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# **Microsystems Technologist Workforce Development Capacity and Challenges in Central New Mexico**

Thor D. Osborn

Prepared by  
Sandia National Laboratories  
Albuquerque, New Mexico 87185 and Livermore, California 94550

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# **Microsystems Technologist Workforce Development Capacity and Challenges in Central New Mexico**

Thor D. Osborn

Microsystems Outreach Department  
Sandia National Laboratories  
P.O. Box 5800  
Albuquerque, NM 87185-0892

## **ABSTRACT**

Sandia National Laboratories has made major investments in microsystems-related infrastructure and research staff development over the past two decades, culminating most recently in the MESA project. These investment decisions have been made based in part upon the necessity for highly reliable, secure, and for some purposes, radiation-hardened devices and subsystems for safety and sustainability of the United States nuclear arsenal and other national security applications. SNL's microsystems development and fabrication capabilities are located almost entirely within its New Mexico site, rendering their effectiveness somewhat dependent on the depth and breadth of the local microsystems workforce. Consequently, the status and development capacity of this workforce has been seen as a key personnel readiness issue in relation to the maintenance of SNL's microsystems capabilities. For this reason SNL has supported the instantiation and development of the Southwest Center for Microsystems Education, an Advanced Technology Education center funded primarily by the National Science Foundation, in order to foster the development of local training capacity for microsystems technologists. Although the SCME and the associated Manufacturing Technology program at Central New Mexico Community College have developed an effective curriculum and graduated several highly capable microsystems technologists, the future of both the center and the degree program remain uncertain due to insufficient student enrollment. The central region of New Mexico has become home to many microsystems-oriented commercial firms. As the demands of those firms for technologists evolve, SNL may face staffing problems in the future, especially if local training capacity is lost.

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## EXECUTIVE SUMMARY

The improvement of education in the Science, Technology, Engineering, and Mathematics (STEM) fields has developed into a national imperative, propelled by widely publicized studies such as Rising Above the Gathering Storm disparaging the educational preparedness and future economic competitiveness of the United States. The National Science Foundation (NSF), the Department of Education (DoE), and the Department of Labor (DoL), among other federal agencies, have all offered programs intended to improve U.S. preparedness in these areas. Even the Department of Energy (DOE) has been provided funding to support educational efforts in the STEM fields, although these efforts have generally been more focused on specific mission objectives.

Sandia National Laboratories (SNL), a DOE federally-funded research and development center, has made major investments in microsystems-related infrastructure and research staff development over the past two decades, culminating most recently in the MESA project, representing an investment of approximately \$500 Million. These investment decisions have been made based in part upon the necessity for highly reliable, secure, and for some purposes, radiation-hardened devices and subsystems for the safety and sustainability of the United States nuclear arsenal and other national security applications. SNL's microsystems development and fabrication capabilities are located almost entirely within its New Mexico site, rendering their effectiveness somewhat dependent on the depth and breadth of the local microsystems workforce. Consequently, the status and development capacity of this workforce has been seen as a key personnel readiness issue in relation to the maintenance of SNL's microsystems capabilities. For this reason SNL has supported the instantiation and development of the Southwest Center for Microsystems Education (SCME) at Central New Mexico Community College (CNM), an Advanced Technology Education center funded primarily by the National Science Foundation (NSF), in order to foster the development of local and regional training capacity for microsystems technologists. SNL has expressed its support for the SCME by encouraging NSF funding of the center, by providing paid internships for selected students of the associated Manufacturing Technology program, and by providing and substantially funding the SCME Executive Director as a loaned employee via a cost-sharing agreement with CNM.

Although the SCME and the associated Manufacturing Technology program at CNM have developed an effective curriculum and graduated several highly capable microsystems technologists, the future of both the center and the degree program remain uncertain due to insufficient student enrollment. Most community colleges within the United States, including CNM, operate on an open-entry/open-exit basis. This mode of operation provides a high degree of flexibility to the student while making class headcounts more unpredictable, forcing the college to make difficult decisions regarding class closures on limited information. These class closures delay student progress through the affected programs, thereby discouraging students from persisting in those programs and creating a self-defeating pattern that often ultimately leads to program elimination. As of this writing, CNM's Manufacturing Technology program remains in jeopardy.

The central region of New Mexico has become home to many microsystems-oriented commercial firms. At present, most of them are small and their staffing is heavily weighted toward researchers with advanced degrees. While as a trend the manufacturing of high-volume products has increasingly been performed offshore, many Microsystems-based products are manufactured in relatively small quantities where the disadvantages of offshore production including technology transfer costs, risks of intellectual property loss, and increased complexity of operations often outweigh the advantages of low per item costs. Therefore, as these firms grow they are expected to draw heavily on the local Microsystems Technologist workforce for manufacturing purposes. As the demands of those firms

for technologists evolve, SNL may face staffing problems in the future, especially if local training capacity is lost due to short-term considerations.

A *laissez-faire* approach to New Mexico's growing SmallTech industry and supportive public policy and educational elements may jeopardize the state's economic future. Other states, notably Oregon and Oklahoma, have statewide SmallTech champions with a charter to promote innovation and development and ensure good communication both among their respective institutions within the state and with their partner organizations in other states as well. New Mexico's two major Department of Energy national laboratories place the state in an envied position in terms of SmallTech innovation and human capital. However, while Sandia National Laboratories (SNL) and Los Alamos National Laboratories (LANL) provide technical leadership and sources for licensed intellectual property that may be used within the state to catalyze economic development, their national missions and federal sponsorship prevent them from playing narrowly focused advocacy roles. A long list of organizations provides elements of leadership and support, but similarly, none of them has the combined wherewithal and charter to act as a state champion. It would appear to fall to the State of New Mexico to seize a leadership role in this arena for the betterment of the state as a whole. As of this writing, however, a state-sponsored body to provide coordination and act as a point of contact and clearinghouse for information has not been designated.

In summary, the central region of New Mexico has become a nexus for Microsystems talent and activity but the educational branch of these activities is demonstrably vulnerable. Given the restrictions on the national laboratories and the small size of the many Microsystems-based businesses in New Mexico, a natural champion with both a vested interest and the resources necessary to coordinate state and local efforts has not emerged. Thus, New Mexico's enviable leadership positions in the SmallTech fields and in SmallTech education may be short-lived. SNL should therefore plan on the basis that any future hiring surges in Microsystems Technology may not be cushioned by a deep local reservoir of talent or training capacity.

## THE NATIONAL IMPERATIVE FOR STEM EDUCATION

Over the past few decades several nationally publicized studies have been issued lamenting the decline of education in the sciences, technology, engineering, and mathematics (STEM). These studies have underlined the importance of science and technology to the past success and future economic security of the United States, while expressing concern over declining total or proportional native educational attainment in those fields. The underlying rationale for this repetitious cycle of hand-wringing and consternation is the low production of engineers and scientists of U.S. extraction in U.S. universities as compared with the output of similarly educated workers by other nations. Within the context of economic globalization and an increasingly competitive global marketplace where success is critically dependent on technological prowess, these trends are indeed disturbing. As the President of the United States, George W. Bush, stated in an American Competitiveness Initiative discussion<sup>1</sup>:

**...there's a direct connection between research and development, technology, and quality of life. This country has a chance – it needs to make a choice: Are we going to lead, or are we going to fear the future? ... ... we ought not to fear the future, but shape the future, and continue to be the leader. And by leading, our people will realize a more peaceful world and a more prosperous world, and a chance to realize dreams. And that's what America has been all about in the past and it should be about in the future.**

As noted in Rising Above the Gathering Storm, distance no longer protects much of our intellectual product as the internet has made physical separation largely irrelevant<sup>2</sup>. Moreover, from a very coarse big-picture perspective, the number of workers available in the U.S. is falling away from the number required to maintain present economic growth rates over time<sup>3</sup>. In order to counter these trends, the U.S. must increase the pipeline of students reaching the conclusion of high school with the basic preparation needed to pursue a STEM degree, and retain more of those students with an expressed interest in such careers as they progress through baccalaureate programs and beyond. Given that one-third of students declaring the pursuit of an engineering degree quit before completion, there is significant opportunity for improvement.

In addition to the aforementioned Rising Above the Gathering Storm report, a few key publications expressing concern regarding the U.S. education system include “The Glenn Commission Report,” Engineer 2020, and Workforce Crisis, but there are many others. This succession of expressions of alarm has led to a *de facto* national imperative to counter these trends, and the generation of several federal agency programs intended to improve STEM education and workforce preparation at one or more stages within the educational system. One such program is the National Science Foundation’s Advanced Technology Education program, intended to improve technology education in the lower division of post-secondary education and to improve the capabilities of teachers to prepare students in the K-12 pipeline and retain their interest within the post-secondary system. This program has been the primary support for the Southwest Center for Microsystems Education (SCME).

## Reports Advocating Renewed Emphasis on STEM

### ***Rising Above the Gathering Storm (2007)***

This publication, the results of a study performed by a noteworthy panel of leaders from industry, academia, and the national laboratories and compiled with the support of the National Academy of Science, the National Academy of Engineering, and the Institute of Medicine, incorporates 592 pages with myriad observations and recommendations<sup>2</sup>. The broad theme is, however, well-captured in this quotation from the book's preface:

**The prosperity the United States enjoys today is due in no small part to investments the nation has made in research and development at universities, corporations, and national laboratories over the last 50 years. Recently, however, corporate, government, and national scientific and technical leaders have expressed concern that pressures on the science and technology enterprise could seriously erode this past success and jeopardize future US prosperity. Reflecting this trend is the movement overseas not only of manufacturing jobs but also of jobs in administration, finance engineering, and research.**

The authors emphasize that deteriorating economic conditions are inextricably linked with corresponding deterioration in social conditions – an impact that extends to all levels of society. In the book's Executive Summary, the authors note the importance of technology to per capita income and the dramatic changes in the worldwide economic landscape wrought by modern communications technologies that have drastically lowered the competitive barriers posed by geographic distance. Although it is a logical *non sequitur* to expect that past recipes for success will automatically confer a golden future if followed today within a dramatically changed milieu, nevertheless Rising Above the Gathering Storm clearly makes the case that the United States as a nation is not keeping up with past attainments in STEM fields and their associated research and technology areas, that citizens of other nations are pursuing those fields vigorously, and that those nations are indeed catching up to the U.S. from an economic perspective. Rising Above the Gathering Storm makes a host of recommendations intended to counter these trends.

### ***Before It's Too Late – The Glenn Commission Report (2000)***

This report by the National Commission on Mathematics and Science Teaching for the 21st Century is also known as The Glenn Commission Report after its chairman, senator and former astronaut John Glenn. Acknowledging many of the ongoing concerns regarding national competitiveness, nevertheless the recommendations of "Before It's Too Late" focus on improving STEM education in the K-12 system to better prepare and encourage students to pursue higher education in STEM fields. Specifically, these recommendations are:

1. Establish an ongoing system to improve the quality of mathematics and science teaching in grades K-12;
2. Increase significantly the number of mathematics and science teachers and improve the quality of their preparation; and
3. Improve the working environment and make the teaching profession more attractive for K-12 mathematics and science teachers.

### ***A Nation at Risk (1983)***

Presented as an open letter to the American people 25 years ago, “A Nation at Risk,” subtitled “The Imperative for Educational Reform,” summarized the state of the nation’s educational system as follows:<sup>4</sup>

**If an unfriendly foreign power had attempted to impose on America the mediocre educational performance that exists today, we might well have viewed it as an act of war. As it stands, we have allowed this to happen to ourselves. We have even squandered the gains in student achievement made in the wake of the Sputnik challenge. Moreover, we have dismantled essential support systems which helped make those gains possible. We have, in effect, been committing an act of unthinking, unilateral educational disarmament.**

The report made several recommendations aimed at improving student achievement and working conditions for educators in the United States. Among these recommendations, several were focused on improving STEM education or have direct relevance to STEM:

- **Definition of minimal achievements in mathematics, science, and computer science that should be required of all graduates**
- **Reduction of administrative and disciplinary enforcement demands on teachers to enable greater focus on teaching and learning**
- **Student placement and graduation policies guided by academic progress as opposed to age**
- **Professionally competitive, market-sensitive, and performance-based salaries for teachers to counter the dearth of qualified teachers in mathematics and the sciences**
- **Incentives to attract outstanding students to the teaching profession, especially in areas of critical shortage**
- **Utilization of technically qualified individuals such as retired scientists to augment faculty in areas of need**

The recommendations of “A Nation at Risk” do not appear to have been rigorously implemented across the United States. This report is mentioned here only to underscore the longstanding nature of our nation’s challenges in STEM education.

## Selected Federal Efforts Furthering STEM Education

### *The National Science Foundation Advanced Technology Education Program*

A recent National Science Foundation program announcement synopsis characterizes the NSF Advanced Technology Education program as follows<sup>5</sup>:

**With an emphasis on two-year colleges, the Advanced Technological Education (ATE) program focuses on the education of technicians for the high-technology fields that drive our nation's economy. The program involves partnerships between academic institutions and employers to promote improvement in the education of science and engineering technicians at the undergraduate and secondary school levels. The ATE program supports curriculum development; professional development of college faculty and secondary school teachers; career pathways to two-year colleges from secondary schools and from two-year colleges to four-year institutions; and other activities. A secondary goal is articulation between two-year and four-year programs for K-12 prospective teachers that focus on technological education. Additionally, the program invites proposals focusing on applied research relating to technician education.**

Condensed down to its fundamental strategic aims, two key goals underpin the ATE program:

- 1. Produce more science and engineering technicians to meet workforce demands**
- 2. Improve the technical skills and the general science, technology, engineering, and mathematics (STEM) preparation of these technicians and the educators who prepare them.**

In support of these goals, the ATE program funds projects, resource centers, and regional and national centers of excellence to develop and promote educational programs and capabilities in specific areas of technology. The Southwest Center for Microsystems Education is one such Regional Center of Excellence. The SCME is discussed in greater detail in a subsequent section of this report. While the number of these Centers of Excellence supported by the NSF varies based on available funds, at present there are approximately 30 Centers nationwide, as compared with approximately 1200 community colleges. Thus the SCME represents a significant, focused, and somewhat prestigious investment on the part of NSF toward meeting national needs in microsystems education.

### ***Department of Labor Programs***

The Department of Labor awarded a \$5 Million Workforce Innovation in Regional Economic Development (WIRED) grant to the State of New Mexico in 2007. The grant encompasses several objectives but was conceived as a means of promoting workforce and economic development to encourage so-called green manufacturing in New Mexico<sup>6</sup>. Green manufacturing includes advanced manufacturing, green building (energy-sparing and low ecological-impact construction and operation), clean and renewable energy sources, aerospace, microelectronics, and optics. More specifically, these opportunities include support for microsystems and nanotechnology as drivers of New Mexico's economic future. The grant activities include:

- **Teacher Science and Math [i.e., STEM] Advanced Training\***
- **Entrepreneurship Training**
- **Community College Training Programs Development**
- **Career Information Dissemination**
- **Scholarships and Internships**

Although the thrust of the Department of Labor WIRED grant is aimed more directly at local economic and job development, one of the fundamental vehicles for these aims is improvement and expansion of STEM education along with focused technical training to address near-term workforce requirements.

