Academic Program Review

Doctor of Philosophy in Computational Science

The University of Tennessee at Chattanooga

May 10-14, 2021

Introduction

The University of Tennessee (URC) Computational Science Program is a one-of-a-kind doctoral program structured into three concentrations: Computational Engineering, Computer Science, and Computational and Applied Mathematics. Rather than house doctoral degrees in individual departments, computational and faculty resources are pooled to allow THEC doctoral graduation requirements (an average of three students yearly) to be met. The students pursue their studies in a uniquely interdisciplinary environment with world-class state-of-the-art computer infrastructure at their disposal. Students further benefit through their access to the Multidisciplinary Research Building, which houses several facilities. Among them, the SimCenter and the Center for Urban Informatics and Progress (CUIP) are the most closely associated with the Computational Science Program.

Below, I address most of the questions provided Guideline for the Narrative report. In order, I cover Learning Outcomes, Curriculum, Student Experience, Graduate Faculty Quality, Learning Resources, and Summary Recommendations. The answers to many of these questions are addressed in the excellent UTC review produced by Program Director James Newman and are, for the most part, not repeated.

1 Learning Outcomes

1.1 How would you rank this Program with similar ones in the state, region, and nation?

The Computational Science Program at the University of Tennessee at Chattanooga (UTC) is a top-notch program at the state and national levels, even though in its infancy. Integration computation, mathematics, and applied science has always been difficult and many institutions have not achieved it fully. At UTC, however, circumstances beyond your control conspired to force creating thinking and brought departments together to form a well thought out curriculum that combine the three tenets of Computational Science. The program takes multidisciplinary further by ensuring team-based research, being flexible in the creating of committees and allowing students to take courses across departments as necessary. The proximity of advanced hardware resources (SimCenter and Oakridge) provide opportunities that other institutions would envy. The program is currently enjoying steady growth that hopefully will continue into the future.

1.2 Are the intended program and learning outcomes clearly identified?

Student outcomes have three components: academic preparation, independent research, and marketable skills. These components are tracked via quantitative metrics. Academic preparation takes place through written and oral exams, independent research through a dissertation proposal, a written dissertation, a public defense[1] and marketable skills demonstrated through the excellent job placement of all students upon receiving their doctoral degree. Detailed rubrics address all three components. After collection, a yearly analysis of the data serves as a basis for improvements to the Program.

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[1] Students can request a private defense under extenuating circumstances.

The Program has very well thought out assessment rubrics, students all participate in team-based research of direct relevance to city, state, or national priorities.

Faculty development is in place and functional. All new faculty undergo mentoring by a senior faculty member, and progress is tracked with the help of rubrics. What criteria does the department use to evaluate sufficient achievement of intended program outcomes? Are the criteria appropriate for such evaluation and/or for the Program? How?

The evidence used to evaluate the students across the three learning outcomes is standard in the educational system. They take place through a written and oral preliminary exam, graded via a detailed rubric, which is used to determine whether students require remedial courses, or other additional work or training, such as writing skills, communication, or use of the English language. Students have access to UTC support services to improve oral delivery, technical skills, and other scholarly activities. These procedures are detailed on pp. 13-17 and are very well thought-out.

1.3 Does the department use evaluation information and/or information obtained from student, alumni, and employer surveys and/or data from institutional research to strengthen and improve the Program?

Each student has a committee of four to five faculty who follow their progress throughout their graduate studies. The committee helps the student chart a course of study and involves the student in one or more interdisciplinary teams that drive the research. Course instructors, program concentrations, along with the relevant department Chairs and Deans (Engineering & Computer Science, and Arts & Science), meet regularly in different groups to discuss the curriculum, needed changes, additions, and deletions. These decisions are based on the measured learning outcomes and current trends in technology.

1.4 Does the Program fit/align within the institutional mission?

The Program aligns with the missions of both the SimCenter and the Institution. The SimCenter mission is to establish, expand, and sustain a cohesive multidisciplinary effort in applied computational sciences through mentoring of students and faculty, seed funding in key thrust areas, and state-of-the-art research computing facilities. The Program's mission is to prepare graduates to develop and apply advanced modeling, simulation, numerical algorithms, and design software for a broad range of real-world scientific analysis and product design problems. The innovative and advanced curriculum, interdisciplinary research endeavors on "real-world" problems, and the national and international reputation of the faculty lead to a perfect alignment between the program activities and the two missions mentioned above.

