AC 2011-1399: SOLVING THE ENGINEERING PIPELINE CHALLENGE

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Solving the Engineering Pipeline Challenge

Abstract – A comprehensive analysis of our engineering student retention and graduation rates for first time freshmen in a School of Engineering major quantified a compelling need for enhancing early (freshmen and sophomore) retention rates and graduation rates. A Summer Engineering Enrichment Program (SEEP) was initiated in 2009 and early indications from the first two cohorts indicate success [1]. Those analyses and early indications of SEEP success led to the realization that a relatively near term solution to our highly publicized and well documented United States engineering pipeline challenge is within our grasp, if we (the USA) have the resolve to make it happen. The solution proposed, documented and quantified is to use the supply of US citizen/permanent resident high school graduates with Math ACT scores in the 17-25 range, coupled with Summer Engineering Enrichment Programs or SEEPs, and engineering scholarships and/or stipends, at all ABET accredited engineering programs at public universities (partnered with local Community Colleges) to more than double the number of BS engineer graduates within a decade. The program component for community colleges focuses on enhancing retention of at risk students and developing a seamless transfer of community college graduates to public university ABET accredited engineering programs. Total estimated cost of the program for 320,000 entering students /annually when it reaches a steady state is $8.343 billion (2020 dollars). At full implementation the program produces another estimated 128,000 BS engineers/computer scientists per year in May 2020 at an average estimated cost of approximately $59,453 per engineer. The return on investment for the US taxpayers should be realized relatively quickly from increased IRS revenues and all states would gain substantial increased revenue from state taxes (sales taxes, income taxes, etc). Additional research can better quantify the Return On Investment (ROI) at national and state levels. This analysis does not account for the huge national economic and national security benefits realized from maintaining the technological superiority of the USA, which we have enjoyed since World War II. We postulate that the solution is at hand to rise above the gathering storm in the near term while the longer term solution of enhancing elementary, middle school and high school math and science interest and performance is being undertaken.

Keywords: retention rates; graduation rates; ACT; summer programs; engineer pipeline;

Background

Our University is an HBCU with an open admissions policy where 92% of university undergraduate students are African American (84% of School of Engineering students are African American). Students' academic preparation varies considerably and is illustrated by a wide range of ACT scores for First Time Freshmen students. A ten week, Summer Engineering Enrichment Program (SEEP) was initiated in 2009 to enhance retention rates and increase graduation rates. A number of summer bridge/enrichment programs have been implemented nationwide with a variety of approaches and objectives [2, 3, 4, 5, 6, 7]. We found the analyses and insight articulated in [2] to be especially comprehensive and impressive, although not aimed at the student population (17-25 ACT Math Scores) we are dealing with in this paper. Figure 1 and 4 vividly illustrate the fact that our first time freshman students average ACT Math scores are below 20 and our six year graduation rate is below 20%. The preponderance of universities nationwide would not admit most of these students to the Colleges of Engineering. The SEEP was formulated after six years experience dealing with the students population shown in Figures 1 and 4 and was designed in an attempt to maximize retention/graduation from this student population. In discussing 13 schools with highly successful graduation rates for at risk students [2] states "However, the theme of personal concern for at risk students permeated all 13 schools. All retention efforts were centered in the dean's office,…". We believe this is a precise description of the concept of our retention efforts. We found no other summer bridge/enrichment program with a 10 week duration or that enrolled students in College Algebra and Trigonometry for academic credit and placed the students in Calculus I during the fall semester to decrease the time to graduate while enhancing first and second year retention. Although the students earn 6 hours college credit for Algebra and Trigonometry, it does not count toward the 128 semester hours required for graduation in a School of Engineering major. The many other components of the summer program are described in [1] and briefly in the following sections [tutoring, Introduction to Engineering, study periods, student mentors from previous summers, trips to engineering employers, etc.]. SEEP students who earn a 3.5 and above GPA receive a scholarship, renewable with good academic performance, that pays at least one-half their tuition. It should be noted that, although 84% of School of Engineering students are African American, the SEEP is open to any JSU student with an ACT math score in the 17-25 range. This program was described in Summer Enrichment Program to Enhance Retention by Whalin and Pang [1]. Some results from that publication showing student ACT scores and graduation rates are shown below in Figures 1 thru 5.

