HECB
RECEIVED
MAY 02 2011
ACADEMIC AFFAIRS

FORM 2

COVER SHEET

NEW DEGREE PROGRAM PROPOSAL

Program Name: ***M.S. Computational Science***

Institution Name: ***Central Washington University***

Degree Granting Unit): College of the Science

Degree: M.S. Computational Science Level: Master Type: Science

Major: Computational Science, CIP Code: 30.3001, Minor *(if required for major)*: None

Specialization(s) *(if applicable)*:

Proposed Start Date: Fall 2011

Projected Enrollment (FTE) in Yr One: 13 At Full Enrollment: 20 in year 3

Funding Source – (*State FTE, Self Support, Other)*: CWU Office of Continuing Education

Mode of Delivery / Locations

____ Off Site

_X_ Single Campus Delivery - ***Ellensburg***

____ Distance Learning

_X_ Other Single campus; traditional, laboratory-based, and field-based classes; technology-enhanced or web-based classes as appropriate

Scheduling

_X_ Day Classes ___ Evening Classes ___ Weekend Class ___ Other

Attendence Options

_X_ Full-Time ___ Part-Time

Total Credits: 45 _X_ Quarter ___Semester

Contact Information (Academic Department Representative)

Name: Razvan Andonie, Title: Program Director

Address: 400 E. University Way, Hebeler Hall, Ellensburg, WA 98926-7520

Telephone: 509-963-1430, Fax: 509-963-1449, Email: andonie@cwu.edu

4/27/11 11-22-10

Chief Academic Officer **Date** **Dean of College** **Date**

Computational Science Master Program Proposal

Central Washington University, College of the Sciences

1. Introduction

Over the last decade, technological developments have revolutionized data gathering and data storage methods. Enormous amounts of data routinely need to be collected, stored and analyzed in a wide variety of disciplines. In particular, data-driven sciences rely on such large databases along with a corresponding means of analysis.

For instance, biologists in genomics increasingly rely on computational methods to analyze DNA microarrays or on statistical methods to identify complex diseases and/or physical traits. Ecologists make extensive use of mobile sensor technologies to accumulate data from remote locations, such as the poles, high mountain peaks, or deserts. This data is then used to model both local and global changes and the interactions between various ecosystems. Geologists use similar techniques to study tectonic plates, and predict earthquakes more accurately. Chemists and physicists also generate large amounts of data for modeling and computer simulation, for example, to address problems such as the ternary and quaternary structure prediction of proteins, which is the foundation of modern drug discovery in the biomedical field and in the pharmaceutical industry.

Thus, many scientists rely more and more heavily on having computing core of their work principally because of the pervasive nature and amount of data that is being accumulated. Given the rate of data accumulation, it is critical to develop truly multidisciplinary computing programs to ensure adequate collaboration and communication between computer scientists, mathematicians, and professionals in data-driven sciences. It is collaborations like this that will lead to the development of adequate data analysis tools.

Computational Science is the field of study concerned with constructing mathematical models and quantitative analysis techniques and using computers to analyze and solve scientific problems. In practical use, it is typically the application of computer simulation and other forms of computation to problems in various scientific disciplines.

The field is distinct from computer science. It is also different from theory and experiment which are the traditional forms of science and engineering. The scientific computing approach is to gain understanding, mainly through the analysis of mathematical models implemented on computers.

Computational Science is now commonly considered a third mode of science, complementing and adding to experimentation/observation and theory. The essence of Computational Science is numerical algorithm and/or computational mathematics. In fact, substantial effort in Computational Sciences has been devoted to the development of algorithms, the efficient implementation in programming languages, and validation of computational results.

The term *computational scientist* is used to describe someone skilled in scientific computing. This person is usually a scientist, an engineer or an applied mathematician who applies high-performance computers in different ways to advance the state-of-the-art in their respective applied disciplines in physics, chemistry or engineering. Scientific computing has increasingly also impacted on other areas including economics, biology and medicine. Computational scientists work in and across all areas of the sciences by applying high-performance computing to fuse data sets, visualize theoretical possibilities and create knowledge. The goal is to engage cutting-edge technology to answer the most perplexing scientific questions.

Scientific computation is most often studied through an applied mathematics or computer science program, or within a standard mathematics, sciences, or engineering program. At some institutions, a

specialization in scientific computation can be earned as a "minor" within another program (which may be at varying levels). However, there are increasingly many bachelor's and master's programs in Computational Science. Some schools also offer the Ph.D. in Computational Science, computational engineering, Computational Science and engineering, or scientific computation. There are also programs in areas such as computational physics, computational chemistry, etc.

Central Washington University (CWU) seeks approval to establish a self-sustaining Master of Computational Science degree program beginning fall 2011. Housed within the Computer Science Department of the College of Science in the Ellensburg campus, this graduate degree would be offered full-time.

This multidisciplinary modular program is designed to prepare professionals in computing-related disciplines. Further the program will promote the expansion and strengthening of the collaborative educational and research efforts across the College of the Sciences. It will also advance research productivity and student participation in research, while adhering to the vision and mission of Central Washington University.

Computational Science – the use of advanced computing capabilities to understand and solve complex problems – has become critical to scientific leadership, economic competitiveness, and national security. The PITAC believes that Computational Science is one of the most important technical fields of the 21st century because it is essential to advances throughout society.

The boldest statement about the importance of a strong educational program in Computational Science can be found in the 2005 Report to the U.S. President, authored by the President's Information Technology Advisory Committee (PITAC):

> *"Computational Science – the use of advanced computing capabilities to understand and solve complex problems – has become critical to scientific leadership, economic competitiveness, and national security. The PITAC believes that Computational Science is one of the most important technical fields of the 21st century because it is essential to advances throughout society.*
>
> *Computational Science provides a unique window through which researchers can investigate problems that are otherwise impractical or impossible to address, ranging from scientific investigations of the biochemical processes of the human brain and the fundamental forces of physics shaping the universe, to analysis of the spread of infectious disease or airborne toxic agents in a terrorist attack, to supporting advanced industrial methods with significant economic benefits, such as rapidly designing more efficient airplane wings computationally rather than through expensive and time-consuming wind tunnel experiments.*
>
> *However, only a small fraction of the potential of Computational Science is being realized, thereby compromising U.S. preeminence in science and engineering."*
>
> *"Our report recommends that both universities and Federal R&D agencies must fundamentally change these organizational structures to promote and reward collaborative research."*
>
> *"As part of this national effort, we recommend that the Federal government provide an infrastructure that includes and interconnects Computational Science software sustainability centers, data and software repositories, and high-end computing leadership centers with each other and with researchers. We also recommend that our Computational Science R&D be rebalanced to focus on improved software, systems with high sustained performance, and sensor- and data-intensive applications."*[1]*:*

[1] *Computational Science: Ensuring America's Competitiveness,* Report to the President from the President's Information Technology Advisory Committee (June, 2005).

This proposal presents a thorough justification for the need of a new graduate program at CWU, a description of the program, its timelines and costs.

2. Statement of Need

Program need

Despite the less than perfect economic climate, there are several reasons to develop a Master of Computational Science program at CWU, and guarantee a high return on investment with minimal risks.

The most authoritative employment demand projections are made semi-annually by the U. S. Bureau of Labor Statistics (BLS). According to a BLS recent projection, covering the ten-year period 2008-2018, computer occupations are expected to add a significant number of new jobs in the future[2] :

> *"Computer and mathematical occupations are expected to add 785,700 new jobs from 2008 to 2018, and, as a group, they will grow more than twice as fast as the average for all occupations in the economy, according to projections. It is anticipated that computer specialists will account for the vast majority of this growth, increasing by 762,700 jobs. Demand for computer specialists will be driven by the continuing need for businesses, government agencies, and other organizations to adopt the latest technologies... New computer specialist jobs will arise in almost every industry..."*

Figure 1shows BLS projections for job growth in five major Science and Technology (S&T) categories between 2008 and 2018. For each field, "New Jobs" represents expansion while "New Jobs + Replacements" represents total available positions. The dominance of Computer Science specialists is clear. While there will be inevitable variations in demand for every field, the long-term prospects for employment in computer related occupations in the United States are exceedingly strong. All other S&T fields pale by comparison.

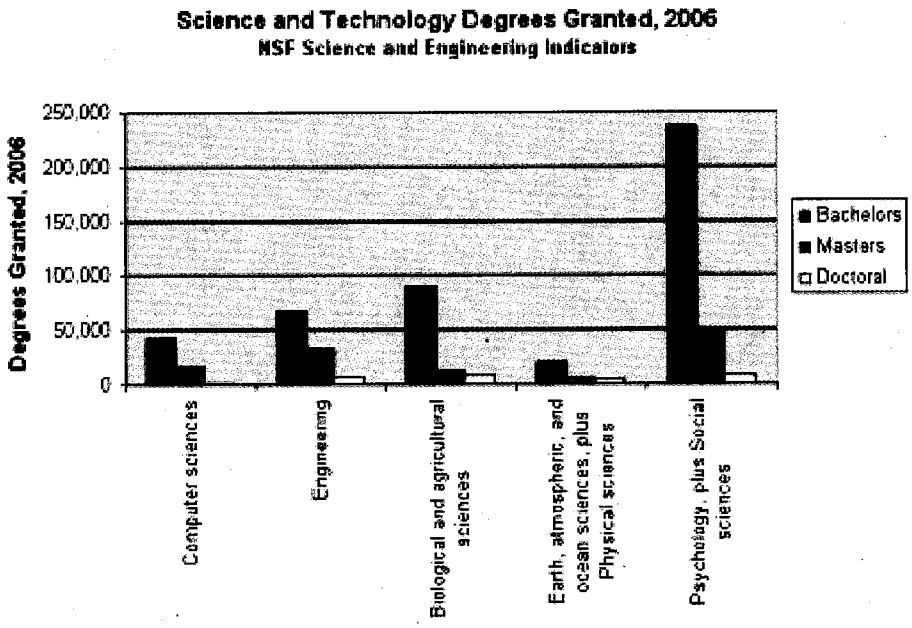

Figure 1

[2] *"Occupational Employment Projections to 2018"*, November 2009, Monthly Labor Review, U.S. Bureau of Labor Statistics.

