AC 2007-2348: ARE TODAY'S ELECTRONICS TECHNOLOGY PROGRAMS DOOMED TO EXTINCTION OR IS THEIR MISSION CHANGING?

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Are Today's Electronics Technology Programs Doomed to Extinction or is their Mission Changing?

Abstract - Across the nation, numerous legacy electronics technology programs at the two-year college level are: being converted to Cisco and A+ based computer networking and repair programs, increasingly being asked to teach electronics fundamentals to non-electronics based technologies, and, most significantly, experiencing declining enrollments. In some cases, programs have been discontinued entirely due to a persistent lack of students. In essence, the basic core mission of the legacy electronics technology program, to produce "electronics technicians", has been morphing into a hybrid educational endeavor. This fact is being driven by the increasing use of complex electronic systems and sophisticated instrumentation, which may or may not be networked, in other non-electronics based technology fields. This technology evolution has increased the need for legacy ET programs to assume the role of an "academic service department" for these other programs while the ET programs themselves still struggle with the problems of attracting students and eventually graduating them as electronics technicians. Another interesting development is industry's emerging, widespread, and seemingly rapid embrace of embedded, networked sensor systems and their future impact upon the ET curriculum. This paper will examine these phenomena and the certain resulting changes that will occur to the landscape of ET programs as electronics and its derivative technologies continue to evolve.

I. Overview

For some time now, many of us involved in the teaching of electronics technology (ET) at the AS degree level have been extremely concerned over the relative health of these legacy technology programs. Declining enrollments have taken their toll in terms of a lack of new faculty hires and, in some cases, where there has been an attrition of faculty members through retirement or for other various reasons, this has signaled the end of the ET program if the college decides to redirect its resources elsewhere. This problem of declining enrollment and program elimination has not just occurred overnight. It has been happening steadily over the last two decades. If one looks at the statistics available from the National Science Board (NSB), the total number of students enrolled in the field of Engineering Technology has been declining from an all time high in the early 1980s to today's lower full time equivalent (FTE) student count. According to the NSB figures, degrees awarded in the Engineering Technologies (typically in the fields of civil, electrical/ electronics, construction, computer, and mechanical technology) have fallen from approximately 53,667 in 1985 to 35,544 in the year 2000. One might note that during the same time frame, AS degrees awarded in the computer sciences rose from 26,500 to 33,700 [1]. In a survey taken in 2002, a majority of respondents said that enrollments in their ET programs had declined 20 to 90% in the last decade [2]. Today, most faculty teaching in these programs will say that, in general, enrollment has gotten worse over the last five years.

While little has been written about these declining enrollments at the community college level, there has been much ado made about the future of our country's competitiveness in the global marketplace in terms of degrees awarded in the sciences and engineering (S&E) fields at the bachelor degree level. There have been many mainstream publications that have pointed out that the number of engineering degrees that countries like India and China award far exceed those awarded in the United States and that they will continue to increase at a faster rate than in the

US. This is of great concern if you are convinced, as author Thomas Friedman is, that *The World is Flat*. One could probably make the case that this new world paradigm involving S&E education will carry over to the AS or "Foundation" degrees awarded for technician level study without receiving a great deal of argument. Government policy setting organizations like the NSB have been busy attempting to advance the agenda of increased enrollment in S&E through the National Science Foundation (NSF). In particular, the NSF has become active in the promotion of technology education through the Advanced Technology Education (ATE) program and its ATE Centers [3]. While many of the ATE projects and Centers tend to address new and emerging technologies, several ATE projects have attempted to address the perceived declining state of electronics technology education. However, at the present time, there is a lack of hard facts to indicate that their efforts have had any appreciable impact; only anecdotal stories suggest that this is might be the case. In the United States, it is a fact, that for a myriad of reasons, high school graduates and young adults are just not being attracted to the science, mathematics, engineering, and technology (SMET) areas like they are in many other countries [4]. Interestingly, this trend of increased S&E enrollment is not only happening in Asian countries but in European countries as well! Other organizations such as the American Society for Engineering Education (ASEE) have also expressed concern over the lack of students enrolled in S&E majors but this group tends to focus its attention on four-year Engineering and Engineering Technology degrees and in particular those programs that have ABET accreditation. Many ABET accredited two-year Electronics Engineering Technology (EET) programs have as their main goal transferability and therefore their degree graduates are not worried about getting a job immediately upon graduation but are more concerned about being accepted by a receiving four-year program. In this author's opinion, those types of programs are somewhat more immune to the effects of declining enrollments than the two-year programs that have a primary goal of preparing the student for the workplace at graduation. Of course, this does not mean that they have not experienced declines in enrollment as well.