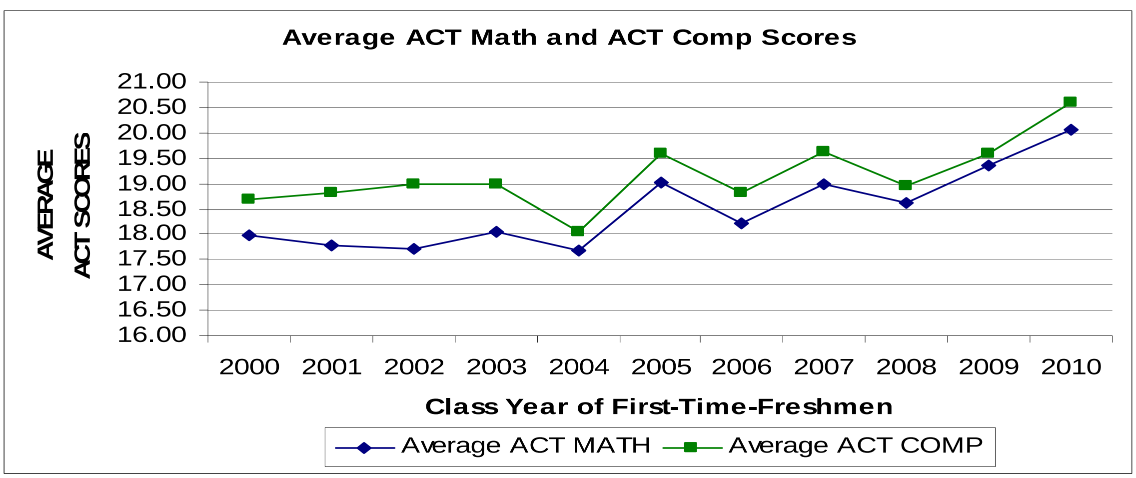

Figure 1. Average ACT Math / Composite Scores of First-Time-Freshmen

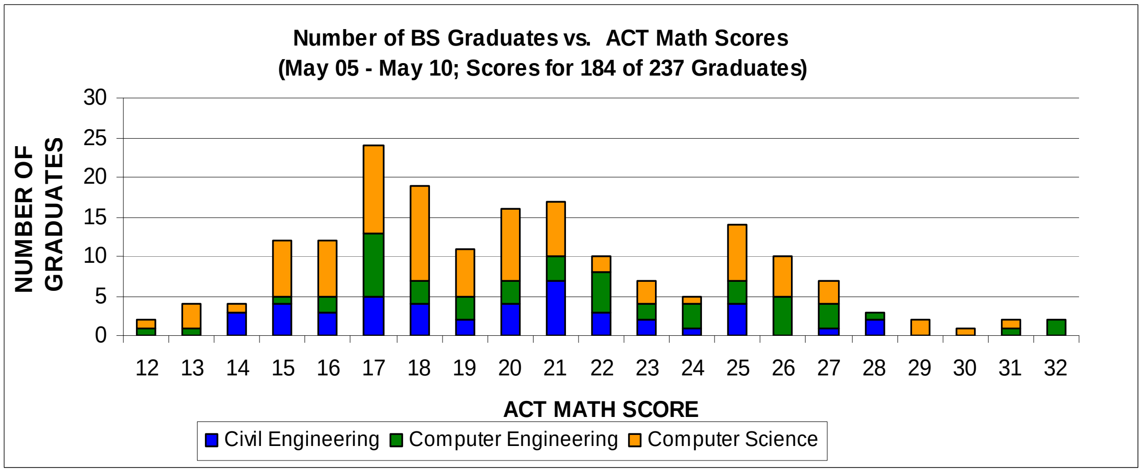

Figure 2. Number of BS awarded vs. ACT Math

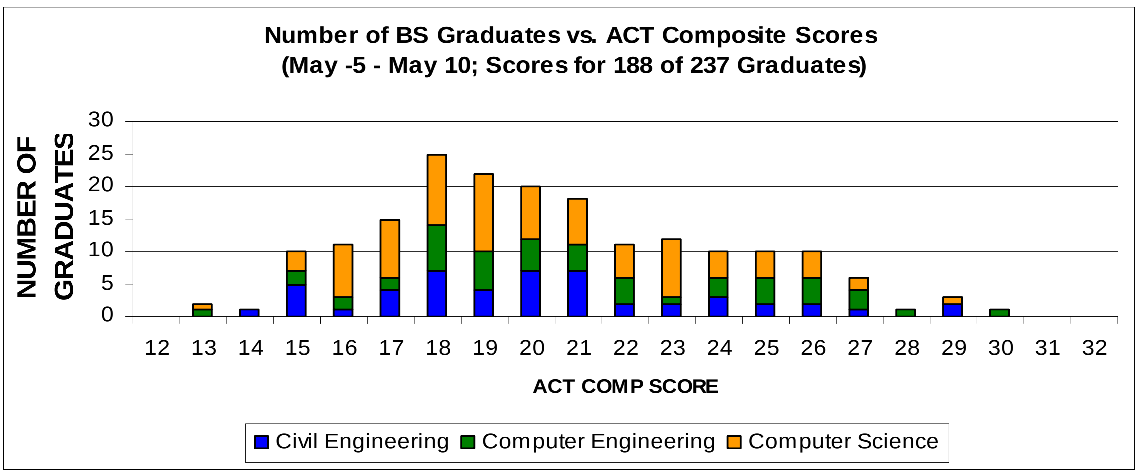

Figure 3. Number of BS awarded vs. ACT Composite

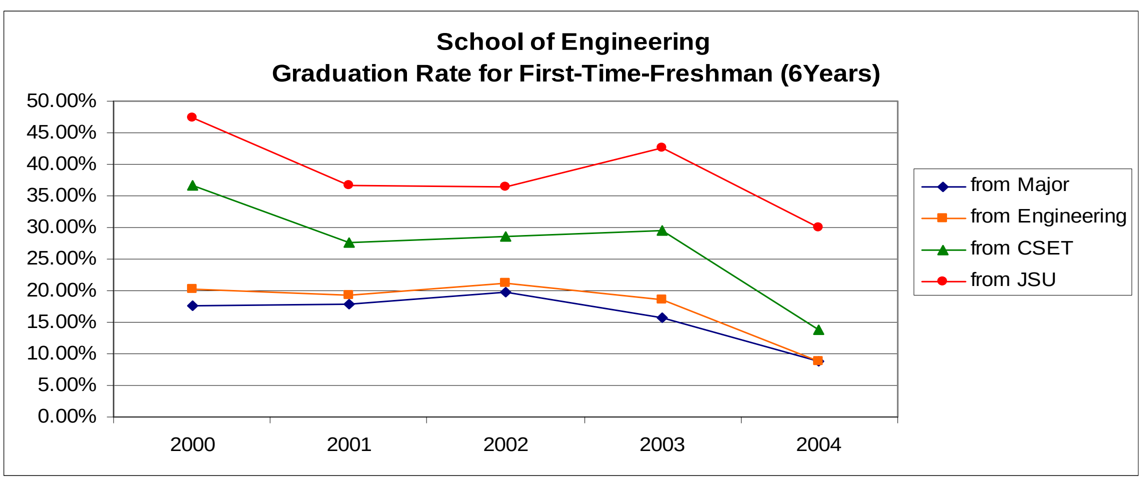

Figure 4. 6-Year Graduation Rate for First-Time-Freshmen

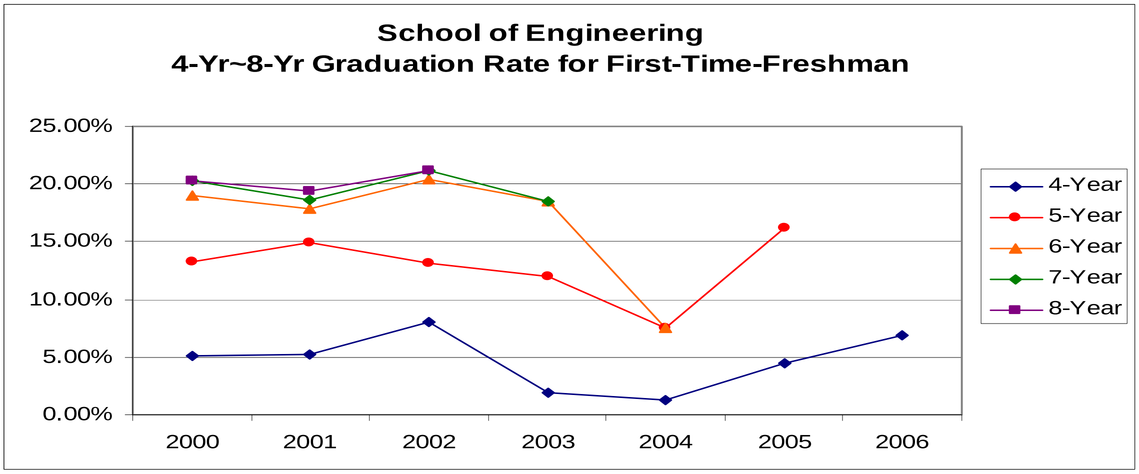

Figure 5. 4-8 Year Graduation Rate for First-Time-Freshmen

Many publications [8, 9, 10, 11, 13, 14, 15] have documented the engineering pipeline challenge in the United States and the dire threat to our engineering leadership and economic vitality posed by the worldwide rapid increase in production of engineering graduates, especially in southeast Asia (China, India, Korea, etc). "Rising Above the Gathering Storm" [8] describes the challenge quite eloquently. One estimate is that, in 2004, China graduated about 350,000 engineers, computer scientists and information technologists with 4-year degrees, while US graduated about 140,000. China also graduated about 290,000 with 3-year degrees in these same fields, while the US graduated about 85,000 with 2- or 3-year degrees. India is graduating an ever increasing number of engineers as are many other nations. In South Korea, 38% of all undergraduates receive their degrees in natural science or engineering. In France, the figure is 47%, in China, 50%, and in Singapore 67%. In the United States, the corresponding figure is 15%. [13] Some 34% percent of doctoral degrees in natural sciences (including the physical, biological, earth, ocean, and atmospheric sciences) and 56% of engineering PhDs in the United States are awarded to foreign-born students.[8]In the US science and technology workforce in 2000, 38% of PhDs were foreign-born.[9] The American Society for Engineering Education data for BS degrees awarded in Engineering indicated 74,391 and 74,170 BS degrees in the 2008 and 2009 academic year respectively and African Americans comprised 4.3% and 4.4% respectively.[16] The United States must ameliorate this threat to our national security by substantially increasing the number of US citizen engineering graduates. Results from [1] inspired us to perform additional analyses, described below, of our data and these analyses led to the relatively short term solution presented.

Analyses of Engineering Graduates