2 Curriculum

The structure of the Program, organized around concentrations, lends itself to a flexible curriculum, which, although developed by individual departments, lends itself to promote flexibility in the topics offered to the Computational Science doctoral students. The Program is organized around a set of core courses in Computer Science and Mathematics, taken by students of all concentrations. A set of 7000-level elective courses target the Ph.D. students through advanced content and specialty courses from the various member departments form the electives. We note that Master-level students can and do attend the 7000-level courses, so they are justified at the departmental level. The student advisors create individualized course plans for each student specific to the desired study goals and commensurate with the dissertation proposal and research. Students are also allowed to take courses in departments that are not formally members of a particular concentration (e.g., Biology or Physics).

2.1 Is the current curriculum appropriate to the level and purpose of a graduate program? Is the Program more advanced in academic content when compared to related undergraduate programs?

Each concentration must provide a minimum number of 7000-level courses that are at a substantially higher level than 5000 and 6000-level courses usually taken by MS students. All levels, from 5000 through 7000-level courses, are more advanced than related undergraduate courses found in the various undergraduate programs.

2.2 How has the Program designed a process by which students can be assured of making timely progress in the degree program? How is it determined that courses are offered? Is there a set schedule for course offerings upon which the student can rely? Does the department clearly outline program requirements and offer courses regularly to ensure timely completion of the Program?

All doctoral students take a preliminary exam at the completion of all coursework, which usually takes two years (48 credit hours). Course instructors create questions for the courses they are responsible for and together, these questions constitute the student preliminary exam. Scheduling of his exam is the responsibility of the student advisor. Detailed rubrics for written and oral exams determine whether a student is admitted to doctoral candidacy or must retake one or both of the exams. Detailed policies are in place. Once a student passes the preliminary exam, they must deliver a dissertation proposal to their committee, and eventually defend their dissertation. There does not appear to be an established timeline to complete these two benchmarks through the course of study, except that the student has eight years from time they enter the Program.

Students develop a plan of study with their advisor, which is then approved by the Graduate Program Coordinator and the UTC Graduate School. Core courses are delivered yearly, electives sometimes less frequently depending on faculty availability and the number of students. Special topics courses take the place of electives when the need arises. Thus, students always complete the desired courses study. Nonetheless, as described later in this report, there is a need in some departments to hire additional faculty to increase the selection of electives.

All course requirements and schedules are clearly stated on the online graduate catalogue, together with sample course plans.

2.3 Does the curriculum align with the program learning outcomes? How is mastery assured through the curriculum? How is the content reviewed on a regular basis with results used to determine actions to take to improve the curriculum? Does the department regularly review and revise curriculum content and organization to ensure that it is appropriate and that it prepares students to meet the specified learning outcomes? Will the department need to update the curriculum and/or develop new or alternative offerings in the near future?

The synergy between the curriculum structure and the desired student outcomes is very well developed. All courses are interdisciplinary, and the students go through a rigorous preliminary exam (oral and written) to test their knowledge and communication skills and to confirm whether they are qualified to enter into doctoral candidacy. The results of this test are recorded in a detailed rubric used to identify the need for additional courses, directed individual studies (DIS), or special topics classes, which are also excellent vehicles to share advanced material when there not enough students to justify a formal course.

The procedures established by the Program allow for course reviews several times during the year through a two-step process. Since the courses belong to the member departments, they are reviewed as a part of the regular departmental activities. In addition, there are inter-departmental reviews that include the input from the concentration leaders, program director, and department chairs. Conclusions from these meetings are then shared with the course instructors. The processes in place are excellent and need no adjusting.

2.4 Is the curriculum adequate to enable students to develop the skills and attain the outcomes? Does the curriculum include knowledge of the disciplinary literature?

The curriculum includes special topics courses and directed individual studies through which literature can be studied through the reading and discussion of papers. I do not believe there are courses formally dedicated to a discipline's literature, except indirectly through learning about computer algorithms and the scientists who created them. Of course, every student does an extensive literature review for their dissertation proposal. Their dissertation research is then developed off a clear understanding of what has been done and how the proposed novel research fits within existing research.