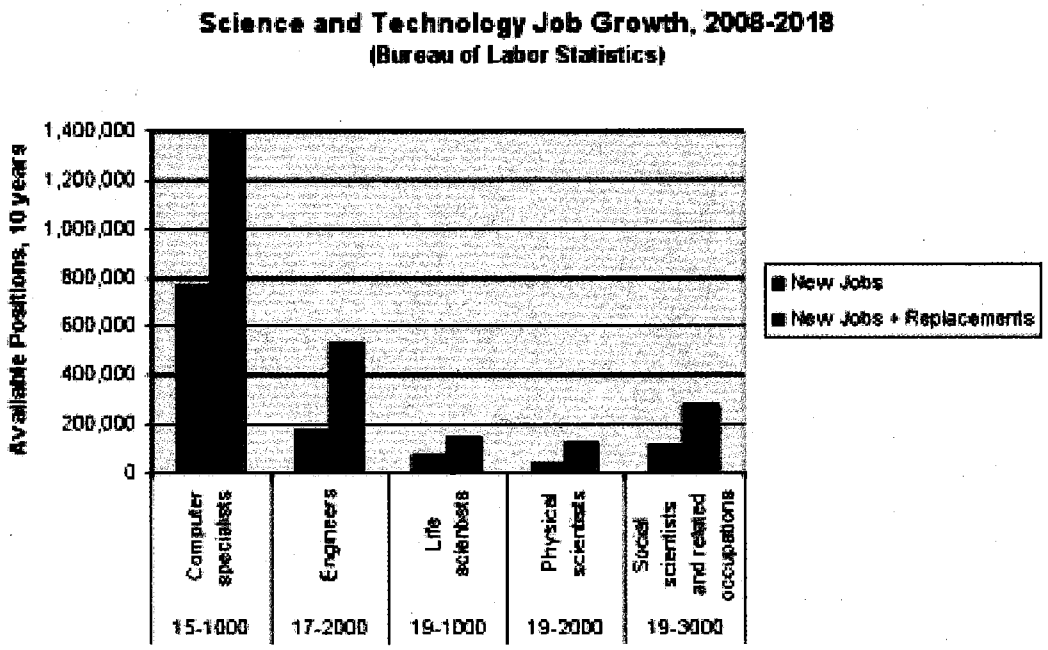

Figure 2

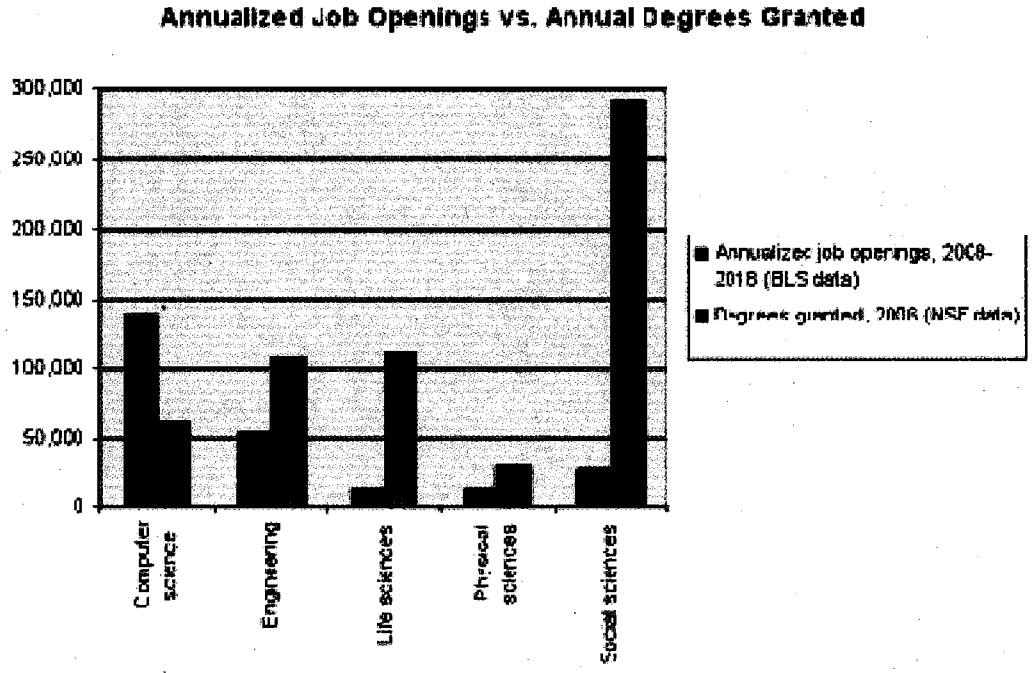

Figure 3

The supply side of the equation is a cause of great concern. Figure 2 shows NSF statistics for degrees granted in 2006 in the S&T fields corresponding to the five BLS categories[3]. Degrees in psychology and the social sciences dominate, with degrees in other S&T fields lagging far behind.

It is difficult to make direct field-by-field comparisons between available jobs and degrees granted: Individuals with degrees in many fields work in NIT occupations, and individuals with NIT degrees work in many fields. With this caveat, Figure 3Figure 3 compares annualized job openings (BLS data) to total annual degrees granted (NSF data) for the five S&T fields reported in the previous two figures.

Over the last decade, the professional scientific world has become increasingly competitive and as the references at the end of this section demonstrate, multidisciplinary scientific positions frequently require a master degree rather than a bachelor degree.

Future hires are often required to be very good in their primary fields but also need to be able to interact with experts from other fields, indeed, to have some breadth of knowledge in these secondary areas. For example, chemists, biologists, and geologists are expected to be able to develop models, program, store data in databases, and analyze these data sets. Mathematicians and computer scientists are often expected to work with professionals in other disciplines and thus required to understand these fields to some degree. As a matter of fact, browsing through current job descriptions in the fields listed above will almost always require multidisciplinary skills. This is further supported by the work done by the professional society SIAM's working group on Computer Science and Engineering (CSE) education.[4] The SIAM group has put together extensive resources and references that show the critical need for graduates with a multidisciplinary Computational Science background. In describing CSE, the working group comments:

> *"One point we would like to emphasize in this document is that CSE is a legitimate and important academic enterprise, even if it has yet to be formally recognized as such at some institutions. Although it includes elements from computer science, applied mathematics, engineering and science, CSE focuses on the integration of knowledge and methodologies from all of these disciplines, and as such is a subject which is distinct from any of them."*[5]

Thus, despite this pervasive growth of computation throughout engineering and science, university level computing education is still largely separated from other disciplines. When this is considered in the light of the growing needs of data-driven sciences, it is crucial to develop a computer science based workforce that has a thorough understanding of the fundamental conceptual ideas from computer science that pertain to a specific domain together with the skills necessary to apply them to their field of expertise.

Conversely, it is also necessary to expand computing education into the other fields comprising data-driven sciences. Our program addresses both these needs by developing a comprehensive approach to helping students develop skills in relevant aspects of computation and in a wide variety of scientific disciplines.

CWU's master degree in Computational Science will allow many students in the College of the Sciences to acquire such skills and will generate a new cohort of students with a background in both a primary discipline and computer science. Such students are still rare but there is a growing need for them by employers, in both the private and federal sector and at various levels across the state. Here are a few highlights of major corporations hiring graduates in Computational Science:[6] Google, Amazon, Microsoft,

---

[3] National Science Foundation, Division of Science Resources Statistics. (October 2008). Science and Engineering Statistics, S&E Degrees. (1966-2006). http://www.nsf.gov/statistics/nsf08321/content.cfm?pub_id=3785&id=2

[4] Society for Industrial and Applied Mathematics, http://www.siam.org/students/resources/report.php, June 2010.

[5] ibid.

[6] SimplyHired, http://www.simplyhired.com/a/jobs/list/q-computational+chemistry+scientist, June 2010.

Boeing, the pharmaceutical industry (Merck, Pfizer, GlaxoSmithKline).[7] More generally, job opportunities for our future graduates can be found at numerous web sites.[8,9]

The program aims to prepare students for the following occupations:

- scientific software developer and scientific software architect in the following complex industrial domains: pharmaceutical industry, green technologies, non-conventional energy, geospatial industry, bio-technology
- research and development careers at institutions such as Pacific Northwest National Laboratory (PNNL) and Boeing
- software engineering in location-based mobile computer services and defense

While it is difficult to separate the types of jobs identified above from the aggregated statistics of the long-term occupational employment report from the Washington Employment Security Department, one thing is clear – computer-related jobs will be among the fastest growing over the next decade.[10] Continuing the highlights of the previous section, regionally, aside from the employers already cited, Fred Hutchinson Cancer center offers various positions for Computational Science graduate.[11]

At the federal level, agencies such as NIH, USGS, and NASA all offer a very wide range of opportunities for graduates with a compu-centric multidisciplinary background. This is complemented by the various reports of job opportunities described by the SIAM working group.[12]

It is not realistic to achieve multidisciplinary skills, coupled with depth in one domain, within the timeframe of a bachelor degree. Therefore, a Master Program in Computational Science would allow many students in the College of the Sciences to be a lot more competitive when applying for positions.

Enrollment and target audience

A student survey was completed during the Fall 2009 and Winter 2010 quarters in the Computer Science Department, across 4 different classes. The survey shows that 39/53 = 73.5% of the students expressed a strong interest in pursuing a Computational Science graduate degree at CWU. The results of this poll were consistent with a survey of alumni, conducted in Fall 2008. This second survey had a 22 percent return rate, with 48 percent of respondents indicating an interest in such a program.

Based on these results, we anticipate that at least 13 students will enroll in Year 1 of the program, and are aiming at an enrollment of 20 students within three years. The success of the graduate program of the Department of Geological Sciences shows that enrollment will likely follow in the other departments of the College of the Sciences.