An analysis was preformed of School of Engineering graduates from Summer 2004 thru May 2010 (six academic years). This time frame was selected because the first engineering graduates were in May 2005 and ABET accreditation was granted effective October 2004 for BS engineering degrees (Civil Engineering, Computer Engineering, and Telecommunications Engineering). The Computer Science program has been ABET accredited for many years. MS degrees are awarded in Computer Science and Engineering (with emphasis areas of Civil Engineering, Environmental Engineering, Geological Engineering, Computer Engineering, Computational Engineering, Electrical Engineering, and Telecommunications Engineering).

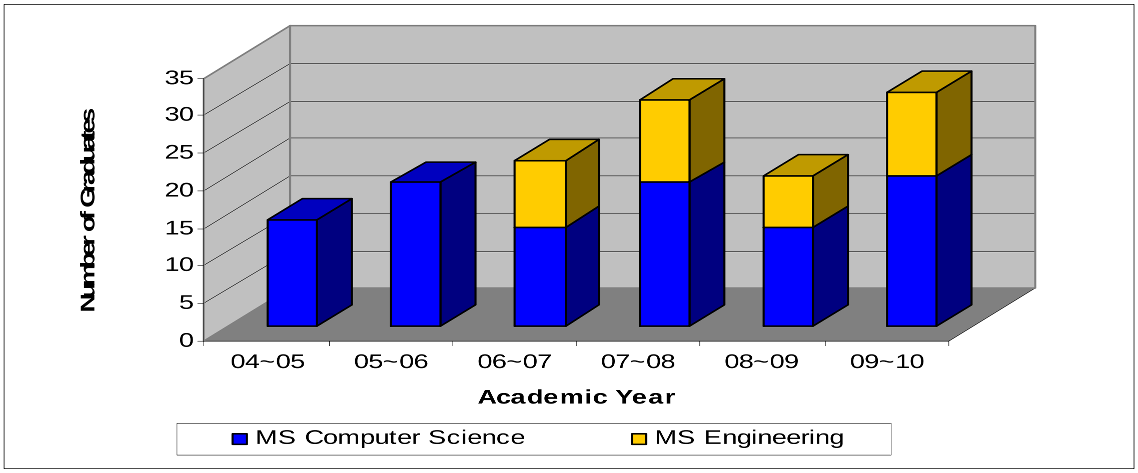

Figure 6. MS Graduates

Figure 6 shows the number of MS degrees awarded in Computer Science and Engineering for the past six academic years. An analysis of employment/academic status of alumni documents those working in engineering positions and those attending graduate school. The total number of BS graduates during this period was 237. We have been successful at identifying the destination of 159 (67%) of these BS graduates. About 30 (22%) of the MS graduates (136) were international students that returned to their country of origin and we were unsuccessful locating these graduates. We are continuing to actively locate more of these graduates and are updating the database continuously. Table 1 shows those working in industry and government (federal, state, or municipal: 109 or 47%) and Table 2 those enrolled in graduate school at universities nationwide (50 or 21%).

Fed/State/Industry Employers	Number of Alumni
Industry	77
Federal Government	21
State Government	12
Graduate School	50
Professional School	2
Military	4
Lost Track	71
Total	**237**

Table 1. Placement (Industry/Government) of BS School of Engineering Alumni

Some examples of the employers of our alumni are: U.S. Army Corps of Engineers Vicksburg District – 10 alumni, U.S. Army Corps of Engineers New Orleans District- 8 alumni, Caterpillar (Peoria, IL) – 7 alumni, Raytheon (various locations) - 6 alumni, Lockheed Martin (various locations) - 5 alumni, etc.

Graduate Schools	Number of Alumni
Jackson State University	38
Texas A & M University	2
Columbia University	1
Arizona State University	1
University of Illinois, Urbana	1
Mississippi State University	2
Washington University, St. Louis	1
Penn State	2
Mississippi College (Law School)	2
Unknown	2
Total	**52**

Table 2. Graduate Schools (MS Programs) attended by BS School of Engineering Alumni

The total number of MS graduates during this six academic year period was 136 and we know the destination of 59 (43%) while 30 (or 22%) returned to their country of origin. Table 3 and 4 show their location nationwide; Table 3 shows those in industry or government and Table 4 shows those in PhD engineering or computer science programs.