Particular circumstances in the Computer Science department have led to insufficient electives available to the students. Two factors have led to this situation. First, the Directors of the SimCenter and of CUIP teach zero and one course a year, as opposed to the usual three or four. Second, three faculty have left the department in the past two years and have not been replenished. As a result, some required courses in Data Science and Computational Science are not available with sufficient regularity, and some students have had to consider alternatives. Another issue is that an increasing number of doctoral students have taken their masters in the Computer Science department, and they have already taken some of the available electives. The low number of total electives then creates a problem for these students. The problem can be solved by hiring more faculty, thus generating more electives.

2.5 Are opportunities available to students that allow them to engage in research, professional practice, or training experiences? How are those opportunities communicated to students?

UTC is fortunate to be an hour away from Oakridge National Laboratory and to have the MDRB building on campus, which houses the SimCenter and the CUIP Program. Both are integral to the success of the current Computational Science Program. The SimCenter provides offices for all students in the Program, computer facilities, and various support services. Faculty from the different departments work at both Centers and facilitate research with the latest hardware on real-world problems. The CUIP is uniquely poised to be at the forefront of the Data Science revolution and the Internet of Things (IoT). Data of all forms is projected to grow at exponential rates for at least the next several years. As stated earlier, all student research takes part as a team effort, with faculty from multiple departments to best serve the students' research goals. The problems solved are often chosen at the request of the Chattanooga community or support grant activity. A result of this interdisciplinary work in a state-of-the-art Center is that graduating students are in demand, which is reflected in the fact that all students found jobs in their respective areas. These jobs are in government labs, academia, and industry, ranging from data science to engineering to CFD. All have computers in their job description.

2.6 Is the Program offered through distance education or online? If so, how are those offerings assessed compared to on-ground programming?

This Computational Science Program does not offer an online curriculum or degree. An online degree might be something to explore in the future to increase enrollment. However, this also leads to additional complexities such as creating new offerings, the need for more faculty to maintain the current face-to-face course structure, and additional funding. My view is to not include an online component in the Computational Science doctoral program.

2.7 Are appropriate pedagogical and/or technological innovations included that enhance student learning? Are the department's instructional practices consistent with the standards of the discipline?

Courses are modified regularly to incorporate advances in software and hardware. Access to modern infrastructure motivates these changes and allows the student to experience the latest algorithms and technology directly, preparing them to integrate into the workforce and hit the ground running.

3 Student Experience

3.1 Does the Program have enough students to allow an appropriate group of peers as they participate in the Program?

In the first 13 years, the Program graduated 43 students, which averages 3.3 students per year. However, the last few years saw a steep decline due to severe funding issues, and the yearly graduates dropped to close to two per year, below THEC requirements. In the past five years, the Program conferred 24 doctoral degrees or an average of almost five degrees yearly, and enrollment is growing. There were 40 students enrolled in the Program in Spring 2021, and this number will continue to grow due to the Math and Computer Science concentrations, which are only a few years old. To increase robustness, the Program must grow further, both in the number of students per concentration and in the number of concentrations.

3.2 Are students offered the opportunity to evaluate both the curriculum and the faculty? How? Are these methods effective in getting feedback about the Program and teaching effectiveness?

Students evaluate all courses and the faculty delivering them by answering 15 survey questions, including open-ended questions. These replies help the department heads to assess the faculty and the instructors to improve course delivery. This approach is an accepted standard across the nation's universities and is effective. Of course, there should be a minimum of five or six replies to reduce variability. What is less clear is how to induce the students to fill the questionnaire.

3.3 Are there appropriate curricular and co-curricular offerings to enhance student experiences?

The Computational Science program is unique in three unique aspects. First, the proximity of Oakridge National Laboratory provides an opportunity for student internships and professional development in preparation for the marketplace. Second, the SimCenter and CUIP interact closely with all the students through team-based research, seminars, and workshops. They further provide students with real-world data and research projects demanded by the Chattanooga community. Third, the flexible nature of the program makes it easy to integrate student research with research in the departments. Research takes place in teams and supplements a challenging and up-to-date curriculum.