### ***The America Competes Act***

This Act, signed by President Bush on August 9<sup>th</sup>, 2007, authorizes action by federal agencies in support of the American Competitiveness Initiative. The Act is a response to Rising Above the Gathering Storm and is a product of the legislative evolution of the American Innovation and Competitiveness Act of 2006 and the Protecting America's Competitive Edge Through Energy Act of 2006<sup>7</sup>. The Act requires substantive actions on the part of U.S. federal agencies funding scientific research. Specifically, the Act's primary objectives are to:

- **Increase research investment**
- **Improve STEM educational opportunities**
- **Develop U.S. innovation infrastructure**

The Act affects several federal agencies:

- **National Science Foundation (NSF)**
- **Department of Energy (DOE)**
- **National Institute of Standards and Technology (NIST)**
- **National Aeronautics and Space Administration (NASA)**
- **National Oceanic and Atmospheric Administration (NOAA)**

Notably, the Act authorizes the doubling of funding for NSF by 2011 to \$11.2 Billion, and increases in funding for the DOE Office of Science by 50% to \$5.6 Billion over the same period. The Act also stipulates that Summer Institutes aimed at strengthening the skills of thousands of science and mathematics teachers will be held at the DOE national laboratories, and that the national labs will partner with local high-needs high schools to create centers of excellence in education. Programs and assistance for science and math teachers and post-secondary students in STEM fields are key elements of the America Competes Act.

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\* It is worth noting here that the Department of Labor prefers to use the term “training” whereas the National Science Foundation prefers to use the term “education” in reference to educational initiatives. While the Department of Labor programs often emphasize the use of institutions of higher education to provide vocationally-oriented short-term programs that may not confer a degree, despite the semantic differences there is often substantial overlap between “training” and “education.”

## Future STEM Workforce Requirements

If the future economic success of the United States depends on a well-educated workforce and leadership in the STEM fields, then it follows that current trends leading U.S. post-secondary students away from STEM fields must be reversed. As Ken Dychtwald, *et al.*, show in Workforce Crisis, however, future growth prospects for the U.S. economy may be hampered by simple demographic trends<sup>3</sup>. The number of educated workers needed to maintain U.S. Gross Domestic Product growth at historical rates will exceed the available pool starting *circa* 2008. Even if recent trends away from STEM education were halted, the required number of workers would continue to diverge from the number available by approximately 1.5 Million per year for at least the next two decades. Assuming their estimations are found to be substantially accurate, and that immigration policies are not adjusted to compensate, U.S. economic growth may be expected to stagnate over this period. Given the expected downward pressure on the U.S. capital markets during this same timeframe as a surge of retiring baby-boomers draws more and more heavily against retirement funds backed by market-traded securities, the need to halt and even reverse the trend away from STEM – and the associated high value-added jobs – in the education of U.S. citizens is glaringly evident.

## CENTRAL NEW MEXICO MICROSYSTEMS TECHNOLOGIST NEEDS

Against the backdrop of national STEM imperatives, the various states and regions within the United States have particular technical workforce requirements and corresponding educational needs. A brief survey of employers within the greater Albuquerque area shows a substantial and growing demand for workers with microsystem technology background and skills. The precise skill sets required to meet each employers business needs naturally will vary according to the specific nature of each business.

Sandia National Laboratories directly or indirectly employs at least 250 personnel falling into the broad category of Microsystems Technologist. This estimation combines the microfabrication laboratory processing personnel – many of whom are staff augmentation contractors – and the technologists associated with the packaging, testing, evaluation, and experimental work associated with microfabricated devices. Thus it is clearly evident that the Microsystems Technologist role at SNL is really several multi-faceted roles. Nevertheless, the general microsystem technologies skill set is critically important to Sandia's workforce.

In addition, the population of microsystems and nanotechnology oriented organizations within the greater Albuquerque area has burgeoned in recent years. An aerial view depicting the distribution of these organizations across the region is presented in Figure 1. Many of these organizations are start-up firms and these tend to focus initially on developing intellectual property and prototype products. Consequently they do not demand large numbers of technologists. On the other hand, some of the firms identified in Figure 1 have evolved into the manufacturing stage of development or are local arms of much larger and more mature firms. For example, Schott Solar is a division of Schott AG, an international company based in Mainz, Germany, employing approximately 16,800 personnel worldwide<sup>8</sup>. The branch presently under construction within the Mesa del Sol economic development area is intended to be a 200,000 square foot manufacturing plant initially employing 350 personnel, with expansion plans for up to 800,000 square foot and 1500 personnel, many of whom will undoubtedly require microsystem technology skill sets in order to perform their jobs. Other local companies employing large numbers of personnel in a manufacturing or manufacturing-oriented applied research and development capacity include Cabot Superior Micropowders<sup>9</sup> (*circa* 95 employees in Albuquerque) as well as Emcore and Advent Solar.

A recent analysis of data compiled by the New Mexico State Department of Workforce Solutions<sup>10-12</sup> indicates that growth in the total number of technician jobs within the state of New Mexico over the next decade is expected to be modest, averaging approximately 56 per year on a base of about 15,000, but that a substantial number of job openings – about 420 per year – are expected to be made available by the need to replace departing workers. This trend is congruent with the national trends and concerns predicted in Workforce Crisis as a surge in retirement of baby boomers is expected to severely deplete the worker pool<sup>3</sup>. Given that 45% of New Mexico's 37,000 manufacturing sector jobs are found in Bernalillo County (as is Albuquerque), the need for manufacturing workers in the greater Albuquerque area will be acute. Meanwhile, the specific need for workers knowledgeable in Microsystems is expected to grow with the evolving business landscape. Consequently, while total employment of technologists may not grow dramatically, there is predicted to be an ongoing need for Microsystems Technologists. This need may be filled by hiring from outside New Mexico, of course, potentially at the expense of displacing local workers. But there appears to be a need for endogenous workforce development capacity both for retraining purposes and to enable new workers to enter the marketplace.



**Figure 1. Central New Mexico SmallTech employers and educational institutions.** SmallTech includes both microsystems and nanotechnologies. This aerial view was generated using NASA World Wind 1.4 incorporating public domain Zoomit! and United States Government image data.

## **AFFIRMATION OF URGENCY: THE NEW MEXICO SMALLTECH WORKFORCE SUMMIT**

A meeting entitled “New Mexico SmallTech Workforce Summit” was held on August 27<sup>th</sup>, 2007. The purpose of the meeting was to bring together luminaries from throughout New Mexico with a stake in the state’s future development in Microsystems and nanotechnology, termed SmallTech. The motivation for this undertaking was the recognition by representatives of Sandia National Laboratories (SNL), the Micro and Nanotechnology Commercialization Education Foundation (MANCEF), and Central New Mexico Community College (CNM), that whereas substantial SmallTech-related innovation, ventures, and small business activity are ongoing within New Mexico, and an excellent foundation has been laid for future SmallTech growth, coordination and stewardship of these diverse activities has been lacking.

Specific areas for exploration at the summit were the expected economic growth related to these technologies, models for SmallTech stewardship and economic development, the status and needs of NM’s SmallTech educational capabilities, and the pantheon of organizations promoting micro and nanotechnology related activities and how they might be better coordinated. As a testament to the sense of community spirit among the people of the State of New Mexico, and the complementary strengths of Sandia National Laboratories, MANCEF, and SCME, nearly 40 of the state’s leaders were brought together for an all-day meeting with less than four weeks notice. The summit was attended by 39 people with diverse backgrounds and positions in government, public policy, education, research, economic development, venture capital, and industry ranging from startup firms to established small businesses to major international corporations. The diversity among the attendees is depicted in Figure 2. The meeting agenda and attendee list are provided in the Appendix. Interactive working sessions were used to collect ideas and impressions from this diverse body of attendees and a professional facilitator and note-takers were engaged to assist the flow and capture of information.

In brief, the outcomes of the summit were:

- 1. Substantial growth of SmallTech industry is expected over the next decade, although this growth is not expected to exceed the employment losses generated by Intel Corporation’s increasing factory automation – workforce training and retraining will be needed to navigate this transition**
- 2. Education, and especially the articulation of educational credit and programs across institutions are critical to success**
- 3. Lack of coordination among New Mexico’s economic development and educational branches and unsupported assumptions regarding the roles of the national laboratories challenge NM’s ability to respond effectively and in a proactive fashion to the opportunities of SmallTech**
- 4. There is substantial passion and broad agreement for a full-time statewide champion to inventory and coordinate ongoing activities, plan for the future, and promote the capabilities of NM’s SmallTech cluster nationally and internationally for economic development.**

The scope of the meeting was very broad, and the attendees generally left with the impression that much was still to be determined, but also with a sense of energy and urgency for NM to move

forward. With the knowledge that the annual budget of Oregon's state champion organization ONAMI is about \$9 Million, and that Oklahoma's OKNano organization is supported by a \$1 Billion endowment, a consensus emerged that proactive, focused, and coordinated action would be valuable toward propelling New Mexico's SmallTech growth, and that the state's role as a leader in microsystems and nanotechnology could rapidly diminish in the absence of concerted action.

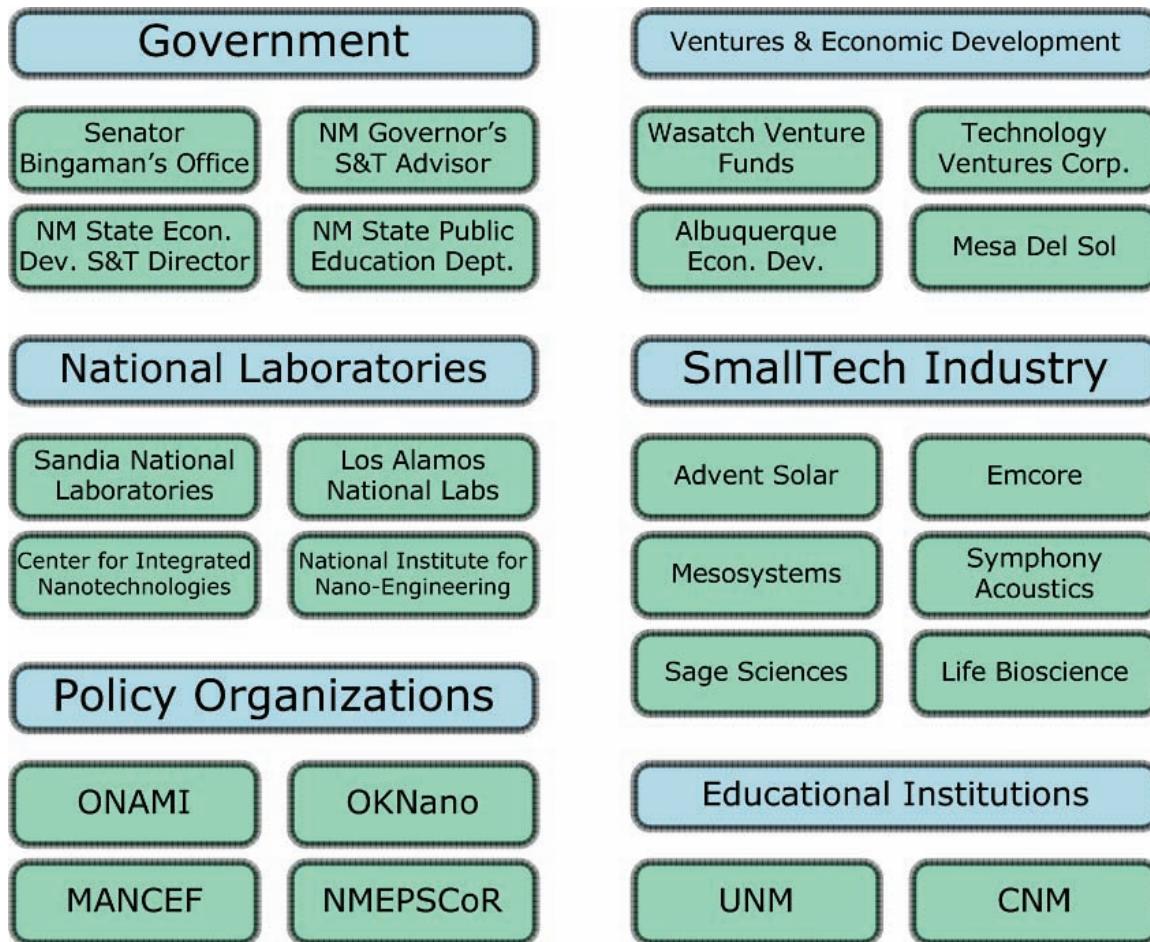


Figure 2. Diversity of New Mexico SmallTech Summit Attendees.

# **MICROSYSTEMS TRAINING CAPABILITIES WITHIN NEW MEXICO**

## **The Southwest Center for Microsystems Education**

The National Science Foundation's Advanced Technological Education Program, Division of Undergraduate Education, awarded the Albuquerque Technical Vocational Institute (TVI, recently renamed CNM) grant DUE-0402651 in 2004 to found the Southwest Center for Microsystems Education, a Regional Center of Excellence in Undergraduate Education.

### ***Mission, Goals, and Activities***

#### **Mission**

The Southwest Center for Microsystems Education will serve as a sustainable resource center that identifies microsystems technologist competencies, creates and disseminates educational materials and models, and provides professional development activities to develop a skilled microsystems workforce that can support research and development and manufacturing environments.

#### **Goals**

The broad purposes of the SCME are twofold:

- **Increase educational capacity to produce technicians skilled in assisting microsystems research, design, and commercialization activities**
- **Increase the general public's awareness of the microsystems industry**

#### **Activities**

The NSF-ATE program has identified several preferred types of objectives for grant-funded projects that are explicitly listed in its program announcements. Selected ATE program objectives directly addressed by SCME are given in Table I, along with more specific descriptions of SCME's efforts supporting those objectives.