Further, it is our belief that these estimates are conservative. This is based on the review of the current trends in hiring qualified professionals in computing-related disciplines with multi-disciplinary skills and a computing-centric as described in previous sections combined with a slow economy.

We plan to actively recruit students into this program, both at Central, in the colleges in the region, and more generally in the state of Washington and the Pacific North-West.

---

[7] Merck, http://jobs.merck.com/go/Research-Jobs-at-Merck/212977/, June 2010.

[8] Bioinformatics Organization Career Center, http://www.bioinformatics.org/jobs/, June 2010.

[9] Ecoinformatics.org Job Listings, http://www.ecoinformatics.org/jobs.html, June 2010.

[10] Washington Occupational Employment Projections, Washington Employment Security Department, Labor Market and Economic Analysis Branch, May 2010.

[11] Fred Hutchinson, https://erecruit.fhcrc.org/Erecruit.htm, June 2010.

[12] op. cit.

Consequently, we plan to enroll in this program 13 FTE students in Year 1 and achieve full enrollment of 20 FTE students by Year 3. At full enrollment, it will graduate 20 students per year.

To be considered, an applicants to this graduate program must have been awarded (or about to be awarded) a 4-year bachelor's degree, with a 3.25 or higher.

The target audience will consist primarily of computer science graduates (i.e., graduates with a Major in computer science). We also target graduates with a Minor in computer science and a Major in one of the application domains (mathematics, biology, chemistry, physics, and geology). On a case by case basis, graduates from the application domains, without a Minor in computer science, may be also accepted, if they have enough credits from computer related courses (computer programming, algorithms and data structures, and computer organization).

Relationship to Other Institutions

This program will be the first of its kind in Washington. Our program is different than a traditional computer science or mathematics program because it is an interdisciplinary program. Faculty from different disciplines (i.e., computer science, mathematics, biology, chemistry, physics, and geology) will teach and supervise students. The Master's thesis/project will be interdisciplinary. The heart of the program is computer related, but the applications will be generally not in computer science, but in other scientific domains. The program is also not a bio-computing or a computational chemistry program because the student will be exposed to applications in several, not a single domain.

3. Relationship to Institutional Role and Mission

University and Departmental Mission

The University has worked hard to develop a consistent and extensive plan for the next years, to strengthen its position without losing sight of its vision and mission, essentially towards students. More specifically, one of the goals of CWU is to increase its research productivity, and its external funding. The College of the Sciences should lead this effort, particularly now, when federal funding is at it's highest of the past ten years, and chances of success are greatly increased.

The development of a Master of Computational Science offers an opportunity for 6 departments to greatly increase their research productivity and funding. With graduate students working across these departments, faculty members will be able to:

- Develop strong multidisciplinary research programs, at a time where the stimulus packages are geared towards such cross-disciplinary projects.
- Increase publication levels in high-level conferences and journals, and consequently.
- Increase chances for receiving external funding.

Given that this will be the sole Computational Science Master Program in the state of Washington, CWU and the College of the Sciences will end up in an ideal position to lead the state with the first cross-multidisciplinary program, and will improve national recognition, as well as the ability to increase research productivity in data-driven disciplines. It is a unique opportunity, at a nearly perfect moment to capitalize on our respective expertise.

The program has been designed to conform to the missions of the Computer Science Department and of CWU. Let us look at the relevant portions of each beginning with one of the prominent aspects of the department's mission followed by a selection from the university mission:

> *"Computer Science faculty and students working in partnership with each other and with interdisciplinary colleagues will help address significant local, regional, and national problems through the use of this flexible, robust discipline."*

"Faculty, staff, students, and alumni serve as an intellectual resource to assist central Washington, the state, and the region in solving human and environmental problems. … Graduate programs develop partnerships between faculty and students to extend scholarship to important areas of research and practice."

Further, CWU has worked hard to develop a consistent and extensive plan to strengthen its position without losing sight of its vision and mission. More specifically, part of this plan is to increase its research productivity, and its external funding. The College of the Sciences should lead this effort, particularly now, when federal funding is at its' highest of the past ten years, and chances of success are greatly increased. The interdisciplinary nature of this program is designed to take a lead in this direction.

Diversity

CWU is an equal opportunity employer that values an inclusive campus and welcomes a diversity of ideas and people.[13]. CWU remains committed to reaching its affirmative action goals, and it continues to use a variety of action oriented programs designed to achieve these goals. President James Gaudino makes diversity of our student body a high priority. CWU is also committed to affirmative action for Asians/Pacific Islanders, Blacks, Hispanics, American Indians/Alaskan Natives, women, persons forty years of age or older, persons of disability, and protected veterans.

In accordance to this university policy, a particular focus of our program will be on the recruitment of underrepresented minorities, and women (largely underrepresented in computing related disciplines). This focus aligns well with the current goals of federal funding agencies, such as NSF and NIH, eager to see more done for underrepresented groups. For instance, NSF's Broadening Participation in Computing Program supports such efforts.

CWU is located in the proximity of an underserved rural area and the Yakama Indian Reservation. The general policy of the university is to attract students by organizing periodical visits of the local and regional schools in the campus and by developing relationships with local organizations.

Since we do hire new faculty, we do not need a specific hiring policy to recruit diverse faculty for this program. To recruit students especially from the underrepresented groups, we would create a partnership with community colleges in underserved areas of central Washington, like the Heritage University (Toppenish) and the Yakima Valley Community College.

As other measures, we would:

- Appoint at least one participant from underrepresented populations to the program's advisory board.
- Endeavor to submit grant proposals that focuses on educational improvement for under-served populations.

4. Relationship to the Strategic Master Plan for Higher Education in Washington

The program fits into several aspects of the Strategic Master Plan described by the Higher Education Coordinating Board (HECB) in 2008.[14] The program is designed to encourage enrollment in STEM and other high-demand fields in an innovative manner – one of the implementation plans for future work described in the Master Plan. The Master Plan also notes that even if all of the state institutional growth plans are fully funded, the state's four-year institutions will not meet strategic plan goals for bachelors and advanced degrees by 2018. Indeed, the Master Plan indicates that the state will need increase advanced

[13] Office of the President, CWU Policy Statement March 1st, 2010.
[14] 2008 Strategic Master Plan for Higher Education in Washington, HECB, December 2007.

degree production by 8,600 over that period. Further, even with the downturn in the economy this is a growing need. According to the Annual Skill Gap Report 2008:

> *"[The] gap between skilled workers and employer demands will increase. Education and training [are] more vital than ever for workers in down economy."*[15]

The document *"A Skilled and Educated Workforce"* (March 2009)[16] is a recent joint report of the HECB, the State Board for Community and Technical Colleges and the Workforce Training and Education Coordinating Board. According to this report:

- There is *"underproduction of degrees in Washington at the bachelors and graduate level, in sciences and engineering fields, when compared to other states and the overall demand for these degrees."*
- Computer science is a high demand program of study. The 2004-2006 average annual supply for baccalaureate and graduate degrees in computer science by Washington institutions is 2,052. The additional supply needed to meet average annual demand for 2011-2016 is 2,973. Actually, in computer science, the gap between current supply and forecast demand has grown.
- The U.S. must not simply produce more engineers and scientists, but foster and develop the creative and interdisciplinary talent of students in these programs.

Our master program is in accordance to all these three conclusions of the report.

Another motivation for developing this program was inspired by the NSF. The NSF has been pushing strongly for the development of Computational Science programs through several of its programs including Broadening Participation in Computing[17] and CPATH – revitalizing computing education[18].

The final motivation for our program is the report, titled "*The Impact of Interstate Migration on Human Capital Development in Washington",* written by HECB Academic Affairs Director Randy Spaulding, and posted September, 2010 on the HECB website.[19] According to this report, more Washington high school graduates leave the state to pursue a college education degree than come here for the same purpose. This constitutes a "brain drain" for the state. Washington ranks first nationally in the employment of engineers, sixth in computer specialists, and ninth in life and physical scientists. However, we rank 38th nationally in the production of bachelor's degrees in science and engineering and 42nd in the production of graduate degrees in these fields. According to Randy Spaulding, one of the ways we can reduce our reliance on highly educated workers from other states and countries is by encouraging more qualified Washington residents who are already prepared and motivated to enroll in the state's higher education system. As the recession ends and global economic activity heats up, countries with the best-educated workforces will lead the way.

Our program is designed and well positioned to address the concerns and predictions of HECB.

5. Objectives and Vision of the Program

CWU will offer this masters program with the aim to prepare students for professional Computational Science careers in the Pacific Northwest and beyond, or to pursue a doctoral degree. The computational core of the program will be materialized in by modular and flexible inter-departmental collaboration.

---

[15] Annual Skill Gap Report 2008, Workforce Training and Education Coordinating Board (WTECB), December 2008.

[16] http://www.hecb.wa.gov/research/Issues/NeedsAssessment.asp

[17] Broadening Participation in Computing, http://www.nsf.gov/pubs/2009/nsf09534/nsf09534.html?org=NSF

[18] CPATH, http://www.nsf.gov/cise/funding/cpath_faq.jsp

[19] http://www.hecb.wa.gov/research/documents/2010migrationReport-final.pdf

Objective 1 – Interdisciplinarity. The foci of the degree offered are in computational biology, computational chemistry, computational geology, computational mathematics, and computational physics. It will prepare students for careers in various industries, such as the pharmaceutical industry and environment-related/green industries. The departments involved in the program already strongly encourage an integrative, multi-disciplinary approach.

Objective 2 – Modularity. A main theme of the program is: modularity. Although, as expected for any Computational Science program, there should be a strong mathematical and computing core, students with interest in any field involved will be able to study their discipline of choice. More specifically, the program will be designed as follows:

- Core computing topics: advanced algorithms and programming.
- Core mathematical topics: probabilities and statistics, differential equations, numerical methods.