The College of Engineering and Computer Science Speaker Series, the SimCenter Seminar Series, and the Mathematics Colloquium Series provide more professional development opportunities than the time available to participate. It is up to the students to attend. They are encouraged to do so by their advisers, but not as a formal programmatic requirement. Students can also interact with professionals working in industry, academic institutions, and national labs through faculty research collaborations.

Further professional development occurs through membership in professional societies through which they attend conferences, deliver presentations, and publish peer-reviewed articles. Although students appreciate all these options and opportunities, conference attendance and publishing are not mandatory. Instead, each student gets different recommendations from their advisors. On occasion, a student graduates with no publications or without having attended a conference. Some students suggested that there should be minimum requirements regarding publications, presentations, and even internships, to increase the value of doctoral graduates further.

3.4 Our diverse perspectives and experiences provided for the students both through the curriculum and through extracurricular activities?

This question overlaps with question 3.3. Additional experiences provided by the students include summer internships that provide real-world experience and are often paid. The university also offers travel awards to encourage the students to attend conferences and other professional activities. Of course, there are never enough funds.

3.5 Are students provided with appropriate academic support services? What services are offered? Do students use the services? How well do they meet the needs of the students?

Support services available to students are those provided by the UTC campus and not specifically by this Program. The students can get support through one-on-one at the SimCenter, and through the Graduate School and the UTC Library. Students learn about these services during orientation services, but it is up to them whether to make use of them or not. I suggest providing a list of these services in a special section of the program website, even if already listed in the individual departments. Students are more likely to take advantage of them the more they come across the information.

4 Faculty

4.1 Are the faculty competencies/qualifications those needed by the program and by UTC? Do all graduate faculty meet the standards set by the Program and expected SACSCOC faculty credentials?

All the faculty in the Program have the proper terminal degrees commensurate with their discipline and have obtained Graduate Faculty Status at UTC. Thus they satisfy SACSCOC accreditation standards. They all have an excellent record of research and student mentoring, along with significant grant activity. All new faculty go through a process with several levels of approval, from the Department head to the SACSCOC Liaison.

4.2 Are faculty teaching loads sufficiently reasonable and equitable to accommodate the highly individualized nature of a graduate program, especially the direction of theses or dissertations?

UTC is a teaching university with a few doctoral programs in a small number of departments. One reason for creating the Program in Computational Science was to pool resources, including funding, to produce doctoral students while satisfying THEC requirements. Thus, the Program is hybrid teaching and research program, where faculty perform research, compete for grant money, and mentor students. While individual departments can release faculty from course duties if they conduct research and advise students, even after release, the faculty still teaches three courses each semester, which does not leave much time for other activities, such as grant writing. To further improve the quality of research, increase the influx of funds, and increase the student population, a strategy should be developed to decrease teaching loads further down to two courses per semester to bring the Program closer to the conditions in Tier-1 research universities. Of course, a lower number of courses reduces the number of electives unless more faculty lines become available. There is a need to balance faculty hires against potential grant activity and deliver the courses required by the Program.

4.3 With respect to ethnicity, gender, and academic background, is faculty diversity appropriate for the Program? Do the program student and faculty diversity mirror the demographics of the discipline?

The faculty diversity reflects the diversity in the individual departments. The self-study report analyzed the distribution of gender for the various concentration departments and found that two departments with a percentage of females slightly below and one department slightly above the national average. The number of faculty used for this calculation is too low for reliable results.

4.4 Do the faculty have regular opportunities for professional development such as travel and participation in professional organizations, workshops, and other learning experiences? Do faculty take advantage of the opportunities provided?

Even though faculty teach three or four courses each semester, they still find the time to attend conferences, publish papers, and write grants. Research grants usually cover these activities. However, departments also provide for professional development, such as travel to support ongoing research. New faculty are mentored following a rubric that tracks their activity. The faculty take full advantage of the different outlets for professional development.