Destination	Location	Fed/State/Industry	Number of Alumni
Army Research Lab	Adelphi, MD	FEDERAL	1
CIA	Washington, DC	FEDERAL	1
U.S. Army Corps of Engineers Vicksburg District	Vicksburg, MS	FEDERAL	2
Ameristar Casino	Vicksburg, MS	INDUSTRY	1
Boeing	Los Angeles, CA	INDUSTRY	1
Caterpillar	Peoria, IL	INDUSTRY	1
Cellular South	Ridgeland, MS	INDUSTRY	1
CUTEC	Jackson, MS	INDUSTRY	1
Entergy	Brandon, MS	INDUSTRY	1
Free Scale, Inc.	Austin, TX	INDUSTRY	1
IBM	Austin, TX	INDUSTRY	1
Lockheed-Martin	Various Locations	INDUSTRY	5
Master card	O'Fallon, MO	INDUSTRY	1
Nissan	Canton, MS	INDUSTRY	1
Raytheon	Tucson, AZ	INDUSTRY	4
SAKS New York	New York, NY	INDUSTRY	1
Union Pacific	Omaha, NE	INDUSTRY	2
U. S. Army		MIL	1
Jackson State University	Jackson, MS	STATE	6
Technology School	Mobile, AL	STATE	1
University of Southern Mississippi	Gulfport, MS	STATE	1
MDEQ, MDOT, State Financing, PERS	Jackson, MS	STATE GOV	10
Total			**45**

Table 3. Placement (Industry/Government) of MS Alumni

Graduate Schools	Number of Alumni
Mississippi State University	5
Georgia Institute of Technology	1
Auburn University	1
Louisiana State University	1
Indiana University - Purdue University Indianapolis	1
University of Memphis	1
Louisiana Tech	4
Total	**14**

Table 4. Placement (PhD Programs) of MS Alumni

Based on the data shown in Tables 1, 2, 3 and 4, we conclude that our BS/MS alumni are employed in productive engineering/computer science careers or are matriculating in MS and PhD programs.

Thus far we have established that about 67% of engineering/computer science BS alumni, for which we have ACT data, have ACT Math scores between 17 and 25. A Summer Engineering Enrichment Program was initiated with the objective of increasing the retention rates (especially first and second year), increasing graduation rates in a School of Engineering major and decreasing the time to graduate (to four/five years). It has been established that the preponderance of School of Engineering alumni are in productive engineering/computer science positions. We might add that these alumni are valuable federal and state taxpayers with relatively high paying professional positions.

Analysis of SEEP Results to Date

The Summer Engineering Enrichment Program described in [1] revealed some interesting trends, although it will take another 3-5 years to have sufficient data to quantify the retention and graduation rate impact of SEEP in a statistically significant manner. SEEP intakes students with Math ACT scores from 17 to 25 inclusive. They are enrolled in College Algebra during the first summer term and in Trigonometry during the second summer term. Classes are Monday thru Thursday during each summer term. A non-credit Introduction to Engineering course is taught during the first summer term. Laboratory study sessions are open 10:30am-12:30pm and 1:30pm-4:00pm. Labs are open in the evening as needed, Monday thru Thursday. Graduate students, who attend the morning lectures, are available to assist students during morning /afternoon/evening study sessions. A full-time SEEP Coordinator of Intervention Services works year long with SEEP students/parents (advising, connecting, monitoring performance) and helps chaperone students on visits to engineering employers throughout the local area (Nissan, Engineer Research and Development Center, US Army Corps of Engineers New Orleans District and Vicksburg District, Mississippi Department of Transportation, Jackson Municipal Water District, Entergy Corporation, Stennis Space Center, Diversified Technology, and others).

The first SEEP cohort (Summer 2009) has completed 3 semesters of college work and the 2010 cohort has completed one semester. Performance data are shown in Tables 5 and 6.

Cohort / Data	2009 Cohort	2010 Cohort	2011 & Beyond Plans
Number of Students (School of Engineering)	26	39	50 (planned)
Number with C or better in College Algebra	26 of 26	39 of 39	---
Number with C or better in Trigonometry	21 of 26	39 of 39	---
Number of students enrolled in Fall Semester	24 of 26	39 of 39	---

Table 5. Performance Data for SEEP Cohorts

Cohort / Performance Data	2009 Cohort		2010 Cohort	
Engineering Majors in Cohort, Fall 2010	12		38; (1 Transferred to Biology)	
Number of Students with C or above in Cal. I, Cal. II and Cal III, as of January 2011	Cal I	11 of 12	34 remain in cohort, (2 Transferred to Community College and 2 Transferred to other 4-Year College)	
	Cal II	11 of 12	Cal I	30 of 34
	Cal III	10 of 11		
ACT Math ≥ 20 (Jan 2011)	11 (11/13)		20 (20/20)	
Remaining students with 17 ≤ ACT Math < 20 (Jan 2011)	1 (1/11)		14 (14/19)	

Table 6. Calculus/Physics Performance Data for SEEP Cohorts

Based on data contained above and the distribution of ACT Math scores for School of Engineering graduates (Figure 2), it appears that perhaps even though there are the maximum number of graduates with ACT Math scores at 17/18 (Figure 2 and Figure 3), that may be a little misleading. The preparedness of students (including graduates) enrolled before 2006 was lower (Figure 1) as confirmed by ACT Math and Composite data for First Time Freshmen students. This is most likely because formal accreditation notification for engineering programs was not received until August 2007 even though accreditation was effective as of October 2004. Consequently, we analyzed the 1-year and 2-year retention rates and graduation rates for two groups of First-Time-Freshmen students; Math ACT < 20 and Math ACT ≥ 20 and compared these with data in [1] for Math ACT < 17 and Math ACT ≥ 17. These data are shown in Figures 9, 10, 11, 12, 13, and 14.