Specialization track: computational biology, computational chemistry, eco-informatics, geology, computational methods, computational mathematics and computational physics.

Objective 3 - Flexibility. Students who are part of the program will be required to do a Master's Thesis or a Project at the end of the program. The two alternatives (thesis or project) show flexibility. Students may choose between a research and a professional orientation. This way, we will attract students from both categories in our program.

Whenever possible, courses will be cross-listed across departments, at both the senior level (with instructor's approval) and graduate level. This will allow us to keep a high enrollment, and at the same time, recruit more students in the program.

The program will be entirely delivered at the CWU Ellensburg campus and will be a combination of traditional courses, seminar, and research work amounting to a total of 45 credits.

The COTS departments involved in the creation of this program are listed in the following, along with the faculty members representing the department in this project, and the research goals underlying the educational developments.

Department of Biological Sciences

The Department of Biological Sciences has numerous faculty members interested in computational biology. In particular, several faculty members are involved in ecological science, which requires data gathering through sensor networks, data storage in databases, and data analysis. There is also a push for more research in computational biology, in particular DNA microarray methods and, the more recent genome wide association techniques, requiring a strong collaboration between biologists, mathematicians / statisticians, and computer scientists, to understand complex diseases, and physical traits, which usually depend on large DNA segments, comprised of numerous genes.

Department of Chemistry

One of the key foci in chemistry, is computational chemistry. Dr. Fabry-Asztalos leads (with Dr. Razvan Andonie) a computational chemistry research group, showing that there already are strong connections between these two departments. Modern drug discovery methods rely on this kind of research. Indeed, modern drug discovery relies on understanding ideal location sites for a drug to bind onto a protein, the so-called protein-ligant docking problem. This problem is very complex because of the high number of degrees of freedom of the system, and requires heavy distribution of the computations on heterogeneous systems, high-parallelization, and pruning methods to ignore the non-valid binding sites.

Department of Computer Science

The Department of Computer Science is strongly and entirely supportive of this effort. Four faculty members (Andonie, Gellenbeck, Kovalerchuk, Schwing) have direct research collaborations with other departments involved in this proposal, and have published in various areas of Computational Science.

Department of Geological Sciences

The Department of Geological Sciences at CWU is the most productive department of the College of the Sciences when it comes to external funding. Most faculty members are very active in their research field, and several of them require extensive computing expertise, and computational power. For instance, the department is making a strong push to develop novel methods for earthquake predictions, based on remote sensing and GPS data sets. This research would greatly benefit from additional mathematical and computational expertise.

Department of Mathematics

Mathematics is not only a language of the sciences, it provides many of the core ideas behind computation. The topics selected for the core mathematics classes have wide applicability to all scientific disciplines and in particular to the departments involved in this proposal. The Department of Mathematics has expertise in modeling, analysis, differential and partial differential equations, statistical and stochastic methods, as well as numerical and symbolic methods. In summary, the Department of Mathematics is well placed to supervise students, and provide basic core skills for the proposed Computational Science program.

Department of Physics

Physics is (at least partly) a data-driven science. Indeed, many physical problems are represented by either standard differential equations or partial differential equations, which are computationally heavy to solve using numerical methods. Thus, it is natural to see a strong collaboration between physics and computer science, as well as mathematics.

6. Curricular Program Description

The focus of the program is to prepare students to do work in a multidisciplinary environment, through course work, and doing research. Students will complete 22 credits of core course work in computer science and mathematics and 5 credits of thesis/capstone project work. Additionally, students will have to complete elective courses in their selected area(s) of expertise amounting to 18 credits.

Overall, the program will require 45 credits of coursework and research. The normal course load for graduate students not holding graduate assistantship is 16 credits per quarter, 10-14 for those with assistantships. At least 25 credits of the total required for the degree must be numbered 501 or above.

A typical break down for a student in the program would be:

- 22 credits core courses
- 18 credits electives, including graduate research
- 5 credits Master's thesis / capstone project

Students will have to complete the core course work of the program:

- Advanced data structures and algorithms
- High-performance computing
- Advanced algorithms for scientific computing
- Applied numerical methods I
- Applied numerical methods II

Since research is a key part of student development in this program, the rest of the work in the Master of Computational Science will focus on a (year-long) research project with an advisor in their selected area of expertise. Alternatively, and with the approval of the Computational Science Program Committee, students will have the option to do research, or work on a project in the industry. However, this work shall be done under the supervision of an academic advisor, in agreement with the industrial partner of the program. Regular attendance to research seminars will also be required.

The Thesis/Project Committee, having at least three members, will be chaired by a graduate faculty from the Computer Science Department. All actual professors from the Computer Science Department have the Graduate Faculty status. According to the CWU Masters Degree Regulations, interdisciplinary membership in the graduate committee is strongly recommended. For this program, the graduate committee will be generally interdisciplinary.

Program's students outcomes

The goal of the master's program is to produce professional computational scientists with the ability to conduct original and meaningful scientific research. Professional computational scientists possess a broad grounding in computing related areas, mathematics, and sophistication in their area of concentration. In particular, students will be able to

- Critically read and interpret published scientific literature as a basis for a research project.
- Design and implement an original research project that develops multiple hypotheses, predictions from hypotheses, data gathering strategy, and data analysis, and utilizes the published scientific literature.
- Report the results of original research using standard Computational Science formats and conventions.
- Present research results, both orally and in writing.
- Know and practice scientific ethics.
- Evaluate uncertainties with respect to observations and measurements.
- Demonstrate working knowledge of standard Computational Science reference tools and resources.
- Students should possess in depth knowledge in their area of specialization.
- Gain experience in teaching Computational Science in the classroom or field.

Course description

Students will specialize in one of the following application areas:

- Biological and environmental sciences
- Chemistry
- Computer science
- Geology
- Mathematics
- Physics

A. Core courses – 22 credits

- **Computer Science (12 credits)**

  Advanced Data Structures and Algorithms
  Course name: CS 528 (Advanced data structures and algorithms).
  Credits: 4 credits.
  Prerequisite: CS301 (Data structures) and MATH330 (Discrete mathematics), or equivalent.
  Remarks: Required for MS in Computational Science.
  Content: This course is a continuation of previous undergraduate classes (programming, data structures and algorithms) and has the role of reviewing but also introducing more advanced topics. As a first computer science course in the program it will bring students which may come with different computational background to the same basic level. It focuses on the understanding and design of fundamental algorithms, with a more thorough presentation of time and space complexity.

  Advanced Algorithms for Scientific Computing
  Course name: CS 529 (Advanced algorithms for scientific computing).
  Credits: 4 credits.
  Prerequisite: CS528 Advanced data structures and algorithms.

Remarks: Required for MS in Computational Science.
Content: The course presents specialized algorithms for the considered application domains mathematics, biology, chemistry, physics, and geology: FFT, randomized algorithms, string matching, graph matching, multithreaded algorithms, approximation algorithms. It also introduces advanced data structures: B-trees, Fibonacci heaps, van Emde Boas trees, disjoint sets and union-find.

High-performance computing
Course name: CS 530 (High-performance computing).
Credits: 4 credits.
Prerequisite: CS528 Advanced data structures and algorithms.
Remarks: Required for MS in Computational Science.
Content: This course provides an overview of computer hardware, software, and numerical methods that are useful on scientific workstations and supercomputers. Topics include high-performance computer architectures, software tools and packages, characteristics of commonly used numerical methods, graphical presentation of results, and performance analysis and improvement.

- **Mathematics (10 credits)**

Applied Numerical Methods I
Course name: Math 565 (Applied numerical methods I).
Credits: 5 credits.
Prerequisites: Math265 (Linear Algebra I), Math 173 (Calculus II).
Remarks: Required for MS in Computational Science.
Content: applied linear algebra, numerical stability, iterative methods, canonical forms of matrices, singular value decomposition, computation of eigenvalues and eigenvectors, dominant eigenvalue.

Applied Numerical Methods II
Course name: Math 567 (Applied numerical methods II).
Credits: 5 credits.
Prerequisites: Math265 (Linear Algebra I), Math 173 (Calculus II).
Remarks: Required for MS in Computational Science.
Content: Least square approximation and projections, discretization, numerical stability, well posed problems, numerical solutions to ODE's, interpolation, linear programming and the Simplex method.

B. Master Thesis / Project – 5 credits

Master's Thesis/Project
Course name: CS700 (Master's Thesis/Project)
Credit: 5 credits.
Prerequisites: Permission of the chair of student's graduate faculty supervisory committee.
Content: research.
Remarks: The Master's Thesis/Project may be repeated for up to 5 credits.

C. Specialization / Tracks

- **Biology (biology electives)**

Research Methods and Techniques
Course name: BIOL 501 (Research Methods and Techniques).
Credits: 4 credits.
Remarks: Elective for MS in Computational Science.
Content: An introduction to methods, techniques, and procedures commonly used in biological research.

Biometry
Course name: BIOL 598 (Biometry).
Credits: 4 credits.
Remarks: Elective for MS in Computational Science.
Content: Recent technical advances have made large datasets of biological information available, including information on entire genomes as well as large collections of field data. Analysis of such data lies outside

the realm of typical statistics courses and is a critical skill set needed for graduate students within the biological sciences.

- **Chemistry (chemistry electives)**

  Medicinal Organic Chemistry
  Course name: CHEM 564
  Credits: 3 credits.
  Prerequisite: CHEM 363 and CHEM 431 or equivalent or permission of the instructor.
  Remarks: Elective in chemistry track.
  Content: A multi-component study of drugs and other biologically potent materials in terms of chemical synthesis, radiochemistry, biochemical evaluation and biological ligand-receptor interactions.

  Quantum Chemistry
  Course name: CHEM 583
  Credits: 3 credits.
  Prerequisite: Mathematics through multivariable calculus, CHEM 383, or equivalent
  Remarks: Elective in chemistry track.
  Content: Principles of quantum chemistry: basic theories, methods, and applications.