4.5 Are faculty engaged in the planning, assessment, and improvement processes that measure and advance student success?

The personnel directly involved with planning, assessment, and improvement of the Program include the program director, the concentration coordinators, the Deans of the participating Colleges, and the Vice-Chancellor. New course proposals undergo a rigorous review process through committee evaluations and eventually become part of broader discussions. The courses belong to the individual departments. Thus, the department chairs sometimes participate in the discussions. To summarize, faculty members at all levels are not directly involved in the various program improvements unless they directly concern a new course they are proposing or a course they are currently teaching. This level of interactivity is excellent and need not change. Given the course load, research, and mentoring responsibilities, the faculty should have lower service responsibilities if possible.

4.6 Does the Program use assessment data, etc., to improve teaching, scholarship, and creative activity and service? How does this work? Are the processes effective?

Procedures for data assessment usage are detailed in the program review document on pp 31-32. The program tracks and measures everything and uses the collected data to incrementally improve the doctoral Program. The process is meticulous, governed by rubrics and a variety of meetings at all levels within the Program and involving the departments and higher-ups.

5 Learning Resources

5.1 Does the Program regularly evaluate its equipment and facilities and pursue necessary improvements?

The departments and the SimCenter manage equipment and facilities. Without a doubt, the computer infrastructure available to the Program is one of the best in the nation, with continuous hardware upgrades secured from grants written by the SimCenter director and a small budget provided by the university. Research utilizing these resources depends on students supported by the university (six students) and grant activity. Equipment upgrades are not determined by the Computational Science Program but by the SimCenter, although some of the SimCenter Staff are faculty in the Program. There is no evidence that the equipment and upgrades are evaluated by the faculty and students, although an informal questionnaire requesting yearly feedback from both groups would be appropriate.

The Program is structured to minimize and share budgetary resources. Students belong in departments. Thus, funding of students is the responsibility of faculty within the concentration departments. Typically, students are supported on grant money, except for six students supported in their first two years by the Graduate School. Additional funds are necessary to support students in their first 1-2 years of study if the Program is to grow. Bridge funds are also necessary to fund students on grants when the research starts before the grant money disbursement.

5.2 Are library holdings and other learning and information resources current and adequate to support the teaching and learning needs of the discipline? Are there resources adequate to support the research and publication needs of the faculty and staff?

The UTC library is very well stocked, with physical and E-journals that cover the needs of the various concentrations. Note, however, that most papers dating from the mid-1990s are available online except for special collections. The library staff conducts specialized workshops to help students conduct and prepare for research and publications. Topics such as email, Excel, Powerpoint, Word, EndNote, Copyright, reading articles, Writers bloc, plagiarism, and getting a job have proven invaluable to ease entry into research and help the students working on publishing their research.

The SimCenter provides offices and computers for all students, facilitating interactions between students and faculty in a centralized location. Finally, the MDRB provides administrative support to both the Computational Science Ph.D. program and the SimCenter, CUIP, and other Centers housed at MDRB.

6 Support

The Computational Science Program was born in the 2015-2016 academic year after serious funding problems and many faculty leaving the existing doctoral Program in the Department of Computational Engineering. Starting in 2017, the Program acquired a separate budget line after decoupling from the SimCenter/MDRB. By the start of the 2019-2020 academic year, funding specific to the Program only had two components: graduate student support and one Additional Duties Assignment (ADA) for the director. The latter component has a fixed of $9600, which is inconsequential compared to the other component, which has an average yearly cost of approximately $160,000 and will probably increase.

6.1 Is the Program's operating budget consistent with the needs of the Program?

Overall, the Program has minimal budget requirements compared to the concentration departments, which are not directly impacted by the Program since their courses are attended by MS students. Thus, they generate enough credit hours to justify them. Note that the faculty teach 7000-level courses, which decreases the number of courses for the undergraduate and MS students. Although some MS students do take the 7000-level courses, they do not necessarily have the requisite skills.

The Graduate School provides support for six graduate students, as it does to many departments and colleges on campus. In anticipation of a program with growing cohort sizes exceeding six students each year, the six-student investment by the Graduate School will not suffice.

The most pressing need for the Program is funding for incoming students for two years while they develop the necessary skills to actively participate in research activities supporting grant award commitments. As more departments join the Program and the number of students in each department keeps increasing, the student funding deficit will compound. A solution to this problem is imperative, regardless of where the actual money source.