#### ***Structure and Partners***

The SCME has been prosecuting this mission since 2004. The main office has been staffed with the Principal Investigator, the Executive Director, the Administrative Coordinator, and a variety of Graphic Designers and Student Assistants since shortly after inception. This core staff coordinates and delivers workshops, educational materials, and recruiting (marketing) materials. The SCME is a regional center of excellence with a broad charter and ambitious goals, however, and its successes to-date have depended heavily on its partner organizations and subawardees. SCME's partners include:

**Table I. National Science Foundation ATE Program Objectives and SCME Activities.**

ATE Program Objective	SCME Activity
<b>Adaptation of exemplary educational materials, courses, and curricula developed elsewhere</b>	Conversion of software and lessons produced by the UNM Manufacturing Engineering Program into Shareable Content Objects for a consistent look and feel when integrated with other SCME educational materials
<b>Professional development of college faculty and secondary school teachers</b>	SCME has held several weekend and one-week hands-on workshops for high school and community college faculty to impart direct experience in a semiconductor / MEMS fabrication laboratory
<b>Design and implementation of new educational materials, courses, laboratories, and curricula</b>	Development of Shareable Content Objects for the broad field of Microsystems Technology including such topics as Laboratory Safety, Photolithography, Wet Etch, Dry Etch, Depositions, MEMS Applications, BioMEMS, RF MEMS, Optical MEMS, et cetera
<b>Internships and field experiences for students, faculty, and teachers</b>	SCME has encouraged the development of student internships with local microsystems companies and has provided student positions to aid in educational materials development SCME has provided externships for community college faculty in partnership with MATEC
<b>Give prospective technicians insight into real-world work environments</b>	In addition to promoting student internships, SCME has coordinated tours of the MTTC facility and technology startup incubation center
<b>Serve the needs of not only first-time students but also returning students and workers wishing to acquire new skills</b>	SCME educational materials are designed to be highly modular for customization to faculty and student learning objectives, and are produced with generational communication style variations in mind
<b>Implement national science, mathematics, technology, and industry standards in education</b>	SCME has conducted workshops with K-12 teachers to explicitly incorporate New Mexico state standards into a subset of microsystem technology SCOs intended to generate interest among secondary school students
<b>Use information technology and other educational technologies to improve learning and teaching</b>	Principal Investigator Matthias Pleil has utilized SCME-generated Shareable Content Objects to create an online hybrid Introduction to MEMS course

**The Maricopa Advanced Technology Education Center (MATEC) – MATEC began as an ATE center and has been in operation since 1996. MATEC organizes and runs the annual SAME-TEC conference in addition to conducting ongoing research and educational materials development.**

**Bio-Link –** This ATE center is located at the City College of San Francisco and is focused on building stronger networks and providing professional development for educators within the biotechnology fields. Bio-Link has coordinated a network of consultants to aid in the development of a suite of BioMEMS educational materials for SCME.

**The UNM Manufacturing Training and Technology Center (MTTC) –** MTTC researchers have past experience in NSF ATE projects, and the MTTC cleanroom facilities provide essential capabilities for supporting experiential workshops for teachers. MTTC also provides personnel, expertise, and previously generated educational materials for incorporation into SCOs.

**Sandia National Laboratories –** Sandia has been involved with SCME since the proposal phase, and has provided the Executive Director for the grant by personnel loan via a cost-sharing arrangement, as well as providing access to content experts in microsystems and focused internships for students.

**The Micro and Nanotechnology Commercialization Education Foundation (MANCEF) –** MANCEF has provided substantial organizational networking support in addition to coordinating the development of a nanotechnology familiarization kit for the classroom.

**MJ Consulting –** Operated by a former CNM educator, MJ Consulting provides assistance in the generation and refinement of SCORM-compliant educational materials.

### ***Evaluation of Microsystems Technologist Skills Requirements***

One of the primary thrusts of the SCME is to develop and disseminate a suite of flexible, modular educational materials. These materials are intended to aid in the dissemination of Microsystems Technologist programs across the nation by facilitating curriculum development and providing sufficient flexibility to instructors to customize their courses to suit their own needs and objectives. Effective materials should be thoroughly aligned with the genuine needs of graduates as they enter the workforce. Yet often instructors must design and develop course materials based on their personal experience or with input from management at industrial firms. Neither source is fully effective because personal biases about the information and concepts technologists should understand may deviate from actual workplace needs and practices. SCME has adopted the WorkKeys™ methodology to better assess the actual needs of technologists in the workplace toward improved optimization of educational materials and of the MEMS courses offered at CNM.

Application of the WorkKeys approach involves substantial observation of hands-on practices over a period of days – known as job shadowing – as well as assessment of required skill levels through in-depth interviews of the shadowed technologists addressing the actual tasks performed during the shadowing period. Ideally, several assessments of this type over a broad variety of jobs and organizations should be performed to garner a solid understanding of real workplace needs. An example WorkKeys report for technologists performing photolithography work at Sandia National Laboratories is presented in Table II below. The key outputs of this process are the required skill levels for success on the job. Implementation of these results consists of adjusting the course materials and assessments to aid students' development in the required skills areas, and to encourage students to perform periodic WorkKeys testing to ensure that their skills meet the required levels upon graduation.

**Table II. WorkKeys™ Skill Levels Required by Microsystems Technologists.**

WorkKeys™ Skill	Skill Level Range	Entry Skill Level	Effective Performance Skill Level	Number of Tasks Requiring This Skill	Portion of Tasks Requiring This Skill
<b>Applied Mathematics</b>	<b>3 – 7</b>	<b>4</b>	<b>4</b>	<b>19</b>	<b>13%</b>
<b>Applied Technology</b>	<b>3 – 6</b>	<b>3</b>	<b>3 – 4</b>	<b>24</b>	<b>16%</b>
<b>Business Writing</b>	<b>1 – 5</b>	<b>4</b>	<b>4</b>	<b>19</b>	<b>13%</b>
<b>Listening</b>	<b>1 – 5</b>	<b>3*</b>	<b>5</b>	<b>22</b>	<b>15%</b>
<b>Locating Information</b>	<b>3 – 6</b>	<b>5</b>	<b>6</b>	<b>64</b>	<b>42%</b>
<b>Observation</b>	<b>3 – 6</b>	<b>5**</b>	<b>6</b>	<b>135</b>	<b>89%</b>
<b>Reading for Information</b>	<b>3 – 7</b>	<b>5</b>	<b>5</b>	<b>24</b>	<b>16%</b>
<b>Teamwork</b>	<b>3 – 6</b>	<b>3***</b>	<b>5</b>	<b>27</b>	<b>18%</b>

\* After three months must be at least 4

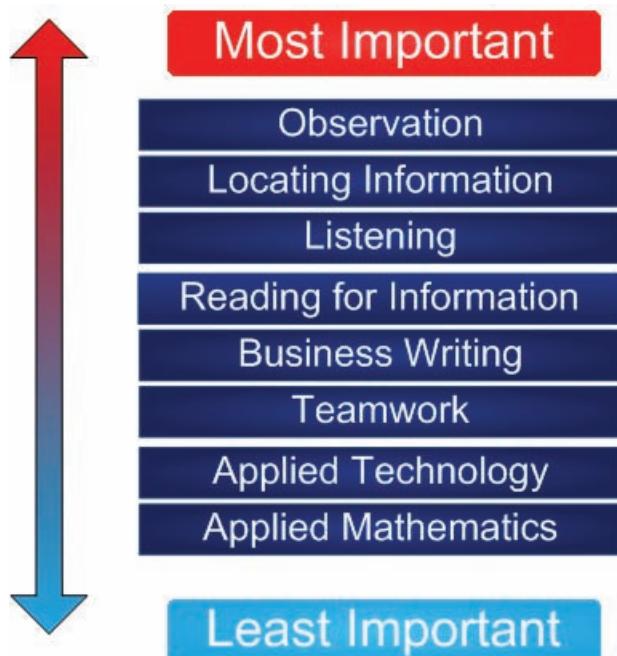
\*\* After three months must be 6

\*\*\* After three months must be 5

An important finding from the WorkKeys process is that sometimes the most critical job skills are counter-intuitive to those who manage such employees or write job descriptions for hiring them. As illustrated in Figure 3, the importance of applied technical and mathematics skills are diminished relative to the skills used in gathering information to do the job. This finding does not imply that the technical skills are irrelevant. Rather, it implies that an excessive emphasis on educating technologists with the in-depth mathematical skills of engineers or applied physicists may be counterproductive. Teamwork matters, but much of the work is performed independently and requires focused attention to detail and assimilation of information from various sources for success. These and similar findings have guided the development of SCME's educational materials.

## ***Development of Microsystems Technologist Educational Materials***

The SCME adopted the Shareable Content Object Reference Model (SCORM) approach to the development of its Microsystems Technology educational materials at the inception of the Center. This approach employs modular and independently applicable Shareable Content Objects, or SCOs, as the smallest unit of instruction. While improper usage from a SCORM context, the modules have also been referred to as Self-Contained Objects, underscoring their independent utility. SCOs are intended to contain only enough material for a maximum of one hour of the student's time, and ideally have no more than three fundamentally critical points, colloquially referred to as take-home lessons. Within the SCME's materials there are only three types of SCOs: Primary Knowledge, Learning Activity, and Assessment.



**Figure 3. WorkKeys™ skills and priorities relevant to Microsystems technologists.** The applicable skills are ranked in order of relative importance to success on the job.

## ***Educational Program Dissemination***

The materials produced by SCME are extremely flexible and have been successfully demonstrated in the traditional classroom and as an excellent foundation for the generation of online course materials. Since broad dissemination of the Microsystems Technology program and materials is an ongoing SCME objective, an extended effort has been made to find or create a suitable distribution mechanism for the materials. Several models were considered. The iTunes University™ approach sponsored by Apple Computer, Inc., is a powerful model for providing open access to all interested educators. Unfortunately, iTunes University requires that all materials be provided at no charge to the user. Consequently, some of the materials are of dubious quality, even those from highly esteemed universities. Given the nature of human psychology, the SCME leadership made the decision to employ a fee-based distribution channel to ensure that potential users properly value the materials. MATEC has utilized a site-license approach for its educational materials suites, such that every institution pays an annual license for a large collection of materials. However, this approach obviates

much of the advantage of the SCORM method, which was intended to provide a much greater degree of flexibility. The NSF has founded several national resource centers with the goal of ensuring access to materials. Unfortunately, it does not appear that any of the relevant centers have achieved the critical volume necessary to sustain the enterprise without ongoing NSF financial support. At present, the SCME is in the process of developing a business relationship with the Center for Hands-On Learning in Rio Rancho, New Mexico. Originally founded with a modest NSF grant, the CHL has operated successfully for over a decade building and distributing educational activity kits and classroom materials to a nationwide clientele. The use of CHL leverages a powerful local resource and frees SCME to focus on its core competencies.

## **The University of New Mexico Manufacturing Engineering Program**

The Manufacturing Engineering Program (MEP) at the University of New Mexico sponsors master's degree programs in Manufacturing Engineering and a combined Manufacturing Engineering and Management of Technology master's degree with UNM's Anderson School of Management. Within the MEP, the Manufacturing Training and Technology Center (Figure 4) is a key asset. The MTTC is also a key resource for Microsystems Education and workforce development in central New Mexico.

### ***MTTC Facilities, Mission and Impact***

A recent informational brochure succinctly summarizes the mission and features of the MTTC:

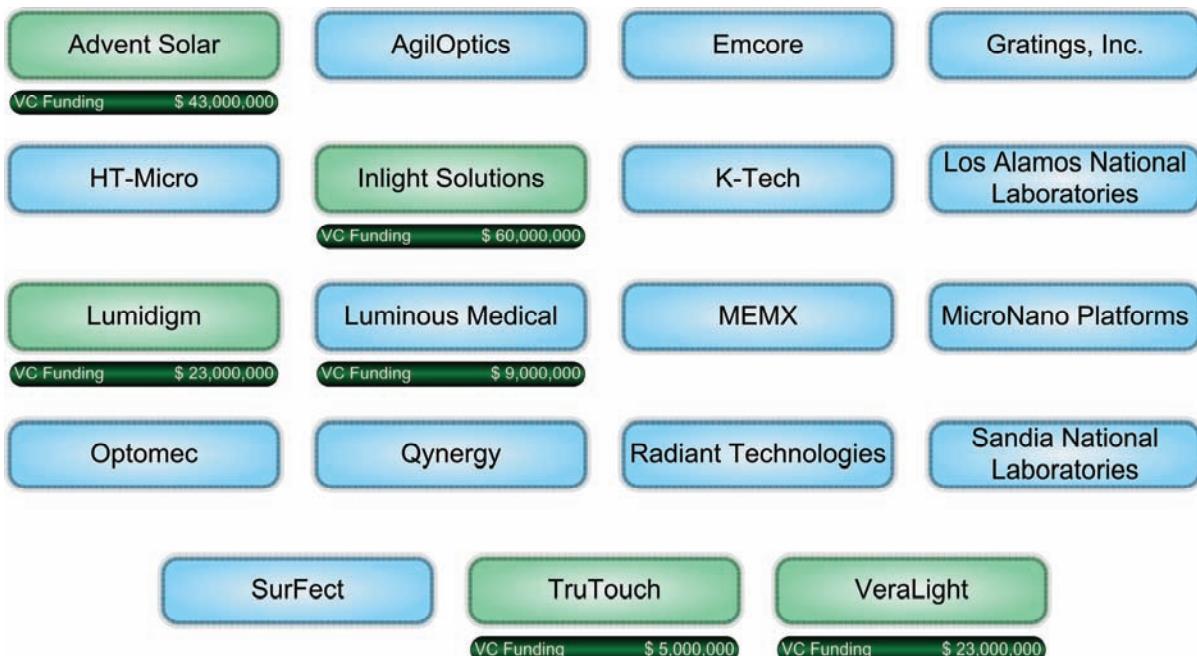
**The Manufacturing Training and Technology Center (MTTC) is a 56,000 SF facility situated on the University of New Mexico (UNM) Science and Technology Park. The mission of the MTTC is to support regional workforce development, technology development, and economic development. Consistent with that mission, the MTTC houses academic programs, research and training facilities, and commercial tenants. The facility includes classrooms, offices, labs, auditorium, café, manufacturing bays and a semiconductor/MEMS cleanroom.**

The economic impact of the MTTC within New Mexico has been substantial. The MTTC provides a secure and effective environment for the incubation of new technology firms, including office space, meeting rooms, and facilities for technology prototype development. Prominent companies and organizations aided by the MTTC are featured in Figure 5. The venture capital funding attained by each firm is listed as appropriate. In 2005, MTTC tenants raised in excess of \$55,000,000 in venture capital, amounting to 40% of the total venture funding raised in the State of New Mexico, and MTTC tenants and users have raised over \$230,000,000 altogether.

The MTTC also has a powerful impact on Microsystems education, providing semiconductor cleanroom support for courses at UNM and CNM, workshops to expose high school and community college faculty to hands-on experiences with microsystem fabrication technology, and tours promoting public awareness of microsystem technologies and employment opportunities. In addition, the cleanroom supports cutting edge MEMS research and enables engineering graduate, undergraduate, and technologist students to participate in cross-training within a hands-on factory-like environment and better prepare for entry into the workforce. Recent courses, workshops, and tours supported by MTTC are listed in Table III. A selection of educational materials and methodology projects conducted by MTTC are listed in Table IV. The MTTC has established a rare critical mass of microsystems oriented industrial activities and educational offerings that expose engineering and technologist students to hands-on research and internship opportunities in conjunction with relevant formal coursework employing forward-thinking teaching tools.



**Figure 4. The University of New Mexico's Manufacturing Training and Technology Center.** The 56,000 square foot facility houses a 6,200 square foot cleanroom supporting education, research, and economic development within a professional workplace setting in the UNM Science and Technology Park.



**Figure 5. Commercial Tenants and Users of the MTTC.** Tenants are highlighted in green, and Users are highlighted in blue. Callouts below selected firms list total venture capital funding raised as appropriate.

