

AGENDA ITEM SUMMARY

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University of Central Missouri Program Proposal
Coordinating Board for Higher Education
December 14, 2017

DESCRIPTION

The University of Central Missouri (UCM) has submitted a proposal to offer a baccalaureate degree in software engineering. This agenda item is submitted to the Coordinating Board for Higher Education (CBHE) for its consideration and possible action.

Background

Section 173.005 of Missouri Revised Statutes assigns the Coordinating Board for Higher Education responsibility for approval of new degree programs offered by the state institutions of higher education. The Board exercises this authority through the Missouri Department of Higher Education (MDHE) and the rules promulgated in 6 CSR 10-4.010, currently being revised (see Tab K)

MDHE staff reviewed a similar proposal from UCM in November 2016. Staff determined, based on the information submitted, the program would unnecessarily duplicate existing programs. Additionally, other institutions raised concerns about program delivery within the Kansas City metropolitan area, particularly as discussions were being held to revise the academic program approval process as part of the Higher Education System Review. UCM submitted to the MDHE in June a revised proposal, one that provided additional information regarding program demand and addressed concerns raised about the initial proposal.

MDHE staff concluded it did not have the requisite expertise and enough information to recommend approval of the proposal, and recommended an external review of the proposal to determine both the actual need for the program and the capacity of existing programs to meet that demand. MDHE and UCM both agreed to the use of external consultants, and UCM agreed to pay for the services of the consultants. These consultants' reports will be considered as part of UCM's proposal to offer the program.

Parameters for External Consultants

MDHE staff provided UCM with guidelines regarding the external consultants' scope of work. The consultants were asked to address the following questions:

- a. Is there sufficient student demand for the proposed program? Do institutions with existing programs have the capacity to satisfy student demand?
- b. Is there a demonstrated occupational or work force need that existing programs cannot satisfy?
- c. If approved, would the proposed program serve students that existing programs have not or cannot serve? If yes, is access to existing programs limited by geography? Costs? Preparation? Other factors?

UCM, in consultation with MDHE staff, contracted with the following consultants:

- Dr. Thomas B. Hilburn, Professor Emeritus in the Department of Electrical, Computer, Software, and System Engineering College of Engineering at Embry-Riddle Aeronautical University, contracted to assess the market demand for the program in the region, as well as the capacity of existing programs to meet that need. Dr. Hilburn's report is included as an attachment; his curriculum vitae is on file with the MDHE.
- The Educational Advisory Board Company (EAB) is conducting a market demand analysis of software engineering need in the region and state. EAB reports typically rely on market data from Burning Glass Labor/Insight tool, JobsEQ tools, U.S. Census Bureau, and Bureau of Labor

Statistics. EAB will submit its report to UCM and MDHE by December 8, 2017. Upon receipt, MDHE will share the report with the larger academic community.

Representatives of UCM will appear before the CBHE Academic Affairs & Workforce Needs Committee on December 13 to discuss the proposed program. Representatives of other institutions may also provide information at the meeting.

Discussion of Pertinent Issues

This proposal raised several complicated issues for MDHE staff to consider during its review.

1. **Mission.** UCM argues an engineering program with CIP (Classification of Instructional Program) number of 14 is an “applied science,” which aligns with its statewide mission in the “applied sciences and technology.” MDHE staff considers engineering programs generally to be outside of any institutions’ mission, except for the University of Missouri. This does not preclude UCM from submitting a proposal for an engineering program. The revised academic program approval process directly addresses proposals for new engineering programs as outside of the mission of all institutions but the University of Missouri.

UCM specifically asked Dr. Hilburn to address this question, and he generally supports UCM’s view. While mission remains an important element of program review, in this instance, it is not the sole or even primary concern.

2. **Duplication of existing programs.** The University of Missouri-Columbia (UMC) and the University of Missouri-Kansas City (UMKC) offer programs that are similar to the one proposed by UCM. Dr. Hilburn notes that no other Missouri university offers a bachelor’s degree in software engineering. He makes a compelling case that UCM’s program, particularly its curriculum, is distinct from those offered by UMC and UMKC. Curricular distinctiveness alone, however, is not enough to demonstrate unnecessary duplication. Another factor to consider is UMKC and UMC have different price points than does UCM, which is not an insignificant consideration.

The mere existence of a program in a given area is insufficient to justify denying the approval of a similar, perhaps even duplicative, program. The state’s investment in certain programs requires that thoughtful consideration be given to the impact a new and similar program would have on existing programs. However, if current programs do not have the capacity or the intent to satisfy the societal and occupational need for the degree, then a similar program would not unnecessarily duplicate the existing programs. Dr. Hilburn’s report does not adequately address the capacity of current programs to meet demand.

3. **Demand.** UCM believes there is strong demand—among students and employers—for software engineers, a belief that is supported by Dr. Hilburn. Unemployment rates for applications, systems, and software developers, in Missouri and in Kansas City, are very low. Location quotients—which measure local employment needs relative to the rest of the nation—are higher in Kansas City than in the rest of Missouri, which is a reasonable measure of actual need (see Table 3 in Hilburn Report). Projected growth rates are modest.

What is missing from Hilburn’s report is an assessment of what capacity existing programs have to meet employer and student demand. Complicating the picture is the fact that many job postings for “software engineer” do not require a degree in software engineering. A cursory search for “software engineer” on leading job websites (Indeed.com and Monster.com, for example) returned more than 1,000 results. A closer examination, however, reveals that most of the posts for software engineers require a bachelor’s degree in a computer science field or several years of equivalent work experience. In other words, a degree in software engineering does not appear to be—at the present time, at least—a prerequisite to finding work as a software engineer.

MDHE staff believe the market demand analysis being conducted by EAB will provide a much clearer picture of the actual demand in the Kansas City region for workers with degrees in software engineering. EAB's report is due to UCM and MDHE on December 8, 2017.

STATUTORY REFERENCE

Sections 173.005.2(1), 173.005.2(8), 173.005.11, 173.030(1), and 173.030(2), RSMo – Statutory requirements regarding CBHE approval of new degree programs

RECOMMENDED ACTION

MDHE staff will refrain from making a recommendation on the proposal submitted on behalf of the UCM to offer a baccalaureate degree in software engineering until it has received and reviewed the market demand analysis being prepared by EAB.

ATTACHMENT(S)

Attachment A: UCM program proposal

Attachment B: Report on University of Central Missouri Software Engineering Program (Hilburn)



NEW PROGRAM PROPOSAL FORM

Sponsoring Institution(s): University of Central Missouri

Program Title: Software Engineering

Degree/Certificate: Bachelor of Science

Options: None

Delivery Site(s): Main Campus in Warrensburg, Missouri and Central Summit Campus in Lee's Summit, Missouri

CIP Classification: 14.0903

Implementation Date: Fall 2018

Cooperative Partners: None

AUTHORIZATION:

Dr. Kim Andrews, Vice Provost for Academic Programs and Services



06/16/2016

Name/Title of Institutional Officer

Signature

Date

Dr. Xiaodong Yue, yue@ucmo.edu

660-543-4930

Person to Contact for More Information

Telephone

Rationale for the B.S. in Software Engineering Program

Over the past thirty years, the practices of everyday life have become increasingly infused with and mediated by software. The capacities and growing pervasiveness of software make it the lifeblood of today's emerging information society. Software is shaping our world from all aspects of our lives, from the launch of billion-dollar spacecraft to more mundane work such as measuring and displaying time, controlling traffic lights, and monitoring the washing of clothes. Indeed, whatever the task-domestic chores, paid work, shopping, traveling, communicating, governing, playing - software increasingly makes a difference as to how social and economic life takes place, and enables members of society to work more efficiently. To maintain a competitive edge, industry and commerce continue to make creative engineering advances as well as produce high quality products. More than ever, there is a demand for a highly prepared work force with Software Engineering training that is enabled to deliver quality software and innovation. The proposed B.S. in Software Engineering program will prepare our students in a much-needed area and is well aligned with the University of Central Missouri's mission of preparing students with the knowledge, skills and confidence to succeed and lead in the region, state, nation and world.



STUDENT ENROLLMENT PROJECTIONS

Year	1	2	3	4	5
Full Time	15	25	35	45	55
Part Time	5	5	5	5	5
Total	20	30	40	50	60

Please provide a rationale regarding how student enrollment projections were calculated:

Due to the high market demand in the region and an insufficient number of software engineers available to fill the open positions, the program is expected to grow and achieve the above projection. In addition, as shown in Table 6, the average enrollment of several ABET accredited Software Engineering programs from master level institutions is more than 100, we expect a similar enrollment for the proposed program. ABET is an internationally recognized accrediting body for colleges and universities programs in the disciplines of applied science, computing, engineering, and engineering technology.

Provide a rationale for proposing this program, including evidence of market demand and societal need supported by research:

Background

In the decades since the 1960s, Association of Computing Machinery (ACM), along with leading professional and scientific computing societies, has endeavored to tailor curriculum recommendations to the rapidly changing landscape of computer technology. Computing Curricula 2005: The Overview Report, published by ACM in 2005, provides undergraduate curriculum guidelines for five defined sub-disciplines of computing [1]. Table 1 lists the definitions for Computer Science, Computer Engineering and Software Engineering. While computer engineering emphasizes on hardware and computer science (like other sciences) focuses on creating new knowledge, software engineering (like other engineering disciplines) focuses on rigorous methods for designing and building things that reliably do what they're supposed to do. In addition to its computer science foundations, software engineering also involves human processes that, by their nature, are harder to formalize than are the logical abstractions of computer science. Experience with software engineering courses within computer science curricula showed many that such courses can teach students about the field of software engineering but usually do not succeed at teaching them how to be software engineers [1].



Table 1 Definition for Computer Science, Computer Engineering and Software Engineering - Computing Curricula 2005: The Overview Report [1]

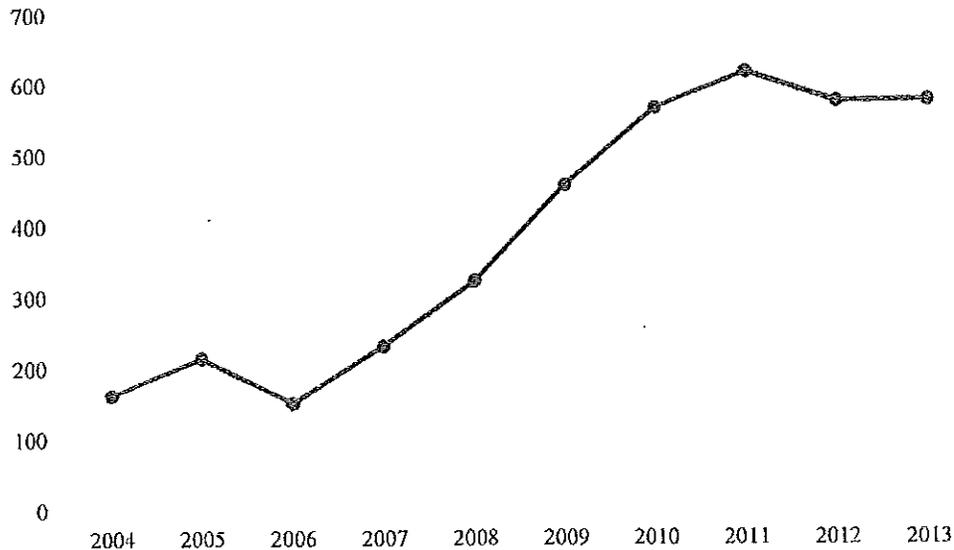
Computer Science	Software Engineering
Computer Science spans a wide range, from its theoretical and algorithmic foundations to cutting-edge developments in robotics, computer vision, intelligent systems, bioinformatics, and other exciting areas.	Software Engineering is the discipline of developing and maintaining software systems that behave reliably and efficiently, are affordable to develop and maintain, and satisfy all the requirements that customers have defined for them.
Computer Engineering	
Computer engineering is concerned with the design and construction of computers and computer-based systems. It involves the study of hardware, software, communications, and the interaction among them. Its curriculum focuses on the theories, principles, and practices of traditional electrical engineering and mathematics and applies them to the problems of designing computers and computer-based devices.	

The history of Software Engineering education is a story of academics struggling to fulfill industry needs with little support from computer science curriculum designers [2]. Most practicing software engineers do not have a degree in Software Engineering, but rather in Computer Science and some other related discipline. In the United States, degree programs in software engineering, designed to provide a more thorough foundation than can be provided within computer science curricula, began to emerge during the 1990s. The Department of Education published data regarding the number of students receiving a bachelor's degree in Software Engineering in the Digest of Education Statistics [3]. The report shows an upward trend (see Figure 1 below).

Figure 1 The Number of Students Receiving a Bachelor's Degree in Computer Software Engineering (source: Digest of Education Statistics).



B.S. in Software Engineering Graduates



While these statistics indicate solid growth in the number of bachelor's degrees granted, the number of Software Engineering graduates is still extremely small when compared with the number of software engineers needed in the workforce. Details regarding market demand are described in the next section.

In 2004, the Institute of Electrical and Electronics Engineers (IEEE) Computer Society published The Guide to the Software Engineering Body of Knowledge (SWEBOK) which describes generally accepted knowledge about software engineering, and continuously revised and updated to the most recent version SWEBOK 3.0 in 2014 to accompany the change of practices, body of knowledge, etc. [4]. In order to create curriculum recommendations in several computing disciplines including Software Engineering, the ACM Education Board and the IEEE Computer Society also prepared the undergraduate curriculum guidance on software engineering (SE2004 & SE2014) [5] for institutions of higher education.