Another budgeting issue that *might* arise from reducing faculty teaching load as UTC continues to transition from teaching to research. Almost all faculty in tier-1 research universities have a 2-2 teaching load, whereas, at UTC, most faculty teach four courses per semester but have the option of buying back their courses if the department curriculum is not adversely affected. Even so, the teaching load rarely goes below three courses per semester. A lower teaching load will increase the pressure to open new faculty lines and increase hiring, thus incurring additional expense.

As the Program expands further, and as faculty decrease their teaching loads to accommodate mentoring of more students and research activity, additional budgetary resources are unavoidable. A doctoral program adds costs covered by a combination of grants and funding resources from Chattanooga and the state of Tennessee. Budgeting resources might have to be reshuffled, and the distribution to the concentration departments increased to allow for additional hiring. The program budget will also require an increase to support more graduate students in their first two years. Some of this funding will derive from increased grant activity.

6.2 Does the Program have a history of enrollment and graduation rates sufficient to sustain high quality and cost-effectiveness?

Enrollment currently stands at 40 graduate students, with a graduation rate of about five per year, above the THEC mandated average of three graduating students over a rolling five-year window. Over the past five years, the Program growth witnessed was partially due to the introduction of two additional concentrations (Computer Science and Mathematics) and their popularity. Given that the Program is less than five years old, it is too early to discuss history. However, the numbers tell a good story, an. Thetinued importance of computers in our lives and the explosion of data all around us suggest that the Program will continue to grow, thus increasing its robustness to unexpected external events.

A unique feature of the Computational Science program is the 7000-level courses, which are high-quality courses substantially above the level of 5000- and 6000-level courses normally taken by MS students. Each department joining the Program must create at least two 7000-level courses for their course electives. Master students can attend the 7000-level courses if they have taken the required prerequisites.

As explained earlier, the dominant budgetary commitment of the Program is two years of support for six students (presumably yearly), which will have to increase as the Program expands. Nonetheless, the Program is extremely cost-effective since most of the students taking the 5000- and 6000-level courses are MS students in the different concentration departments. The number of doctoral students hardly influences the number of credit hours.

6.3 Is the Program responsive to local, state, regional, and national needs of the discipline?

Yes, the Program is responsible for the needs at the state, regional and national levels. These needs are documented by Governmental reports on computational science, which is now morphing into data science. Listed below are several links to a few governmental reports espousing the importance of Computational Science and Data Science to the United States competitiveness in software and algorithm development and the handling of large and complex data:

- Advanced Scientific Computing Research (https://www.energy.gov/science/ascr/advanced-scientific-computing-research)
- Research and Education in Computational Science and Engineering (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6168210/)
- The National Artificial Intelligence Research and Development Strategic Plan: 2019 Update (https://www.nitrd.gov/pubs/National-AI-RD-Strategy-2019.pdf)

All the students graduating from the Program started their careers in Computational Science, consistent with their education. The Program continues to make programmatic changes in response to changes in technology, hardware, advanced algorithms, and the needs of the local, state, and national needs.

6.4 Does the Program regularly and systematically collect data related to the success of its graduates, including placement? Do they also incorporate the results of that data to inform program improvements?

Demographics, enrollment, and degrees awarded are collected and reviewed. One hundred percent of graduating students landed jobs compatible with their Program of study.

6.5 Are the program policies reviewed on a regular basis to ensure alignment with institutional policies and mission?

Concentration coordinators review Program policies. Departments review anything not directly relevant to the Computational Science Program.

6.6 Considering current budget constraints, what are the most pressing resource needs of the Program?

See the answer to question 6.1 above.

7 Overall Summary

7.1 Overall, what are your impressions of the Program?

The Computational Science Program was an innovative response to a difficult funding situation in 2015-2016, which led to the departure of many faculty and imperiled the Doctoral Program in the College of Engineering and Computer Science. A concentration-based approach that serves all the departments interested in research the Computational Science and pools resources is maximally effective and leads to only a slight increase in bureaucracy. Existing structures remain unmodified within the departments. Faculty assignments within the department remain unchanged, with only a slight increase to monitor student and faculty quality metrics, suggest improvements, and implement said improvements. The curriculum structure is excellent, with courses that cover the latest advances in the field of algorithm, software, and hardware. The structure of the Program is interdisciplinary at its core, best seen in the team-based student research that often involves multiple departments and one or more centers within the MDRB. The unique proximity of Oakridge National Labs and state-of-the-art hardware and digital facilities in the GigCity provide excellent opportunities for doctoral students that uniquely position them for a fast-paced marketplace. Co-location of multiple computational Centers within a single building (the MDRB) also contributes to close interaction of an interdisciplinary nature.