A second aspect of the "health" of community college ET programs has to do with the present curriculum. Some of us involved in the teaching of this subject matter have contended that it has become out-of-date and in many cases irrelevant to the skill sets needed by the modern ET technician [5,6]. This is certainly a debatable issue but it appears that more and more programs have opted to begin to change their curricula in an attempt to make it more in line with what are perceived as the skills desired by the workplace. Of course, maybe that is one of the biggest problems – converging on and reaching consensus on just what the skills are that an electronics technician needs, or for that matter, first defining what an electronics technician does. Again, this issue does not effect the two-year ABET programs as much since they are inclined to emphasize the basics for two years and tend to defer the applications of the technology to the upper-level four-year programs. These curriculum issues will be addressed in more detail later in various sections of this paper.

How have ET faculty reacted to the problem of declining enrollment? During the last decade, across the nation, numerous legacy electronics technology programs at the two-year level have opted to become Cisco and A+ based computer networking and repair programs by adding these options to their degree offerings. Many faculty in ET programs will tell you that becoming involved with Cisco Networking and/or A+ computer repair saved their departments and possibly either saved or extended their careers in higher education. Also, at the same time that enrollments have been shrinking, the ET faculty has been asked to teach more and more courses in DC/AC electrical fundamentals or customized electronics courses or modules to students enrolled in non-electronics based technologies such as alternative energy, automotive, bio-medical, computer, energy systems, laser optics, and telecommunications technology, to name but a few. One would expect this trend to continue as these technologies embrace and adopt complex electronics systems and instrumentation into their sphere of influence. In the New England and New York area, the Verizon NextStep program [7], a decade old cooperate specific program for company technicians that leads to an AAS degree with a concentration in telecommunications has injected new life into the electronics programs of the 26 collaborating community colleges in this region. Many of the faculty participating in this program will suggest that it has kept their regular ET programs in business.

II. How did we get to this point?

Today, the world's economies produce and consume more electronics components and products than ever before, computers and cell phones are ubiquitous, electronics devices and systems are embedded in more goods than ever. These products and systems are more complex and sophisticated than ever before, and all these systems are increasingly becoming networked together. That said, why is there not a greater than ever need for electronics technicians? Typically, anytime there is more of a certain type of product, take for instance the automobile, there is more need for support personnel to repair and maintain that particular product (or fleet in the case of the automobile). The answer to this question as it pertains to electronics products is somewhat paradoxical. However, before addressing the question, let's take a short look at the evolution of the typical electronics technology program curriculum to see what forces have been at work to bring us to this point.

The early electronics curriculum was tied to the technology of the time. During the 1970s and through the 1980s, the ET student was taught the subject matter to the part or component level where the device's actual electronics behavior occurred. As the fields of digital logic and digital computers evolved this new material was typically added to the ET curriculum and it was also taught to a part level. The very technical topics of transistor biasing, operating point, and load line were standard fare for the ET student, as were Op-Amps, 7400 series logic gates, Karnaugh maps, and "gate pounding" techniques (to name but a few topics in that era's electronics technician's skill set). Of course, teaching this way was perfectly natural since the electronics or computer technician of the day would need to troubleshoot faulty equipment, manufactured in that era, to the defective component. It was therefore necessary for the electronics technician to understand the how's and why's of the component's operation, its terminal characteristics, its function in the circuit and so on, if repairs to malfunctioning electronic systems were to be made successfully.

