M2M: The Wireless Revolution
A Technology Forecast

Implications for Community & Technical Colleges
in the State of Texas

iC²INSTITUTE
The University of Texas at Austin

Authored by:
Jim Brodie Brazell, Laurel Donoho, John Dexheimer
Robert Hanneman, Ph.D. and **George Langdon**

Program Manager for Research, IC² Institute
Eliza Evans, Ph.D.

Programs for Emerging Technologies, Program Director
Michael Bettersworth, M.A.

Texas State
Technical College

M2M: The Wireless Revolution

Authored by:

Jim Brodie Brazell

Laurel Donoho

John Dexheimer

Robert Hanneman, Ph.D.

George Langdon

Program Manager for Research, IC² Institute

Eliza Evans, Ph.D.

Contributors:

John Green

Prakash Chakravarthi, Ph.D.

Corey Carbonara , Ph.D.

Michael Korpi, Ph.D.

Research Assistant:

Charles Pridgeon

Programs for Emerging Technologies, Program Director

Michael Bettersworth, M.A.

Texas State
Technical College

3801 Campus Drive
Waco, Texas 76705
Main: 254.867.3995
Fax: 254.867.3993
www.tstc.edu

Table of Contents

List of Appendices

List of Figures

List of Tables

Preface

In 1999 the Texas State Senate mandated Texas State Technical College System to "develop and administer a program to forecast the types of technical education programs that are needed to maintain and improve the State's economic and technical competitiveness" (SB1819). In 2001, the Texas Higher Education Coordinating Board (THECB) provided funding under a Carl D. Perkins grant to the Texas State Technical Collect System (TSTC) to develop a process, later called Programs for Emerging Technologies www.forecasting.tstc.edu, for accomplishing the Senate's goals with regard to the state's community and technical colleges.

The research presented in this report is one in a series of ongoing forecasts based on this legislation. Each report is designed to provide Texas collage instructional officers and curriculum directors with timely analysis and actionable insights into emerging technologies and their potential impacts on existing and new technical education curricula. A highly skilled workforce is essential to the success of Texas companies and the overall economic competitiveness of the state. By anticipating workforce demands, college curriculum offerings can be a constructive force in attracting high-tech companies to the state and ensuring existing high-tech companies continue to have appropriately skilled employees.

Through this research, Texas State Technical College (TSTC) hopes to drive the development and support of emerging technology curricula and facilitate informed and accurate future curriculum development efforts for all Texas colleges.

This research was conducted by the IC[2] Institute at the University of Texas at Austin in 2004. Although this report is designed for Texas educators, the contents may also be useful for a variety of regional economic development efforts.

Acknowledgments

Although there are many people who have assisted us in the preparation of this report, the authors would like to give special thanks to the following people:

The primary foundation of this report is the input that we have received from the listed experts, primary research and third party sources consulted during the conduct of this research. The report reflects the authors' interpretations of these inputs. Any misinterpretations of these inputs are the fault of the authors, and we apologize for these to the people who have so obligingly contributed to our efforts.

What is M2M?

M2M is an acronym for the term "Machine to Machine." It is a category of Information and Computing Technology (ICT) that combines communications, computer and power technologies to enable remote human and machine interaction with physical, chemical and biological systems and processes. In addition, M2M represents a new kind of application for computing where data are streamed to and from the physical and biological environments (Krishnamurthy, Laksham, 2003).

M2M applications include:

- Sensors of temperature, pressure, humidity, illumination, presence, gases and many health-related diagnostics

- Actuators mirrors, motors, smart surfaces, micro-robots, micro-electromechanical systems (MEMS) (Krishnamurthy, 2003)

- Location services for humans, animals, vehicles, products and property

- Remote monitoring for life, health, property and employee efficiency

- Remote control and/or management of simple machines (such as consumer electronics and vending machines), micro-robotics (such as MEMS devices) and complex systems (such as factory automation, industrial control or space-based systems)

- Identity, Rights Management and Fungible Media including identity management, Digital Rights Management (DRM), authentication, funds transfer, service location, digital economy concepts and consumer rights management (adapted from M2M Europe, n.d., p. 1).

Despite M2M's limited applications to date, its influence and importance as a technology will only continue to grow, due to:

- Increased scope of the Internet to include M2M devices, systems and processes that were previously not networked

- Miniaturization and integration of self-powered sensors with computation and communication capability to form a new class of computing—"motes" (Krishnamurthy, Laksham, 2003, p. 1)

- Increased transparency of these devices, systems and processes

- Internetworking of these devices, systems and processes across institutions (government, education, military, industry)

- Incorporation of M2M into the design of objects both physical and biological, so that data, information, knowledge and communication are "subsumed into" rather than "affixed to" these objects (Smith, J. T., 2004).

M2M Market

There is a spectrum of forecasts for M2M, but the common thread is that analysts are optimistic. **Some experts predict that by 2010, there will be 10,000 Internet-connected machines for every person connected to the net** (Hardy, 2004, p.1). **The FocalPoint Group projects that M2M will extend to literally trillions of devices over the next six years** (The FocalPoint Group, 2003, p. 6). And, **traditional M2M over cellular networks is forecast to grow 40 percent annually through 2010,** according to ABI Research (The FocalPoint Group, Inc., 2003, p. 1). This report identifies the most promising of these markets including:

- Critical infrastructure and heavy industry sensor and process control networks

- Intelligent transportation systems and logistics management

- Monitoring the structural health of bridges, dams and other structures

- Environmental monitoring

- Radio frequency identification tags in retail and wholesale trade

- Automated meter reading and resource management in the utility industry

- Health monitoring, diagnosis and treatment

- Home computer and entertainment networking

M2M and the State of Texas

M2M is important in the context of workforce and policy issues in the State of Texas because:

- **The M2M global market is projected to be $100 billion in 2005, growing to $700 billion in 2010** (Harbor Research, 2003, p. 4).

- **M2M technology impacts virtually every industrial sector** (Harbor Research, 2003, p. 4). Key Texas growth markets are medicine, health care, logistics, transportation, industrial control, wholesale-retail trade and critical infrastructure protection.

- The labor market will be affected because the number of installers, testers and field personnel required by industries using M2M applications will increase with adoption and deployment of the technology. The number of embedded hardware and software engineers nationally will increase at a compound annual growth rate of 7.3% with the embedded software industry growing at the higher rate of 8.6% (Guaning, 2003, p.1).

- M2M technologies may create structural unemployment as new jobs are created and workers are displaced by automatic control technologies that create efficiencies and reduce dependence on humans in both manual and intellectual jobs. New jobs emerging from M2M may require different skills and incumbent workers' skills may not be relevant in this new highly automated domain.

- The M2M wireless technology industry as a whole is in the early adoption stage. Many applications are entering the growth stage spurred by demonstrable return on investment (ROI), military and homeland security investment in sensor-based M2M technologies, existing telecommunications infrastructure, increased capability and use of unlicensed radio spectrum and cross appropriation of semiconductor manufacturing techniques to accelerate MEMS-based M2M applications.

- Between 2004 and 2010, M2M technologies will be accelerated by advancements in the convergent sciences (nano-science, bioscience, information science, cognitive science, environmental science) that expand the applications of M2M, decrease the cost, open up direct manipulation of chemical and biological processes and enable infinitesimal M2M platforms (Neil, 2003, p. 1).

Survey of M2M Employers

A survey of 58 Texas and national M2M employers provided original data on M2M value chains, market and technology trends and workforce needs.

- **86% of surveyed companies expect to hire new technicians in the next three years, amounting to approximately 700 new technician hires.**

- Nearly half of the companies preferred 4-year degrees for these positions and **38% preferred hires with certificates, associates or other credential.** However, in a separate question on the importance of the availability of certain resources, including human and financial capital, **58% identified the availability of technical college graduates as either important or very important.** By comparison, 56% identified the availability of undergraduates and 48% identified angel investment capital as critical resources.

- **40% of survey respondents anticipate the highest job growth among wireless systems engineers and security specialists.** Other high growth jobs include systems architect, applications engineer, project managers, RF engineers and wireless digital communications engineers. With the exception of applications engineer, most of these high growth jobs are associated with educational attainment beyond an associate's degree.

The M2M Workforce

Wireless M2M job domains are discussed in terms of:

- **Device Hardware**—design of wireless-related integrated circuits, transmission and receiving devices and network components.

- **Infrastructure**—the wireless system and hardware as well as the interface with conventional systems such as fiber optic backbones.

- **Software Applications**—development of software solutions primarily for business purposes.

- **Systems Integrators**—modification and assembly of existing disparate hardware and software for a unified business solution.

- **System Operators**—multiple functions such as help desk employees, system maintenance and data analysts. Most associate's and certificate level hires will be in this domain.

For each domain, general job requirements, skill level and, where available, expected job growth are discussed in this report. Example jobs in entry-level positions in each M2M market are discussed and select inventories of knowledge, skills and abilities are provided in the appendix.

Preparing the Texas Workforce for M2M

The technology in the M2M industry will require a workforce educated in wireless, embedded systems and Internet technologies. Trends in the emerging M2M industry displace old technologies and methods and require workforce retraining and new hires with new knowledge, skills and abilities. To accommodate emerging workforce demand, we recommend that extant and new M2M curricula incorporate the following emphases:

- Hybrid networking with a focus on inter-networking rather than an exclusive focus on one delivery medium such as cellular, 802.x or DSL.

- **Digital communication and conversion from analog to digital communication (especially in telematics applications where analog terminals will be phased out in 2006). Colleges should seek partnerships with major analog telematics users to develop a workforce skilled in conversion from analog to digital systems. Local police, fire, ambulance, taxi and fleet managers are candidates for partnerships.**

- Legacy and open systems protocols, especially IPv6.

- Proprietary bus structures and Open Systems within the context of specific applications (such as RFID, Asset Utilization and Tracking, Building Control and Physical Security).

- New computing architectures, especially P2P and ad hoc networking.

- Inter-networking and "network of network" concepts.

- Messaging between and across control networks; for example, messaging across environmental sensing, environmental control and physical security.

- Information assurance and cryptography.

- Event-based management, automatic control systems and intelligent systems.

- Object-oriented techniques relevant to small footprint devices in a network of networks environment.

- **Educational institutions seeking differentiation should focus on issues related to Human-to-Machine Collaboration (HMC), Human Systems Integration and Human Factors.** Ideally, curricula will unite new media and human factors to create a new generation of designers capable of designing HMC environments.

Industry experts interviewed for this research project suggest that curricula should combine troubleshooting techniques and a systems-oriented approach similar to the approach CISCO uses with its network certification processes. Recommendations include:

- **M2M learning environments need to be inquiry-based and immersive, where students are allowed to learn by trial and error.**

- **The learning environment should be lab-based** and supportive so that repeated failure is supported by instructor direction and feedback.

- Many M2M devices: routers, switches and gateways require command-line training rather than windows-based environments. M2M technicians will need advanced training similar to CISCO technicians.

- **Peer collaboration will be important to M2M learning because technicians will often work in teams to deploy M2M systems.** Cross-disciplinary communication, teaming and project management skills should be emphasized.

- **Real world operating systems should be used in the lab with a focus on Internet connectivity and the availability** of computing resources from home as well as physical lab environments.

- Currently, CISCO certified training is the benchmark for the network infrastructure training industry. Similar to CISCO, M2M curricula should leverage simulations and virtual environments for early, basic training. After introductory training, hands-on equipment availability is essential.

M2M: Introduction

Traditionally, we think of the computer revolution as a progression from Babbage's Computational Machine to the ENIAC, mainframe computers, minicomputers, video games and Personal Computers (PCs), Local Area Networks (LAN) and Wide Area Networks (WAN) to the Internet. Simultaneous to the publicly heralded Internet revolution, however, a silent revolution was brewing—the Machine-to-Machine (M2M) revolution.

As early as 1999, the number of embedded microprocessors found in the average middle-class household in North America was 45 (Lewis, 2001, p. 1) and today, there are more than 110 sensors in the average automobile with the number having doubled in the past four years (Dexheimer, Hannemann, n.d., p. 21-22).

To understand the significance of M2M, consider that the number of embedded Central Processing Units (CPUs) manufactured in 1999 surpassed the number of microprocessors packaged inside of traditional computers such as PCs by a factor of 100 to 1 (Lewis, 2001, p. 1). **The M2M is a movement to network these islands of hidden computers and to make the devices, systems and processes they control transparent to human and machine actors.** Methods of networking will be wireless, fixed-line and hybrid (wireless and fixed-line). Once these M2M devices (embedded microprocessors and controllers) are connected to a network, a kind of domino effect will take place in which all "things" will be connected to the global network.

M2M is a category of Information and Computing Technology (ICT) that combines communications, computer and power technologies to enable remote human and machine interaction with physical, chemical and biological systems and processes. In addition, M2M represents a new kind of application for computing where data are streamed to and from the physical and biological environments (Krishnamurthy, Laksham, 2003).

M2M has many synonyms including "pervasive computing," "hidden computing," "invisible computing," "wireless sensor networks," "motes," "smart dust" and "ubiquitous computing." These terms are all descriptive of M2M: pervasive because M2M will spread to all aspects of life including work, play, learning and even war; invisible and hidden because we will not see M2M devices or be confounded by their operation as we are by legacy computers; wireless because they use the air waves to exchange communications and in some cases to scavenge energy for operations; motes because these computers can be the size of a "speck of glitter" (Yang, 2003, p. 1); smart because these devices are capable of intelligence at the edge of the network, dynamic configuration and swarm-like semi-autonomous behavior; and ubiquitous because M2M devices are embedded into buildings, automobiles and the environment.

Although this sounds futuristic, Harbor Research forecasts that **by the end of 2003, 9.5 million M2M devices will be Internet-connected and, by 2010, 1.5 billion devices will be Internet-connected worldwide** shifting the focus of computing from PCs and mobile phones to embedded computers and microcontrollers (Harbor Research, 2003, p. 4). Many of these M2M technologies are available today using Commercial-Off-The-Shelf (COTS) technologies and existing manufacturing techniques. **Potential consequences include accelerated adoption, accelerated workforce demand and accelerated need for training of existing workers.**

Figure 1   Pervasive Internet Device Hierarchy

Device Examples	Pyramid Level	2005 Forecast
Mobile Phones, PDAs, Scanners, Web Tablets, GPS, etc.	Mobile Info Appliances	1.5 billion
PCs, Servers	Static Info Appliances	500 million
Vehicles, Cargo Containers, Supply Chain Assets (SKUs), Tankers, etc.	Mobile Devices	350 million (SKUs: trillions)
Medical Devices, HVAC, Industrial Machinery, Distributed Generation, Home Appliances, Pipelines, etc.	Static Devices	375 million
Industrial Controllers, Appliance Controllers, etc.	Controllers	500 million
Accelerometers, Pressure Gauges, Flow, Position, Speed, Temp, Biosensors, etc.	Smart Sensors	750 million
8-, 16-, 32-, 64-bit chips, etc.	Microprocessors and Microcontrollers	35 billion

Source: Harbor Research, 2003, p.4

There is a spectrum of forecasts for M2M, but the common thread is that analysts are optimistic. Some experts predict that by 2010, there will be 10,000 Internet-connected machines for every person connected to the net (Hardy, 2004, p.1). The research group **The FocalPoint Group projects that M2M will extend to literally trillions of devices over the next six years** (The FocalPoint Group, 2003, p. 6). **Traditional M2M over cellular networks is forecast to grow 40 percent annually through 2010** (ABI Research in The FocalPoint Group, Inc., 2003, p. 1).

M2M applications include:

- Sensors of temperature, pressure, humidity, illumination, presence, gases and many health-related diagnostics.

- Actuators mirrors, motors, smart surfaces, micro-robots, MEMS (Krishnamurthy, 2003).

- Location services for humans, animals, vehicles, products and property.

- Remote monitoring for life, health, property and employee efficiency.

- Remote control and/or management of simple machines (such as consumer electronics and vending machines), micro-robotics (such as MEMS devices) and complex systems (such as factory automation, industrial control or space-based systems).

- Identity, Rights Management and Fungible Media including identity management, Digital Rights Management (DRM), authentication, funds transfer, service location, digital economy concepts and consumer rights management.

  (Adapted from M2M Europe, n.d.)

To date, M2M has existed in four primary applications: (1) **Radio Frequency** (RF) - **based communication** to stationary and mobile devices or systems; (2) **industrial automation and process control** via wireless, fixed-line or hybrid network services; (3) **space-based systems** involving wireless telemetry and remote control systems; (4) **generically**, as a term to describe machine-to-machine communication (for example: client-server, peer-to-peer (P2P) and server-to-server communications).

Given the presence of M2M in the past, one may ask "What is so revolutionary?" The answer is:

- Increased scope of the Internet to include devices, systems and processes that were previously not networked.
- Miniaturization and integration of self-powered sensors with computation and communication capability to form a new class of computing —"motes" (Krishnamurthy, Laksham, 2003, p. 1).
- Increased transparency of these devices, systems and processes to human and machine actors.
- Internetworking of these devices, systems and processes across institutions (government, education, military, industry).
- Incorporation of M2M into the design of objects both physical and biological, so that data, information, knowledge and communication are "subsumed into" rather than "affixed to" these objects (Smith, J. T., 2004).
- Extended reach of applications to include new human, machine and business transactions as well as physical, chemical, biological and neurological systems, processes and environments.

The most advanced M2M technologies represent the birth of 4th generation computing. The terms "smart dust" and "motes" are being used to describe miniature systems on a chip. Fourth generation computing packages integrate circuits, a radio and an energy source on a single miniature platform. Several universities, small companies (encouraged by government programs) and firms such as Intel are actively working on 4th generation computers.

4th generation computing is characterized by:

- System-on-a-chip with integrated communications, computing and power (Krishnamurthy, Laksham, 2003, p. 1).
- Streaming information to and from the chip through radio communications (Krishnamurthy, Laksham, 2003, p. 1).
- Increased scope of devices to include networking physical, chemical, neurological and biological systems, processes and environments.

Philmetron's Smart Band-Aid (Cowhey, n.d., p.16) is an example of a 4th generation computer. It is a non-invasive platform consisting of a transdermal patch and a 4th generation computer with physical, chemical and biological sensing to enhance wound care. This kind of Band-Aid shifts the point-of-care to the wound and has revolutionary implications for healthcare.

Figure 2 PhiloMetron Smart Band-Aid

The Human Body Will Become an Internet Data Source
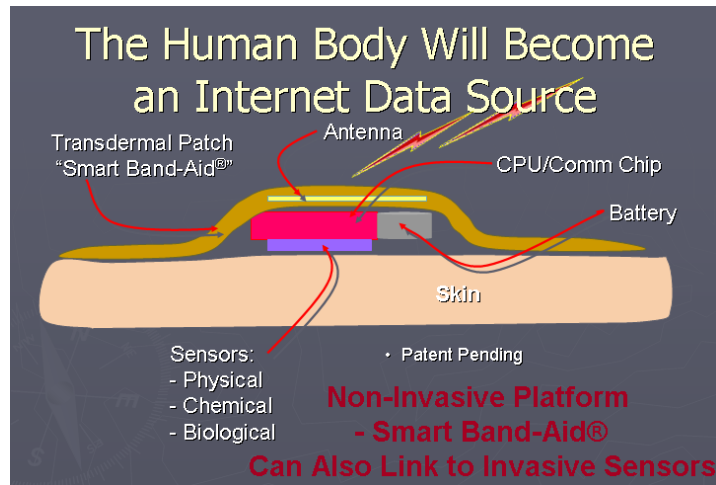
4th generation computing represents a paradigm shift in computing. The shift is from the centrality of information and knowledge in the context of human and machine communication and transaction processing to a new focus on informationalization and control of physical, chemical, biological and neurological processes, systems and environments—the Cybernetic Age.

Figure 3 Cybernetic Age: Shift from Content to Process Convergence
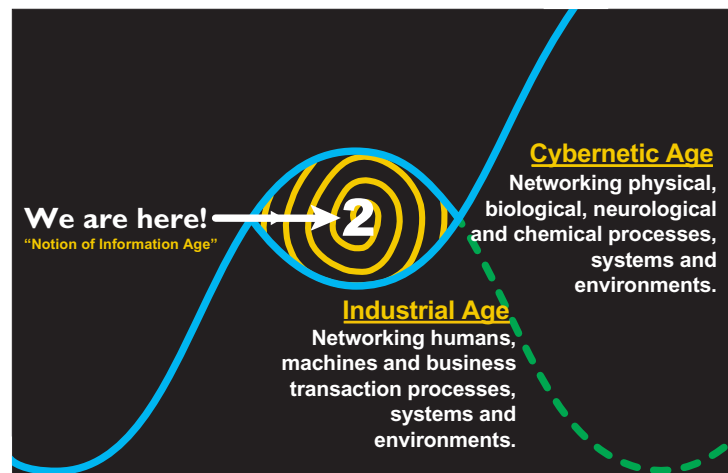
The Industrial Age and the Information Age are synonymous in our view. Frederick Winslow Taylor's "Scientific Management" depended on the informationalization of work and thus the birth and ultimate success of the assembly line, the factory and functional specialization of work depended on a new information revolution. Certainly, the computer and networks bring new qualities to the industrial/information age, however, they simply improved older systems and processes related to humans, machines, transactions and scientific management. **The Cybernetic Age is ultimately a shift to the informationalization and control of new domains—specifically, physical, chemical, biological and neurological systems, processes**

and environments. This paradigm places emphasis on techniques related to automatic control systems, operations research, general systems theory, design, process architecture, human systems integration, transdisciplinarity and convergent science (nano-bio-info-cogno-enviro-neuro).

Cybernetics is important in the context of economic development, competitive advantage and global markets because it engenders:

- Internetworking of processes across industries, markets, governments, economies, financial systems and the military.

- Internetworking of processes across spatial domains (air, sea, land, space, cyber).

- Internetworking of physical, chemical, biological and neurological processes, systems and environments.

- New relations between human-machine, machine-machine, machine-environment, human-environment.

- New level of abstraction enabling codification of "process architectures," real-time transaction processing, remote measurement and remote control.

- Global reach and ability to cross appropriate value from one process and entity to another.

- Technology diffusion pressuring social, political and economic systems.

M2M is important in the context of workforce and policy issues in the State of Texas because:

- The M2M global market is projected to be $100 billion in 2005, growing to $700 billion in 2010 (Harbor Research, 2003, p. 4).

- M2M technology impacts virtually every industrial sector (Harbor Research, 2003, p. 4). Key Texas growth markets are medicine, health care, logistics, transportation, industrial control, wholesale-retail trade, critical infrastructure protection and homeland security.

- The labor market will be affected because the number of installers, testers and field personnel required by industries using M2M applications will increase with adoption and deployment of the technology. The number of embedded hardware and software engineers nationally will increase at a compound annual growth rate of 7.3% with the embedded software industry growing at the higher rate of 8.6% (Guaning, 2003, p.1).

- M2M technologies may create structural unemployment as new jobs are created and workers are displaced by automatic control technologies that create efficiencies and reduce dependence on humans in both manual and intellectual jobs. New jobs emerging from M2M may require different skills and incumbent workers' skills may not be relevant in this new highly automated domain.

- The M2M wireless technology industry as a whole is in the early adoption stage. Many applications are entering the growth stage spurred by demonstrable Return-On-Investment (ROI), military and homeland security investment in sensor-based M2M technologies, existing telecommunications infrastructure, increased capability and use of unlicensed radio spectrum and cross appropriation of semiconductor manufacturing techniques to accelerate MEMs-based M2M applications.

- Between 2004 and 2010, M2M technologies will be accelerated by advancements in the convergent sciences (nano-science, bioscience, information science, cognitive science, environmental science) that expand the applications of M2M, decrease the cost, open up direct manipulation of chemical and biological processes and enable infinitesimal M2M platforms (Neil, 2003, p. 1).

Adoption of M2M is accelerated by successful implementations and demonstrable ROI in specific market segments. There have been both failures and successes in implementation. The significance of M2M-related ROI is illustrated in the following examples:

- According to a 1997 White House panel of advisors, M2M can increase industrial production by ten percent and reduce industrial emissions by twenty-five percent (Legg, 2004, p. 1).

- Radio Frequency Identification (RFID) at the pallet and case level has been forecast to save one major retailer up to $8 billion annually by streamlining its supply chain, reducing overstock and replacing products on its store shelves more quickly (Lillich, 2004, p. 1).

- Intelligent Vehicle Highway Systems (IVHS), such as Transguide in San Antonio, Texas, utilizing hybrid M2M networks, have illustrated a 15 percent reduction of accidents and have cut emergency response time by 20 percent (Texas Department of Transportation, 1998, p.1).

- A California study indicates that peak-rate usage can be shaved by 20 percent if utilities use Automated Meter Reading (ARM) for accurate pricing information. Each megawatt of reduction can equate to $400,000 in savings per year (Jackson, 2004, p. 1), saving California utilities and consumers an estimated $5 billion annually.

- Large retailers, such as Wal-Mart and Target, and large government agencies, such as the Department of Defense, are announcing plans to require their largest suppliers to apply RFID tags to pallets and cases by 2005 (Lillich, 2004, p. 1) with the catalyst being ROI.

- "In healthcare, one [M2M] sensor-based system has been applied successfully in intensive care units (ICU). Patient care in ICUs accounts for 25% to 35% of hospital operating budgets, but ICUs often are marginal or money-losing operations. The data indicate an ability to reduce ICU and hospital lengths of stay by 10% to 20%, freeing up ICU beds and nursing resources to add 15% to 20% of "new" capacity and reduce ICU mortality by 25%. This translates into a contribution of approximately $150,000 a year, or more, per bed" (Dexheimer, Hannemann, p. 23).

M2M Trends

Significant innovation, technology and industry trends are converging to accelerate change in the emerging supply side of the M2M industry. This spells both challenge and opportunity for M2M industry players and customers.

M2M Innovation Trends

Key M2M innovation trends include:

- **Accelerated development and deployment of M2M technologies across virtually all market segments and industries.**

- **The cross appropriation of industrial control processes and technologies to broader applications.** For example, Micro-electromechanical Systems (MEMS) and mesh sensor networks to Department of Defense, homeland security and transportation markets.

- **The cross appropriation of transportation-based telematics such as vehicle location technology to broader applications.** For example, human, property and livestock tracking.

- **A surge of start-up companies in the M2M space,** largely attributable to the legacy telecommunications industry's slowness to innovate. Examples of Texas companies that represent this trend include SecureOrbit Laboratories, LLP., NovusEdge, Inc., Armida Technologies, Inc., DevicePoint, Inc., SensorLogic, Inc. and Aleron, Inc.

- **The infusion of R&D investment motivated by Department of Defense and Homeland Security.** R&D focuses in part on integration of M2M, Geographic Information Systems (GIS), Geographic Positioning Systems (GPS), encryption, digital topographic mapping, remote control instrumentation, Radio Frequency Identification (RFID), digital command and control (C2) systems, edge computing, intelligent systems and new methods of Human-to-Machine Cooperation (HMC).

- **R&D advancements in the convergent sciences** (nano science, bio science, information science, cognitive science, environmental science). These expand the applications of M2M, decrease the cost, open up direct manipulation of chemical and biological processes and enable infinitesimal M2M platforms. One example of this is a marriage of micro-electromechanical systems (MEMS) technology and nanotechnology, which enables revolutionary "lab-on-a-chip" technology (Neil, 2003, p. 1).

M2M Technology Trends

Key M2M technology trends include:

- **The evolution of telecommunications mobile networks to become digital, data-centric and Internet native.** The rapid evolution of disparate communications infrastructures in the past 10 years toward Internet standards.

- Low cost, legacy M2M modules that are relatively simple components that deliver real-time M2M features without a heavy bandwidth burden (North American Wireless Analyst, 2004, p. 1).

- Fragmented M2M technologies evolving from market specific solutions to general technology platforms and components that may be used across multiple markets.

- Increased complexity of internetworking M2M networks, devices and data with enterprise applications, networks, devices and data.

- **M2M proprietary bus architectures migrating to Internet-based open standards** (M2M, n.d., p. 1).

- Widespread coverage and faster transmission rates for existing wireless options, coupled with dropping installation rates (The FocalPoint Group, 2003, p. 5).

- **Evolution away from centralized, decentralized and distributed computing architectures toward dynamic and hybrid architectures based on intelligence at the edge of the network.** This is a shift in process control enabling, in some cases, autonomous or semi-autonomous control actions to emerge and/or be determined at the edge of the network independent of human or "server" authorization.

M2M Industry Trends

Key M2M industry trends include:

- Emergence of a new and dynamic M2M value system including pure play M2M companies, incumbents from related industries (factory automation, industrial control, telematics, etc.), start-up companies and new entrants that cross over to the M2M industry from other industries.

- Emergence of new types of companies to fulfill market demand for M2M-based subscription, outsourcing and transaction services.

- Emergence of transdisciplinary industry or company teams to perform simultaneous R&D, learning and commercialization activities within companies and across companies and industry segments (adapted from Rohringer, Ischebeck, 2004, p. 22-24).

- Conglomeration of industries that form the M2M segment (telecom, industrial instrumentation, semiconductors, software, hardware, IT) evolving into a unique industry.

- **New workforce demands pressured by accelerated adoption of M2M. As a result, employers in the M2M industry will need to focus on retraining existing workers as well as hiring workers with new skills.**

This chapter identifies the demand-side vertical market for current and emerging M2M technologies. Each market forecast section discusses the market's stage of development, catalysts and inhibitors. **The purpose of this chapter is to illustrate the breadth of economic opportunity associated with M2M technologies which influences workforce need.** Specific workforce implications are discussed fully in the following Industry chapter and Texas-specific expertise in wireless and M2M are discussed in the Workforce chapter.

Critical Infrastructure and Heavy Industry

Wireless M2M for heavy industry and critical infrastructure is a significant market. Today's industrial M2M controllers and sensors are commonly based on closed proprietary systems with monolithic architectures. These systems are also lacking information assurance and cyber security protections to prevent unauthorized network entry and to enable threat detection. Critical infrastructure crosses many segments, including Agriculture, Food, Water, Public Health, Emergency Services, Government, Defense Industrial Base, Information and Telecommunications, Energy, Transportation, Banking and Finance, Chemical Industry and Postal and Shipping (Center for Infrastructure Expertise, n.d., p. 4).

M2M is critical to the protection, survivability and preparedness of national critical infrastructure. US government investment in M2M-related technologies is spurring innovation. **The Department of Homeland Security (DHS) is focused on new technologies and regulations that prevent unauthorized entry, detect threats and protect critical infrastructure with a focus on preparedness, response and recovery from attacks** (Barami, 2004, p. 3). Within DHS initiatives there are a large variety of M2M applications, including Airline and Airport Security (Symbol Technologies, n.d., p. 1), tracking of carriers and cargo (rail, sea, air and highways); monitoring and tracking of critical infrastructure (such as oil pipelines, electrical grids and lines, water supplies); cyber security (securing computer systems and networks against attack); building and event monitoring and surveillance; intelligent vehicles (Government Technology, 2004, p. 1) and possibly even Intelligent mail (I-mail) for the US postal service (Symbol Technologies, n.d., p. 1).

Figure 4   Wireless sensors improve container security

Optional Wireless Remote Sensing Nodes

Master Sensing and Communication Node

Door Intrusion Sensors
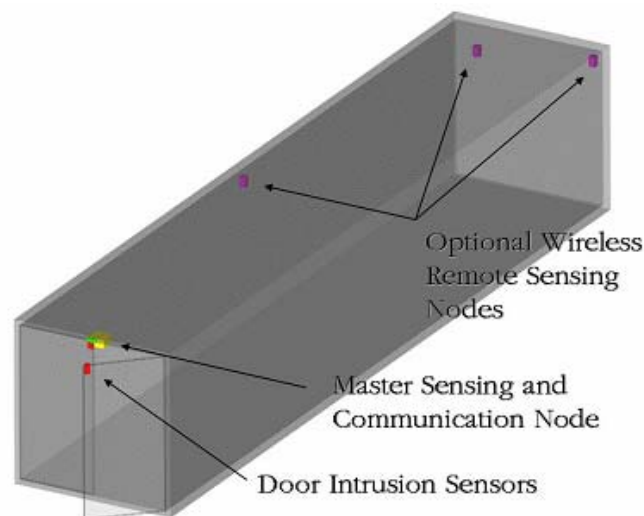
Source: Courtesty MicroStrain, Inc.

As a result, the U.S. Department of Energy's Technologies Program forecasts a ubiquitous world of wireless sensors, controllers and actuators by 2010. Projections include "autonomic" swarm-like networks that are adaptive, autonomous, self-configuring, self-calibrating, self-identifying, self-reorganizing, self-healing, self-powering and inexpensive (U.S. Department of Energy Industrial Technologies Program, 2002, p. 1).

Market Forecast

Wireless M2M sensor networks and process control systems are expected to be areas of significant growth. **Demand for Radio Frequency (RF) Modules used for industrial monitoring and control was approximately 1.9 million units in 2004 and is expected to climb to 165 million units in 2010** (Legg, 2004, p.1).

Market research firm Frost & Sullivan has projected the industrial wireless sensors market to move from $24 million in 2001 to over $100 million in annual sales in 2008 (Donoho, 2002, p. 1). Further, "the market for Supervisory Control and Data Acquisition (SCADA) systems is projected to grow from $3.1 billion in 2004 to over $4 billion by 2007. As most M2M networks lack adequate security, **the SCADA security software market is expected to grow by 50% annually through 2007**" (Kuykendall, 2004, p. 1).

Market Stage

Both wireless sensor networks and wireless process control networks are in the **early adopter stage** of development. Technology developments, national security precautions and the increasing value-to-performance ratio are spurring market demand and adoption.

M2M Market Inhibitors/Catalysts

Market inhibitors for wireless sensor networks include:

- Proprietary nature of systems, lack of interoperability with other systems and networks.
- The challenge of packaging wireless sensors in lightweight, affordable, yet rugged forms for hostile environments.
- Cost and reliability.
- Powering sensors, battery power and life deficiencies.

Market inhibitors for wireless Supervisory Control and Data Acquisition (SCADA) security include:

- Proprietary nature of systems.
- Legacy industry perception that cyber security is not needed.
- Lack of market awareness regarding technology capabilities.

Market catalysts for wireless sensors networks include:

- Reduced cost of installation and maintenance of networks.
- Demonstrable ROI for key applications.
- **Wireless M2M sensor technology enabling the investigation of areas that have not been possible to observe, and enabling a more granular level of data collection to existing areas of observation.**
- Increased quantity and quality of real-time data.
- Moore's Law: Price, performance ratio decreasing costs, decreasing size and increasing performance of sensors and communications equipment.

- Network effects resulting from increased networking of M2M micro devices and macro systems.

- The significant (and increasing) flow of government funds being directed to HS and the DoD for M2M wireless technologies.

Market catalysts for wireless SCADA include:

- Homeland security: growing awareness of the vulnerability of critical infrastructure networks.

- **Effectiveness of integrated M2M networks (system of systems) rather than silos of multiple heterogeneous networks for industrial control, monitoring and security.**

- Moore's Law: Price, performance ratio decreasing costs, decreasing size and increasing performance of controllers and communications equipment.

- Network effects resulting from increased networking of M2M micro devices and macro systems.

- **The significant (and increasing) flow of government funds being directed to HS and the DoD for M2M wireless technologies.**

Transportation and Logistics

Transportation is a highly targeted area for deployment of wireless M2M technology. Applications include logistics, intelligent transportation systems (including intelligent parking) and vehicle telematics.

Logistics

There are over 30 million fleet vehicles and over 4.8 million trailers in the United States. Using a combination of Radio Frequency (RF), embedded computers and Geographic Positioning Systems (GPS) (Space Data Corporation, 2004, p. 1), fleet operators manage their fleets using digital technology. Capabilities of wireless M2M for logistics include:

- Monitoring trucks and trailers from a central control location, a service center technician's PDA or the web.

- Giving remote service center technicians access to vehicle operating systems in real-time.

- Sharing data with transportation company, other departments and third party technicians or outside agencies.

- Remotely accessing alarm and control points and monitoring conditions.

- Enabling remote control by other devices or remotely controlling other devices (DPAC Technologies, 2003, p. 1).

Figure 5   Wireless fleet management
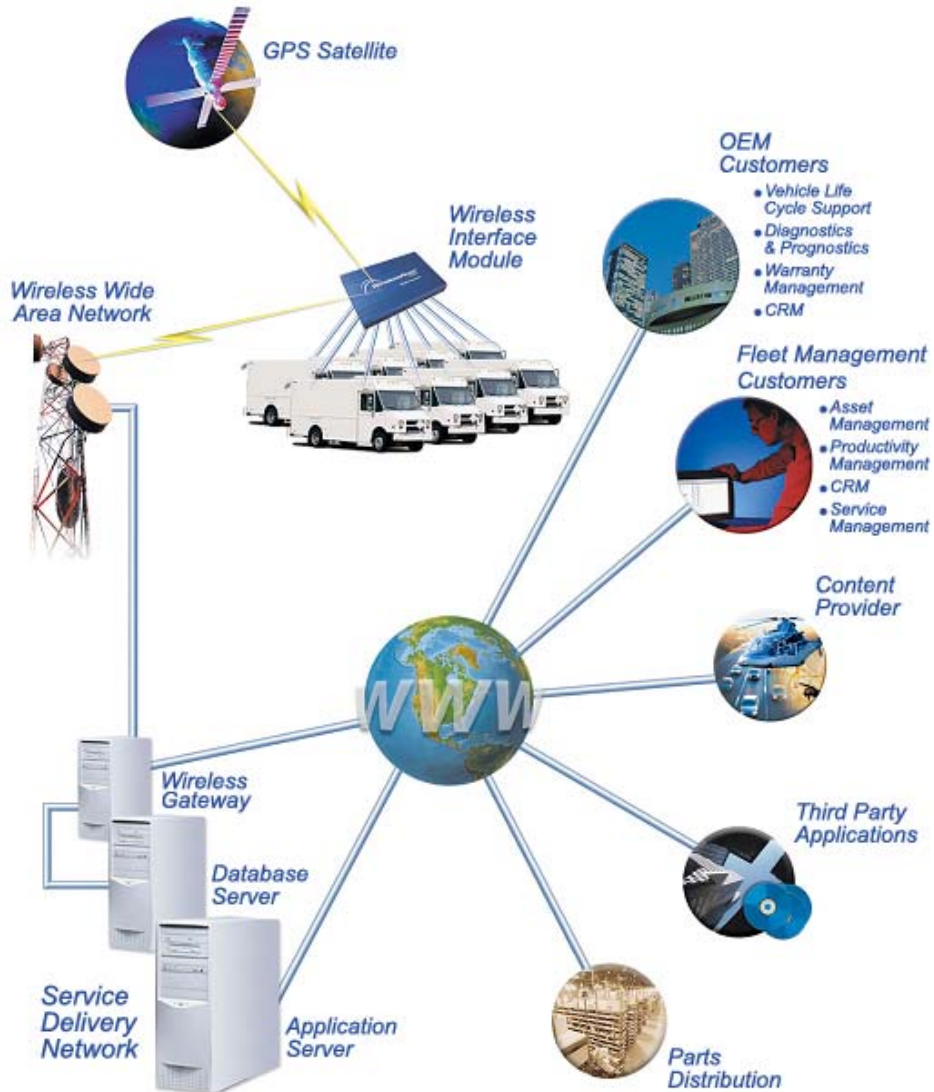
In addition to managing vehicles, M2M wireless systems can be used to affect other aspects of the logistics topology, including dock and yard management, route scheduling, Internet/intranet customer services and recording and communicating cargo and vehicle security information (DPAC Technologies, 2003, p. 1).

Market Forecast

According to ABI, equipment for the automotive and asset tracking segments accounted for nearly 50% of the global GPS market in 2003, with forecasts of continued growth to become a $22 billion market by 2008 (MobileInfo, 2003, p. 1).