  Current Topics in Chemistry
  Course name: CHEM 505.
  Credits: 1 credit.
  Prerequisite: graduate status or permission of instructor.
  Restrictions: may be repeated for credit when subject matter differs to a maximum of 5 credits.
  Remarks: elective in chemistry track.
  Content: varies.

  Graduate Student Seminar
  Course name: CHEM 589.
  Credits: 2 credits.
  Remarks: May be repeated for credits.
  Content: A one hour professional seminar encompassing a contemporary topic is provided by the student to the department and campus community.

- **Computer Science (computer science electives)**

  Data Visualization
  Course name: CS 545 (Data Visualization).
  Credits: 4 credits.
  Prerequisite: CS528 Advanced data structures and algorithms.
  Remarks: Elective for MS in Computational Science
  Content: this course provides students with an introduction to computer graphics, geometric modeling and data visualization tools, and how they apply to various application domains, as they relate to Computational Science.

  Data Mining
  Course name: CS456 / CS556 (Data mining).
  Credits: 4 credits.
  Prerequisite: Permission of instructor.
  Remarks: Elective for MS in Computational Science.
  Content: this course provides students with Data mining methods for discovering hidden patterns in large databases and data warehouses with applications in business, science, and engineering.

  Algorithms for Biological Data Analysis
  Course name: CS 540 (Algorithms for biological data analysis).
  Credits: 4 credits.
  Prerequisite: CS529.
  Remarks: Elective for MS in Computational Science
  Content: this course introduces advanced algorithms used in bioinformatics: biological pattern analysis, gene clustering analysis, phylogenetic supertrees, Bayesian analysis of gene expression, Hidden Markov

Models gene prediction, gene splicing models, sequence alignment using HMM, Markov Chain Monte-Carlo and stochastic simulation.

Computational Intelligence
Course name: CS457 / CS557 (Computational intelligence).
Credits: 4 credits.
Prerequisite: CS528 Advanced data structures and algorithms.
Remarks: Elective fro MS in Computational Science.
Content: Introducing concepts, models, algorithms, and tools for development of intelligent systems: artificial neural networks, genetic algorithms, fuzzy systems, swarm intelligence, and hybridizations of these techniques.

Parallel Computing
Course name: CS473 / CS573 (Parallel Computing).
Credits: 4 credits.
Prerequisite: CS528 Advanced data structures and algorithms.
Remarks: Elective fro MS in Computational Science.
Content: This course introduces principles, paradigms, and models of parallel computation on multiprocessors, graphic processing units (GPU's) and distributed architectures. It challenges students to apply in a new context the concepts and tools they have studied in earlier computer science courses.

Graduate Research
Course name: CS595 (Graduate Research)
Credits: 1-10
Prerequisite: Permission of instructor.
Remarks: may be repeated for up to 10 credits.

Seminar
Course name: CS599 (Seminar).
Credits: 1 credit.
Content: A one hour professional seminar encompassing a contemporary topic is provided by the student to the department and campus community.

- **Geology (geology electives)**

Remote Sensing
Course name: GEOL530 (Remote sensing)
Credits: 5 credits
Prerequisite: GEOL410, GEOL210, or permission of instructor.
Remarks: Elective for MS in Computational Science
Content: Principles of acquisition, analysis, and use of remotely sensed data (LANDSAT, SPOT, Ikonos, etc.). Applied experience using image processing software.

Seismology
Course name: GEOL553 (Seismology)
Credits: 5 credits
Prerequisite: MATH173 or permission of instructor.
Remarks: Elective for MS in Computational Science.
Content: Elasticity theory, the wave equation, ray theory, diffraction, waveform modeling, travel time inversion. Data analysis.

Hydrogeology
Course name: GEOL545 (Hydrogeology)
Credits: 5 credits
Prerequisite: GEOL101, GEOL102, and GEOL 101Lab, MATH154, or permission of instructor.
Remarks: Elective for MS in Computational Science.
Content: Study of the occurrence and movement of ground water using geology, hydrology, and geochemistry, with an emphasis on practical problems in water management.

Seminar
Course name: GEOL504 (Seminar)

Credits: 1 credit.
Content: research seminar.

- **Mathematics (mathematics electives)**

  Seminar
  Course name: MATH599 (Seminar).
  Credits: 1 credit.
  Content: research seminar.

- **Physics (physics electives)**

  Advanced Computational Physics
  Course name: PHYS 461 / PHYS 561 (Advanced computational physics).
  Credits: 4 credits
  Prerequisites: Math 376, Phys 361 or equivalent.
  Remarks: This is an elective course for students in the new Computational Science masters program. The course is also suitable for undergraduate students with appropriate background (as noted in the prerequisites).
  Content: Applications of standard numerical modeling techniques to physics problems involving nonlinear and/or differential equations, including wave propagation, fluid flow, thermodynamics, electrodynamics, and particle physics.

  Multiphysics modeling using COMSOL
  Course name: PHYS 562 (Multiphysics modeling using COMSOL)
  Credits: 4 credits
  Prerequisites: Math 376, Phys 561 or equivalent.
  Remarks: This is an elective course for students in the new Computational Science masters program.
  Content: students will learn how to use the multi-physics software package COMSOL to solve problems that involve multiple kinds of physical processes (including chemical and geological processes) that interact. An example of such a problem is the mutual effect of temperature and electric current within a metal conductor. Emphasis will be on setting up the problem, establishing the geometry of the system (including the use of CAD programs), achieving a useful computational mesh of all boundaries, choosing appropriate differential equations and boundary conditions, and displaying and interpreting the results.

7. Program and Student Assessment

Assessment of the program will be modeled according to the CWU general procedures. The plan for ongoing assessment of the program is centered on measuring student learning outcomes and how effective the program meets student expectations. We will use the following assessment measures:

- Peer review of teaching materials by faculty to ensure high quality courses
- Course evaluations will be used to examine course content and the relevance of the content to the larger program.
- Entry surveys will assess student expectations of the program and student goals.
- Exit surveys will ask questions related to the effectiveness of the whole program and identify future plans and job prospects.
- Since the number of students will be relatively small, it will be easy to organize informal gatherings with students to discuss their progress and possible improvements of the program.
- Surveys of industry partners and capstone project clients will be used to measure satisfaction with student performance.
- We will follow-up with graduates to assess employment and career impact.
- We plan to create an advisory board which will annually assess the effectiveness of the program. This advisory board will meet bi-annually to review the program. Members of the advisory board should be from the academia and industry. The advisory board should include out of state members.

Data from all of the above measures will be used to assess and revise content and curriculum of the program by the program faculty, the program director, the Dean of The College of Science and all superior administrative levels of the university.

PROGRAM GOALS ASSESSMENT PLAN FOR THE M.S. COMPUTATIONAL SCIENCES

Program Goals	Department/Program Goals	Related College Goals	Related University Goals	Method(s) of Assessment (What is the assessment?)	Who/What Assessed (population, item)	When Assessed (term, dates)	Criterion of Achievement (Expectation of how good things should be?)
1. Facilitate student progress to advanced levels of knowledge and practice in science	Goal I. Promote the role of computer science and computer literacy in undergraduate education at Central Washington University.	Goal I: Provide for an outstanding academic and student experience in the College of the Sciences.	Goal I: Maintain and strengthen an outstanding academic and student life on the Ellensburg campus.	Pre-post survey	Graduate Student (for each outcome)	During class-work Before and at end of graduate program	GPA above 3.0 and no grade lower than a C in required core content and elective classes on student's course of study form Successful completion of project study or paper/ internship Evidence of improved knowledge via pre-post survey
2: Prepare students for professional and career advancement	Goal II. Offer undergraduate programs that train students as computer specialists with a fundamental understanding of technology.	Goal I: Provide for an outstanding academic and student experience in the College of the Sciences.	Goals I & II: Maintain and strengthen an outstanding academic and student life on Ellensburg and University Center campuses. Goal VI: Build inclusive and diverse campus communities that promote intellectual inquiry and encourage civility, mutual respect, and cooperation	Student survey Internship Internship supervision evaluation Project study Paper/ portfolio Pre-post survey	Graduate Student (for each outcome)	Yearly after graduation Core courses	Completion of project study or paper/portfolio Satisfactorily complete internship Evidence of improved knowledge via pre-post survey 50% of graduates obtain employment or career advancement in Computational Science related jobs within 2 years of completion of degree.

3: Maintain a program that is relevant to the Computational Science profession	Goal III. Maintain an intellectually stimulating learning environment where diverse perspectives are valued and encouraged.	Goal VII: Create and sustain productive, civil, and pleasant learning environments.	Goals I & II: Maintain and strengthen an outstanding academic and student life on Ellensburg and University Center campuses Goal IV: Build mutually beneficial partnerships with the public sector, industry, professional groups, institutions, and the communities surrounding our campus communities Goal VI: Build inclusive and diverse campus communities that promote intellectual inquiry and encourage civility, mutual respect, and cooperation.	Alumni survey Survey of program graduates Survey of Law and Justice Advisory Board Survey of internship supervisors	Under-graduates M.S. graduates Members of the Computational Science Advisory Board Internship supervisors	Bi-annually 2 years after graduation and every 2 years Yearly after 1st graduates After completion of internship supervision	Over 60% of M.S. graduates say the program is relevant Over 75% of Advisory Board members identify it as relevant Over 50% of internship supervisors say it is relevant
4: Facilitate students understanding and appreciation of applied research	Goal V. Play a leadership role in scholarship by making basic and relevant scientific contributions to our respective sub-disciplines. Goal IV. Sustain a productive team of faculty and staff. Goal VI. Build an interdisciplinary	Goal IV: Develop a diversified funding base to support curriculum and academic facilities, student and faculty research and scholarships, as well as faculty development, service and applied research	Goals I & II: Maintain and strengthen an outstanding academic and student life on Ellensburg and University Center campuses Goal IV:	Pre-post survey	Graduate students	In courses Pre-post survey	GPA above 3.0 and no grade lower than a C in required core content and elective classes on student's course of study form Improved understanding and appreciation from pre to post study survey

	program and an associated Masters Degree program.	in college disciplines Goal III: Provide for outstanding graduate programs that meet focused regional needs and achieve academic excellence.	Build mutually beneficial partnerships with the public sector, industry, professional groups, institutions, and the communities surrounding our campus communities Goal VI: Build inclusive and diverse campus communities that promote intellectual inquiry and encourage civility, mutual respect, and cooperation Goal V: Achieve regional and national prominence for the university.				