Due to the high demands for software engineers, the School of Computer Science and Mathematics at the University of Central Missouri (UCM) is requesting approval for a new program, a B.S. in Software Engineering degree. The proposed addition is important to the UCM School of Computer Science and Mathematics' continuing efforts to enhance its contributions to prepare the 21st century technical workforce in a STEM field of national interest.

Market Demand

This program will be the first of its kind in Missouri to cater to the growing market demand of skilled software engineering professionals. A quick job search on June 12, 2017 on *indeed.com* for software engineer returned 2718 open positions in Missouri, just for the month of June alone, many of which are in the St. Louis and Kansas City area [6].

The job outlook for software engineers is very positive. Growth will increase much faster than average compared to other U.S. occupations. The demand is expected to increase due to a large

need for computer software used in industries like mobile technology and healthcare computer systems [7].

According to The Bureau of Labor Statistics [8], the overall employment of software engineers is projected to grow by 17 percent from 2014 to 2024. In particular, employment of applications software developers is projected to grow 19 percent, and employment of systems software developers is projected to grow 13 percent.

The following are the employment projections for different software developers [8]:

- Applications Software Developers: 2014 employment – 718,400; projected 2024 employment – 853,700; 19% change from 2014-2024
- Systems Software Developers: 2014 employment – 395,600; projected 2024 employment – 447,000; 13% change from 2014-2024

Figure 2 Total U.S. STEM Jobs Through 2024, U.S. Bureau of Labor Statistics [9]

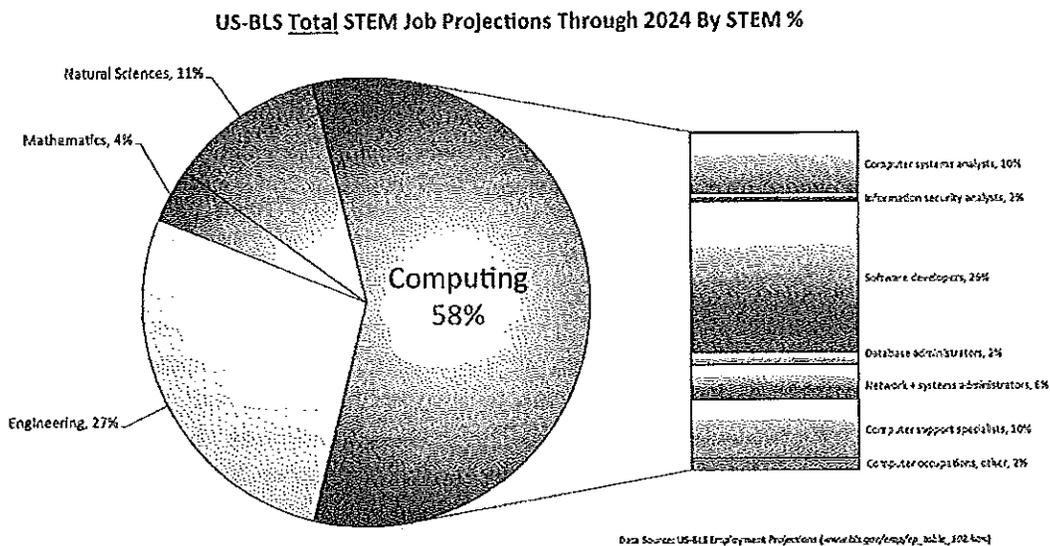
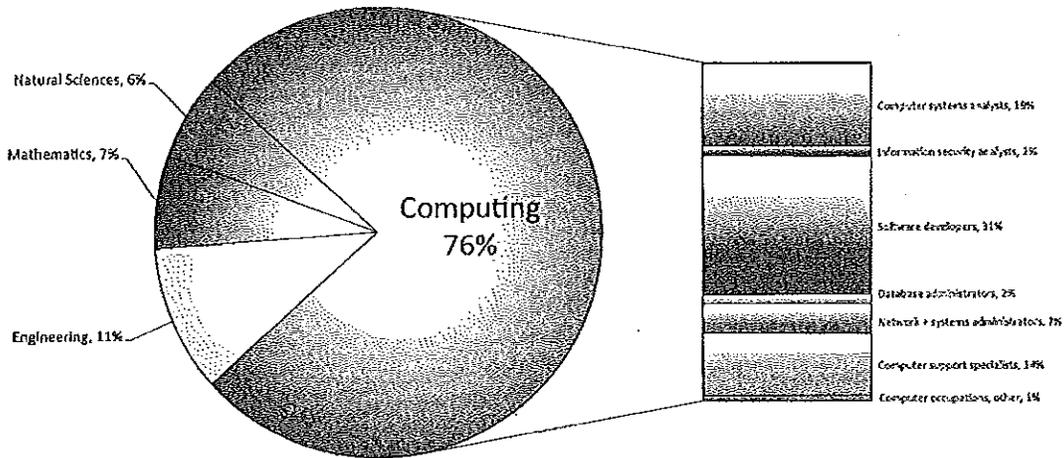


Figure 2 shows the distribution of total U.S. STEM jobs through 2024. 58% of total STEM jobs in U.S. are computing related. Among all computing jobs, 26% of the jobs are in software development. In other words, there will be nearly as many openings in software development as there will be in all the branches of traditional engineering combined [9]. Figure 3 shows the distribution of U.S. new STEM jobs through 2024. There is an expectation that 76% of new STEM jobs in U.S. will be computing related. As can be seen in the chart, the U.S. Bureau of Labor Statistics is predicting 31% of the new STEM jobs will be in software development (aka software engineering) alone as compared to 11% in the combined branches of traditional engineering.

Figure 3 U.S. New STEM Jobs Through 2024, U.S. Bureau of Labor Statistics [9]

US-BLS New STEM Job Projections Through 2024 By STEM %



Data Source: US-BLS Employment Projections (www.bls.gov/emp/prog_102400)

Table 2 lists the top 10 occupations in US with the most openings 2014-2024. Applications software developer is ranked No. 6. Similar to the national trend, applications software developer is ranked No. 8 in Missouri for the top 10 occupations with the most openings 2012-2022.

Table 2 Top 10 Occupations with the Most Openings in US, 2014-2024 (www.careerinfonet.org)

#	Occupation	Employment 2014	Projected Annual Job Openings
1	Registered Nurses	2,751,000	108,840
2	General and Operations Managers	2,124,100	68,880
3	Accountants and Auditors	1,332,700	49,800
4	Elementary School Teachers, Except Special Education	1,358,000	37,870
5	Secondary School Teachers, Except Special and Career/Technical Education	961,600	28,400
6	Software Developers, Applications	718,400	23,800
7	Management Analysts	758,000	20,850
8	Computer Systems Analysts	567,800	19,160
9	Middle School Teachers, Except Special and Career/Technical Education	627,500	17,550
10	Financial Managers	555,900	16,930

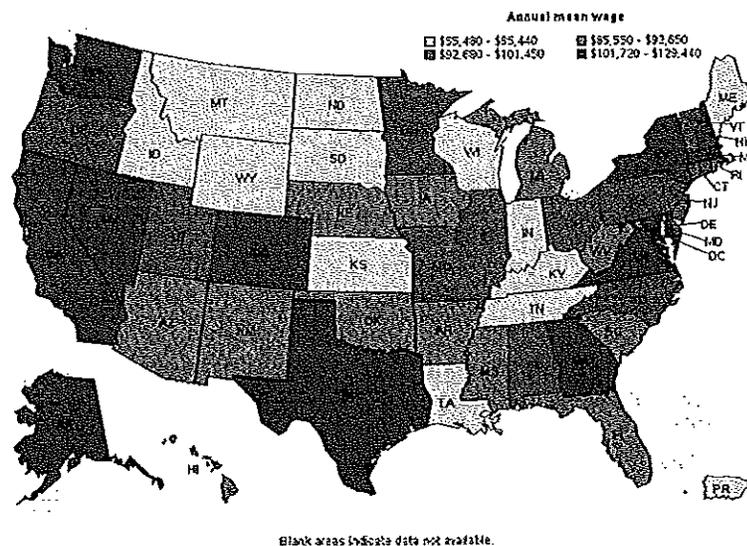
Table 3 Top 10 Occupations with the Most Openings in Missouri, 2012-2022 (www.careerinfonet.org)

#	Occupation	Employment 2012	Projected Annual Job Openings
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1	Registered Nurses	66,970	2,100
2	General and Operations Managers	53,130	1,500
3	Accountants and Auditors	25,850	1,090
4	Elementary School Teachers, Except Special Education	23,150	750
5	Secondary School Teachers, Except Special and Career/Technical Education	19,970	610
6	Middle School Teachers, Except Special and Career/Technical Education	13,910	450
7	Computer Systems Analysts	10,950	390
8	Software Developers, Applications	11,750	320
9	Cost Estimators	5,010	280
10	Coaches and Scouts	6,830	270

Figure 4 shows the most recent annual mean wage of applications software developers by state published by the U.S. Bureau of Labor Statistics. The mean salary in Missouri is \$92,680-\$101,450.

Figure 4 Annual Mean Wage of Applications Software Developers, by State, May 2016, US
 Bureau of Labor Statistics (<https://www.bls.gov/oes/current/oes151132.htm>)
 Annual mean wage of software developers, applications, by state, May 2016



Career website Glassdoor cross-referenced its salary data with official cost of living figures from the federal government to see where tech industry salaries go the furthest [10]. Table 4 below ranks each city by their salary, which takes into account the cost of living. Software Engineers earn a higher salary compared with some other jobs in similar areas. Two cities in Missouri, St. Louis and Kansas City, ranked No. 6 and No. 28 among the best cities in the US to be a software engineer.



Moreover, the information technology industry in Missouri continues to grow. As a matter of fact, software is one of Missouri's information technology industry's three niches [11]. Specifically, the Kansas City area has many IT related companies. For example, Cerner anticipates a large expansion of its Kansas City workforce over the next 10 years that will involve hiring thousands of software engineers [12] [13]. According to the most recent (December 2016) Information Technology Industry Real Time Labor Market Summary published by the Missouri's Economic Research and Information Center (MERIC) [14], there were over 1,500 job postings in the Information Technology Industry for the previous 6 month period in Missouri. The top occupation was Applications Software Developers. In another report [15] published by MERIC titled 2016 STEM Labor Demand Analysis, the top STEM job ads for the Missouri Workforce Development Area (WDA) regions were mostly Applications Software Developers.

Table 4 Salary Data with Official Cost of Living Rank

Metro Area	Cost of Living Index	"Real" Soft. Eng. Salary \$	Rank	"Real" Prog. Analyst Salary	Rank	"Real" Sys. Admin. Salary	Rank
Seattle, WA	107.0	107,540	1	79,945	6	72,639	10
San Jose, CA	122.0	107,121	2	73,387	14	84,530	1
Raleigh, NC	95.2	102,950	3	87,131	2	71,758	12
Portland, OR	100.5	101,592	4	72,687	18	70,635	16
San Francisco, CA	121.3	101,006	5	78,439	7	81,162	2
St. Louis, MO	88.9	97,821	6	83,585	3	80,271	3
Denver, CO	104.3	97,442	7	93,783	1	72,893	9
Atlanta, GA	95.6	95,519	8	73,222	15	77,797	5
Austin, TX	98.5	95,262	9	72,710	17	62,509	27
Boston, MA	111.6	94,717	10	69,256	26	72,275	11
Dallas, TX	101.0	94,417	11	74,505	12	75,817	6
Phoenix, AZ	99.7	93,649	12	77,056	9	70,729	15
Pittsburgh, PA	93.4	92,981	13	74,116	13	70,752	14
San Diego, CA	119.0	90,739	14	84,813	28	82,511	28
Columbus, OH	93.8	90,616	15	81,636	5	74,017	6
New York, NY	122.2	90,543	16	70,296	23	66,841	21
Los Angeles, CA	118.2	90,421	17	69,914	24	67,948	18
Chicago, IL	106.8	89,027	18	72,094	19	67,397	20
Tampa, FL	99.4	88,658	19	77,594	8	63,684	25
Miami, FL	105.0	88,487	20	71,734	22	64,099	23
Houston, TX	100.7	88,450	21	73,087	16	61,878	28
Minneapolis, MN	103.0	87,998	22	69,318	25	84,717	22
Baltimore, MD	109.4	87,887	23	65,360	27	71,386	13
Philadelphia, PA	106.0	87,030	24	71,828	20	70,252	17
Orlando, FL	98.0	86,735	25	74,851	11	63,856	24
Detroit, MI	97.8	86,578	26	75,435	10	74,530	7
Washington, DC	120.4	84,801	27	71,779	21	67,841	19
Kansas City, MO	92.7	79,585	28	82,183	4	77,923	4

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Source: Glassdoor Economic Research; U.S. Bureau of Economic Analysis. Salaries are inflation-adjusted median total compensation reported on Glassdoor from 2010 to June, 2015 [10].

In addition, Software Engineer is ranked No. 8 among the best jobs of 2015 [16], and has a high growth outlook. Software engineers are in high demand. Skilled software engineers are well paid and rarely have trouble finding work. The unemployment rate for this career is consistently below the national average [17]. According to the Best Computer Careers Reviews in 2016 [17], software engineer is ranked No. 1 among top ten computer careers. The detailed comparison is shown in Table 5.