In addition, the **"Strategis group forecasts the penetrable market for Fleet and Asset Tracking at over $3.5 Billion/year in a mature market.** Those dollars do not count the monies these fleets will also spend on voice and data communications" (Fall Creek Consultants, n.d., p. 1). Finally, **the adoption of vehicle-based Location Services in private**

fleets and by consumers is anticipated to grow this burgeoning industry from $1 Billion to $33 Billion by 2005" (WebTech Wireless, n.d., p. 1).

Market Stage

Wireless deployment in logistics is in the **early growth stage.** While the technologies employed in this segment are not new, the convergence of GPS, embedded microcomputers (sensors and actuators) and communications components has spurred growth through novel applications and new technologies.

Market Inhibitors/Catalysts

Market inhibitors in logistics include:

- Buyer confusion resulting from the rapid pace of technology innovation and vendor product announcements.

- Proprietary nature of systems, lack of interoperability with other systems and networks.

- Lack of agreement on common technology standards and means of interchanging data across systems (Mobile Wisdom, 2004, p. 3).

- Increasing number of protocols discouraging potential users who fear adopting a protocol that will become obsolete (Mobile Wisdom, 2004, p. 3).

Market catalysts for logistics include:

- Homeland security: location and management of hazardous materials.

- The significant (and increasing) flow of government funds being directed to HS and the DoD for M2M wireless technologies.

- Increased accuracy of real-time data for customers, shippers and crew.

- Reduced maintenance costs and prevention of unplanned downtime.

- Increased productivity through automation of routine telephone and paperwork (DPAC Technologies, 2003, p. 1).

- Moore's Law: Price, performance ratio decreasing costs, decreasing size and increasing performance of sensors, embedded computers and communications equipment.

- Network effects resulting from increased networking of M2M micro devices and macro systems.

Intelligent Transportation Systems (ITS)

ITS-based M2M systems encompass several different applications, including Automatic Vehicle Location, Transit Signal Priority, Automatic Passenger Counters, Mobile Data Terminals, Electronic Fare Collection Systems, Emergency Response Systems, Smart Parking, Vehicle Diagnostics Systems and In-Terminal On-Board Traveler Information Systems (Smith, Roth, 2003, p. 1).

TransGuide in San Antonio, Texas was developed by the Texas Department of Transportation (TxDOT) and Southwest Research Institute and is one of the most advanced traffic management systems in the world (Texas Department of Transportation, 1998, p. 1). The system is composed of machine-to-machine sensors, video cameras, message signs and hybrid communications (fixed-line fiber-optics and wireless) to monitor and broadcast traffic information to drivers and a central operations center. **The system is designed to locate incidents within two minutes and then warn motorists within 15 seconds, enabling more effective emergency response** (Purcell, 2003, p. 1).

Figure 6   Screen shot of "Current Conditions" from San Antonio's intelligent transportation system
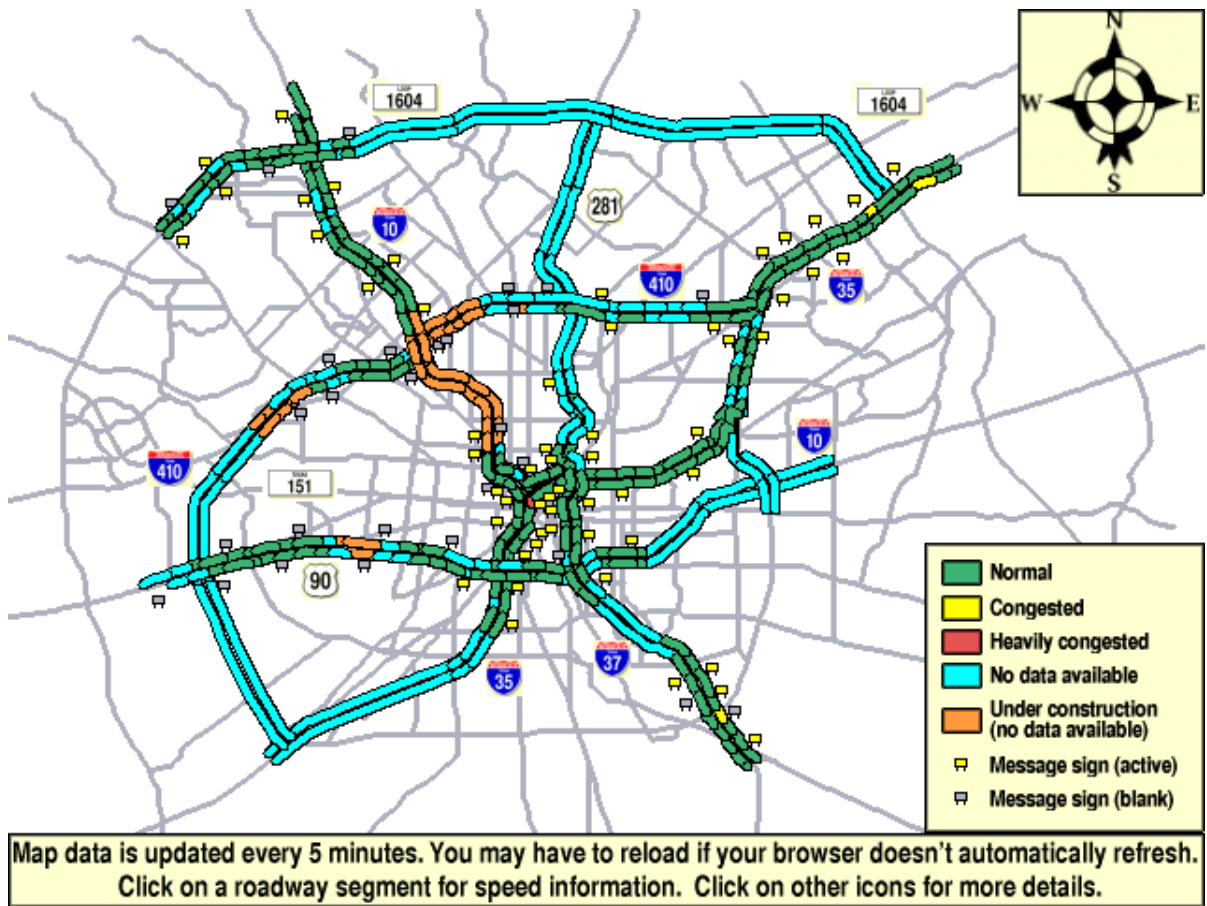
The US Department of Transportation is currently in the process of developing a public use system known as the Intelligent Transportation System (ITS). **The ITS is intended to reduce traffic and is expected to have 17 million users and to generate $10 billion in non-hardware revenue by 2005.** This requires the integration of multiple sensor and video sources to be collected and integrated in real time (Dexheimer, Hannemann, n.d., pp. 21-22).

Market Forecast

According to a report authored for the state of California, the U.S. market for Intelligent Transportation Systems (ITS) is expected to exceed $450 billion by 2015 (Hagler Bailly Services, Inc., n.d., p. 1).

Market Stage

ITS recently entered a **growth stage.** While some portions of this segment are more advanced in market phase (electronic toll collection, for example), other portions, such as smart parking and traffic management systems, are relatively new.

Market Inhibitors/Catalysts

Market inhibitors for ITS include:

- Historic lack of investment funds for companies in the industry (Hagler Bailly Services, Inc, n.d., p. 3).

- Lack of awareness by both consumers and potential buyers (e.g. municipalities) as to benefits and need for ITS (Hagler Bailly Services, Inc, n.d., p. 4).

- The significant (and increasing) flow of government funds being directed to HS and the DoD for M2M wireless technologies.

- **Concerns regarding invasion of privacy by some US citizens and "watchdog" groups.**

Market catalysts for ITS include:

- **Homeland Security: Potential of ITS networks to serve as surveillance networks on US highways, to enable increased efficiency in emergency response and to act as command and control hubs for emergency operations during critical events.**

- The significant (and increasing) flow of government funds being directed to HS and the DoD for M2M wireless technologies.

- Flexibility in deployment of wireless sensors, cameras or other machines in areas where running wire or cable is not feasible.

- Availability of real-time data such as traffic, event and hazard information and its application to save lives and cut costs.

- Moore's Law: Price, performance ratio decreasing costs, decreasing size and increasing performance of sensors, embedded computers and communications equipment.

- Network effects resulting from increased networking of M2M micro devices and macro systems.

Telematics

Telematics broadly refers to advanced-generation wireless automotive information systems (Freedonia, 2002, p. 1). The telematics industry and the logistics industry are increasingly aggregated as a single industry. An example of the current state of telematics is the General Motors On-star system, which, among many features, allows: communication via cell phone, operator services, emergency notification, global positioning system, roadside assistance, stolen vehicle notification, remote door control and a voice-activated email and entertainment directory.

Market research firm VDC sees a convergence of navigation and telematics systems to an overall integrated driver information system including voice, data, video and application capabilities approximating that of a home office (VDC, n.d., p. 1).

Market Forecast

While there are different ways of defining telematics, market research firm VDC estimates that consumption of **automotive navigation and driver information systems was approximately $655 million in 2002 and forecasts this market to grow to $1.7 billion in 2006."** (VDC, n.d., p. 1). **Parks Associates estimates that the automobile telematics market will grow from $2.7 billion in 2001 to $10.7 billion in 2005,** while Allied Business Intelligence estimates that the US telematics market for personal vehicles will grow to $13 billion in 2006" (GartnerG2, 2002, p. 1).

Market Stage

Telematics is in the **growth stage** of development. Based on multiple market projections, telematics is expected to be an area of growth for wireless and M2M technologies over the next two to four years.

Market Inhibitors/Catalysts

Market inhibitors in the telematics segment include:

- High product costs
- Low consumer interest
- Technological challenges (VDC, n.d., p. 1).

Market catalysts for this sector include:

- Safety
- **Convergence with logistics technology and market enabling economies of scale for vendors across consumer and commercial markets**
- Moore's Law: Price, performance ratio decreasing costs, decreasing size and increasing performance of sensors, embedded computers and communications equipment
- Network effects resulting from increased networking of M2M micro devices and macro systems.

Structural Health Monitoring

Structural health monitoring (SHM) is defined as the instrumentation of structures, including buildings, dams, bridges, highways, rockets or other vehicles with sensors, and accompanying equipment to assess structural integrity, maintenance needs, wear patterns and damage to structures. This may be event-driven, such as instruments brought in after an earthquake, or long-term, in which sensors and equipment are permanently installed to monitor structures on an ongoing basis. Traditionally, SHM systems have been hardwired, which is expensive and maintenance-intensive. Wireless M2M sensors are becoming commercially available to overcome these restrictions (Kottappali, V. et al, 2003, p. 1). The continued evolution of M2M wireless sensors both in capability and price reduction has spurred market growth in the structural engineering community (Lynch, 2004, p. 2).

Figure 7   Differential variable reluctance transducers monitor crack in Liberty Bell as it is moved to new museum space.
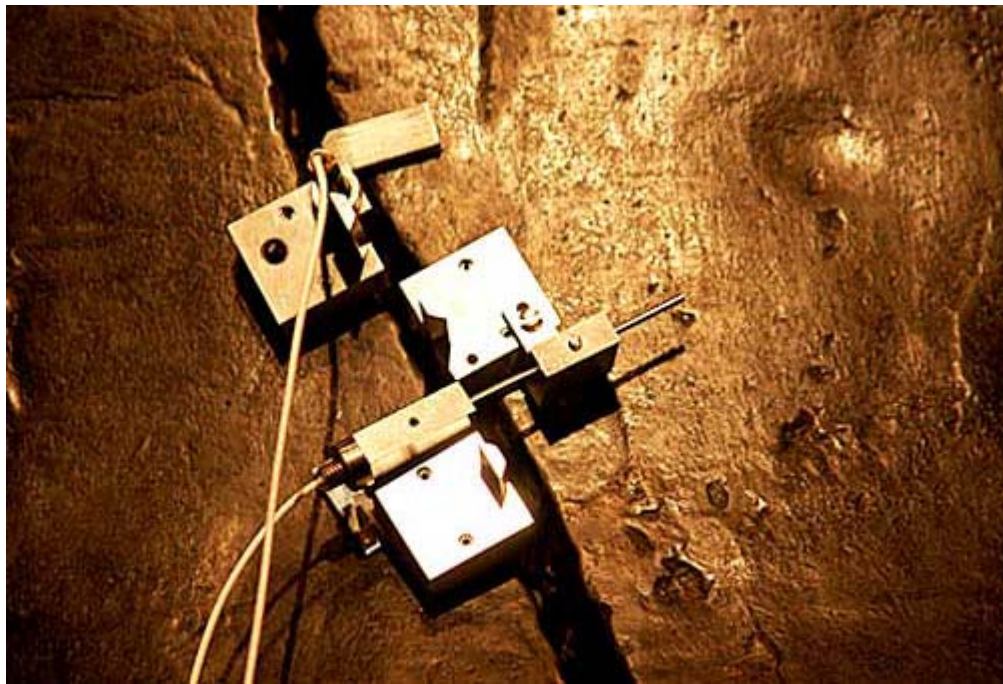
Market Forecast

The current deployment of wireless instruments for SHM is very limited; however, the market potential is very large. **The civil infrastructure of the US includes nearly 80 billion square feet of commercial and government facilities and buildings, and more than 100 billion square feet of dams and bridges.** Most of these assets are exposed and sparsely monitored for rapid and reliable assessment of vulnerabilities and detection of damage (Sensametrics, 2003, p. 1). In addition, the rehabilitation, renewal, replacement and maintenance of this infrastructure is estimated to require expenditures of at least one trillion dollars nationwide (Elgamal, et al, n.d., p. 1). **Sensametrics has calculated the aggregate SHM M2M market potential to be $50 billion** (Technology Ventures Corporation, n.d., p. 1).

Figure 8   Wireless Bridge Monitor

Market Stage

The structural health monitoring market is in its infancy (Inaudi, Casanova, 2002, p. 3). We characterize wireless M2M deployment for structural health monitoring as being in the **late R&D stage.**

Market Inhibitors/Catalysts

Market inhibitors for SHM include:

- Perception of need versus cost (SHM is in need of a clear value proposition).
- The challenge of packaging wireless sensors in lightweight, affordable, yet rugged forms for hostile environments.
- Powering sensors, battery power and life deficiencies.

Market catalysts for SHM include:

- Homeland Security: capability to monitor critical infrastructure.
- The significant (and increasing) flow of government funds being directed to HS and the DoD for M2M wireless technologies.
- **Wireless M2M sensor technology enabling the investigation of areas that have not been possible to observe and enabling a more granular level of data collection to existing areas of observation.**
- Aging US infrastructure and concerns for public safety.
- Cost savings associated with installation and maintenance versus wired systems.
- Moore's Law: Price, performance ratio decreasing costs, decreasing size and increasing performance of sensors and communications equipment.
- Network effects resulting from increased networking of M2M micro devices and macro systems.

Environmental Monitoring

The use of M2M technology for environmental monitoring has many applications. For the purposes of this report, we will look at two areas of environmental monitoring. First, monitoring and control in natural environments, and second, building control and automation.

Examples of environmental monitoring in building control and automation typically consist of the devices and networks associated with HVAC (heating, ventilation, and air conditioning) systems and monitoring of indoor air quality. Monitoring in natural environments includes such activities as data collection in spaces such as forests, wildlife habitats and other natural environments (Cardell-Oliver, 2004, p. 1), and enhancement of water-monitoring techniques in soils, stream, and other water bodies.

In this latter application, the potential for M2M is seen in the development and use of mesh sensor networks, as typified by experiments currently underway at a variety of academic institutions. "UCLA, for example, is testing deployment of sensor networks in such disparate areas as monitoring of marine microorganisms, contaminant transfer in groundwater and mapping and defining the biocomplexity of ecosystems" (Estrin, Govindan, Heidemann, 2003, p. 3).

Natural Environments

Market Forecast

Monitoring of natural environments with M2M devices and networks is in the R&D and early market stage, thus, forecasts for this market are not readily available. However, given the magnitude of the environmental monitoring market in the natural environment, we may take into consideration the United States Geological Survey (USGS). **The USGS is charged by the US government with scientific data collection, monitoring, and management of water resources, hazards, biology and those programs that directly support science-based land and natural resource management. The proposed budget for this single organization in 2004 was in excess of $800 million** (Wood, Harris, 2003, p. 1), with much of this going toward water resource investigations and biological research and monitoring (USGS, 2003, p. 1).

Figure 9   RFID sensors enable forest tracking

Figure 10   Tree tags are powered by by the reader's signal
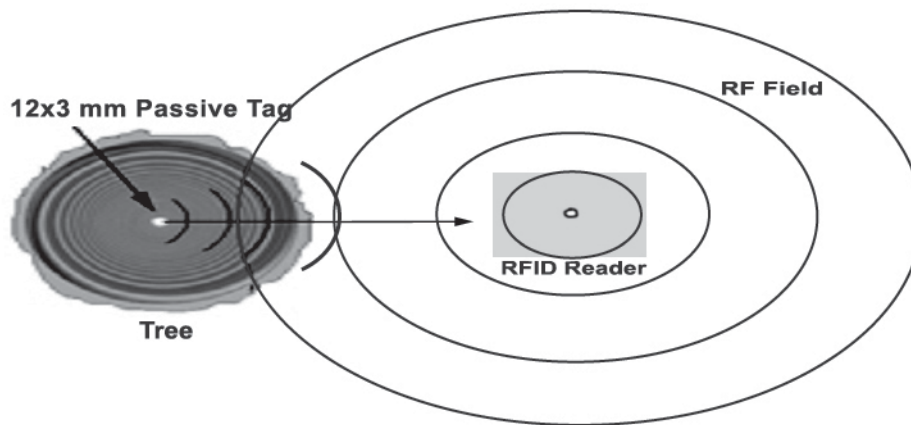
Market Stage

Wireless M2M for environmental monitoring of natural habitat is still in the **early R&D stage.** Much of the reason for this is that the technology (sensors and RF components) are still in the process of being proven for the application. However, as reductions in cost for monitoring system components and improvements in sensing and communications technologies continue, there is expected to be notable growth in this area.

Market Inhibitors/Catalysts

Market inhibitors in the natural habitat monitoring segment include:

- The challenge of packaging wireless sensors in lightweight, affordable, yet rugged forms for hostile environments (Delin, 2004, p. 1).

- Setup of field networks, given that "one size does not fit all" when it comes to deploying numerous measuring points in varied types of terrain (Delin, 2004, p. 1).

- Some technology challenges still exist for equipment deployed in this application, including power issues and scaling challenges if using a large number of distributed nodes (Estrin, n.d., p. 4).

Market catalysts in the natural habitat monitoring segment include:

- Wireless M2M sensor technology enabling the investigation of areas that have not been possible to observe and enabling a more granular level of data collection to existing areas of observation.

- The opportunity to increase the quality and quantity of data available to researchers and scientists, resulting in better understanding of ecosystems and reduced labor costs associated with maintaining and calibrating water-monitoring systems (Fondriest, n.d., p. 1).

- Moore's Law: Price, performance ratio decreasing costs, decreasing size and increasing performance of sensors and communications equipment.

- Network effects resulting from increased networking of M2M micro devices and macro systems.

Building Automation

Market Forecast

The **global market for building automation systems,** as estimated by ARC, is projected to move from **$19 billion in 2001 to $24 billion by 2006.** In addition, revenues associated with operating these systems after installation (known as facilities management services) **are projected by Frost & Sullivan to go from $12 billion in 2002 to $22 billion by 2009.** A key to this growth is the increasing ability of building systems to share information with each other in real time, utilizing improved IT infrastructure technology and the Internet (Sinclair, n.d., p. 2).

Market Stage

M2M technology, as part of the ongoing growth in building automation technology, is currently in an **early growth stage.** This segment is projected to see marked growth as the benefits of utilizing this technology are increasingly realized.

Market Inhibitors/Catalysts

Market inhibitors in the building automation segment include:

- Erosion of the functionality of hardware, and the transfer of that functionality to software. The challenge becomes to build controls more cheaply and yet avoid commoditization (Sinclair, n.d., pp. 4-5).

- Slowness of the industry to grasp how the new barrage of real-time data available from M2M systems converges with enterprise systems (Sinclair, n.d., p. 5).

- Client and potential customers are at the beginning of the education curve in understanding how the magnitude of data can be useful and properly managed (Sinclair, n.d., p. 5).

- The complexity of the technologies involved in creating seamless systems can be intimidating, especially given the position of users on the education curve (Sinclair, n.d., p. 6).

Market catalysts in the building automation sector include:

- Reduced HVAC costs through more efficient and precise control (Sinclair, n.d., p. 2).

- Web-based networked control systems can ensure building energy is purchased at the lowest cost from the environmentally correct source, providing greatest comfort for least environmental impact (Sinclair, n.d., p. 2).

- **Operational benefits that decrease cost and increase efficiency, such as the provision of real-time feedback from the building system to designers to ensure that desired system function and results are achieved (Sinclair, n.d., p. 2).**

- Adoption of industry standards based on open protocols, such as BACnet, which allows communications between different types and brands of building system devices (Sinclair, n.d., p. 3).

- Moore's Law: Price, performance ratio decreasing costs, decreasing size and increasing performance of sensors and communications equipment.

- Network effects resulting from increased networking of M2M micro devices and macro systems.

Retail and Wholesale Trade

Much of the attention and development of wireless M2M in retail and wholesale trade focuses on the use of Radio Frequency Identification (RFID). RFID tags are miniscule microchips (embedded machines) that listen for a wireless radio query and respond by transmitting a unique identification code. Because of the diminutive size and minimal cost of these **M2M units, they have become a favored technology to replace the venerable bar code and to expand the application of real-time, self-reporting product tracking across the retail, wholesale and manufacturing environments.**

Market Forecast

While forecasts of RFID demand in retail and wholesale markets do vary somewhat, they all tend to show a fairly bullish market. Palmer, Bryan & Co. report that retail accounted for 5% of the global RFID market revenue totaling $750 million in 2002. This includes readers, transponders, software, and services. **VDC projects global shipments of RFID systems to increase by approximately 24.0% annually to reach $2.65 billion by 2005** (VDC, n.d., p. 1).

A Krannert School report forecasts that by 2008, unit costs of RFID will fall below five cents representing a total annual market of $5 billion (Lillich, 2004, p. 1).

Market Stage

RFID in wholesale and retail markets is characterized as **early growth stage** and close to entering growth mode. While RFID has been utilized for decades, applications seen as potential "blockbusters" are relatively new. The mandate of RFID adoption by such institutions as Wal-Mart and the Department of Defense (DoD) will most likely have the effect of accelerating RFID technology into the mainstream, particularly in distribution channels and warehousing.

Market Inhibitors/Catalysts

Market inhibitors for RFID in this market segment include:

- Cost of tags (becoming less of an issue as prices are under 20 cents per tag and forecasted to drop to .05 per tag in the next five years).

- Concerns regarding invasion of privacy by some US citizens and "watchdog" groups.

Market catalysts for RFID in retail and wholesale markets include:

- **Potential major savings in the warehousing and distribution activities from reduction in errors, increased automation, speed of processing, management of theft and reduction of out of stock merchandise in time of demand.**

- Improved customer service and sales through greater in-stock positions and being able to target merchandise to regions of greatest sales.

- "Auto-ID" initiatives involving many key market, industry and academic leaders.

- Moore's Law: Price, performance ratio decreasing costs, decreasing size and increasing performance of RFID, embedded computers and communications equipment.

- Network effects resulting from increased networking of M2M micro devices and macro systems.

Utilities

Automated Meter Reading (AMR) is a M2M application that uses a small device installed on an electric, gas or water meter to enable data to be collected remotely via wireless, fixed-line or hybrid network communication. Although AMR is not new in the utility industry, recently demonstrated Return-on-Investment (ROI) analysis is spurring market demand and adoption.

Market Forecast

There are currently more than 25 million AMR units installed on gas (21 percent), water (11 percent) and electric utility (16 percent) meters. Nine million units shipped in 2002 **with a total meter market of 200 million units yet to be changed out to AMR** (Jackson, 2004, p. 1).

Market Stage

AMR has exited the early adoption stage and is entering the **early growth market.** This market will grow as utilities maximize the ROI benefits of AMR.

Market Inhibitors/Catalysts

Market inhibitors for this sector include:

- Proprietary nature of systems and lack of common standards, negatively affecting interoperability of equipment (proprietary nature of systems) (Bechtel, n.d., p. 1).

- High initial investment costs (Metering International, 1997, p. 1).

Market catalysts for this industry include:

- Utility industry restructuring.

- **Customer demand for reduction in cost, improved billing accuracy, increased protection from price swings and increased service.**

- **The realization that AMR technology can increase value to other departments within utilities and lower operating costs through effective energy management and purchasing (Jackson, 2004, p. 1).**

- Moore's Law: Price, performance ratio decreasing costs, decreasing size and increasing performance of AMR, embedded computers and communications equipment.

Healthcare

Developments in M2M, wireless, MEMS (micro-electromechanical machines), sensors and nanotechnology are setting up **unprecedented potential for health monitoring, diagnosis and treatment.**

Current and potential examples of M2M technology in healthcare include:

- Remote monitoring and connectivity among electrocardiogram machines, blood pressure monitors, drug pumps and even stethoscopes (Dexheimer, Hannemann, n.d., pp. 23-24).

Figure 11   Ad hoc sensor network for emergency medical care
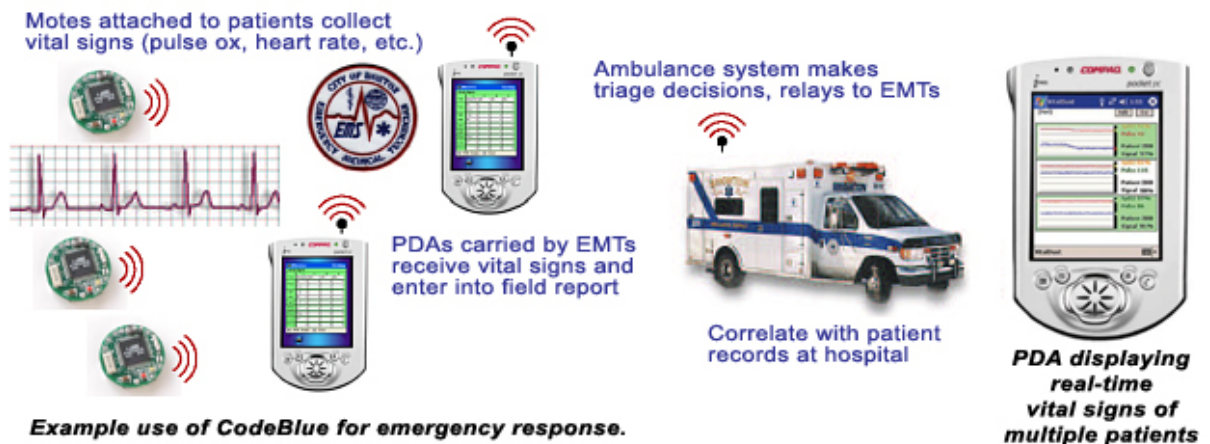
Source: Malan et al, 2004.

- Functional sensor networks—the goal of these networks is to use sensor data to build assistive processes that support and enhance people's abilities to conduct normal daily activities. Information can be accessed by caregivers, emergency personnel and family members on demand or as needed to provide the appropriate level of care. Firms such as Honeywell, ADT, Intel and various medical programs and organizations are working on this technology, with several companies slated to enter the market in 2004 (Dexheimer, Hanneman, pp. 23-24).

Figure 12   Wireless sensors improve artificial joint performance

eye tremor

depth of corneal implant

orientation sensor for improved tooth crown prep

shoulder ligament strains

spinal ligament strains

wireless vertebral bone strains

elbow ligament strains

wireless emg and ekg

3DM-G measures orientation and motion

hip replacement - sensors for measuring micromotion

wrist ligament strains

smart wireless sensor measures implant subsidence

knee ligament strains

smart total knee replacement

ankle ligament strains

achilles tendon strains

wireless smart insoles measure force

arch support strains

Source: Courtesy of MicroStrain, Inc.

Market Forecast

According to market research firm Frost & Sullivan, the wireless healthcare market reached over $330 million in 2003, and is projected to reach $637.3 million by 2007. This represents a compound annual growth rate of about 18% per year for this time period. Estimates include both network systems and patient monitoring devices (Frost & Sullivan, 2004, p. 1).

Market Stage

While wireless communications technology has been used for some time in many healthcare facilities, the use of wireless devices for direct patient monitoring and care is new. Wireless and M2M patient diagnosis, monitoring and care is currently in the **early adoption stage** of its market life.

Market Inhibitors/Catalysts

Market inhibitors for this sector include actual and perceived security challenges of wireless networks (Gainer, et al, n.d., p. 1).

Market catalysts for this industry include:

- Moore's Law: Price, performance ratio decreasing costs, decreasing size and increasing performance of sensors and communications equipment.

- Network effects resulting from increased networking of M2M micro devices and macro systems.

- "Rising patient volumes.

- "Acute staff shortages.

- "A rapidly aging population.

- **"Increased instances of medical errors and adverse drug effects (ADEs)—with their huge potential to reduce medical errors, increase workflow efficiency, and thereby decrease overall costs, M2M wireless solutions help healthcare professionals achieve one of their prime objectives — providing better care with less financial expenditure.**

- "Growth in monitoring markets for remote care.

- **"The growing focus on enhanced patient safety and privacy by The Health Insurance Portability and Accountability Act of 1996 (HIPAA), driving healthcare facilities to replace outdated technology with cutting-edge HIPAA-compliant solutions."**

Frost & Sullivan, p. 1

Home

Home networking entered the mainstream in 2003 and early 2004, as large numbers of broadband users installed home networks to share Internet connections and electronics vendors delivered new products to send high-value entertainment content over the network (In-Stat/ MDR, 2004, p. 1). M2M applications are emerging in the home along with greater broadband and wideband connectivity (fixed-line, wireless and hybrid).

M2M home networking involves the PC cluster of devices (broadband modem, router/AP device, desktops, laptops, PDAs, web tablets) becoming connected to the entertainment cluster of devices (audio/visual equipment such as televisions, DVD players and so forth). A further step in networking the home is home automation—being able to centrally manage and monitor home systems (HVAC, security, etc) and equipment using a network interface.

Figure 13   Wireless home networking
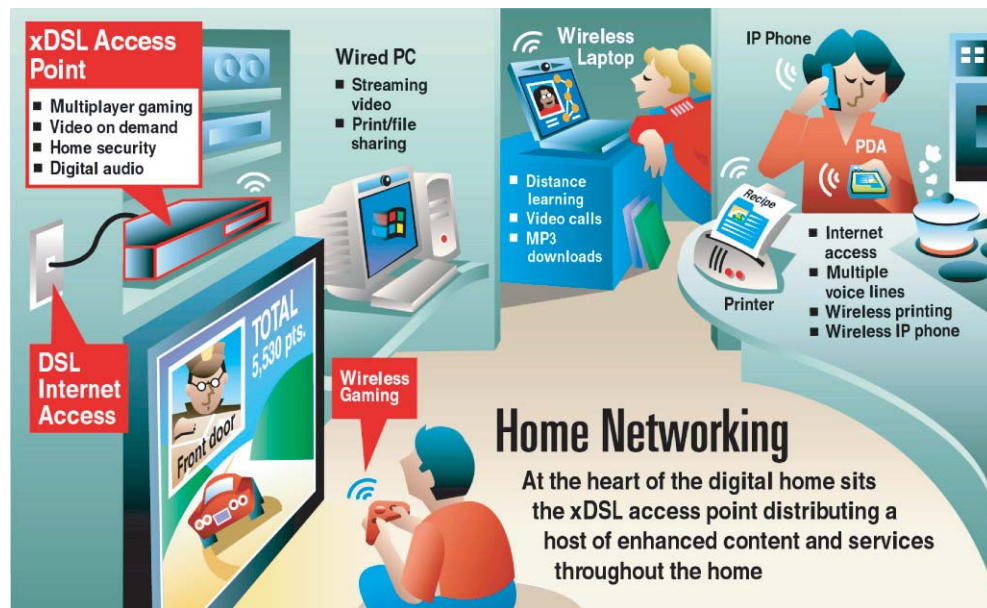
Source: DSL Forum

Market Forecast

The following forecasts for home connectivity for networks and devices illustrate the anticipated dynamism of this market:

- According to In-Stat/MDR, the continued need for broadband sharing and a growing interest in entertainment networking will drive the **total value of equipment with a home networking connection of some type from $8.3 billion in 2004 to $17.1 billion by 2008.** (InStat/MDR, 2004, p. 1).

- According to Parks Associates, the number of US households subscribing to broadband, data networks, multimedia networks, music, gaming and Voice Over IP (VoIP) services are expected to increase significantly every year through 2008 (Scherf, 2004, pp. 2, 11-12).

- According to InStat/MDR, **global unit sales of smart appliances (including Internet-enabled electronic devices and white goods) will grow from about a million units in 2004 to almost 4 million units by 2007** (In-Stat/MDR, 2004, p. 1).

Market Stage

Adoption of M2M in the home is in the **early growth stage.**

Market Inhibitors/Catalysts

Market inhibitors for this sector include:

- The cost of installing network systems and some types of devices (especially high-end audio and video products) has historically been prohibitive for all but the wealthy. This inhibitor is just starting to be somewhat mitigated by falling prices and increased deployment of networks in new homes (Zanthus, n.d., p. 3).

- Slow adoption of broadband/high-speed services that facilitate home networking (again, being mitigated as adoption is increasing at a much faster pace currently) (Gill, 2002, p. 1).

- Perception by potential users that home networks are complicated to set up and maintain (Kistner, 2002, p. 1).

- Perceived lack of need, complexity of technology choices and lack of comprehensive and reliable sources of information (Zanthus, n.d., p. 3).

Market catalysts for this industry include:

- **Trends in consumer demand** (especially regarding video and music platforms) **revolving around choice, content, convenience and comfort** (Scherf, 2004, p. 23).

- Advances in technology in the areas of compression, middleware, IP communication and media processing (Scherf, 2004, p. 23).

- Increasing number of devices being manufactured for use in M2M and H2M applications in the home.

- **Users wish to maximize effective use of PCs and computing devices in the home** (Zanthus, n.d., p. 3).

- Moore's Law: Price, performance ratio decreasing costs, decreasing size and increasing performance of sensors and communications equipment.

- Network effects resulting from increased networking of M2M micro devices and macro systems.

M2M: Industry

This section discusses the current and emerging supply-side value system in the M2M space. In addition, critical industry, technology and value system trends are presented, along with key implications for workforce education in the evolving M2M industry.

Industry Value System

A value system is an analytical framework that captures supplier, manufacturing, channel and buyer value chains in a single model (Porter in Brazell, et al., 2004, p. 24). The M2M value system is defined by the aggregation of value chains from several distinct industries including telecommunications, semiconductor, computer hardware, computer software, IT professional services, industrial instrumentation, telematics, data centers and R&D. In the M2M industry we can identify 13 value system entities including:

- **Research and Development.** Basic and applied research in the science and engineering of new processes or new products. Research and development does not include manufacturing quality control, routine consumer product testing, market research, sales promotion, sales or service (ASU, (n.d.), p. 1).

- **Backbone Infrastructure Hardware.** Companies involved in the manufacture of backbone infrastructure hardware, including products such as gateways, routers, switches and communication systems.

- **Backbone Infrastructure Software.** Companies that produce backbone infrastructure software (server and/or client software that support infrastructure hardware such as OSS, carrier connectivity, billing, network management, etc.). This segment may also include the platform, front-end applications and development tools sold in a single offering or as a hosted offering.

- **Chip Manufacturer.** Companies that manufacture chips specifically with M2M and wireless circuitry involved. Chips are electronic computers made from miniaturized transistors and other circuit elements on a single semiconductor integrated circuit (IC) (WordiQ, n.d., p. 1).

- **Platform Device Hardware.** Companies involved in the manufacture of device hardware platforms, which include products such as access points, base stations, mobile/cell systems, soft switches, class 5 switches, PDAs, mobile terminals and phones.

- **Platform Device Software.** Companies involved in the production of platform device software, which includes server and/or client software to support device hardware (OS, security, device management, native application software).

- **Middleware.** Companies involved in the production of middleware. This is defined as server and/or client software that either extends the reach of existing IP or other enterprise applications, including ERP, CRM, SCM, SFA, etc. Mobile middleware may include the platform, front-end applications, and development tools as sold in a single offering or as a hosted offering.

- **Network Operator (Carrier/ Service Provider).** Companies that provide wireless voice and/or data services, support, network management and QoS, including Wireless Internet Service Provider (WISP).

- **Content or Application Service Provider.** Companies that are "third-party entities that manage and distribute software-based services and solutions to customers across a wide area network from a central data center. In essence, ASPs are a way for companies to outsource some or almost all aspects of their information technology needs" (Upstream CIO, n.d., p. 1). These companies are also known as Wireless Application Service Providers (WASP) and M2M Application Service Providers.

- **Content or Service Aggregator.** Companies that allow consumers to gain wireless access at multiple wireless data services and applications (content, portals, exchanges, etc.) through a single provider (Molta, D., 2002, p. 1).

- **Integrator/Value Added Reseller (VARs).** Companies "that take an existing product, add proprietary 'value' usually in the form of a specific application for the product (for example, a special computer application) and resell it as a new product or 'package'" (search390.com, n.d., p. 1). This segment includes wireless business technology consulting, professional services and systems integrators.

- **Customer:** Consumer or business that pays for products and/or services.

Value System Dynamics and Trends

As M2M proliferates, a sea change is predicted for the telecommunications industry and the nascent M2M industry. The primary catalyst is value migration and the shift from technology-centric to service-centric M2M business and technology models.

Value migration is the shifting of value-creating forces first proposed by A. J. Slywotzky in his classic 1996 book *Value Migration, How to think several moves ahead of the competition.* In Slywotzky's theory, value migrates from outmoded business models to business designs that are better able to satisfy customers' priorities. There are three stages of value migration:

- **Value inflow stage** - value is absorbed from other companies or industries. See table below.

- **Value stability stage** - competitive equilibrium with stable market shares and stable profit margins. See table below.

- **Value outflow stage** - companies lose value to other parts of the industry - reduced profit margins - loss of market share - outflow of talent and other resources. See table below.

The value system in the M2M wireless industry consists of participants from several industries including telecommunications, semiconductor, industrial instrumentation, transportation-based telematics, IT professional services, data centers, Application Service Providers (ASPs), computer hardware and computer software industries. Each industry is at a different Value Migration Stage.

Table 1   M2M Industry Value Stages

	Value inflow stage	Value stability stage	Value outflow stage
Telecom	No	No	Yes
Semiconductor	No	Yes	No
Industrial Instrumentation	No	Yes	No
Telematics	Yes	No	No
IT Professional Services	No	No	Yes
Data Centers	No	Yes	No
ASPs	No	Yes	No
Hardware	No	No	Yes
Software	No	No	Yes
Pure Play M2M	Yes	No	No

Source: IC² Institute

There are several key segments that face challenges in this dynamic emerging industry, most notably telecommunications companies and systems integrators. The next several sections offer an overview of these two segments of the value system and introduce the concept of the M2M-specific service provider.

Telecommunications Value Shift

Many industry analysts predict a major value shift away from telecommunications companies who currently serve wireless Internet markets towards service providers and content providers (Aslam, et al., 2003, p. 10), (Insignia.com, n.d., p. 1), (Black, n.d., p. 1), (Turner, Demers, 2004, pp. 7-8). **According to recent research by KPMG, telecommunications companies will shift from receiving 70 percent to as little as 25 percent of the value in the delivery of Internet services to markets.**

Laggard telecommunication industry innovation, diffusion of M2M technologies and services to broader markets and this value shift away from Telcos places pressure on the industry to evolve business models to retain, capture and increase profitability. As industry researcher Ovum points out, **"operators are facing an uphill struggle to re-engineer in-house platforms for service delivery, both in terms of technological challenges and cost barriers"** (Ovum Research, 2003, p. 1). This dramatic change signals the need for telecommunications companies to modify their business models to incorporate a wider range of third-party relationships to deliver data-centric services and professional services (McLatchie, n.d., p. 1).