**Table III. Educational Courses, Workshops, and Tours Supported by the MTTC.**

<b>Academic Term (Most Recent)</b>	<b>Educational Institution</b>	<b>Course Number(s)</b>	<b>Course Description</b>	<b>Achievements</b>
Spring 2006	UNM	ECE-474/574	Microelectronics Processing	Total of 51 students have created field effect transistors (FETs)
Spring 2007	UNM	ECE-595	MEMS, Transducers, Devices and Technology	Nine students created pressure sensors and a prototype drug delivery probe
Fall 2007	SCME	Workshop	One Week MEMS Workshop	Hands-on experiences in micro-fabrication. Participants have included two Mexican technical college instructors, five high school teachers from New Mexico, and one high school teacher from Vermont.
Fall 2007	UNM	ChNE-586	Statistics for Design of Experiments in Semiconductor Manufacturing	
Fall 2007	CNM	MEMS-101	Introduction to MEMS	Total of 37 students etched patterns into silicon dioxide coated wafers
Fall 2007	CNM	MEMS-220	MEMS Fabrication Techniques	Total of 12 students fabricated pressure sensor arrays
Fall 2007	UNM	ME-461E/561E ECE-519 NSMS-519 ST	Theory, Fabrication, and Characterization of Nano / Micro-Electro-Mechanical Systems (NEMS / MEMS)	Total of 27 students created MEMS pressure sensors and MEMS actuators
Spring 2008	Santa Fe Indian School	Tour	Facilities Tour	Improved awareness for 35 high school students
Spring 2008	Albuquerque High School	Tour	Facilities Tour	Improved awareness for 41 high school students over two years
Spring 2008	CNM	ENGR-1010	Facilities Tour	Improved awareness for 40 community college students over two years
Spring 2008	Southwest Indian Polytechnic Institute	Tour	Facilities Tour and Half-Day Fabrication Experience	Improved awareness of microsystems processing requirements and of the nature of microfabrication work for 28 students.

**Table IV. Selected Educational Materials and Methods Projects Produced by MTTC.**

Project Title	Sponsor Agency	Objectives / Accomplishments
Cross-training Technicians and Engineers for Semiconductor Manufacturing	National Science Foundation – ATE Program	Development of nine computer-based training modules for co-training of technicians and engineers covering lithography, metalization, design of experiments, etch, chemical vapor deposition, statistical process control, oxidation, thermal processing, and factory dynamics.
Apprenticeship-Oriented Education and Extension Training for Semiconductor/ Electronics Manufacturing	Technology Reinvestment Program	Coordination of technical and business manufacturing experts from regional and national companies, private consultants, and federal laboratories to provide lectures, curriculum definition, apprenticeship-oriented company and federal lab site lectures, practicums and mentoring.
The UNM Manufacturing Engineering Program: Manufacturing Enterprise Simulator	Technology Reinvestment Program	The MES is designed to enable students, via game-based learning, to quickly understand the dynamics of a manufacturing enterprise, from molecular-level descriptions of manufacturing processes, to global-level, market-driven decision making.
Southwest Center for Microsystems Education*	National Science Foundation – ATE Program	Development of over 90 educational modules termed Shareable Content Objects (SCOs) as part of 21 suites covering most aspects of Microsystems technology including Safety, Microfabrication, and MEMS Applications. Development of a pressure sensor kit for national distribution as a classroom teaching aid for use when access to a semiconductor cleanroom facility is unavailable.

\* The SCME was established at CNM with UNM participating under a subaward. As of this writing, the SCME NSF/ATE Regional Center of Excellence is in transit from CNM to UNM and will be housed in the MTTC.

## The Manufacturing Technology Program at CNM

Central New Mexico Community College (CNM), established in 1965 as Albuquerque Technical Vocational Institute (TVI), is the second largest educational institution in New Mexico. The college has a long history of excellence in technical education aimed at providing adults with marketable skills. In the mid-1990s, the college established a Manufacturing Technology program for the purpose of providing trained workers for semiconductor manufacturing. The need for semiconductor manufacturing technicians began to dissipate at the turn of the millennium, leading the college to adapt the Manufacturing Technology program for microsystem technology, also known as micro-electro-mechanical systems, or MEMS.

### ***Current Program Objectives and Requirements***

The Manufacturing Technology Program had up to three separate concentrations at one time, but is now focused in a single combined concentration referred to as “MEMS/SMT Technician”. The Program offers a certificate as well as an Associate of Applied Science degree for completion of the

full course of study. In addition to several required courses encompassing such areas as electronics, manufacturing concepts, semiconductor manufacturing, chemistry, physics, and technical communications, the Program requires the student to complete six courses in MEMS:

- **Introduction to MEMS**
- **MEMS Manufacturing Process**
- **MEMS Design I**
- **MEMS Design II**
- **MEMS Manufacturing Technology Theory**
- **MEMS Manufacturing Technology Laboratory**

The Program is unique within the United States in providing a thorough grounding in theory and practice for graduates at the Associates degree level. In addition, while not strictly required, the MEMS Design II courses have in the past incorporated team design projects as part of the Sandia National Laboratories University Alliance Design Competition, placing highly in 2005 and 2007, and winning the novel design category in 2006 against teams of engineering students from four-year institutions. These sorts of group projects add greatly to the student's educational experience<sup>13</sup>.

### ***Manufacturing Technology Microsystems Graduates Meet Employer Needs***

CNM's Manufacturing Technology Program graduates concentrating in MEMS have almost universally met with success in the job marketplace. Detailed statistical information on this rather select group of graduates is not available. However, students graduating the Program with an AAS degree have generally found employment with starting salaries between \$30,000 and \$45,000 per year working stimulating jobs in high technology industries. Many students participating in the program have also left prior to completion, yet have used the skills obtained from the program toward productive ends. Some students become impatient with the delays posed by course cancellations, while others have no need of an AAS degree (e.g., returning students with advanced degrees) but simply want to augment their skill sets for greater employability. A few examples are cited in Table V.

### ***Manufacturing Technology Program Status***

Despite substantial student and graduate success in the job market, CNM's Manufacturing Technology Program is presently in dire straits. The average number of students in the program's MEMS courses has been below the threshold required by CNM's administration as an indicator of a healthy and sustainable program for several years, and remains under heavy scrutiny at annual program reviews. In the 2008 Spring term, all of the on-campus Introduction to MEMS courses were cancelled, thereby ensuring that the flow of students through the program's pipeline will not recover within the near future and dramatically reducing the opportunity for advanced MEMS courses to have sufficient enrollment to run in the ensuing academic terms. This situation is expected to place further pressure on the program at the next review cycle since annual student throughput will performce be extremely low. Barring unforeseen externally-driven intervention it is difficult to envision a means by which the program will continue in future.

Table V. Selected Students and Outcomes of Manufacturing Technology Program.

Student	Present Status
S. C.	Working as an intern at Sandia National Laboratories while pursuing a Mechanical Engineering baccalaureate degree
L. P.	Working full time at a micro optical startup MEMS company while completing the Manufacturing Technology AAS degree
B. S.	Completing the Manufacturing Technology AAS degree with plans to pursue a degree in Engineering
P. T.	Completed the Manufacturing Technology AAS degree and working on a Photonics AAS degree – presently working in an advanced jet aircraft company
D. F.	Completed the Manufacturing Technology AAS degree and now works at an environmental control company participating in design and fabrication of humidity and temperature control systems
J. S.	Augmented technical background with CNM MEMS courses – now pursuing future business in custom platform and packaging solutions for microsystems components
R. C.	Presently employed as a technologist at Sandia National Laboratories with plans to pursue an Engineering degree
B. A.	Did not complete AAS degree but is presently pursuing an Engineering degree and working at the Center for High Technology Materials at UNM

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## LOCAL INCENTIVES AFFECT PROGRAM SUSTAINABILITY

Regardless of national imperatives for STEM education, the management of educational institutions within the United States is primarily governed by incentives emplaced by state and local governments. Consequently, decisions made at the local level may be eminently sensible to college administrators given their sphere of influence, yet run counter to national objectives. Federal funding for education is primarily in the form of student loan guarantees and grants to students based on financial need. These funds are available for students taking courses in any accredited program without regard for national educational objectives. Targeted funding for specific educational objectives is relatively modest. While federal organizations such as the National Science Foundation may invest in projects and centers to enhance or catalyze the establishment of local activities responsive to federal objectives, these funding streams tend to be short-term in nature. Therefore, in the long run, local incentive structures sway most administrative decisions regarding academic programs, whether beneficial or detrimental to national imperatives.

## Incongruities Amongst Higher Education Support Mechanisms

### *Federal Educational Incentives*

#### **Federal Support to Institutions of Higher Learning**

The U.S. federal government directly supports colleges and universities by various grant programs offered by federal agencies. A few of these programs, such as the Perkins grants, are ongoing and renewable. Perkins funds are especially helpful to technical education because they may be used to purchase laboratory equipment. Most federal grants aimed directly at institutions of higher education are limited in scope and timeframe, however, and may be viewed as startup funds to initiate an ongoing activity, or limited-term project funds to achieve a specific objective. As such, from an administrator's point of view they are temporary distortions and their potential disruptive effects on the ongoing operations of the school must be contained.

#### **Federal Support to Students**

The U.S. federal government supports students through a variety of grants, direct loans, and loan guarantees. Grants are provided to students demonstrating greater financial need, and loans are made available to supplement grants or provide assistance to students with lesser demonstrated need. Despite federal concerns regarding national deficiencies in STEM fields, the vast majority of federal student aid is not focused toward specific fields of study. Rather, federal aid is based on an assessment of financial requirements and is provided for any accredited program of study regardless of national need. A notable exception is the SMART (Science and Mathematics Access to Retain Talent) grant aimed at support of science, engineering, mathematics, and certain other fields determined to be essential to national security. The SMART grants, however, are only available to third and fourth year students pursuing a baccalaureate degree and therefore have no bearing on community college technical programs. Federal student aid is generally contingent on the student's full-time attendance *but does not require every course to propel the student's progress toward a degree.*

## ***State Management of Higher Education***

The funding formula for support of colleges and universities within the State of New Mexico is determined by state government. Other states, notably California<sup>14</sup>, operate under similar principles, although the universality of this approach is not clear. Infrastructure funding is compensated on a square-foot basis and instructional funding is compensated on a student-credit-hour basis. CNM offers a wide variety of programs but instructional reimbursement is handled on the basis of three classifications. Technical courses are aggregated together for these purposes, so that emerging technologies courses on topics such as photonics or microsystems are compensated in the same manner as welding or plumbing courses despite substantial differences in instructional requirements.

## ***Local Funding and Administrative Decisions***

Funding for Central New Mexico Community College is provided from a variety of sources<sup>15</sup>. The greatest contribution comes from State appropriations (54%), but a property tax levy on Bernalillo County residents provides 32% of annual unrestricted operating expenses. Despite this substantial local contribution toward CNM, local influence over CNM's operation is restricted mainly to the election of board members representing districts within CNM's primary area of service and providing broad guidance to CNM's executive team.

## ***Misalignment of Federal, State and Local Actions***

Considering the various governmental entities involved in higher education as described above, certain incongruities appear.

### **Nonspecific Federal Support Encourages Throughput at Expense of Attainment**

Despite clear federal interest in furthering STEM education, most federal funds support education in a non-specific fashion. The modest grant funds provided to institutions in support of particular activities are temporary and may not sensibly be relied upon by college administrators for long-term planning purposes. The requirement that students maintain full-time attendance to receive financial aid indirectly encourages colleges to cancel small classes, knowing that students will pad their schedules with less relevant courses in order to maintain full-time, federally supported status and thus remain in school.

### **Simplistic State Funding Formula Discourages Specialization**

It stands to reason that virtually any state requires a diversified workforce to address the complexity of a modern economy. It also stands to reason that since people with established ties to their communities provide stability to those communities, the vocational and professional aspirations of native or long-term residents should be supported where practicable. By confounding together the reimbursement schedules for a broad variety of different technology program courses, the state effectively encourages popular programs (college net revenue generation) at the expense of specialty programs (college net revenue loss) without consideration of the value of workforce diversity, the specific workforce development needs of the state and its regions, or whether the degrees conferred will tend to attract economic base jobs, derivative jobs, or no jobs whatsoever to those communities<sup>16</sup>. The reason for this unintended consequence is that the higher education reimbursement system is essentially an immediate cost-recovery mechanism. Lacking integral (memory) or derivative (future-predictive) elements, this approach depends on extremely clear and finely parsed directives regarding the use of funds to achieve specific complex results. Amalgamation of a diverse ecosystem into a simple average essentially eliminates such nuances.

## Financial Incentives Favor Cancellation of Small Classes

Although it might seem unlikely based on national news stories regarding the need for more scientists, engineers, and technologists within the United States, and for a more mathematically and technologically educated general populace, the funding of higher education at public institutions such as CNM is based on student demand as represented by headcount. Basic capabilities classes required of many students for graduation, such as English Composition or Introductory Chemistry, garner large numbers of students on a steady basis. Specialty classes required of only a few students participating in highly specialized programs of study garner small numbers of students, and in a more erratic fashion due to the larger proportional variance inherent in small-number statistics. Within the State of New Mexico, funding is set by the state legislature according to formulae aimed at achieving aggregate cost recovery, without regard to the relative value of those activities respecting vocational employment projections or the needs of economic development initiatives and objectives.

The New Mexico State funding formulae for higher education relevant to programs at CNM are presented in Table VI below. All of the various courses offered by the institution are clustered into groupings based on a nationally standardized scheme, and the clusters are grouped into funding tiers based on broad similarity in costs. Tier one is comprised mainly of courses that require an instructor and a classroom, but do not require advanced equipment or teaching laboratories. These courses are casually referred to by the instructors as “chalk and talk.” Tier two is comprised of courses that have additional equipment or laboratory requirements, and may require additional personnel in the form of Instructional Aides or maintenance personnel. This tier includes most courses in the Applied Technologies division and therefore the Microsystems program courses. Tier three comprises health sciences or public safety courses that require the participation of highly compensated professionals, such as nursing or dental hygiene classes that must be supervised by licensed doctors or dentists, respectively.