Table 5 Software Engineer Ranked No. 1 Among Top Ten Computer Careers

Career	Overall Rating	Salary	Opportunity	Education	Work Environment
Software Engineer	10.00/10	10.00/10	10.00/10	10.00/10	10.00/10
Systems Analyst	9.40/10	9.38/10	8.75/10	10.00/10	10.00/10
Network Security Specialist	8.73/10	9.38/10	8.75/10	8.75/10	9.38/10
Network Architect	8.53/10	10.00/10	6.88/10	8.13/10	9.38/10
Database Administrator	8.07/10	8.75/10	6.25/10	8.75/10	9.38/10
Network Administrator	7.95/10	8.75/10	5.88/10	8.75/10	9.38/10
Web Developer	7.82/10	8.13/10	6.50/10	8.13/10	10.00/10
Computer Tech Support	6.60/10	7.50/10	7.50/10	3.13/10	9.38/10

Student Demand

Currently there are approximately 60 undergraduate software engineering programs in the United States [18]. The number of programs is growing steadily (compared with about 40 undergraduate software engineering programs in 2011). The enrollments and graduates are growing steadily, too [19]. The following table lists the enrollment of several ABET accredited Software Engineering programs from master level institutions. Considering the overall student population for each institution, the software engineering enrollment is strong in all those institutions. It is also worth



mentioning that all those institutions also offer a BS in Computer Science. These figures demonstrate that Software Engineering is a viable undergraduate program in the US which has a strong, consistent and increasing student demand.

Considering that there is no existing undergraduate software engineering program in Missouri and Kansas while the demand for software engineers is very high, we anticipate there will be strong student demand for such a program.

Table 6 Enrollment of Several ABET Accredited Software Engineering Program from Master Level Institutions

Institution Name	Enrollment
California Polytechnic State University, San Luis Obispo	180
Clarkson University	34
Embry-Riddle Aeronautical University - Daytona Beach	53
Kennesaw State University	207
Milwaukee School of Engineering	214
Monmouth University	70
Pennsylvania State University, Behrend College	55
Rochester Institute of Technology	492
Rose-Hulman Institute of Technology	133
University of Michigan - Dearborn	134
University of Wisconsin - Platteville	183

Societal Need

Over the past thirty years, the practices of everyday life have become increasingly infused with and mediated by software. The capacities and growing pervasiveness of software make it the lifeblood of today's emerging information society. Software is shaping our world from all aspects of our lives, from the launch of billion-dollar spacecraft to more mundane work such as measuring and displaying time, controlling traffic lights, and monitoring the washing of clothes. Indeed, whatever the task- domestic chores, paid work, shopping, traveling, communicating, governing, playing - software increasingly makes a difference to how social and economic life takes place, and enables members of society to work more efficiently [20]. To maintain a competitive edge, industry and commerce continue to make creative engineering advances as well as produce high quality products. More than ever, there is a demand for a highly prepared work force with Software Engineering training that is enabled to deliver quality software and innovation.



above the state figure, and the average median household income is significantly below the state figure. At the same time, a clear majority of UCM students are from our 21 service counties according to the most recent report released by the UCM Office of Institutional Research. As a comprehensive regional university with a statewide mission in professional applied sciences and technology programs, it is our mission to provide Missouri citizens in our own service region and/or beyond the access to affordable undergraduate study in Software Engineering with reasonable cost and driving distance.

Table 7 Average Percent of Poverty and Average Median Household Income

Area	Average Percent of Poverty (2010-2014)	Average Median Household Income (2010-2014)
UCM service area (21 counties)	16.4%	\$44,162
State of Missouri	15.5%	\$47,764

Source: US Bureau of Census

Duplication and Collaboration: If similar programs currently exist in Missouri, what makes the proposed program necessary and/or distinct from the others at public institutions, area vocational technical schools, and private career schools?

By searching the program inventory provided by Missouri Department of Higher Education (<http://collegesearch.mo.gov/>) using the CIP code 14.0903 designated for the proposed program, no institution in Missouri offers a BS in Software Engineering program. As a result, there is no duplication issue.

It is worth mentioning that University of Missouri-Kansas City (UMKC) offers a software engineering option in its BS in Computer Science program. The proposed software engineering program has a different curriculum than UMKC's computer science programs. More specifically, the proposed software engineering program has a rigorous curriculum as specified by the ABET accreditation guidelines on software engineering program. Its curriculum differs significantly from a computer science program. Another factor making our proposed program unique is its emphasis on secure programming and secure software engineering. There are two dedicated courses (6 credit hours) in the curriculum. One of our faculty members had specialized SANS training on secure programming and has the GSSP-JAVA certificate. To the best of our knowledge, there is no other existing software engineering program with such emphasis.

Furthermore, the proposed program is also designed to meet the expressed needs of our industry partners. UCM's Computer Science program has a long tradition of working closely with local companies to provide the curriculum needed for their workforce of the future. Our programs have a very active industry advisory board with representatives from many local companies such as Cerner, Garmin, DST systems, Sprint, Honeywell and Commerce Bank, etc. The Board meets each Fall and Spring semester. A few support letters from local companies are attached to our proposal.



UCM's Computer Science program strives to provide our students with hands-on learning experiences. During their study, our students have opportunities to work on projects from small to large scales either through individual or team efforts. Often our industry partners create these projects. In addition, many students have internship experiences. Currently, UCM's Computer Science program has 11 faculty members with software engineering training and/or software engineering work/research experiences among whom 6 are tenured or tenure-track. Although the majority of our faculty have a Ph.D. in Computer Science, we do have two faculty members with a Ph.D. in Electrical and Computer Engineering. They complement other faculty members by incorporating engineering practices into our curriculum.

Notably, UCM traditionally attracts very different student populations as compared with UMKC. Our students prefer a small college environment, rural campus setting, small class size and teaching-focused faculty. On the other hand, as Missouri's research university, UMKC offers a large campus, urban setting and more research-oriented faculty. Furthermore, affordable cost is another major factor for students and their families when considering to attend UCM.

UCM's undergraduate students have very different socioeconomic backgrounds, academic preparation and career goals as compared with those in UMKC. As specified in the MDHE Policies and Guidelines, UMKC has a selective admission criteria which requires an ACT score of 24 or better for admission. More specifically, UMKC's engineering and computer science programs require an ACT math score of at least 25 and ACT composite of at least 24 or a class rank in the upper 25 percent if the minimum ACT score is not met. On the other hand, UCM has a moderately selective admission criteria which only requires an ACT score of 21 or better for admission. There is no additional admission criteria for the proposed software engineering major.

Given that the University of Central Missouri's statewide mission in professional applied sciences and technology programs, UCM is a natural home for the proposed B.S. in Software Engineering program. A clear majority of UCM students are from our traditional 21 service counties which include Jackson County and are tied to this area by jobs and/or family responsibilities. Many of the students have circumstances making attendance at another university or college difficult or impossible particularly due to ACT requirements and/or family financial situations. The options available to them are largely determined by the options provided at UCM. As a comprehensive regional university with a statewide mission in professional applied sciences and technology programs, it is our goal to provide Missouri citizens in our service region and/or beyond more access to affordable undergraduate study in software engineering.

Does delivery of the program involve a collaborative effort with any external institution or organization? If yes, please complete Form CL.

No. The current Computer Science faculty members at UCM are qualified and sufficient to handle the new program. Delivering the program will not involve collaborative efforts with any external institution or organization.



References:

1. Computing Curricula 2005: The Overview Report, http://www.acm.org/education/education/curric_vols/CC2005-March06Final.pdf
2. Forging a discipline: An outline history of software engineering education. On the Internet at: <http://link.springer.com/article/10.1023/A:1018953214201#page-2>
3. Digest of Education Statistics. On the Internet at: <https://nces.ed.gov/programs/digest>
4. SWEBOOK. On the Internet at: <https://www.computer.org/web/swebok>
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16. On the Internet at: <http://www.careercast.com/slide/best-jobs-2015-no-8-software-engineer>
17. Software Engineer Review 2016, by Nicole Tripp. On the Internet at: <http://computer-careers-review.toptenreviews.com/software-engineer-review.html>
18. Software Engineering Programs in the US. On the Internet at: <http://personal.stevens.edu/~mardis/GMaps/se.html> Software Engineering Education, by Mark A. Ardis. On the Internet at: <http://personal.stevens.edu/~mardis/papers/SEEd1111.pdf>
19. Introducing Code/Space. On the Internet at: https://mitpress.mit.edu/sites/default/files/titles/content/9780262042482_sch_0001.pdf
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PROGRAM STRUCTURE

A. Total credits required for graduation: 120

B. Residency requirements, if any: minimum 30 credit hours at UCM

C. General education: 44

Course Number	Credits	Course Title
CS 1000	3	Computers and Modern Society
COMM 1000/1050	3	Public Speaking/Foundation of Oral Communication Competency
MATH 1151	5	Calculus & Analytic Geometry I
Areas/Category	Credits	Notes
Writing I	3	
Writing II	3	
Managing Info.	2	
Literature	3	
Fine Arts	3	
Another Course for Knowledge Area I	3	Choose one additional course from Literature/Fine Arts or Languages/Humanities
Science with Lab	4	
Another Course for Knowledge Area II	3	Choose one additional course from Science or Mathematics
History	3	
Social/Behavioral Sciences	3	
Additional Courses for Knowledge Area III	3	Choose one additional course from History or Social/Behavioral Sciences

D. Major requirements: 73

Core Courses (50 credits):

Course Number	Credits	Course Title
CS 1100	3	Computer Programming I
CS 1110	3	Computer Programming II



CS 2300	3	Data Structures
CS 2400	3	Discrete Structures
CS 3130	3	Secure Programming
CS 3900	3	Software Requirements Engineering
CS 3910	3	Software Engineering
CS 4300	3	Algorithms Design and Analysis
CS 4600	3	Database Theory and Applications
CS 4920	3	Senior Project
CS 4930	3	Software Testing & Quality Assurance
CS 4940	3	Software Design and Architecture
CS 4950	3	Secure Software Engineering
MATH 1152	5	Calculus & Analytic Geometry II
ACST 3311	3	Introduction to Mathematical Statistics
INDM 4250	3	Project Management

Electives (9 credits):

Course Number	Credits	Course Title
CS 3100	3	Programming Languages
CS 3110	3	App Prog. With C# and .NET
CS 3120	3	Client Side Web Programming
CS 3200	3	Computer Organization & Architecture
CS 3300	3	Intro. to Cryptography
CS 3500	3	C and UNIX Environment
CS 3800	3	Apps. Development with VB.NET
CS 3810	3	Intro. To Game Design
CS 4000	3	Special Problems in CS
CS 4110	3	Mobile App. Prog. With Android
CS 4120	3	Advanced App. Prog. In Java
CS 4130	3	Server Side Web Programming
CS 4140	3	Web Applications Security
CS 4500	3	Operating Systems



CS 4510	3	Intro. to Distributed Systems
CS 4610	3	Intro to Cloud Computing
CS 4620	3	Big Data Systems
CS 4630	3	Data Mining
CS 4700	3	Artificial Intelligence
CS 4710	3	Machine Learning
CS 4800	3	Computer Networking
CS 4810	3	Computer Graphics
CS 4820	3	Intro. to Information Assurance

Math and Science Electives (14 credits):

*Minimum 8 credit hours science, from Elective Group II & III, must be selected in the electives. Total math and science, from the following lists, combined must be at least 14 credit hours.

- **Elective Group I (0-6 credits):**

Course Number	Credits	Course Title
MATH 2153	3	Calculus & Analytic Geometry III
MATH 2221	3	Foundations of Geometry
MATH 3151	3	Differential Equations
MATH 3710	3	Linear Algebra
MATH 4450	3	Introduction to Graph Theory

- **Elective Group II (0-3 credits):**

Course Number	Credits	Course Title
BIOL 1110	3	Principles of Biology
BIOL 2010	3	Human Biology
BIOL 2510	3	Basic Genetics
BIOL 4102	3	Evolution
EASC 3010	3	Environment Geology
EASC 3112	3	Astronomy

- **Elective Group III (8-14 credits):**



Course Number	Credits	Course Title
PHYS 1101/2121	4/5	College Physics I or University Physics I
PHYS 1102/2122	4/5	College Physics II or University Physics II
BIOL 1111	4	Plant Biology
BIOL 1112	4	Animal Biology
CHEM 1131	5	General Chemistry I
CHEM 1132	5	General Chemistry II
EASC 1004	4	Intro. to Geology
EASC 1114	4	Weather and Climate
EASC 2100	4	Engineering Geology
EASC 2200	4	Historical Geology
EASC 4300	4	Earth Resources

E. Free elective credits: 3

(Sum of C, D, and E should be larger or equal to A.)

F. Requirements for thesis, internship or other capstone experience:

CS 4920 Senior Project serves as a capstone course for the program which is required.

G. Any unique features such as interdepartmental cooperation:

N/A



PROGRAM CHARACTERISTICS AND PERFORMANCE GOALS

Institution Name: University of Central Missouri
Program Name: Bachelor of Science in Software Engineering
Date: Fall 2018

(Although all of the following guidelines may not be applicable to the proposed program, please carefully consider the elements in each area and respond as completely as possible in the format below. Quantification of performance goals should be included wherever possible.)

1. Student Preparation

- Any special admissions procedures or student qualifications required for this program which exceed regular university admissions, standards, e.g., ACT score, completion of core curriculum, portfolio, personal interview, etc. Please note if no special preparation will be required.

No special admission procedures or student qualifications required. The proposed program will adopt the same admission criteria for undergraduate students at UCM.