However, this is where Moore's Law comes in and changes the dynamics of the evolution of electronics technology. Simply put, Moore's Law talks about the doubling of chip capacity every 18 to 24 months (See Figure 1). Most of those familiar with this tenet relate to it in terms of the evolution of the PC (e.g. consider the ever increasing base amount of internal RAM memory). The result of this trend for a PC is that increased RAM capacity allows for more complex software and therefore more sophisticated computer applications. Other aspects of Moore's Law are a corresponding reduction in price and an increase in speed of operation. The evolution of PC hardware has been an embodiment of Moore's Law for decades. However, what is not talked about as much in reference to Moore's Law is the corresponding doubling of chip functionality that occurs during the same time span! At this point in the evolution of microelectronics technology, we produce gigascale ICs that enable: system-on-chip (SoC), system-in-package (SiP), programmable system-on-chip (PSoC), and sensor system-on-chip (SSoC) technology. Somewhere along the microminiaturization of electronics path, a tipping point was reached and as a direct consequence of these innovations (i.e. the resulting amount of memory and embedded control and processing now available on a chip) changes started to occur in the way we now deal with electronics and relate to it. This author contends that the physical layer (i.e. electronics hardware) has evolved from what it once was. The new physical layer consists of sub-layers that can control and configure the core hardware devices.