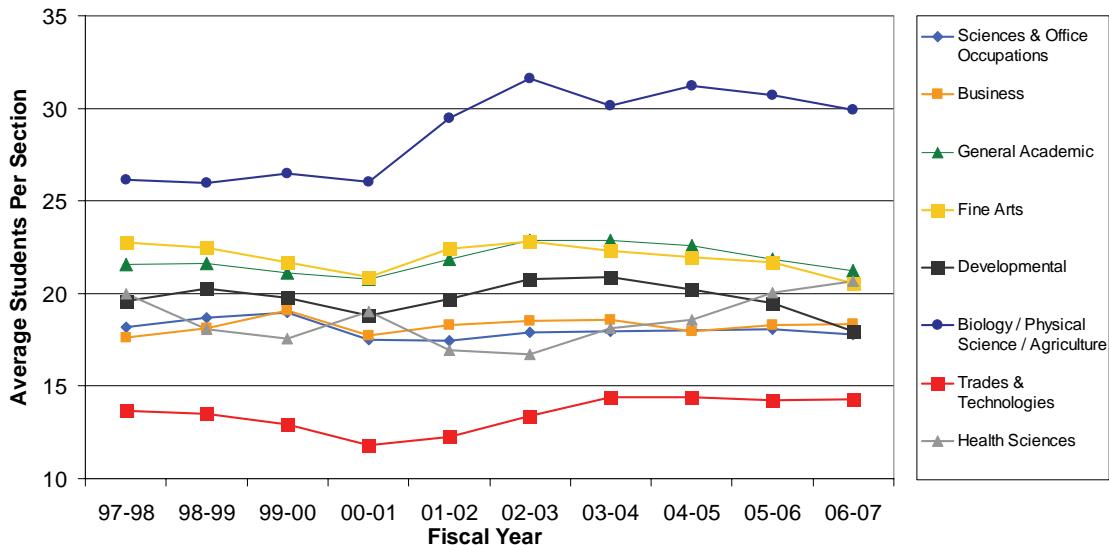
At a glance, the funding formula rate for Technologies courses is nearly 50% greater than the rate for typical academic “chalk and talk” courses, which would seem to provide strong financial incentive in support of technical education. It is important to remember, however, that the funding formula is applied on a per student credit hour basis. Therefore, the compensation to CNM for a given course is proportional to student enrollment. Average course section enrollment in the Trades and Technologies cluster in the 2005-2006 academic year was 14 students. By contrast, in the General Academic cluster, an average of 22 students were enrolled per course section. Consequently, the funding formula reimbursement was similar, despite the higher costs involved in providing technical education. The other Tier 2 cluster – the Sciences – achieved double the reimbursement of General Academic courses by virtue of having an average student headcount of 31 per section.

The trend in enrollments across these cluster categories over the past decade is illustrated in Figure 6. Most of the course clusters fall within the 18 to 22 student average range. The two outliers are the Sciences cluster and the Trades and Technologies cluster. Enrollments per course section in the Sciences have surged upward from approximately 26 to 30 students per section over the past decade. Meanwhile, Trades and Technologies enrollments have increased by less than one student over the same time period. One might reasonably ask why such a discrepancy would arise. Over the past decade, enrollments in the Sciences have risen about 60%, from 45,079 student credit hours in the

**Table VI. New Mexico State Formula Funding by Funding Tier and Cluster at Central New Mexico Community College.**

Funding Tier	Tier 1					Tier 2		Tier 3
Cluster	0100	0500	0800	1000	4900	2300	5300	1200
Formula Amount (2005 - 2006)	\$123.47	\$123.47	\$123.47	\$123.47	\$123.47	\$184.47	\$184.47	\$297.40
Fiscal Year	Sciences & Office Occupations	Business	General Academic	Fine Arts	Developmental	Biology / Physical Science / Agriculture	Trades & Technologies	Health Sciences
1997-98	18	18	22	23	20	26	14	20
1998-99	19	18	22	22	20	26	13	18
1999-00	19	19	21	22	20	26	13	18
2000-01	17	18	21	21	19	26	12	19
2001-02	17	18	22	22	20	29	12	17
2002-03	18	19	23	23	21	32	13	17
2003-04	18	19	23	22	21	30	14	18
2004-05	18	18	23	22	20	31	14	19
<b>2005-06</b>	<b>18</b>	<b>18</b>	<b>22</b>	<b>22</b>	<b>19</b>	<b>31</b>	<b>14</b>	<b>20</b>
2006-07	18	18	21	21	18	30	14	21
Average Funding for 3 Credit Hour Course (2005-06 Data)	\$6,694	\$6,784	\$8,100	\$8,039	\$7,216	\$16,990	\$7,868	\$17,906

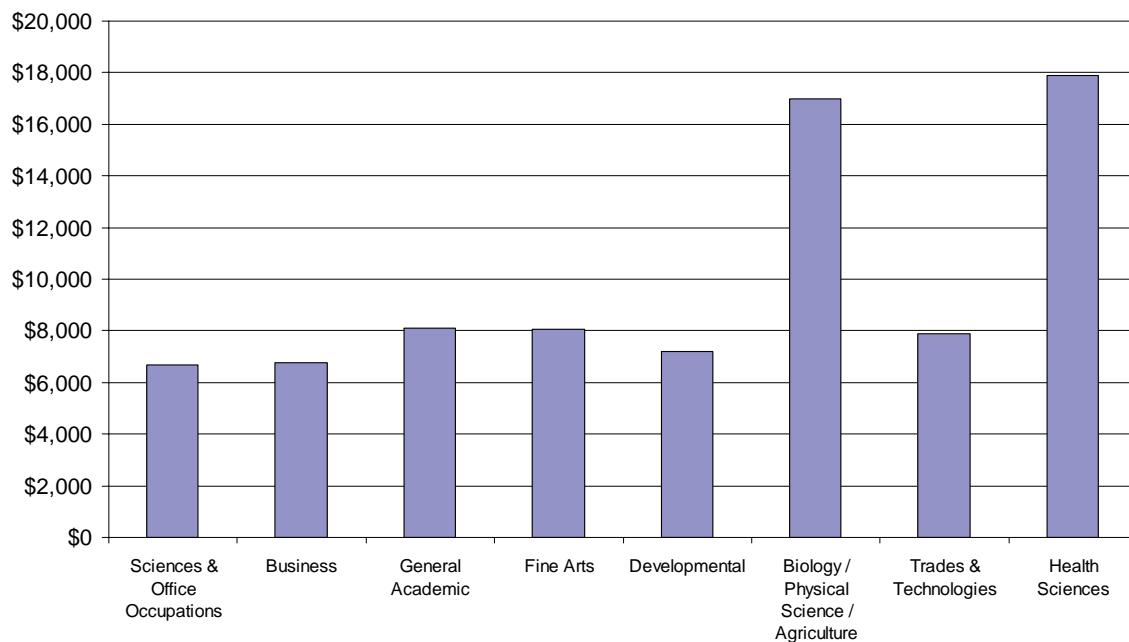
**N.B. Central New Mexico Community College charges tuition for many of the classes in Tier 1 but has not traditionally charged tuition for Trades and Technologies courses. However, the effective remuneration to CNM is not affected by tuition charges because the New Mexico State funding formula amount is reduced by any tuition collected.**



**Figure 6. Average course section sizes at CNM by cluster over time.**

1994- 1995 academic year to 74,760 in the 2004-2005 academic year, spread over seven course prefix categories. In sharp contrast, student enrollments in the Trades and Technologies have risen less than 10%, from 35,658 to 39,561 in the same time period, spread over 28 course prefix categories. While this presents a simplistic view of these enrollment issues, it is easy to see that a division with 1,413 student credit hours per course prefix per year would tend to have smaller classes than a division with

an average of 10,680 student credit hours per course prefix per year. In the Trades and Technologies, administrative decisions around courses often revolve around whether a single-section course will be retained or cancelled. In the Sciences, the decisions tend instead to revolve around the number of course sections to run. Thus, there is a substantial difference in funding formula reimbursements between the two cluster areas, as depicted graphically in Figure 7, yet the costs of running courses in either area tend to be similar.



**Figure 7. Average funding for a three credit hour course by cluster at CNM.**

## **Administrative Practices and Student Morale Cooperatively Impact Program Stability**

Although the financial incentive structure within the State of New Mexico is not highly supportive of small, specialized technical programs, there is also no clear mandate from the State requiring that technical courses or programs be cancelled due to financial considerations. Nevertheless, there are more direct reasons why technical courses and programs are cancelled that are intimately tied with the economics of academia. CNM has set a standard course section threshold of 12 students, below which courses are in jeopardy of cancellation. Presumably, this threshold ensures that the average class size remains high enough to maintain full cost-recovery for the institution as a whole.

Moreover, CNM has an open-entry / open-exit tradition, meaning that students may attend starting at any time, and may leave and return at will regardless of their progress toward a degree. Thus, there is no management of student cohorts moving through programs in an orderly fashion. Rather, enrollment is *ad hoc* and highly variable. The coupling of high variance in small-number statistics and the operation of programs near course attendance thresholds tends toward a downward spiral of course cancellations leading to reduced student confidence and further course cancellations. Policies allowing enrollment to continue into the first week of classes, whereas course cancellations are decided in advance of the start of classes, also tend toward cancellation of specialized courses. Policies regarding payment of tuition and fees within 24 hours of registration further test specialized

programs given that many students have limited means and rely on financial aid disbursements – delayed until the third week of attendance – to pay for their education.

### ***Class Viability is Highly Sensitive to Student Morale***

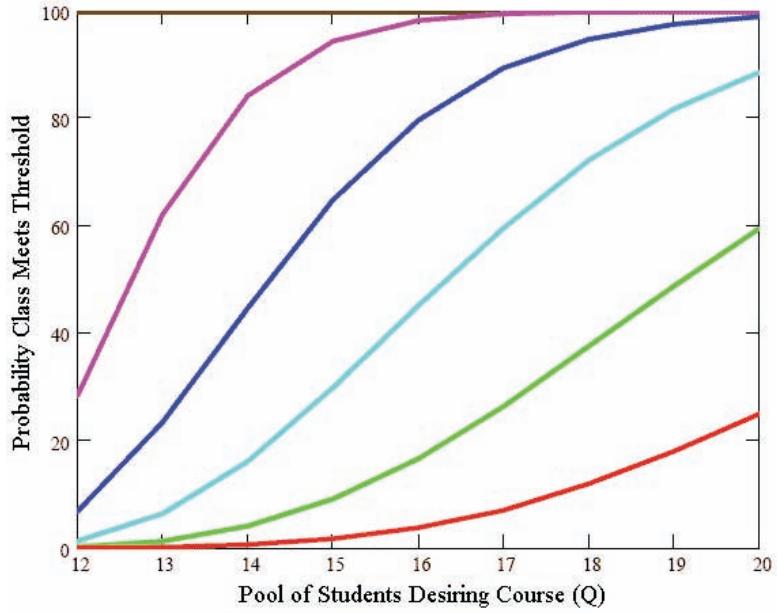
In an effort toward understanding the effects of student discouragement on course cancellations and program viability, a statistical modeling effort was undertaken using MathCAD (Version 8) to simulate the expected likelihood of a class meeting attendance threshold. MathCAD employs a somewhat symbolic script for execution that resembles standard symbolic mathematics but with many functions represented by abbreviated English designations similar to those employed by Microsoft Excel. The MathCAD pseudo-equation at the heart of this numerical simulation is given in Equation 1.

$$\text{Results}_Q := \left[ \sum_{p=1}^{\zeta} \left[ \left[ \sum_{n=1}^Q \text{ceil}(\text{rnd}(1) - (1 - P)) \right] \geq N \right] \right] \cdot \left( \frac{100}{\zeta} \right)$$

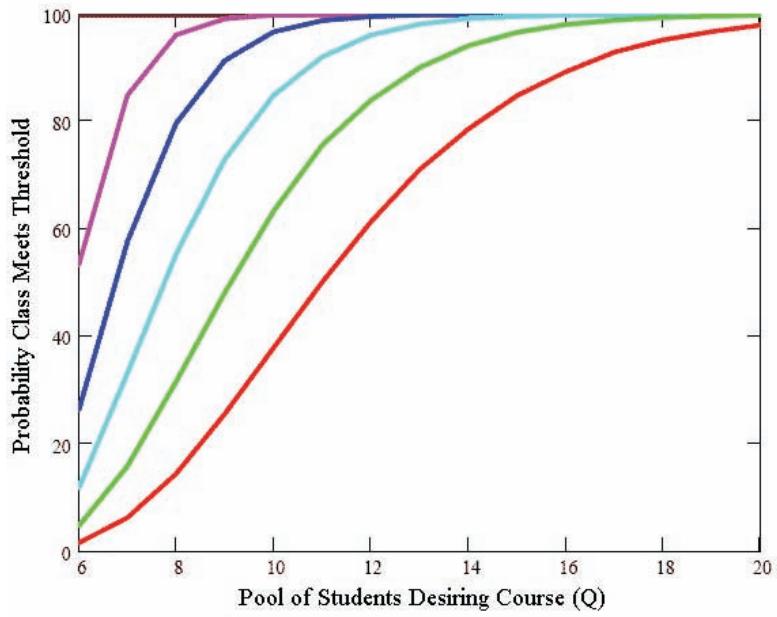
**Equation 1. MathCAD pseudo-equation representing the statistical estimation of likelihood that a course section will meet threshold enrollment requirements.** In this representation,  $Q$  is the number of students with an interest in the course,  $P$  is the probability that an individual student will enroll for the academic term under consideration, and  $N$  is the enrollment threshold. The variable  $\zeta$  is set to a large value to generate a large number of virtual experiments and obtain an accurate probability estimate.

The results employed in Figure 8 were generated using  $\zeta=10^5$  for model stability and accuracy, although  $\zeta=10^4$  appeared sufficient to limit run-to-run variability below 1%. These results clearly illustrate that unless the number of students maintaining an interest in a class is well above threshold, the probability of course cancellation is substantial, even if each individual student has a high probability of enrollment. For example, if among the pool of interested students the individual probability of enrollment for a given term is 70%, even a pool of 20 students does not ensure a 90% probability that the course will run. Moreover, if the students become discouraged to the extent they are only 60% likely to enroll, the probability that the course will run becomes less than 60%. Very modest negative influences on student behavior can have a disastrous impact.

Given that second-year courses had in the past sometimes been allowed to run with as few as six students, a similar modeling exercise was run with a threshold of six students, as show in Figure 9. Once again, a large pool of potential students or a very high probability of individual enrollment is necessary to ensure that the course will run.



**Figure 8. Probability that a course section will meet a threshold of 12 students.**  
 Likelihood estimation given  $Q$  interested students and individual probabilities of enrollment for each student of (red) 50%, (green) 60%, (aqua) 70%, (blue) 80%, (magenta) 90%, and (brown) 100%.



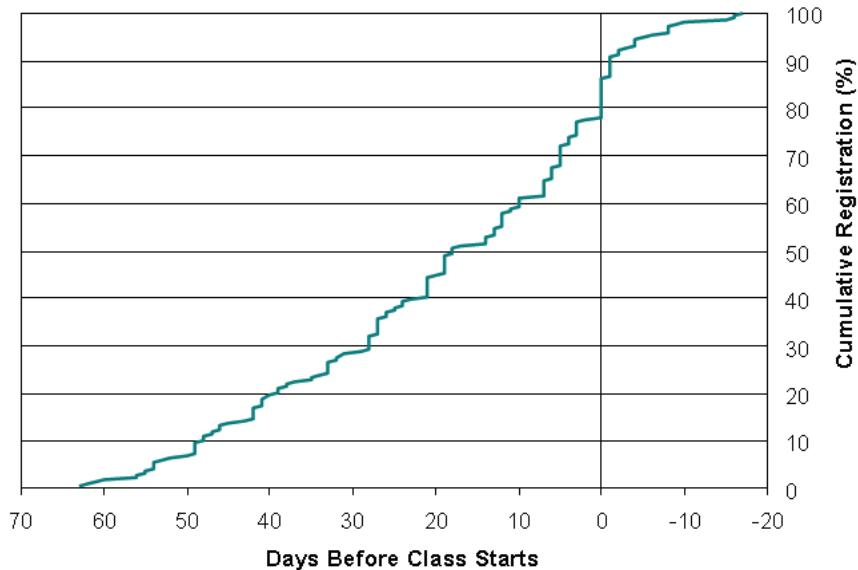
**Figure 9. Probability that a course section will meet a threshold of six (6) students.**  
 Likelihood estimation given  $Q$  interested students and individual probabilities of enrollment for each student of (red) 50%, (green) 60%, (aqua) 70%, (blue) 80%, (magenta) 90%, and (brown) 100%.

