS majors at the bachelor's, master's, and PhD level, training these students as if they were destined to become software developers or CS researchers. This mission is vital and we remain committed to it. Our graduates are our most important product, and we will strive to scale the CS major to accommodate the fast-growing numbers of students who want to join the ranks of our profession. The job outlook for CS graduates remains outstanding. It is often stated that the future is promising for jobs in STEM fields (science, technology, engineering, and mathematics); what is perhaps less well known is that even among STEM fields, CS dominates projections for job growth. A report by the US Bureau of Labor Statistics projected...
CS-related jobs to be 71% of STEM job growth during the period 2010-2020.

Undergraduates at Wisconsin are increasingly interested in studying CS. Enrollment in our introductory programming course has almost tripled in the past eight years. We suspect this growth to be a result both of the spectacular job prospects for CS majors and of the “buzz” created by popular culture and by the prominence of such companies as Google, Facebook, and Twitter.

To reach our potential as a department contributing to a large and diverse university, we need to look beyond the educational program for our CS majors. We must also broaden our scope to include students for whom CS courses will form a valuable component of their education, but who will not major in CS. There are many students of this type. Within the College of Letters & Science, this group includes students not only in the physical sciences, but also in the social sciences and humanities. Within the College of Engineering, the demand for relevant CS courses continues to change and grow. Courses that teach computational thinking, familiarizing students with its tools and techniques, are also becoming critical for students in the School of Business, the College of Agricultural and Life Sciences, and the School of Medicine and Public Health.

The full range of challenges and opportunities we face in undergraduate education is daunting, but we are determined to meet them, as we believe that computational thinking is essential to all walks of modern life. We have set an initial goal of doubling the number of credit hours we teach in the next three years. We will continue to innovate and create...
courses of broad interest and utility to non-CS students, as exemplified by our new course CS 202 (an intro to CS for non-majors), experimental sections of CS 368 (a one-credit course teaching technology useful for domains other than CS), and the newly approved CS 301 (an introduction to programming in a scripting language expected to be useful for students doing data wrangling in any number of non-CS fields).

Finally, we will partner with other L&S departments to create “X+CS” degree programs, where “X” is some other discipline. Through coordination of requirements, these degrees will require fewer total credits than a double major, but they will be much more substantial than a certificate program. (Our proposed program is inspired by the successful “CS+X” program initiated at Illinois and recently adopted at Stanford.)

When we consider our educational role beyond the university’s boundaries, nontraditional students present a further opportunity and responsibility. To meet this challenge, we have recently initiated two professional programs:

**The Professional Certificate program** provides students who majored in disciplines other than CS the training they need to enter the workforce as software developers. We hasten to add that the certificate is not a vocational program. Like the rest of our program, it teaches core principles of CS.

**The Professional Master’s program** provides in-depth, advanced training to people already in the workforce who have a CS undergraduate degree (or equivalent education or experience) but desire additional training in the principles and practice of computer science.

The professional certificate and master’s programs embody a 21st-century version of the Wisconsin Idea, as they use knowledge developed and disseminated from the university to train Wisconsin workers for the benefit of the state’s economy and society.

Finally, we are committed to raising the number of women and underrepresented minorities in our classes. This is a challenging task with no easy solutions, but we have embarked on several initiatives that we believe will be helpful. To improve our incoming pipeline of students, we have created a service-learning course (CS 402) in which CS students work in teams leading CS clubs and workshops for K-12 students in the Madison area. To help retain students once they have enrolled in our courses, we have instituted the WES-CS (Wisconsin Emerging Scholars-Computer Sciences) program, in which juniors and seniors lead small problem seminars for freshmen and sophomores. In a related vein, we intend to create a “Computer Science Learning Center” so that students can receive proper guidance in their coursework and projects, removing roadblocks as they arise and freeing the student to focus on the intrinsic challenges of the material. We will enhance and expand these initiatives, as well as create new ones, to broaden the group of students who benefit from our courses.

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Research

Our plan for the future also depends on a fresh vision for our research program. We propose an expansion of scope, complementing our successful research programs in technology-focused computer science with programs that are more outward looking, and establishing a virtuous cycle between the two branches of our program that strengthens research in both.

We do not attempt to predict specific topics of future importance; few of our department’s major research contributions could have been predicted in advance. What we do propose is to set the stage for a research program that enables future contributions with possibly even greater impact. In this section, we present context for our plan, describing the current state of the department, motivating our choice of direction, and outlining our strategy for realizing the vision.