As the anticipated shift in the value system occurs, the traditional telecom scenario looks precarious. However, embracing M2M and adapting to meet the coming opportunities also appears to be a promising move for companies in this industry. An indication of this is recent research by ABI finding that the **"cellular radio Machine-to-Machine application market will grow at 40 percent annually through 2010, versus cellular radio growth in the cellular handset market at 10 percent"** (ABI Research, 2004). The M2M market, therefore, presents telecom with an opportunity to stay the revenue shift by delivering value added services.

While the changing M2M value system portends challenges to the telecom segment, there is also opportunity. A key challenge however, is the need for telecom to increase its rate of technological and business process innovation in parallel to this emerging industry.

Workforce Implications:

- **The value shift away from Telecommunications companies portends greater workforce layoffs in general.** The current trend at AT&T represents this scenario— once over 1 million workers worldwide, AT&T currently employs 61,000 workers (Simon, 2004, p. L1).

- Telecommunications companies that harness and profit from M2M value inflow may be able to sustain and increase profitability placing **new demands on the existing workforce (requiring retraining)** and creating **new demand for a technical workforce with Internet- and M2M-based skills.**

- Service-centric models will place demands on Telecommunications providers for new infrastructure and business processes. In turn, **this will place demand on existing workforce (requiring retraining) and create new demand for a technical workforce with transformative experience in Business Process Redesign, Business Process Innovation and XML standards for business process architecture such as EbXML** (EbXML, n.d., p. 1).

- M2M-based process convergence across industries facilitated by the telecommunications industry will require greater accountability to customers and greater reach into customer business processes and systems than traditionally supported by the telco industry. This will **require a technical workforce with customer industry and business process knowledge and a greater emphasis on multidisciplinary communication and problem solving in the technical disciplines.**

Systems Integrators

In the current M2M market, the systems integrator is the nexus that draws together fragments of M2M into a solution including bundled products and services. **Systems integrators are key players in the value system today as they eliminate complexity for customers; manage multiple partners from across industries; and provide expertise in fragmented technologies including specific technology of the customer's industry** (Salomaa, 2003, p. 35).

Figure 14 The Big Role of System Integrator in the Value Network
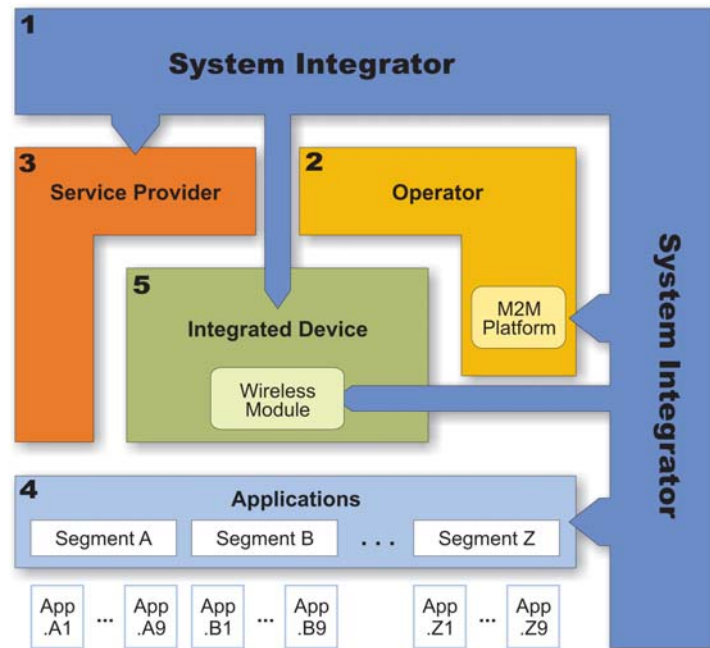
As illustrated in Figure 14, "the systems integrator (SI) owns the customer" by pulling together the different components needed for an M2M solution. The SI's (1) overarching role taps the network operator (2) for the telecom network and gateway, the service provider (3) for such things as SIM card and telecom customer service (this function is usually accomplished by operators, also), the applications provider (4) for custom design and the device manufacturer (5) for the wireless device or module (Salomaa, 2003, p. 32).

This figure illustrates the value of the SI in today's value system: without the SI as the one customer interface, clients seeking M2M solutions in the RFID space, for example, would have to coordinate at least seven separate supplier touch points (Rohringer, Ischebeck, n.d., p. 22). This is problematic from both time and cost angles for customers. It thus becomes clear that the ability to create a single interface for customers is a key factor in speeding adoption of M2M solutions in the current value system.

A useful example of a legacy company that is bundling several types of services in the M2M environment is IBM's Business Consulting Services' contract with the Department of Defense. In their capacity as an integrator for the Department of Defense's RFID rollout, IBM has played roles that vary from education to managing deployment of technology, to creating measurement metrics to support the business case, to assisting the Department of Defense with longer-term planning. In this case, IBM's role goes beyond even the SI's as described in the above diagram to include business consulting services in addition to technology services.

While the position and importance of SI's is currently apparent, it may not be immune to potential disruption in the value system, just as in the telecom industry. As pointed out in the trends discussion, the market is dynamic, with companies from many areas prowling for positioning in the early stage of M2M market.

Thus:

> "As the M2M market matures, customers requiring the reach of a national or global telecommunications company to serve its M2M needs may shift the locus of control to network operators who own the telecommunications networks and gateways in the value system." (Salomaa, 2003. p. 32).

This makes the customer interface role—now dominated by SI's—a logical target for operators. **The complexity of achieving a seamless end-to-end M2M network, as well as the speed of technological innovation, makes a single customer service point critical for M2M adoption.** While SI's currently fill that role—and are still expected to be a significant piece of the emerging value system—the rise of the M2M service provider could challenge their primacy.

Workforce Implications:

- Systems Integrators (SI) focused on M2M markets will likely experience short term (1-3 year) workforce growth placing new demands on the existing workforce (requiring retraining) and creating new demand for business and technical workforce.

- Service-centric models will place demands on SIs to expand their business model into subscription and transaction services or to partner for these required services. Where SIs add new subscription computing services, demand will be created for workforce with experience in ongoing datacenter and telecommunications operations.

- SIs will require a workforce with transformative experience in Business Process Redesign, Business Process Innovation and XML standards for business process architecture such as EbXML (EbXML, n.d., p. 1).

- SI's will likely experience growth in consulting, architecture, implementation, maintenance, training and ongoing adaptation of these systems requiring expansion of the workforce.

Rise of the M2M Service Provider

M2M Service providers may be telecommunications companies, system integrators or third-party hybrid companies that provide a combination of products and services that reach into customer enterprise systems such as Supply Chain Management (SCM), Customer Relationship Management (CRM), Enterprise Resource Management (ERP), Partner Relationship Management (PRM), Sales Force Automation (SFA) or call center applications.

"M2M Service Providers sell airtime and services, but instead of owning the network they rent network capacity from mobile operators, offering their customers a compelling M2M proposition: instead of multiple subscriptions, customers get just one bill for all their M2M services. M2M service provision may include application development, system integration, mobile virtual network operator activity, content provision or any combination of these" (Nokia, n.d., p. 7).

Figure 15 illustrates Nokia's vision of how the M2M service provider serves as a bridge between GSM-based remote customer applications and Internet-based enterprise servers.

Figure 15   M2M Service Provider
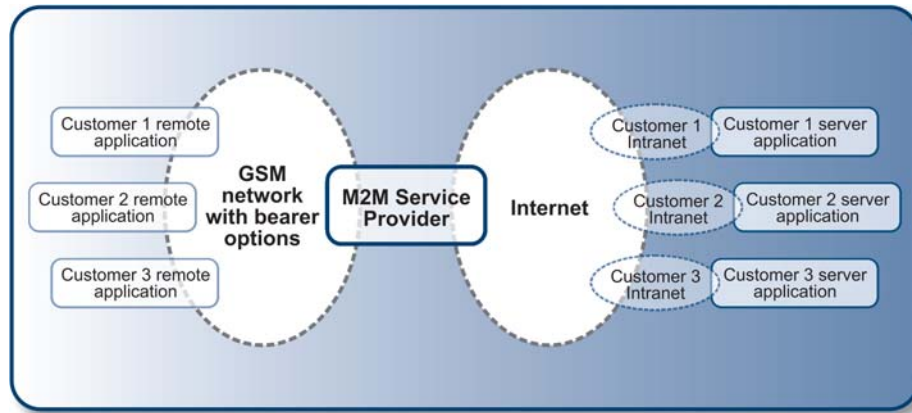
Although this is a useful example, the rise of the M2M service provider is not proprietary to specific companies or even industries. In fact, lack of action on the part of much of the legacy telecom industry has created a void being filled by new entrants. The appearance of M2M-specific service providers is an example of the dynamism of the M2M value system. In the old model, service providers might include a number of entities, including network operators, applications service providers, and aggregators. In the new model however, the M2M service provider promises to provide a point of expertise that combines multiple functions (data center operations, network monitoring and control services and systems integration services) to integrate enterprise systems and remote applications over heterogeneous networks. Thus, the rise of the M2M service provider will challenge existing business models and create new opportunities for industry incumbents and new entrants alike.

Workforce Implications:

- The M2M Service Provider's function may be provided by pure play M2M, Systems Integrator (SI), Telecommunications or other industry segment firms. As this is a new breed of data services, workforce needs are emergent but most similar to data center, call center and telecommunications Network Operations Centers (NOC).

- M2M Service Provider's will likely require a workforce with transformative experience in Business Process Redesign (BR), Business Process Innovation and XML standards for business process architecture such as ebXML (EbXML, n.d., p. 1).

- M2M-based process convergence across industries facilitated by M2M Service Providers will require a technical workforce with customer industry and business process knowledge and a greater emphasis on multidisciplinary communication and problem solving in the technical disciplines.

Over the past year, the popular press has leapt onto the bandwagon of things-to-things communications as the Next Big Thing. Radio frequency identification (RFID), intelligent sensor networks, and M2M (machine-to-man or machine-to-machine) are heralded as applications and transforming technologies that are at the stage of exploding. The expectation is that devices and M2M sensor technologies, coupled with available and emerging communications infrastructure and integrated with a range of software, will enable an entire new class of systems to be designed and deployed with breakthrough results in numerous market applications.

This section provides a survey of relevant technology efforts and suggests a set of roadmaps with which to understand the technology for curricula developers.

M2M sensors provide the next evolution of information systems. With this evolution, new services will be possible and the existing infrastructure of computing, communications and data analysis will be extended, morphed and in many cases re-architected because of data flow and the interconnectivity of M2M networks across industries, markets and institutions.

Figure 16   Convergence

"Computers, communications, and sensing technologies are converging to change the way we live, interact, and conduct business"

Services

Systems

Components
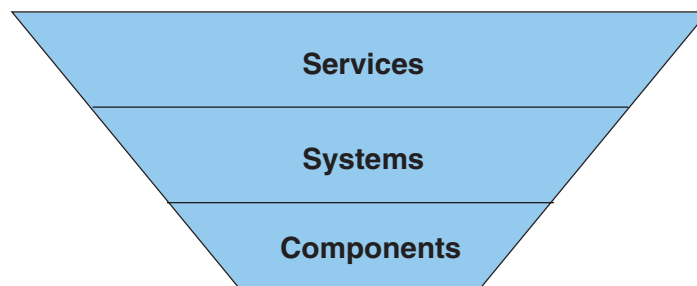
"It's like PCs in the early 80s"

Source: Dexheimer and Hannemann, 2004

M2M Sensor Network Primer

M2M sensors collect information of some type that can be used for some action. Every M2M sensor is part of a network, even if it simply provides a point-to-point manual reading. However, many applications of M2M sensors use communications networks—proprietary industrial and military bus structures—to link data to some central site.

Figure 17   Role of Sensor Networks

Value Driven Design: The required data must be disseminated, on a timely basis, to the proper end users (self-actuated or manual).
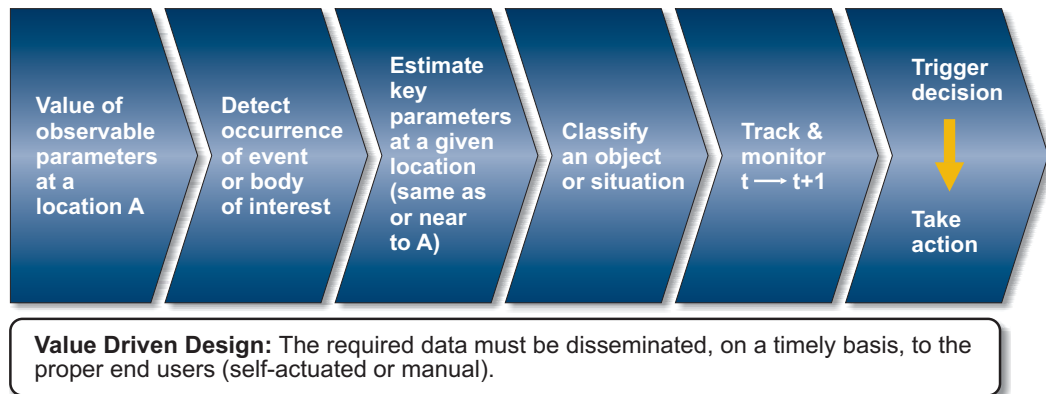
Source: Dexheimer and Hannemann, 2004

M2M sensors can be segmented several ways: by function; by technology; and by application market.

- Functionally, the major classes are: a) physical properties (20% today) such as motion, speed, force, vibration, inertia, shock and torque; b) process properties (26% today) such as temperature, pressure, flow and level; c) electrical, magnetic, chemical liquids, chemical gases and bioinformatics (23% today); and d) other, such as position, proximity, rotation, acoustic and imaging (22% today).

- Technologies used include mechanical, electrical, magnetic, ultrasonic, acoustic, photoelectric, infrared, fiber optic and semiconductor. **Semiconductor-based MEMS M2M sensors now have approximately 40% share of the dollar volume and are growing.**

- Current commercial applications can be segmented as follows: a) automotive (26%); b) structures, including buildings, aircraft and ships (17%); c) process industries (18%); d) other industrial (10%); e) consumer/electronics (12%); and f) other, including medical and utilities (17%).

Evolution of M2M Sensors

We see three major transforming technologies that will drive the industry and new applications:

- MEMS and other micro- and nano-based products have been transforming functionality and will continue to do so.

- The increase of autonomic and intelligent systems involving self-calibration, self-diagnostics and self-configuration, either on board or via network intelligence.

- The evolution of M2M sensor networks to allow "plug and play" for efficient and effective distributed control.

Figure 18   The Sensor Market

The Sensor Market: Enabled for Dramatic Change and Growth

Sensor Node Communication	Inter-Node Fusion/Collaboration

Addressable: *Sensor Networks* (Yes), *Sensor Networks* (No)

Non-Addressable: *$50 billion market today* (Yes), *Sensor Networks* (No)
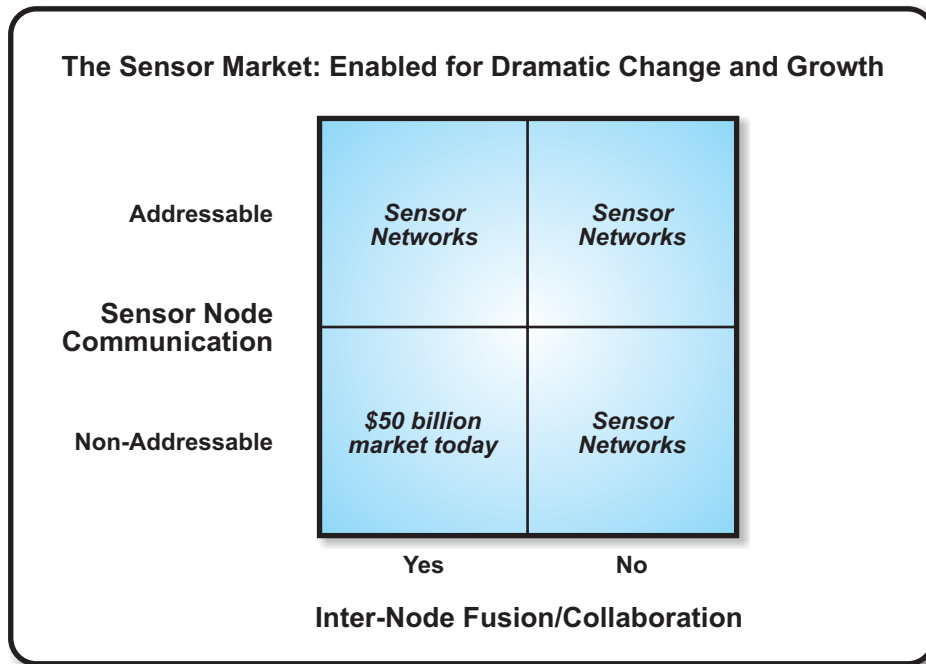
Source: Dexheimer and Hannemann, 2004

M2M sensor network requirements, as outlined by the National Institute of Standards and Technology (NIST), include the following for many applications:

- **Large numbers of M2M sensors (stationary or mobile):** Aside from the deployment of M2M sensors on the ocean surface and the use of mobile, unmanned M2M sensors in military operations, most nodes in smart M2M sensor networks are stationary. Scalability of these networks will be an issue because networks of thousands of nodes are envisioned.

- **Low energy use:** In many applications, the M2M sensor nodes will be placed in a remote area. Because of this, service and maintenance of these nodes may not be possible. The lifetime of a node may be determined by the battery life, thereby requiring the minimization of energy expenditure.

- **Network self-organization:** Given the large number of nodes and their potential placement in hostile locations, it is essential that the network be able to self-organize when manual configuration is not feasible. Moreover, nodes may fail (either from lack of energy or from physical destruction) and new nodes may join the network. Therefore, the network must be able to periodically reconfigure itself so that it can continue to function. Individual nodes may become disconnected from the rest of the network, but a high degree of connectivity must be maintained.

- **Collaborative signal processing:** Another factor that distinguishes these networks from LANS and MANS is that the end goal is detection/estimation of some events of interest and not just communication. To improve the detection performance, it is useful to fuse data from multiple M2M sensors. This data fusion requires the transmission of data and control messages, which may constrain the network architecture.

- **Querying ability:** A user may want to query an individual node or a group of nodes for information collected in the region. Depending on the amount of data fusion performed, it may not be feasible to transmit a large amount of the data across the network. Instead, various local sink nodes will collect the data from a given area and create summary messages. A query will be directed to the sink node nearest to the desired location.

The technological origin of the M2M sensor market is rooted in military applications. This conceptual military framework can be extended to help understand non-military applications of this technology as well. Vice Admiral Art Cebrowski, in his 1998 article "Network-Centric Warfare: Its Origins and Future," defined three grids working in concert to achieve success:

- The M2M sensor grid rapidly generates high levels of environment awareness and synchronizes awareness to operations.

- The engagement grids exploit the awareness and translate it into increased competitive or service power.

- The information grid enables the operational architecture of the M2M sensor and engagement grids.

This conceptual framework suggests the major design characteristics and elements of M2M. This is shown in Figure 19 below.

Figure 19   Smart Sensor Networks
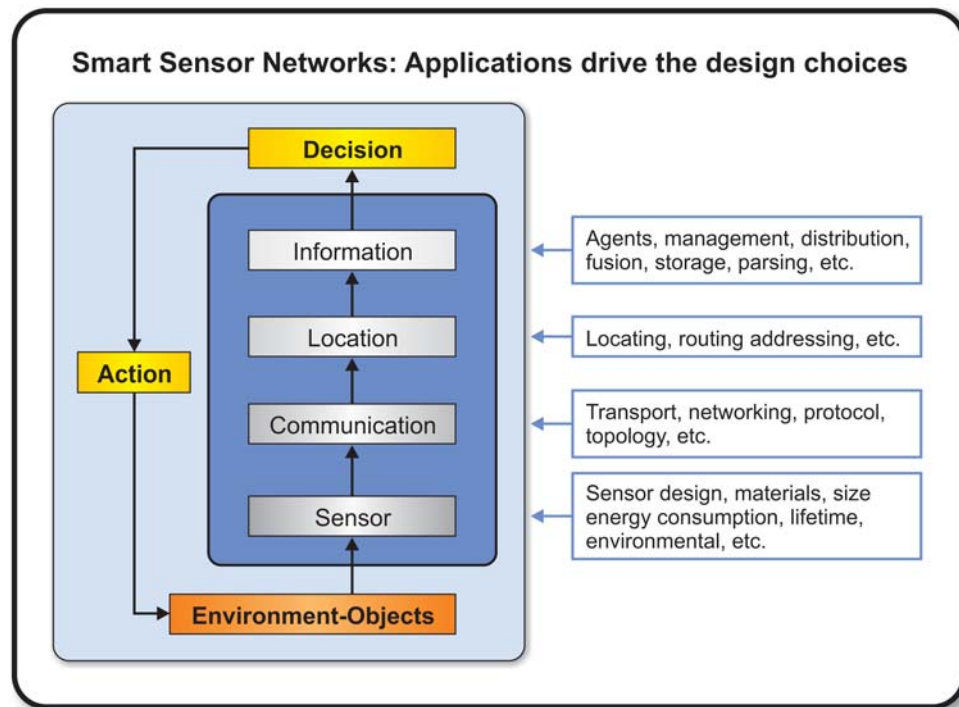
Source: Dexheimer and Hannemann, 2004

This framework provides for centralized, decentralized, distributed and hybrid points of control from an operations standpoint, as well as post operation tracking and feedback. It presents degrees of flexibility, complexity, adaptability and self-synchronization not found in existing IT infrastructures.

The framework illustrates that several key variables arising from a given application define the cost-value trade-offs. Specifically, every application has differing parameters on what is defined and required for: "the environment," "rapidly," "awareness," "translate," "synchronize" and "exploit."

We have designed the following map to provide a core design-decision hierarchy underlying every application. While evolving standards and the deployment of new technologies will decrease costs and enable growth in networks, the diversity in needed applications will, in the near term, keep the market highly fragmented.

These 11 characteristics factor into any M2M sensor network design and result. Each has several main breakpoints—leading to several hundred thousand potential design permutations. The application will drive the specific choice within each, and cost, functionality and reliability depend on these. For example, while wireless technology enables significant new applications, in many cases end-to-end wireless functionality may be gratuitous for a given application. It may be more costly or less reliable than what is available through a hybrid communication transport that can piggyback on unused landline infrastructure. Similarly, local fusion may or may not be needed or may raise untenable security/reliability risks or unnecessary costs.

Figure 20   Mapping Product-Technology Choices
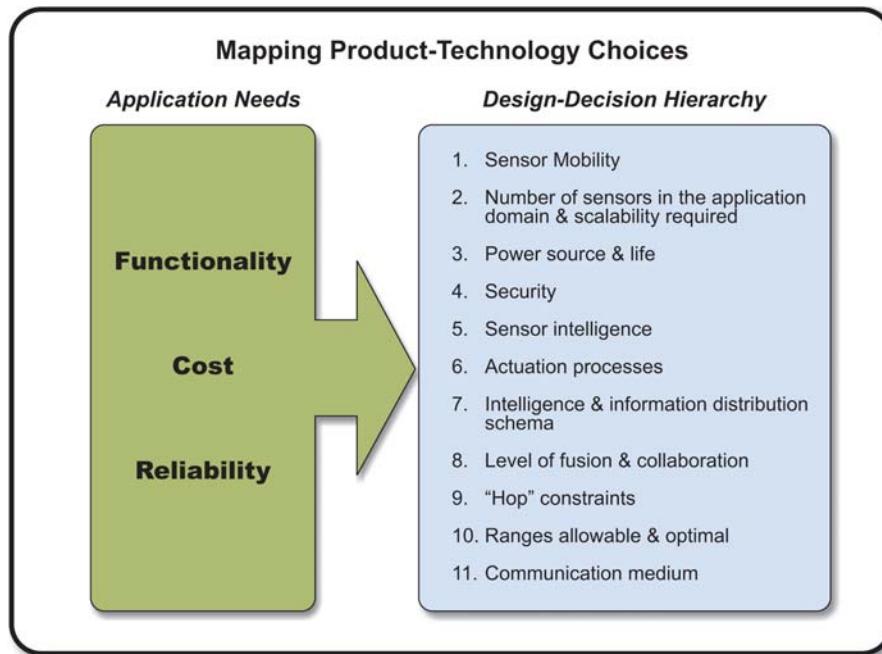
Source: Dexheimer and Hannemann, 2004

Matching the application to the product-design choices will be based on ROI and value creation. The application greatly influences both physical layers and the gatekeeping and backbone information layer. These gatekeeping and backbone layers should connect and integrate information from all remote M2M sensors via any communications medium. Decisions or actions might be either automatically actuated or operator-actuated, and they might be made either in the field or in a central network operating center (NOC). Fusion and collaboration are required for non-central intervention, since they can cut delays and upstream data transmission.

Table 2   Sensor Network Design

Sensor Network Design Permutations	
1. **Sensor Mobility**	Fixed; movable-planned/known; random motion
2. **Number of sensors in the application domain & scalability required**	
	1 to 10; 10 to 1000; 1000 to 100000; 1000000+
3. **Power source & life**	Wired; wireless on pre-existing; wireless separate supply
4. **Security**	High; low; encryption
5. **Sensor intelligence**	Single or multi-function; dumb; addressable, 2-way, multi-path, broadcast
6. **Actuation processes**	Tightly coupled or separate actuator; auto or manual trigger; Local, intermediate or NOC decision point
7. **Intelligence & information distribution schema**	
	All to central NOC or distributed intelligence at remote sites; secure vs. non-secure sites; level of remote data storage
8. **Level of fusion & collaboration**	Multi-sensor or multi-node direct communication; query capability from sensor site, other in field, NOC
9. **"Hop" constraints**	Internode; to actuation; to NOC
10. **Ranges allowable & optimal**	Internode; to router or node sink; to secure site
11. **Communication medium**	Wired; wireless entirely; wired to router/node sink then wireless; multi-node

Source: Dexheimer and Hannemann, 2004

The Institute of Electrical and Electronics Engineers (IEEE) in a 2003 survey of current commercial and military M2M sensor user requirements highlighted several factors affecting wireless M2M sensor networks. In order of importance, these factors are: data reliability; battery life; cost ; transmission range; data rate; data latency; physical size; and data security.

As indicated however, the application will drive use, design and cost characteristics. For example, one user set from the IEEE survey had the following requirements among these selected parameters:

- Transmission distance: M2M sensor to node: 32% less than 10 meters, 41% from 10 to 100 meters, 27% over 1000 meters.

- Minimum M2M sensors per node: 20% at 5 or less, 15% at more than 50.

- Battery life: 30% at 1 month or less, 10% at greater than 24 months.

- Latency: 10% at less than 10 milliseconds, 45% at 10 to 250 ms, 30% greater than 2000 ms.

- Data rate: 18% at 100 or more messages per second, 23% at 10 to 100 per second, 34% at 1 to 10 per second, 16% at 100 seconds or greater per message.

As these data illustrate, applications have vastly different needs. New technologies will enable yet an even greater array of applications and with those applications will come design and cost trade-offs. A 2002 study by the U.S. Department of Energy (DoE) highlighted several reasons for wireless networking of M2M sensors in industrial applications:

- Wireless is now cheaper to install, as wiring costs range from $100 to more than $1,000 per foot to install in harsh environments.

- Wires crack or fail, adding to maintenance costs that wireless avoids.

- Connectors are the single biggest failure point in wired networks.

- Wireless provides flexibility in placement that wired M2M sensors cannot.

- Wireless enables rapid deployment.

At volumes, MEMS and other semiconductor approaches allow integration of multiple functions and lower-cost packaging into a more reliable package than a wired M2M sensor. The DoE has forecast that, by 2010, the cost of wireless M2M sensor systems could be one-tenth the cost of current wired systems (DOE, 2002).

What's Next? In our view, six critical enablers of growth, moving in parallel, are reshaping the industry:

- **New Methods of Human-to-Machine Cooperation**
- **Device advances**
- **New network methods**
- **Standards for M2M sensor devices**
- **Applications development**

Human-to-Machine Cooperation

Human-to-Machine Cooperation (HMC) is concerned with the cognitive and perceptual relation between humans and machines. Related domains include cybernetics, Human-Machine Interaction (HMI), Human Systems Integration (HIS) and Human Performance. HMC sensor networks are associated with:

- Increased data aggregation, information overload and cognitive overload.
- Event-based management in complex environments with high stakes.
- Mission critical systems.
- Convergence of physical security, cyber security, environmental control and process control.
- Complex control networks (land, sea, air, space and cyber).
- Threat identification and mitigation.

HMC is concerned with the design of effective operational environments and the cognitive division of labor between humans and machines in complex control networks.

HMC technology applications are associated with critical infrastructure such as: oil and gas pipelines; industrial and factory automation; telecommunications networks; transportation systems such as Intelligent Vehicle Highway Systems and Telematics; digital battlefield and command and control systems; and generally, networks of sensors and actuators governed by humans and machines. Operational environments are typically dynamic, event-driven and process-oriented. Additionally, they feature centralized, decentralized, distributed and hybrid command and control structures.

Figure 21   Human-Machine Cooperation Model
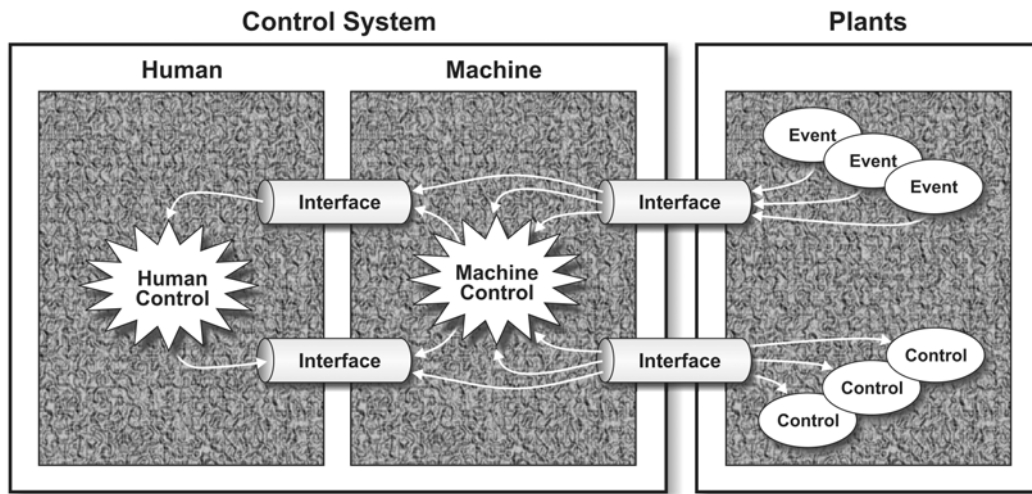
HMC environments are especially important in the following contexts:

- **Critical infrastructure operations, security and transportation logistics.**
- **Emergency operations across civil, DoD, state and federal government authorities.**
- **Joint battlefield operations.**

HMC is relevant in the context of individual human-to-machine interactions; human team-to-machine interactions; and interactions at various operational levels across critical infrastructure operations networks (Emergency Operations Centers; Tactical Operations Centers; Naval Operations Centers; Air Traffic Control Centers, etc.).

HMC interfaces and control systems are undergoing rapid technological evolution as a result of:

- Information and cognitive overload now characteristic in data-intensive environments, especially network-centric command and control environments.
- The commercial and technological viability of machine learning, machine intelligence and other "cybernetic" technologies infusing the operational landscape of M2M networks, processes and control systems.
- Unique contributions of human factors, new media and cognitive science professionals to the HMC landscape, especially in converged operational, simulation and learning environments. **The impact of these features is a qualitative transformation of digital media to a state beyond "converged media" that is reflective of game worlds, virtual reality and new augmented reality paradigms.**
- **Increased emphasis of virtual teams,** distributed operations and communities of practice across geography, functional disciplines and functional control domains (land, sea, air, space and cyber).
- **Deployment of edge computing and the general trend toward intelligence at the edge of the network.** Military R&D, acquisition and deployment of M2M and HMC technologies related to joint operations, network-centric warfare, battle space awareness, sensor networking, advanced distributed learning, smart weapons, virtual operations centers and battle command on the move.

A noteworthy trend in the HMC space is the convergence of planning, rehearsal, operational and human learning environments. According to Dr. Cavalli, researchers at the University of Texas at Austin and in the San Antonio-Austin-Waco region are using artificial intelligence (AI), machine learning, modeling and simulation (M&S) and peer-to-peer computing architectures to combine operational, simulation and assessment systems into a single platform. Heretofore, these systems have existed as stove pipes. Their convergence will enable more effective learning, decision making and execution of endeavors that involve the coordination of multiple machine and human actors to achieve desired mission outcomes (Interview, Cavalli).

Key workforce requirements for HMC applications include operators for control environments and new media designers with a background in human performance and usability. Although the US Bureau of Labor Statistics discounts the importance of new media as an area of employment growth (Interview, Cisneros), new media designers who have the appropriate background in human factors and usability are an essential ingredient in designing effective HMC-based control, simulation and assessment environments for training operations.

Device Advances

M2M sensor networking is enabled by advances on several device fronts:

- Micro-miniature, rugged M2M sensors based on several materials platforms, including silicon CMOS, fiber optic, MEMS and gallium nitride.

- New battery technologies that enable remote, non-wired operations.

- Improvements in both RF and fiber optics (both free space and tethered) for transmissions.

- High levels of integration among these three elements via design optimization simulation tools, SOC (System On Chip) and manufacturing processes to provide substantially lower costs at better performance.

M2M sensor functionality is being enhanced via the incorporation of multiple functions within a given platform. Single-function MEMS and fiber optic M2M sensors have been used in the field for years in many applications. They are being expanded rapidly into other applications and are at the early stages of multi-function integration.

The terms "smart dust" and "motes" are being used to describe a class of M2M sensors that are packaged together with a battery and a radio. Several universities, small companies (encouraged by government programs) and firms such as Intel are actively working on these programs. These include some early commercial deployments. The term "brilliant rocks" is being applied to a class of M2M sensors that are multimedia oriented— usually wired—and deployable where power is available.

Many M2M sensors— including temperature, pressure and acceleration M2M sensors— from MEMS and CMOS processes can be attached to a mote. A receiver circuit converts photocurrent from an incoming laser into a data stream to be used to interrogate or reconfigure the mote. Several transmission systems can also be used, such as a passive corner cube reflector (CCR) for communication to a base station or an integrated laser with beam to steer MEMS structures for inter-mote communication. Components are mounted with a battery, a solar cell or rely on other ambient sources of power, such as wind, thermo electrical energy, water, vibration or strain. An application-specific integrated circuit (ASIC) handles measurement recording, data storage and system control.

Power consumption has been a major obstacle and design issue for wireless systems. In addition to handling power issues via the design of a network's architecture, various battery solutions driven by other markets (consumer, military, RFID, medical) are evolving to provide a platform for traditional and new wireless M2M sensor applications. For example, there are now thin film batteries that can be integrated directly within integrated circuits (ICs) or built into the electronics they power. Processes now exist to design microscopic rechargeable energy sources onto almost any substrate. There is no need for contacts for battery recharge because the built-in battery is recharged through inductive, RF or ambient means. By designing application-specific solutions, products can dramatically reduce overall size and weight of the energy source.

Beyond traditional wired communications media for M2M sensors, RF wireless and fiber optics—both free space optics and connected fiber— are emerging as keys for new applications. When line of site is available, free space optics can have several advantages over RF via low energy consumption and relatively simple electronics. Fiber-based transport has been proven over decades, and cost structures have benefited from the telecom build-out of the past decade. Fiber-based transport is increasingly used in harsh environments, where applications support infrastructure and have unique, high-performance requirements such as in oilfields, planes, ships and other structures.

RF antennas are being pulled in many directions by the range and volumes of demands from both the consumer and military sectors. Antennas are becoming custom-designed components via development toolkits and foundries that are unique to each OEM's performance, size and cost requirements. Applications, including many for M2M sensors, require non-traditional antennas in order to: 1) achieve higher gain, allowing reduction in transmitter battery power and better reception in "dead spots"; 2) allow multiple frequency operation within a single antenna permitting integration of multiple applications or real-time frequency tuning; 3) be embedded in a packaged device; and 4) provide wider channel bandwidth for large data rate requirements.

New Network Methods

Large-scale wireless M2M sensor networks represent a new generation of real-time embedded systems with significantly different characteristics and constraints from traditional networked systems. M2M sensor networks have energy, computation, storage and bandwidth constraints. Additionally, their usage scenario, impact on traffic and interaction with users is very different. Current architectures for Internet and ad hoc wireless networks are not ideal for wireless M2M sensor networks for several reasons:

- The number of nodes in a M2M sensor network can be substantially larger.
- M2M sensor nodes experience failures much more frequently.
- M2M sensor nodes are simpler than nodes in the Internet and ad hoc networks.
- M2M sensor nodes can be very limited in power.

This limited power suggests that acknowledgment packets should be used sparingly and querying processes must be power-efficient.

To date, most M2M sensor networks have been designed with custom architectures for specific tasks, thus providing inflexible operation and interaction capabilities. Newer architectures involving multi-hop rather than passive, centralized schemes are targeted to combine power and routing awareness, integrate data with networking protocols, communicate power efficiently through the wireless medium and share tasks and data among neighbors.

Because M2M sensor networks involve interaction with a physical environment, communication often has timing constraints. These are in the form of end-to-end deadlines. Unlike traditional systems, in a wireless M2M sensor network individual M2M sensors and nodes are often dedicated to individual tasks with nodes operating in groups. This is because individual M2M sensor capabilities may be limited and not reliable to perform activities alone. Data fusion and aggregation can achieve energy savings by selecting the best path and by selectively storing and processing data in the network.

M2M sensor networks are application-specific distributed systems that may require different distributed algorithms for different applications. The application needs can change dynamically based on both external factors and central or distributed field control points. M2M sensor nodes cannot store every possible application in their own local memory. Thus, a method for dynamically deploying new applications via distributed algorithms is needed. The programming support (including scripting languages and middleware) of the entire network should deploy a power-sensitive operating system (OS) and facilitate user-friendly and energy-efficient dynamic deployment of algorithms.

Current commercial embedded OSs are far larger than wireless M2M sensors can support. Emerging M2M sensor OSs such as TinyOS, EYES and MagnetOS are much smaller— often by factors of ten or more. By automatically and transparently partitioning applications into components and dynamically placing these components on nodes within the network, these architectures reduce energy consumption, avoid hotspots and increase system longevity. Each application needs to re-implement the same migration, monitoring and communication mechanisms, correctly, on every M2M sensor node. **There has been a substantial effort to develop these algorithms and programs over the past five years, and several commercial companies are at the early phases of roll-outs on various scale networks. We expect increasing maturation and scalability.**

Standards for M2M Sensor Device Networking

Major users in several segments have developed standards in order to decrease costs and foster improved supply chains. For example, the emergence of RFID standards in the retail sector has been driven by users such as Wal-Mart, Proctor & Gamble and Gillette. With the military's active role in M2M sensor utilization and the drive by DoD for COTS (Commercial Off The Shelf), the current base of more than 100 proprietary M2M sensor networks in use today, as identified by the Navy, is a major limitation to operational efficiency, scalability and interoperability.

In spite of the commonly desired push for standards, it is clear that:

- Differing standards will co-exist, with specific relevance depending on the application.

- Certain standards or requirements from a particular end-user industry may in fact be inconsistent with relevant M2M sensor standards.

- Many applications are not best implemented via the available standards (for performance or cost reasons).

As an example, in February 2004 Intel and its partners left the existing standards organization and developed their own version of ultra-wideband (UWB) technology. Several standards efforts are relevant to M2M sensor networking; most have been in evolution for several years and are beginning to have market impact that will grow over the next two to three years.