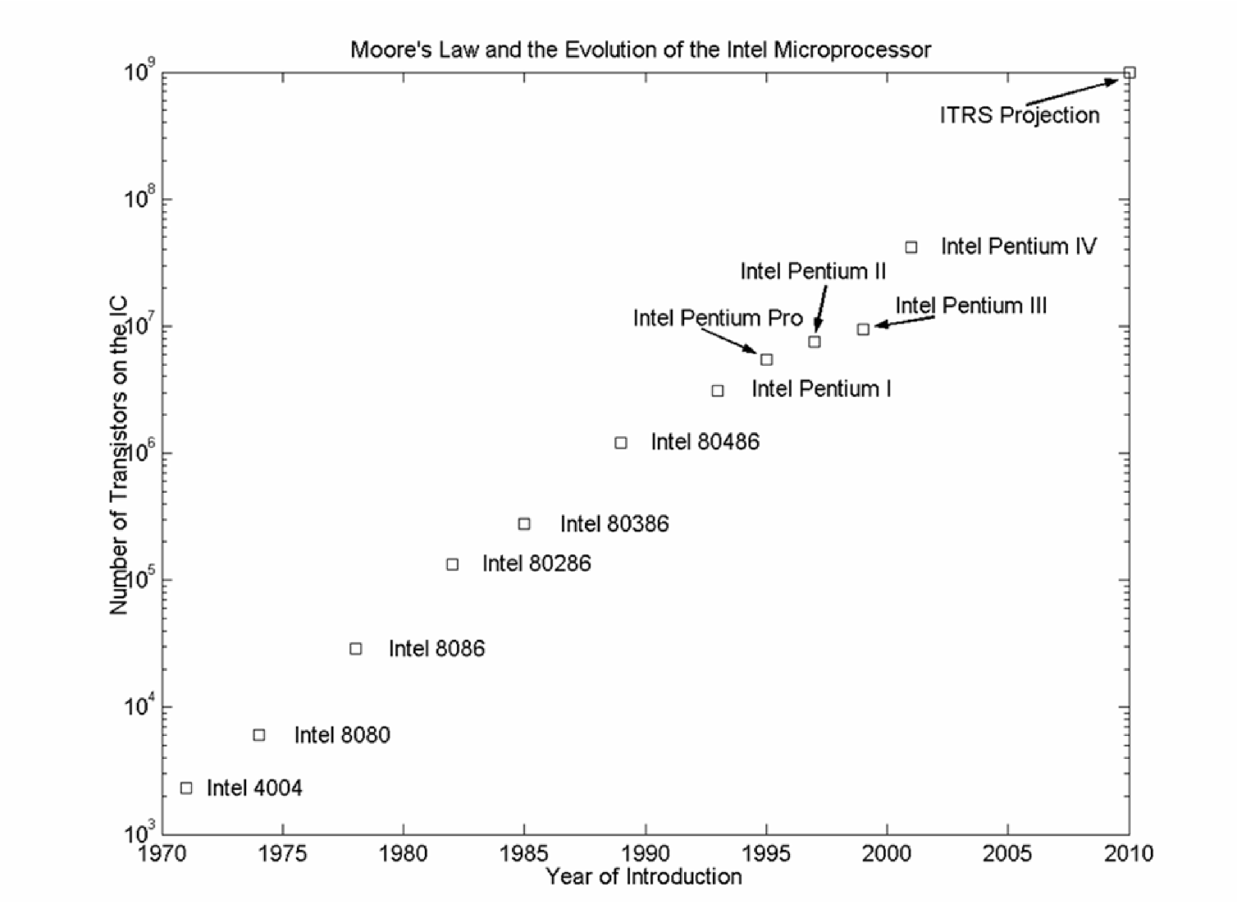

Figure 1 – Moore's Law and the total number of transistors on Intel microprocessor ICs (Source: Mullett, Gary J. (2003). *Basic Telecommunications: The Physical Layer,* Clifton Park, NY: Delmar Learning)

The old physical layer consisted of hardware that was fixed in its purpose and its functionality and consequently these facts in some sense determined the way electronics was taught. An electronic system like the classic superheterodyne radio receiver had but one basic function. Its operation could only be altered through physical operator intervention (e.g. the receiving frequency, tuning range, and output volume were adjustable). We will call this type of hardware "user unaware" since it allowed no high-level interaction with the user. Early digital computers also consisted of fixed hardware elements. However, they exhibited a new type of versatility through their ability to be programmed and hence their ability to change their operational flow and function (i.e. the use of different hardware elements was under software control). This ability to change system operation via software heralds the beginning of a systemic change in hardware functionality and also introduces the use of the expression "the software is the hardware". Today's new physical layer [8] is embodied in today's digital hardware. Typically, its function can be altered through software control (i.e. interfacing with the control sub-layer of the hardware). This existing ability allows one to build functioning electronic systems that are reconfigurable. Figure 2, Mullett's model of the physical layer, illustrates this new paradigm in hardware control and management.