STUDENT LEARNING OUTCOMES AND ASSESSMENTS FOR THE M.S. COMPUTATIONAL SCIENCES

Student Learning Outcomes (performance, knowledge, attitudes)	Related Program/ Departmental Goals	Related College Goals	Related University Goals	Method(s) of Assessment (What is the assessment?)*	Who Assessed (Students from what courses – population)**	When Assessed (term, dates) ***	Standard of Mastery/ Criterion of Achievement (How good does performance have to be?)
1. Basic knowledge: Graduates will demonstrate an understanding of each of the subject areas that define the discipline as well as the interrelationships that exist among them.	Goals 1 & 2. Promote the role of computer science and computer literacy in undergraduate education at Central Washington University. Offer undergraduate programs that train students as computer specialists with a fundamental understanding of technology.	Goal I: Provide for an outstanding academic and student experience in the College of the Sciences.	Goal I: Maintain and strengthen an outstanding academic and student life on the Ellensburg campus.	MFT taken by graduating students Performance in the core courses	Graduate Student (for each outcome)	During program of study	GPA above 3.0 and no grade lower than a C in required core content and elective classes on student's course of study form Successful completion and presentation of culminating project in Capstone course. Evidence of improvement in exit survey compared to entry survey.
2. Critical Thinking Skills: Graduates will demonstrate the ability to utilize appropriate theoretical constructs for problem solving: definitions, and axioms, theorems, proofs, and interpretation of results.	Goal 2. Offer undergraduate programs that train students as computer specialists with a fundamental understanding of technology.	Goal I: Provide for an outstanding academic and student experience in the College of the Sciences.	Goal I: Maintain and strengthen an outstanding academic and student life on the Ellensburg campus.	Capstone Project Entrance/ Exit Survey Class Performance	Graduate Student (for each outcome)	During program of study Pre-post survey	GPA above 3.0 and no grade lower than a C in required core content and elective classes on student's course of study form Successful completion and presentation of culminating project in Capstone course. Evidence of improvement in exit survey compared to entry survey

3. Research Skills: Graduates will have the ability to apply basic research methods in computer science.	Goals 3, 5 & 6. Maintain an intellectually stimulating learning environment where diverse perspectives are valued and encouraged. Play a leadership role in scholarship by making basic and relevant scientific contributions to our respective sub-disciplines. Build an interdisciplinary program and an associated Masters Degree program.	Goal VII & III: Create and sustain productive, civil, and pleasant learning environment. Provide for outstanding graduate programs that meet focused regional needs and achieve academic excellence.	Goal VI & V: Build inclusive and diverse campus communities that promote intellectual inquiry and encourage civility, mutual respect, and cooperation. Achieve regional and national prominence for the university.	Student participation in local and national conferences, including SOURCE Student participation in research projects and groups.	Graduating Student (for each outcome) Students involved with conference Students involved in graduate research	Reviewed annually.	All graduates will produce a successful research paper. Range from a constant to an increasing number presenting at SOURCE Eexternal research presentations or publications annually with student participation.
4. Technical and Theoretical Background: Graduates will demonstrate knowledge of recent technological and theoretical developments, general professional standards, and have an awareness of their own strengths and limitations as well as those of the discipline itself.	Goals 3 & 5. Maintain an intellectually stimulating learning environment where diverse perspectives are valued and encouraged. Play a leadership role in scholarship by making basic and relevant scientific contributions to our respective sub-disciplines.	Goal VII & III: Create and sustain productive, civil, and pleasant learning environment. Provide for outstanding graduate programs that meet focused regional needs and achieve academic excellence.	Goal VI & V: Build inclusive and diverse campus communities that promote intellectual inquiry and encourage civility, mutual respect, and cooperation. Achieve regional and national prominence for the university.	Performance in core classes. Performance in MS Thesis / Project presentations	Graduate students.	Reviewed annually.	Students meet the student learning outcomes of core classes. All student groups will meet professional standards in generating course documents.

5.Communication Skills: Graduates will have the ability to communicate effectively.	Goal 2. Offer undergraduate programs that train students as computer specialists with a fundamental understanding of technology.	Goal I: Provide for an outstanding academic and student experience in the College of the Sciences.	Goal I: Maintain and strengthen an outstanding academic and student life on the Ellensburg campus.	Capstone Project Entrance/ Exit Survey Class Performance	Graduate Student (for each outcome)	During program of study Pre-post survey	GPA above 3.0 and no grade lower than a C in required core content and elective classes on student's course of study form Successful completion and presentation of Thesis / Capstone Project. Evidence of improvement in exit survey compared to entry survey

*Method(s) of assessment should include those that are both direct (tests, essays, presentations, projects) and indirect (surveys, interviews) in nature

**Data needs to be collected and differentiated by location (Ellensburg campus vs University Centers – see NWCCU standard 2.B.2)

***Timing of assessment should be identified at different transition points of program (i.e., admission, mid-point, end-of-program, post-program)

8. Program Costs

Initially, the program will be implemented through CWU Office of Continuing Education as a self-supported-program, thus requiring no state funds. At the moment, and at least for the first 1-2 years of the program, we do not anticipate that any hire will be necessary to teach the appropriate classes.

Given the current salary and benefits expense, the total cost at full enrollment is $121,930.00. The total revenue from tuition and fees will be $230,670.00 (see Form 7 for full details.) Since at existing site, equipment and support services are already available, the entire cost, will be for salaries. At full enrollment, staffing for the program amounts 1.08 FTE, with 1 FTE for faculty and 0.08 FTE for administration.

Overall, the program will require 45 credits of coursework and research. At the present cost of $256.30 per credit, assuming that credits are distributed relatively uniformly between quarters, tuition for a Washington resident for the whole program would be $11,533. This is an overestimate, because a student may take up to 18 credits per quarter and such an unequal distribution of credits may reduce the total cost.

Indirect costs (Room & Board) in Ellensburg are $8,900 per year. Since most of the students will be Washington residents, also because the relatively low living costs in Ellensburg, we consider that the program will be relatively affordable compared to other master programs in Washington.

For an enrollment of 13 students, during the first two years, we expect to obtain two assistantships. For 20 students, we expect more assistantships.

9. Response to External Reviews

External reviews (see Appendix A) were conducted by the following experts:

- Dr. Stephan Olariu (Computer Science Department, Old Dominion University)
- Dr. Sukhamay Kundu (Computer Science Department, Louisiana State University)
- Dr. Robert T. Brigantic (Operations Research Scientist, PNNL, and Adjunct Professor of Operations Research, Washington State University).

We greatly appreciate their time and effort in reviewing our proposal.

Dr. Olariu was very impressed with the overall quality of the faculty in the Computer Science Department at CWU as well as with the substantial impact the proposed program will have. He recommended special care in the periodical evaluations of the interdisciplinary courses.

We are aware of this problem and plan to review periodically the content and the assessments of these courses during the periodical curricular meetings, with all instructors involved. The advisory board will have a critical role in this effort. This is why members of the board should be interdisciplinary, both from academia and industry, and include out of state members. According to Dr. Olariu, including out of state members is an obvious necessity, since computational science programs are relatively rare and, especially during the development phase, the program should incorporate a national perspective to keep on track.

Dr. Brigantic is not familiar with the CWU computing facilities, but believes that "the capabilities seem sufficiently adequate to allow the initiation of the proposed Masters Degree program in Computational Science".

In order to answer this possible question, we have to mention that the College of Science has adequate computing facilities. The Computer Science Department alone hosts about 120 computers. The Geology

Department has, beside other computers, 20 Linux workstations and a high-performance 64-processor computer used in geological simulations. The Chemistry Department has several powerful workstations used in molecular modeling.

In previous years, the Computer Science Department has obtained access to some of the PNNL supercomputing capabilities. We plan to continue this strategy and implement some of the research projects in collaboration with PNNL.

In addition, we have received Letters of Support (see Appendix B) from the following executives:

- Steven Hagan, VP, Oracle
- Chee Chew, Director, Google Kirkland

The two letters clearly support our program.

10. Conclusion

CWU now has a chance to develop a unique multidisciplinary program, in the College of the Sciences. This program will be the first of its kind in the state, and will rely on the extensive expertise of academics in six different departments. This program will address the needs of the students by offering a very competitive cross-disciplinary degree, at a time where more and more graduates are expected to be proficient in more than one field. Our polls of students and alumni show that enrollment will follow with many students already expressing a strong interest.

The Master of Computational Science will also allow several departments to participate a graduate degree where none currently exists. This in turn, will enhance already strong research productivity and allow students to become involved in high-level research.

REQUIRED COURSE WORK
Part 1

Include this form with new degree program propsals. Staff will post this information and the program proposal on the HECB Web site during the public comment period.

Prerequisite Courses		
Course Number	**Course Title**	**Credits**
MATH330	Discrete mathematics	5
CS301	Data Structures	4
	Total Credits	**9**
Program Requirements		
Course Number	**Course Title**	**Credits**
CS528	Advanced data structures and algorithms	4
CS530	High-performance computing	4
CS529	Advanced algorithms for scientific computing	4
MATH565	Applied numerical methods I	5
MATH567	Applied numerical methods II	5
two electives		up to 10
Graduate Research		up to 10
Thesis/Project		5
	Total Credits	**45**

FORM 5

ENROLLMENT AND GRADUATION TARGETS
Part I

Include this form with a new degree program proposal or a Notice of Intent to extend an existing program. Staff will post this information to the HECB Web site during the comment period.