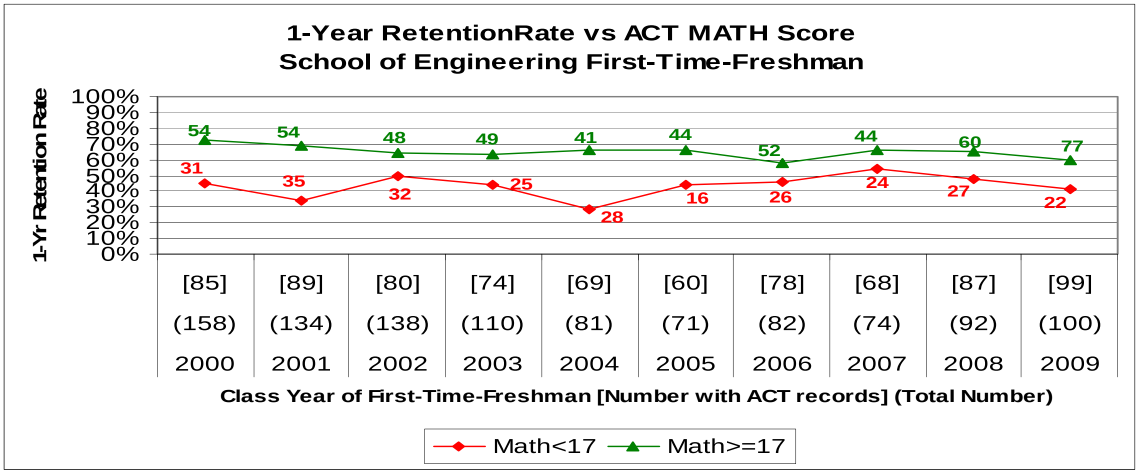

Figure 7. 1-Year Retention Rate vs. ACT Math for First-Time-Freshmen in School of Engineering

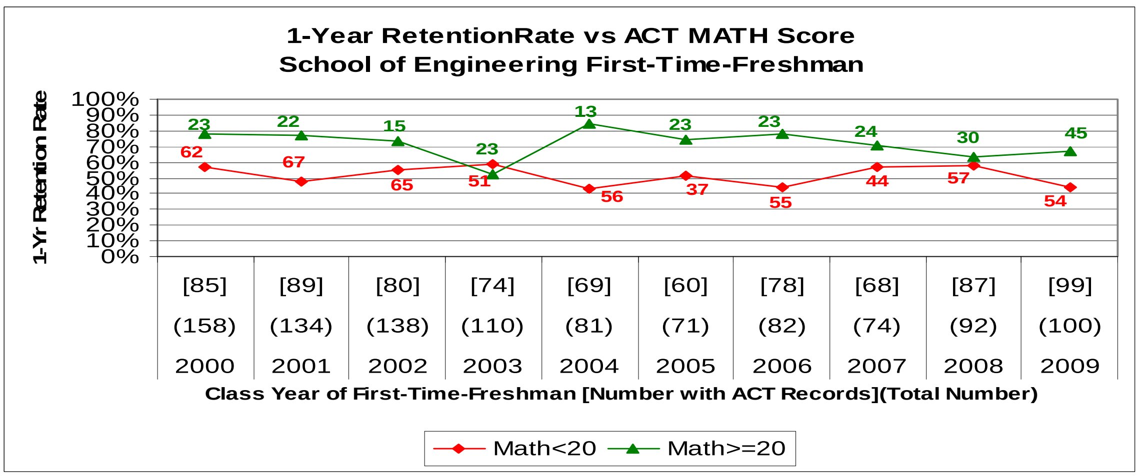

Figure 8. 1-Year Retention Rate vs. ACT Math for First-Time-Freshmen in School of Engineering

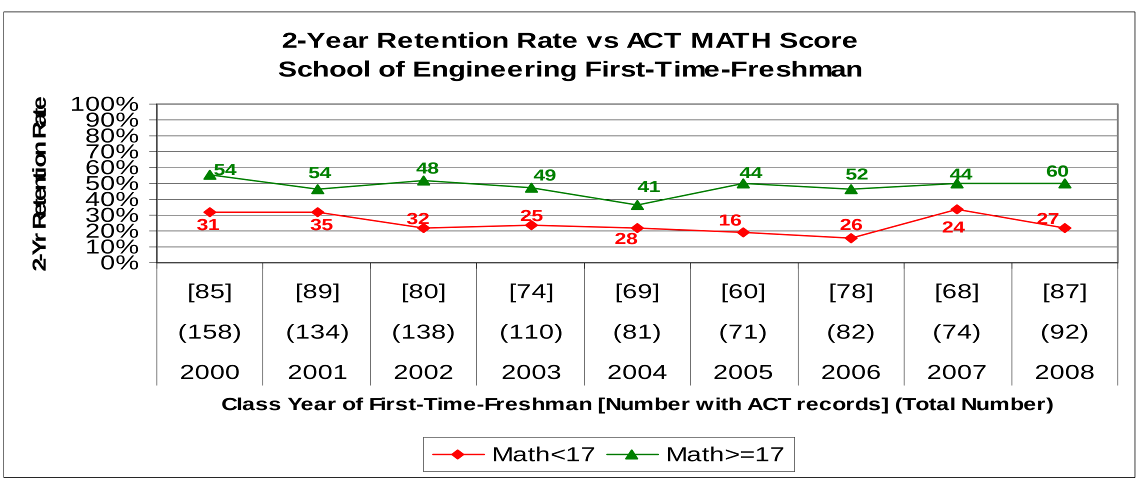

Figure 9. 2-Year Retention Rate vs. ACT Math for First-Time Freshmen in School of Engineering

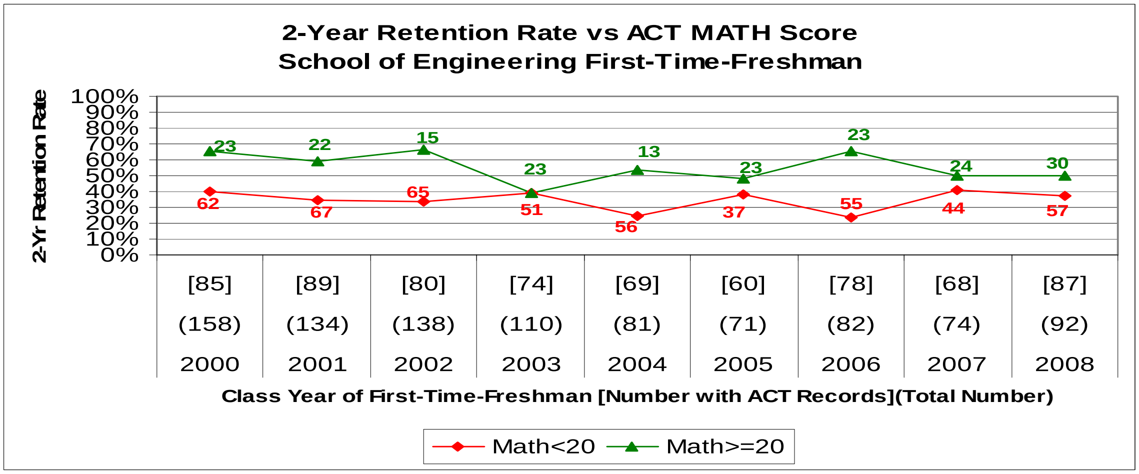

Figure 10. 2-Year Retention Rate vs. ACT Math for First-Time Freshmen in School of Engineering