Overall, the program structure is extremely creative and benefits from local resources and the goodwill of the participating departments who understand that the Computational Science Program increases the prestige of UTC. Its colleges attract better faculty and students, which in turn lead to recognition and further growth and investment by the State of Tennessee.

One major weakness (whose resolution is not clear) is the very high teaching load for research faculty who are expected to write grants, conduct research, and mentor students. A load of 4-4 is far higher than in most research universities. A 2-2 teaching load is far more common, which sometimes goes as low as 1-2 or 1-1. There are a few minor weaknesses that care easily addressed. Currently, summer internships for students are not required, nor is publishing a paper or attending a conference. Perhaps they should be, as expressed by some of the students. Additional issues regarding funding are covered in the Recommendations section. Another issue is the infrastructure needs of Computational Science. The SimCenter has sufficient resources at this time, but there is some fear that as the Program grows, these resources will not be sufficient, and some planning is necessary.

7.2 What goals would you suggest the Program set for the next five years? Please list goals in order of priority (i.e., the most important goal first, followed by the second most important goal, etc.)

An overarching goal is to increase the robustness of the Program to unanticipated external events. To this end:

- Increase the number of concentrations by including more STEM departments
- Increase the number of students in each concentration for a total of 60 students enrolled in the Program
- Find a sustained source of funding for all students for the first two years. This would greatly increase the stability of the Program
- Decrease the number of courses taught per semester from four to three, and allow a faculty to buy out a course to reduce it further to two courses. As a result, increase the number of faculty members in the departments to ensure that the doctoral candidates have a sufficient number of electives in their curriculum.

7.2.1 How can the program work to achieve these goals over the next five years?

To increase the number of STEM departments joining the Program, I suggest identifying concentrations that serve multiple departments. For example, a new concentration in *Computational Applied Sciences* might involve Chemistry, Physics, and Biology departments with 7000-level elective courses in Specialized Computational algorithms, multiscale methods, and other computational subject matters common to the various disciplines within the new concentration. This lowers the barriers to entry and decreases the impact on the smaller departments who join the Program. Another concentration might be Computational Health, which might combine the talent and resources from the departments of Biology, Health & Human Performance, Psychology, and Physical Therapy. As one moves away from STEM, fewer students will have the requisite skills to thrive. However, one or two students from each department still significantly affect enrollment growth. Another advantage of the proposed approach is that the number of new 7000 courses per concentration remains the same. Still, the impact on the smaller departments can be reduced since two different departments can each develop one course.

Increasing the number of students in each concentration will continue through continued academic excellence, grant activity, and continuing to provide state-of-the-art resources. Students are also more likely to join if they are confident that UTC will fund their initial two years of study.

A sustained funding campaign from UTC alumni and the state might help with student support. I also suggest tapping into industry to provide some funding in exchange for a commitment from the students to work 1-2 years at that company. My understanding that is it has been tried unsuccessfully. However, the key might be to identify anything that a company needs and does not have. The need for computational scientists, especially data scientists, is accelerating. It might be possible to position the Program to guarantee a pipeline to these companies in exchange for funding help, although it is a longshot. Establishing an industrial steering committee to have a say in the research direction of the Program might give industry an incentive to increase its support.

8 Recommendations

Below I enumerate a series of recommendations that emerged from my interactions with the various groups at UTC, including students, alumni, faculty, concentration leaders, Center directors, Deans, and the Vice-Chancellor of the Graduate School. Some of these recommendations might contradict others. Unfortunately, these contradiction are inevitable a complex organization that is growing. The task of UTC is to thread the needed through the recommendations below to optimize the results.