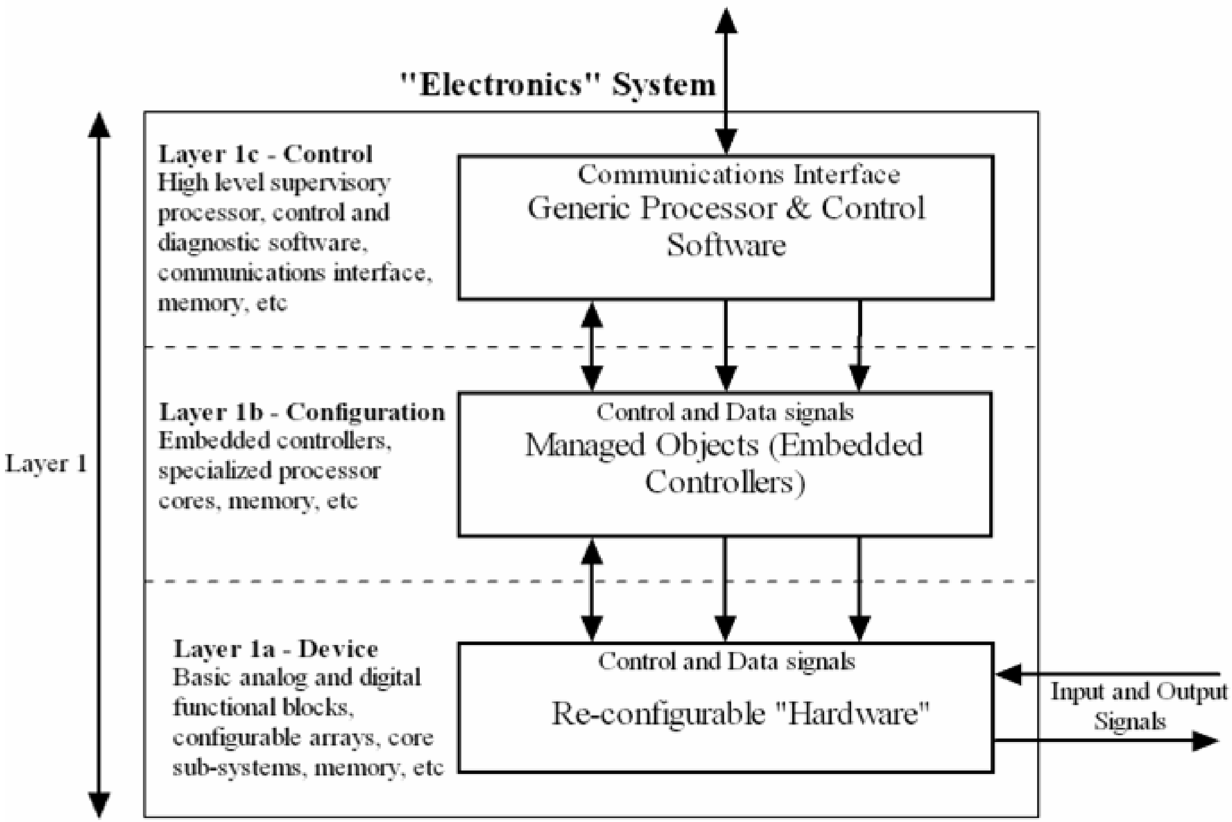

Figure 2 – Mullett's model of the new Physical Layer (Source: *The 2010 Gigascale Imperative*, Proceedings of the 2005 ASEE Annual Conference and Exposition)

In the near future, it is predicted that various analog and mixed mode (i.e. analog and digital signal) systems-on-a-chip will even have a limited capacity to "evolve" on their own in response to how well they perform their desired operations. In other words, they will be self-reconfigurable. Presently, new complex programmable logic devices (CPLDs) are including embedded processing "cores" as functional parts of these chips. This fact gives today's system designers unparalleled chip functionality with potentially limitless possibilities. In an indication as to where this trend is going, Intel Corp. recently made public a technology initiative known as "Platform 2015" that proposes that the next generation of hardware will be "user aware". Intel suggests that future microprocessor development will key on multiple parallel-processing "cores" that can not only reconfigure their architecture and interconnections but more importantly can sense the particular use or application that a human has for the hardware and respond accordingly.

What impact has the evolution of electronics had on ET education? Today's technician typically does not repair to the part level. Instead, today's technician evaluates system operation and performance, performs maintenance by replacing field replaceable units (FRUs) or sub-systems, and alters equipment operation and functionality through software patches and/or upgrades via a connected laptop computer. The traditional "hands-on" aspect of repair has taken on a new look. Industry today is looking for individuals that can troubleshoot from a systems perspective and that also have the soft skills necessary to deal with the customer and other members of the company "team". Has the typical ET program's curricula kept up with these changes? In most cases, this author would guess that the answer is, unfortunately, not as well as they should have.