- Characteristics of a specific population to be served, if applicable.

N/A

2. Faculty Characteristics

- Any special requirements (degree status, training, etc.) for assignment of teaching for this degree/certificate.

Ph.D. in Computer Science, Software Engineering or a closely related area required for tenure track faculty. M.S. in Computer Science, Software Engineering or a closely related area required for non-tenure track faculty.

- Estimated percentage of credit hours that will be assigned to full time faculty. Please use the term "full time faculty" (and not FTE) in your descriptions here.

All courses will be taught by full-time faculty.

- Expectations for professional activities, special student contact, teaching/learning innovation.

Faculty teaching in this program will be expected to be professionally active, as evidenced by peer reviewed publications and/or externally funded grants. Faculty will also be expected to attend and/or present at professional meetings, participate in workshops/seminars in areas related to their specialties and be involved in other related professional activities. Faculty are expected to continue improving their teaching by keeping up to date on material or pedagogy.

3. Enrollment Projections



- Student FTE majoring in program by the end of five years.

60 students

- Percent of full time and part time enrollment by the end of five years.

91.5% full time, 8.5% part time

4. Student and Program Outcomes

- Number of graduates per annum at three and five years after implementation.

Three years-5, Five years-12

- Special skills specific to the program.

Graduates with a Bachelor of Science degree in Software Engineering will demonstrate the following specific student outcomes:

- *An ability to identify, formulate, and solve engineering problems by applying principles of engineering, science, and mathematics*
- *An ability to apply both analysis and synthesis in the engineering design process, resulting in designs that meet desired needs.*
- *An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.*
- *An ability to communicate effectively with a range of audiences.*
- *An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.*
- *An ability to recognize the ongoing need for additional knowledge and locate, evaluate, integrate, and apply this knowledge appropriately.*
- *An ability to function effectively on teams that establish goals, plan tasks, meet deadlines, and analyze risk and uncertainty.*

- Proportion of students who will achieve licensing, certification, or registration.

N/A

- Performance on national and/or local assessments, e.g., percent of students scoring above the 50th percentile on normed tests; percent of students achieving minimal cut-scores on criterion-referenced tests. Include expected results on assessments of general education and on exit assessments in a particular discipline as well as the name of any nationally recognized assessments used.

None available.

- Placement rates in related fields, in other fields, unemployed.



95% in Software Engineering related fields, 5% in other fields, 0% unemployed

- Transfer rates, continuous study.

N/A

5. Program Accreditation

- Institutional plans for accreditation, if applicable, including accrediting agency and timeline. If there are no plans to seek specialized accreditation, please provide a rationale.

The program will seek ABET accreditation.

6. Alumni and Employer Survey

- Expected satisfaction rates for alumni, including timing and method of surveys.

There is an expected satisfaction rate of around 90%. A survey will be sent to graduates at periods of one and three years after their graduation to gauge how the program has prepared them for their careers. Data from the survey will be compiled and analyzed to improve the quality of the program.

- Expected satisfaction rates for employers, including timing and method of surveys.

There is an expected satisfaction rate of around 90%. A survey will be sent to employer(s) every three years requesting their input on quality of the program and its graduates. Data from the survey will be compiled and analyzed to improve the quality of the program. The UCM Software Engineering Advisory Board, which meets once per year and consists of representatives from industry, alumni, and students, will also provide input.

7. Institutional Characteristics

- Characteristics demonstrating why your institution is particularly well equipped to support the program.

Founded as a teacher's college in 1871, the University of Central Missouri has maintained its commitment to excellent teaching. UCM has a statewide mission in applied sciences and technology programs. Our average undergraduate class size is 24. UCM's six-month job-placement rate for undergraduates is 92 percent, and, reflecting our excellent financial support packages, our students benefit from one of the lowest student-debt ratios in the state. Publicly supported, richly diverse in our people and programs, UCM offers a remarkable educational experience.

November 21, 2016

Rusty Monhollon, Assistant Commissioner
Missouri Department of Higher Education
205 Jefferson Street, P.O. 1469
Jefferson City, MO 65102

Dear Rusty:

The University of Missouri has a number of concerns about the proposed bachelor of science degree in Software Engineering proposed for delivery at main campus and Central Summit Campus in Lee's Summit. As we do with each MDHE posting, we shared the information with our campus provosts who then distributed the materials to the appropriate faculty. We received concerns from the faculty and deans from the College of Engineering at MU as well as the School of Engineering and Computer Science at UMKC.

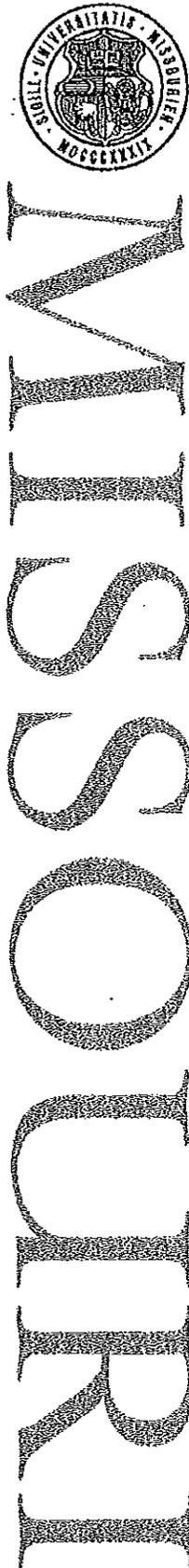
The major concerns relate to the following points – with specific details provided in the material articulated below:

- Given that MDHE is currently finalizing new guidelines for offering engineering programs in Missouri that will require collaboration as a prerequisite for engineering programs, we do not believe it is prudent to approve a new software engineering program shortly before the guidelines are put in place.
- Naming the program as an “engineering” degree when it would not be offered by a school or college of engineering - an ABET accredited school.
- Indicating that the program would be unique in meeting needs by being the only software engineering program in the state. Both the College of Engineering at MU and the School of Engineering and Computer Science at UMKC offer software engineering programs through their computer science and engineering programs. Both schools are ABET accredited.
- This new program could unnecessary duplication, particularly in the Kansas City area. Both the MU and UMKC programs have capacity to enroll more students.
- There are concerns about the nature and structure of the program as proposed.

The sections below provide details to our concerns about this proposal. MU and UMKC are willing to discuss collaborative partnerships with UCM to strengthen their current program offerings and enhance their undergraduate and master's graduate programs.

Titling the program as an “engineering” degree when it would not be offered by a school or college of engineering - with ABET accredited programs.

Concerns were expressed by both the MU and UMKC faculty about offering an “engineering” degree from a campus that is not dedicated to engineering. The program is called “software engineering” so it implies a certain level of engineering expertise within the faculty and that the programs are operated by an “engineering” based faculty. The basic standard for offering engineering degree programs would be



through an engineering college where all the degree programs have received ABET accreditation. Both UMKC and MU offer programs similar to this proposed program and all their programs have received ABET accreditation.

UCM is proposing to create an ABET accredited software engineering bachelor's degree program, consequently extensive additional resources would be required to secure ABET accreditation for the program. Currently their BS computer science and BS Cybersecurity programs are not ABET accredited. Accreditation of one or more degree programs would require extensive resources and investments from the state in a resource constrained and diminishing state budget for higher education.

To be successful, UCM would need to recruit tenure track faculty with extensive industry experience in software development and software engineering as part of a process to improve the quality of their degree offerings. UCM currently has five full professors, no associate professors and 23 assistant professors. Of all of these faculty, only two of the assistant professors appear to specialize in software engineering. Further, it is not clear how many of their assistant professors are tenure track versus short term temporary contracts. This structure of a fluctuating population of instructors makes it difficult to develop high quality ABET accredited programs given that such programs require a sustained effort over many years with a dedicated group of committed faculty.

Indicating that the program would be unique in meeting needs by being the only software engineering program in the state.

This is not the first program of its kind in Missouri. UMKC offers the BS and MS degrees in computer science and both have emphasis areas in software engineering. Currently the BS degree with an emphasis in software engineering has over 120 students enrolled and the MS degree program with an emphasis in software engineering has over 150 students. The programs are ABET accredited and this is an area of growth for UMKC with plans to add three additional faculty members in software engineering in the next two years.

As of this date, UMKC School of Computing and Engineering has not turned away any qualified student in the software engineering programs and has a strategic vision of growing these programs to twice the current enrollments with the new faculty hires. Until this growth is achieved, it would not be prudent to add additional programs in the KC region, especially in the Lee Summit area. It would only conflict with an existing ABET accredited program.

Likewise, software engineering is an important area of study within the broader field of MU College of Engineering and the Computer Science department has a strong programming project emphasis and exposure to industry standards and norms of practice. On some campuses, software engineering may be offered as a separate degree program. However, this is not the case at MU or UMKC or other AAU institutions.

MU already offers a number of courses that provide for a strong course of study as part of a Software Engineering emphasis area, track or potentially a minor that MU students can choose. This could include courses focusing on the world-wide web, data base programming, object-oriented programming and design, software engineering, and mobile applications.

To summarize, the MU computer science program, which is ABET accredited, is already offering these software engineering area courses. The MU information technology program is also able to offer a software engineering emphasis area in addition to the current areas (mobile computing, systems administration, modeling & animation, game design) by sharing these courses.

Create unnecessary duplication, particularly in the Kansas City area. Both the MU and UMKC programs have capacity to enroll more students.

UMKC School of Computing and Engineering (SCE) is informed about the computing job market, today as well as the projections. The UMKC computer science faculty (which includes trained software engineers) is the largest group of faculty and they teach the largest number of students. SCE has 20 full time CS faculty and 10-12 adjunct faculty and 8 of the faculty members are dedicated full time to software engineering. The bachelor's and master's computer science programs have over 600 students with more than 270 of them in the software engineering emphasis area.

UMKC plans to add three full time faculty and to double the number in the software engineering emphasis area. The UCM software engineering program will be an impediment to that growth. There is a demand as 90% of all of the BSCS students, including software engineers, have jobs at graduation ... which speaks to the quality and the desire to increase the numbers within this ABET accredited and well established program.

UMKC is working closely with local companies to provide the curriculum needed for their workforce of the future. Currently UMKC has over 500 alumni working at Cerner with nearly 200 of those alums coming from UMKC SCE (which is only 15 years old). Furthermore, Kansas State University is the largest supplier of software engineers to Cerner.

In the case of UMKC, SCE has discussed adding a separate degree in software engineering, but decided not to pursue that option as the enrollments in the emphasis are quite robust and growing. Further, many of the courses in the computer science bachelor's program serve a broader set of emphasis areas, making it easier for students to design a curriculum that suits their desires or industry needs.

The proposed program from UCM may not have an immediate short term impact on student enrollment at the University of Missouri System campuses in the computer science or information technology degree programs. But it may have long term negative impacts -- especially for students who are interested in commercial software projects, software application development, software engineering industry practice and tools. Specifically, enrollment estimates from UCM projects only 60 students in five years, a very small increase relative to UCM's current graduate student population of around two thousand students. Such a small increase is not compelling to justify the extensive resources required for creating a high quality new degree offering that would improve the workforce capability in software and IT within the state of Missouri as opposed to focus on existing programs already in place at MU and elsewhere in the UM system.

There are concerns about the nature and structure of the program as proposed.

- 1) Lack of exposure to industry practice and industry collaborative partnerships: The proposed degree program from UCM is essentially a computer science degree program with a few additional courses: 3900 Software Requirements Eng, 3910 Software Eng, 4930 Software Testing & Quality Assurance, 4940 Software Design and Architecture, 4950 Secure Software Eng.

Software engineering education should have significant elements outside standard course work. Experiential learning, team-based projects, internships, and industrial collaboration are especially essential for training students to be software engineers as opposed to just programmers. None of these critical components are addressed. It is therefore unclear

whether UCM can prepare its students well for a career in software engineering that reflects well on the quality of graduates in this field from the state of Missouri.

Greater student involvement in developing or maintaining large scale projects, interactions with industry partners, certification opportunities, and coverage of the large body of ISO/IEC standards for software engineering quality management is needed. The proposal does not include the necessary hands-on, large scale projects and the strong partnership efforts with industry that are essential for a successful degree program in Software Engineering.

- 2) Strengthening the quality of existing programs at UCM will provide better employment prospects: The UCM School of Computer Science and Mathematics (SCM) already offers two related undergraduate and graduate degrees: BS in Computer Science, BS in Cybersecurity; MS CS and MS in Cybersecurity and Information Assurance, which began in Fall 2016. UCM has many emphasis areas for undergraduates including software development, computer science, computer networking, game development, data science, computer science minor.

UCM indicates that they have an enrollment of over two thousand students in their MS graduate program (primarily international students) and supports the largest computer training program in the state of Missouri with industry relationships in the Kansas City area. If this is true, we would recommend that UCM strengthen their current programs in order to produce higher quality graduates to satisfy the needs of industry and build stronger industry-academic partnerships with local companies.

- 3) It is necessary to first explore alternatives and accurately gauge demand for UCM graduates: Instead of a separate BS software engineering degree, UCM could offer a minor, track, or emphasis area similar to their Software Development program within the computer science degree and their minor in Cybersecurity. This could be accomplished by offering the proposed new SE courses for several areas as part of their current BS CS degree and then gauging more accurately the appropriate data on enrollment and future demand.
- 4) The report that was submitted lacked data on the demand for Software Engineers in the state of Missouri. For example, the number of companies interested in this area and the number of students in previous years who have been hired with a software development emphasis were not included. The report lacks important information on specific collaborations between UCM and companies in the state of Missouri that are focused on software engineering.