Standards efforts are generally a positive force in moving customers and vendors to concrete action and to develop largely reusable development tools and test procedures. These will offer benefits in terms of time to market, reliability and cost reductions for users, whether using a standard or proprietary approach.

Through several cooperative efforts, the National Institute of Standards and Technology (NIST) and the Institute of Electrical and Electronics Engineers (IEEE) Technical Committee on Sensor Technology, Instrumentation and Measurement have been working to establish smart sensor communication interfaces and a standard physical layer (PHY) interface. The P1451.0 working group is in the process of defining common functions, protocols and formats. The P1451.1 working group in 1999 completed a common object model for smart transducers (another term for M2M sensors), along with interface specifications for the components of the model. The goal of P1451.2 is to define a smart transducer interface module (STIM), a transducer electronic data sheet (TEDS) and a digital interface to access the data from any network, including the Internet. The P1451.3 working group is defining a digital communication interface for distributed multi-drop systems.

The aim of the P1451.4 working group is to define a mixed-mode (analog and digital) communication protocol for smart transducers. Finally, the P1451.5 group is responsible for wireless communications and remains in process. **This family of IEEE 1451 standards is designed to work in concert to ease the connectivity of M2M sensors and actuators with a device or field network, to create "plug and play" integration with any network, incorporating self-documentation and ease of configuration.**

Numerous choices exist for communications media, and standards are currently being developed. The IEEE 802.15 working group provides standards at both the PHY and MAC (Wireless Media Access Control) layers for low-complexity and low-power consumption wireless connectivity. Wireline communications protocols standards such as ModBus, LonTalk or DeviceNet are in use today in many M2M sensor environments. There are currently four IEEE 802.15 standards in development using different environments, with the last being most relevant for M2M sensors:

- IEEE 802.15.1—1Mb/s WPAN/Bluetooth v1.x derivative work
- IEEE 802.15.2—Recommended Practice for Coexistence in Unlicensed Bands
- IEEE 802.15.3—20+ Mb/s High Rate WPAN for Multimedia and Digital Imaging
- IEEE 802.15.3a—110+ Mb/s Higher Rate Alternative PHY for 802.15.3 (UWB)
- IEEE 802.15.4—200 kb/s max for M2M sensor and automation needs

While 802.15.4 is specifically targeted for M2M sensor needs, its specifications will not meet the requirements of all users. For example, other emerging standards will have an impact on M2M sensors (depending on the application) at either the transmission or physical interfaces including:

- MICS for some medical devices and IEEE1073 and Digital Imaging and Communications in Medicine (DICOM) for others.
- FlexRay for automotive.
- ISO18000 and EPCglobal for RFID at numerous frequencies (860 MHz to 930 MHz, 135 MHz, 1356 MHz, 13.56 MHz, 5800 MHz, 433 MHz and 2450 MHz); 4) UWB at 3.1 GHz to 10.6 GHz and 22 GHz to 29 GHz.
- EPCglobal's distributed data, server and software architectures. Further, there is always room for proprietary methodologies.

For example, representatives of the U.S. Navy reported at an IEEE meeting that the Navy's requirement in wireless M2M sensor applications is for five-year battery life, up to 10 years of mean time between failures (MTBF), 100 meters to 2 kilometers range and 1 Mbps data rate. These parameters fall outside the specifications in any proposed standard within the foreseeable future. The result of communications standards efforts is historically that, even at maturity, a standard might achieve 30% to 70% share. Thus, applications will continue to determine the standard adopted for a given application.

Fifty organizations, including a number of leading chip manufacturers and large systems firms, formed the ZigBee Alliance and have begun to deliver their first products. Working with the draft IEEE 802.15.4 standard, which focuses on low-data-rate personal area networking and defines both PHY and MAC layers, ZigBee defines the upper layers of the protocol stack, from network to application, including application profiles. In essence, 802.15.4 acts as the physical radio and ZigBee supplies the logical network and application software. **The ZigBee standard targets control in homes and buildings, automation, security, consumer electronics, PC peripherals, medical monitoring and toys.** Nominal data rate and range is 250 kbits/s at 30 meters. ZigBee requires very low power, specifically, much less than Wi-Fi and significantly less than Bluetooth. ZigBee and IEEE 802.15.4 use three license-free frequency bands, including 2.4 GHz, 915 MHz, and 868 MHz and offer the building blocks for star, mesh and cluster tree networking.

Table 3 Personal Area Network Comparison

	ZigBee 802.15.14	Bluetooth 802.15.1	Wi-Fi 802.11b	GPRS/GSM 1xRTT/CDMA
Application Focus	Monitoring and Control	Cable Replacement	Web, Video,	Email WAN, Voice/Data
System Resource	4KB -32KB	250KB+	1MB+	16MB+
BatteryLife (days)	100-1000+	1-7	.1-5	1-7
Nodes Per Network	255/65K+	7	30	1000
Bandwidth (KB/s)	20-250	720	11,000+	64-128
Range (meters)	1-75+	1-10+	1-100	1000+
Metrics	Reliable Low Power Cost Effective	Cost Convenience	Speed Flexibility	Reach Quality

Source: Helicomm in Dexheimer and Hannemann, 2004

Existing wireless standards, such as IEEE 802.11b and Bluetooth, are generally not well-suited for the communications needs of monitoring and control applications. Wide area wireless technologies, including GPRS, GSM and Wi-Fi, are also not well-suited for many M2M sensor applications due to power consumption, costs and inability to communicate with more than one device. **Based on the current vendor and user support, West Technology Research estimates the overall ZigBee component market alone will reach $1.7 billion by 2007.**

Application Development

At its core, an M2M sensor network is a distributed database. Unlike most traditional database applications, an M2M sensor network is also vastly different in that with the exception of simple RFID data, M2M sensor readings by nature are approximations. Most existing M2M sensor applications rely on a centralized system for collecting M2M sensor data. These systems lack flexibility because: 1) data are extracted in a predefined way and 2) they do not scale to a large number of devices because large volumes of raw data are transferred regardless of the queries that are submitted. An M2M sensor database collects samples at intervals that are subject to error and (in wireless mobile architectures) noise, frequent failure of a given node, power consumption, remote physical storage limitations, fusion among M2M sensors and query workloads. All factor into the creation, retention and location of database tables. The features of M2M sensor queries do not lend themselves to easy mapping to relational databases, and M2M sensor data is different from traditional relational data since it is not stored in a database server and it varies over time.

A well-designed distributed approach is flexible (different queries extract different data from the M2M sensor network) and efficient (only relevant data are extracted from the network). There are two basic approaches for processing M2M sensor queries: the warehousing approach and the distributed approach.

The warehousing approach is the current state of the art. In this approach, processing of queries and access to the M2M sensor network are separated; the M2M sensor network is simply used for data collection. The warehousing approach is well suited for answering predefined queries over historical data.

In the distributed approach, the query workload determines the data that should be extracted from M2M sensors or from data stored elsewhere on the network. A number of new database architectures and query techniques are evolving to dramatically increase query throughput and decrease query response times in wide-area M2M sensor databases. For example, incorporating fuzzy pattern recognition techniques to compress uncertain M2M sensor measurements allows substantially faster query and communications times. These extensions to existing relational models are needed to enable energy efficiency, M2M sensor data fusion, adaptive optimization and complex queries that wide-scale M2M sensor networks require.

The multiplier effect of these new M2M sensor devices and systems will be massive. For example, when RFID is rolled out in scale, the density of readers, volume of data created and transmitted, and potential uses of the information will be staggering. Stores, branches, warehouses and delivery vehicles will create enough data to overwhelm existing applications. Large systems integrators such as Cap Gemini expect the major applications of ERP, supply chain management, and business intelligence software will need to be rewritten to take advantage of the real-time data flows and distributed intelligence that becomes available. **The industry forecasts typically estimate direct software and implementation services alone for RFID will generate four to five times the amount of revenue generated by hardware alone.** Taking this a step further along the value chain into the impact on upgraded and new software applications, real-time monitoring, and value-added transaction and intelligence services, one industry forecast by Harbor Research estimates the multiplier is over 20 times as scale is achieved. Major players in mainstream corporations are beginning to grasp the implications. As the CIO of 7-Eleven stated in March 2004, "RFID will require levels of bandwidth and access and storage such as we've never contemplated." Having examined some of the applications and service opportunities currently on the market as well as those on the verge of being made available, it is clear that the impact of networked devices and the data provided will be substantial and pervasive.

State of the Art Wireless M2M Sensor Networks

New networking architectures are needed for the cost effective and reliable networking of M2M sensors. The applications for these networks range from monitoring M2M sensors in industrial facilities to HVAC and appliance control for energy management systems. In addition, the technology should be scalable for large-scale gathering of data from utility meters in residential markets, to multiple emerging applications such as shoreline monitoring of environmental M2M sensors, to biohazard monitoring around a city, to transportation applications.

A significant advantage of radio frequency (RF) mesh networking of M2M sensors is that there is bi-directional communication between the M2M sensor and the application server at all times. This permits data transmission and alarm reporting for data retrieved on demand.

M2M Sensor Configurations

Numerous configurations for M2M sensors and applications exist. The wireless operation is typically in the unlicensed band. As a result, there is no transaction cost associated with data collection. In addition, the whole wireless transmission design is based on low power consumption that prolongs the battery life. There are applications where M2M sensor networking is in a licensed radio spectrum, such as for the military, owners of spectrum, such as government agencies or private parties. The framework presented in this section does not preclude such scenarios.

M2M Sensor Cluster

M2M sensor cluster refers to a collection of many M2M sensors over a geographical area. Figure 22 is an illustration of this type of configuration. This section discusses several configurations for M2M sensor clusters and the optimum solution for each one. The type of sensor cluster shown in Figure 22 is typically found in applications such as residential utility meter reading, biohazard monitoring in a metropolis or pollution monitoring over a landfill. M2M sensor clusters can be large or small. Electric meter reading in a city constitutes a large-scale M2M sensor network, while factory floor process monitoring would constitute a small scale M2M sensor network.

Figure 22   Representative M2M Sensor Cluster

EkaNet™ with the Ad-hoc network of
M2M sensor nodes communicating
with the EkaNet™ Wireless Gateway
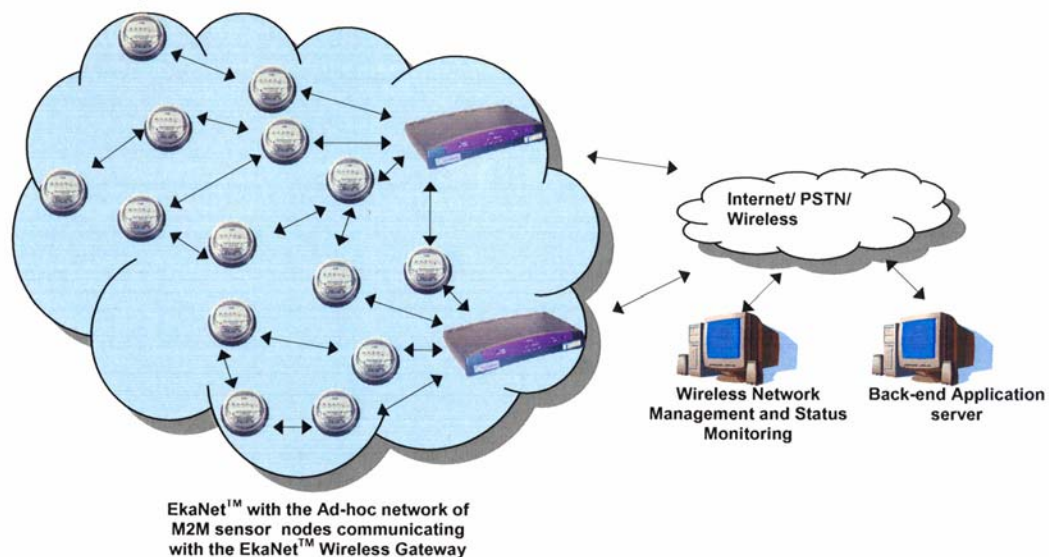
Source: EkaNet in Dexheimer and Hannemann, 2004

The distance between an M2M sensor and its closest neighbor should be less than 1,000 meters (3,300 feet). In practice, this distance is expected to be much shorter for many applications. Each M2M sensor has a wireless radio that communicates to its neighbor until the data reaches the wireless gateway at the edge of the cluster. The gateway collects data from all the M2M sensors and puts it out on the Internet through an interface that could be telephone line, optic fiber, wireless cellular, etc. Note that as shown in Figure 23, all data is bi-directional. In other words, any M2M sensor can be commanded to send its data/messages on request from a remote site.

A significant advantage of this configuration is that fault-tolerance is automatically built into the geometry. If one of the M2M sensor radios does not work, the M2M sensors that communicate to the faulty M2M sensor radio will automatically redirect themselves to the gateway along a path of working M2M sensors. Furthermore, the information of the route change will be passed on to the application server, alerting the application of the faulty M2M sensor radio. In addition, a regularly scheduled self-test can be performed, for example, once a day, to ensure that all the M2M sensors are operating correctly. If the results of the self-test are not as expected, the information can be sent to the application server. This process has the advantage that the application does not have to wait too long (a programmable parameter) to take any necessary action.

Several M2M Sensor Clusters

In numerous applications, several M2M sensor clusters exist. Figure 23 illustrates this type of scenario, where electric meter clusters are found in apartment complexes as well as at some commercial locations.

Figure 23   Configuration of Several M2M Sensor Clusters
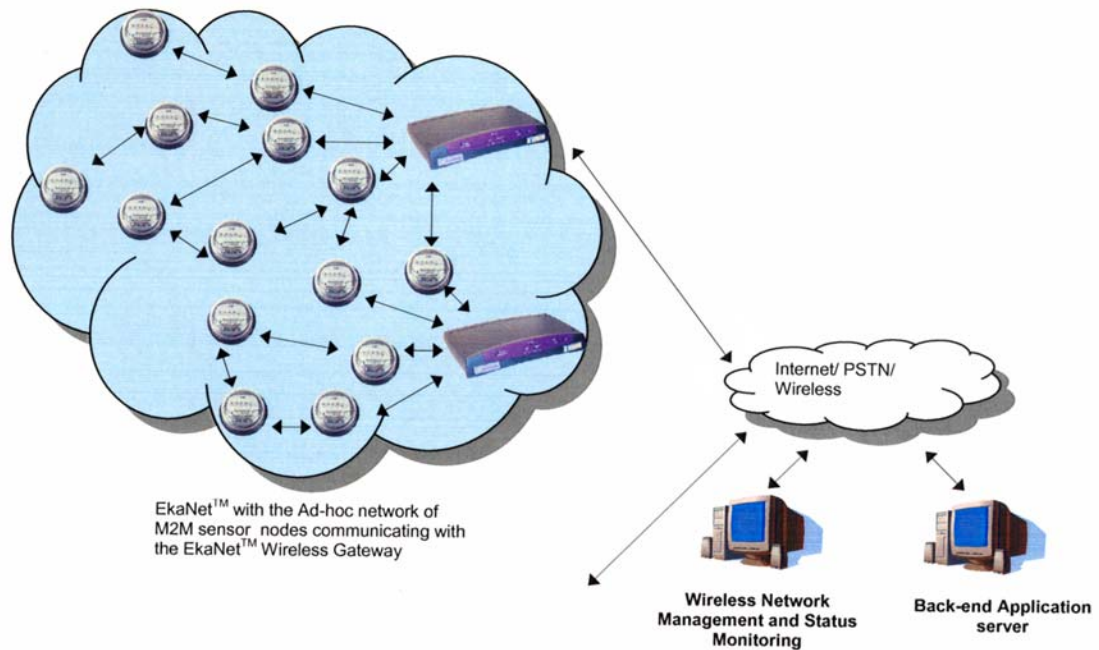
Source: EkaNet in Dexheimer and Hannemann, 2004

One or more gateways may serve all the M2M sensor clusters in Figure 23. If there is only one gateway, the maximum distance between adjacent clusters needs to be less than 1,000 meters. However, for fault-tolerance purposes more than one gateway can exist. If one gateway becomes faulty, communications automatically switch to a different gateway. The gateways form a master network in this configuration. All the M2M sensor data information from each cluster is sent to the gateway. The data is then sent to the application server.

Note that there is tremendous flexibility in the frequency and period of data collection using this approach. Also, bi-directional communication is present at all times. Any M2M sensor in any cluster can be accessed with a unique address and this process can be performed remotely.

There is no constraint on the type of M2M sensor in this solution; all M2M sensors do not have to be of the same type. Any mix of utility, industrial or environmental M2M sensors (where applicable) can be networked using this solution.

To determine M2M technology trends and workforce needs, we conducted an industry survey and interviews targeted at M2M and wireless industry participants. At the conclusion of this chapter, we distill this information into specific recommendations.

A total of 58 industry professionals responded to an Internet-based survey. In addition, 8 more telephone interviews were conducted with Texas industry representatives to gather additional in-depth information on key areas covered in the survey. In the data discussion that follows, percentage results and numbers are from the on-line survey. Information from personal interviews is used to supplement or highlight survey data. For the discussion, percentages are rounded to whole numbers.

Although 31 of the 58 respondents were from Texas, there were also respondents from around the United States and several foreign countries, including Mexico, Singapore and Brazil.

Target respondents for both the on-line survey and interviews included job titles such as CEO, President, Founder, CTO, Director of Marketing and Marketing Manager.

As shown in Figure 24, most (62%) respondents described their primary role in the value system as that of business services. Business services indicate that the majority of industry participants we surveyed focus on business M2M applications, technologies and services rather than consumer services. The role of integrator/VAR was also a significant portion of the respondent base (44%). Responses for secondary roles were most pronounced in middleware (47%), research and development (R&D) (43%) and infrastructure software (39%).

Figure 24   Value System Segments Represented by Respondents
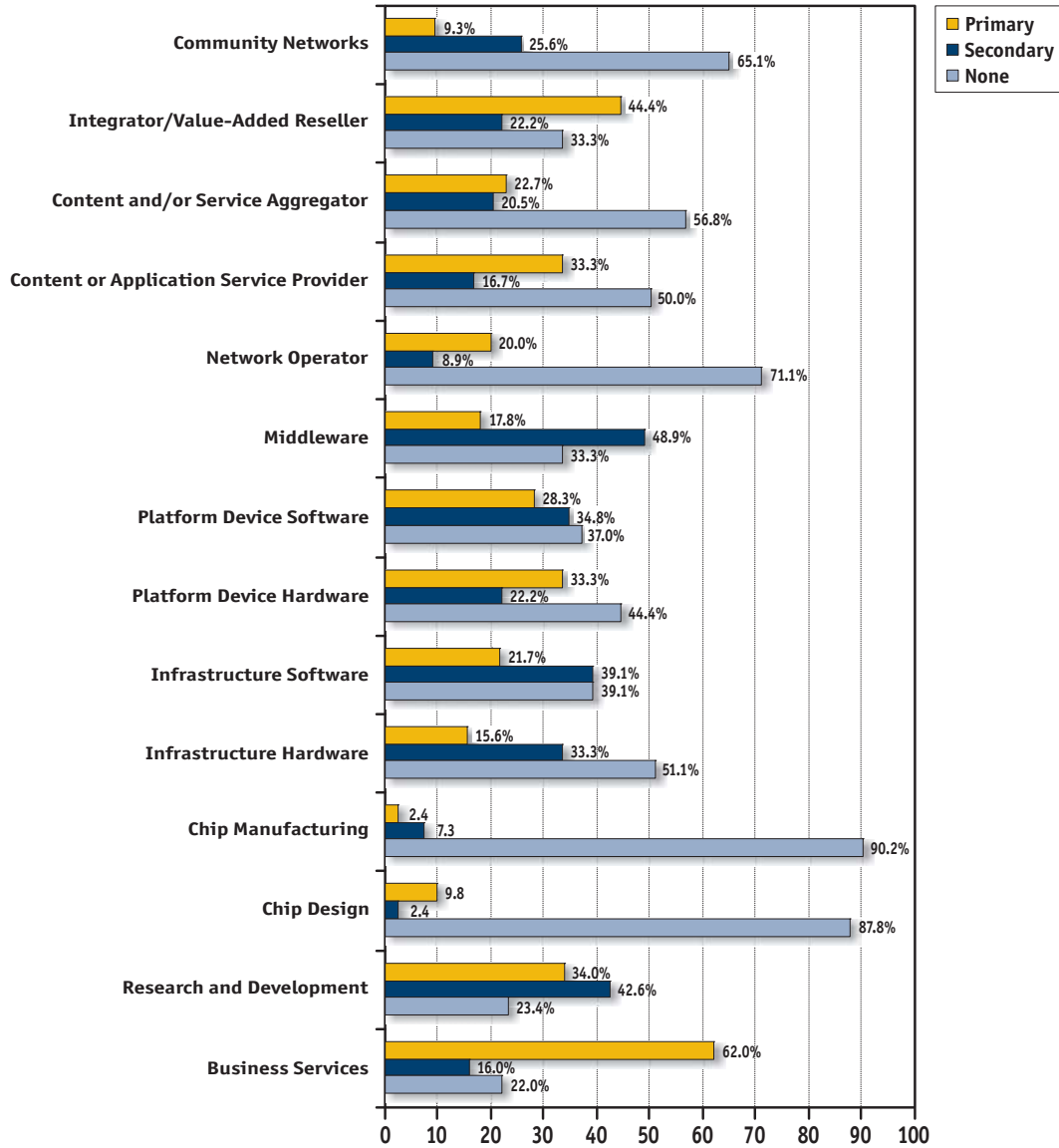
About 49% of the respondents classified themselves as startup (negative to $1 million in annual revenues) or small ($1-9 million) companies. About 14% were mid-sized ($10-50 million) and 13% were large (over $50 million). About 23% of respondents declined to answer.

Trends and Technologies

This section presents and analyzes a series of questions that focus on trends in technologies and standards.

Figure 25 shows the results regarding respondents' expected wireless technology products over the next 3 years.

Figure 25   Planned Technology Product Offerings Over the Next 3 Years
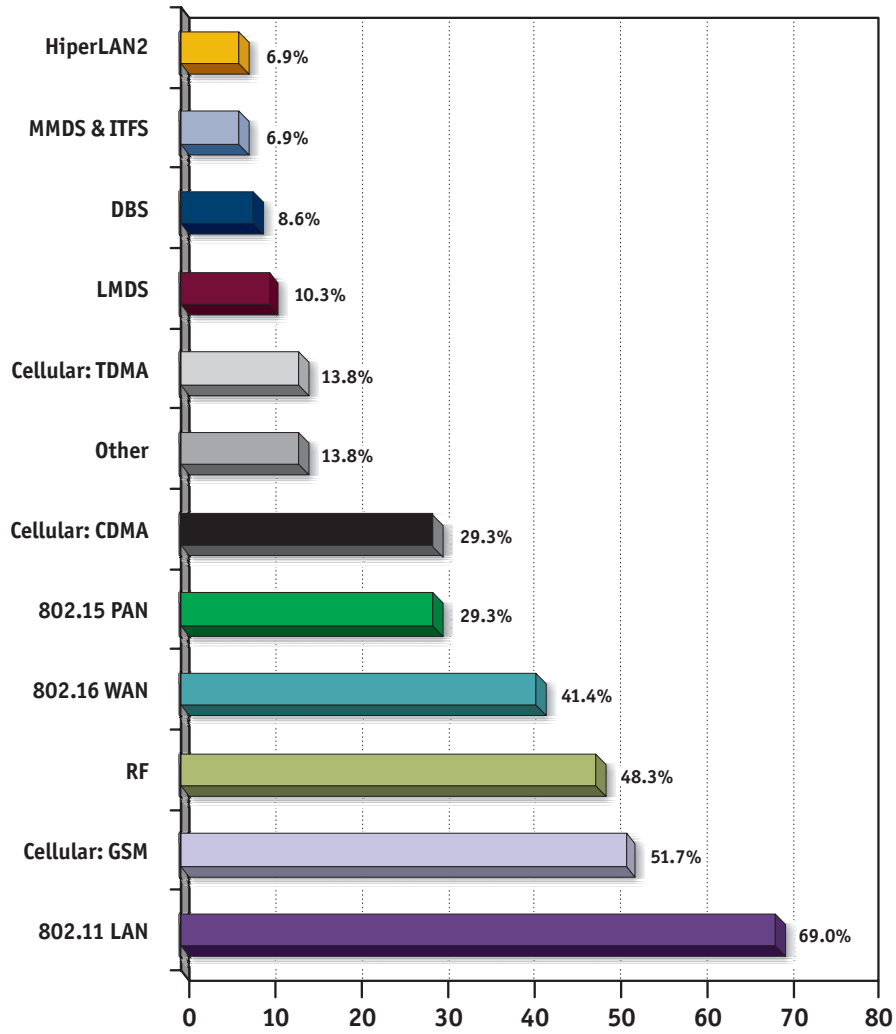
As can be seen, 802.11 LAN is strongly favored, with 69% of respondents selecting this technology. Also poised for significant targeting are GSM cellular (52%), Radio Frequency (RF) (48%) and 802.16 WAN (41%). Additionally, about 30% of respondents expect to have 802.16 PAN and CDMA cellular technology in their product mix. Beyond these choices, the responses fall off dramatically, indicating a fairly strong leaning toward 802 incarnations, RF and selected cellular technologies.

Figure 26 shows which M2M applications respondents plan to address during the next 3 years.

Figure 26   Planned Application Focus for Respondents Over Next 3 Years.
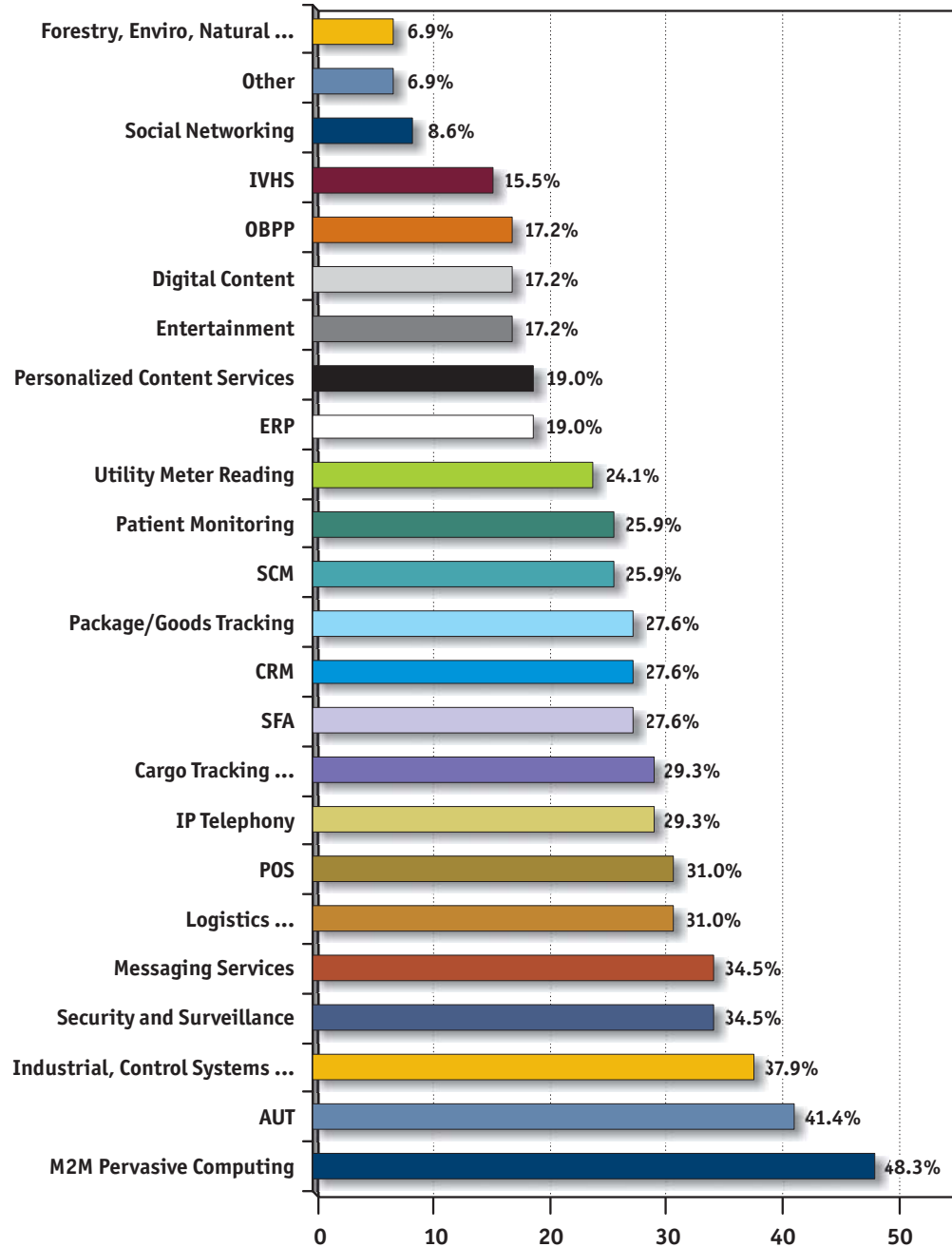
M2M pervasive computing is the strongest expected application, garnering 48% of responses. Several other segments are expected to attract significant attention, including AUT (41%) and industrial and control applications (38%). 30-35% of respondents also plan some future focus on security and surveillance, messaging services, logistics, POS, IP telephony and cargo tracking.

Respondents were asked to rate the importance of current and potential trends on their businesses. Figure 27 shows the spread of responses.

Figure 27 Importance of Current and Potential Trends for M2M Businesses

Legend:
- Very Important
- Important
- Neither
- Unimportant
- N/A

Acceptance of IP
- 42.6%
- 35.2%
- 13.0%
- 3.7%
- 5.6%

Interoperability of Devices
- 49.1%
- 28.3%
- 15.1%
- 0.0%
- 7.5%

Mobile/Fixed Line Interoperability
- 42.6%
- 37.0%
- 7.4%
- 1.9%
- 11.1%

Internetworking of Disparate Networks
- 7.5%
- 32.1%
- 32.1%
- 15.4%
- 13.2%

Service-Based Subscription
- 23.5%
- 37.3%
- 19.6%
- 7.8%
- 11.8%

Flat Rate Subscription
- 19.2%
- 36.5%
- 25.0%
- 9.6%
- 9.6%

Payment for Download
- 18.9%
- 24.5%
- 35.8%
- 7.5%
- 13.2%

Dedicated Wireless Devices
- 23.6%
- 40.0%
- 27.3%
- 1.8%
- 7.3%

Embedded Systems & M2M
- 32.1%
- 42.9%
- 14.3%
- 3.6%
- 7.1%

Plug & Play Devices
- 41.8%
- 36.4%
- 16.4%
- 1.8%
- 3.6%

Ad Hoc Networks
- 14.5%
- 30.9%
- 36.4%
- 9.1%
- 9.1%

Proprietary Networks
- 7.4%
- 22.2%
- 44.4%
- 18.5%
- 7.4%

Open Networks
- 43.6%
- 23.9%
- 25.5%
- 0.0%
- 7.3%

Proprietary Systems
- 5.6%
- 27.8%
- 38.9%
- 24.1%
- 3.7%

Open Systems
- 42.9%
- 35.7%
- 17.9%
- 0.0%
- 3.6%

More than 75% of respondents identified six top trends as being either "important" or "very important":

- Mobile/fixed-line interoperability
- Open systems
- Plug/play devices
- Acceptance of IP
- Interoperability of devices
- Embedded systems and M2M

Following these trends/activities, other important areas (with 60% or more of aggregate responses) included open networks, dedicated wireless devices and subscription-based services. Trends dealing with proprietary systems had the greatest "not important" ratings and were last in the ranking.

When asked which technology standards they expected to use in the next three years, respondents indicated a fairly wide spread of answers. This is shown in Figure 28 below.

Figure 28   Projected Use of Technology Standards Over the Next 3 Years

Standard	Percentage
CC/PP	1.7%
SyncML-DM	5.2%
ONS	5.2%
Other	5.2%
Jini	6.9%
PML	6.9%
JXTA	10.3%
EPC	10.3%
HiperLAN	12.1%
UDDI	15.5%
WSDL	17.2%
RMI	17.2%
JNDI	17.2%
IBurst	19.0%
LDAP	20.7%
J2SE	20.7%
UHF	22.4%
Java	24.1%
MMS	24.1%
UWB	24.1%
J2ME	24.1%
SOAP	25.9%
Ad-Hoc	27.6%
Mesh Networks	29.3%
PPTP	31.0%
P2P	31.0%
J2EE	32.8%
SSL	34.5%
WEP	37.9%
SMS	39.7%
WAP	39.7%
IPv6	39.7%
BlueTooth	43.1%
WiMax IEEE 802.16	44.8%
XML	44.8%
WPA	44.8%
VPN	46.6%
RFID	46.6%
Wi-Fi	53.4%
Web Services	58.6%
WLAN	67.2%

With 67%, WLAN garnered the greatest responses. However, Web services and Wi-Fi also had response percentages of greater than half of respondents. The top ten technologies are rounded out with: RFID; VPN; WPA; XML; Wi-MAX; BlueTooth and IPv6.

Workforce Needs

One of the critical aspects of this research is the ability to understand the immediate future needs of the Texas M2M industry workforce. The key objective of this data is for academic institutions, especially community and technical colleges, to create curricula that will generate the trained workforce of the future. This section presents the data gathered pertaining specifically to workforce and education issues.

The pie chart in Figure 29 depicts data for expected technician hires (both new and replacement) over the next three years.

Figure 29   Expected Hiring of Technicians by M2M Companies Over the Next 3 Years

Legend:
- 1 to 5 – 19.3%
- 6 to 10 – 24.6%
- 11 to 25 – 10.5%
- 26 to 50 – 8.8%
- 51 to 100 – 3.5%
- More Than 100 – 1.8%
- Don't Know – 17.5%
- None – 14.0%
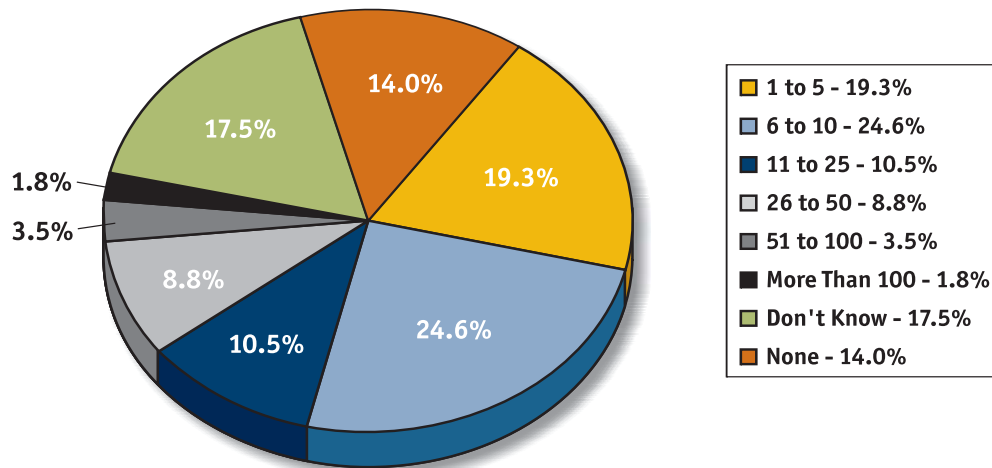
A significant number of respondents (86%) plan to hire M2M technicians over the next three years. The greatest area of concentration (with 45% of responses) is in the range of one to ten hires. However, 14% plan to hire from 26 to over 100 individuals.

When asked the preferred educational attainment level new technicians, a notable percentage (48%) indicated that undergraduate level was preferred (see Figure 30).

Figure 30   Preferred Education Levels for M2M Technicians

Advanced – 11.5%
Undergraduate – 48.1%
Associates – 19.2%
Certificate – 7.7%
Other – 11.5%
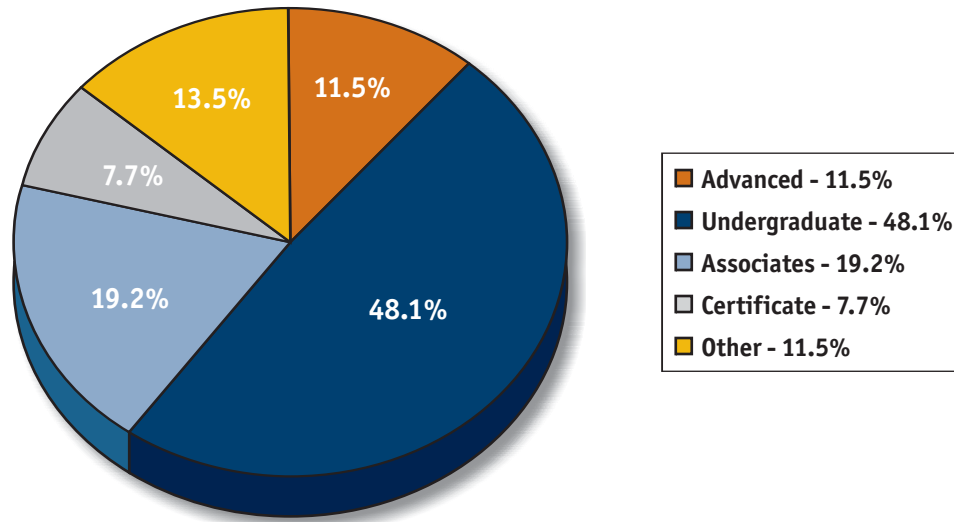
On the other hand, at least 38% of respondents prefer some type of certificate or degree. Interestingly, advanced degrees are one of the least preferred levels of educational achievement.

Respondents were asked if they would be willing to partner with academia in creating curricula for the M2M workforce (see Figure 31).

Figure 31   Percentage of Respondents Willing to Partner for Curricula Development

Yes – 39.1%
No – 15.6%
Don't Know – 45.3%
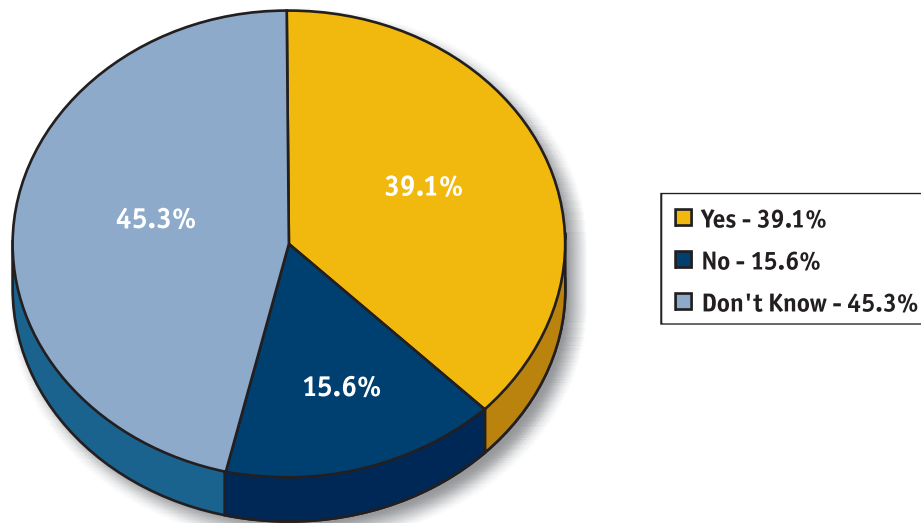
As can be seen, this question had a high **"don't know"** response rate, likely attributable to the open nature of the question; that is, it is an indication of the lack of detail respondents had in understanding what activities and time the partnering might entail. However, the absolute negative response to this question was only 16%. This indicates a potential strong pool of support for curricula development with the M2M industry.

Given the many areas of expertise involved in the coming M2M landscape, it is important to try to understand what job positions are expected to be in greatest demand in the immediate future. Figure 32 shows the survey results for this question.