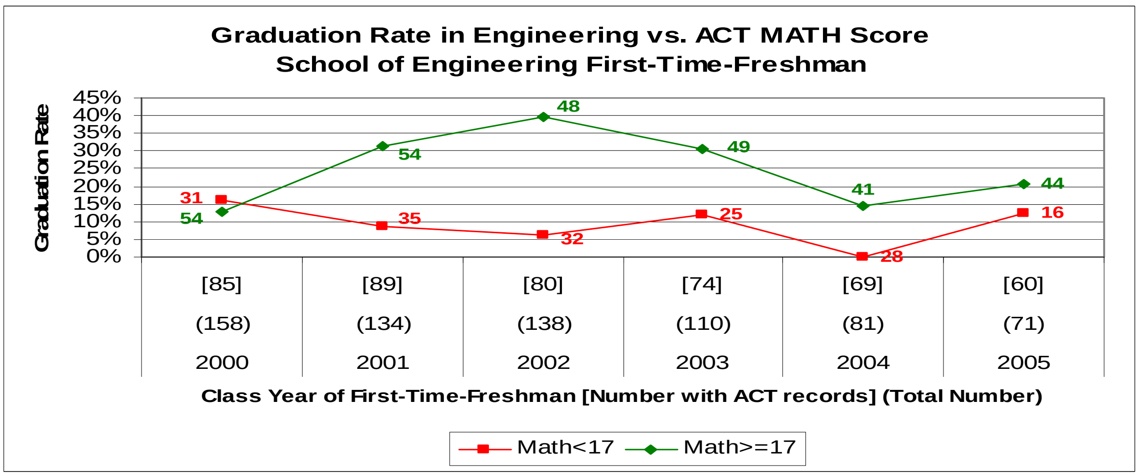

Figure 11. Graduate Rate vs. ACT Math for First-Time-Freshmen in School of Engineering

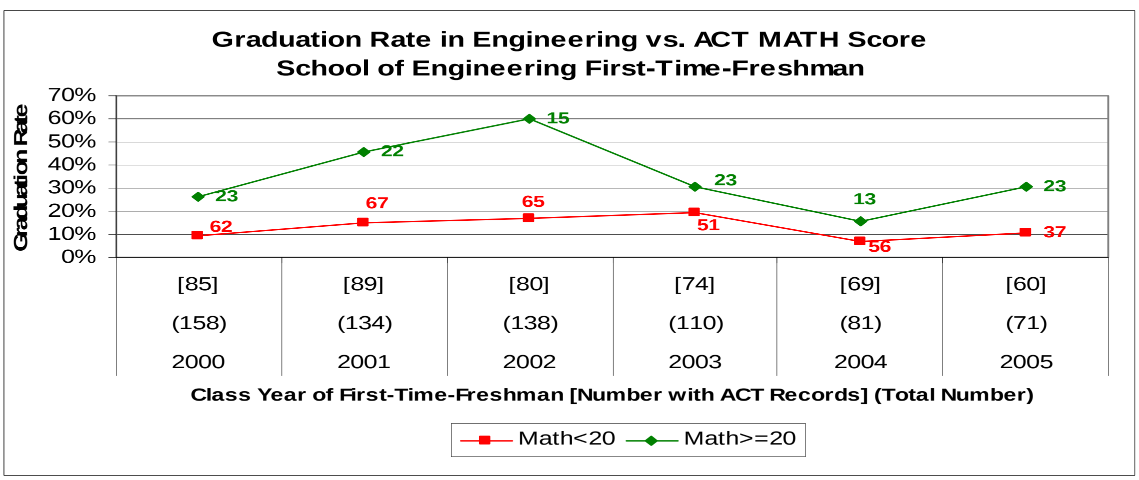

Figure 12. Graduate Rate vs. ACT Math for First-Time-Freshmen in School of Engineering

These data clearly illustrated that significantly higher retention rates and graduation rates occur for those students with ACT Math ≥ 20 relative to those with ACT Math ≥ 17.* This observation profoundly impacted recommendations in the following section for solving the engineering pipeline challenge. The following table summarizes the comparison.

	1-Year Retention Rate	2-Year Retention Rate	Graduation Rate
Math ACT ≥ 17	65%	48%	25%
Math ACT < 17	43%	25%	9%
Math ACT ≥ 20	71% 80%*	55% 70%*	34% 50%*
Math ACT < 20	51% 65%*	34% 50%*	13% 30%*

Table 7. Comparison of Retention/Graduation Rates

*The red percentages in Table 7 are target retention rates and graduation rates as a result of SEEP. Based on results to date, we are confident they are achievable within the seven years of the summer program (2009 – 2015). These are the rates used for the Group 2 computations and the last two years of the Group 1 computations in Tables 9, 10, 11 and 12 in the following sections. Each entry (black) in Table 7 above is computed from one line of data in Figures 7-12. That is, a weighted (i.e. equal weight for each student) average percent retention/ graduation is computed from the sum of the number of students times the percent retention/ graduation for each year divided by the total number of students for all years producing a weighted percent retention/graduation for each line of the six graphs of ACT Math Scores in Table 7.

Solution to the Engineering Pipeline Challenge

Given the fact 67% of School of Engineering alumni over the past six academic years had ACT Math Scores in the 17-25 range, the fact that all those located are holding well paying professional positions or attending graduate school and the apparent emerging success of the SEEP for this ACT group; a solution to the engineering pipeline challenge seemed apparent. The solution is to more than double the production of our next generation of engineers and obtain these new majors from the relatively large supply of U.S. citizen (and permanent resident) high school graduates with 17 ≤ ACT Math ≤ 25 (over 1.6 million annually [3][5]). The proposed solution is elucidated below:

1) The supply of First-Time-Freshmen will come from high school graduates in the 17 ≤ Math ACT ≤ 25 group (about 20% of the group). [3][5] This has a relatively small overlap (based on personal communications) with engineering programs nationwide since the majority of Colleges of Engineering do not accept majors from most for this group.
2) Select two groups as follows 17≤ Group 1 (Math ACT) ≤ 19 and 20 ≤ Group 2 (Math ACT) ≤ 25.
3) Summer SEEP programs will be offered for each group. Group 1 students will attend Community Colleges that are paired with one or more public universities in each state with ABET accredited engineering programs. It is suggested that the Community Colleges be subcontractors to participating universities in order to insure a seamless coupling of the programs. Group 2 students attend SEEP programs at public universities with ABET accredited engineering programs nationwide. Note: if some public universities do not wish to participate, that is fine, the number of students can be increased at participant universities to compensate for those universities who do not participate. Group 1 and Group 2 programs will vary with the objective of maximizing graduation rates of each group.
4) SEEP students in engineering majors and in good academic standing will be awarded Full Tuition Scholarships at either the Community College or the University, renewable each

year they maintain a good academic standing and maintain sustained progress in a School of Engineering major for four years.