We welcome the opportunity to discuss some sort of collaborative program with one of the UM campuses.

Sincerely,



Steve Graham
Senior Associate Vice President

June 12, 2017

Rusty Monhollon, Assistant Commissioner
Missouri Department of Higher Education
205 Jefferson Street, P.O. 1469
Jefferson City, MO 65102

Dear Dr. Monhollon:

The University of Central Missouri is resubmitting the new program proposal for a BS in Software Engineering. Below addresses the concerns raised by Dr. Steve Graham in his letter to you dated November 21, 2016 as well as the letter we received from MDHE on November 23, 2016.

The sections below provide details to address the concerns listed in Dr. Graham's letter.

Naming the program as an "engineering" degree when it would not be offered by a school or college of engineering -- an ABET accredited school.

We contacted Dayne Aldridge the Adjunct Accreditation Director for the Engineering Accreditation Commission (EAC) of ABET. His response is listed below

"There is no requirement in our policy or criteria that dictates the administrative structure for ABET accredited programs. There are a significant number of accredited engineering programs that are administered in units other than colleges or schools of engineering."

It is clear that there is no requirement for an engineering program to be in a college or school of engineering to be accredited by ABET. In addition, it is worth mentioning that University of Central Missouri already has several ABET accredited programs. For example, the BSBA in Computer Information Systems is accredited by the Computing Accreditation Commission (CAC) of ABET; the BS in Occupational Safety and Health and MS in Industrial Hygiene both are accredited by the Applied and Natural Science Accreditation Commission (ANSAC) of ABET.

UCM's BS in Computer Science program had a very successful ABET site visit in October 2016 and we are currently waiting for the official accreditation decision which will be announced in August 2017. The ABET onsite visit for the BS in Cybersecurity program has also been confirmed for October 2017. Considering that the accreditation guidelines and processes are fairly consistent among different commissions of ABET, the University of Central Missouri has the necessary knowledge, experience and resources to secure ABET accreditation for the proposed software engineering program. Most importantly, none of UCM programs' accreditation efforts have required any additional resources and investments from the state. It is also worth mentioning that during our computer science site visit, the ABET team had no single concern with regards to our curriculum, faculty, facility and institutional support.

Currently, UCM's Computer Science program has 11 faculty members with software engineering training and/or software engineering work/research experiences among whom 6 are tenured or tenure-track. Although the majority of our faculty have a Ph.D. in Computer Science, we do have two faculty members with a Ph.D. in Electrical and Computer Engineering. They complement other faculty members by incorporating engineering practices into our curriculum. Furthermore, the Computer Science program plans to add another tenure track faculty (due to a recent retirement) with expertise in Software Engineering in 2018-2019 academic year.

Below is the ABET 2017-2018 Program Criteria for Software and Similarly Named Engineering Programs concerning the faculty criterion

2. Faculty

The program must demonstrate that faculty members teaching core software engineering topics have an understanding of professional practice in software engineering and maintain currency in their areas of professional or scholarly specialization.

It is clear that there is no specific requirement on the number of faculty who must be in the software engineering area to be accredited by ABET. As indicated earlier, during our Computer Science ABET visit, there was no single concern about our faculty specialization. Therefore, we are confident that our current computer science faculty structure and expertise are well equipped to secure ABET accreditation for the proposed software engineering program.

Indicating that the program would be unique in meeting needs by being the only software engineering program in the state.

The proposed BS in Software Engineering program (CIP 14.0903) is indeed a unique program in the state of Missouri for the following reasons.

1. There is no Missouri institution that offers a bachelor degree with software engineering in the degree title.

UMKC offers a software engineering emphasis area in its BS in Computer Science program (CIP 11.0701). MU offers several software engineering related courses in its BS in Computer Science program (CIP 11.0101). In both cases, students receive a computer science degree but not software engineering (note that the CIP codes are also different). Association for Computing Machinery (ACM), the leading international professional organization which provides curricula guidelines to computing disciplines, in its *Computing Curricula 2005: The Overview Report* states there are five major computing disciplines. They are Computer Science, Computer Engineering, Software Engineering, Information Systems and Information Technology. The differences between computer science, software engineering and computer engineering are also listed in our program proposal.

2. The curriculum of the proposed BS in Software Engineering program follows the ABET accreditation guidelines on software engineering curriculum.

Both MU and UMKC's computer science program curriculum follows the CAC/ABET's accreditation criteria for a computer science program just like UCM's computer science program. On the other end, the proposed software engineering program adopts the EAC/ABET accreditation criteria for a software

engineering program. To meet the ABET software engineering curriculum requirements, seven software engineering focused courses (3130 Secure Programming, 3900 Software Requirements Engineering, 3910 Software Engineering, 4250 Project Management, 4930 Software Testing and Quality Assurance, 4940 Software Design and Architecture and 4950 Secure Software Engineering) are included in the curriculum to differentiate the proposed program from a computer science program. Considering the mandated minimum 30 credit hours in mathematics and science, and 42 credit hours general education, the 21 credit hours software engineering coursework represent 44% of the remaining 48 credit hours major requirement in the program.

Another factor making our proposed program unique is its emphasis on secure programming and secure software engineering. There are two dedicated courses (6 credit hours) in the curriculum. One of our faculty members had specialized SANS training on secure programming and has the GSSP-JAVA certificate. To the best of our knowledge, there is no other existing software engineering program with such emphasis.

Below is the ABET 2017-2018 Program Criteria for Computer Science, Software Engineering and Computer/Electrical Engineering concerning the curriculum criterion

Computer Science	Software Engineering
<p>Students must have the following amounts of course work or equivalent educational experience:</p> <p>a. Computer science: One and one-third years that must include:</p> <ol style="list-style-type: none"> 1. Coverage of the fundamentals of algorithms, data structures, software design, concepts of programming languages and computer organization and architecture. 2. An exposure to a variety of programming languages and systems. 3. Proficiency in at least one higher-level language. 4. Advanced course work that builds on the fundamental course work to provide depth. 	<p>The curriculum must provide both breadth and depth across the range of engineering and computer science topics implied by the title and objectives of the program.</p> <p>The curriculum must include computing fundamentals, software design and construction, requirements analysis, security, verification, and validation; software engineering processes and tools appropriate for the development of complex software systems; and discrete mathematics, probability, and statistics, with applications appropriate to software engineering.</p>
Computer/Electrical Engineering	
<p>The structure of the curriculum must provide both breadth and depth across the range of engineering topics implied by the title of the program.</p> <p>The curriculum must include probability and statistics, including applications appropriate to the program name; mathematics through differential and integral calculus; sciences (defined as biological, chemical, or physical science); and engineering topics (including computing science) necessary to analyze and design complex electrical and electronic devices, software, and systems containing hardware and software components.</p>	

<p>The curriculum for programs containing the modifier “electrical,” “electronic(s),” “communication(s),” or “telecommunication(s)” in the title must include advanced mathematics, such as differential equations, linear algebra, complex variables, and discrete mathematics.</p> <p>The curriculum for programs containing the modifier “computer” in the title must include discrete mathematics.</p>	
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It is obvious that computer science, software engineering, and computer engineering are completely different degree programs since they have different curricula and focuses. Even ABET uses two different commissions to review these programs: computer science is under CAC while software engineering and computer/electrical engineering are under EAC.

3. The proposed program, if approved, will be part of the University of Central Missouri’s Missouri Innovation Campus (MIC) initiative.

The Missouri Innovation Campus is an exciting, progressive collaboration between the Lee’s Summit R-7 School District, Metropolitan Community College and the University of Central Missouri. By engaging business partners and community organizations, the MIC is reshaping the way students experience education.

The MIC students graduate with:

- A bachelor's degree, two years after high school.
- Little to no student debt.
- Applied experience through paid internships.
- Highly sought-after skills for high-paying careers.

One of the most significant obstacles facing students who pursue a college education is cost. The MIC delivers the value of a bachelor’s degree with little to no student debt through:

- Student Employment
- Tuition Forgiveness
- Institutional and Departmental Scholarships
- Shared Tuition
- Low-Interest Loan Programs
- Paid Internships

To the best of our knowledge, there is no such software engineering program in Missouri or surrounding states with the features listed above.

This new program could create unnecessary duplication, particularly in the Kansas City area.

As indicated in the previous section, the proposed software engineering program has a different curriculum than MU and UMKC's computer science programs. Notably, UCM traditionally attracts very different student populations as compared with MU and UMKC. Our students prefer a small college environment, rural campus setting, small class size and teaching-focused faculty. On the other hand, as Missouri's research university, MU and UMKC offers a large campus, urban setting and more research-oriented faculty. Furthermore, affordable cost is another major factor for students and their families when considering to attend UCM.

UCM's undergraduate students have very different socioeconomic backgrounds, academic preparation and career goals as compared with those in MU and UMKC. As specified in the MDHE Policies and Guidelines, MU and UMKC have a selective admission criteria which requires an ACT score of 24 or better for admission. More specifically, MU's engineering and computer science programs require an ACT math score of at least 26 and ACT composite of at least 26 or a class rank in the upper 25 percent if the minimum ACT composite score is not met. UMKC's engineering and computer science programs require an ACT math score of at least 25 and ACT composite of at least 24 or a class rank in the upper 25 percent if the minimum ACT score is not met. On the other hand, UCM has a moderately selective admission criteria which only requires an ACT score of 21 or better for admission. There is no additional admission criteria for the proposed software engineering major.

Given that the University of Central Missouri's statewide mission in professional applied sciences and technology programs, UCM is a natural home for the proposed B.S. in Software Engineering program. A clear majority of UCM students are from our traditional 21 service counties which include Jackson County and are tied to this area by jobs and/or family responsibilities. Many of the students have circumstances making attendance at another university or college difficult or impossible particularly due to ACT requirements and/or family financial situations (as shown in our proposal, the average poverty rate for the UCM service area is above the state figure, and the average median household income is significantly below the state figure.). The options available to them are largely determined by the options provided at UCM. As a comprehensive regional university with a statewide mission in professional applied sciences and technology programs, it is our goal to provide Missouri citizens in our service region and/or beyond more access to affordable undergraduate study in software engineering.

There are concerns about the nature and structure of the program as proposed.

I. Lack of exposure to industry practice and industry collaborative partnerships

As mentioned in the previous section, the proposed software engineering program has a rigorous curriculum as specified by the ABET accreditation guidelines on software engineering program. Its curriculum differs significantly from a computer science program. Furthermore, the proposed program is also designed to meet the expressed needs of our industry partners. UCM's Computer Science program has a long tradition of working closely with local companies to provide the curriculum needed for their workforce of the future. Our programs have a very active industry advisory board with representatives from many local companies such as Cerner, Garmin, DST systems, Sprint, Honeywell and Commerce Bank, etc. The Board meets each Fall and Spring semester. A few support letters from local companies are attached to our proposal.

UCM's Computer Science program strives to provide our students with hands-on learning experiences. During their study, our students have opportunities to work on projects from small to large scales either through individual or team efforts. Often our industry partners create these projects. In addition, many students have internship experiences. For example, just in Summer 2017, there are 19 undergraduate

students interning with various companies in the Kansas City and St. Louis areas. The actual number could be higher since not every interning student chooses to take an internship course for credit.

Currently, UCM's Computer Science program has 11 faculty members with software engineering training and/or software engineering work/research experiences among whom 6 are tenured or tenure-track. Although the majority of our faculty have a Ph.D. in Computer Science, we do have two faculty members with a Ph.D. in Electrical and Computer Engineering. They complement other faculty members by incorporating engineering practices into our curriculum.

2. Strengthening the quality of programs at UCM will provide better employment prospects

UCM strives to provide high quality programs in Computer Science and Cybersecurity. As indicated in the previous sections, our programs are designed according to ABET accreditation criteria for Computer Science and Cybersecurity. The Computer Science program is expecting the official ABET accreditation decision in August 2017 and the Cybersecurity program will conduct the ABET onsite visit in October 2017. We are confident that our programs hold the same high standard as other ABET accredited programs which include MU and UMKC's Computer Science programs.

UCM's Computer Science graduates are highly sought by employers. Our placement rate is consistently high. The most recent UCM Graduate Employment Statistics published by the UCM Office of Career Services indicates a 95% job placement for 20 Computer Science graduates in the 2014-2015 academic year with an average starting salary of \$65,001-\$70,000. Our BS in Cybersecurity program was implemented in Fall 2015 and just had its first graduate in May 2017. That student is currently employed with Cerner.

3. It is necessary to first explore alternatives and accurately gauge demand for UCM graduates

When the Cybersecurity program was added, we did not see a decline in our Computer Science majors. Rather, we had new incoming freshman and transfer students looking specifically for Cybersecurity. We also have seen many students wanting both programs and choosing to double major. In addition, we had prospective students-both domestic and international-asking specially for a Software Engineering program. It is expected that with the addition of Software Engineering we will be able to reach new students with specific interests in this field rather than shift current students from Computer Science to Software Engineering.

Furthermore, creating a software engineering track or emphasis area in our Computer Science or Cybersecurity programs will prevent us from securing EAC/ABET accreditation for the proposed Software Engineering program. Based on the current ABET Accreditation Policy and Procedure Manual, the program name determines the commission and the criteria applicable to its review. A track or emphasis area under Computer Science will be reviewed by CAC/ABET using Computer Science program criteria. Without ABET accreditation, our ability to attract prospective students as well as our graduates' competitiveness in the job market will be negatively affected.