1. Explore combining multiple departments per concentration as done by the College of Engineering. Perhaps a concentration in *Computational Applied Sciences* (Chemistry, Physics, Biology) with 7000-level elective courses in Specialized Computational algorithms, multiscale methods, and other computational subject matters common to the various disciplines within the new concentration. This lowers the barriers to entry and decreases the impact on the smaller departments who join the Program. Another group of departments could form a concentration in *Computational Health,* and might include the Health & Human Performance, Psychology, and Physical Therapy departments.
2. I recommend a vertical-integrated meeting once a semester between department heads and the Computational Science Ph.D. team (director, concentration coordinators, Vice-Chancellor of Research (or Dean of the Grad School).
3. Meetings with the Vice-Chancellor of Research and the Deans should involve all college Deans within the Program with an equal voice (like the structure of the US Senate). That will help promote the participation of additional new departments (or sets of departments) into the Program.

4. Explore the sharing of indirect costs across multiple departments contributing to a grant. Currently, indirect cost distribution is shared between the colleges participating in a grant, not the departments. The colleges then allocate their portion of the funds to their departments, and sometimes they might not. I recommend that a formula be established to ensure that all departments participating in a grant get a fraction of the indirect cost, decided ahead of time.
5. A few students stated that there was an insufficient number of 7000-level courses on the curriculum. I recommend developing at least one more 7000-level course for each concentration. The question then will be whether to ask the students to take three 7000-level courses or leave the requirements at two.
6. Explore reducing faculty course loads from four to three courses per semester and the option to buy out one additional course each academic year contingent on successful grant activity. This recommendation moves UTC one step closer to Tier-1 status.
7. Look into creating a rollover account funded by the university to simplify the funding of students on grants when the starting dates do not coincide with the start of the semester. This would contribute to robustness by decreasing uncertainty. Provide a mechanism for reimbursement to the university from the grant. Thus, the student might start three months before grant initiation and end three months before grant termination (and the grans would return the money to the university). My understanding from Vice-Chancellor of Research J. Romagni is that such discussions are underway. I further recommend that any request for bridge funds be directed to her office to ensure clear communication channels.
8. I recommend standardizing requirements such as conference attendance, a minimum of one peer-reviewed journal or conference proceedings publication (JANIF exists for classified work), and one internship during the Ph.D. program, increasing student competitiveness in the marketplace. Currently, the Computational Science program requires attendance (poster or presentation) at one conference. A course related to scientific conferences (preparation, paper writing, with an industrial visitor, would be welcome by the students.
9. Provide a centralized list (hosted on the Program website) of internship opportunities for summer work. Alumni and current students who have done internships (locally or in other states) have expressed great satisfaction from their experiences. One summer as an internship should be a minimum requirement.
10. I recommend that UTC explore the possibility of generating matching funds for infrastructure grants as a motivational incentive towards increased grant activity, in addition to a fixed recurrent budget to help build infrastructure at the SimCenter (which supports the Computational Science program and UTC).
11. Explore the creation of new faculty lines, especially for the Computer Science department, whose faculty depletion of recent years remains unfilled. And yet, doctoral student enrollment from Computer Science is increasing. This lack of faculty lowers the availability of electives.
12. Identify niches of excellence to establish the uniqueness of the various activities within the MDRB. The uniqueness of the SimCenter initially focused on the area of CFD within the original Ph.D. program in the College of Engineering and Computer Science. This level of expertise disappeared around 2015-2016 due to funding problems, with a commensurate decrease in national standing, affecting job placement. New world-class expertise should be a goal, perhaps in blockchain, the internet of things, data handling, or specialty hardware. The specialty should strive to include as many of the disciplines as possible by seeking a field of research or activity that is common to all member departments. Multiscale modeling comes to mind. Big data is another possibility.

13. A funding path for six years should be clear for new students entering the Program. As the Program grows, this becomes increasingly important. Students should be encouraged to write grants to the NSF, DOE, NASA, and perhaps other agencies, in their first two years, with the help of staff at the SimCenter and student advisors.
14. Given the strong emphasis on computation, it is appropriate to create a rubric to allow students and faculty to evaluate the infrastructure at the SimCenter. This would provide the Director valuable feedback.
15. I recommend creating a new rubric to allow faculty and students to evaluate the resources at the SimCenter from a variety of perspectives. There is no evidence that such an evaluation is currently in place.
16. Lastly, I recommend making sure that future concentrations all have a strong computational component to avoid any potential problems in the future with UTC and THEC.

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