So let's return to the question at hand, why are ET enrollments declining? Aside from the obvious reasons, that fewer young people are enrolling in S&E programs. In no particular order here are some observations and thoughts on this subject:

- A simple explanation is that there are fewer positions to be filled hence less demand for ET grads. Fewer manufacturing jobs and a change in the field service and repair dynamic leads to fewer job postings for ETs. Additionally, the off-shoring of technology jobs is in the news, the fact that recent ET grads are not able to find immediate employment as easily as in the past, and negative word-of-mouth tales paint an overall bleak employment picture. Eventually, one may have the classic "death spiral" where the perception is worse than the reality and enrollment plummets until either enough time passes that local demand for employees increases dramatically, due to a natural attrition in the workforce, or some disruptive event changes the status quo (e.g. the introduction of a new technology) and turns the situation around.

- Why are there fewer jobs? Better reliability and lower product cost are part of the answer. There is a perception that electronics has become a "throw-away" technology while at the same time electronic equipment has become extremely reliable through present day microelectronics manufacturing techniques. Therefore, fewer technicians are needed to maintain and repair the products out in the field. These prior statements are basically true however the throw-away tag applies more to consumer electronics products then anything else. Although, try to convince someone that owns a large screen HDTV that develops a malfunction after the warrantee has expired that the throw-away term applies to their TV!

- The present ET faculty is basically an aging faculty that was hired years ago during the time when enrollments were peaking. As a group, they are not as up-to-date as they could be and as a consequence enrollment suffers to varying degrees as the curriculum starts to fall out of alignment with current technology. As an observational side note, the average electronics instructor in the Verizon NextStep program is very close to retirement age!

- Related to the above statement, some community college administrations are unable or unwilling to spend the required money to keep ET lab equipment and facilities on the cutting edge of technology and also provide professional development opportunities for the faculty. New labs and equipment attract students. Of course, most of the time, more resources typically go to the programs with the highest enrollments or increasing enrollments. This problem becomes a vicious circle if your program's enrollment is in decline!

- Returning to the issue of a lack of interest by college aged individuals in S&E majors, a whole host of problems at the middle and high school level exist involving the teaching of science, mathematics, and technology. In general, students seem to develop negative perceptions about careers in these fields while in grades 6-12. There aren't too many TV shows that glorify S&E careers. For those that do, not everyone can be a crime scene investigator (CSI).

- Also, according to the U.S. Department of Education, for the last twenty plus years more women than men are attending college [9] and the relative percentage of women versus men enrolled continues to grow. Historically, it has been extremely difficult to draw females into the technologies and this trend persists today even with all the proactive initiatives that have been put in place over the past decade. Percentage wise there are more female graduates in the engineering technologies but the overall numbers of females enrolling in S&E majors has been remaining fairly level according to the NSB statistics.

- Certainly, the spin-off from legacy ET programs of computer and computer networking, laser electro-optics, and telecommunications technology programs, to name a few, have resulted in a splitting of the available applicant pool as these derivative programs have matured. Ironically, to a great extent, today's electronics technician has the least comprehensible job title and therefore the least identifiable job duties as far as the general public is concerned. Just what do they do? Where can an ET get a job? This lack of identity is a definite negative when it comes to attracting applicants to a program.

- Compounding matters, there is always the problem of geographically matching graduates to the availability of jobs. It is a fact of life, when industry relocates, the relocation area benefits and the area relocated from, suffers job losses. Typically, for ETs this type of problem is further exacerbated by the unwillingness of graduates of two-year level schools to relocate to where the jobs are.

Many of these reasons for declining enrollment are interrelated and do not have easy or fast fixes available. There still is and will be a demand for an electronics technician that possesses the skill sets desired by industry. However, that demand will most likely never again grow at the pace that is has at times in the past. The evolution of the technology has changed the way the game is played. Highly reliable and inexpensive entire systems on a chip with built-in-self-test features and network accessibility change the repair and maintenance dynamic to dealing with sub-systems and remote diagnostics. Electronics devices and systems are now designed and manufactured in such a way as to put ourselves out of the product support end of the business! Hence the paradoxical answer to the earlier question, there is exponentially more electronics but it does not need nearly as much support as it used to! Furthermore, the trend will continue to skew the employment needs in a negative fashion.