4. The report that was submitted lacked data on the demand for software engineers in the state of Missouri

The Market Demand Section of our program proposal listed extensive data and information concerning the demands of software engineers both in Missouri and in the U.S. Many industry representatives serving on

our Computer Science Advisory Board also expressed interest in the proposed Software Engineering program. A few support letters from local companies are attached with our proposal.

The sections below provide details to address the concerns listed in the letter received from MDHE.

Duplication of Existing programming

The letter received from MDHE dated on November 23, 2016 listed the following existing programs as duplication.

140901	UM-C	B.S. Computer Engineering
140901	MS&T	B.S. Computer Engineering (Network/Software Engineering Option)
141001	UMKC	B.S. Electrical & Computer Engineering
110701	UMKC	B.S. Computer Science (option is Software Engineering)

As indicated in previous sections, Software Engineering, Computer/Electrical Engineering and Computer Science are different disciplines with different curricula and focuses. It is worth mentioning that MS&T's B.S. Computer Engineering program does not have an option called Network/Software Engineering. Its undergraduate catalog lists four options: Computational Intelligence, Computer Architecture and Embedded Systems, Integrated Circuits and Logic Design, and Networking, Security and Dependability. MDHE program inventory (<http://collegesearch.mo.gov/>) also confirms our finding.

Delivery of programs within Kansas City region

Kansas City (Jackson County) is one of UCM's traditional 21 service counties. It must also be noted that the proposed program is the first Software Engineering program in the state of Missouri, and we attract different student populations than UMKC. We, therefore, believe that the proposed program will not add competition in the Kansas City region.

Respectfully,



Kim Andrews, Ph.D.
Vice Provost for Academic Programs and Services
University of Central Missouri



Summit Technology Academy

777 NW Blue Parkway, Suite 3090
Lee's Summit, Missouri 64086-5712
(816) 986-3410 • Fax (816) 986-3435

Director: Elaine Metcalf, EdS

Assistant Director: Jeremy Bonnasen, EdD

April 27, 2017

RE: LETTER OF SUPPORT

To Whom It May Concern:

On behalf of the Summit Technology Academy and the Lee's Summit R-7 School District, I am writing this letter to note our support of the University of Central Missouri's School of Computer Science and Mathematics, specifically the addition of a Bachelor of Science degree in Software Engineering.

The University of Central Missouri (UCM) is poised and ready to be an emerging leader in the delivery of innovative solutions that will entice traditional and nontraditional college students to earn a software engineering degree. The UCM vision includes creating a pipeline of competent, skilled graduates ready to meet the demands of the 21st century. This will ensure that a diverse and sustainable STEM workforce becomes a reality in the Kansas City area and beyond.

The professors and leaders in the School of Computer Science and Mathematics are masters at developing an environment that leverages the strengths of educators, STEM organizations, and local industry. Working together with Summit Technology Academy, as well as the area community college, UCM is a leader in innovation K-16 practices, such as the nationally recognized program called The Missouri Innovation Campus (MIC). UCM faculty know how to establish a program of study that meets learning outcomes for software engineers, as well as ensuring high academic standards for their students.

The addition of a software engineering program would make a big impact on the students pursuing higher education in this geographic region. Summit Technology Academy and the Lee's Summit School District are pleased to be able to provide our full support to UCM for an exciting new program.

Sincerely,

Elaine Metcalf
Director



Warrensburg R-VI School District

District Office
201 S. Holden St., P. O. Box 638
Warrensburg, MO 64093

Phone: (660) 747-7823
Fax: (660) 747-9615
Web Site: warrensbu6.org

Dr. Scott Patrick, District Superintendent

Ms. Shelby Dalton, Director of Special Programs

Mrs. Jackie Duvall, Director of Curriculum and Assessment

Dr. Andy Kohl, Assistant Superintendent

Dr. Michael Scott, Assistant Superintendent

April 28, 2017

Dr. Zora Mulligan, Commissioner
Missouri Department of Higher Education
205 Jefferson Street
P.O. Box 1469
Jefferson City, MO 65102-1469

It is with great pleasure that I write this letter of support on behalf of the Warrensburg R-VI School District for the proposed new Bachelor of Science in Software Engineering program at the University of Central Missouri. This proposed program is important to the UCM School of Computer Science and Mathematics' continuing efforts to enhance its contributions to preparing the 21st century technical workforce in a STEM field of national interest.

As a long-standing academic partner with the University of Central Missouri, we also understand the importance of these types of programs for our students and our organization. Without the ability to continue to prepare a highly-qualified workforce in Software Engineering, our information society will suffer.

If you have any further questions regarding our district's support of this proposed program, please do not hesitate to contact me.

Sincerely,

Scott W. Patrick, Ed.D.
Superintendent

May 10th, 2017

Dr. Zora Mulligan, Commissioner
Missouri Department of Higher Education
205 Jefferson Street
P.O. Box 1469
Jefferson City, MO 65102-1469

To Dr. Zora

As Assistant Vice President of software development at Commerce Bank, I am writing this letter in support of the proposed Bachelor of Science in Software Engineering degree at the University of Central Missouri (UCM).

Commerce has been an industrial partner of UCM's School of Computer Science and Mathematics for the last five years through a variety of activities such as classroom-sponsored projects, presenting at Association for Computing Machinery (ACM) meetings, career fairs and participation on the Advisory Board. I have personally hired many talented students for internships and fulltime software development positions. We also participated in building curriculum for the software development and security cohorts for the Missouri Innovation Campus (MIC) and we sponsored a student.

Through these activities, I have observed UCM's ongoing attention to shaping their programs and offerings to the mutual benefit of students and industry. Considering the demand for people trained in software development is expected to significantly increase in the near future, I see the proposed degree program as an essential continuation of UCM's excellent tradition of necessary and appropriate innovation.

Please do not hesitate to contact me if I may be of further assistance in this matter.

Respectfully,

Darren J. Abels
Assistant Vice President
Commerce Bank



Metropolitan Community College

Longview

May 12, 2017

Dr. Zora Mulligan, Commissioner
Missouri Department of Higher Education
205 Jefferson Street
P.O. Box 1469
Jefferson City, MO 65102-1469

I am writing in support of University of Central Missouri's proposal of a new Bachelor of Science in Software Engineering. I have reviewed the proposed curriculum and supporting documentation. This proposed program is important to the community at large due to the continued growing demand for Software Engineers. The increasing growth of technology in mobile applications and healthcare has influenced an above average growth rate.

The Computer Science Department at Metropolitan Community College has had a long-standing relationship with the University of Central Missouri. We have partnered with the University of Central Missouri to provide students a smooth 2 + 2 pathway towards degree completion. We have also experienced increasing enrollment in our software development program and continued requests from industry partners to increase the pipeline of workers.

As Software Engineers continue to consistently increase in demand, it is imperative that students have an avenue for educational training in this field.

If I can answer any questions on behalf of Metropolitan Community College's Computer Science department, please contact me.

Regards,

A handwritten signature in cursive script that reads 'Cindy Herbert'.

Cindy Herbert
Computer Science Faculty & Program Coordinator
cindy.herbert@mccckc.edu

"College of the Year"
by TIME/The Princeton Review 2001



2800 Rockcreek Parkway
Kansas City, MO 64117
816.201.1024 ^{Tel}
816.474.1742 ^{Fax}

May 25, 2017

Dr. Zora Mulligan, Commissioner
Missouri Department of Higher Education
205 Jefferson Street
P.O. Box 1469
Jefferson City, MO 65102-1469

Dear Dr. Mulligan:

It is my privilege to provide this letter in support of the proposed Bachelor of Science in Software Engineering degree at the University of Central Missouri (UCM). I support the proposed degree program because it will provide an excellent opportunity for students in a technology field that continues to grow. There are not enough software engineering graduates to fill all the software engineering jobs in the business community today. This proposed degree program would prepare additional software engineers to move our companies forward.

Cerner has been a partner of the School of Computer Science and Mathematics for over 20 years. Over the past seven years, Cerner has hired two hundred and eighteen graduates from UCM with a majority of those graduates filling a technical role within our organization.

As a member of the Advisory Board for the Computer Science Department, I know that the faculty and staff of the School of Computer Science and Mathematics are dedicated to preparing students to meet the software engineering needs of today's businesses.

Sincerely,

Aaron Guest

A handwritten signature in black ink that reads 'Aaron Guest'. The signature is written in a cursive style with a long horizontal line extending from the end.

Director, Physician Development

Dear Sir/Madam:

Re: Support for Software Engineering at UCM

We at DST in Kansas City, MO recruit heavily from the University of Central Missouri. Our partnership exists in many forms including our partnership with the MIC program and attendance at the university Career Fairs in the Fall and Spring semesters each year.

DST is a technology firm and we have always sought individuals in the Computer Science area. Additionally, we recently expanded our Cyber Security area and we anticipate seeking to expand in the Software Engineering area in the coming years. The capacities and growing pervasiveness of software make it the lifeblood of today's emerging information society as the demand will certainly increase for a highly-prepared workforce in Software Engineering who can deliver quality software and innovative solutions.

We fully support UCM's addition of a BS degree in Software Engineering and look forward to reaping the benefits of a degree program in Software Engineering.

Sincerely,

DST's University Relations Team

Andy Cole -- University Relations Program Leader

Ashley Washington, University Relations Talent Advisor

Katy Howard -- University Relations Talent Advisor

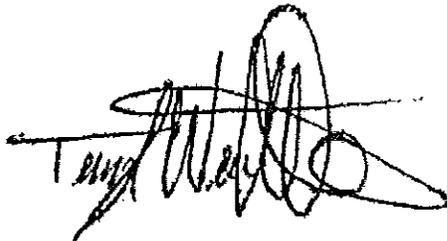
Hello Dr. Yousef,

I'm honored to give my endorsement for the proposed Bachelor of Science in Software Engineering program at UCM. As a graduate of UCM's Masters of Science in Computer Science program, a member UCM's Computer Science Advisory Board, and an Aviation Software Engineer at Garmin I believe I am uniquely qualified to give this endorsement.

Developing and maintaining software under the FAA's watchful eye is a challenging process. The challenge arises from the need for Aviation Software to be developed from thorough and unambiguous requirements and for that software to be tested to the FAA satisfaction. Translating an idea into a set of high quality requirements and developing tests that verify those requirements while also exercising all facets of the written code are two tasks I regularly see new hires struggle with. A thorough understanding of Software Engineering concepts like requirements development and software testing are absolutely essential for a Software Engineer to thrive in the Aviation industry. I believe that more end-to-end exposure to common Software Engineering processes and concepts at the university level will result in graduates who are better prepared and more confident to take positions as Software Engineers in any industry, but especially those industries with rigid software development guidelines like those found in the Aviation industry. I believe the proposed Bachelor of Science in Software Engineering program will give students this exposure, thus providing local industries with high quality Software Engineers, keeping UCM graduates in demand.

Please let me know if there is anything else I can do to support the proposed program.

Sincerely,

A handwritten signature in black ink, appearing to read "Terryl Westerhold". The signature is stylized with a large, circular flourish at the end.

Terryl Westerhold

June 15, 2017

Dr. Zora Mulligan, Commissioner
Missouri Department of Higher Education
205 Jefferson Street
P.O. Box 1469
Jefferson City, MO 65102-1469

Roger Stanley
Director of Enterprise Architecture
DST Systems, Inc.
210 W. 10th Street
Kansas City, MO 64105

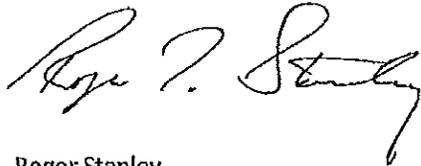
Dear Dr. Mulligan,

I am writing in support of the new Software Engineering program being proposed by the University of Central Missouri. In a day and age in which the depth and breadth of software engineering is growing rapidly, programs with a strong emphasis on programming, project management and mathematics are badly needed.

We currently see many areas of rapid growth in the software industry. Internet of things (IoT), Data Analytics (Big Data), cloud computing, and neural net programming (Artificial Intelligence - AI) are just a few examples of how software engineering is continuing to push the boundaries of what computers can do. In a world with this type of dramatic growth of capabilities, we need students graduating with a strong background in software engineering and mathematics who can join the work force ready to contribute.

As an alumnus of UCM who came into a software development field, I know the challenges these students face. The information technology field continues to grow and expand, but it's also becoming more competitive than ever before. Students need to graduate ready to contribute and ready for the challenges of developing software fast and with great quality. A program like the new Software Engineering program will help students enter the work force ready for these challenges.

Sincerely,

A handwritten signature in black ink that reads "Roger Stanley". The signature is written in a cursive style with a large, stylized "S" and "R".

Roger Stanley

Report on University of Central Missouri Software Engineering Proposal

Thomas B. Hilburn, PhD
Professor Emeritus, Distinguished Engineering Professor
Embry-Riddle Aeronautical University
hilburn@erau.edu

A. Software Engineering Proposal

In June of 2016, the University of Central Missouri (UCM) proposed the establishment of a Bachelor of Science program in Software Engineering. The proposed program is intended to prepare students to pursue the profession of software engineering. The proposal states that the program is “well aligned with the University of Central Missouri’s mission of preparing students with the knowledge, skills and confidence to succeed and lead in the region, state, nation and world”.