Our department has traditionally excelled at technology-driven research, that is, research focused on the computer and the software systems that run on it. We will refer to this kind of research as endogenic CS research (or “endo” for short), as it focuses on problems that arise from within the discipline. By contrast, research that is motivated exogenously, by computational problems and demands from outside the
The field of CS has reached a stage of development at which the core should be refreshed by closer contact with users of computational technologies.

core of the discipline, could be termed exogenic CS research (“exo” for short). Such research includes development of innovative computational techniques to address important problems that arise in end-user applications, or in other branches of science and engineering. Our plan is to move our department toward giving equal weight to endo and exo CS research, and to promote fruitful interaction across the spectrum of endo- to exo-motivated research.

Examples of endogenic CS research include the following: a database researcher inventing new ways to process classes of queries faster, a computer architect inventing ways to process certain instruction streams faster, and a theoretical computer scientist exploring the computational complexity of a new class of algorithms. Often, the ultimate motivation for this research comes from the wide community of computer users, whose appetite for more powerful computer systems is insatiable. But the work is “endo” in that the researchers are not motivated primarily by a need to address a particular application or problem class; they are more concerned with developing and understanding computational technology.

Exogenic CS research, on the other hand, tends to draw its motivation from important problems that are being tackled by users of computer technology, such as sequencing genomes, using sensor data to identify faults in a power grid, or designing mechanisms for conducting online auctions fairly and efficiently. In tackling an “exo” project, a CS researcher typically abstracts the problem to a level that retains its relevance to the motivating application but also broadens the impact of the research beyond this application, and develops computational techniques that solve the abstracted problem.

CS research projects can only rarely be classified as purely endo or purely exo. They typically fall along a spectrum between the two, and deciding where a given project or research area appears in this continuum can be a subjective judgment. Despite these ambiguities, our proposed shift to weighting both types of research equally is a significant event, and its implications for our future growth as a department are substantial and clear.

The research in our department over the years has had a mostly endo flavor. By no means have we ignored exogenic CS research. We have had success in providing for the data analysis needs of the Large Hadron Collider project in its search for the Higgs boson; developing machine learning models for breast cancer detection; providing robust, high-bandwidth wireless connectivity for ambulances in meeting critical patient care needs; developing a “flight simulator” for training novice surgeons; and equipping robots with human-like gestures to enhance their interactions with people.

But it is fair to say that our focus has traditionally been on endogenic research. This focus has served us well; we have sustained a high level of excellence in endogenic research over most of our history. Some evidence for this claim can be seen in Figure 1, which ranks CS departments in systems research by the number of faculty who rank 50th or higher in number of papers at selected CS Systems venues. (Systems research tends to be endogenic.)

The arguments for elevating exogenic CS research to parity with endogenic research are strong. First, applied projects have been playing a larger and more prominent role in CS of late. Data science and bioinformatics are two fields in which exo research plays a major role. Second,
we believe that the field of CS has reached a stage of development at which the core should be “refreshed” by closer contact with users of computational technologies. Extreme-scale applications and radically new applications of computing are appearing at an increasing rate. These applications are stressing and stretching the discipline; researchers excited by these applications are envisioning computing capabilities that do not exist today and that defy our current capabilities of analysis and understanding. Endo research will profit greatly from the challenges of dealing with such applications.

Strong interactions between endogenic and exogenic CS research are an essential part of our vision. These interactions are not a one-way street. Endo continues to provide the computational substrate that enables successes in exo, while exo projects pose new challenges and opportunities for endo research. Today’s most challenging applications can be tackled only because of years of revolutionary advances in endogenic CS research. The virtuous cycle between endo and exo is key to the synergy that we seek to create within our department. We are in a strong position to establish and promote this virtuous cycle, given UW’s all-around strength in science, engineering, and medicine—all important drivers of exo research.

Concretely, our vision of emphasizing both endo and exo research, and the interaction between the two, will result in three main activities going forward.

1. **Reinforcing.** We will reinforce the existing strength of our department, which will lead to strategic hiring in traditionally “endo-leaning” areas. Research of this type has been the...
foundation of the department’s success; our future success will depend crucially on maintaining this foundation and building on it. If we sacrifice endo to build exo, both are likely to fail.

2. Leveraging. We will leverage existing strength in the university outside CS to jump-start our increased presence in exo research. Our department has already established deep interdisciplinary collaborations with exo-leaning faculty in such departments as Biostatistics and Medical Informatics, Industrial and Systems Engineering, and Electrical and Computer Engineering. We continue to build collaborations with these and many other departments. Many of our close collaborators from around campus are already affiliate faculty in our department, but we can do more to enhance and publicize their involvement in our research program.