III. What can we do about it?

To improve the health of today's electronics technology education, several basic things must happen. First, ET programs must prepare their graduates for the world of work as it exists today and as it will exist in the future. This begins with an honest appraisal of what the skill sets are that local industry needs. In many cases, this means looking at "light" manufacturing and small businesses unless there is one or more large employers in the area that hire the majority of the program's graduates. In that case, the faculty will most likely have a good idea of what industry expects through feedback from their past graduates and their industrial advisory board. However, without a major employer in the area, most likely, program graduates will be "single hires" that will assume the major responsibility for a small company's electronics systems, computers, and networks. This author firmly believes that a shift towards a systems approach to the teaching of electronics technology is necessary as we move forward. Others [10] at the engineering level are advocating the introduction of systems engineering BS degrees and an increasing systems level approach to the teaching of various engineering topics. A systems level approach to teaching technicians means that fundamental electronics devices are not dealt with on a part level to any great extent. This does not mean that students are not taught basic fundamental concepts or introduced to the analog and digital components and devices that are used to construct electronic systems. However, the amount of time spent on skills that only designers of electronic circuits need is drastically reduced. Also, the curriculum must look at the big picture and include coverage of topics in communications, computers, controls and embedded microcontrollers, instrumentation and data acquisition, photonics, sensors, power supplies, programming, computer applications, and both wired and wireless networking with familiarity with the higher layers of the OSI model included. A graduate of an electronics technology program should be adept at understanding how all of these topics are utilized in the operation and control of modern electronic systems. Furthermore, students should be given experience, through laboratory work and projects, dealing with real-world electronics systems. This aspect of the ET program should start in the first semester and continue throughout the program culminating with a capstone senior project of the student's own design. The curricula must keep the students interested and engaged. It also goes without saying that the curricula must also emphasis soft skills and be revisited periodically to be fine-tuned. For examples of systems based approaches to repair and maintenance, one can look to today's automotive industry and find forward looking curricula like that employed in the Ford Asset Program [11] at the community college level or the telecommunications industry's Verizon NextStep Program [12] which also places an emphasis on employee soft skills.

Make no mistake, transitioning to this type of program is no easy matter. Faculty that have become comfortable with teaching the same courses year in and year out will balk at the change, and other faculty will insist that students still need to know how to bias transistors or do Karnaugh maps. Text books that embrace the systems approach are not as plentiful as the best sellers about devices and DC/AC fundamentals that are into their tenth revision. It is also important that the college administration is supportive of curricula change and, if need be, the faculty professional development that is needed to facilitate the changes. Your program Dean can be a strong source of support and help to facilitate the necessary program changes.

Once a viable curricula is in place, the program will naturally differentiate itself from other technology programs and attract students that are interested in the opportunities the program will offer in terms of job skills and/or transfer potential. At this point, this author believes that the faculty must also commit to selling its program to potential students through recruitment visits, open houses, and program web sites or by whatever other means it takes to start to draw in students to the program. This task will not be easy either and requires a team effort by program personnel.

Lastly, the program must embrace and welcome the requests from other non-electronics based technologies to teach their students about the needed electronics necessary for them to deal with the ever increasing proliferation of electronic controls, sensors, and instrumentation that in many cases is networked and even accessible though the Internet. This is an opportunity to create customized courses that, utilizing a systems level approach, will provide these non-electronics students with the necessary skills needed to be successful in technology areas not directly related to electronics. When asked to service other programs, the ET program should not use the philosophy that "one size fits all" and try to teach a traditional ET courses to students in another technology. Without being responsive to the needs of the requesting programs very little benefit will be acquired from this cross training. Most ET programs will eventually get into this area of instruction (i.e. service to another program) and it may mean the difference between program survival or program reductions or total elimination. Be proactive and not reactive in this area. This author believes that this hybrid type of program instruction will become more and more commonplace as electronics keeps evolving and moves into areas not touched by complex technology systems in the past (i.e. agriculture, security, infrastructure health, etc). If the majority of the steps outlined in this section are taken, one's ET program should continue to have a viable life for many years to come.