Year	1	2	3	4	5
Headcount	13	26	33	40	40
FTE	13	26	33	40	40
Program Graduates	0	13	13	20	20

Appendix A: External Reviews

OLD DOMINION UNIVERSITY
Department of Computer Science
College of Sciences · Norfolk, Virginia
23529-0162

January 5, 2011

Razvan Andonie, Professor
Computer Science Department
Central Washington University
Ellensburg, WA 98926, USA

Dear Professor Andonie,

I have now had time to evaluate the documents you submitted and to write a comprehensive review of the proposed MS program. I must say that I was very impressed with the overall quality of the faculty in the Computer Science Department *at* Central Washington University as well as with the substantial impact that the proposed program will have.

In summary, I wholeheartedly support your initiative and wish you all the best with its implementation.

Should you have any questions, please do not hesitate to get in touch with me

Yours sincerely,

Stephan Olariu
Professor of Computer Science
Old Dominion University
Norfolk VA
olariu@cs.odu.edu

Old Dominion University is an equal opportunity, affirmative action institution

Introduction

It is my pleasure to support the proposed MS program in Computational Sciences from the Computer Science Department at Central Washington University. The following document describes my review of program and my reasons for that support. The document includes the following sections: first a note describing my research interactions with one of the computer science faculty members at Central, this is followed by a short biographical sketch highlighting my background, a look at the program need and enrollment, a review of the program design and curriculum, a review of the faculty, a note on assessment, and finally, my conclusion.

Research Interactions

It is important to begin this evaluation by noting that from September 1986 through August 1998 Dr. Jim Schwing, the current chair of Computer Science at Central Washington, and I were both on the faculty here at Old Dominion University. Indeed, we worked on numerous projects together during that time resulting in many publications. However, since 1998 when Jim left Old Dominion, we published work in the pipeline (the last article appearing in 2001) and have not collaborated on any new work.

Regardless of this relationship, I believe that I have the background and perspective to give an honest evaluation of this program proposal.

Biographical Sketch

I have held many different roles and responsibilities as a member of numerous organizations and teams. Much of my experience has been with the design and implementation of robust protocols for wireless networks and in particular sensor networks and their applications. I am applying mathematical modeling and analytical frameworks to the resolution of problems ranging from securing communications, to predicting the behavior of complex systems, to evaluating performance of wireless networks. My research interests are in the area of complex systems enabled by large-scale deployments of sensors and more specifically in securing systems of systems.

I have been invited and visited more than 120 universities and research institutes around the world lecturing on topics ranging from wireless networks and mobile computing, to biology-inspired algorithms and applications, to telemedicine, to wireless location systems, and security. I have coauthored/edited five books including: *Solutions to Parallel and Distributed Computing Problems: Lessons from Biological Sciences* (with A. Zomaya and F. Ercal), Wiley and Sons, 2001, *Numerical Simulations and Case Studies*, (with S. Salleh, A. Zomaya and B.

Sanugi), Wiley and Sons, 2005. I have also published over 150 articles in archival journals and over 100 papers in conference proceedings.

I am an Associate Editor of *Networks* and *IEEE Transactions on Parallel and Distributed Systems* and serve on the editorial board of *Journal of Parallel and Distributed Computing, Journal of Ad hoc and Sensor Networks, and Parallel, Emergent and Distributed Systems.*

I have attached a more complete curriculum vita for your review.

Program Need and Enrollment

In my experience, one of the developing needs in graduate education in the STEM disciplines is that of interdisciplinary programs that fold together mathematical framework with an understanding of the highly computational problems that arise in modern scientific research and development. Despite this, programs that provide this focus are relatively rare nationally - indeed, internationally. I believe that the statement cited in the proposal from the President's Information Technology Advisory Committee (PITAC, 2005) which says that the lack of people trained in computational science is directly compromising US preeminence in science and engineering. is even more crucial today.

While I am less familiar with the state of Washington, I know that here in Virginia there is a strong demand for students trained with this background. And I know that this generally is a growing need across the country. Data presented in the proposal is convincing that this need is important to the state of Washington as well. Given the known need and the results of student surveys, I believe that the enrollment targets are modest.

Program Design and Curriculum

To bring some perspective to my comments here, let me note that I have been involved in the design and implementation of graduate curriculum at both the masters and doctoral level for the past twenty-four years. I have supervised 12 doctoral and 15 masters students over that time.

The proposal emphasizes three objectives: interdisciplinarity, modularity, and flexibility. I agree with the thrust of these objectives especially the first. Interdiscipliarlity, provides the linchpin to overall success. From my experience, and in all of the references citied in the proposal from the President's Commission, PITAC, to comments from the Society of industrial and applied Mathematics, the need in scientific computation is for people who have an acute understanding of computation (theory and practice) and the associated science.

The modularity and flexibility objectives help address the varied backgrounds and interests of potential students.

The curriculum calls for 45 quarter credits with 22 credits of core courses. First consider the core courses. The course in advanced data structures and algorithms will ensure that students have a good common understanding of basic computer science. The courses in advanced algorithms for scientific computing and high performance computing will ensure that students have an intimate knowledge of the state-of-the-art tools used in scientific computing. The course courses in numerical analysis will ensure that students have the basic theoretical underpinnings of numerical computation along with the basic algorithms used in solving typical scientific problems. Next, the interdisciplinary nature of the available electives will address the desire for the program to provide access to a diverse arena in scientific computing.

Given that it is expected that students will enter the program with a mixture of backgrounds from those with degrees computer science to science majors with only a computer science minor, it is essential that the core lay a firm basis for the work that will go on later and bring all students to a known minimum background. It appears to me that the computer science and mathematics core courses are designed with this in mind.

Given that the elective courses are offered by faculty within the specific discipline, the program continues to address one of its most important features - its interdisciplinary aspect. None the less, most of the elective courses seem to be designed with a dual purpose in mind - namely, meeting the needs of students pursuing masters degrees within the specific department and those students in the scientific computing masters degree. Care will need to be taken by the instructors that the needs of both sets of students are being met. To my mind this will require special assessment of these courses as they proceed.

The number of credits in the curriculum seems typical from my experience. The amount of core credits may at frist seem a little high but upon reflection is appropriate to the type of students expected to enroll in the program. I believe that the mix of core and elective courses along with a strong opportunity for research (as noted in the faculty section below) provides for a solid curricular design.

Faculty

To my thinking, faculty will form a critical component of a computational sciences program like this. The faculty must understand the broad interdisciplinary nature of such a program and appreciate both the mathematical and computational underpinnings to deliver an appropriate background and understanding to the students. With that in mind and as it was not included in the copy of the

proposal I received, I asked to see the vitae of the likely faculty participants in each of the participating departments.

Computer Science: Razvan Andonie, Ed Gellenbeck, Boris Kovalerchuk, and Jim Schwing.
Mathematics: Stephan Galsby and Dan Curtis.
Biological Sciences: Lixing Sun
Chemistry: Levente Fabry-Asztalos
Geological Sciences: Tim Melbourne
Physics: Andy Piacsek

All are active researchers (indeed in several cases world-class investigators) with extensive experience in the computational sciences. Indeed, I note that there is already joint work between the faculty of computer science, mathematics, geology, chemistry, and biology. I also note that all faculty are acttively engaged in research with students and that all have had experience mentoring graduate students. Indeed, three of the computer science faculty have mentored doctoral students.

With this strong track record, I believe that the base of the program would be in good hands. Clearly the faculty have the experience to develop and oversee this program.

Assessment

As noted above, I have helped design and implement graduate curricula for almost 25 years. The proposed assessment measures will provide important feedback to the program. As the program proceeds, I believe that two of these measures will provide critical feedback.

- Course evaluations will be used to examine course content nad the relevance of the content to the larger program.

We plan to create an advisory board which will annually assess the effectiveness of the program. Members of the board should be from academia and industry. The advisory board should include out of state members.

The first of these measures will be extremely important. As I noted in the section on program design and curriculum, most of the discipline-specific courses seem to be designed with a dual purpose, to serve both the discipline-specific masters program and the computational science masters program. As I noted the has both pro and con aspects, but this assessment will be important to ensure that these courses continue to address the important aspects of computational applications.

The inclusion of the second point noted should be of obvious necessity -

computational science programs are relatively rare and as such especially during the development phase, the program should incorporate a national perspective to keep it on track.

Conclusion

In summary then, I find that the proposed program clearly addresses an important neec for the country - one that will find many opportunities for graduates in government and industry. In addition, I find that the program design is well conceived and that the courses, both core and elective, should provide students with a solid background and opportunities for both applications oriented work and research. Finally, I find the faculty to be highly qualified for a program of this type and complexity. In conclusion, I recommend approval of this program as proposed.

Stephan Olariu
Professor of Computer Science
Old Dominion University
Norfolk, VA 23529

January 2011

LOUISIANA STATE UNIVERSITY

College of Basic Sciences
Computer Science

02 Dec 2010

Prof. B. Kovalerchuk
Computer Sc. Dept.
Central Washington University
Ellensburg, WA 98926

Dear Prof. Kovalerchuk:

Please find enclosed the review-report of your proposed MS program in Computational Science. It is a good proposal.