5) Future dialogue can discuss additional incentives for students to choose engineering as their major such as inclusion of laptops in fees, purchasing engineering books and/or awarding stipends after successful completion of years 2 and 3. This would add a relatively small % to the total cost.

Based on the limited performance data to date in the two SEEP program cohorts, it is concluded that the relatively rapid (College Algebra in first summer term and Trigonometry in second summer term) teaching of mathematics skills is a little too much for Group 1 students with $17 \leq$ ACT Math < 20. Consequently, a Community College experience is recommended with the entire summer (10 weeks typically) after high school being used to teach Group I students College Algebra. This reserves Trigonometry for the first semester in the Fall of their Freshman year and Calculus I for the Spring semester of the Freshman year. This necessitates a second summer session after the Freshmen year for Community College Group 1 students so they can receive an Associates degree in May of their sophomore year and join their high school peer group at the University for their Junior Year. Table 8 summarizes the Group 1 and Group 2 four year programs from the mathematics curriculum perspective.

	Group 1 (Community College) **$17 \leq$ Math ACT ≤ 20**	**Group 2** **$20 \leq$ Math ACT ≤ 25**
Summer Program	1A. College Algebra (8-10weeks) 1B. Not Applicable 2. Introduction of Engineering (non-credit) 3. Study Labs, tutors, learning community, mentors, awards	1A. College Algebra (5 weeks) 1B. Trigonometry (5 weeks) 2. Introduction to Engineering (non-credit) 3. Study Labs, tutors, learning community, mentors, awards
	4. Friday Trips to Engineering Employers	
Fall Semester Freshmen	1. Trigonometry 2. Other courses	1. Calculus I and Chemistry I 2. Other courses
Spring Semester Freshmen	1. Calculus I and Chemistry I 2. Other courses	1. Calculus II/Physics I 2. Other courses
Summer	1. Calculus II	1. Internship/Other
Fall Semester Sophomore	1. Calculus III/Physics I 2. Other courses	1. Calculus III/Physics II 2. Other courses
Spring Semester Sophomore	1. Differential Equations/Physics II and/or Calculus IV	1. Differential Equations and/or Calculus IV
Summer	1. Internship/Other	1. Internship/Other
	FALL JUNIOR YEAR AT UNIVERSITY	. UNIVERSITY FALL JUNIOR YEAR AT

Table 8. Suggested SEEP's for Community College (Group 1) and University (Group 2)

Some Universities/Community Colleges teach different calculus sequences for engineering majors (i.e. three four hour courses or four three hour courses) but most all total 12 semester hours. This is another reason it is recommended that Community Colleges be subcontractors to a participating ABET accredited university in each state. This arrangement can insure a seamless transition from the Community Colleges to the Universities which is essential to maximize productivity of engineering graduates. Those managing the program in the US Department of Education can ascertain if they wish to award a grant/cooperative agreement/contract to one (others would be subcontractors) or every participating ABET accredited University in each state. There may be management merit in dealing with only one formal funding vehicle per state; however, there are also drawbacks. This can be sorted out by Department of Education on implementation. The recommended legal vehicle is a Cooperative Agreement because it best represents a true partnership between the federal government and the executing organization (ABET accredited university in this case).

It is proposed that the US Department of Education authorize a new budget line for providing an expedient near term solution to the "Gathering Storm" Challenge in the FY 2013 budget. A suggested budget for Year 1 is $0.88 Billion, increasing to $2.16 B, $3.83B, and $5.80B over a four year period. Year four is a full funding level for an intake of 320,000 Freshmen SEEP students nationwide. Future year intake would remain constant at 320,000 students annually and the projected steady state graduation would be 128,000 additional engineers/computer scientists annually reached in May 2020. This is an increase of 172.6% over the estimated US production in 2009 of 74,170 [16]. The program would produce an additional 128,000 engineers (and computer scientists) annually by 2020 starting with an increase of about 32,000/annually in May 2017. The assumptions, estimates, costs and ROI follow that comprise this proposal. Table 9 summarizes student intake and projected engineers graduating. Table 10 shows the number of students each year.

One substantial asset of this program would be that a much greater number of minority US citizens would become engineers/computer scientists since it is well known that their percentage of the population in the $17 \leq$ ACT Math ≤ 25 range is significantly greater than their percentage of the population in the ACT Math > 25 range.

It is recommended that the first years intake be 80,000 SEEP students (1/4 of the number at full implementation) and that the intake be increased every year by 80,000. A preliminary recommendation is that an equal number be taken in Group 1 and Group 2. It will be shown that these numbers achieve an additional estimated 128,000 BS engineer/computer science graduates by 2020 beginning with 32,000 graduating in 2017. Table 9 below displays the intake information described above.

		Student Intake		**Projected Graduates**		
Year	**Cohort**	**Group 1**	**Group 2**	**Group 1**	**Group 2**	**Total**
2013	1	40K	40K	---	---	---
2014	2	80K	80K	---	---	---
2015	3	120K	120K	---	---	---
2016	4	160K	160K	---	---	---
2017	5	160K	160K	12K	20K	32K
2018	6	160K	160K	24K	40K	64K
2019	7	160K	160K	36K	60K	96K
2020 & beyond	8& beyond	160K	160K	48K	80K	128K

Table 9. Proposed Student Intake and Projected Graduation (in Thousands, K)

Table 10 below documents the retention/graduation rates used for the program cost computations displayed in Tables 11 and 12. These rates are estimated based on SEEP results, data shown in

Table 7 and best judgment estimates of SEEP achievements for both Group 1 and Group 2 students.