3. Expanding. We will expand our department with new hires in areas with a strong exo flavor. Our goal is to build three groups consisting of three to four faculty each, with each group clustered around specific exo problem domains. Historically, our department has found that building groups with a similar research focus is more effective than creating multiple “islands” of isolated faculty. We expect to find focal topics within two broad areas of established and continuing importance that complement existing strengths in our department and around the UW campus. The first area is Computational and Data Science, defined broadly to encompass computational and data issues in the physical sciences, biological sciences, medical sciences, and social sciences. The second area involves very large, interconnected computational systems in the physical world, including both what is sometimes referred to as the “Internet of Things” and what is referred to as “Cyber-Physical Systems.”

All three of these strategies—reinforcing, leveraging, and expanding—build upon initiatives already underway in our department.
Contributing to the Community

Centers of high-tech industry are located near leading CS departments. Silicon Valley has Stanford and Berkeley, the Boston Route 128 corridor has MIT, Seattle has the University of Washington, and Austin has the University of Texas—all of them top-ten CS departments. While not fully appreciated until recently, a dynamic high-tech community is springing up in the Madison area. Our department has played an important role in this development. A key element of our plan is to continue catalyzing the growth and enrichment of this community.

Madison’s high-tech community has many drivers, foremost among them Epic Systems. Add to Epic the presence of Google and Microsoft research labs, numerous established smaller companies, and a budding startup culture, and we see that the foundation has been laid for Madison
to become the technology hub of the Midwest. The necessary ingredients are in place: a top CS department, a population base large enough and a culture vibrant enough to attract high-tech workers, and a large software company as “anchor tenant.” No other city in the Midwest has this combination of assets. The national press is beginning to notice. A recent *Forbes* article [“The Cities Winning the Battle for Information Jobs,” Joel Kotkin, *Forbes* 5/27/14] ranks Madison as 5th in the nation for rate of growth of its tech community. We are the only city in the Midwest ranked in the top 10.

Continuing this rate of growth would be transformative for the greater Madison area and for Wisconsin, and we are passionate about making this happen. One key contribution we can make is to continue to attract and educate students, who will become the employees and entrepreneurs fueling the growth of local industry. We will continue to build our program for encouraging entrepreneurship among our students. We will strive to facilitate transfer of our research output into tech spinoffs and established tech companies. Above all, the most fundamental contribution we can make to the local tech community is to remain a top CS department. All other contributions we could make flow from this one objective.

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Execution

This document outlines our vision at a high level. Converting this vision to a strategy and then executing that strategy will require further planning, hard and focused work, and the identification of new resources. First, it will require our department to grow beyond its current size. At some point, it may be appropriate to follow the lead of such schools as Carnegie Mellon, Cornell, Georgia Tech, and others, and create a School of Computing, perhaps within the College of Letters & Science.

Second, we will need better infrastructure to support this larger, more complex, more diverse, and more active department. This infrastructure will include more space and better space. People who build systems dealing with the external world tend to need lab space in which to play, and large courses with hands-on components require nontraditional classrooms. It also includes more and different types of department members. We will need more tenure-track professors, certainly, but we will also benefit from the creation of research faculty positions. Similarly, our broader educational mission will require not only more professors but also more faculty associates. Additional staff are also key to the success of both the research and education components of our plan.

An immediate challenge that we face is the difficulty of faculty recruiting. Our success in hiring has been less than desired in recent years, and with our peers expanding rapidly—several of them have more than ten open new positions—we will continue to face challenges in attracting top talent. We will examine our recruiting strategies and be prepared to make decisive changes if they improve our prospects of attracting the best candidates.

We acknowledge that resources are scarce, so we will maintain and accelerate efforts to generate our own resources, to explore any and all opportunities to make use of existing on-campus resources, and to partner with the university administration to leverage all investments in our department.

Our vision as described here represents a bold change for our department. In education, we used to focus primarily on educating a small number of CS majors. Now and in the future, we will educate a large number of majors and even more non-majors. In research, our strength and reputation has historically come from endogenic CS research; we will shift to a model of emphasizing exo and endo research equally, and to promoting the interaction between them. We believe these changes will serve UW–Madison and our Computer Sciences Department well and that, through them, we will build on the successes of the first 50 years to achieve even greater success and impact as we embark on our next half-century.
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