Figure 32   Highest Growth Job Positions Over the Next 3 Years
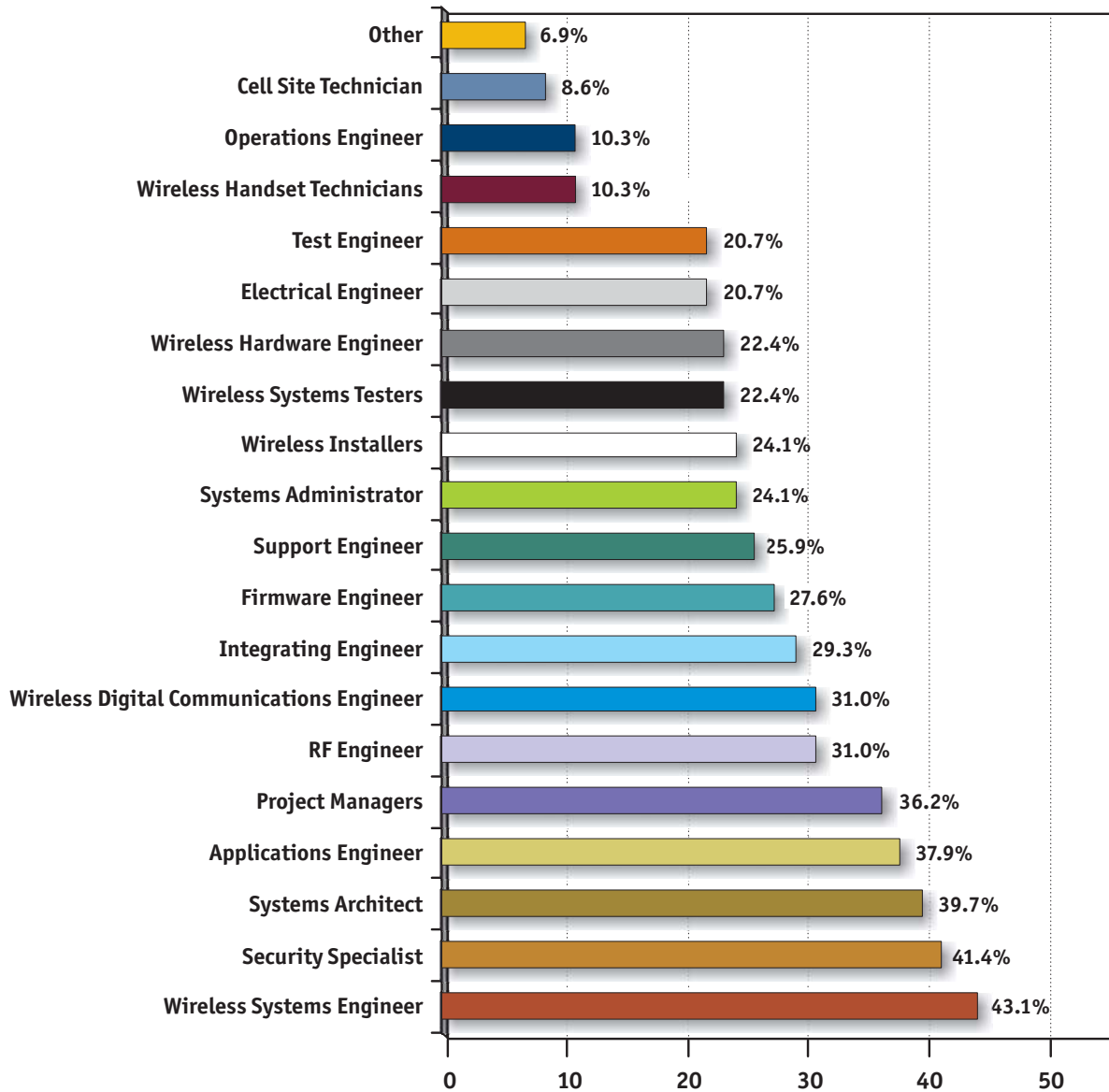
Wireless systems engineers and security specialists, with over 40% of responses, are expected to be the highest growth positions. Other important job titles, with between 30% and 40% of responses, are systems architect, applications engineer, project managers, RF engineers and wireless digital communications engineers. Electrical Engineers fall notably low on the demand scale.

Respondents were asked to identify which of the listed jobs were considered entry level positions. Figure 33 shows the spread of responses for this question.

Figure 33   Identification of Entry Level Positions for the M2M Industry
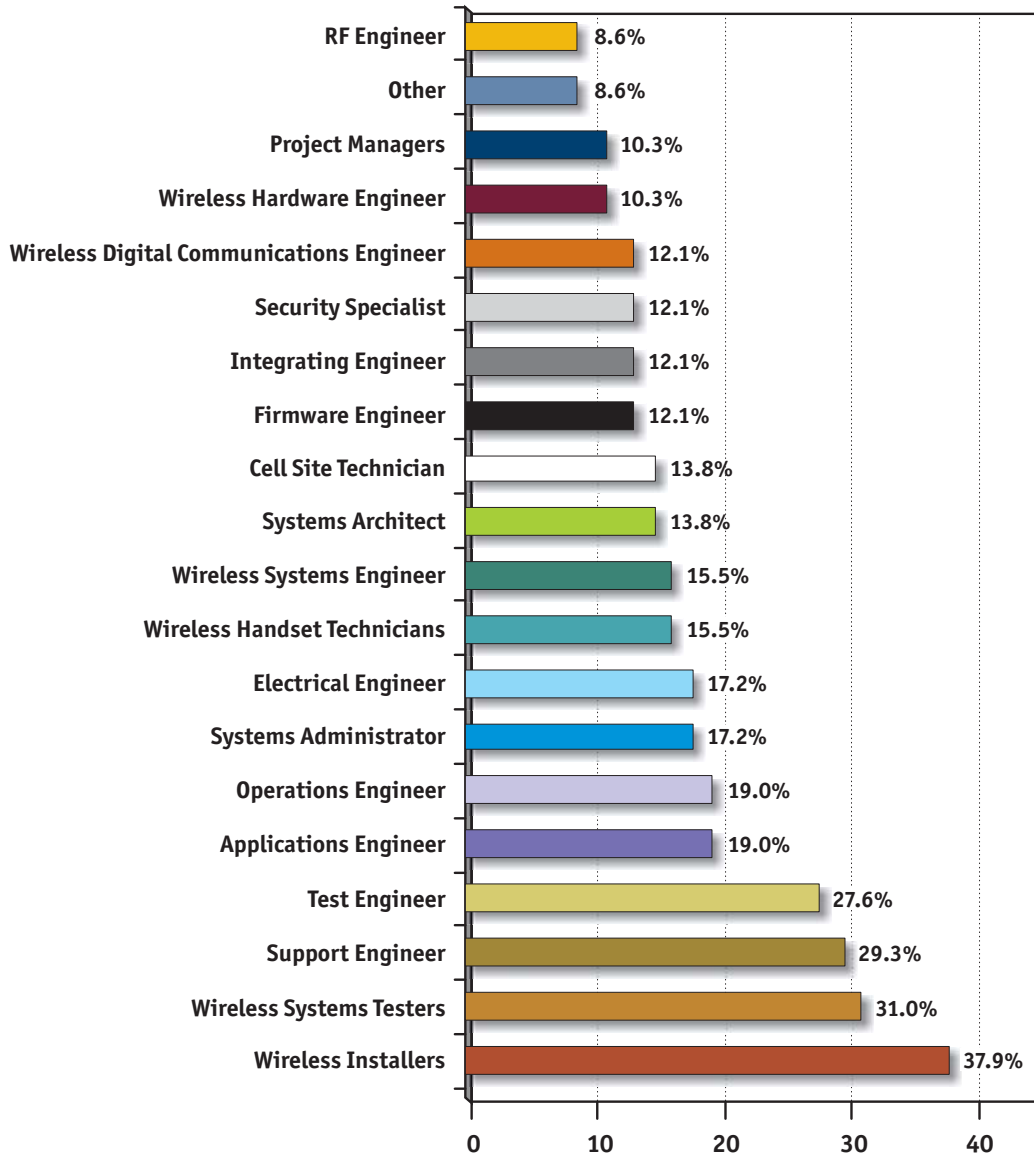
Wireless installers (38%), wireless systems testers (31%), support engineers (29%) and test engineers (28%) were identified as entry level positions.

When asked which technical certifications gave credibility to potential employees, respondents expressed a wide range of opinion (see Figure 34).

Figure 34 Technical Certifications Lending Credibility to Entry Level Employees

Certification	Percentage
AAS Engineering Technology	10.3%
Programming Certificate	12.1%
ESC Telecommunications & Networking	12.1%
Other	12.1%
Electronic Communications Technology Certificate	17.2%
Wide Area Networking Certificate	17.2%
Radio Communications Electronics Certificate	19.0%
Internet Development Technologies	19.0%
Systems Administration Certificate	22.4%
Networking & Communications Certificate	22.4%
FCC Wireless Report Standards	22.4%
Telecommunications Technology Certificate	22.4%
Electronics Engineering Technology Certificate	22.4%
Vendor Specific Certifications	25.9%
Network Security Technology Certificate	29.3%
Computer Systems/Networking Technology Certificate	36.2%

The top response was computer systems/networking technology certificate. This was followed by network security technology certificate and vendor specific certifications. Rather than interpreting responses to this question as indicative of lack of consensus or uncertainty, we assert that the diversity of opinion among respondents reflects firm-specific needs.

When asked if their companies would fund continuing education for employees, there was a strong inclination to support this activity (see Figure 35).

Figure 35   Respondent Financial Support for Employee's Continuing Education
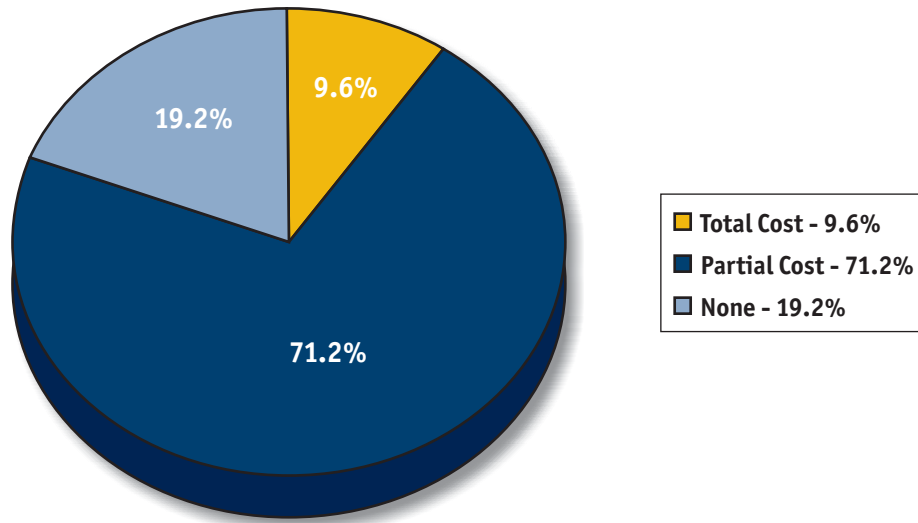
Only about 10% of respondents said that they would not support some degree of financial support for their employees' continued educational endeavors.

Finally, respondents were asked to rate the importance of availability of an array of resources for their businesses over the next three years. The results are shown in Figure 36.

Figure 36   Importance of Available Resources for Firms Over the Next 3 Years
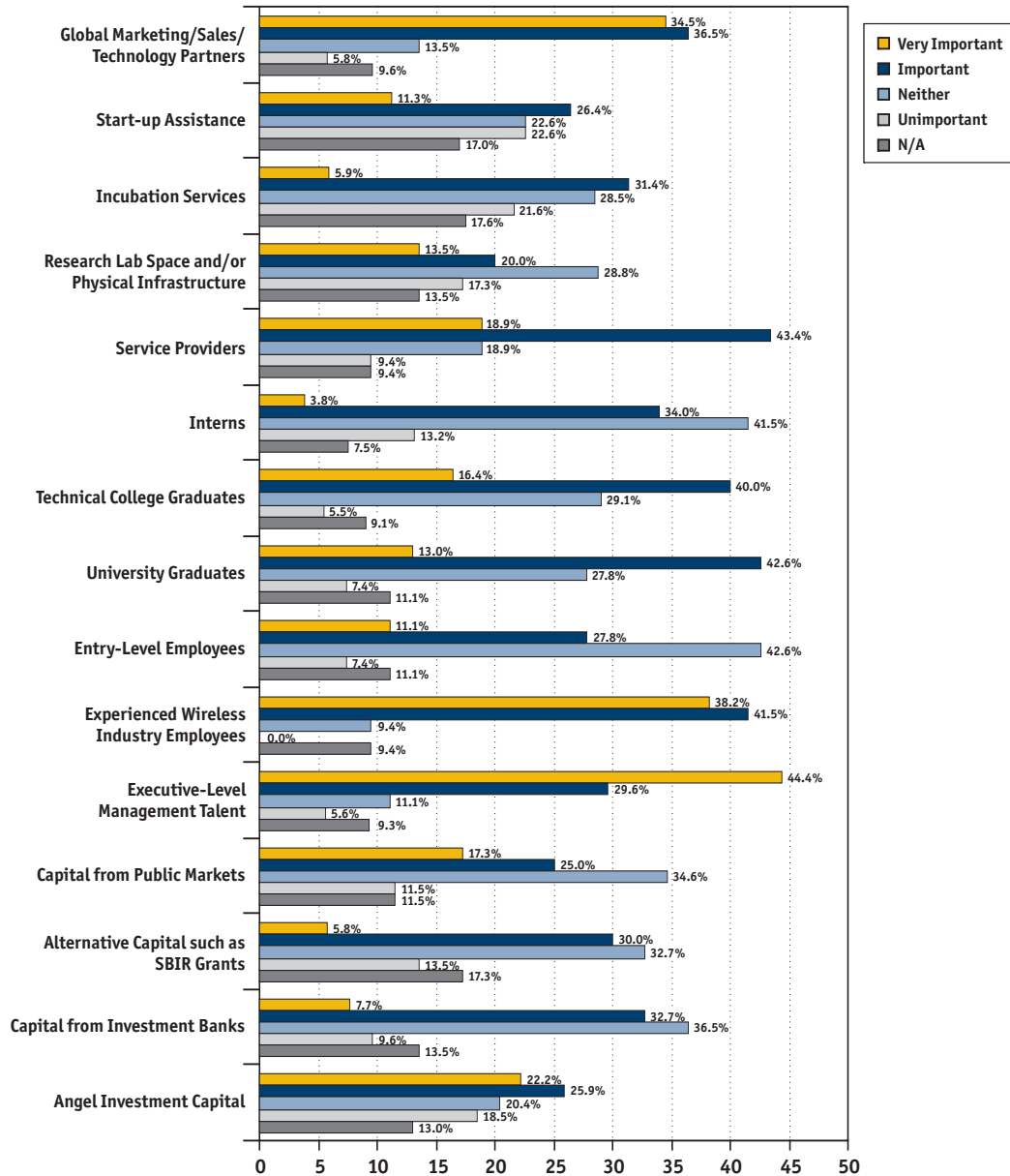
Top responses to this question identified experienced wireless industry employees as the most important available resource. The top eight responses, which respondents identified as either "very important" or "important," are shown in the table below.

Table 4   The Top Eight Resource Needs for M2M Companies Over the Next 3 Years

Resource	Very Important or Important Response %
Experienced wireless industry employees	80.5
Executive level management	74.0
Global marketing/sales/technology partners	70.5
Service providers	62.3
Technical college graduates	56.4
University graduates	55.6
Angel investment capital	48.1
Public market capital	43.3

It is clear from these results that the importance of human resources appears critical, surpassing even funding as a key need in the immediate future.

The machine-to-machine (M2M) industry spans a broad range of disciplines and applications. This span complicates the task of determining current workforce size as well as job growth projections related to this technology. Workers currently versed in wire based M2M networks often have skills directly transferable to new wireless M2M networks. As is the case with most new technologies, wireless M2M developments will make some current jobs obsolete while creating new ones. The focus of this section is on M2M wireless communication and this technology's effect on the labor marketplace.

Communication systems are simultaneously becoming more robust and more efficient. As a subset of the communications industry, wireless technology allows businesses to remotely monitor and in some cases remotely service machines in the field. The net effect of these activities is that maintenance technicians spend less time in transit to remote sites, resulting in a reduced demand for technicians. **Indeed, the U.S. Bureau of Labor statistics predicts that jobs for radio and telecommunications equipment installers and repairers are expected to decline by 2012, and job growth for electrical and electronics installers and repairers is expected to be below the national average** (2004).

Within the machine-to-machine space however, spending is expected to greatly increase. As reported by Ian Barkin of The FocalPoint Group in "Business Week," **spending on M2M communication for hardware, software and services could increase from $34 billion today to $180 billion by 2008. Undoubtedly, portions of this money will promote job growth related to the deployment of new wireless infrastructure, as well as service jobs built around this technology. As this technology develops, workers will need training to provide satisfactory service.**

Many service jobs related to wireless technology will reside in non-technology based firms. This scenario is comparable to many technology firms having in house IT staff. These services are expected to become major employment drivers, and thus deserve attention when developing future curricula.

Another area of job growth related to the wireless industry is the development of complementary technologies. This includes products such as chemical and electrical sensors. Wireless communications allow these sensors to be deployed economically, driving demand for these devices. Sensors themselves are undergoing rapid change as nano-scale research results in improved system performance. One often quoted example of this technology is "smart dust", miniscule devices that can be scattered over an area and then relay information wirelessly back through a network.

As is the case with many electronic devices, the manufacturing of future wireless devices is expected to occur primarily overseas, although some domestic manufacturing can be expected for niche markets. Jobs skills required for these positions are similar to those currently required for semiconductor manufacturing jobs.

Wireless M2M R&D in the State of Texas

The Austin, San Antonio, Dallas/Ft Worth and Houston metropolitan regions each have wireless and M2M R&D strengths. While there is some overlap, each region's business community focuses on various aspects of the M2M value system. Austin has concentrations in semiconductor, software and wireless R&D firms; Dallas/Ft. Worth has telecom, semiconductor and medical R&D centers; Houston has medical, energy, communications and nanotechnology centers; and San Antonio has many network security, defense and medical R&D firms. Taken

together, these regions form a complete system for the M2M industry. This system bodes well for future economic development in Texas. The strengths of various regions are described in detail below.

Austin

Austin currently has many firms in both the semiconductor and software industries. The industry consortium Sematech conducts leading edge research in semiconductor manufacturing, while The University of Texas at Austin conducts research across a broad range of engineering and computer science areas. UT Austin's Wireless Networking and Communications Group unites many leading researchers in their respective disciplines. Major local employers who impact the M2M industry include Dell, Freescale Semiconductor, IBM, and AMD. Private industry research labs include IBM's Pervasive Computing Lab and SBC's Research Lab. In addition, there are hundreds of medium and small size firms that provide various forms of hardware, software and service M2M solutions. Entrepreneurial companies in the M2M arena continue to receive venture funding, such as Novus Edge which recently raised $9.5 million (Novus Edge 2004) and Alereon that raised $31.5 million (Alereon 2004). **Employment growth related to M2M can be expected in basic research, circuit design for mobile communications and software applications.**

Dallas/Fort Worth

The Dallas/Fort Worth Metroplex is known for its strong ties to the telecom industry. The region's "Telecom Corridor" hosts many of the world's top telecommunication firms. The University of Texas-Dallas, Southern Methodist University and The University of Texas-Arlington have developed strong research departments that support the local telecommunications industry. Major technology employers include Texas Instruments, Nortel Networks, Electronic Data Systems and L-3 Communications Integrated Systems (NCTCOG 2004: 3). **The Dallas region also hosts the Nokia division responsible for that firm's M2M development** (M2M 2004). Much like Austin, the Dallas/Fort Worth region has hundreds of small and medium size firms that specialize in all areas of communications. The Metroplex also has strengths in the aerospace and medical industries. Both of these industries are expected to be heavy users of M2M technology (Larson 2003). **M2M related employment growth in this region can be expected in circuit design, network component design and integrated services.**

Houston

Houston based energy firms have historically driven demand for technological innovation. Managing oil and gas wells in remote regions is a difficult challenge. Many Texas based firms already use wireless based communication to track their assets. Thus, several M2M service providers can be found in Houston including Able Communications, Caprock Communications and FuelQuest.

Beyond the energy industry, Houston produces world-class research at Rice University's Center for Multimedia Communications. Rice also supports nanotechnology research that may blossom into new M2M technologies. The University of Houston has also recently opened a Telecommunications Center in their engineering department. These institutions produce engineering talent for future M2M firms.

Other demand drivers for M2M capabilities in Houston come from the strong medical research institutions there. **Future job growth can be expected in firms that create custom solutions for these industries.**

San Antonio

Many security-centric firms have developed in San Antonio, drawing on the region's large military presence. Further support for the San Antonio industry's emphasis on security comes from The University of Texas-San Antonio's Center for Infrastructure Assurance and Security. This specialization is receiving much interest as IT experts have shown that wireless M2M systems are susceptible to attack. For example, one expert demonstrated that hackers with readily available equipment could reprogram current RFID (Cheung 2004). **Indeed, our employer survey indicates that network security knowledge is a primary desired skill for potential employees.**

The first VLSI implantation of the IEEE 802.11b wireless LAN protocol was by Fischer from Intersil in San Antonio, cementing the city's role in wireless technology development (Sitetrek 2003, p.2).

San Antonio also boasts the non-profit Southwest Research Institute (SWRI). This institute performs over $350 million in research annually across many technical domains. Technology developed in SWRI's labs is then transferred to various private and public firms. Sensors, RF medical devices and RF design are SWRI's core target areas of research that support the M2M industry. Other employers in the region that foster M2M growth are SBC, Valero Energy and General Dynamics. Increasingly, the proximity of Austin and San Antonio promotes cooperation between firms in these cities, forming a Central Texas technology corridor. **M2M employment in this region can be expected to continue for network security firms, R&D, homeland security and defense.**

Appendix D lists wireless related companies in the state of Texas. These companies run the gamut from fundamental communications research to software development to business services. **As reported by the Bureau of Labor Statistics, employment of electrical and computer engineers in the state exceeds 20,000 with an additional 20,000 technicians. Network administrators and computer data analysts total an additional 30,000 employees. Replacement for workers leaving these professions will also drive demand for workers with wireless technology skills.** As wireless technology matures, undoubtedly, many thousands of support positions will evolve around wireless-based services.

This section focuses on machine-to-machine industry work domains, job descriptions, salaries, entry-level positions and the skills required for selected positions. Due to the broad nature of products and services offered by wireless firms, positions undoubtedly exist which blend characteristics of several of the domains listed below.

Functional Workforce Domains

Future M2M technologies benefit from wireless communication developments. Wireless technology companies require employees to have many of the same skills as traditional information technology workers. Wireless refers to the medium of communication, so necessary skills revolve around this medium's unique transmission and security protocols. Basic knowledge of software and computer networks is helpful to all wireless industry employees. The Global Wireless Education Consortium identified several competencies for wireless industry employees.

In this report, wireless related M2M jobs have been split into five basic categories:

- Device Hardware
- Infrastructure
- Software Applications
- Systems Integrators
- Systems Operators

Wireless Chip Jobs and Salaries

The wireless device hardware domain includes the design of wireless related integrated circuits, transmission and receiving devices and network components. Developers rely on their understanding of electrical engineering fundamentals to design wireless device hardware.

Electrical engineers constitute the bulk of the workers in this domain. These telecommunication engineers typically have bachelor's degrees emphasizing knowledge of mixed-signal circuits and RF theory. Increasingly, a master's level degree or higher is required to enter this field. **There remain many support level roles in this field for electrical technicians, specifically in conducting experiments testing wireless designs. Candidates with two-year degrees that emphasize Electrical Engineering techniques can fill these positions. These technicians need to know basic electronic circuit concepts and how to use test equipment to evaluate circuits.**

Employees attracted to this field have an affinity for physical sciences and problem-solving. Most are interested in both how technology works and how it is used. This field also allows for great creativity in problem-solving. Employees that enjoy interacting with customers often gravitate to the applications engineering and support side of this domain.

Table 5   Examples of Device Hardware Occupations

Design	Production
RF/Analog Circuit Designer	Test Engineer
Circuit Validation and Test Engineer	Package Engineer
Digital Signal Processing Circuit Designer	Quality Assurance Engineer
Applications Engineer	Quality Assurance Technicial
	Process Engineer
	Product Engineer
	Test Technician
	Equipment Engineering Technician

Hardware Engineer salaries in Texas start around $47,000 annually, with median salaries of nearly $73,500 (BLS, 2004). Experienced wireless hardware engineers garner salaries in excess of $105,000, however, engineers in this field are experiencing downward salary pressure from competition from lower cost Asian labor markets (EE Times, 2003). Electrical engineering technician salaries start around $28,000 with median salaries of nearly $45,000. Engineering technicians that distinguish themselves can earn nearly $70,000 annually.

Figure 37   Texas Device Hardware Salaries
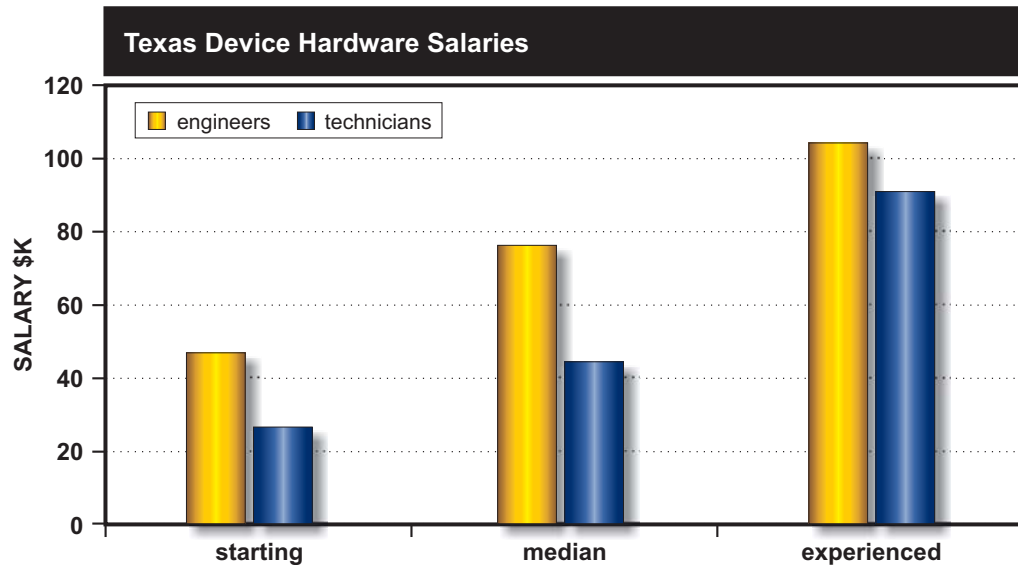
Source: Bureau of Labor Statistics

Infrastructure Jobs and Salaries

Infrastructure Jobs include engineers and technicians who build broad level systems around wireless hardware. These systems mesh with conventional communications infrastructures such as fiber optic backbones. For example, companies that create and deploy cellular communication systems fit into this category. Software engineers also play a large role in wireless infrastructure development as they create algorithms to control hardware components. In addition, security experts play a key role in this work domain. Due to the open broadcast nature of wireless devices, data security presents a unique challenge to companies that employ wireless capabilities. **Our survey shows that employers place a premium on employees with network security expertise.** Companies are hard at work devising ways to ensure secure communications through wireless infrastructures.

Wireless systems engineers use network design principles to create useful infrastructure. They often manage projects from design to testing to deployment stages. Cell site technicians also fall into this category. These technicians install, test and maintain wireless communications infrastructure sites. Wireless systems engineers typically have bachelor or master degrees in Electrical Engineering. Degrees in computer science with an emphasis in computer networks are also highly desired. **Technicians may have an AAS degree in electrical engineering technology, preferably with a certificate in computer networks or telecommunication technology. The most often requested certification is for network security.** This job domain has much overlap with the preceding wireless device domain and the following software application domain.

Table 6   Examples of Wireless Infrastructure Jobs

Hardware	Software
Switch Engineer	Wireless Software Network Development
Switch Technician	Software Quality Technician
Network Technician	Network Security Engineer
Wireless Systems Engineer	
Cell Site Technician	

Figure 38   Texas Infrastructure Salaries
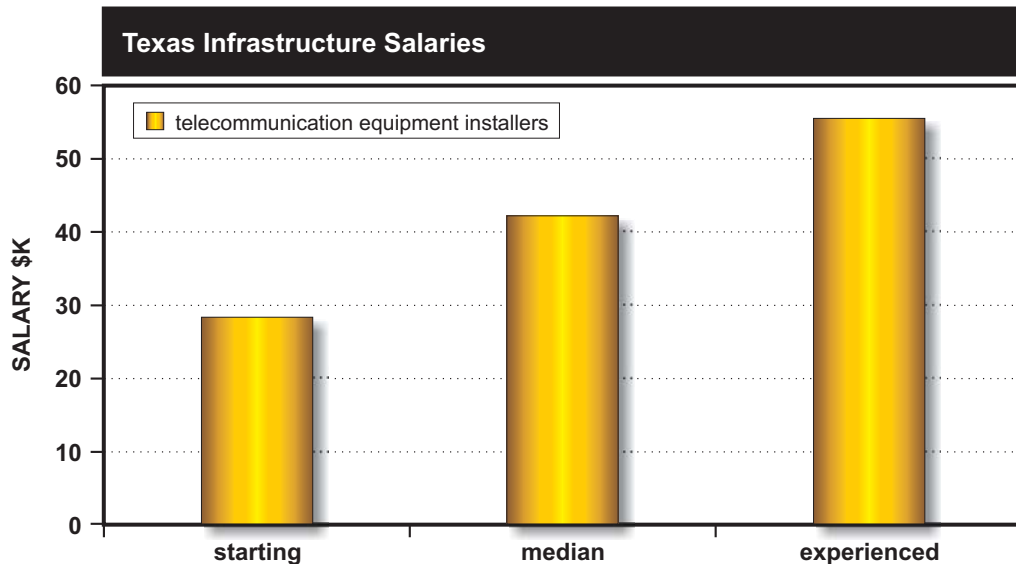
Source: Bureau of Labor Statistics

The number of installers, testers and field personnel required by industries using M2M wireless applications will increase with adoption and deployment of the technology. The number of embedded hardware and software engineers nationally will increase at a compound annual growth rate of 7.3% with the embedded software industry growing at the higher rate of 8.6% (Guaning, 2003, p. 1).

Software Application Jobs and Salaries

The software application domain includes software system architects and application software writers. This group works closely with business analysts to evaluate current business problems and then create software solutions to address those problems. Traditional software employees can create wireless-based applications, although software team members may need to learn the unique transmission and security protocols necessitated by wireless communications. M2M wireless applications can serve a wide variety of needs from tracking company inventory to monitoring environmental pollution.

Companies prefer software engineers and programmers who have experience in applications development. Many programmers have degrees in computer science, but experience can be substituted for various forms of formal education. Entry-level positions exist for software programmers who have been trained in the latest computer languages. In wireless M2M, the most relevant languages are J2ME, C, C++ and processor specific assembly languages (Giguere, 2004).

Table 7   Examples of Software Application Jobs

Software Engineer

Lead Application

Developer Database

Development Software Quality

Figure 39   Texas Software Salaries
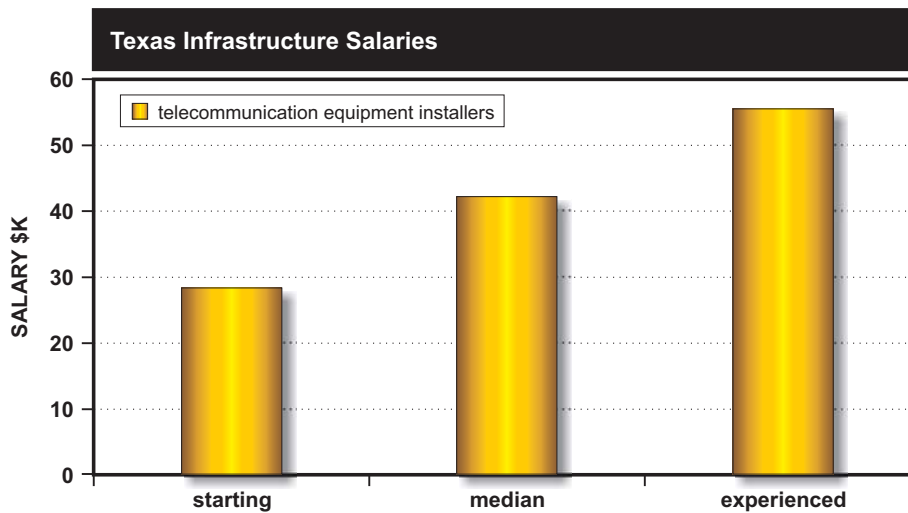
Source: Bureau of Labor Statistics

Systems Level Integrators

Systems level integrators modify and assemble existing disparate hardware and software to create a unified business solution. For example, an agricultural firm may join moisture sensors, wireless networks and proprietary software to create an automated irrigation system. This field requires analytical skills to determine new uses for existing tools. Systems level integrator jobs are often found in consulting firms or value-added resellers.

Key knowledge points required for this field include LAN and WAN architectures, wireless security requirements and knowledge of the industry for which the solution is proposed. Employees in this domain often write software to manage the interaction between the components that they are integrating. Technicians in this field require primarily the same skills as technicians employed by infrastructure developers. Technicians often interface with customers, placing greater importance on communication skills.

Table 8   Examples of Systems Level Integrator Occupations

Business Management	Product Development
Business Analyst	Firmware Programmer
Market Researcher	Quality Assurance
Systems Sales	Technician Network Architect

Figure 40   Texas Systems Integrator Salaries
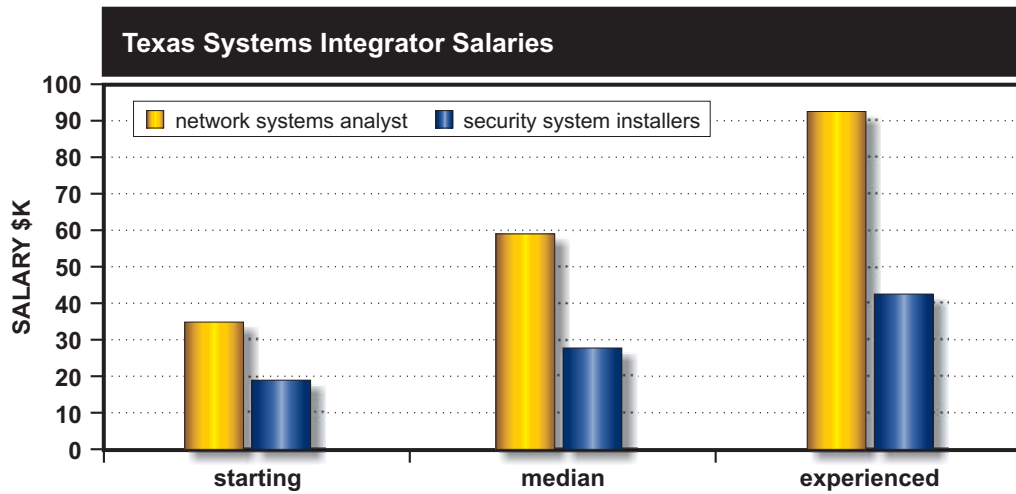
Source: Bureau of Labor Statistics

System Operator Jobs and Salaries

Wireless system operations require a multitude of employee types. Positions in this domain include help desk employees who troubleshoot problems for customers; system maintenance technicians who perform routine and emergency maintenance on deployed wireless systems and data analysts who aggregate information retrieved from wireless systems to provide useful intelligence. This domain is projected to provide the most entry-level jobs for technical school graduates.

Help desk employees need knowledge of common wireless LAN problems as well as training on the specific system for which they are providing support. For instance, if the product solution provided is for wireless access to patient medical records in a health care setting, then these technicians will need to understand both the application software interface and networking concepts.

Both written and oral communication skills play a major role in these jobs. Help desk employees must decipher customer concerns and then determine appropriate recommendations. Employers look for workers with the requisite technical knowledge often provided by AAS programs.

Systems maintenance also requires problem-solving skills and knowledge of component capabilities. The trend in machine-to-machine or machine-to-human communications systems is modular design. This trend results in technicians simply replacing boards with

suspected defective devices as opposed to diagnosing problems at the individual device level. Again, the system type varies depending on the targeted application. Systems in use today include GPS, RFID and cellular based communications. Applications already in use include factory asset tracking, delivery service vehicle tracking and remote utility meter monitoring.

Data analysts require training in database management and utilization. Knowledge of statistics and data mining concepts is also useful. Need for analysts will increase because wireless systems will allow economical collection of massive amounts of new data.

The level of automated data analysis in a system determines the appropriate employee expertise level.

Table 9   Examples of Systems Level Integrator Occupations

Technical	Service Support
Cell Site Technicians	Help Desk Technician
Electrical Technicians	Database Administrator
	Data Analyst

Figure 41   Texas System Operator Salaries
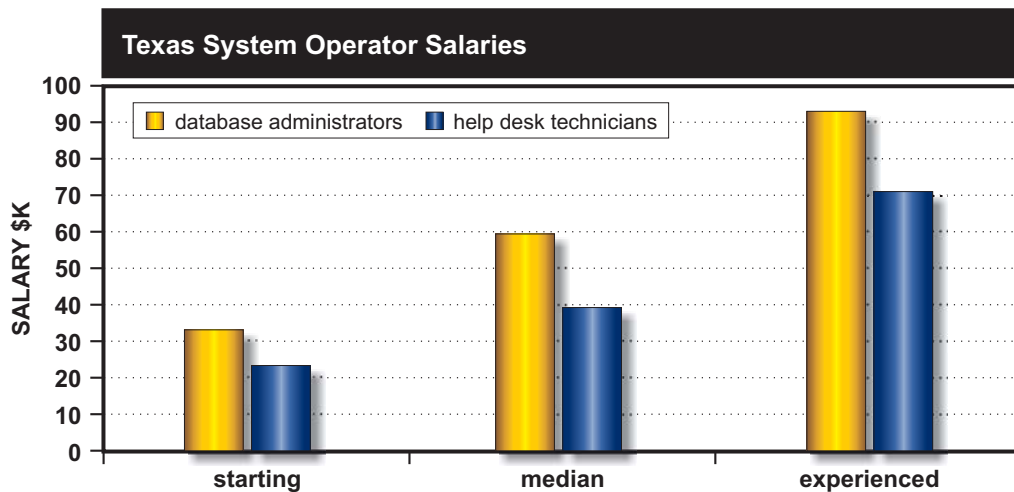
Source: Bureau of Labor Statistics

Entry Level and Future Jobs

Due to the evolving nature of this industry, positions will be available for graduates with the latest training. **Entry-level jobs into the wireless field include apprentice hardware installers, apprentice maintenance personnel, software programmers and customer service/help desk positions.** Most employers seek experienced workers with high education levels to act as systems architects or device-level designers.

Much job growth related to wireless technology is anticipated in applications such as logistics, asset management and remote machine monitoring. Already, major retailers are

experimenting with RFID tags to track inventory, while shipping companies are tracking their trucks through GPS devices. Employment opportunities will increase for employees who are able to adapt to the new mobility capabilities provided by wireless communications.

Table 10 shows currently available positions across several fields that enable and utilize M2M technology. KSAs for the highlighted positions are provided in the appendix for illustrative purposes.