## **Administrative Practices Discourage Specialization**

### **Preemptive Class Cancellations**

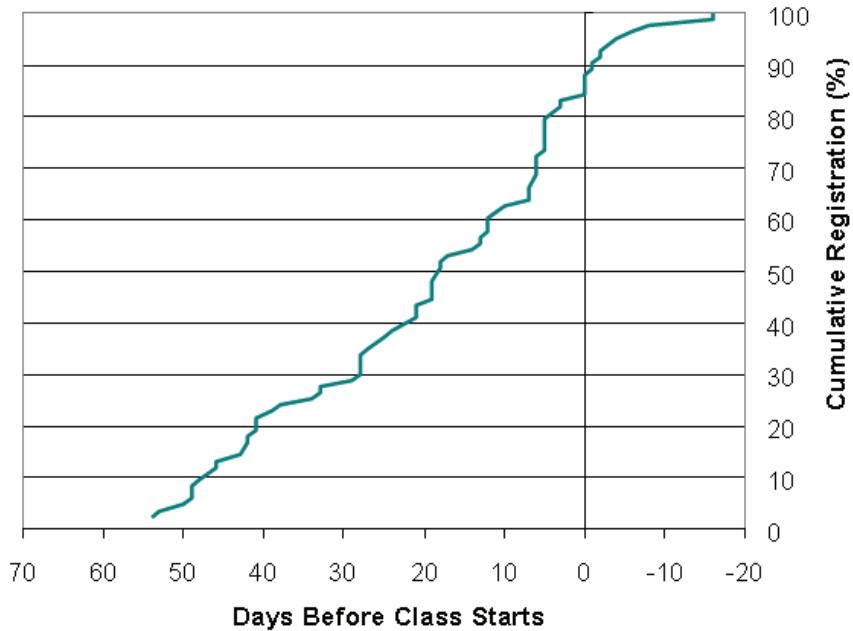
While the interested student pool and the probability of enrollment are key factors influencing whether courses are run, the *temporal pattern* of enrollment behavior also has a strong influence. Decisions regarding course cancellations are typically made several days before the start of classes in order to avoid the chaos that ensues when students must suddenly replace their classes in mid-stream. The pattern of enrollment for CNM's introductory Microsystems course is shown in Figure 10. Eliminating the interfering effect of course cancellations on this enrollment behavior, a more limited dataset is illustrated in Figure 11. The corresponding behavior for the intermediate Microsystems course is given in Figure 12. With only slight variation among Figure 10 - Figure 12, the expectation one week prior to the start of classes is that approximately 60 to 70% of the students who will eventually enroll have done so. Yet the decisions to cancel courses are made at about this time within the enrollment cycle based on the information at hand.

**MEMS 101 Student Registration Pattern**



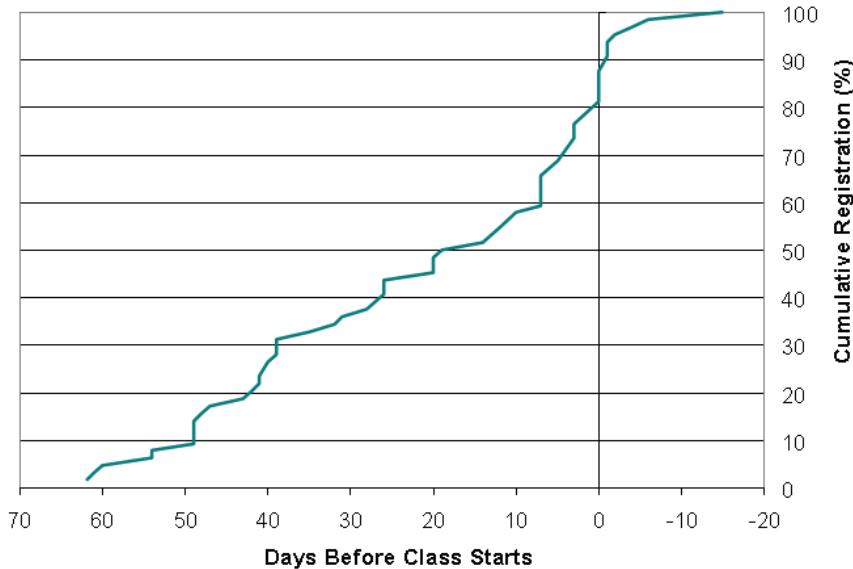
**Figure 10.** Registration pattern for CNM introductory Microsystems course.

### MEMS 101 Registration -- No Cancellation Interference



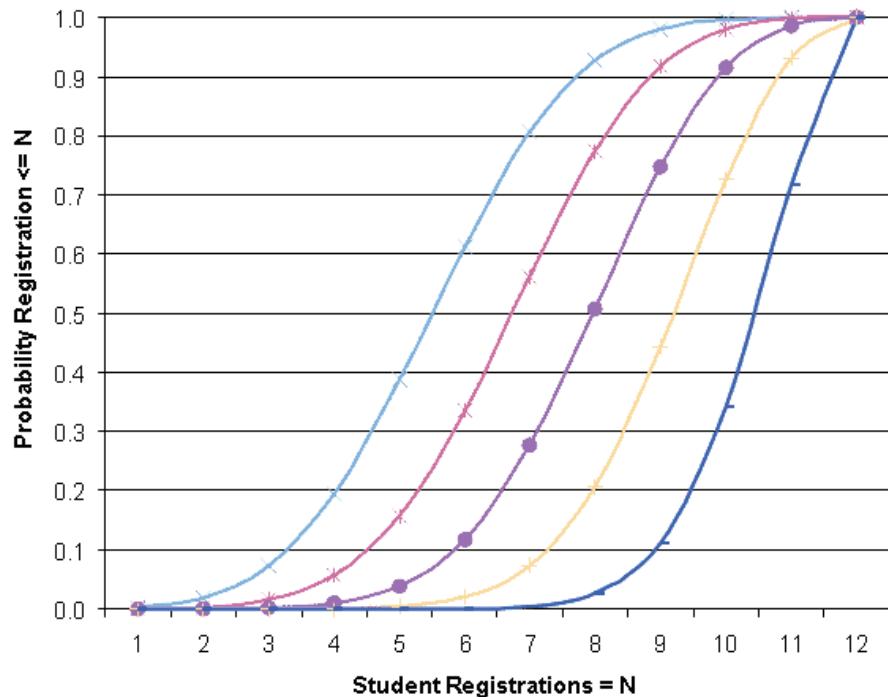
**Figure 11. Registration pattern excluding interference of section cancellations.** Student enrollment in CNM introductory Microsystems course excluding terms when section cancellations affected enrollment behavior.

### MEMS 220 Student Registration Pattern



**Figure 12. Registration pattern for CNM intermediate Microsystems course.**

This early cancellation approach, while conservative, is especially penurious to small, specialized programs, because the vagaries of small-number statistics are accentuated. Expectations based on a binomial cumulative probability model are presented in Figure 13. The family of curves assumes that the course will eventually achieve the required threshold of 12 enrolled students. Each curve represents a mean probability of enrollment. Thus, at seven days prior to the start of classes, the 60% curve applies, and the probability that seven or fewer students will have enrolled by that time is greater than 50%. Viewed alternatively, there is a less than 50% chance that more than seven students will have enrolled by that time. Therefore, even when a class is on track to meet threshold, it may appear risky at the time when preemptive course cancellations are entertained. On the other hand, the numbers are small enough that one cannot say with any certainty that a course with seven students enrolled one week before the start of classes will necessarily meet threshold. Thus, in an academic environment where unreliable and seemingly random student behavior is not corralled by formal cohorts or other proactive grouping strategies, school administrators face an awkward dilemma: choose certain defeat or risk running classes at a financial loss.



**Figure 13. Cumulative student registration probabilities.** Expected registration in advance of final totals for individual student registration probabilities from 50 to 90% for a class eventually achieving 12 total registrations. Color coding, starting at left: aqua (50%), red (60%), purple (70%), orange (80%), blue (90%).

### Course Splitting

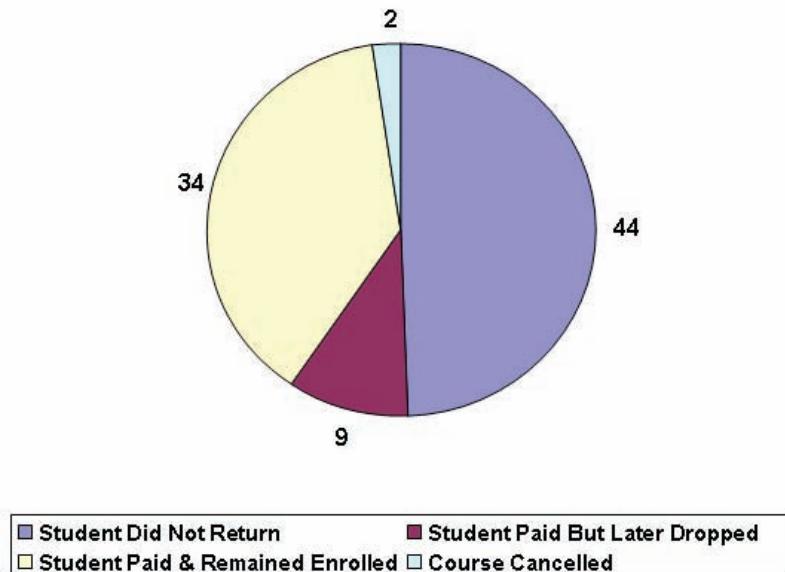
Often, multiple sections (classes) of the same course are offered for a given academic term. Given the absence of formal cohorts that would tend to cluster student availability into specific timeframes,

administrators are essentially forced to guess the best class times to maximize student interest. Sometimes when a sub-critical course section is cancelled the affected students may transfer into one of the remaining sections, bolstering class size. Often, however, students are unwilling or unable to switch due to other commitments. Thus, splitting courses into multiple sections can have severe drawbacks. In the most recent Spring term at CNM, all three of the on-campus entry-level MEMS (Microsystems) courses were cancelled due to insufficient enrollment.

### Financial Dis-Enrollments

Yet another structural problem of note with respect to maintaining small programs is the CNM penalty for early enrollment. Since students may enroll several weeks in advance of classes, and since the classes they would prefer may be cancelled if enrollments are insufficient, there would appear to be an incentive for students to enroll early. This incentive is countered by CNM's demand for payment within 24 hours of enrollment. If payment is not received, the student is administratively dis-enrolled. The negative impacts of administrative dis-enrollment are blunted in regard to common high-throughput courses such as basic Chemistry or English because course sections tend to be large so that a single student enrollment is unlikely to affect whether the course runs. Further, if a section is dropped, others are generally available, and if those are inconvenient, the student may be fairly certain the course will run again in the next academic term. None of these assumptions are reasonable in the context of a small specialty program such as Microsystems. A diagram showing the eventual fate of students dis-enrolled from MEMS 101 for financial reasons is provided in Figure 14.

**MEMS 101 & 220 Students Disenrolled for Non-Payment**



**Figure 14. Eventual fate of Microsystems students administratively dis-enrolled.**  
Financially based dis-enrollments for failure to immediately pay of tuition and fees.

### Special Problems Courses

When a small number of students enroll in a class but critical mass for a standard course is not attained, CNM's administration sometimes approves a Special Problems course intended to enable the affected students to continue to progress through their degree program. This special avenue is a boon to the students and has benefited many participants in the Manufacturing Technology program, but it

also generates a cascade of side effects. Special Problems courses act much like a relief valve and in so doing, further reduce the accumulation of students waiting for a course, thereby contributing to a reduced opportunity for future regular courses to achieve the requisite number of students. Moreover, below a certain number (e.g., five) of students, the instructor is not paid for his time. While the institution may posit that students be properly educated in any event, unpaid projects do not tend to receive the same attention that paid efforts do. The most insidious effect of Special Problems courses is that they enable students to pass through the program without contributing to the statistical records used to evaluate the viability of programs, contributing to the perception that the program is not valued.

### Program Review Criteria

The primary formal criteria used to evaluate programs at CNM include the number of Associates degrees conferred and the average size of classes within the program. Certain types of certificates of completion for smaller groupings of classes may also be considered among graduations. Given that CNM operates in an open-entry / open-exit mode, and that many non-traditional students desire simply to take individualized groupings of classes or even a single class in order to augment their workplace skill sets, an emphasis on graduations as a key success criterion seems misguided from a customer service perspective. Nevertheless, students who do not complete the program negatively impact retention scores regardless of their intentions, and the fixation on graduations as a marker of value persists, denigrating much of the value that the local community – who provide substantial support to the college through a property tax levy – sought from CNM when it was founded as the Albuquerque Technical Vocational Institute (TVI) and continues to enjoy today.

## Synthesis, Results and Conclusions

Total enrollment in CNM's MEMS 101 course over 12 successive academic terms is presented in Figure 15. The figures are highly variable but it is important to consider that if a section is too small it will simply be cut, and while some of the students may be able to transfer into a remaining section, many may not. Experience has shown that approximately 30% of the students who enter MEMS 101 eventually take MEMS 220. Viewed from a critical mass perspective, then, the number of students needed in MEMS 101 in order to run one MEMS 220 course per year would be about 60, depending on the persistence of the resulting pool of students interested in MEMS 220. However, in order to achieve an average of at least six graduates per year in the program, enough students would have to pass MEMS 220 to feed the other second-year courses. While this aspect was not analyzed in depth, one would reasonably expect attrition rates of at least 20%, and therefore that an additional 15 entry-level MEMS students would be required to keep the pipeline full. Unfortunately, even in the best academic year, only about 70 students enrolled in MEMS 101. Recent trends in Manufacturing Technology and related programs as presented in Table VII and Table VIII do not encourage high expectations for a surge of enrollments in the near future.