Sincerely yours,

Sukhamay Kundu
Computer Science, LSU

Computer Science • 298 Coates Hall • Baton Rouge, LA • 70803 • 225-578-1495 • Fax 225-578-1465 • www.csc.lsu.edu

Review of
Computational Science Master Program Proposal
Central Washington University (CWU), College of Sciences

by

Dr. Sukhamay Kundu
Computer Sc. Dept. Louisiana State University
Baton Rouge, LA 70803

1. **Overall assessment;**
   This is a well-thought out and well-designed MS program in Computational Science to meet both the industry needs and preparing students for further advanced degree (PhD) in Computational Science. The CWU is well positioned to initiate this MS degree program in Computer Sc dept, with the cooperation of Biology, Chemistry, Geology, Mathematics, and Physics depts. Each of these disciplines has major applications of Computational Science and will both benefit from and contribute to the strength of the proposed Computational Science MS program.
2. **Program Size:**
   The program size (starting with 13 students in 1st year and aiming at 20 students in 3 years) looks achievable based on the survey of students' interests during 2008-2010.
3. **Program's Credit Requirement:**
   The total 45 credit required for the MS degree (22 for core courses, 18 for electives, and 5 for thesis/project, of which 25 or more being at courses numbered 501) is balanced and is consistent with other MS programs at CWU.
4. **Program's Curricula:**
   The spread of the required courses in Computer Science and Mathematics together with that of the elective (specialization) courses in Biology, Chemistry, Computer Science, Geology, Mathematics, and Physics will provide sufficient breadth and depth for a well-balanced degree program in Computational Science.
5. **Faculty Research Strength in Computational Science:**
   Many faculty in the various departments participating in the proposed MS program has strong research interests in Computational Science area of Computational Sciences. This adds to the strength of the proposed MS program.
6. **Adequacy of Computing facility:**
   The CWU has reasonable computing facility to initiate the proposed MS degree program in Computational Science. (Additional computing facility in future can be a boost to expand the proposed MS program.)

Kundu
2 Dec 2010

Short Biography of Dr. Sukhamay Kundu:

Computer Science Dept.
Louisiana State University, Baton Rouge, LA 70803, USA
Tel: (225) 578-2246, fax: (225) 578-1465, email: kundu@csc.lsu.edu

RESEARCH EXPERTISE

Software engineering; Distributed Algorithms; Efficient graph algorithms; Machine learning and Data mining.

EDUCATION

Ph.D.	Math.	University of California, Berkeley	1971
M.S.	Probability & Statistics	Indian Statistical Inst., Calcutta (rank: 1st Class 1st)	1967
B.S.	Math. (Hons.)	Burdwan University, W.Bengal, India (rank: 1st Class 2nd)	1965

FULBRIGHT AWARD

- Fulbright award for Lecturing in Sofwtare Engineering and Networking (Indian Ins titute of technology, Kharagpur), 2004.
- Fulbright award for Lecturing in Artificial Intelligence (Indian Institute of Ma nagement, Kolkata and Indian Institute of Statistics, Kolkata), 1994.

NATO ADVANCED STUDY INSTITUTE

Lectured on Fuzzy Sets at the ASI meeting on Computational Intelligence, 1996.

ACM NATIONAL LECTURER

ACM National Lecturer for 1988-1990 in Artificial Intelligence.

TEACHING EXCELLENCE AWARD

Graduate teaching-excellence award in the College of Basic Sciences, Louisiana State University, 1992.

INNOVATIVE-TEACHING AWARD

Service-Learning Faculty Scholar award, Louisiana State University, 2009.
Innovation-in-teaching award, Louisiana State University, 1995.

RECENT VISITING FACULTY POSITIONS HELD

Sprg. 10	Visiting Professor at Indian Institute of Technology at Patna, India. Offered a 2-week intensive course of Software Engineering.
Sprg. 08	Visiting faculty at Mararishi University of Management, Iowa, USA. Offered 2-week intensive course on Algorithm Design and Analysis.
Sum. 06	Visiting faculty at University of West Indies, Jamaica. Offered 4-week course on Database.
Sum. 05	Visiting faculty at University of West Indies, Jamaica Offered 4-week course on Database.
Sum. 01	Visiting Professor at Kyungpook National University, Korea..RE

JOURNAL PUBLICATIONS

- More than 50 refereed Journal publications, including Pattern Recognition, SIAM J. of Computing, Information Processing Letters, Communications of ACM, Journal of Theoretical Computer Science, IEEE Trans. on Software Engineering, J. of Experimental and Theoretical Artificial Intelligence, J. of Intelligent Information Systems, J. of Combinatorial Thoery, Fundamenta Informaticae, Fuzzy Sets and Systems, etc.

CONFERENCE PUBLICATIONS

- More than 75 refereed conference publications in major International and national conferences.

Dec 2010

Review of Computational Science Master Program Proposal, Central Washington University (CWU), College of Sciences

Submitted by

Dr. Robert T. Brigantic
Operations Research Scientist and Adjunct Professor of Operations Research, Washington State University
Richland, WA 99352
Robert.Brigantic@pnl.gov

1. Overall assessment:
I wholeheartedly endorse this proposed Masters program in Computational Science at CWU. This program is designed to help meet current needs and the anticipated demand in both industry and government computer science areas. Moreover, the program will help to prepare and satisfy prerequisites for students wishing to pursue a Ph.D. in Computational Science. Other significant programs (e.g., Biology, Chemistry, Geology, Mathematics, and Physics) at CWU are also supportive of the initiation of this Masters Degree program. All of these programs have clear cut applications and needs in the computational science domain, and thus, this program will contribute to the strength of the university as a whole.

2. Program Size:
The proposed initial program size in terms of student load and planned goals in growth over a 3 year timeframe are reasonable and are also consistent with recently completed student surveys.

3. Program's Credit Requirement:
The total credit requirement for the award of the Masters Degree in Computational Science is well thought out and seems to be consistent with other Masters programs at CWU and other universities that I am familiar with.

4. Program's Curricula:
I am pleased with the mix of required courses in computer science and mathematics at CWU and believe this is on target to a successful program that can meet user needs for this degree. Moreover, the offered the electives for a specialization area provide a well suited mix of coverage areas and specialized depth.

5. Faculty Research Strength in Computational Science:
I am familiar firsthand with some of the outstanding faculty at CWU in this proposed degree program and believe they are of national/international caliber and recognition, with a mix of research and teaching aptitude that will fully enable the program to succeed.

6. Adequacy of Computing Facility:
I am personally not that familiar with the CWU computing facilities, but do believe the capabilities seem sufficiently adequate to allow the initiation of the proposed Masters Degree program in Computational Science.

Signed,

Dr. Robert T. Brigantic

DR. ROBERT T. BRIGANTIC (PI) is an Operations Research Scientist specializing in modeling and simulation, statistical pattern recognition, artificial intelligence, imagery analysis, design of experiments, and optimization. His research is focused on operational modeling and simulation of pandemic diseases and associated impact/effectiveness analyses; operational modeling and simulation of radiation/nuclear screening processes (e.g., passengers screening at airports and small vessels in maritime domain); and imagery analysis and automated target detection methods (e.g., feature extraction and automated conflation). Dr. Brigantic holds a Ph.D. in Operations Research from the Air Force Institute of Technology, an M.S. in Space Operations from the Air Force Institute of Technology, and a B.S. in Chemical Engineering from Oregon State University. He also serves as an adjunct professor of Operations Research with Washington State University and the Air Force Institute of Technology.

Appendix B: Letters of Support from Employers and Professionals

November 22, 2010

Professor James Schwing
Central Washington University
400 E. University Avenue
Ellensburg, WA 98926

Dear Professor James Schwing,

It was good to hear you received the Oracle Spatial book; I hope it is valuable to CWU students.

I read with great interest your Notification of Intent for an MS in Computational Science. This is an excellent idea and should be implemented.

As you describe, the volume of data being collected in the scientific world, for both the hard and soft sciences, is increasing exponentially and shows no sign of abatement. Sensors and image generation systems, as well as LIDAR, are being adopted ever more widely as costs of the devices lowers and resolutions increase. Key enablers are that the costs of computation continue to drop with Moore's law, along with the costs of persistent storage, and the flavors of storage are increasing.

These hardware trends cause a continuing demand for computer scientists to develop algorithms to effectively use these new technologies. However the knowledge and skills from several of the domains you describe (Imaging, Genomics, Proteomics, Environmental Studies, Pharmaceuticals, and statistics / Bioinformatics) are key to effective algorithm development – most computer scientist no longer operate in a purely role, abstracted from the end usage.

I always recommend to all computer oriented students to attain at least a masters degree prior to going to industry or government activities / employment, and having domain knowledge in addition to base computer science skills is a major plus in the eyes of hiring organizations. CWU students with the skills and knowledge in the proposed curriculum will do well in the industrial world; this should be true for at least the next few decades.

Yours Truly,

Steven R Hagan
Vice President Engineering
Oracle Corporation

Google Inc.
747 6th Street South
Kirkland, WA 98033

Main 425.739.5600
Fax 425.739.5601
www.google.com

Google

November 10, 2010

To: The Washington Higher Education Coordinating Board

The computer industry continues to rapidly advance in computational power and storage capacity. From the health industry, to transportation, to retail sales, to aerospace, to government services, virtually all modern industries and services are leveraging technology advancements to collect vast amounts of data. In many ways, our ability to maximize the knowledge we can learn from this data is not limited by computational power or the ability store and manipulate vast amounts of data. Industries are increasingly limited by the lack of knowledge of how to properly leverage our technology to model and analyze the data properly in context.

Years ago, we realized the symbiotic value of computer science with disciplines such as mathematics and physics. The computer's ability to handle complex algorithms quickly and accurately has unquestionably accelerated the work of mathematicians and physicists, among others. In return computer science has also benefited in numerous areas such as video and audio processing, data compression, physics engines, virtual reality, language processing, etc.

Looking forward, computational sciences offers a similar benefit when paired with a wide range of professional disciplines. At Google, we believe firmly in this principle and invest heavily in data processing, analysis and modeling. We see benefits in understanding things ranging from health trends to purchasing behaviors. Developing degree programs that intentionally target professional development in computational sciences, such as that proposed by CWU, will be valuable in a wide range of industries.

Chee Chew

Chee Chew
Engineering Director
Google Kirkland

FORM 6

PROGRAM PERSONNEL

To obtain program personnel information, please contact Mark Bergeson at 360-753-7881 or markb@hecb.wa.gov

FORM 7

SUMMARY OF PROGRAM COSTS AND REVENUE

To obtain program cost and revenue information, please contact Mark Bergeson at 360-753-7881 or markb@hecb.wa.gov