		University	
Cohort Year	Community College Group I	CC Transfer Group I	University Group 2
1 Summer Fall	I 0.95I	---	I 0.95I
2 Summer Fall	(0.95)(0.65)I (0.95)(0.65)I	---	--- (0.95)(0.80)I
3 Fall	---	(0.5)I	(0.95)(0.70)I
4 Fall	---	(0.30)I	(0.50)I
Graduates		(0.30)I	(0.50)I

I = Summer Program Intake

Table 10. Number of Students with Retention Rates

The estimated cost for solving the engineer pipeline challenge is displayed in Tables 11 and 12 using the intake data and retention rates shown in Tables 9 and 10. Table 11 displays the estimated cost and number of graduates from Group 1 and Group 2 students from the first class in 2013 which is assumed to graduate in May 2017.

Fiscal Year	Community College	University	Total Cost (First Class)	FY Total (First Class)
2013 Summer Academic Year	200M $152M	300M 228M	500M 380M	880M
2014 Summer Academic Year	60M 102M	--- 188M	60M 290M	349M
2015 Academic Year	127M*	178M	306M	306M
2016 Academic Year	79M*	127M	206M	206M
Total	720M	1,201M	1,741M	1,741M
Students graduated	12K	20K	32K	32K
Cost per graduate	$59,967	$51,072	$54,408	$54,408

Table 11. Program Cost (in Millions, M) by Fiscal Year; Class of 2013 (First Class)
(Assumed 3% Inflation/Year)
***Cost for Community College students that transferred to University**

The following assumptions were used to produce the cost information in Table 11 and Table 12.

1. Cost of First Year Summer Program is $7,500/student at University including Tuition, Room and Board, Books, Professors, Graduate Assistants, Enrichment Travel, Program Director, and Part-Time Program Assistant. Estimate based on current SEEP costs.
2. Estimated Cost for same at Community College is $5,000/student
3. Cost for Tuition/Fees during Freshmen Year (Fall 2013) at University is estimated at $6,000 and at Community College is $4,000 (Fall 2013).
4. Projected retention rates and graduation rates are show in Table 7.
5. A 3% annual inflation rate was used for all expenses each academic year after 2013.

It was assumed in Table 11 that 100% of the estimated number of students that began their senior year (30% of Group 1 intake and 50% of Group 2 intake) graduated. This compares with the national average graduation rate of 52% for Colleges of Engineering [2]. The assumption that all students graduate in four years is certainly overly optimistic; however, the program is based on a four year funding cycle and the number of graduates projected is reasonable, even if some delay in graduation by co-op opportunities or students who take a lesser course load to help insure good academic performance. If the students take five or six years to graduate, then they must deal with the cost for the additional years themselves (i.e. through student loans; paying themselves, undergraduate student research for faculty, etc.).

The lesser cost per engineer for the 4 year university student relative to students who attended a community college for two years and transferred to a university is due to the extra summer session after their freshmen year (tuition scholarship during second summer) and the projected larger attrition rate for the Group I students (17 ≤ ACT Math ≤ 19). Some may suggest that Group I students be abandoned because the ROI is less than that for Group II students. I would argue strongly that this is an unwise, albeit economically expedient, course of action. The transfer major of choice for many students not retained in engineering programs is a Technology program (ATMAE or ABET accredited). The nation has a dire need for Technology graduates and it is hypothesized that students who are not retained in a pre-engineering program at a Community College, will likely gain an Associate Degree in Technology and will also become highly productive members of the US technological workforce.

	In-take	80K	160K	240K	320K	320K	320K	320K	320K	
Grads	FY	2013 Cohort	2014 Cohort	2015 Cohort	2016 Cohort	2017 Cohort	2018 Cohort	2019 Cohort	2020 Cohort	FY Cost Millions
---	2013	880M	---	---	---	---	---	---	---	0,880M
---	2014	349M	1,813M	---	---	---	---	---	---	2,162M
---	2015	306M	720M	2,901M	---	---	---	---	---	3,826M
---	2016	206M	629M	1,112M	3,846M	---	---	---	---	5,794M
32K	2017	---	424M	973M	1,528M	3,962M	---	---	---	6,886M
64K	2018	---	---	656M	1,336M	1,573M	4,081M	---	---	7,645M
96K	2019	---	---	---	900M	1,376M	1,621M	4,203M	---	8,100M
128K	2020	---	---	---	---	927M	1,417M	1,669M	4,329M	8,343M
128K	2021	---	---	---	---	---	955M	1,456M	1,719M	---
128K	2022	---	---	---	---	---	---	983M	1,503M	---
128K	2023	---	---	---	---	---	---	---	1,013M	---
128K	2024	---	---	---	---	---	---	---	---	---
128K	2025	---	---	---	---	---	---	---	---	---
Cost per Cohort		1,741 M	3,586M	5,642M	7,610M	7,838M	8,074M	8,311M	8,564M	
Cost per Engineer		$54,406	$56,031	$58,771	$59,453	$61,234	$63,078	$64,930	$66,903	

Table 12: Estimated Program Cost (in Millions) by Cohort (in Thousands, K) and by Fiscal Year

It has been shown that the US can reasonably substantially ameliorate our engineering pipeline challenge in the near term by taking advantage of the supply of potential engineers with 17 ≤ ACT Math ≤ 25 coupled with Summer Enrichment Programs, tuition scholarships, student mentoring, communities of learners and a caring/nurturing Community College/University environment. This challenge can be solved with the existing elementary/high school systems while the US takes on the longer term challenges described in [8]. The cost to more than double

(+172%) our engineer/computer scientist BS graduation rates at full implementation is reasonable, estimated at about $8.3 Billion/year in 2020 and it is projected that the program will be cost neutral for the US taxpayer by 2020-2025 due to increased tax revenue (both federal and state) and will be a money making government/taxpayer investment thereafter.

Summary

The purpose of this paper is to stimulate a national dialogue to initiate a program in the Department of Education, as soon as possible, to solve our compelling engineer/computer scientist pipeline challenge in the near term. The nominal cost of such a program to more than double the annual production of engineers by 2020 is $8.3 Billion (in 2020 to produce another 128,000 engineers), beginning with about $1 Billion in the 2013 budget to produce another 32,000 engineers in 2017. We hope a national dialogue will lead to initiation of a similar program (about $1 Billion in 2013) utilizing assets of all/most US public Universities and Community Colleges as suggested. It is believed that such a program is imperative for maintaining our national economic and technological security while the US takes on the longer term challenge described in [8] which may ultimately double/triple the supply of potential engineering majors in the ACT>25 group.

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