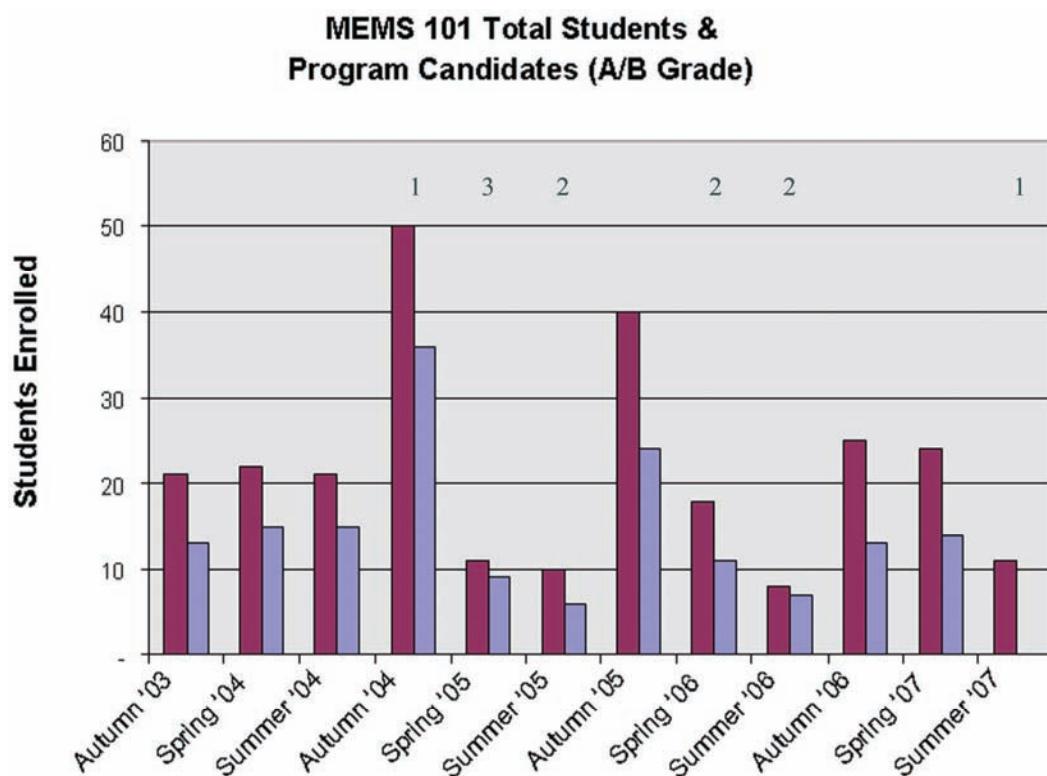
**Table VII. Graduates by Academic Year for Three Microtechnology Related Programs in Central New Mexico Community College's Applied Technologies Division.**

Academic Year	2003-04	'04-'05	'05-'06	Total
Electronics Technology	32	34	18	84
Mfg. Technology (MEMS/SMT)	18	6	4	28
Photonics Technology	10	15	6	31
<b>Total Graduates in Targeted Programs</b>	<b>60</b>	<b>55</b>	<b>28</b>	<b>143</b>

**Table VIII. Declared Majors by Academic Year for Three Microtechnology Related Programs in Central New Mexico Community College's Applied Technologies Division.**

Academic Year	2000-01	'01-'02	'02-'03	'03-'04	'04-'05	'05-'06
Electronics Technology	225	261	306	267	222	205
Mfg. Technology (MEMS/SMT)	202	169	123	85	85	74
Photonics Technology	N/A*	14	41	48	44	49
<b>Total Declared Majors</b>	<b>427</b>	<b>444</b>	<b>470</b>	<b>400</b>	<b>351</b>	<b>328</b>

\* Photonics Technology was a concentration within Electronics Technology prior to 2001.



**Figure 15. Student enrollment in CNM introductory Microsystems course over time.** The number of course sections cancelled in each term is enumerated above the graph bars. Purple bars indicate total enrollment. Blue bars indicate students receiving an A or B grade in the course.

In CNM's most recent Spring 2008 academic term, all three entry-level MEMS course sections were cancelled due to insufficient enrollment, despite a peak total enrollment among the three sections of 28 students a few days before the start of the semester<sup>17</sup>. Given the considerations discussed above regarding the inherent dilemma of early class cancellations and concerns about cost recovery, the decision to cancel these classes is understandable, yet nevertheless highly regrettable. Without continuous renewal of the student pipeline, the advanced classes become impossible to fill, and future graduations become ever more unlikely. Under these circumstances a successful annual program review is likewise impossible, and the future of the program appears untenable barring special intervention.

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## **TRANSFER OF THE SCME TO UNM**

### **CNM Decision to Forego Pursuit of SCME Renewal**

On Wednesday, October 3<sup>rd</sup>, 2007, CNM's Acting Vice President for Academic Affairs, Dr. Susan Murphy, announced in a meeting with SCME Principal Investigator Dr. Matthias Pleil, SCME Executive Director Dr. Thor Osborn, Applied Technologies Dean Diane Burke, and CNM Grant Writer Susan Meyerer-Ortiz, that she would not forward a proposal to the National Science Foundation for a three year continuation of the SCME to the CNM Executive Committee for approval. In effect, this action prohibited the SCME from applying for renewal since the proposal was due on October 11<sup>th</sup> and it was impractical to submit the proposal through SCME's partner organizations within that timeframe. Reasons cited for this action were a desire to return the instructors' focus back to the classroom and on marketing the program to increase student enrollment. This decision led to considerable consternation and confusion among the SCME staff and partner organizations as conditions within the region and news items leading up to that meeting had seemed favorable to furtherance of microsystems and the SCME (see Figure 16). Further, a preliminary proposal had previously been approved by CNM's Executive Committee and submitted to the NSF, receiving a recommendation to submit a full proposal, and discussions regarding partnering opportunities on additional grants with SRI International, Pennsylvania State University, and North Seattle Community College were underway. All of these organizations, as well as SCME's pre-existing partners MATEC (of Maricopa Community College), BioLink (of City College of San Francisco), and MTTC (of University of New Mexico) were thus forced to rapidly reevaluate their plans. At the conclusion of this meeting, it was mutually agreed that the SCME should be moved, if possible, to UNM, thereby removing it as a distraction to CNM faculty, while enabling it to continue its outreach and educational materials development activities.

Ironically, within a few days of CNM's decision not to renew the SCME, New Mexico Cabinet Secretary for Higher Education Dr. Reed Dasenbrock issued a brief report on his tour of Singapore's technical education system. Dr. Dasenbrock described the impressive progress that Singapore had made, and drew parallels between Singapore's success and his vision for the State of New Mexico:

**...surely every New Mexican counts: we are smaller in population than Singapore and we justifiably pride ourselves on our sense of community. I have certainly heard from many of you and from others expressions of concern about the state of technical and vocational education in the state, and I think there is an understanding that a stronger network of technical and vocational education may be part of the solution to keeping more of our children in school... ... We live in a small state; we can't afford to lose anyone, can we?**

Coordination between the state cabinet vision and actions at the local level was not forthcoming, at least with respect to excellence in microsystems education.

Subsequent discussions with Dr. John Wood of UNM and with Dr. Gerhard Salinger, SCME's NSF Program Manager, led to a tentative agreement to pursue the transfer of SCME from CNM to UNM. A Research Assistant Professor position was created for Dr. Pleil within UNM's Mechanical Engineering Department and the processes established by NSF for transfer of grant activities from one institution to another are underway as of this writing, with expected completion in April, 2008.

Key News Events Leading Up to the Planned Submission to NSF for SCME Grant Renewal			
June	Department of Labor awards \$5M Workforce Innovation in Regional Economic Development (WIRED) grant to support workforce development in Green Manufacturing (Includes Microsystems Technology)		
July	Joint National Science Foundation / Department of Labor Workshop in St. Louis Encourages Cross-Leveraging of Workforce Development Funding and Initiatives of Both Agencies	NSF Pre-Proposal Review Recommends Submission for SCME Grant Renewal	
August	CNM & UNM Sign MOU Pledging Future Talks on Articulation	Sandia, MANCEF, & SCME Co-Host the New Mexico SmallTech Workforce Summit	America Competes Act Signed – Mandates Funding for DOE Labs to Engage STEM Education Initiatives
September	Landmark Higher Education Bill Provides \$200M for Hispanic-Serving Colleges for STEM Education	New Mexico Public Education Department Requests SCME Assistance for Online High School Nanoscience Course	SRI International Seeks SCME Partnership
October	CNM Administration Declines to Submit Proposal for Three-Year Renewal of SCME	New Mexico Cabinet Secretary for Higher Education Dr. Reed Dasenbrock Reports on His Tour of Singapore's Technical Education System	

Figure 16. News events in the months prior to SCME grant renewal proposal due date.

## Effects of Transfer on Pursuit of SCME Objectives

The Southwest Center for Microsystems Education was established as a National Science Foundation Advanced Technology Education Regional Center of Excellence, with goals including outreach to educators and the general public, the creation and dissemination of educational materials and curricula, and the acceleration of Microsystems Technologist education locally, regionally, and nationally to provide a better-prepared workforce to support Microsystems-oriented economic growth within the United States. NSF's ATE thrust is a major element of its Division of Undergraduate Education (DUE) and is aimed primarily at two-year degree programs and the initial two years of baccalaureate programs. Thus, it is focused on the application of technology and on generation of interest in technology and engineering programs, as opposed to the teaching of theory or the performance of research activities. For these reasons, a forward-thinking community college is generally viewed as a more natural home for an ATE Center of Excellence than a university. CNM's realignment of its efforts away from its traditional focus on excellence in technical education and toward a more dynamic tactical approach based in the economics of student headcounts and clear expressions of interest from market-dominating employers makes a reliance on CNM as the testing ground for advances in Microsystems Technologist education perilous at best. On the other hand, the greater freedom of action afforded Principal Investigators of grants within UNM may enable the SCME to develop stronger and more effective alliances with other postsecondary educational institutions for the trial and dissemination of educational materials and curricula.

Given that the transfer of the SCME is not yet complete, only time will tell whether the opportunities afforded SCME at UNM will compensate for the destabilization and loss of its activities at CNM.

One clear impact on the ability of SCME to meet its objectives is the effective reduction in funding resulting from higher fringe and indirect overhead costs at UNM, amounting to an effective reduction in direct funding of approximately 30%, coupled with the necessity of extending the period of performance of the original grant from four years to five in order to enable submission for renewal of the grant in the October, 2008 NSF cycle. An immediate consequence of these funding dilutions is the withdrawal of the loan of personnel from Sandia National Laboratories to act as the Executive Director of the SCME, as the 50% matching funds for the Executive Director position are not available under the new severely restricted budget. Some of the previously planned outreach activities have also been eliminated, although an application for supplemental funding from NSF to enable their continuation may be filed in the near future.

## **Comments of the National Visiting Committee Regarding Grant Transfer**

The National Visiting Committee provides an annual evaluation and report to the National Science Foundation regarding the status of the SCME from a semi-independent and therefore more objective viewpoint. The most recent NVC meeting was held February 28<sup>th</sup> and 29<sup>th</sup>, 2008. The committee's views on the transfer of the SCME from CNM to UNM are expressed in Table IX below in terms of both positive and negative expectations.

Table IX. National Visiting Committee Commentary on the SCME Transition to UNM.

Benefits	Disadvantages & Challenges
Improved opportunity for negotiating the growing and highly synergistic three-way collaboration among SCME, UNM and the Southwest Indian Polytechnic Institute (SIPI)	Reduced influence over the uncertain future of the CNM Manufacturing Technology Microsystems program and the continuing CNM Microsystems students
New opportunities for collaborations at UNM in emerging Microsystems-related technology areas – <ul style="list-style-type: none"> <li>• Energy Systems</li> <li>• Bio-Systems</li> <li>• Nanosystems</li> </ul>	Declining institutional support for Microsystems classes from CNM
Greater access to UNM's Manufacturing Training and Technology Center for technology students to obtain team work experience and exposure to engineering principles in a simulated workplace environment	The loss of the loaned Executive Director and of a formal focused internship program with Sandia National Labs should be countered by exploring other ways to maintain a connection to the national labs
	SCME does not have sufficient local visibility within New Mexico – SCME and UNM must work hard to enhance visibility within the state

## CONCLUSIONS AND RECOMMENDATIONS

The summary highlights of this report are as follows:

- **STEM education is a national imperative that has spawned many federal incentives including the National Science Foundation's Advanced Technology Education Program**
- **Sandia National Laboratories and the Central New Mexico region both need skilled Microsystems Technologists – this is the rationale for NSF and SNL support for the Southwest Center for Microsystems Education**
- **CNM's Manufacturing Technology program with Microsystems concentrations has proven well-suited to employer needs**
- **CNM faces counter-intuitive economic pressures challenging its ability to continue to offer the Manufacturing Technology Microsystems program or support the Southwest Center for Microsystems Education**
- **The mismatch between national imperatives and local funding and administrative mechanisms supports reexamination and potential redesign of federal educational incentive programs**

Despite the best intentions on the part of all involved parties at the outset, the development of the Southwest Center for Microsystems Education at Central New Mexico Community College did not proceed as expected. It would be unreasonable to expect all endeavors to proceed as planned, or that they are sufficiently predictable that any failure must be due to avoidable errors. Nevertheless, given that total investments by NSF and SNL in the SCME exceed \$3,000,000 it seems prudent to reexamine those investments for lessons learned.

## Reevaluation of SNL Approaches to Foster Workforce Readiness

Microsystems are a key technology area for Sandia as the circa \$500,000,000 investment in the MESA facilities clearly demonstrates. Sandia's involvement in the inception and development of the Southwest Center for Microsystems Education was based in the best of intentions regarding workforce preparedness and service to the nation. The development of the SCME has not gone as planned, however, and a reevaluation of this approach to workforce development seems worthwhile.

Sandia has invested heavily in Microsystems Technologist education. These investments match Sandia's core competency areas as well as other local employer needs and broad national imperatives. However, Sandia has not fully leveraged these investments in its hiring practices and there are discrepancies between national imperatives and state and local policies supporting higher education and workforce development. Consequently, the impact of Sandia's investment in this area has been blunted, as has that of the National Science Foundation in its attempts to encourage the expansion and improvement of technologist education within the United States.

Sandia has a variety of projects and activities aimed at improved workforce readiness in key technical areas. In general, Sandia relies on educational institutions to provide the necessary formal education and training. As the management pressures on those institutions evolve from excellence toward

throughput volume, the value of their product – graduates – to Sandia may be diminished. Assuming Sandia nevertheless chooses to support a particular program or type of program, an awareness of the modern economics of education should be beneficial. Within any educational institution there will be a lower limit signifying critical mass. If a program lacks critical mass, then internships and other measures directly encouraging student participation may provide more benefit for a given outlay of funds than sharing personnel or technical information. On the other hand, a clear assessment of the program's prospects and sustainability, and the level of resources that Sandia would consider providing on an ongoing basis, may result in a decision to disengage. In either case, decisive action will probably yield more efficient use of funds.