IV. What does the future hold?

Much of what has been stated in this paper is dependent upon continued change and the evolution of technology to provide the sustained need for electronic technicians to deploy or install new technology and then to support this technology over its lifespan. One might question this statement and even surmise that technology will evolve to maintain itself from what has been mentioned previously. Self diagnostics and redundancy might be the norm for future technology but someone must still deal with the technology system infrastructure (the physical layer).

Also, an important new technology convergence is occurring. It is the deployment of systems consisting of networks of complex sensors with embedded (ambient) intelligence coupled with advanced actuators. Combined with modern networking technologies and application-enabling software these systems have the potential to change how we live. Many predict a future world with a ubiquitous sensing skin that provides data about almost every aspect of our environment. Some have called this the "next tier" of the Internet. Networked embedded sensors systems have the very genuine potential to significantly impact almost every aspect of human endeavor and commerce by increasing productivity, reducing energy consumption, and improving health and safety. Applications are envisioned in all technology fields including: Aerospace, Agriculture, Automotive, Biomedical, Building Automation, Energy Exploration and Production, Entertainment, Environmental Monitoring, Healthcare, Homeland Security, Industrial Automation, Infrastructure Monitoring, Information Technology, Manufacturing, Military, Pharmaceutical, Telecommunications, Transportation, Weather Forecasting, and any other technology field one can imagine. Who will industry call upon to install, maintain, and upgrade these networked sensor systems? Newer sophisticated sensors will combine reconfigurable, gigascale semiconductor technology with emerging nano- and micro-electromechanical systems (NEMS & MEMS) and exotic new nanotechnology subsystems (i.e. bio-systems, chemical, molecular, fiber-optic, photonic, etc). One notes that basic sensor operation/theory is heavily math and science based. If one thinks about these sensor systems, there appear to be several different points of possible system failure: the sensor or actuator and their support electronics, the particular type of area network connection, or the system software. Furthermore, access to many sensor sites or settings will require the additional knowledge and skill sets of the non-electronics based technology disciplines that have deployed the systems or are the end users of these systems. Given these facts, will it be the IT person who is tasked with installing, maintaining, and upgrading these systems or is the electronics technician or a cross trained ET a better fit for this task? This author's personal belief is that the infrastructure of these emerging networked sensor applications will be best deal with by a technician with a good knowledge of electronics at the physical layer and knowledge of the data link and networking layers above it. The electronics technician is the most obvious choice to be called upon to fill this coming need if they are provided with the correct skill sets by their ET program of study.

V. Conclusions

Electronic systems will continue to evolve. Moore's Law will continue to provide guidelines to future device capacity for another decade. Electronic systems will increasingly become more sophisticated, reconfigurable, networked, and less repairable below the system level. The technician will deal with these gigascale systems primarily through software (possibly, over a network connection and at a distance). The electronics technician will need to be more familiar with the OSI model layers above the Physical Layer (Layer 1) – since everything electronic is becoming networked (Layer 3). The rapidly approaching era of networked sensor systems will create job opportunities for the ET graduate. Furthermore, more soft skills will be needed by the graduating ET as the type of work they perform is transformed over time. Increasingly, electronics technology programs will be asked to provide academic support for non-electronics based technologies as they embrace and adopt more complex electronic and sensor systems and instrumentation into their disciplines. Eventually, it might seem that we should morph the electronics technician into a "systems technician" that has a basic knowledge of the electronics and networking concepts and cross training in the other technologies that will be used by future, complex electronics based systems. However, that thought comes under the heading of "Educating Technicians for 2020 and Beyond" – its discussion will be left for another day.

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