Table 10   M2M Occupations

Markets	Software Applications	Systems Integrators	Service Operators
Healthcare	Software Architect **Application programmer** Business Analyst	Wi-fi installer Network architect	**Help Desk Technician**
Industrial	Machine communications software programmer Smokestack pollution control software Firmware developer	**Machine communications technician** Quality assurance technician	Machine communications maintenance technician
Home	Game programmer Firmware developer	Home automation installer	Help Desk technician **Neighborhood antenna maintenance technician**
Retail / Wholesale trade	**RFID software systems developer** Inventory systems developer	802.16 installer Theft prevention system installer	RFID operator
Transportation/Logistics	Geo-location programmer **Software test technician**	Microwave communications technician **Vehicle tracking system installer** 802.16 installer	Telematics maintenance technician Fleet dispatch operator
Education	Education game programmer	**802.11x installer**	Wi-fi maintenance technician
Homeland Security	Sensor control software developer	**First response communications system installer** Network security tester Security analyst	Criminal database administrator
Utilities	Wireless meter software developer	Remote thermostat controller Pipeline monitoring	Meter repair technician **Asset management specialist**
Government	Traffic system developer	Police dispatch solution architect WAN security tester	Public WLAN administrator
Agricultural/ environmental/ structural monitoring	**Irrigation control software developer**	Seismic warning system architect Forest fire sensor installer	**Water quality technician** Wind speed data analyzer

Workforce Need: Survey Analysis and Recommendations

Comparing favorably with projected strong growth in the M2M industry (see Markets chapter), respondents to the survey overwhelmingly indicated they would be hiring new and replacement employees. A preponderance of small and start-up companies in the survey sample most likely explains the dominance of small projected numbers for new hires (1 to 10 employees over the next three years). However, of this range, the choice "6 to 10 hires" comprised the larger percentage of responses.

The M2M industry is in an emerging stage, so it is difficult to determine the exact workforce needs. Given this, educational institutions should determine need through local outreach.

Recommendation: *Create outreach tailored to small to medium size M2M technology companies, entities involved in homeland security and large enterprises that require M2M technology, including critical infrastructure, emergency response systems and heavy industry.*

There is potential support for colleges and companies partnering for curricula development, continuing education and workforce development. The jobs considered by respondents to be most in demand are wireless systems engineers, security specialists, system architects and application engineers. These are not, however, entry-level jobs. **This data supports the expressed need of respondents for experienced people in an emerging technology, creating an overwhelming opportunity for continuing education.**

The greatest need will be for experienced people. As a result, there is potentially strong support for companies to finance their employees' continuing education. The level of support for at least partial funding of continuing education on the part of respondents bodes well for technical colleges.

Recommendation: *Based on these findings, community and technical colleges should create a program whereby engineers experienced in other disciplines can receive continuing education. Curricula should respond to industry demand for M2M wireless and security.*

Preferred educational attainment levels are split between undergraduate and those with certifications or degrees. This is an indication that jobs will be available across a spectrum of expertise. It is positive news especially for technical colleges that provide outplacement directly to employers or transfers to a university for attainment of an advanced degree.

Recommendation: *Create curricula for students to exit to market after two years (with a degree or certificate) and create continuity between two-year and four-year educational institutions in the form of articulation agreements ensuring transferability of credit between institutions.*

Prominent jobs such as Electrical Engineer and Systems Administrator are expected to exhibit much less demand in the M2M space than are specific area experts, such as wireless, security and RF engineers.

Recommendation: *This educational demand shift suggests the need for workforce candidates with specific application experience rather than general knowledge; institutions seeking differentiation should respond accordingly.*

The responses regarding entry-level job positions are almost inverted versus expected high-growth jobs. Of the top seven high-growth job positions, all but one fell to the low end of the entry-level rating. Applications Engineer was the only high-growth job deemed entry level by 19% of respondents.

Recommendation: *Educational institutions seeking to train new hires should focus on M2M application engineering and respective technologies.*

Other jobs indicate a level of experience needed, again reinforcing respondents' preferences for experienced hires.

The top two choices for which types of certifications lend credibility to employees (computer systems/networking technology and network security) corroborate the top two highest job growth choices (wireless systems engineers and security specialists). There is little clarity in the breadth of responses for this issue, except that wireless systems and network security both appear important.

Recommendation: *M2M curricula should focus on wireless and security.*

Responses show clearly that human resources are by far the most important resource needed in the next three to five years, and experienced people are most preferred.

Recommendations from Experts

Expert interviews were conducted to inform curricula recommendations and workforce needs. The following represent statements of consensus or points made by specific experts. Among the experts interviewed, there was consensus on the following:

- **The current labor pool for M2M industry employees is vastly behind the industry needs.** M2M technology is moving at a very fast pace to disrupt existing market and industry players. Therefore, much of the innovation in this burgeoning industry will come from M2M pure play start-ups rather than from the legacy telecommunications industry.

  Recommendation: *Colleges should seek partnerships with large enterprises adopting this technology.*

- **Almost all experts echoed that M2M growth will be similar to the growth in the Internet from 1994 to the present.** "Many people do not see this coming even though the writing is on the wall" (Kuykendall, 2004). The primary catalysts for this industry are defense and homeland security. Growth will likely eclipse analyst predictions.

- While M2M will automate many job tasks, other jobs will be created in order to monitor and maintain systems.

  Recommendation: *Curricula should emphasize a combination of embedded control, networking and security. Further, the curricula should feature substantial hands-on experience (the most commonly iterated suggestion from experts).*

- New paradigms are emerging, the most important of which is augmented reality - the overlay of data and knowledge on the physical world.

- Ideally, curricula will blend engineering, human performance, simulation and modeling for M2M.

  Recommendation: *A special focus is needed in new media and human performance related to Human-to-Machine Cooperation (HMC) as the environments of M2M control are shifting from windows-like interfaces to computer visualization and 3-D video game-like environments.*

- Historically, people interested in a technology field as a career typically pursue that technology as a hobby in their young life. **The ideal situation would be to foster interest in complex systems, cybernetics, robotics and networking in youth.** It is

difficult to leap high school graduates with current attainment levels in mathematics, science and engineering to the new levels of knowledge and skill required for success in these complex operating environments.

Recommendation: *Programs should be developed to enable young people to have hands-on experience with these technologies at a very young age. Encouragement and support of constructive hacking was the most commonly suggested knowledge acquisition process for young people.*

- While the technology piece is important (that is, training future employees in the proper technical grounding), so is the business side of the equation. At some point, products tend to become commoditized. It is services that become important in satisfying customers and making money—thus, the sales and marketing engineers of the future M2M market are also important for their business acumen.

Technological Shifts Driving Workforce and Education Requirements

The technology in the M2M industry will require a workforce educated in wireless, embedded systems and Internet technologies. Major trends in the emerging M2M industry that necessitate new curricula include fundamental technological shifts. These displace old technologies and methods and require workforce retraining and new hires with new knowledge, skills and abilities. These technological shifts include:

- **Shift from Cellular Networks to Hybrid Networks.** In the past, commercial M2M networks have primarily used cellular wireless communication. They are now inclusive of fixed-line, cellular, wireless and hybrid networks (multiple network types for one application).

  Recommendation: *M2M curricula should incorporate hybrid networking with a focus on inter-networking rather than an exclusive focus on one delivery medium such as cellular, 802.x or DSL.*

- **Shift from analog to digital.** Legacy cellular networks are analog, while telecommunications networks in the US and globally are now converting to digital standards.

  Recommendation: *M2M curricula should focus on digital communication and conversion from analog to digital communication (especially in telematics applications where analog terminals will be phased out in 2006). Colleges should seek partnerships with major analog telematics users to develop a workforce skilled in conversion from analog to digital systems. Local police, fire, ambulance, taxi and fleet managers are candidates for partnerships.*

- **Shift from proprietary protocols to open Internet protocols.** TCP/IP Internet is the emerging standard for virtually all communication systems. Internet Protocol version 6 (IPv6) is the emerging protocol of import to M2M communications.

  Recommendation: *Curricula should focus on both legacy and open systems protocols, especially IPv6.*

- **Shift from proprietary industrial and military bus structures to open systems.** M2M systems of the past can be compared to the Mainframe and Mini generation of computing. M2M was based on proprietary operating systems, protocols and Application Programming Interfaces (APIs), however, emerging M2M technologies are based on Open Systems.

  Recommendation: *Curricula should emphasize proprietary bus structures and Open Systems within the context of specific applications (such as RFID, Asset Utilization and Tracking, Building Control, Physical Security, etc.).*

- **Shift from centralized and decentralized computing architectures to distributed and ad hoc network architectures.** M2M architectures of the past were based on centralized and decentralized computing models. Because of economic and security requirements, emerging M2M architectures are distributed and ad hoc systems, exhibiting flexibility and dynamic network configuration.

  Recommendation: *Curricula should emphasize new computing architectures, especially P2P and ad hoc networking.*

- **Shift from Local Area Networks (LAN) to Network of Networks.** Many legacy M2M systems are based on closed LAN or WAN environments that are now being connected into a system-of-systems within the context of the Internet.

  Recommendation: *Curricula should emphasize inter-networking and "network of network" concepts.*

- **Shift from stand-alone control networks to inter-networked control networks.** Legacy M2M networks are largely stand-alone networks, whereas emerging M2M networks form an interconnected ecosystem of networks which trigger events from one control system to another.

  Recommendation: *Curricula should emphasize messaging between and across control networks, for example, messaging across environmental sensing, environmental control and physical security.*

- **Shift from non-encrypted networks to encrypted networks.** Legacy M2M networks are for the most part non-encrypted, while emerging M2M networks are protected by encryption and information assurance techniques.

  Recommendation: *Curricula should emphasize Information Assurance and cryptography.*

- **Shift from passive control networks to active event-based management.** Legacy M2M networks are generally geared toward data collection and passive monitoring. Emerging M2M networks actively monitor and trigger responses in the network and the network's control environment.

  Recommendation: *Where appropriate, and according to application requirements, curricula should emphasize event-based management, automatic control systems and intelligent systems.*

- **Shift from monolithic systems to a system-of-systems of very small devices.** Legacy M2M systems are monolithic, whereas emerging M2M systems are composed of many inter-related systems all of which share a common trait—a small footprint. This shift in M2M technology requires engineers to have experience writing very small applications that have precise code and object architecture to call remote functions.

  Recommendation: *Curricula should focus on Object Oriented techniques relevant to small foot print devices in a network of networks environment.*

- **Shift from physical, centralized operations centers to virtual, distributed operations.** Legacy operations centers are centralized, physical environments. Emerging M2M operations enable field accessible Command and Control (C2) interfaces and virtual teams of people to interact across geography.

  Recommendation: *Educational institutions seeking differentiation should focus on issues related to Human-to-Machine Collaboration (HMC), Human Systems Integration and Human Performance. Ideally, curricula will unite new media and human performance to create a new generation of designers capable of designing systems and environments for distributed operations.*

M2M Technologies: Survey Analysis and Recommendations

802.11 LAN, GSM and RF dominate the technologies expected in future product offerings. This is not surprising, given the installed base of 802.11 and RF. As one industry expert pointed out, "people are still investing in Wi-Fi networks…you can't walk away from an installed base." (Interview, Stumberg). And, although GSM has lagged behind in the United States, momentum is gaining as providers realize, as Nokia has, that GSM can facilitate M2M networks currently under development.

In addition, interviewed industry experts agreed that given the momentum and the amount of investment in 802.11 products and services, this technology will be dominant in the near future.

M2M pervasive computing is a major target application for survey respondents. AUT and industrial/control are also applications with strong future interest. As has been noted, a significant portion of the survey sample was start-up and small firms. This M2M focus supports the trends explained in the industry research and evaluation, citing that a surge of start-ups would help propel focus on a strictly M2M space.

Trends such as mobile/fixed-line interoperability, open systems and interoperability of devices, are expected to be of most significance for respondents. This data supports our conclusion that convergence and open systems are key factors driving M2M adoption. As discussed in the Industry chapter research, the actualization of these two trends is key to achieving ubiquity in the M2M movement. In addition, as discussed in the Market chapter research, a key driver of the M2M market overall is adoption of Open Systems standards.

The technology standards expected to be important in the near future are not surprising; WLAN, Wi-Fi and RFID are in the top four choices of technology that respondents plan to use in the next three years. Wi-Max is also strongly in the mix, as are VPN, WPA, XML and BlueTooth.

The proliferation of protocols has both its positive and negative aspects. One serious negative is the confusion that different standards create for the average consumer. However, as industry experts pointed out, multiple protocols/standards do not have to slow down M2M adoption. The use of standards is application driven, and having different standards that excel in specific applications creates a more robust data network for those applications.

Wireless Competencies and Skill Standards

Because the primary focus of the industry is on the deployment of secure wireless networks, **The Global Wireless Education Consortium's competencies and the Washington State Skill's Standards for Wireless Communications serve as an excellent framework for M2M curricula.**

Global Wireless Education Consortium's (GWEC) competencies include:

- Understanding of computer networks.

- Understanding of electronics and radio communications.

- Strong problem-solving skills.

- Strong communication skills.

The Global Wireless Education Consortium (GWEC) is a collaboration of wireless industry companies and academic institutions focused on expanding wireless technology curriculum in academic institutions worldwide. **GWEC offers education and industry members online access to forty-six complete curriculum modules with Instructor Guides. GWEC may be found on the web at GWEC.org.**

The Global Wireless Education Consortium, partnered with the Seattle Central Community College, North Seattle Community College and Bellevue Community College to produce "Skill Standards for Wireless Communications" (Mitchell, n.d., p. 4).

Washington State's Skill Standards for Wireless Communications include:

- Radio Transmission – RF Theory
- Switch/Basic Data Communications
- Switch/Basic Switching Systems
- Transmission and Trunking
- Switch/Basic Telephony Systems
- Switch/Reuse and Planning
- Switch/Basic Data Networks
- Communications Circuit Design
- Air Interface Technologies
- RF Propagation
- Digital Voice Coding
- Microwave Systems
- Power Plant
- Test Tools/Equipment Software
- Regulatory/Standards/Conventions
- Health and Safety
- Electromagnetic Compatibility (EMC)

(Mitchell, n.d., p.13-14)

Although these skill standards are applicable to wireless telecommunications, authors of this report could not find any skill standards developed for M2M technology specifically. This presents the state of Texas with an opportunity to lead the nation in the development of integrated skill standards inclusive of M2M, wireless and security as a whole.

Recommendation: *State curricula studies should be funded to secure Texas leadership in this emerging space. Texas should seize this opportunity and be the first entity in the world to create a certificate program for M2M Wireless and Security.*

Expert Curricula Recommendations

John Green from the Austin Telecommunications Council offered the following issues and recommendations for M2M Curricula.

Operating Context

- Provide an operational Mobile IPv6 network environment supporting a variety of user communities and a wide range of demanding applications.
- Trials of new services in the real world environment that will roll out to business consumers over the next several years.

- Investigation of deployment strategies for large Mobile IPv6 networks and experimentation throughout the actual roll-out phase.

- Examination of service deployment and interoperability tests with new network technologies, protocols and services that require access to production systems.

- Context and location-aware ubiquitous services for users on the move. This will add a degree of complexity most network services and web services have never dealt with before regarding mobility and across wireless technologies.

- Issues arising from IPv4/v6 transition, Quality-of-Service and Network Management in mobile environments.

- Enhanced support for Mobile IPv6 networks, such as auto-configuration, ad-hoc networking, handoff optimization, security and adaptive applications.

Recommendations

This operating context requires M2M curricula to combine troubleshooting techniques and a systems-oriented approach similar to the approach CI SCO uses with its network certification processes. Curricula recommendations include:

- M2M learning environments need to be inquiry-based and immersive, where students are allowed to learn by trial and error.

- The learning environment should be lab-based and supportive so that repeated failure is supported by instructor direction and feedback.

- Many M2M devices: routers, switches and gateways require command-line training rather than windows-based environments. M2M technicians will need advanced training similar to CISCO technicians.

- Peer collaboration will be important to M2M learning because technicians will often work in teams to deploy M2M systems. **Cross-disciplinary communication, teaming and project management skills should be emphasized.**

- Curricula should blend behaviorist, cognitive and constructivist pedagogy to enable learning. The curricula must be structured so that tasks build onto each other, but require integration at various points in time throughout the curricula.

- Real world operating systems should be used in the lab with a focus on Internet connectivity and the availability of computing resources from home as well as physical lab environments. Availability of network resources from school and remote locations will be a clear competitive advantage for educational institutions.

- Currently, CISCO certified training is the benchmark for the network infrastructure training industry. Similar to CISCO, M2M curricula should leverage simulations and virtual environments for early, basic training. After introductory training, hands-on equipment availability is essential.

IC² Institute's vision is a quest for constructive forms of capitalism that will allow communities and nations to grow and prosper.

IC² (Innovation, Creativity & Capital) Institute is an international, transdisciplinary "Think and Do" tank devoted to solving unstructured problems to accelerate wealth & job creation and shared prosperity at home and abroad. As a research unit at The University of Texas at Austin, IC² is focused on knowledge exploration, dissemination and application, across a broad range of academic and applied areas.

IC² Institute's "Think and Do" research results are articulated and disseminated through IC²'s varied educational programs, conferences & workshops and publications. IC²'s "early experiments" such as the Austin Technology Incubator (ATI), The Capital Network, and the Austin Technology Council, are ongoing activities that continue to contribute to the Austin region's tech-based growth, and continue to serve as "experiential learning laboratories" nationally and internationally.

In addition to ATI, IC²'s core programs include IC² Institute Fellows, Commercialization Training & Consulting, Masters of Science in Science and Technology Commercialization (MSSTC) degree and Visiting Scholars. These programs expand the Institute's international network of talent and educational outreach. IC²'s "new experiments" such as the Clean Energy Incubator (CEI), Cross Border Institute for Regional Development (CBIRD) and the Digital Media Collaboratory (DMC) continue to apply IC²'s vision in new ways, improving quality of life and promoting civil societies at home and abroad.

Dr. George Kozmetsky (1917-2003) founded the IC² Institute at The University of Texas at Austin in 1977 while he was Dean of the College of Business Administration and the Graduate School of Business. Kozmetsky, a lifelong educator, was the co-founder and former Executive Vice President of Teledyne, Inc. and was awarded the National Medal of Technology in 1993 as an acknowledged expert in –and champion of–high technology entrepreneurship. The Institute is currently under the leadership of Dr. John Sibley Butler, Director, and Dr. Alex Cavalli, Deputy Director.

Jim Brodie Brazell is a consulting analyst, IC² Institute, President, VentureRamp, Inc. and co-founder of DevicePoint, Inc. Jim's work with IC² Institute focuses on emerging technologies and their relation to science, education and the workforce. He is also a member of the Digital Media Collaboratory focusing on the application of "serious games" to various fields of human development.

Jim is involved in several initiatives to connect Technology, Engineering, Art, Mathematics and Science (TEAMS) to education and workforce. He is on the advisory board of the Digital Charter School for Military Aviation (San Diego-Orlando-Austin-San Antonio), the Digital Convergence Initiative (San Antonio-Austin-Waco) and the Learning Strategies Consortium (USA).

Jim is an active member of the San Antonio and Austin high-technology communities, including the San Antonio Technology Accelerator Initiative (SATAI), Technology Advocates of San Antonio (TASA), San Antonio Council for the Cooperation of Scientific and Technical Societies (SACCESS), the Information Technology and Security Academy (ITSA), the Corridor Nano-Bio-Tech Summit and IC² Institute.

Jim received his Bachelor of Science, Sociology, Summa Cum Laude, Bradley University, Peoria, IL, 1995.

Laurel Donoho is a principal and co-founder of VentureRAMP. Prior to VentureRAMP, Ms. Donoho served as a director of research at Frost & Sullivan. In Laurel's twenty-plus years of business experience, she has authored numerous market research reports and been involved in a wide range of strategic consulting projects. She has advised clients on market trends, implications, and strategies on such diverse topics as wireless sensors, nanotechnology, consumer and commercial electronics products, industrial measuring and monitoring equipment, medical markets and state/local community business development projects.

Publications include North American Industrial Wireless Sensors Markets, World SCADA Systems Markets, United States (US) Condition Monitoring Markets, US Process Control Instrumentation Markets, World Flow Sensor Markets, World Level Sensor Markets, Analysis of the US Residential High End Audio and Video Market, North American Commercial and Professional Audio Markets and Financial and Structural Analysis of the World Sensor Industry.

Laurel received her MBA (with a specialization in marketing) from San Jose State University and graduated Magna Cum Laude with a BA in History from Point Loma College. She is an active member of the San Antonio and Austin high-technology communities, including service to the San Antonio Technology Accelerator Initiative (SATAI), Technology Advocates of San Antonio (TASA) and IC² Institute.

John Dexheimer is a partner in First Analysis Private Equity Fund IV (specializing in sensor-based products and services), is a founder of DS3 Partners, and has been president of LightWave Advisors Inc. since 1999. John has advised or led investments in more than 100 completed company financings and mergers in software, communications, electronics, and optics, including transactions involving Philips, SAIC-Telcordia, JDS Uniphase, Novell, EMC, EDS, United Technologies, Cisco, KLA, Intel, Raytheon and Computer Associates.

As a managing director of C.E. Unterberg, Towbin from 1990 to 1999, he led the IPO of Uniphase and its early acquisition growth that transformed it into an industry leader. He also managed the equity research and venture organizations of C.E. Unterberg, Towbin. Prior to 1990, he was in the software industry with General Electric, Data Resources Inc., and Broadview International. He has helped found start-ups from lab spin-outs and has led several turnarounds. He is an advisor to the National Science Foundation-funded Institute of Mathematical Applications. John earned an MBA from Harvard University and a bachelor's degree from the University of Minnesota Institute of Technology.

Dr. Robert Hannemann is a founder of DS3 Partners and, through Atlantic Technologies, provides senior management assistance, including serving as CEO, to advanced technology firms. He was previously vice president of strategic business development for Corning Inc., focused on acquisitions and equity investments in photonic components and systems for telecommunications. Rob joined Corning via its acquisition of Oak Industries, where he was president and general manager of its Lasertron division from 1996 to 1999.

From 1978 to 1996, he worked at Digital Equipment Corp., where he was general manager of Digital's printing systems business after managing R&D, design, technology and manufacturing organizations focused on semiconductors and electronics. Early in his career he was employed by Bell Laboratories and was a faculty member at the University of Maryland. Rob received his Sc.D. in mechanical engineering from the Massachusetts Institute of Technology and is the author of numerous journal articles and other publications as well as a lecturer in microelectronics and photonics packaging and thermal control. He holds three patents.

George Langdon is an engineer by training, having worked in that capacity at both Allied Signal Aerospace and Motorola Semiconductor. George's work experience includes producing control software for commercial radar and managing product testing of 8-bit microcontrollers. While with Motorola, he gained knowledge of wireless devices and machine-to-machine communication. Recently, he has worked on commercializing portable electronic battery technologies developed at The University of Texas at Austin, concentrating on market and competitor analysis.

George's current interests include emerging technologies in clean energy production and entrepreneurship. He works as a research intern for the Clean Energy Incubator. George has a Bachelor of Computer Engineering from the Georgia Institute of Technology and is currently pursuing an MBA from The University of Texas at Austin.

Eliza Evans, PhD, manages the research program at the IC^2 Institute, University of Texas at Austin, where she identifies economic development opportunities in emerging technologies and the economic and social infrastructure to support the growth of knowledge-based companies. Her recent and current work directly related to economic growth and business development in Central Texas includes "Catching the Next Wave: The Convergence of Biotechnology, Nanotechnology, and Information Technology and How the Temple-Austin-San Antonio Corridor can Benefit," "Enriching Economy and Environment: **Making Central Texas the Center for Clean Energy,**" "The Wireless Future: Opportunities for Austin and Central Texas," an analysis of the structure of Central Texas' technology-based business, and development of a regional partnership to assist small technology firms in gaining access to global markets and capital. Her work in economic development, regional innovation systems, and innovation networks has taken Dr. Evans to Western Europe, Russia and the CIS, and South Asia.

Dr. Evans served as professional staff on the U.S. House of Representatives' Education and Labor Committee and has an extensive background in public policy analysis and evaluation of programs related to education and workforce development, high school dropout prevention, math and science education, and tech prep. She holds an MA and PhD in Economic Sociology from the University of Texas at Austin and a BA from Oberlin College.

Appendix: Texas Wireless Educational Programs

College: UT Austin - Wireless Networking & Communications Group, Austin
Website: www.ece.utexas.edu/wncg
Contact: Professor Theodore Rappaport, Director
512.471.2600
Focus: Wide ranging research in six specific areas: propagation and antennas; modulation and coding; signal processing; sensor and ad-hoc networks; network security; network characteristics

College: Rice - Center for Multimedia Communication, Houston
Website: cmc.rice.edu
Contact: Behnaam Aazhang, Director
aaz@rice.edu
Focus: Research in digital signal processing; QoS for networks; and VLSI for signal processing

College: Southern Methodist University, Dallas
Website: engr.smu.edu/ee/research_department.html
Contact: Mandyam D. Srinath Ph.D.
mds@seas.smu.edu
Focus: wireless antenna research; signal processing; telecommunications

College: Texas A&M - Wireless Communications Lab, College Station
Website: wcl3.tamu.edu
Contact: Dr. Costas N. Georghiades, Director, Wireless Communications Lab
georghiades@ee.tamu.edu
Focus: Broad research done on communication systems with an emphasis on wireless networks.

College: UT Arlington - CReWMaN Lab, Arlington
Website: crewman.uta.edu
Contact: Professor Sajal K. Das, Director, Crewman Lab
das@cse.uta.edu; 817.272.7405
Focus: Research on wireless mobile computing, networking, multimedia, and distributed computing

College: UT Dallas - Center for Systems, Communications and Signal Processing, Richardson
Website: www.ee.utdallas.edu/cscsp.html
Contact: Dr. Kamran Kiasaleh, Director, Multimedia and Mobile Communication Lab
kamran@utdallas.edu; 972.883.2990
Focus: Conduct research on systems, communications, and signal processing

College: UT El Paso - Signal Processing and Communications Group, El Paso
Website: http://www.ece.utep.edu/research/webspc/wwwdocs/
Contact: Dr. Sergio D. Cabrera
cabrera@ece.utep.edu; 915.747.5377
Focus: This lab specializes in student / faculty collaborative research of areas related to signal processing

College: UT San Antonio - Center for Infrastructure Assurance and Security, San Antonio
Website: www.utsa.edu/cias/research.html#wire
Contact: Dr. G.V.S. Raju
Focus: wireless encryption

College: University of Houston - Telecom Center, Houston
Website: www.egr.uh.edu/telecom/
Contact: David Nghiem - Director of the Telecom Center
outreach@egr.uh.edu; 713.743.4220
Focus: New lab for telecommunications research

College: Dallas County Community College District, Dallas
Website: www.dcccd.edu/vcea/dtechp/wireless.htm
Contact: hah1661@dcccd.edu
Focus: Training for Wireless Communication Technician; courses on wireless telephony; recently added courses on wireless LAN

College: North Harris Montgomery Community College District - Tomball College, Tomball
Website: eps.nhmccd.edu/DegreesCert/ENGTECH.htm
Contact: Tcinfo@nhmccd.edu; 281.351.3300
Focus: AAS degree in Wireless Telecommunications Engineering Technology; Wireless Telecommunications Technician Certificate

College: Collin County Community College District, Dallas
Website: www.ccccd.edu/cs/areasofstudy/programmaster1.html
Contact: Pete Brierly - Program Chair
972.377.1686
Focus: AAS degree in Telecommunications Technology; recently added classes in wireless technology

College: Houston Community College System, Houston
Website: swc2.hccs.cc.tx.us/contech/wireless.htm
Contact: 281.491.9358
Focus: Certified Wireless Network Administrator program

College: Texas State Technical College, Waco
Website: waco.tstc.edu
Contact: 800.792.8784
Focus: Certificate - Global Communications System Installer; Certificate - Radio Communications Electronics; AAS - Telecommunications Technology

College: ICC Institute: Digital Media Collaboratory, Games Development Institute, Austin
Website: www.ic2.org/main.php?a=9&s=88
Contact: 512.475.8900
Focus: Provides workshops for high school teachers on wireless developments impacting education

Schools with Electrical Engineering but no wireless program per se

College: St. Mary's, San Antonio
Website: www.engr.stmarytx.edu/index.html
Contact: 210.436.3011
Focus: Undergraduate and graduate signal processing and communications courses

College: Lamar University, Beaumont
Website: hal.lamar.edu/~collengr/
Contact: eece@hal.lamar.edu, 409.880.8746
Focus: Bachelor, Master, and PhD degrees in electrical engineering with options for Communications, RF, DSP, and sensor networks

College: Texas A & M University, Kingsville
Website: www.engineer.tamuk.edu/departments/eecs/Faculty/Li/EE_Grad/grad.html
Contact: Dr. Sung-won Park
kfswp00@tamuk.edu
Focus: Undergraduate and graduate signal processing and communications courses

College: Texas Tech University, Lubbock
Website: www.ee.ttu.edu/ee/index.html
Contact: Dr. Pamela Eibeck, Dean, College of Engineering
Pamela.Eibeck@coe.ttu.edu; 806.742.3451
Focus: Major disciplines within Electrical Engineering with laboratories specializing in computer vision and imagery, and advanced vehicles

College: University of Texas, Tyler
Website: ee.uttyler.edu/
Contact: Dr. Ralph Hippenstiel
rdhippen@uttyler.edu; 903.566.7108
Focus: Major disciplines within Electrical Engineering

College: Texas Christian University, Fort Worth
Website: http://www.engr.tcu.edu/
Contact: Engineering@tcu.edu; 817.257.7677
Focus: Interdisciplinary engineering degree with an emphasis on electrical engineering

College: Baylor University, Waco
Website: http://www.ecs.baylor.edu/
Contact: ECS_Dean@baylor.edu; 254.710.3871
Focus: Major areas of study in electrical and computer engineering, Bachelor

College: University of California Irvine
Nation: USA
Website: www.unex.uci.edu/courses/certificate/specialized_wireless_com.asp
Contact: Rogelio Rodriguez
rcrodrig@uci.edu; 949.824.5380
Description: Provide a Specialized Certificate in Wireless Communications Systems
Engineering — part of UC Irvine's extension program

College: Chalmers University of Technology
Nation: Sweden
Website: www.chalmers.se/HyperText/MasterProgrammes/wireless.html
Contact: Joakim Johansson, Program Director
info-com@ep.chalmers.se; +46 31.747.3683
Description: Provides a Masters level degree in wireless communications hardware engineering

College: Auburn University - Wireless Engineering Education & Research Center
Nation: USA
Website: www.eng.auburn.edu/center/wireless/main/index.htm
Contact: Jo Ann Loden; jloden@eng.auburn.edu; 334.884.1825
Description: The first American university to award a Bachelor or Master of Wireless
Engineering - One of three universities awarded grants by the Vodafone US
Foundation Fellows Initiative

College: University of California Berkeley - Berkeley Wireless Research Center
Nation: USA
Website: bwrc.eecs.berkeley.edu/
Contact: Tom Boot
tmb@eecs.berkeley.edu; 510.663.3101
Description: Research is focused on single chip CMOS wireless transceivers for SOC design.
Courses are taught at the masters and PhD level.

College: Technische Universität Berlin - TKN (Technical University of Berlin -
Telecommunication Networks Group)
Nation: Germany
Website: www-tkn.ee.tu-berlin.de/
Contact: tknsekr@tkn.tu-berlin.de; +49.30.314.23819
Description: Research focused on protocols and architecture of communications networks.
Provides graduate level education.

College: British Columbia Institute of Technology
Nation: Canada
Website: www.bcit.ca/study/programs/548epdiplt
Contact: 604.434.5734
Description: Award a "Diploma of Technology" with a wireless Communications and
Computer Networks Option. This program lasts two years with the aim of
preparing students to become Engineering Technologists in the
telecommunications industry

College: Greenville Technical College
Nation: USA
Website: www.greenvilletech.com/
Contact: Russ Willard
russ.willard@gvltec.edu; 864.250.8509
Description: Technical community college which provides a certificate in wireless networking
technology

College:	Global Telecom University / Global Telecom Training Institute (International Telecommunication Union)
Nation:	Switzerland
Website:	www.itu.int/ITU-D/hrd/gtu/index.html
Contact:	+44 22.730.51.11
Description:	Masters level on-line business education aimed at telecommunications managers

College:	Institute for Wireless Education
Nation:	USA
Website:	www.iwe.org
Contact:	507.389.7275
Description:	Provides short courses in wireless technologies aimed at both technicians and non-technical employees

College:	Ridgewater College -Willmar & Hutchinson
Nation:	USA
Website:	www.ridgewater.mnscu.edu/OldRidgewater/courses/technical/elec_career.html
Contact:	320.231.5114
Description:	Provides a two year degree or AAS in Electronics and Wireless Communications

College:	Seattle Central Community College
Nation:	USA
Website:	seattlecentral.edu/proftech/PROwireless.php
Contact:	206.587.6327
Description:	AAS degree or degree option in Wireless Telecommunications

College:	GWEC education partners
Website:	/www.gwec.org/edpartners.cfm?PR=ALL
Description:	List of Universities and Community Colleges which are a part of the Global Wireless Education Consortium

Appendix: Wireless Research Programs

Batelle	broad sensor developments and applications	several universities and corporations
Boston University	Photonics Center	Agilent, NSF, DARPA
Boston University	manufacturing engineering	Fraunhofer
Boston University	Center for Information and Systems Engineering	Army, Air Force, ONR, NASA, NIH, NSF, DARPA, EPRI, DOT, NRL
CIMIT	Technology for Medicine Labs, 50+ medical &	Harvard Medical Schools, MIT, Draper pharma companies
Cornell	sensor database optimization	
Duke	Photonics Center	
Duke	sensors and simulators Michigan	DARPA, with Georgia Tech, Stanford,
EYES	European-based; energy-efficient sensor net	Infineon, plus 4 national institutes
Georgia Tech	sensors and electromagnetic applications	
Jet Propulsion Labs	sensor webs	several universities and corporations
MIT	Network and Mobile Systems Lab	
MIT	Media Labs	approximately 100 corporate sponsors
MIT	Auto ID Center- EPCglobal	nearly 100 corporations
MITRE	Sensor Enabling Center and others	DoD, FAA
NDSU	Sensor Design Lab, Center for xNanoscale	DoD
Oak Ridge National Labs	broad sensor developments and applications	several universities and corporations
PNNL	Energy, Environment, Security	several universities and corporations
Sandia National Labs	broad sensor developments and applications	several universities and corporations
Sarnoff	broad sensor developments	
UC Berkeley	Wireless Research Center	
UC Berkeley	Center for IT in the Interest of Society	20 corporate sponsors-energy efficiency, transportation, environmental, health care
UC Berkeley	Sensor Webs Labs	
UC Berkeley	Sensor and Actuator Center	NSF funded plus over 40 corporate sponsors
UCLA	Wireless Integrated Network Sensors (WINS)	DARPA, Army, Rockwell
UCLA	CENS - Embedded Networked Sensing Systems	NSF, DOE, DoD, JPL, CalTech, Intel, Honeywell, Sun, HP, Cisco, STM, TRW
UConn	Center for Optics, Sensing & Tracking in Homeland Security	Homeland Security
USCD	Homeland Security	
UVA	Real time distributed smart systems	DARPA

Company:	**@ Hand**
City:	Austin
Line of Business:	@Hand's Mobile Work Management product line provides software for automating and improving the mobile business process. The company was established in 1998 in Austin. *ApplicationDesign, VAR/ Integrator*
Company:	**Able Communications Co.**
City:	Houston
Line of Business:	Installs mobile communication equipment aimed at oil and gas companies *VAR/ Integrator*
Company:	**Adaptive Network**
City:	Dallas
Line of Business:	Designs and installs wireless networks for SMBs. *VAR/ Integrator*
Company:	**Adtek Corporation**
City:	Addison
Line of Business:	Designs and installs wired and wireless Ethernet for SMBs. *VAR/ Integrator*
Company:	**Advanced Micro Devices**
City:	Austin
Line of Business:	Advanced Micro Devices (AMD) designs and manufactures integrated circuits, flash memory, and networking products. Although AMD's headquarters are in California, Austin is home to one of the company's production facilities. *Business Associate, Research & Development, Chip Design, Chip Manufacturer, Device Hardware, Device Software, Middleware*
Company:	**Aether Systems**
City:	N/A
Line of Business:	Aether Systems provides systems for mobile tracking and communications. *VAR/ Integrator*
Company:	**Affinegy**
City:	Austin
Line of Business:	Affinegy provides software solutions and consulting services for the broadband and wireless Internet market. The company's solutions let users configure and manage LAN/WAN networks. *Middleware, Application Aggregation, VAR/ Integrator*
Company:	**Airband Communications**
City:	Dallas
Line of Business:	Wireless broadband service provider/VoIP. *Middleware, VAR/ Integrator*
Company:	**AirChalk Wireless**
City:	Austin
Line of Business:	AirChalk operates a network that enables wireless service providers to buy and sell branded, secure roaming access. The newly established company is in its funding phase. *Application Aggregation*
Company:	**Airwalk Communications**
City:	Richardson
Line of Business:	Design and manufacture wireless CDMA radio access network infrastructure equipment. *Infrastructure Hardware*
Company:	**Alamosa PCS Holdings**
City:	Lubbock
Line of Business:	PCS service provider for Sprint (covers service area with 16 million residents.) *Operator*

Company:	**Alcatel**
City:	Austin
Line of Business:	Alcatel creates products for a wide range of sub-sectors in the telecommunications industry, including carriers, service providers and enterprises. Alcatel offers a line of GSM/GPRS products and software for wireless carriers. Alcatel also has a venture capital arm which funds companies that support Alcatel's corporate strategy. The company is headquartered in France. *Business Associate, Research & Development, Chip Design, Infrastructure Hardware, Device Hardware, Device Software, Middleware, Operator*
Company:	**Alereon Inc.**
City:	Austin
Line of Business:	Headquartered in Austin, Alereon, Inc. is a new fabless semiconductor company focused on developing and deploying UWB chipsets for personal area networking applications that comply with the emerging IEEE standard (802.15.3a). *Chip Design*
Company:	**Alliance Data Systems**
City:	Dallas
Line of Business:	Alliance Data Systems provides payment transaction and CRM middleware for internet applications. Major customers are in the utility, petroleum, retail, and transportation industries. *Middleware*
Company:	**Alliance Datacom**
City:	Garland
Line of Business:	Alliance Datacom designs, installs, and repairs WANs and WAN related equipment. *VAR/Integrator*
Company:	**Alpha Datacomm Services**
City:	Houston
Line of Business:	Alpha Datacomm designs and installs WANs with an emphasis on data security. *VAR/Integrator*
Company:	**AMX Communications Ltd**
City:	Dallas
Line of Business:	AMX Communications installs cellular towers. *VAR/Integrator*
Company:	**AMX Corporation**
City:	Richardson
Line of Business:	AMX Corporation specializes in design and installation of systems to control data, sensors, and equipment, remotely. *VAR/Integrator*
Company:	**Antenna Products Corporation**
City:	Mineral Wells
Line of Business:	Antenna Products designs and manufactures transmission antennas for industrial and government customers. *Device Hardware*
Company:	**AnyTime Communications**
City:	Cedar Park
Line of Business:	Established in 2001, AnyTime Communications offers networking services for both residential and business customers. Services include: connectivity, networking, upgrades and maintenance for wireless, wired broadband and dial-up Internet access. *Application Aggregation*
Company:	**Appliance Lab**
City:	Austin
Line of Business:	App-Lab designs and manufactures systems for remote data collection, aggregation and system control through a thin client structure. *Device Hardware, Device Software, VAR/Integrator*