The proposal includes the following features:

- student enrollment projections
- definitions of the disciplines of software engineering, computer science, and computer engineering
- the market demand for software engineers
- information about existing B.S. programs in Software Engineering

In this report we will elaborate on some of these issues and provide additional information and opinion related to the UCM proposal. Also, in Table 4, we compare features of the UCM software engineering proposal to other B.S. computing programs at Missouri universities.

B. The Nature of Software Engineering

1. Engineering and Applied Science

Concerning the nature of “Engineering”, there is a question about whether Engineering is an “Applied Science”. If we were to query practicing engineers about this question, most would probably say something like “as an engineer I apply science in my practice of engineering, but I would not call it an applied science discipline – like applied physics, chemistry, or biology”. However, as the following definitions illustrate, engineering is strongly connected with applied science:

- Merriam Webster defines engineering as “the application of science and mathematics by which the properties of matter and the sources of energy in nature are made useful to people”.
- Engineers Council for Professional Development (ECPD) [ECPD 1941], the predecessor of ABET (Accreditation Board for Engineering and Technology), defined engineering as “The creative application of scientific principles to design or develop structures, machines, apparatus, or manufacturing processes, or works utilizing them singly or in combination ...”.

- ABET (<http://www.abet.org/>) defines engineering as “Engineering is the profession in which a knowledge of mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind”.
- ABET Criteria for Accrediting Engineering Programs [ABET 2016 -2] states that graduates of engineering programs must attain “an ability to apply knowledge of mathematics, science, and engineering”.

2. Differences between Software Engineering and the Traditional Fields of Engineering

Software engineering is defined in various documents as follows:

- The *SEI Report on Undergraduate Software Engineering Education* [Ford 1990] defines software engineering as “that form of engineering that applies the principles of computer science and mathematics to achieving cost-effective solutions to software problems.”
- ISO/IEC/IEEE 24765 Standard - Systems and Software Engineering Vocabulary [IEEE 24765]
 - Defines software engineering as “the systematic application of scientific and technological knowledge, methods, and experience to the design, implementation, testing, and documentation of software”.
 - Defines computer science as “the branch of science and technology that is concerned with information processing by means of computers”.

Software Engineers work on the development of various types of software systems in a variety of domains, such as transportation, health services, education, business/financial affairs, entertainment, and government affairs.

- The engineering of software systems is often more complicated than other types of systems: it typically involves development of multiple subsystems and modules, which must interact with other systems; software systems may be extremely large, involving hundreds of thousands of lines of code or more; and such systems require teams of engineers and domain experts to develop, and takes time to develop (many months or years).
- An experienced software engineer needs knowledge and practice in the following areas [Bourque 2014]:
 - computing fundamentals
 - software process models
 - software project management
 - software quality assurance and testing
 - software requirements analysis and specification
 - software architecture
 - software construction
 - software operation and maintenance
- Software engineers may go by other titles – “software developer” or “software system engineer”. Also, the term “Software Engineer” is sometimes imperfectly used for those who only have capability in the software construction of small to moderate-size modules or programs. A more accurate job title for this type of work would be “computer programmer”.

- In *The Mythical Man-Month* [Brooks 1995], Fred Brooks sites key elements of software systems, which distinguish software engineering from more traditional engineering disciplines.
 - Complexity – software systems are typically more complex than other engineered systems. The complexity arises from the large number of unique interacting parts in a software system. Parts encapsulated as functions, objects, modules, and components, which are invoked as needed rather than being replicated.
 - Conformity – conventional engineered systems must conform to the physical world, while there are no similar controlling or guiding principles for software systems. Additionally, in physical systems, if two parts must fit together, they are allowed tolerances at their interface; however, in a software system, the interfaces for two parts must conform perfectly.
 - Changeability – because a software system is not physical, it is easy to change; hence, it is often changed, even in the latter stages of development. However, if the change is not made with thorough analysis and care, the results can cause more problems than they solve.
 - Invisibility - because it has no physical properties, software is considered invisible. It cannot be seen, heard, or felt. The intangible nature of software makes it harder to model and understand. So, software engineers use different representations, at different levels of abstraction, to “visualize” software systems.

Because of this complexity, the engineering of software is often more troublesome than other engineered systems. For example, schedule and cost overruns are more likely for software development, and high-quality software products are more difficult to achieve. Over one-third of software projects experience 150% to 300% cost and schedule overruns, and over 30 % of projects will be cancelled before they are completed. [Chaos 2014]. A major contributor to these problems is that too many software developers lack preparation in software estimation, quality assurance, and software processes.

C. Employment of Computing Professionals

1. Education of Computing Professionals in Missouri

Missouri universities do not currently offer a software engineering degree program. However, there are numerous computer science programs offered. Table 1 shows the enrollment and the number of recent graduates from Missouri schools and some from Kansas.

Table 1: B.S. Computer Science Enrollments and Number of Graduates

Missouri Public	2014-2015		2015-2016		2016-2017	
	Enrolled	Graduates	Enrolled	Graduates	Enrolled	Graduates
MU	280	63	251	74	240	83
MS&T	550	72	605	91	659	94
SEMO	147	11	165	11	183	13
MSU	305	36	358	33	380	61
UMSL	361	33	384	35	380	50

Missouri Western	72		76	12		12
UMKC	259		270	21	294	
UCM	238	27	292	27	307	35
	2014-2015		2015-2016		2016-2017	
Missouri Independent	Enrolled	Graduates	Enrolled	Graduates	Enrolled	Graduates
Wash U	196	21	279	70	399	71
St. Louis U	90	19	102	15	127	23
Maryville	0	1	0	0		
Fontbonne	30	3	29	6		6
Central Methodist University	36	10	35	6	24	9
Avila University	29	7	28	2	44	12
Drury University		0		0	58	0
Southwest Baptist University	100	20	110	21	125	20
Evangel University	24	2	23	11	24	6
	2014-2015		2015-2016		2016-2017	
Kansas Institutions	Enrolled	Graduates	Enrolled	Graduates	Enrolled	Graduates
KU	311	37	343	58		
Kansas State	432	28	558	34	560	68
Washburn	133	14	110	14		24
Wichita State	281	25	343	25	360	24

2. Demand for Software Developers

Tables 2 and 3 provide information on employment data for software developers and programmers in Missouri (<http://www.chmuraecon.com/jobseq>).

Table 2: Employment Data for Software Developers and Programmers in Missouri

2016-2017 Occupation of Software Developers and Programmers in Missouri						
	Computer Programmers	Applications Software Developers	Systems Software Developers	Web Developers	Software Developers & Programmers	Total - All Occupations
Number Employed	6,476	14,532	6,727	2,700	30,436	3,002,177
2016 Avg. Annual Wages	\$79,800	\$95,700	\$99,100	\$61,200	\$90,900	\$45,400
Location Quotient	1.11	0.87	0.77	0.85	0.88	1.00
Unemployed	250	201	97	83	631	n/a
Unemployed Rate	4.2%	1.6%	1.6%	3.3%	2.3%	n/a
Increases over 2012-2017						
	Computer Programmers	Applications Software Developers	Systems Software Developers	Web Developers	Software Developers & Programmers	Total - All Occupations

Number Employed	920	2,093	1,016	201	4,229	167,354
Missouri	3.1%	3.2%	3.3%	1.6%	3.0%	1.2%
Kansas	3.9%	4.3%	1.8%	2.5%	3.4%	0.8%
USA	2.9%	2.9%	2.9%	2.9%	2.9%	2.9%
Projected Changes over Next ten years						
	Computer Programmers	Applications Software Developers	Systems Software Developers	Web Developers	Software Developers & Programmers	Total - All Occupations
Current Online Job Ads	96	1,490	19	701	2,306	138,250
Total Replace Demand	1,460	2,399	915	481	5,256	782,311
Total Growth Demand	-783	2,354	768	655	2,995	80,643
Average Annual Growth %	-1.3%	1.5%	1.1%	2.2%	0.9%	0.3%

Table 3: Employment Data for Software Developers and Programmers in Kansas City Metro Area

2016-2017 Occupation of Software Developers and Programmers in Missouri						
	Computer Programmers	Applications Software Developers	Systems Software Developers	Web Developers	Software Developers & Programmers	Total - All Occupations
Number Employed	2,945	8,182	3,527	1,215	15,868	1,103,396
2016 Avg. Annual Wages	\$77,200	\$91,200	\$97,700	\$60,600	\$88,000	\$48,400
Location Quotient	1.37	1.33	1.09	1.04	1.25	1.00
Unemployed	119	120	55	39	332	n/a
Unemployed Rate	4.0%	1.5%	1.6%	3.1%	2.1%	n/a
Increases over 2012-2017						
	Computer Programmers	Applications Software Developers	Systems Software Developers	Web Developers	Software Developers & Programmers	Total - All Occupations
Number Employed	619	1,650	490	129	2,889	92,266
KC Metro	4.8%	4.6%	3.0%	2.3%	4.1%	1.8%
Missouri	3.1%	3.2%	3.3%	1.6%	3.0%	1.2%
USA	2.9%	3.4%	2.4%	2.6%	3.0%	1.7%
Projected Changes over Next ten years						

	Computer Programmers	Applications Software Developers	Systems Software Developers	Web Developers	Software Developers & Programmers	Total - All Occupations
Current Online Job Ads	45	735	13	309	1,102	71,439
Total Replace Demand	665	1,381	494	220	2,761	288,415
Total Growth Demand	-342	1,703	616	338	2,314	69,444
Average Annual Growth %	-1.2%	1.9%	1.6%	2.5%	1.4%	0.6%

The metric “Location Quotient” (LQ), used in Tables 2 and 3, is an analytical statistic that measures Missouri and KC Metro employment in software development, relative to the nation. The USA has a LQ of 1; Table 2 shows an LQ of 0.77 for Systems Software Developers, which means there is less concentration of this occupation in Missouri than for the whole nation. However, as Table 3 shows, in the Kansas City metro area, the LQs are higher.

The *Occupational Outlook Handbook* [BLS 2016] from the U.S. Bureau of Labor Statistics assesses professional positions in the United States: The following are extracts, which are pertinent to the software engineering employment:

- Computer Programmers write and test code that allows computer applications and software programs to function properly. They turn the program designs created by Software Developers and Engineers into instructions that a computer can follow.
- Software Developers - 2016 median pay: \$102,280 per year, \$49.17 per hour
- Employment of software developers is projected to grow 24 percent from 2016 to 2026, much faster than the average for all occupations.
- Computer programmers – 2016 median pay \$79,840 per year \$38.39 per hour.
- Employment of computer programmers is projected to decline 8 percent from 2016 to 2026.

In 2016, *U.S. News* (<https://money.usnews.com/careers/best-jobs/rankings/best-technology-jobs>) ranked Software Developer #2 in Best Technology Jobs

- 135,300 Projected Jobs \$98,260 Median Salary 2.0% Unemployment Rate

A recent study, *Education Asset Inventory for Greater Kansas City* [MARC 2017], states “In order to grow or attract top technology employers, the region is expected to need more information technology talent capacity, specifically in software development.” The study lists the UCM Computer Science program, with the Software Development, option, as among six programs in Missouri that focuses on software development. The UCM proposed Software Engineering program requires courses in software development that are needed for the development of complex software systems, and which do not exist in any current Missouri program.

3. Employment Opportunities for Software Engineers

Tables 2 and 3 present employment information for a variety of job titles: Computer Programmers, Applications Software Developers, Systems Software Developers, Web Developers, and Software Developers & Programmers. Although a graduate of a software engineering program should be able to fill any of these roles, employers seeking a Systems Software Developer would be most attracted to someone with a software engineering background. That is, someone who has knowledge and competency about such topics as Software Requirements Engineering, Software Design and Architecture, and Software Testing & Quality Assurance, all of which are part of UCM's proposed Software Engineering degree program.

Tables 2 and 3, the 2016 *Occupational Outlook Handbook*, a 2016 *U.S. News* report, and the *Education Asset Inventory for Greater Kansas City* all show excellent employment opportunities for Software Engineers, both in Missouri and the USA:

- some of the highest salaries in the computing profession,
- low unemployment rates,
- and positive employment growth in the next ten years.

D. Comparing Computing Curricula

1. ACM/IEEE-CS Curriculum Guidelines

The ACM (Association of Computing Machinery) and IEEE-CS (IEEE Computer Society) have developed guidance for the development of undergraduate programs in Computer Science [ACM 2013] and in Software Engineering [ACM 2015]. A comparison of the knowledge areas covered in the two sets of guidelines illustrates the profound difference and intent of the two. For example, the Computer Science Guidelines recommends a minimum of 24 class hours for software engineering topics, while the Software Engineering Guidelines recommends a minimum of 208 class hours for software engineering topics

2. Differences in ABET Accreditation Criteria for Computing Programs

The Accreditation Board for Engineering and Technology (ABET) specifies criteria for accrediting engineering and technology programs. The following criteria, listed for three computing programs, do not include all the criteria; but, the extracts are intended to highlight the differences and similarities between the programs.