## **Recommendations on National Agency Approaches to Workforce Development Incentives**

The U.S. federal government and various advocacy groups have sponsored several studies in recent years decrying the relative disinterest of U.S. students in technical fields and predicting dire consequences for the nation in the event that this trend continues. In response to these studies, federal agencies charged with the advancement of science and workforce development, most notably the National Science Foundation and the Department of Labor, but also including the Department of Energy, have developed programs intended to entice Americans into technical fields and to improve the capacity of the U.S. educational system to educate qualified workers for emerging fields. The effects of these programs have in many cases been unsustainable as broad national priorities are easily overwhelmed by strong local incentives and ingrained academic practices, especially once the infusion of funds has concluded. National agency programs are generally envisioned as a form of assistance to initiate local endeavors, with the goal of creating self-perpetuating activities. These investments often have no lasting return because the administrators of local agencies face different reward structures, administration personnel turnover is often rapid, and the typical operating policies of federal agencies enable incentives for desired behaviors but do not enable the formation of contractual obligations for future utilization of national agency investments past the grant period. These policies should be revisited as they engender waste of federal funds and of the efforts of motivated educators.

For example, the NSF has invested \$2,300,000 in the SCME in the hope of catalyzing the development of a sustainable Center of Excellence, and while substantial progress has been made, it is clear that the ground in Central New Mexico is not as fertile for this effort as once hoped. The success of the SCME has always been dependent in part upon the success of CNM's Manufacturing Technology program Microsystems concentrations and therefore upon recruitment into the program. An unwritten *quid pro quo* may have been expected by the NSF when the SCME was funded, in that by providing funding to support the development of top quality educational materials and a national center of excellence that would enhance CNM's prestige, as counterpoint CNM would therefore provide strong and enduring support for advertising and student recruitment efforts in order to leverage the NSF investment. Such support was not forthcoming, however, and the NSF has no established mechanism to encourage it. By policy, NSF shies away from binding agreements affecting the internal administrative procedures and operating policies of educational institutions. Yet, "where you stand depends on where you sit," and the natural choices of community college administrators are founded in criteria that may differ from those of NSF program officers.

Although the experience of the SCME is a solitary and unique example, many of the contextual elements influencing administrative decisions are commonplace in institutions of higher learning across the nation. Therefore, lessons learned in the context of SCME may have bearing on other

Centers of Excellence and major Advanced Technology Education projects. Specific recommendations to the National Science Foundation include:

- **Require Explicit Institutional Commitments**
- **Establish Realistic Timeframes for Support**
- **Identify Characteristics of Successful Centers of Excellence**

Moreover, choices regarding the support of education on a broad national level should be reviewed systematically in order to assess whether they effectively promote desired outcomes. One obvious area of interest would be that of federally-supported financial aid to students of higher education.

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**13.** Pleil, M. W.; Osborn, T. D. In *Enhancing Engineering Interest and Skills in Community College Students through a Project Based MEMS Design Competition*, American Society for Engineering Education Gulf-Southwest Annual Conference, 2008; Albuquerque, New Mexico, 86-99.

**14.** Tsao, W., *Personal Communication*, February 28th, 2008, 2008. Dr. Tsao stated that funding for the City College of San Francisco was based on student credit hours in a manner similar to funding for CNM.

**15.** Central New Mexico Community College Budget Report 2007-2008. [www.cnm.edu](http://www.cnm.edu) accessed April 1st, 2007.

**16.** Cranney, M., *Personal Communication*, November 13th, 2007. Computer animation concentration graduated about 25 students over the past year but only two of them got jobs in their field. This is treated as a success by CNM because substantial numbers of students graduated and the courses had sufficient enrollment to meet threshold requirements, even though the popularity of the program among the student body was not met by workplace demand.

**17.** Pleil, M. W., *Personal Communication*, April 4th, 2008. Since Autumn of 2007, the Southwest Center for Microsystems Education has tracked MEMS course enrollments over time in an effort to better understand enrollment patterns and to capture information that can only be retrieved with difficulty from the CNM database after the fact. This information was captured for the Spring 2008 MEMS courses. A peak of twenty-eight students enrolled. At the time of cancellation (January Tenth) twenty-four students remained, as four had been disenrolled for failure to pay. The classes had five, nine, and ten students, respectively.

## APPENDIX

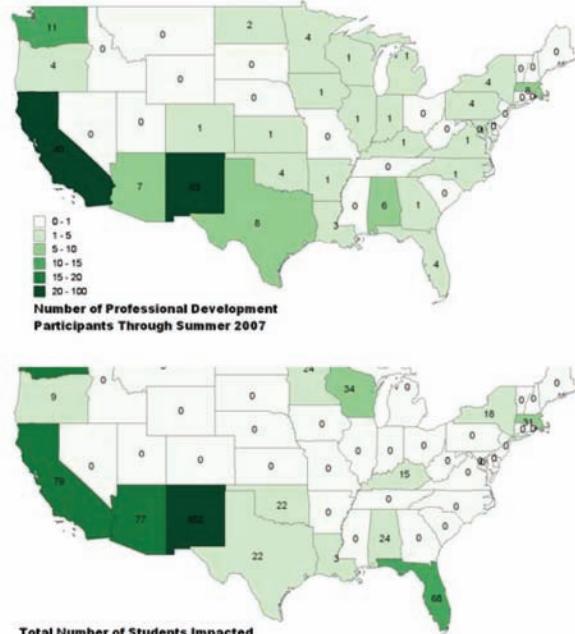
### SCME Impact Highlights Report

#### Southwest Center for Microsystems Education

Matthias Pleil, Ph.D., Principal Investigator  
Central New Mexico Community College  
(505) 224-3355, (505) 363-3428  
mpleil@cnm.edu, pleil@msn.com

Accomplishments of the SCME since inception in 2004:

- Introduced over 200 secondary and post-secondary teachers to Microsystems, fostering over 10,000 student-hours of instruction in Microsystems Technology
- Provided annual professional development opportunities in Microsystems at pre-conference workshops integrated with the SAME-TEC conference
- With partner MATEC, provided the first High Tech U. for Girls Only
- Leveraged commercially available ExpressTrain™ software to establish an efficient development and continuous improvement system for SCORM-compliant educational modules
- Made substantial progress toward a complete set of modular Microsystems educational materials for use by post-secondary teachers and in advanced secondary classes – presently includes Safety/HazMat, History/Overview, Photolithography, BioMEMS, Physical and Chemical Sensors and Actuators, Scale, et cetera.
- Conducted 12 hands-on workshops for YY teachers to give them direct experience in processing Microsystems and the confidence to teach the subject
- Initiated a workshop series to engage secondary and mid-school teachers in adapting Microsystems educational materials for use in the K-12 system with linkages to all relevant required standards and benchmarks
- Coached 20 students over three years through the University Alliance MEMS competition sponsored by partner organization Sandia National Laboratories to develop camaraderie and teamwork skills, achieving first and second-place finishes against a field of major university competitors
- Leveraged ongoing RoboRAVE (“Robots Are Very Educational”) activities to showcase value and relevance of Microsystems to K-12 students
- Developed online introductory MEMS course using SCO modules to increase enrollment in program and aid dissemination nationally.
- Completed global industry survey and job profiling activities. Implementing results into education materials. These activities represent what the technologist actually does on the job, not based on management perceptions. Survey with profile results defined requisite knowledge topics to cover and essential skills to include in activities to reinforce in the classroom.
- Facilitated establishment of internships and jobs at startups and National Labs.



# New Mexico SmallTech Workforce Summit

## *Meeting Agenda*



### NEW MEXICO SMALLTECH BUSINESS AND WORKFORCE DEVELOPMENT – PAST, PRESENT, AND FUTURE

<b>8:00 – 8:15 AM</b>	<b>Welcome and Introduction</b> Thor Osborn – Executive Director, Southwest Center for Microsystems Education
<b>8:15 – 8:35 AM</b>	<b>Introduction to New Mexico State Science and Technology Plan</b> Thomas Bowles – Science Advisor to New Mexico Governor Bill Richardson
<b>8:35 – 8:55 AM</b>	<b>Developing New Mexico's Science and Technology Assets: Near Term Plans for Success</b> Stephan Helgeson – Director, Office of Science & Technology, State of New Mexico Economic Development Department
<b>8:55 – 9:10 AM</b>	<b>Getting to Market</b> Sherman McCorkle – President and CEO, Technology Ventures Corporation
<b>9:10 – 9:40 AM</b>	<b>Past Growth and Present Status of SmallTech-Enabled Business in New Mexico</b> Steven Walsh – Professor, Management of Technology, Anderson School of Management, University of New Mexico

### **9:40 – 10:00 AM** BREAK & NETWORKING

### FUTURE OF SMALLTECH BUSINESS IN NEW MEXICO

<b>10:00 – 11:00 AM</b>	<b>Breakout Session 1A – Business Development &amp; Workforce Expansion Projections</b> Scott Bryant & Suzanne Kryder
<b>10:00 – 11:00 AM</b>	<b>Breakout Session 1B – Projecting Impact of Geopolitical and Economic Trends on the Future of SmallTech in New Mexico</b> Steve Walsh & Thor Osborn
<b>11:00 – 11:30 AM</b>	<b>Presentation and Synthesis of Breakout Session 1 Results – Key Findings and Q&amp;A</b> Thor Osborn & Suzanne Kryder

### **11:30 – 11:50 AM** BREAK, NETWORKING, AND LUNCH PICKUP

### LUNCH AND MODELS FOR ECONOMIC DEVELOPMENT

<b>11:50 – 12:10 PM</b>	<b>ONAMI Overview</b> Skip Rung, President and Executive Director, Oregon Nanoscience and Microtechnologies Institute
<b>12:10 – 12:30 PM</b>	<b>Introduction to the Oklahoma NanoTechnology Initiative</b> Jim Mason, Executive Director, Oklahoma NanoTechnology Initiative
<b>12:30 – 12:50 PM</b>	<b>Mesa del Sol – Linking Economic Development, Land Development, High Technology, and Creative Class</b> Mark Lautman, Director of Economic Development, Mesa del Sol
<b>12:50 – 1:10 PM</b>	<b>BREAK, NETWORKING AND LUNCH BREAKDOWN/CLEANUP</b>



**TRACK A – ROLE OF THE STATE OF NEW MEXICO IN SMALLTECH BRANDING AND MARKETING**

**1:10 – 1:30 PM**      **Review of State SmallTech Resources Inventory and Marketing**  
Scott Bryant, Executive Director, Micro and Nanotechnology Commercialization Education Foundation

**1:30 – 3:00 PM**      **Breakout Session 2A – Role of the State in Marketing and Resource Inventory**  
Scott Bryant & Steve Walsh. Exploration of gaps in promotion of New Mexico's growing SmallTech Cluster and the appropriate role of the state in addressing those gaps.

**TRACK B – NEW MEXICO'S SMALLTECH EDUCATIONAL TOOLKIT**

**1:10 – 1:30 PM**      **SmallTech at CNM – A Benchmark Program for Industry and Education**  
**Partnerships: Manufacturing Technology**  
Robert Hall – Director, Electronics and Manufacturing Technologies, Central New Mexico Community College

**1:30 – 1:50 PM**      **Outline of SmallTech Oriented Programs at University of New Mexico**  
Professor Harry Weaver, University of New Mexico

**1:50 – 3:00 PM**      **Breakout Session 2B – The Vision for SmallTech Education in New Mexico**  
Thor Osborn & Suzanne Kryder. Exploration of strengths and weaknesses in New Mexico's SmallTech educational capabilities and outline of actionable plans to address weaknesses and build on strengths.

**3:00 – 3:20 PM**      **BREAK & NETWORKING**

**SYNTHESIS, ACTION PLANS, AND CLOSURE**

**3:20 – 4:00 PM**      **Report-Out from Afternoon Tracks, Q&A and Clarifications**  
Scott Bryant & Thor Osborn

**4:00 – 4:30 PM**      **Proposed Next Steps**  
Thor Osborn & Suzanne Kryder

**4:30 PM**      **Closing Remarks and Adjournment**  
Thor Osborn

## Attendee List

Attendee Name	Attendee Surname	Organizational Affiliation
Ian	Aeby	Emcore
Tom	Bowles	New Mexico State Governor's Office
Scott	Bryant	Micro and Nano Commercialization Education Foundation
Randy	Burg	Proactive
Diane	Burke	Central New Mexico Community College
Dustin	Carr	Symphony Acoustics
Wendy	Cieslak	Sandia National Laboratories
Rose	Cordova	Micro and Nano Commercialization Education Foundation
Mary Jo	Daniel	New Mexico State Public Education Department
Duane	Dimos	Sandia National Laboratories
Jeb	Flemming	Life BioScience, Inc.
Dominique	Foley-Wilson	Sandia National Laboratories
Denise	Gardner	Central New Mexico Community College
Jill	Halverson	The Hon. Senator Bingaman's Office
David	Hata	TEMPlate
Stephan	Helgesen	New Mexico State Economic Development Department
Donna	Hofmann	Plus Group
James	Hyder	Intel
Justine	Johannes	Sandia National Laboratories
Barbara	Kimbell	University of New Mexico EPSCOR
Suzanne	Kryder	Suzanne Kryder, Inc.
Mark	Lautman	Mesa del Sol
Fabian	Lopez	Central New Mexico Community College, SCME
Jim	Mason	The Oklahoma Nano
Stacy	McKay	Advent Solar
Pete	Mertens	Mesosystems
Susan	Meyerer	Central New Mexico Community College
Eva	Multine	Sandia National Laboratories
Thor	Osborn	Sandia National Laboratories, SCME
Matthias	Pleil	Central New Mexico Community College, SCME
Sherry	Robinson	Techknow NM
Regan	Stinnett	Sandia National Laboratories
Terry	Sullivan	Albuquerque Economic Development
Theresa	Sullivan	Gen-Quest
Katie	Szczepaniak-Rice	Wasatch Venture Fund
Steve	Walsh	University of New Mexico
Jeffrey	Willis	LANL / Center for Integrated Nanotechnologies
John	Wood	University of New Mexico
Tom	Zipperian	Sandia National Laboratories

**N.B. Skip Rung of ONAMI delivered his presentation by telephone.**

## **DISTRIBUTION**

1 Ms. Diane Burke  
Central New Mexico Community College  
525 Buena Vista Dr. SE  
Albuquerque, NM 87106

1 Dr. Robert Hall  
Central New Mexico Community College  
525 Buena Vista Dr. SE  
Albuquerque, NM 87106

1 Mr. Fabian Lopez  
Central New Mexico Community College  
525 Buena Vista Dr. SE  
Albuquerque, NM 87106

1 The University of New Mexico  
Dr. Matthias Pleil  
Mechanical Engineering  
MSC01 1150  
1 University of New Mexico  
Albuquerque NM 87131-0001

1 The University of New Mexico  
Dr. Steven Walsh  
Anderson School of Management  
MSC05 3090  
1 University of New Mexico  
Albuquerque NM 87131-0001

1 The University of New Mexico  
Dr. John Wood  
Mechanical Engineering  
MSC01 1150  
1 University of New Mexico  
Albuquerque NM 87131-0001

1 Dr. Gerhard Salinger  
National Science Foundation, Room 885  
4201 Wilson Boulevard  
Arlington, VA 22230

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