Company:	**Applied Materials**
City:	Austin
Line of Business:	Headquartered in Santa Clara, CA, Applied Materials Inc. supplies products for use in semiconductor manufacturing. Chips made using Applied Materials' equipment are seen in PCs, PDAs, gaming equipment cellular phones and GPS devices. The company's Austin office works in R&D as well as manufacturing. *Research & Development, Chip Manufacturer*
Company:	**Applied Optoelectronics**
City:	Sugar Land
Line of Business:	Applied Optoelectronics designs and manufactures semiconductor lasers for wireless communications (amongst other applications). *Infrastructure Hardware*
Company:	**Applied Systems Engineering**
City:	Fort Worth
Line of Business:	Designs and manufactures amplifiers for wired and wireless communication systems. *Infrastructure Hardware, Device Hardware*
Company:	**Arch Wireless**
City:	Irving
Line of Business:	Arch Wireless provides paging, mobile communications, and mobile internet services. *Operator*
Company:	**Argon Technologies**
City:	Greenville
Line of Business:	Argon provides wireless internet access, as well as consulting services. *Operator, VAR/ Integrator*
Company:	**Artemis Wireless Werks**
City:	Austin
Line of Business:	Artemis Wireless Werks provides software solutions, training, marketing and technical writing services for technology companies. *Application Design, Application Aggregation, VAR/ Integrator*
Company:	**ATX Technologies**
City:	Irving
Line of Business:	ATX designs and builds customized telematics systems (similar to OnStar). *Device Hardware, Device Software, VAR/ Integrator*
Company:	**AZAR Computer Software Services**
City:	Austin
Line of Business:	Azar Computer Software Services Inc. provides billing software to the cable and satellite television industry. The Austin based company has been in business since 1979. *Application Design*
Company:	**Bandspeed**
City:	Austin
Line of Business:	Software and antennas from Bandspeed allow access point manufacturers to increase their coverage and capacity. The company also offers a switch-based architecture for WLAN deployment. *Infrastructure Hardware, Device Hardware, Middleware*
Company:	**Bluebonnet Technologies**
City:	Mount Pleasant
Line of Business:	Bluebonnet Technologies provides wireless broadband services. *Operator*
Company:	**Brazos Cellular Communications**
City:	Olney
Line of Business:	Brazos Cellular provides cellular phone, pager, and wireless internet services. *Operator*
Company:	**Broadband Unwired**
City:	Del Rio
Line of Business:	Holding company. *Application Design, Application Aggregation, VAR/ Integrator*

Company:	**CACI**
City:	Austin
Line of Business:	Focusing on government networking infrastructure needs, CACI International Inc.'s solutions are applied to federal electronic government, intelligence and defense programs. The U.S. Department of Defense is CACI's largest customer. The company was established in 1962 and is headquartered in Arlington, VA. *Application Design, Application Aggregation, VAR/ Integrator*
Company:	**Canyon Semiconductor**
City:	Austin
Line of Business:	Canyon Semiconductor, located in the Austin Technology Incubator, was formed to address wireless infrastructure applications using wide bandgap semiconductors. The company, formed in 2002, focuses on analog semiconductors in high speed communications markets. *Research & Development, Chip Design*
Company:	**CapRock Communications**
City:	Houston
Line of Business:	Caprock provides remote communications services through VSAT technology, targeting primarily the oil and gas industry. *Operator, VAR/ Integrator*
Company:	**Carcomm International**
City:	Austin
Line of Business:	Headquartered in Netherlands, Carcomm provides car cradles for wireless devices. In addition, Carcomm offers antennas and wireless accessories. *Device Hardware*
Company:	**CAZITech Consulting**
City:	Austin
Line of Business:	Clients of CAZITech Consulting can receive business development assistance, strategic planning services and marketing and competitive analyses. CAZITech helps support universal Internet access, open standards and competition in telecommunications. *Business Associate*
Company:	**CCI Telecom**
City:	San Antonio
Line of Business:	CCI designs and installs customized communications networks (wireless and landline). *VAR/ Integrator*
Company:	**Cellular Alarm Products**
City:	Dallas
Line of Business:	Cellular Alarm sells alarm backup systems which communicate through wireless cellular networks. *Device Hardware, VAR/ Integrator*
Company:	**CenterPoint Venture Partners**
City:	Dallas
Line of Business:	VC firm that specializes in internet startups. *Business Associate*
Company:	**Ceterus Networks**
City:	Allen
Line of Business:	Ceterus Networks designs Ethernet transport devices for metro scale Ethernet deployments over existing infrastructure. *Infrastructure Hardware*
Company:	**CFX Engineering**
City:	Austin
Line of Business:	CFX, LP and CFX Construction, LP provide engineering, construction and surveying services. For the wireless industry, CFX provides services for telecommunications infrastructure deployment. CFX was established in 1996. *Middleware*

Company:	**Chiaro Networks, Ltd**
City:	Richardson
Line of Business:	Chiaro designs optical switches and routers for fiber optic backbone infrastructure. *Infrastructure Hardware*
Company:	**Cirrus Logic**
City:	Austin
Line of Business:	Established in 1984, Cirrus Logic supplies high-performance analog, digital signal processing and mixed-signal chip solutions for consumer electronics. Cirrus Logic provides WiFi technology to Motorola. *Chip Design*
Company:	**Cisco Systems Inc.**
City:	Austin
Line of Business:	Cisco Systems Inc. provides networking solutions based on the Internet Protocol. Established in 1984, the company has developed advanced routers, switches, and VoIP for use in broadband and wireless networks. *Research & Development, Chip Design, Chip Manufacturer, Infrastructure Hardware*
Company:	**Communication Solutions**
City:	Austin
Line of Business:	Communication Solutions designs and manufactures high performance SIGINT electronic instruments and subsystems using microwave, RF and digital signal processing technologies. *Infrastructure Hardware, Device Hardware*
Company:	**Computer and Internet Resources, Inc.**
City:	Georgetown
Line of Business:	Located in Georgetown, an Austin suburb, Computer and Internet Resources Inc. is an ISP serving Central Texas and the Hill Country. Users can choose from dial-up, ISDN or wireless Internet connectivity for their home or business. *Operator*
Company:	**Connectione**
City:	Austin
Line of Business:	Connectione provides nationwide multi-carrier wireless and mobility solutions, helping mobile professionals stay connected with their clients and associates. The company was established in 2001. *Application Aggregation, VAR/ Integrator*
Company:	**Constant.com**
City:	Austin
Line of Business:	Constant.com provides wireless, DSL, ISDN, T1, Dialup Internet access, web hosting nationwide. NABI Networks, Constant.com's parent company, was one of the first independent ISPs in Austin. *Application Aggregation, VAR/ Integrator*
Company:	**Converged Cities**
City:	Fort Worth
Line of Business:	Converged Cities is a consulting firm specializing in neighborhood scale and larger analysis of broadband infrastructure deployment. *Business Associate*
Company:	**Corban Communications**
City:	Plano
Line of Business:	Corban Communications provides 'middle mile' communications services and remote equipment monitoring. *Operator*
Company:	**Crown Castle International**
City:	Houston
Line of Business:	Crown Castle designs and deploys wireless telecommunications infrastructure. *Infrastructure Hardware, VAR/ Integrator*

Company:	**Cybercom Corp.**
City:	College Station
Line of Business:	Cybercom provides broadband wireless access. *Operator*
Company:	**CyberTrader**
City:	Austin
Line of Business:	CyberTrader executes online stock trades targeted at high trading volume accounts. CyberTrader has specific trading software for wireless devices. *Device Software*
Company:	**Dashlink Internet Services**
City:	Killeen
Line of Business:	Dashlink provides wireless broadband internet access. *Operator*
Company:	**Dell Computer**
City:	Round Rock
Line of Business:	Headquartered in Round Rock, an Austin suburb, Dell Computer designs and manufactures desktop and notebook computers and peripherals. The company was established in 1984. *Device Hardware, Distributor*
Company:	**DelRio.com**
City:	Del Rio
Line of Business:	DelRio.com provides wireless broadband internet access. *Operator*
Company:	**DGI Technologies**
City:	Richardson
Line of Business:	DGI designs and manufactures wireless and cellular switching products. *Infrastructure Hardware*
Company:	**Diarcy Technologies**
City:	Austin
Line of Business:	Engineering services related to electronics, RF, microwave, and antennas are the specialty of Diarcy Technologies. The native Austin company was established in 1990. *Device Hardware, Device Software, Middleware, VAR/ Integrator*
Company:	**Diverse Networks**
City:	Houston
Line of Business:	Diverse Networks deploys and manages wireless data networks.
Company:	**DRS Broadcast Technology**
City:	Dallas
Line of Business:	DRS designs and manufactures digital and analog RF broadcast transmission equipment. *Infrastructure Hardware, Device Hardware*
Company:	**Druma Inc.**
City:	Austin
Line of Business:	Druma Inc. provides custom programming and integration solutions for businesses who use HP 200LX Palmtops. *Middleware, Application Design*
Company:	**E10 Systems**
City:	Richardson
Line of Business:	E10 Systems provides billing services for prepaid wireless communications. *Middleware*
Company:	**Eagle Wireless International**
City:	League City
Line of Business:	Eagle Wireless manufactures wireless messaging infrastructure products including transmitters, base stations, paging terminals, controllers, repeaters and receivers. *Infrastructure Hardware, Device Hardware*
Company:	**Eastland Internet**
City:	Eastland
Line of Business:	Fixed wireless ISP, *Operator*

Company:	**Efficient Networks (Siemens Subscriber Networks)**
City:	Dallas
Line of Business:	Siemens Subscriber Networks designs and manufactures high speed broadband equipment such as routers, NICs, etc. Siemens also produces software for networks. *Infrastructure Hardware, Device Hardware, Device Software, Middleware*
Company:	**Enfora**
City:	Plano
Line of Business:	Enfora designs and manufactures wireless NICs, telemetry, etc. for wireless LANs and mobile communications. *Device Hardware*
Company:	**Enhanced Services Billing**
City:	San Antonio
Line of Business:	Provider of internet based billing services targeted at telecommunications companies. Their products include clearing and settlement services for wi-fi networks. *Device Software*
Company:	**Ericsson Enterprise**
City:	Plano
Line of Business:	Ericsson Enterprise designs and manufactures wireless communications products such as cell phones, wireless Ethernet, PBX systems, etc. *Infrastructure Hardware, Device Hardware, Device Software*
Company:	**ETS Lindgren/EMC Test Systems**
City:	Cedar Park
Line of Business:	ETS-Lindgren creates components and systems that measure, shield and control electromagnetic energy. The company's products include diagnostic tools and turnkey facilities.
Company:	**Everhardt Antennas**
City:	Fort Worth
Line of Business:	Manufactures mobile communications antennas for vehicles. *Device Hardware*
Company:	**EXCEL Telecommunications**
City:	Dallas
Line of Business:	Provides internet access and cellular telephone services. *Operator*
Company:	**EXP Internet Services**
City:	Bridge City
Line of Business:	Provides internet access through satellite and other conventional means. *Operator*
Company:	**First Capital International**
City:	Houston
Line of Business:	First Capital specializes in home automation. *VAR/Integrator, Customer*
Company:	**Flextronics**
City:	Plano
Line of Business:	Flextronics provides contract manufacturing services, as well as wireless semiconductor design services. *Contract Manufacturer, Device Hardware*
Company:	**Fly Technology**
City:	Austin
Line of Business:	Established in 2000, Fly Technology provides the services layer for wireless technology companies. Specifically, they offer portal software which can be personalized and branded. *Device Software, Middleware*
Company:	**Freshloc Technologies**
City:	Dallas
Line of Business:	Freshloc sells wireless sensor arrays and firmware to remotely monitor and control refrigeration systems. *Device Hardware Device Software, Middleware*

Company:	**Frog Design**
City:	Austin
Line of Business:	Software user-interface design, e-commerce solutions and electronics design are the services offered by Frog Design. Headquartered in Silicon Valley, Frog was founded in 1969. *Application Design, Application Aggregation*
Company:	**Fuel Quest**
City:	Houston
Line of Business:	Fuel Quest provides supply chain and business process management for the petroleum industry. *VAR/ Integrator*
Company:	**Fujitsu Network Communications**
City:	Richardson
Line of Business:	Manufacturer of Internet infrastructure equipment. *Infrastructure Hardware*
Company:	**FWT**
City:	Fort Worth
Line of Business:	FWT Installs communications and utility towers. *Infrastructure Hardware*
Company:	**General Dynamics,** advanced information systems
City:	San Antonio
Line of Business:	Provider of intelligence systems for the DOD often using wireless technologies. *VAR/ Integrator*
Company:	**Grande Communications**
City:	Austin
Line of Business:	Grande Communications delivers high-speed Internet, local and long-distance telephone and digital cable television services over its own advanced broadband network to communities in Texas. Headquartered in San Marcos, the company will offer wireless home access in early 2004. *Operator*
Company:	**Handango**
City:	Hurst
Line of Business:	Develops games and applications for mobile devices. *Application Design*
Company:	**Hewlett Packard**
City:	Austin
Line of Business:	HP is a technology solutions provider to consumers, businesses and institutions globally. HP's Wireless & Mobility solutions seek to remove obstacles to successful wireless, mobile deployment. *Research & Development, Device Hardware, Device Software, Middleware*
Company:	**HillCast Technologies**
City:	Austin
Line of Business:	HillCast Technologies is an Austin based developer of mobile applications for the financial services industry. Users can receive market data, graphs on their wireless devices via the company's software. *Application Design*
Company:	**HubNet**
City:	Lubbock
Line of Business:	Wireless broadband ISP, *Operator*
Company:	**IBM**
City:	Austin
Line of Business:	Personal computer pioneer, IBM, creates notebook computers and caters to the wireless workforce through their e-business segment. *Research & Development, Chip Design, Chip Manufacturer, Device Hardware, Device Software, Middleware, Application Design, Application Aggregation, VAR/ Integrator*
Company:	**iGillott Research**
City:	Austin
Line of Business:	iGillott Research is a market strategy consulting company focused on the wireless and mobile communications industry. Areas of expertise include 2G, 3G, SMS, and mobile commerce. *Business Associate*

Company:	**Impluse Telecommunications**
City:	Dallas
Line of Business:	Specializes in telecom and wireless strategy consulting. *Business Associate*
Company:	**Infinite Technology Corporation**
City:	Dallas
Line of Business:	ITC designs fiber to the home infrastructure products. *Chip Design, Infrastructure Hardware*
Company:	**InnerWireless**
City:	Richardson
Line of Business:	Designs products for in-building wireless networks that comply with nearly all major wireless standards. *Infrastructure Hardware*
Company:	**Intag Communications, Inc.**
City:	Austin
Line of Business:	Intag Communications, Inc., designs, installs and services Structured Cabling Systems and WLANs. Intag was established in 1979 and is headquartered in St. Louis. *VAR/Integrator*
Company:	**Integral Signals Processing**
City:	Austin
Line of Business:	Integral Signals Processing makes satellite weather stations.
Company:	**Intel**
City:	Austin
Line of Business:	Since 1968, Intel has manufactured computer, networking and communications chips and components. Intel developed the Centrino technology for connecting notebooks to WLANs. *Business Associate, Research & Development, Chip Design, Infrastructure Hardware, Device Hardware, Device Software*
Company:	**IntelliMark IT Solutions**
City:	Coppell
Line of Business:	Provides design, installation and management of wireless networks for businesses. *VAR/Integrator*
Company:	**Interconnect Services**
City:	Corpus Christi
Line of Business:	Wireless DSL ISP. *Operator*
Company:	**Intermat**
City:	Houston
Line of Business:	Intermat creates and sells inventory management software. *Middleware*
Company:	**Interphase**
City:	Plano
Line of Business:	Interphase provides wireless voice and data services with off the shelf components. *Device Software, Middleware, VAR/Integrator*
Company:	**Intervoice**
City:	Dallas
Line of Business:	Intervoice specializes in voice recognition software and equipment. *Device Software*
Company:	**IPVoice Communications**
City:	Dallas
Line of Business:	Provider of VOIP services. *Device Software, Middleware, Operator*
Company:	**Isochron Data Corp.**
City:	Austin
Line of Business:	Isochron Data Corp. provides products for wirelessly monitoring and controlling vendor products and inventory. The company is also developing Bluetooth applications. *Device Hardware, Device Software, Middleware*

Company:	**JenaNet.com**
City:	Fort Worth
Line of Business:	Provides engine monitoring services over the internet. *Device Software, Middleware, SOIN*
Company:	**Karta Technologies**
City:	San Antonio
Line of Business:	Provides logistics and asset management services, as well as data/network security services. *VAR/Integrator*
Company:	**Knockabout Games**
City:	Austin
Line of Business:	Entertainment and gaming software for wireless devices are what Knockabout Games creates. Software designers at Knockabout also offer custom designed applications for mobile devices. *Application Design*
Company:	**KTI Networks**
City:	Houston
Line of Business:	Manufactures wireless LAN products such as NICs, transceivers, converters, hubs, and switches. *Device Hardware*
Company:	**Lake Country Internet**
City:	Mineola
Line of Business:	Wireless broadband ISP. *Operator*
Company:	**Less Networks**
City:	Austin
Line of Business:	Less Networks works with open source software to create access portal to providers of free WiFi access. It's a partner with the Austin Wireless City Project. *Application Aggregation, SOIN*
Company:	**LGP Allgon**
City:	Fort Worth
Line of Business:	LPG Allgon manufactures RF power amplifiers, filters, base station antennae for wireless communications. *Infrastructure Hardware*
Company:	**Maxim /Dallas Semiconductor**
City:	Dallas / San Antonio
Line of Business:	Maxim designs and manufactures mixed signal IC's used in 802.11 wireless products. *Chip Design, Chip Manufacturer, Infrastructure Hardware*
Company:	**McGrath RentCorp RenTelco Division**
City:	Plano
Line of Business:	Rent telecommunications testing equipment. *VAR/Integrator*
Company:	**MedPrompt Products**
City:	Spring
Line of Business:	Operates wireless paging services targeted toward medical patients (medicine reminders). *Operator, VAR/Integrator*
Company:	**MetroPCS Communications**
City:	Dallas
Line of Business:	Provider of wireless voice and communications services. *Operator*
Company:	**Metrowerks**
City:	Austin
Line of Business:	Metrowerks was established in 1985, and in 1999 became a Motorola subsidiary. The company offers development tools and services focusing on popular wireless platforms. *Device Software, Middleware*
Company:	**Metso Automation**
City:	Houston
Line of Business:	Provides automation and information management for remote systems. *Middleware, VAR/Integrator*

Company:	**Microtune**
City:	Plano
Line of Business:	Microtune designs and manufactures RF subsystems for broadband and automotive markets. *Device Hardware*

Company:	**Microwave Networks**
City:	Stafford
Line of Business:	Manufactures microwave based broadband communications transmitters (radios, etc.). *Infrastructure Hardware*

Company:	**Monico**
City:	Dripping Springs
Line of Business:	Provides remote monitoring devices which work through satellite and internet communications. *Infrastructure Hardware, Device Hardware*

Company:	**Motion Computing**
City:	Austin
Line of Business:	Using Windows platform and Intel's Centrino technology, Motion Computing offers made-to-order Tablet PCs and related equipment. The company was established in 2001. *Device Hardware*

Company:	**Motive Communications**
City:	Austin
Line of Business:	Founded in 1997, Motive Communications provides technology solutions for ISPs. Motive helps manage "technology ecosystems" so that businesses can take advantages of technology and pass along their savings and success to their own customers. *Device Software, Middleware*

Company:	**Motorola**
City:	Austin
Line of Business:	Motorola supplies wireless infrastructure equipment such as cellular transmission base stations, amplifiers, and network switching systems. Motorola's semiconductor unit is a leader in embedded chips used in wireless, networking, automotive, and consumer products. *Business Associate, Research & Development, Chip Design, Chip Manufacturer, Infrastructure Hardware, Device Hardware, Device Software, Middleware*

Company:	**National Instruments**
City:	Austin
Line of Business:	National Instruments was established in 1975 and is headquartered in Austin with more than 3,000 employees and direct operations in 40 countries. National Instruments creates hardware and software to enhance PC's, including measurement and automation software. *Device Software, Middleware*

Company:	**Navini Networks**
City:	Richardson
Line of Business:	Navini designs and manufactures wireless base stations and modems based on adaptive phased-array antenna.

Company:	**NEC America**
City:	Irving
Line of Business:	Develops and manufacturers a broad range of communications infrastructure and devices. *Infrastructure Hardware, Device Hardware*

Company:	**Netbotz**
City:	Austin
Line of Business:	Netbotz, established in 1999, makes wireless monitoring base stations and accompanying software. Products from Netbotz provide security against human break-ins and physical problems. *Infrastructure Hardware, Middleware*

Company:	**Netrake**
City:	Plano
Line of Business:	Netrake manufactures session controller equipment that controls voice and multimedia across IP networks. *Infrastructure Hardware*

Company:	**Network Associates**
City:	Plano
Line of Business:	NAI creates network security software products.Customer service is in Plano. *Device Software, Middleware*
Company:	**Nexcom**
City:	Grapevine
Line of Business:	Installs high security wireless communication systems and networks. *VAR/Integrator*
Company:	**Nlynx Technologies**
City:	Austin
Line of Business:	Manufactures wireless routers and wired network equipment. *Device Hardware*
Company:	**Nokia Mobile Phones**
City:	Irving
Line of Business:	Design and manufacture mobile communication devices. *Device Hardware*
Company:	**Nortel Networks**
City:	Richardson
Line of Business:	Design and manufacture communications infrastructure equipment Northeast Texas Online. *Infrastructure Hardware*
Company:	**Northeast Texas Online**
City:	Paris
Line of Business:	Provider of wireless internet access. *Operator*
Company:	**OpenConnect Systems**
City:	Dallas
Line of Business:	OpenConnect specializes in software development to allow remote users to securely access data held on mainframes. *Device Software, Middleware*
Company:	**Operational Technologies**
City:	San Antonio
Line of Business:	Provides supply chain management services through wired and wireless devices. *VAR/Integrator*
Company:	**OTM Engineering**
City:	Austin
Line of Business:	OTM Engineering designs communication projects for numerous local, national, and international companies. Services include network design, wireless, cabling, infrastructure, voice systems. *VAR/Integrator*
Company:	**Pexx**
City:	Houston
Line of Business:	Specializes in wireless network design and installation. *VAR/Integrator*
Company:	**Primo Microphones**
City:	McKinney
Line of Business:	Design and manufacture microphones for wired and wireless devices. *Device Hardware*
Company:	**Quanta Services**
City:	Houston
Line of Business:	Communication infrastructure installer. *VAR/Integrator*
Company:	**Qwest Communications**
City:	Austin
Line of Business:	Qwest Communications provides voice, video and data services through broadband, wireless, and cellular networks for residential and businesses. Quest focuses on networking, WiFi, cellular technologies. The company is headquartered in Colorado. *Operator*

Company:	**Raak Technologies**
City:	Austin
Line of Business:	Network security for LANs and WLANs is the goal of Raak technologies. Raak's Wireless LAN security solution combines smart cards with an integrated client application. *VAR/Integrator*
Company:	**RASTRAC**
City:	Austin
Line of Business:	Manning NavComp is an application developer of vehicle tracking solutions. Its RASTRAC software helps tracking commercial vehicles over commercial radio, cellular telephone, Cellular Digital Packet Data or satellite communications. *Application Design*
Company:	**Raven Industries**
City:	Austin
Line of Business:	Raven Industries provides electronics, reinforced plastic, and flow control devices. Raven also designs and manufactures antennas for nearly all GPS needs and applications. *Device Hardware, Middleware*
Company:	**REVA**
City:	Roanoke
Line of Business:	Wireless broadband ISP. *Operator*
Company:	**RF Monolithics**
City:	Dallas
Line of Business:	Manufacturer of radio transmitters and other wireless devices. *Device Hardware*
Company:	**Rich Finney & Associates**
City:	Lakeway
Line of Business:	Rich Finney & Associates focuses on network design and engineering services. They also focus on technology assessments and Internet service in the underserved communities, including the Lockhart Community Network. *VAR/Integrator*
Company:	**Rig Net**
City:	Houston
Line of Business:	Provider of communications for offshore rigs and other remote locations. *VAR/Integrator*
Company:	**Rocksteady Networks**
City:	Austin
Line of Business:	Rocksteady Networks, Inc. provides software solutions that deliver security and premium broadband services to users at the edge of the network. Rocksteady Networks is a founding member of the Austin Wireless Alliance. *Device Software, Middleware*
Company:	**Rush Networks**
City:	Addison
Line of Business:	Rush networks provides wireless communication and data services in McAllen, TX and Tulsa, OK through 220 MHz radio. *Operator, VAR/Integrator*
Company:	**Rx Technology**
City:	San Antonio
Line of Business:	Wireless Broadband ISP; IT systems design. *Operator, VAR/Integrator*
Company:	**Samsung Telecommunications America**
City:	Richardson
Line of Business:	Samsung Telecom conducts R&D, designs, and manufactures mobile communications infrastructure and devices. *Research & Development, Infrastructure Hardware, Device Hardware, Device Software*

Company:	**Satellink**
City:	Garland
Line of Business:	Manufacturer of satellite communications equipment, telemetry products, and RF amplifiers. *Infrastructure Hardware*
Company:	**SBC Communications**
City:	San Antonio
Line of Business:	Major telecommunications service provider. *Middleware, Operator*
Company:	**SBC Laboratories**
City:	Austin
Line of Business:	SBC Laboratories is the R&D subsidiary for SBC Communications Inc. SBC Labs develops solutions for markets, technology, and security through hardware and software working with WiFi, networking, and fixed wireless. *Research & Development, Chip Design, Infrastructure Hardware, Middleware*
Company:	**SchlumbergerSema**
City:	Austin
Line of Business:	SchlumbergerSema is the Information Technology (IT) business segment of Schlumberger Limited and located in Austin. SchlumbergerSema supplies IT consulting, systems integration, and network and infrastructure services, including WLAN networking to the energy industry as well as to the public sector, telecommunications and finance markets. *VAR/Integrator*
Company:	**SecureOrbits Labs**
City:	Boerne
Line of Business:	
Company:	**Security and More**
City:	Lewsville
Line of Business:	Seller of camera security systems. *VAR/Integrator*
Company:	**Sematech**
City:	Austin
Line of Business:	Sematech is an international R&D consortium that focuses on semiconductors and is headquartered in Austin. Members cooperatively develop solutions to critical industry challenges outlined in the International Technology Roadmap for Semiconductors (ITRS). *Research & Development, Chip Design*
Company:	**Sierra Microwave Technology**
City:	Georgetown
Line of Business:	Founded in 1985, Sierra Microwave Technology produces high reliable parts for the military and space industries. The company is headquartered in Georgetown, an Austin suburb. *Device Hardware, Middleware*
Company:	**SigmaTel, Inc.**
City:	Austin
Line of Business:	SigmaTel, Inc. a semiconductor company headquartered in Austin. SigmaTel designs, develops, and markets proprietary, analog intensive, mixed-signal ICs for a variety of products in the consumer electronics and computing markets, including MP3 players, notebook and desktop PCs, DVD players, and digital televisions. *Chip Design*
Company:	**Signalogic**
City:	Dallas
Line of Business:	Developer of DSP related software. *Device Software, Middleware*
Company:	**Silicon Laboratories**
City:	Austin
Line of Business:	Established in 1996, Silicon Laboratories designs integrated circuits. For the wireless industry, the company produces single chip RF synthesizers, cellular handset transreceivers, integrated circuits, and other wireless equipment. *Chip Design*

Company:	**SoloMio Corporation**
City:	Austin
Line of Business:	Spun off from Vignette in 2000, SoloMio Corporation is a global telecom software company. Specifically, the company creates call management software for the cellular industry. *Middleware*
Company:	**Sony Online Entertainment Inc.**
City:	Austin
Line of Business:	Sony Online Entertainment Inc. is located in San Diego and has development studios in Austin. The company's wireless products include role-playing games for cellular phones, and wireless versions of their popular console games. *Application Design*
Company:	**Spatial Wireless**
City:	Richardson
Line of Business:	Spatial Wireless designs and manufactures wireless switches for mobile phone and data networks. *Infrastructure Hardware*
Company:	**Starlink Inc.**
City:	Austin
Line of Business:	Starlink Inc. provides engineering services and products focusing on electronics and radionavigation, particularly GPS tracking systems. The company was established in 1993 and is part of Raven Industries. *VAR/ Integrator*
Company:	**Stillwater Resource Group**
City:	Houston
Line of Business:	Provides broadband wireless and video conferencing services. *VAR/ Integrator*
Company:	**STMicroelectronics**
City:	Carrollton
Line of Business:	STMicroelectronics is a large semiconductor company that designs and manufactures IC's for wireless devices (amongst other things) 972.466.6000. *Chip Design, Chip Manufacturer*
Company:	**Supercircuits**
City:	Liberty Hill
Line of Business:	Manufacturer of custom wireless cameras and security equipment. *Device Hardware, VAR/ Integrator*
Company:	**Survivor Soft**
City:	Austin
Line of Business:	Development studio making use of the Java 2 Micro Edition platform.
Company:	**Swordfish Technologies**
City:	Addison
Line of Business:	Design and install wireless networks. *VAR/ Integrator*
Company:	**SWRI**
City:	San Antonio
Line of Business:	SWRI is a non-profit research group that focuses on physical sciences. *Research & Development*
Company:	**TDK RF Solutions Inc.**
City:	Cedar Park
Line of Business:	TDK RF Solutions Inc. creates automated test systems, software, antennas for use in electromagnetic compatibility test applications. TDK RF designs and manufactures its products. The company is headquartered in Cedar Park.

Company:	**Team Smarty Pants!, Inc.**
City:	Austin
Line of Business:	Team Smarty Pants!, Inc., established in 1994, creates digital media and game content for mobile devices. The company is currently working on an entertainment and communication platform bridging portable and deskbound devices. *Application Design*
Company:	**TechWorks/Buffalo Technology (USA) Inc.**
City:	Austin
Line of Business:	TechWorks/Buffalo Technology (USA) Inc., subsidiaries of Japan's MELCO Group, develops and manufactures computer memory, storage and networking products. Buffalo's AirStation line for WLAN deployment features routers, bridges, antennas, converters and access points. *Infrastructure Hardware, Device Hardware, Device Software*
Company:	**Telcordia Technologies**
City:	Austin
Line of Business:	Telcordia Technologies is a provider of telecommunications software and services for IP, wireline, wireless, WiFi, and cable networks. The company is headquartered in New Jersey and is a subsidiary of SAIC. *Device Software, Middleware*
Company:	**Telegenesis**
City:	San Antonio
Line of Business:	Telegenesis installs video security systems which use wireless transmission. *VAR/Integrator*
Company:	**Teletouch Communications**
City:	Tyler
Line of Business:	Teletouch provides wireless communication and telemetry services. *VAR/Integrator*
Company:	**TengoInternet Inc.**
City:	Austin
Line of Business:	Austin-based WISP TengoInternet Inc. deploys hotspots creating "TengoZones" at hotels and camping/recreation vehicle sites. Established in 2001, Tengo's network reaches 25 cities throughout Texas, New Mexico, Arizona, Nevada, California and Florida. *Operator, Application Aggregation*
Company:	**Teravicta Technologies**
City:	Austin
Line of Business:	For over two years, Teravicta Technologies has manufactured and designed RF switches and relay products. Products from the company are used in WLANs, cellular base stations, RADAR, and satellite with specific uses in both industrial and military contexts. Teravicta's manufacturing and development processes, including packaging and testing, occur in Austin. *Device Hardware, Device Software*
Company:	**Terion**
City:	Plano
Line of Business:	Provider of two-way wireless location and information services. *VAR/Integrator*
Company:	**TerraWave Solutions**
City:	San Antonio
Line of Business:	*Distributor, VAR/Integrator*
Company:	**Texas Instruments**
City:	Dallas
Line of Business:	TI conducts materials level R&D, designs, and manufactures IC's for wireless infrastructure and devices. *Research & Development, Chip Design, Chip Manufacturer, Infrastructure Hardware*

Company:	**Time Warner Cable**
City:	Austin
Line of Business:	Time Warner Cable of Austin is a cable operator and ISP offering Roadrunner, AOL Broadband, and wireless services. *Operator*

Company:	**Titan Corporation,** Systems Integration Sector
City:	San Antonio
Line of Business:	Provide systems to the military which integrate sensor networks, databases, etc. to provide actionable intelligence to soldiers. *VAR/Integrator*

Company:	**T-Manage**
City:	Austin
Line of Business:	Recognizing increasing trends toward mobile and dispersed corporate structures, TManage offers solutions to connect disparate employees and offices to centralized corporate hubs. The company was established in 1988 and was recently acquired by California-based MegaPath Networks. *Middleware*

Company:	**Tokyo Electron, Texas**
City:	Austin
Line of Business:	Tokyo Electron was established in 1963 and has its United States headquarters and research and development office in Austin. Tokyo Electron was the first company to introduce American semiconductor production equipment and integrated circuit (IC) testers to Japan. *Research & Development, Chip Manufacturer*

Company:	**TRAQ Wireless**
City:	Austin
Line of Business:	TRAQ Wireless brings wireless management solutions to businesses relying on cellular phones, PDAs and other mobile communication devices. Currently, the company is working with clients to take advantage of wireless local number portability. Traq was established in 1999. *Device Software, Middleware*

Company:	**Triact Associates Inc.**
City:	Austin
Line of Business:	Triact Associates Inc. provides wireless networking services to businesses. Specifically, the company does site surveys, web and wireless enablement, remote network management, deployment of wireless bridges, project management, and technology consultation. *VAR/Integrator*

Company:	**Trillion Partners**
City:	Austin
Line of Business:	Trillion Partners help bridge the last mile broadband gap by bringing connectivity to schools, government offices, medical facilities, and institutes of higher education. Trillion currently serves over 750 schools and works with the federal E-Rate Program. *VAR/Integrator*

Company:	**Trimble Navigation**
City:	Austin
Line of Business:	Trimble Navigation provides GPS software and equipment, along with laser and optical technology. Applications of the company's technology are seen in asset tracking, vehicle navigation, machine guidance, and mapping. Established in 1978, the company has its headquarters in California. *Device Hardware, Device Software*

Company:	**Tripoint Global Communications**
City:	Longview
Line of Business:	manufacturer of microwave based wireless communications antenna, etc. *Infrastructure Hardware*

Company:	**TSTAR Internet**
City:	Marble Falls
Line of Business:	TSTAR Internet is headquartered in Marble Falls, TX, within the Austin MSA. TSTAR installs and provides wireless services via Ethernet connections and wire-based ISDN, including WiFi technology. *VAR/Integrator*
Company:	**Tuanis Technology**
City:	Austin
Line of Business:	Combining business and technical expertise is the strength of consulting firm, Tuanis Technology. The company specializes in Microwave Data Networking (MDN) utilizing unlicensed spectrum and is an equipment reseller. Tuanis was established in 2001. *VAR/Integrator*
Company:	**UpLink Corporation**
City:	Austin
Line of Business:	UpLink brings the convenience of GPS technology to the golf industry. Courses using UpLink's Golf Course Management System can track golf carts, and measure distances on greens with the aid of colorful display units installed on each cart. *Application Design, VAR/Integrator*
Company:	**UTSA**
City:	San Antonio
Line of Business:	*Research & Development*
Company:	**Victoria Internet Providers**
City:	Victoria
Line of Business:	wireless ISP. *Operator*
Company:	**Vytek**
City:	Austin
Line of Business:	Vytek solutions include infrastructure creation, including wireless infrastructure, applications and connection equipment for messaging, broadband, telemetry, paging, networking, and monitoring. Vytek's headquarters are in San Diego. *Infrastructure Hardware, Device Hardware, Device Software*
Company:	**WaveWare Technologies**
City:	Dallas
Line of Business:	Provides wireless paging and monitoring service. *VAR/Integrator*
Company:	**Wayport**
City:	Austin
Line of Business:	Hotspot access for business travelers is the primary goal of Wayport's Wi-Fi network. Located in over 700 hotels and six airports nationwide, the company's wireless networks gives travelers and mobile workers a quality and consistent Wi-Fi access experience. Wayport was established in 1996. *Middleware, VAR/Integrator*
Company:	**Web Fire Communications**
City:	Wichita Falls
Line of Business:	Wireless broadband ISP. *Operator*
Company:	**WebLink Wireless**
City:	Dallas
Line of Business:	Provider of wireless internet access, GPS, and remote machine monitoring. *Operator, VAR/Integrator*
Company:	**Wellogix**
City:	Houston
Line of Business:	Create software to manage data from well monitoring systems. *Device Software*
Company:	**West Central Net**
City:	San Angelo
Line of Business:	Provide wireless DSL access. *Operator*

Company:	**WhiteHorse Communications**
City:	El Paso
Line of Business:	Wireless broadband ISP. *Operator*

Company:	**WiFi Alliance**
City:	Austin
Line of Business:	Wi-Fi Alliance is a non-profit trade association with the goal of setting industry standards for WLAN interoperability. Since the alliance formed in 1999, over 200 companies, including leaders in the personal computer industry, have joined the alliance. Over 915 wireless products are currently certified. *SOIN*

Company:	**WiFiTexas.com**
City:	Austin
Line of Business:	"Amenity networks, " or commercial grade broadband networks in public spaces, are the output of Wi-Fi Texas.com. The company has deployed hotspots in RV parks, apartment/ condominium complexes, restaurants, and special events.

Company:	**Winstar Wireless**
City:	San Antonio
Line of Business:	Fixed wireless services and secure broadband communications.

Company:	**Wintegra, Inc.**
City:	Austin
Line of Business:	Wintegra, Inc. was founded in 2000 and has its corporate headquarters in Austin. Wintegra, Inc. is a semiconductor company that enables communications infrastructure equipment providers to upgrade their product lines toward the next generation of access networks with single chip solutions. Applications for their chips include wireless technology and capabilities. *Chip Design*

Company:	**Wireless Computing Inc.**
City:	Austin
Line of Business:	Using RF technology, Wireless Computing Inc. creates computer peripherals that free users from the burden of cords and wires. Products include wireless keyboards, wireless mice, and a wireless presentation remote. *Device Hardware*

Company:	**Wireless Frontier Internet**
City:	Fort Stockton
Line of Business:	Wireless Frontier Internet is a dial-up and wireless ISP in West Texas. *Middleware*

Company:	**Wireless Valley**
City:	Austin
Line of Business:	Wireless Valley provides software and measurement solutions for use in wireless network management. Wireless Valley provides software and measurement solutions for use in wireless network management. The company moved to Austin in 2002.

Company:	**WISP Gear**
City:	Pflugerville
Line of Business:	WISP Gear Inc. provides WISPs, businesses and hospitality sites with the hardware, software and expertise needed to deploy wireless networks. The present-day company was established in 2002 after the reorganization of CCMF Wireless and CCMF Computers. WISP Gear is headquartered in Pflugerville, an Austin suburb. *Distributor*

Company:	**Wi-Speed Communications**
City:	Austin
Line of Business:	Wi-Speed Communications offers an alternative to telecom Internet connectivity by bringing fixed wireless to Central Texas. Earlier this year, Wi-Speed introduced its services to Austin by offering services to business that otherwise would have no feasible way to receive broadband connectivity. *Middleware*
Company:	**Xilinx**
City:	Austin
Line of Business:	Xilinx was established in 1984 and is headquartered in San Jose, with a corporate sales office in Austin and a partnership with IBM. Xilinx is a semiconductor company that also produces software design tools, including software design tools for wireless applications. *Chip Design*
Company:	**Xtera**
City:	Allen
Line of Business:	Xtera designs and manufactures infrastructure bandwidth management equipment. *Infrastructure Hardware*
Company:	**Xterprise**
City:	Dallas
Line of Business:	Xterprise designs, installs, and supports RFID inventory tracking systems. *Middleware, VAR/Integrator*

Hardware Development

Hardware Engineer - Analog/RFIC Design Engineer

Analog/RFIC Engineers design circuits that process radio frequency communication signals. They must calculate appropriate circuit complexity, power consumption, functionality and speed in their designs. These engineers often work with a systems level architect to ensure that their designs meet necessary specifications. Their designs allow electronics to communicate with other electronics wirelessly. Demand for Analog/RFIC Designers will remain strong because these engineers allow digital systems to communicate with real-world analog signals such as the human voice.