- Software Engineering: Among other things, the Engineering Accreditation Commission (EAC) [ABET 2016 -2] requires the following:
 - The curriculum must have (1) one year of a combination of college level mathematics and basic sciences (some with experimental experience) appropriate to the discipline. (Basic sciences are defined as biological, chemical, and physical sciences); and (2) one and one-half years of engineering topics, consisting of the engineering sciences and engineering design, appropriate to the student's field of study.
 - The curriculum must include computing fundamentals, software design and construction, requirements analysis, security, verification, and validation; software

- engineering processes and tools appropriate for the development of complex software systems.
- The program must demonstrate that faculty members teaching core software engineering topics have an understanding of professional practice.
 - Graduates must be prepared to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
 - **Computer Science:** Among other things, the Computing Accreditation Commission (CAC) [ABET 2016 -1] requires the following:
 - The curriculum must have one year of a combination of college level mathematics and basic sciences (some with experimental experience) appropriate to the discipline. Basic sciences are defined as biological, chemical, and physical sciences”.
 - The curriculum must have one and one-third years that must include: (1) coverage of the fundamentals of algorithms, data structures, software design, concepts of programming languages and computer organization and architecture; and (2) an exposure to a variety of programming languages and systems.
 - Graduates must be prepared to apply design and development principles in the construction of software systems of varying complexity.
 - Some full-time faculty members must have a Ph.D. in computer science.
 - **Computer Engineering:** Among other things, the Engineering Accreditation Commission [ABET 2016 -2] requires the following:
 - The curriculum must have (1) one year of a combination of college level mathematics and basic sciences (some with experimental experience) appropriate to the discipline. (Basic sciences are defined as biological, chemical, and physical sciences); and (2) one and one-half years of engineering topics, consisting of engineering sciences and engineering design appropriate to the student's field of study.
 - The curriculum must include engineering topics (including computing science) necessary to analyze and design complex electrical and electronic devices, software, and systems containing hardware and software components.
 - Graduates must be prepared to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.

E. Comparison for Missouri Computing Programs

Table 4 compares the curricula for several computing programs in Missouri and the proposed UCM Software Engineering program. The table concentrates on the software engineering topics, which are part of the curricula.

Table 4: Comparison of Missouri Computing Programs

Program	Required Credits	ABET Accreditation	Required Software Engineering Topics	Other Features
UCM B.S. Software Engineering	120	A Proposal, hence not Accredited	Intro. Software Engineering, Project Management, Software Requirements Engineering, Software Design and Architecture, Software Testing & Quality Assurance, Secure Software Engineering, Senior Project	Elective courses: Big Data Systems, Data Mining, Cloud Computing
UMKC B.S. Computer Science	120	Accredited by ABET-CAC	Foundations of Software Engineering and a Capstone course	There is a software engineering option that includes two courses from the following: Software Architecture, Requirements & Design, Software Architecture, Testing & Maintenance
UMKC B.S. Electrical & Computer Engineering	128	Accredited by ABET-EAC	No software engineering courses	Two intro. to programming courses, some assembly, embedded programming courses, and two Senior Design courses.
MU B.S. Computer Science	126	Accredited by ABET-CAC	Intro. Software Engineering, two Senior Capstone courses.	No electives in software engineering topics.
MU S&T B.S. Computer Science	128	Accredited by ABET-CAC	Intro. Software Engineering, Software Systems Development	Electives: second course in Software Systems Development, Software Testing and Quality Assurance
MU S&T B.S. Computer Engineering	128	Accredited by ABET-EAC	No software engineering courses. Two Senior Design courses.	Two intro. to programming courses, elective in Software Engineering.

F. United States B.S. Software Engineering Programs

The creation of software engineering degree programs is a rather recent event. The first program to be accredited was at Rochester Institute of Technology, occurring in 2001. There are currently twenty-eight programs accredited by ABET under the Software Engineering program criteria, while there over 300 ABET accredited programs in computer science.

The reasons for the differences in the numbers is not certain, but several influencing factors seem clear:

- Computer science, as a discipline, has been around much longer. The first Department of Computer Science in the United States was established at Purdue University in 1962.
- A computing department may not possess the expertise to offer such a program. To offer a software engineering program, faculty are needed with backgrounds in software requirements, software architecture, quality assurance and project management. The United States has only eight Ph.D. programs in software engineering, while there are over 200 Ph.D. programs in computer science (some with software engineering options). Also, as stated earlier, ABET requires software engineering faculty to “have an understanding of professional practice”.
- There is still confusion and misunderstanding about the terms “software engineering”, “software developer”, “computer scientist”, and “computer programmer”, both by the general public and in parts of academia.

G. Conclusions

- Software engineering is a distinct and separate discipline from other computing disciplines (e.g., computer science, computer engineering, computer information systems). The other disciplines do not have a central focus on such areas as software project management, software quality assurance and testing, software requirements analysis and specification, and software architecture.
- There is strong evidence that software engineering and other engineering fields involve the application of science and mathematics to solve engineering problems. However, most engineers would probably not classify themselves as applied scientists.
- There is strong demand in industry for software engineers, who have knowledge and experience in the areas described in the *Guide to the Software Engineering Body of Knowledge*, [Bourque 2014]. And, there are currently a limited number of programs offering this desired preparation.
- In comparing the curriculum of the UCM Software Engineering proposed program with other computing programs (Table 4), it is clear that the UCM program is different from the others and would be the only one to satisfy the needs of a software engineering professional as detailed in [Bourque 2014]. Also, the UCM proposed program appears to be the only one from Table 4, which would satisfy the EAC requirements for software engineering [ABET 2016 -2].

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DATA SNAPSHOT

Employer Demand for Bachelor's-Level Software Engineering Professionals

Analysis of Missouri Employer Demand and
Degree Completions

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1) Research Methodology

Project Challenge Leadership at the University of Central Missouri approached the Forum as they considered the market demand for a bachelor’s-level software engineering program. The Forum assessed employer demand for bachelor’s-level software engineering professionals and degree completions bachelor’s-level software engineering and related programs in Missouri.

EAB reports rely primarily on labor market data from the Burning Glass Labor/Insight™ tool (description below). Reports occasionally use data from the United States Census Bureau and United States Bureau of Labor Statistics data to explore occupation and job trends. Market research reports may also incorporate Integrated Postsecondary Education Data System (IPEDS) data to assess student enrollment, demographics, and completion rates across competitor programs.

Methodology and Definitions

Methodology: Unless stated otherwise, this report includes data from online job postings from July 2013 to June 2017. The Forum identified trends in demand over time for bachelor’s-level software engineering professionals in Missouri. The Forum also assessed reported degree completions for bachelor’s-level “software engineering programs” in Missouri.

Definitions: “In-state” refers to Missouri. “Software engineering professionals” refer to the following **O*NET occupation codes:**

- Software Developer, Applications (15-1132),
- Software Quality Assurance Engineers and Testers (15-1199.01), and
- Software Developers, Systems Software (15-1133).

“Software engineering programs” refer to the following **CIP codes:**

- Computer science (11.0701),
- Computer engineering (14.09),
- Computer engineering (14.0901),
- Computer software engineering (14.0903),
- Electrical & electronics engineering (14.1001),
- Systems engineering (14.27),
- Systems engineering (14.2701),
- Computer engineering technologies/technicians (15.12), and
- Computer software technology/technician (15.1204).

Annual growth in job postings is measured in the change between July 2013 and June 2017 by six-month halves (i.e., H2 2013 is July 2013 to December 2013).

Burning Glass Labor/Insight™

EAB's Partner for Real-Time Labor Market Data

This report includes data made available through EAB's partnership with Burning Glass Technologies, a Boston-based leader in human capital data analytics. Burning Glass Technologies specializes in the use of web spidering technology to mine more than 80 million online job postings and analyze real-time employer demand. Under this partnership, EAB may use Burning Glass's proprietary Labor/Insight™ tool to answer member questions about employer demand for educational requirements, job titles, and competencies over time, as well as by geography. The tool considers job postings "unspecified" for a skill, industry, employer, geography, certification, or educational requirement when the job posting did not advertise for one of these particular job characteristics. Unspecified postings represent null values and should be excluded from the total number (n value) of job postings analyzed in the query. A more complete description of the tool is available at <http://www.burning-glass.com/products/laborinsight-market-analysis/>. For more information about the Labor/Insight™ tool, please contact Betsy Denious, Director of Business Development Learning & Policy at bdenious@burning-glass.com or 301-525-6596.

Project Sources

The Forum consulted the following sources for this report:

- EAB's internal and online research libraries (eab.com)
- National Center for Education Statistics (NCES) (<http://nces.ed.gov/>)

2) Missouri Market Demand and Completion Trends

Demand over Time

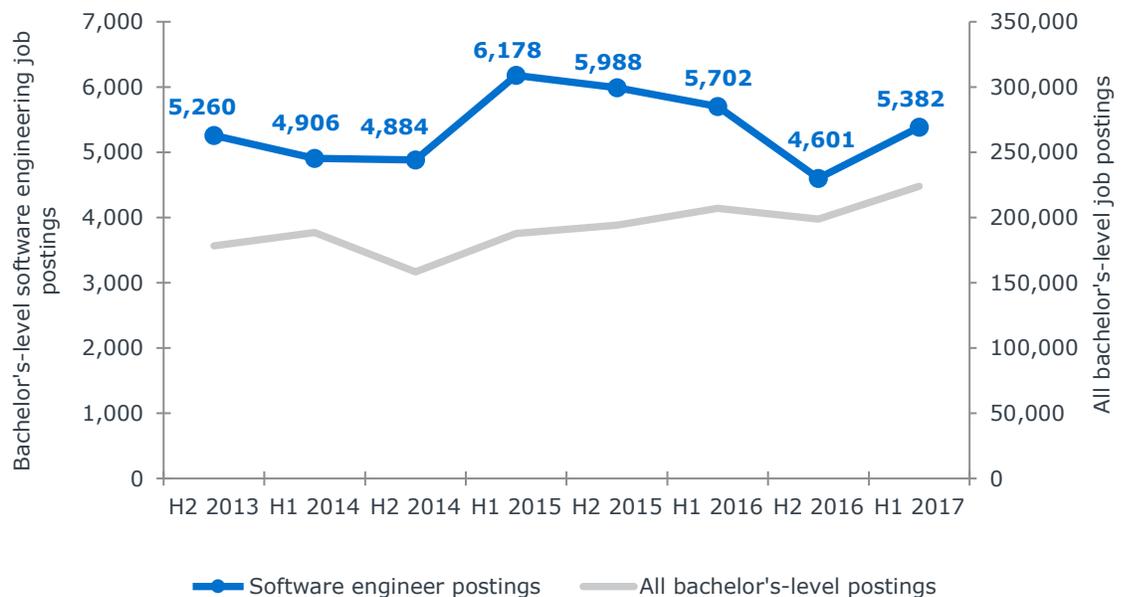
Missouri Employers Posted 10,323 Software Engineering Job Postings in the Last 12 Months

Missouri employer demand for bachelor’s-level software engineering professionals remains experienced minimal growth from July 2013 to June 2017. Missouri employers list 5,382 job postings for bachelor’s-level software engineering professionals in H1 2017, a two percent increase from the 5,260 relevant job postings in H2 2013. Across the last 12 months (i.e., November 2016 to October 2017), employers posted 10,323 jobs for software engineers in Missouri, similar to the number of postings in the last two years. Most recently, employer demand for bachelor’s-level software engineering professionals in Missouri rose 17 percent between H2 2016 and H1 2017 (i.e., 4,601 to 5,382 postings).

Administrators should note employer demand for all bachelor’s-level professionals in Missouri rose 26 percent between H2 2013 and H1 2017, much faster than the two percent growth in demand for bachelor’s-level software engineering professionals in this period. Recently, demand for all bachelor’s-level professionals in Missouri rose from 198,854 job postings in H2 2016 to 223,924 postings in H1 2017 (i.e., a 13 percent increase).

Historical Demand for Bachelor’s-Level Software Engineering Professionals

July 2013-June 2017, Missouri Data¹



1) Burning Glass Labor/Insight™

Missouri Institutions Report 590 Bachelor’s-Level Software Engineering Degree Completions in 2014-15

Reported degree completions for bachelor’s-level software engineering programs do not appear to meet market demand for bachelor’s-level software engineering professionals in Missouri. In-state institutions report a total of 590 degree completions for bachelor’s-level software engineering programs in the 2014-2015 academic year (i.e., the most recent year of data available). However, employers in Missouri posted 12,166 jobs for bachelor’s-level software engineering professionals in 2015.² While professionals from other states may fill bachelor’s-level software engineering roles in Missouri, the magnitude of this disparity may indicate an opportunity to launch a bachelor’s-level software engineering program at the **University of Central Missouri**. Administrators should note the Bureau of Labor Statistics (BLS) [identifies](#) a bachelor’s degree as the entry-level education typically required for “software developer” roles.

The data displayed below aggregates completions from all “software engineering” CIP codes identified by administrators at the University of Central Missouri. Sixteen institutions in Missouri in addition to the University of Central Missouri report bachelor’s-level software engineering degree completions in the 2014-15 academic year.

Reported Degree Completions for Bachelor’s-Level Software Engineering Programs in Missouri

National Center for Education Statistics, “Software Engineering Programs”

The 2014-15 academic year represents the most recent year of available completions data.

Institutions	Reported Completions 2014-15
Washington University in St. Louis	214
University of Missouri-St. Louis	69
University of Missouri-Kansas City	59
Saint Louis University	48
Webster University	36
Missouri State University-Springfield	35
Truman State University	31
University of Central Missouri	26
Park University	17
Southwest Baptist University	11
Central Methodist University-College of Graduate and Extended Studies	10
Columbia College	10
Central Methodist University-College of Liberal Arts and Sciences	8
Drury University	7
College of the Ozarks	4
Hannibal-LaGrange University	4
Maryville University of Saint Louis	1
Total	590

2) Burning Glass Labor/Insight™