Knowledge
- In depth knowledge of RF theory, device physics and signal processing
- Mixed-Signal design experience
- Knowledge of phase lock loops, IF amplifiers, filters and other communications circuits

Skills
- Oral and written communication skills
- Efficient debugging and analytical skills
- Expertise in Spice or other analog design tools

Abilities
- Independently learn new tools and techniques
- Receive and give constructive feedback
- Ability to work with diverse teams
- Manage multiple tasks, projects and deadlines

Hardware Engineer - Wireless Systems Technical Associate

Wireless Systems Technical Associates support the design and development of wireless electronic systems. These technicians are responsible for performing and documenting tests of various software and/or hardware elements. Often these employees spend much of their time in labs in support of engineers and systems architects.

Knowledge
- Basic electronic circuits
- Test design methodology
- Electronic communications knowledge
- Basic physics
- RF theory and measurement

Skills
- Experience with lab test equipment
- Statistical analysis skills
- Documentation skills
- Ability to convert numbers from decimal to binary

Abilities

- Strong communication skills
- Ability to collaborate with others
- Strong organizational ability
- Ability to work on diverse teams
- Ability to meet strict deadlines
- Strong problem solving skills
- Project management ability
- Infrastructure

Infrastructure — Cell Site Technician

Already, over 166 million Americans have mobile phones. As such, demand for additional cell sites comes from technology upgrades and current site maintenance. Cell site technicians provide many valuable services. They are responsible for hardware installation and ensuring that installed equipment provides maximum coverage. These technicians also perform maintenance on existing installations. They use field measurement equipment to perform troubleshooting activities. In addition to knowing the underlying communications technology of the particular cell site, these technicians need to know how to attach power sources and possibly HVAC systems.

Knowledge

- Understanding of underlying communications technology (CDMA, GPRS, etc.)
- Knowledge of FCC specifications
- Knowledge of basic electronic circuits

Skills

- Experience with electrical test equipment
- HVAC installation experience
- Documentation skills

Abilities

- Ability to work independently with minimum supervision
- Independently learn new tools and techniques
- Ability to maintain strict quality standards
- Strong problem solving skills

Infrastructure — Construction Technician

Construction Technicians assess customer sites for optimum wireless, transmission tower locations. These workers then install towers and necessary communications equipment, and they check that the installed system is working properly. The communication system may use a variety of wireless technologies with which the technician must be familiar.

Knowledge

- Knowledge of RF technology including microwave radio transmissions
- Knowledge of FCC specifications
- Knowledge of basic electronic circuits

Skills

- Effective oral and written communication skills
- Documentation skills
- Antenna installation experience

Abilities

- Ability to work independently with minimum supervision
- Work at heights on ladders, towers, etc.
- Work in inclement weather conditions
- Ability to maintain strict quality standards
- Ability to lift heavy loads up to 60 lbs.
- Software

Software – Healthcare Applications Developer

The healthcare industry is both one of the largest and fastest growing industries in the United States. Healthcare related expenditures had a 5.5% CAGR over the late 1990s and this growth rate may well increase as the American population ages. Increasingly, IT solutions are viewed as a way to improve quality of care while controlling costs. Software developers in this domain apply their programming skills to solve problems such as billing systems, medical instrument tracking, and maintaining patient health records.

Knowledge

- Programming languages (assembly programming, C, C++, Java, etc.)
- Healthcare process knowledge

Skills

- Programming experience
- Firmware experience
- Project management skills

Abilities

- Independently learn new tools and techniques
- Ability to meet strict deadlines
- Teach and learn from others
- Ability to work with limited supervision
- Ability to work on diverse teams
- Ability to maintain strict quality standards

Software – Usability Engineer

Usability Engineers concentrate on providing a productive interface between humans and machines. In software, this task is accomplished through thoughtful GUI and database design. These employees design studies, collect and analyze data, deliver results, and follow up on recommendations.

Knowledge

- General knowledge of behavioral research with humans
- Demonstrated background in either longitudinal or cross-sectional study design
- Work in an applied research or product development environment

Skills

- Basic research design skills in experimental design and questionnaire research
- Excellent interpersonal skills
- Excellent written and oral communication skills
- Group presentation skills
- Persuasiveness

Abilities

- Generate and track long-term user-testing plans for products
- Analytical ability
- Ability to work on diverse teams
- Ability to synthesize art, design and technology concepts
- Manage multiple tasks, projects and timelines
- Receive and give constructive feedback
- Independently learn new tools and techniques

Systems Integrator

Systems Integrators – Machine-to-Machine Firmware Technician

Firmware Technicians aid in the development of embedded control systems. These technicians write and debug assembly language code. They assist engineers in prototype development of M2M hardware through product testing. Knowledge of lab measurement systems as well as proper test procedures is important to this position. These workers also engage in the mechanical construction of product prototypes.

Knowledge

- Basic digital and analog electronic circuit knowledge
- I/O protocols for microcontrollers
- Software programming languages (C, assembly)
- Familiarity with various operating systems

Skills

- Multi-meter, logic analyzer, and frequency generator experience
- Microcontroller experience
- Soldering and wiring skills
- Debugging skills

Abilities

- Ability to work independently with little supervision
- Strong verbal and written communication skills
- Ability to independently learn new techniques
- Strong documentation skills
- Mechanical assembly ability

Systems Integrators – Vehicle Tracking Systems Installer

Wireless technologies, such as GPS, allow tagged items to be located within a small radius. Already several companies provide solutions targeted at the transportation vehicle market using these technologies to prevent theft, aid in navigation and to aid emergency services. Installers of these systems use their knowledge of vehicle 12V power systems to correctly install wireless tracking devices. Technicians test the installed system, document all work and communicate with the customer to ensure satisfactory work. Often technicians need to disassemble and reassemble vehicle panels.

Knowledge
- Automotive power system knowledge
- Electronics knowledge
- Test equipment knowledge

Skills
- 12 volt automotive installation experience
- Experience using multimeters
- Soldering experience
- Problem solving skills

Abilities
- Independently learn new tools and techniques
- Oral communication skills
- Detail oriented
- Ability to maintain quality standards
- Ability to work with minimum supervision
- Ability to assemble mechanical structures

Systems Integrator – Emergency Radio Technician

Radio Technicians install, maintain, and repair various radio-based communications equipment. Government agencies use this equipment to manage emergency services such as police and fire units. These employees often work on VHF, UHF, conventional and trunked 800 MHz, as well as microwave radio equipment.

Knowledge
- General communications network knowledge
- Electronic circuit knowledge
- RF theory knowledge
- Antenna selection and positioning

Skills
- NARTE Telecommunications Certification
- FCC General Radio
- PCIA certification
- Microsoft Office

Abilities

- Ability to maintain quality standards
- Ability to work with minimum supervision
- Ability to manage multiple tasks
- Excellent problem solving ability
- Excellent communication skills
- Detail oriented

Systems Operations

Systems Operations – Database Administrator

The U.S. Department of Labor predicts that the job of database administrator will be among the fastest growing occupations. Wireless devices will transmit a tremendous amount of information. Much of this information will be organized and stored in databases set up and maintained by database administrators. These employees typically manage who and at what level others have access to the database. The need for security measures increases with the sensitivity of the information contained in the database. Additionally, database administrators are often responsible for information backup.

Knowledge

- Understanding of server security
- Programming concepts
- Knowledge of database design issues

Skills

- Experience defining, creating, and maintaining database designs
- Experience testing and debugging databases
- Database specific software
- XML, TCP/IP, HTML, CGI, Java, web server and web-based applications

Abilities

- Ability to multitask
- Ability to work with diverse teams
- Strong organizational skills
- Independently learn new tools and techniques

Systems Operators – Asset Management Specialist

Asset Management Specialists track and inventory their firm's capital assets. These workers are employed by organizations that use just-in-time inventory systems, and / or have capital-intensive infrastructure. For instance, the oil and gas industry uses asset management specialists to track drilling equipment in the field. These employees must understand telemetry systems as well as radio communication devices. They must also know how to use their firm's chosen inventory tracking software.

Knowledge

- Knowledge of telemetry systems
- Catalog and inventory management
- R-F knowledge

Skill

- Basic computer operating skills (XP™ MS Office™)
- Experience with two-way radios

Abilities

- Ability to maintain quality standards
- Ability to work with minimum supervision
- Multitasking ability
- Exceptional organizational skills
- Strong verbal and written communication skills
- Problem solving skills
- Detail oriented

Systems Operators – Wireless Help Desk Technician

Help desk employees provide important customer service duties. These employees help resolve customer problems by assessing problem descriptions and then recommending corrective actions. In the process, help desk employees may communicate with customers over the telephone, through e-mail and through internet chat. Help desk employees must know the technology for which they are providing service, and they must know how to effectively communicate recommendations to potentially less technically savvy customers. Problems are normally tracked and documented through a problem ticket system.

Knowledge

- Application specific device hardware knowledge
- Application software knowledge
- LAN security and design concepts
- Application installation knowledge
- PC operating systems

Skills

- Experience with problem ticket software
- Customer contact experience
- Experience configuring wireless data connections

Abilities

- Excellent problem solving ability
- Excellent communication skills
- Willingness to learn new technologies
- Desire to provide quality customer service
- Ability to manage multiple tasks
- Ability to give and receive criticism
- Willingness to work flexible hours

Appendix: Bibilography

ABI Research. (n.d.). Global Markets for Modules, Equipment, and Service Providers. Cellular Machine-to-Machine (M2M) Communications. Retrieved July2, 2004, from http://www.abiresearch.com/reports/M2M.html

ABI Research (2004) Highest Growth Market for Cellular Radios is M2M, Not Cellular Handsets. Tekrati. Retrieved Sept. 16, 2004 from http://www.tekrati.com/T2/Analyst_Research/ArchivedResearchAnnouncementsDetails.asp?SearchStr=%22cellular%22+AND+%22radio%22&Newsid=2623

ASU. (n.d.). COM 003: Definitions. Retrieved July 2, 2004, from http://www.asu.edu/aad/manuals/com/com003.html

ArrayCom. (n.d.). Cooper's Law. Retrieved July 8, 2004, from http://www.arraycomm.com/pcct/coopers_law.htm

Aslam, A., Bamidele, A., Ching, A. L. M. (2003, April 14). Value Migration in the Wireless Industry. Retrieved July 2, 2004, from London Business School Web site: http://www.ee.ucl.ac.uk/~abamidel/wireless_industry_report_finalv3.doc

Barami, B. (2004, April 21-22). Market Trends in Homeland Security Technologies. Paper Presented at the IEEE Conference on Technologies for Homeland Security. Retrieved July 19, 2004 from http://www.volpe.dot.gov/ourwork/dimensions/050604/trends.doc

Bechtel, D. (n.d.). Automatic Meter Reading (AMR). Retrieved July 19, 2004, from http://www.opalco.com/news/archive/ograms/276.htm

Black, A. (n.d.). Shifting the Model for Mobile Communications. Excerpt retrieved July 2, 2004, from http://www.openwave.com/us/openwave_iq/inside_the_wave/2004/january/mobile_comm.htm

Bodymedia. (n.d.) Health. Care. Anywhere. Retrieved July 8, 2004 from http://www.bodymedia.com/index.jsp

Bodymedia. (n.d.) Products and Services that Track and Promote Health and Wellness Through Continuous Body Monitoring. Retrieved July 8, 2004 from http://www.bodymedia.com/ make/overview.jsp

Brain, M. (n.d.) How Motes Work. HowStuffWorks. Retrieved August 22, 2004, from http://computer.howstuffworks.com/mote4.htm

Brazell, J., Brodie, K., Starbuck, H. (2004, February). Structure of the Industry. Gaming, a Technology Forecast: Implications for Texas Community and Technical Colleges. Retrieved July 2, 2004, from http://forecasting.tstc.edu/forecasts/digital%5Fgames/

Cardell-Oliver, R. (2004, July 2). Environmental Monitoring of Soil Moisture with Wireless Sensor Networks. Retrieved July 19, 2004, from University of Western Australia School of Computer Science & Software Engineering Web site: http://www.csse.uwa.edu.au/adhocnets/WSNgroup/soil-water-proj/

Cavalli, A. (2004, July 8). Interview given by Dr. Alex Cavalli, IC[2] Institute.

Center for Infrastructure Expertise. (n.d.) Introduction to Critical Infrastructure. Retrieved July 19, 2004 from National Infrastructure Institute Center for Infrastructure Expertise Web site: http://www.ni2ciel.org/tutorials/CITutorial.PDF

Cheung, H. (2004, August 2). Black Hat: Day 2 Sounds Security Alarm: Interview with Lukas Grunwald. Tom's Hardware Guide. Retrieved August 22, 2004, from http://www.tomshardware.com/business/20040802/black_hat_day2-02.html

Cisneros, G. (2004, July 16). Interview given by George Cisneros.

Committee on New Public Transportation Systems and Technology (AP0201E14), Call for Papers for 2005 Meeting of the Transportation Research Board. (n.d.). Current ITS-Transit Applications and Innovations. Retrieved July 19, 2004, from http://faculty.washington.edu/~jbs/itrans/trb_new_tech_call.htm

Cowhey, P. (n.d.). The Next Revolution in Communications and Information Technology: Its Implications for Economic Growth and Innovation. Retrieved July 8, 2004 from http://www.rieti.go.jp/en/events/bbl/03102801.pdf

Cowhey, Peter E., (n.d.). "The Next Revolution in The Next Revolution in Communications and Communications and Information Technology: Its Information Technology: Its Implications for Economic Implications for Economic Growth and Innovation." University of California, San DiegoUniversity of California. Retrieved May 7, 2005 from http://www.rieti.go.jp/en/events/bbl/03102801.pdf , page 16

Cradduck, C. (2004, January 6). UWB Leader Alereon Closes $31.5 Million Series A Financing. Retrieved August 22, 2004, from http://www.alereon.com/news/040106.asp

Crossbow. (n.d.). MICA2 Datasheet. Retrieved August 22, 2004, from http://www.xbow.com/Products/productsdetails.aspx?sid=72

Crossbow. (n.d). Mote-Kit: Tiny OS Mote Developer's Kits. Retrieved August 22, 2004, from http://www.xbow.com/Products/Product_pdf_files/Wireless_pdf/6020-0048-01_A_MOTE-KIT.pdf

DPAC Technologies. (2003, January). Airborne™802.11b Wireless LAN Node ModuleFor Transportation/Trucking Applications. Retrieved July 19, 2004, from http://www.dpactech.com/transportation.asp

Deffenbaugh, D. (2004, January 28). Southwest Research Institute® receives $1.7 million to develop smart materials system. Southwest Research Institute (SwRI) News. Retrieved August 22, 2004, from http://www.swri.edu/9what/releases/2004/Smart.htm

Delin, K. (2004, April). The Sensor Web: A Distributed, Wireless Monitoring System. Sensors. Retrieved July 19, 2004, from http://www.sensorsmag.com/articles/0404/20/main.shtml

Dexheimer, J., Hannemann, R. (n.d.) Investment Opportunities in Sensor Networking: Dust, Hype, Fuzz, and Reality. A collaboration of Physical Sciences, First Analysis, Inc. and DS3 Partners. Retrieved August 22, 2004, from http://www.facvc.com/Sensors_20040401.pdf

Donoho, L. (2002, November 22). Wireless sensor market to quadruple by 2008. EC&M. Retrieved July 19, 2004, from http://www.ecmweb.com/news/electric_wireless_sensor_market/

DSL Forum. (2004, Dec. 15) Virtual Press Kit. http://www.dslforum.org/PressRoom/virtual_presskit.html

EE Times Staff. (2003, August 28). After 10-yr surge, salaries level off at $89k. EE Times. Retrieved from http://www.eet.com/story/OEG20030828S0040

EbXML. (n.d.). ebXML: Enabling a Global Electronic Market. Retrieved August 22, 2004, from http://www.ebxml.org/

Elgamal, A., Conte, J., Yan, L., Fraser, M., Masri, S., El Zarki, M., Fountain, T., Trivedi, M. (n.d.). A Framework for Monitoring Bridges and Civil Infrastructure. Retrieved July 19, 2004 from the University of California, San Diego Web site: http://healthmonitoring. ucsd.edu/documentation/public/CJUHMCS2004-Framework.pdf

EPC Global, Inc. (n.d.). Welcome to EPC Global Inc. Retrieved August 22, 2004, from http:// www.epcglobalinc.org/

Estrin, D. (n.d.). Embedding the Internet: This Century Challenges. Retrieved July 19, 2004 from http://www.mobile-wisdom.com/pdfs/M2MWPforFleet_March192004.pdf

Estrin, D., Govindan, R., Heidemann, J. (2000, May). Embedding the Internet. Retrieved August 22, 2004, from http://www.isi.edu/~johnh/PAPERS/Estrin00a.pdf

Eyes. (n.d.). Dissemination. Eyes: energy efficient sensor networks. Retrieved August 22, 2004, from http://eyes.eu.org/dissem.htm

Fall Creek Consultants. (n.d.) The Applications We Promote... Retrieved July 19, 2004, from http://www.comm-nav.com/commnav.htm

Federal Communications Commission (FCC). (2003, January 6). Medical Implant Communications. Retrieved August 22, 2004, from http://wireless.fcc.gov/services/ personal/medicalimplant/

Federal Communications Commission (FCC). (2003, January 6). About Medical Implant Communications. Retrieved August 22, 2004, from http://wireless.fcc.gov/services/ personal/medicalimplant/about/

FlexRay. (2004, September 21). FlexRay Communications System Specifications. Retrieved August 22, 2004, from http://www.flexray-group.com/index.php

The FocalPoint Group. (2003). What is M2M? A Primer on M2M Technologies, Companies, and Adoption. Retrieved July 19, 2004, from http://www.thefpgroup.com/Content.htm

The FocalPoint Group. (2003). FocalPoint 40 Profile: nPhase. Retrieved July 2, 2004, from http:// www.m2mpoint.com/Documents/nPhase_Profile.pdf

The FocalPoint Group. (n.d.). The Growth of Device Connectivity. M2M White Paper. Retrieved July 2, 2004, from http://www.thefpgroup.com/Documents/FocalPoint_White_ Paper.pdf

FocalPoint Group, Inc. (2003, November). M2M-enabled Devices; 880 million non-PC devices annually networked by 2010. Retrieved July 19, 2004 from http://www.the-infoshop.com/press/foc16734_en.shtml

The FocalPoint Group. (2003). Cellular Machine-to-Machine (M2M) Communications: Global Markets for Modules, Equipment and Service Providers. Retrieved July 19, 2004, from http://www.thefpgroup.com/Content.htm

Fondreist, S. (n.d.). Recent Developments in Real-Time Environmental Monitoring. Retrieved July 19, 2004, from http://www.netl.doe.gov/publications/proceedings/00/app-rvr00/ 3-1.PDF

Freedonia. (2002, April). New US Industry Study with forecasts to 2006 & 2011: Sensors. Retrieved July 19, 2004, from http://www.freedoniagroup.com/pdf/1539web.pdf

Frost & Sullivan. (2004, March 3). Wireless Solutions Help Healthcare Professionals Meet the Need of the Hour. PDA Cortex. Retrieved August 22, 2004, from http:// www.rnpalm.com/Wireless_Solutions.htm

Gainer, R., van Eckhardt, M., Williams, R. Marks, R. (n.d.).HIPAA and WiFi — Regulatory Tangles for Wireless Health Care Networks. Find Law for Legal Professionals. Retrieved August 22, 2004, from http://library.lp.findlaw.com/articles/file/00010/008895/title/Subject/topic/Professional%20Malpractice_Medical%20Malpractice/filename/professionalmalpractice_2_5093

GartnerG2. (2002, March 11). DUI Now Means Talkers. Center for Media Research: Research Brief. Retrieved July 19, 2004, from http://www.mediapost.com/research/cfmr_briefArchive.cfm?s=108994

Giguere, E. (2002, August 11). The Emerging M2M Market: Sharing Information with Machines. Mobilized Software. Retrieved August 22, 2004, from http://mobilizedsoftware.com/showArticle.jhtml?articleId=26807220

Gill, L. (2002, June 24). Study: Broadband Adoption on the Rise. E-Commerce Times. Retrieved August 22, 2004, from http://www.ecommercetimes.com/story/18355.html

Given Imaging. (n.d.). Expanding the Scope of GI. Retrieved July 8, 2004 from http://www.givenimaging.com/Cultures/en-US/given/english

Given Imaging. (n.d.). M2A Capsule Endoscopy Given Diagnostic System. Retrieved July 8, 2004 from http://www.givenimaging.com/NR/rdonlyres/76C20644-4B5B-4964-811A-071E8133F83A/0/GI_Marketing_Brochure_2003.pdf

Goldsmith, H.R. (n.d.) San Antonio Firsts: SITEtrek. Retrieved August 22, 2004, from http://www.ventureramp.com/Trek.pdf

Government Technology. (2004, June). Garland, Texas, Implements Wireless Network for First Responders: Network Operations Center to monitor wireless broadband system using mesh-based technology. Retrieved July 19, 2004 from http://www.govtech.net/magazine/channel_story.phtml?channel=4&id=9060

Guaning, S. (2003, August 22). Launch of Masters of Science (Embedded Systems) Programme: Address by Dr. Su Guaning, President, NTUL. Retrieved July 8, 2004 from http://www.ntu.edu.sg/CorpComms/Speeches/Launch+of+Masters+of+Science+(Embedded+Systems)+Programme.htm

Hagler Bailly Services, Inc. (n.d.). California ITS: Developing the Business! Final Report: Executive Summary. Retrieved July 19, 2004 from http://www.caats.org/caits/reports/its_business/execsumm.doc

Harbor Research. (2003, July). Let the Circle be Unbroken: How the Information Circle Created by Device Networking / M2M and the Internet Will Automate the Global Enterprise. Retrieved July 8, 2004 from http://harborresearch.com/pdfs/HRI_circle_unbroken.pdf

Hardy, Quentin. (2004, June 9). The Wireless Boom That Won't Need Us. Forbes.com. Retrieved July 19, 2004, from http://forbes.com/wireless/2004/06/09/cz_qh_0609robonet.html?partner=newscom

IBM Adds Wireless to Medical Devices. (2003, November 7). Retrieved July 8, 2004 from http://www.atmeda.org/news/PressReleases/IBM.110703.Adds%20Wireless%20to%20Medical%20Devices.pdf

IEEE (n.d.) IEEE1073 Mobile Device Communications: Overview. Retrieved August 22, 2004, from http://www.ieee1073.org/overview/overview.html

Inaudi, D., Casanova, N. (2002, May 6-10). SMARTEC: Bringing Fiber Optic Sensors into Concrete Applications. Paper presented at the 15th Optical Fiber Sensor Conference. Retrieved July 19, 2004 from http://www.smartec.ch/Bibliography/PDF/I07.pdf

Insignia.com. (n.d.). Motorolla 'White Box' Announcement Shows Shift in Wireless Balance of Power. Wireless Developer Network Daily News. Retrieved July 2, 2004, from http://www.wirelessdevnet.com/news/2002/203/news2.html

InStat MDR. (n.d.). Psychographics and Demographics of Wireless Data Subscribers. Retrieved July 8, 2004 from http://www.instat.com/catalog/Wcatalogue.asp?id=230#IN0401656MCD

In-Stat/MDR. (2004, May 10). Home Networking to Grow Exponentially. Designtechnica. Retrieved August 22, 2004, from http://news.designtechnica.com/article3715.html

In-Stat/MDR. (2004, May 10). Home Networking Market to Reach $17.1 Billion in 2008. Tekrati. Retrieved August 22, 2004, from http://www.industryanalystreporter.com/T2/Analyst_Research/ArchivedResearchAnnouncementsDetails.asp?SearchStr=%22in0401227rc%22&Newsid=2725

In-Stat/MDR. (2003, June 4). Smart and SPOT Appliances Reach a Broader Audience This Year. Retrieved August 22, 2004, from http://www.instat.com/newmk.asp?ID=652

Jackson, M. (2004, March 11). AMR – More than Reading a Meter. The Energy and Utilities Project, 4. Retrieved July 8, 2004 from http://www.utilitiesproject.com/documents.asp?d_ID=2424

Karlof, C., Sastry, N., Wagner, D. (2004, November). TinySec: Link Layer Encryption for Tiny Devices. Retrieved August 22, 2004, from http://www.cs.berkeley.edu/~nks/tinysec/

Karoub, J. (2002, August 30). Wireless MEMS are Loud and Clear while Telecom Suffers Static. Small Times. Retrieved July 19, 2004, from http://www.smalltimes.com/document_display.cfm?document_id=4528

Kentala, J. (2003, November 9). Nokia M2M Business: Let Your Machines Talk. Retrieved July 2, 2004, from http://www.nokia.com.cn/mobile/m2m/down_document/m2m-white-paper-0104-v7.pdf

Kistner, Toni. (2002, March 4). What's in the Way of Home Networking? NetworkWorldFusion. Retrieved August 22, 2004, from http://www.nwfusion.com/net.worker/columnists/2002/0304kistner.html

Kottappali, V., Kiremidjian, A., Lynch, J., Carryer, E., Kenny, T., Law, K., Lei, Y. (2003, March 2-6). Two-tiered wireless sensor network architecture for structural health monitoring. Paper presented at SPIE's 10th Annual International Symposium on Smart Structures and Materials. Retrieved July 19, 2004, from http://www.eecs.harvard.edu/~mdw/course/cs263/fa03/papers/structure-spie03.pdf

Krishnamurthy, Lakshman [Intel Corporation]. (2003, September 24). Adapted from Wireless Sensor Networks with RoI [Powerpoint Presentation]. Boston, MA: MIT Emerging Technology Conference.

Kuykendall, D. (2004, July 23). Interview given by David Kuykendall, Chairman, Secure Orbit Labs, via telephone.

Larson, D. (2003, August). Little Guys Can Make Medical Products Too. Wireless Systems Design. Retrieved August 22, 2004, from http://www.wsdmag.com/Articles/ArticleID/6052/6052.html

Legg, G. (2004, May 6). ZigBee: Wireless Technology for Low-Power Sensor Networks. TechOnLine. Retrieved July 8, 2004 from http://www.techonline.com/community/tech_group/36561

Levis, P. (2003, November 11). Simulating TinyOS Networks. Retrieved August 22, 2004, from http://www.cs.berkeley.edu/~pal/research/tossim.html

Levis, P., Patel, N. (2003, November 11). Maté: Building Application-Specific Sensor Network Language Runtimes. Retrieved August 22, 2004, from the University of California Berkeley Web site: http://www.cs.berkeley.edu/~pal/research/mate.html

Lewis, D. (2001). Fundamentals of Embedded Software: Where C and Assembly Meet [Electronic Version]. Retrieved from http://www.amazon.com/exec/obidos/tg/detail/-/0130615897/002-2529402-1625669?v=glance&vi=excerpt

Lillich, M. (2004, March 29). Krannert School prof, MBA students issue bullish forecast for tech. Lafayette Online Business News. Retrieved July 8, 2004, from http://www.lafayette-online.com/cgi-bin/coranto/viewBusiness.cgi?id=EplpVlFFuAkMjbxrPm

Lynch, J. (2004, June 10-11). Overview of Wireless Sensors for Real-Time Health Monitoring of Civil Structures. Paper presented at the 4th International Workshop on Structural Control and Monitoring. Retrieved July 19, 2004 from http://www-personal.engin.umich.edu/~jerlynch/papers/IWSCM04Paper.pdf

M2M 100. (n.d.). M2M 100 Solutions Directory: Nokia. M2M Magazine. Retrieved August 22, 2004, from http://www.m2mmag.com/m2m100/enhanced.asp?company_id=8

M2M Europe. (n.d.) What is M2M?. Retrieved July 8, 2004 from http://www.m2mexpo.com/europe/whatisM2M.htm

McLatchie, H.L. (n.d.). M-Commerce: Believe It! Agilebrain.com Journal of Business Innovation. Retrieved July 2, 2004, from http://www.agilebrain.com/mobileecom.html

Malan, David, Thaddeus Fulford-Jones, Matt Welsh, and Steven Mouldon. (2002) CodeBlue: An Ad Hoc Sensor Network for Emergency Medical Care. Cambridge: Harvard University, Department of Electrical Engineering and Computer Science. http://www.eecs.harvard.edu/~mdw/papers/codeblue-bsn04.pdf

Mallinson, K. (2004, April 12). Wireless Services Now Represent 25 Percent of U.S. Corporate Telecom Spend, Says Yankee Group. Yankee Group, News Releases. Retrieved July 8, 2004 from http://www.yankeegroup.com/public/news_releases/news_release_detail.jsp?ID=PressReleases/news_04122004_wmec.htm

Metering International. (1997). Do future trends favour automatic meter reading? Retrieved July 19, 2004, from http://www.metering.com/archive/972/14_1.htm

Minges, Michael. (2003, June 22-24). Is the Internet Mobile? Measurements from Asia-Pacific. Paper presented at the 2003 International Telecommunications Society Asia-Australasian Regional Conference. Retrieved July 8, 2004, from http://www.itu.int/ITU-D/ict/papers/2003/Measuring%20mobile%20Internet.pdf

Mitchell, M. (n.d.) Skill Standards for Wireless Telecommunications. Retrieved August 22, 2004, from http://www.wa-skills.com/PDFs/wireless_tele/WIRELESS.pdf

Mobile Village. (2004, February 25). Poll: more wireless subscribers to cut the cord. Retrieved July 8, 2004 from http://www.mobilevillage.com/news/2004.03.01/gowireless.htm.

Mobile Wisdom. (2004, March 19). Mobile Communications for Fleet Management. Retrieved from http://www.mobile-wisdom.com/pdfs/M2MWPforFleet_March192004.pdf

MobileInfo.com. (2003, October 22). Market Outlooks and Trends: ABI Forecasts Bright Outlook for GPS Market. Retrieved July 19, 2004, from http://www.mobileinfo.com/ News_2003/Issue27/GPS_outlook.htm

Mohr, Werner. (2003, July24-25). The Wireless World Research Forum. Paper presented at the 2003 ITU-T Informal Forum Summit. Retrieved July 8, 2004, from http://www.itu.int/ itudoc/itu-t/ifs/072003/pres_org/wwrf.pdf

Molta, Dave. (2002, March 6). Ready for Wireless Microcarriers? Mobile Observer: Airtime. Retrieved July 2, 2004, from http://www.networkcomputing.com/shared/ printArticle.jhtml?article=/mobile/columns/030602colmolta.html&pub=nwc

Neil, Stephanie. (2003, July). Sensors: the New Frontier [Electronic version]. Managing Automation Online. Retrieved July 19, 2004, from http://www.nphase.com/pdfs/ sensors_the_new_frontier.pdf

Neil, S. (2003, July). Sensors: the New Frontier. Managing Automation Online. Retrieved July 2, 2004, from http://search390.techtarget.com/sDefinition/0,,sid10_gci213274,00.html

Nokia. (2004, May). Nokia M2M Business FAQ. Retrieved July 2, 2004, from http:// www.forum.nokia.com/main/1,6566,1_70_80_10,00.html

Nokia. (n.d.). Machine to Machine: Let Your Machines Talk. M2M White Paper. Retrieved July 2, 2004, from www.nokia.com.cn/mobile/m2m/ down_document/m2m-white-paper-0104-v7.pdf

North American Wireless Analyst. (2004, May 28). M2M offers billions in revenue for savvy operators and partners. Retrieved June 30, 2004, from http://www.telecoms.com/ NASApp/cs/ContentServer?pagename=marlin/home&siteid=30000000461&mp_ channelid=30000000378&Marlin ViewType=ARTICLEVIEW&mp_articleid=10678617 13158&mp_pubcode=MC&mp_seqnum=87

North Central Texas Council of Governments (NCTCG). (2004, June). 2004 Major Employer Publication. Retrieved August 22, 2004, from http://www.nctcog.org/ris/majemp/ majemp04.pdf

Ovum Research. (2003, November). Wireless ASPs: moving up the value chain. Retrieved July 2, 2004, from http://www.ovum.com/go/content/SDV.htm

Park, H., Kim, B., Lim, K. (2001, March). Measuring the Machine Intelligence Quotient (MIQ) of Human-Machine Cooperative Systems. IEEE Transactions on Systems, Man, and Cybernetics – Part A: Systems and Humans, Vol. 31, No. 2, March 2001. Retrieved July 8, 2004 from http://rtcl.kaist.ac.kr/pdf/IJ26.pdf

Pescovitz, D. (2003, March 28). The Real World as Database. Retrieved August 22, 2004, from http://intel-research.net/berkeley/features/tiny_db.asp

Phister, P., Plonisch, I. (n.d.) Knowledge Centric Warfare: Next Evolution of Network Centric Warfare. Retrieved July 8, 2004 from http://www.dodccrp.org/events/2004/ CCRTS_San_Diego/CD/presentations/188.pdf

Polar. (n.d.). Fitness. Retrieved July 8, 2004 from http://www.polar.fi/polar/channels/eng/ segments/Fitness.html

Purcell, B. (2003, May 30). Transguide. The Texas HighwayMan Pages. Retrieved July 19, 2004 from http://home.att.net/~texhwyman/transgd.htm

Ringstad, Matt, Thomas Mohr, Jeremy Tryall. (n.d.) RFID Tagging of Seedlings. Seattle: University of Washington Precision Forestry Cooperative. http://www.cfr.washington.edu/research.pfc/research/rfid.htm

Rohringer, S., Ischebeck, B. (2004, March 30). RFID Solution Excellence Center: Opening: System Lab. Infineon. Retrieved August 22, 2004, from http://www.infineon.com/cmc_upload/RFID_Graz_300304.pdf

Rorden, C. (n.d.). The Dicom Standard. Retrieved August 22, 2004, from http://www.psychology.nottingham.ac.uk/staff/cr1/dicom.html

SIP Center. (2004, March 18). NetCentrex Unveils VOIP Video Strategy. The SIP Center. Retrieved July 2, 2004, from http://www.sipcenter.com/sip.nsf/html/2004+March+7+of+11

Salomaa, V. (2003). Opportunities in Wireless M2M Telematics. Retrieved July 2, 2004, from Helsinki University of Technology, Department of Industrial Engineering and Management, Institute of Strategy and International Business Web site: http://www.tuta.hut.fi/studies/Courses_and_schedules/Isib/TU-91.167/Old_seminar_papers/Salomaa_Ville.pdf

Scherf, K. (2004, May 4). Home Network Outlook. Retrieved August 22, 2004, from http://www.homeplug.com/news/presentations/%20may04_2004/HP_MM_050404_Analyst_KScherf.pdf

Search390.com. (n.d.). VAR. Definitions. Retrieved July 2, 2004 from http://search390.techtarget.com/sDefinition/0,,sid10_gci213274,00.html

Sensametrics. (2003, July 16). Sensametrics, Inc. Wireless Sensing Solutions for Civil Structures. Retrieved July 19, 2004 from http://www.sensametrics.com/html/sensor_news.html

Simon, E. (2004, August 8). The Long Fall of AT&T. San Antonio Express News, p. L1.

Sinclair, K. (n.d.) Building Automation: Reaching for the Sky. Retrieved August 22, 2004, from http://www.lonmark.org/news/pub/iaa_0204.pdf

Sirer, Emin Gun. (n.d.). The MagnetOS Operating System. Retrieved August 22, 2004, from the Cornell University Web site: http://www.cs.cornell.edu/People/egs/magnetos/

Smith, J. T. (2004, July 29). Interview given by James T. Smith, Institute for Scientific Research, Inc., via telephone.

Smith, L., Roth, H. (2003, July 29). ITS Decision: Services and Technologies. Retrieved June 30, 2004, from University of California at Berkeley and Caltrans Institute of Transportation Studies from http://www.calccit.org/itsdecision/serv_and_tech/Parking_Systems_Technologies/parking_systems_tech_report.htm#ADVANCED%20PARKING%20SYSTEMS

Southwest Research Institute. (n.d.). Medical Device Development: Medical Electronics and Sensors. Retrieved August 22, 2004, from http://www.swri.edu/4org/d10/bioeng/meddev/sensors.htm

Southwest Research Institute. (n.d.).RF Engineering Services: Wireless Communications. Retrieved August 22, 2004, from http://www.swri.edu/4org/d10/comm/RFE/RFEng/wireless.htm

Space Data Corporation. (2004). Transportation. Retrieved July 19, 2004, from http://www.spacedata.net/transportation.htm

Stumberg. (2004). Interview given my Stumberg, via telephone).

Symbol Technologies. (n.d.). In Transportation, Logistics and Aviation. Retrieved July 19, 2004 from http://www.symbol.com/solutions/homeland_security/secmrkt_lta.html

Technology Ventures Corporation. (n.d.). California Equity Capital Symposium: September 16-17, 2004: Sensametrics. Retrieved July 19, 2004 from http://ca-ecs.org/html/present.html

Telecommunications Industry Association (TIA). 2004, January 31). U.S. Wireless Market to Reach $190.8 Billion by 2007. Mobile Tech News. Retrieved July 8, 2004 from http://www.mobiletechnews.com/info/2004/01/31/125931.html

Texas Department of Transportation. (1998, July 21). Transguide. Retrieved July 8, 2004 from http://www.transguide.dot.state.tx.us/mdi/rollout.html

TinyDB. (n.d.). TinyDB: A Declarative Database for Sensor Networks. Retrieved August 22, 2004, from http://telegraph.cs.berkeley.edu/tinydb/

TinyOS Community Forum. (n.d.) Mission Statement. Retrieved August 22, 2004, from http://www.tinyos.net/special/mission

Turner, C. (2003, March 3) EPC and ISO 18000-6: Confused about differences between the AutoID Center's Electronic Product Code and ISO 18000-6? Chris Turner offers some clarifications. Retrieved August 22, 2004, from http://www.rfidjournal.com/article/articleview/325/1/2/

Turner, R.B., Demers, B. (2004, April 6). Decade of Enhanced Services: Focus on Conferencing. NMS Communications. Retrieved July 2, 2004, from http://www.nmscommunications.com/file/webinarapr04enhancedservices.pdf

M2M: The Wireless Revolution A Technology Forecast
Implications for Community & Technical Colleges in the State of Texas

What is M2M? M2M is an acronym for the term "Machine-to-Machine" and the birth of a 4th generation of computing. M2M is a category of information and communication technology that combines communications, computer, and power technologies to enable remote human and machine interaction with physical, chemical, and biological systems and processes. M2M represents a new kind of application for computing where data are transmitted to and from physical and biological environments (Krishnamurthy, Laksham, 2003). In many ways, M2M represents a "Wireless Revolution," as all things are increasingly connected to the network via wireless telemetry. Analysts are optimistic that a spectrum of promising markets and opportunities abound with an established $100 billion market in 2005. This report provides analysis of this technology and its markets, industries, and workforce needs. Promising markets include:

- Critical Infrastructure and Heavy Industry,
- Transportation and Logistics,
- Structural Health Monitoring and Environmental Monitoring,
- Retail and Wholesale Trade,
- Healthcare and Medical Devices,
- Home Networking, and
- Utilities.

A highly skilled workforce is essential to the success of Texas companies and the overall competitiveness of the State. Through this research, TSTC hopes to facilitate the informed development or enhancement of emerging high-tech education and training curricula at Texas colleges. By proactively responding to new and emerging workforce requirements, Texas colleges ensure that Texas employers will continue to have the highly skilled employees they need to succeed and prosper in an increasingly innovative marketplace.

Programs for Emerging Technologies

This research was conducted by The IC² Institute and Texas State Technical College in the third quarter of 2004. Programs for Emerging Technologies (PET) identifies and forecasts new and emerging technologies and related curriculum development opportunities for Texas community and technical colleges. This program fulfills a legislative mandate enacted by the 76th Legislature which charges Texas State Technical College with developing and administering a program to identify, evaluate, and forecast potential emerging technology programs which are likely to have a positive impact on the State's economy (SB1819). Visit **www.forecasting.tstc.edu** for more information and to download this and other PET publications. Special thanks to M2M Magazine for assisting in the distribution of the industry survey within.

For additional information contact:

Michael A. Bettersworth, Associate Vice Chancellor
Texas State Technical College System
3801 Campus Drive, Waco, Texas 76705, U.S.A.
michael.bettersworth@tstc.edu   v. 254.867.3995

www.forecasting.tstc.edu