HIGHLIGHTS OF THE 2002 NATIONAL ELECTRONIC MANUFACTURING TECHNOLOGY ROADMAPS AND THEIR APPLICABILITY TO CHINA

Dr. Robert C. Pfahl, Jr.
Vice President of Operations
National Electronics Manufacturing Initiative (NEMI)
2214 Rock Hill Road, Suite 110
Herndon, VA 20170 USA

ABSTRACT
This presentation describes the roadmapping process used in North America, highlights key global results of the 2002 edition, and suggests how this roadmap and the roadmap process might benefit the electronics industry in China. The 2002 National Electronic Manufacturing Technology Roadmap (NEMI, 2002) was released by NEMI on April 1, 2003. This edition of the biennial roadmap is over 1000 pages long and was produced by over 350 individuals from over 170 industrial, government, and academic institutions in North America in cooperation with SIA (Semiconductor Industry Association), IPC, IMAPS (International Microelectronics and Packaging Society), USDC (United States Display Consortium), NSIC (National Storage Industry Consortium), and OIDA (Optoelectronics Industry Development Association). It contains eighteen individual technology roadmaps covering all aspects of the global electronics industry and its supply chain.

I. THE NEMI ROADMAPPING PROCESS

What is the NEMI Roadmap?

Every two years, the National Electronics Manufacturing Initiative (NEMI) maps the future manufacturing technology needs of the North American electronics industry. The purpose is to identify the key technology and infrastructure developments required to ensure the competitiveness of the North American electronics manufacturing supply chain over the next decade.

How is it Produced?

NEMI solicits input from industry experts representing all perspectives within the North American electronics manufacturing supply chain. Development of the 2002 NEMI roadmap involved approximately 350 individuals representing 170 organizations. Efforts are organized into two types of activity groups: Product Sectors and Technology Working Groups (TWGs).

Product Sector Groups, each led by a "product champion" from a major original equipment manufacturer (OEM) in the sector, define the future manufacturing needs of "virtual products" from five sectors: (1) consumer, (2) portable, (3) office systems, (4) large business systems and (5) automotive and aerospace/defense (*see Table 1*). Included in each sector's discussions are future product attributes plus key cost and density drivers.

Product Sector	Characteristics
Consumer	High-volume products for which cost is the primary driver
Portable	Hand-held, battery-powered products driven by size and weight reduction
Office systems	Require maximum performance within a few thousand dollar cost limit
Large business systems	High-end products for which performance is the primary driver
Automotive & aerospace/ defense	Products must operate in extreme environments

Table 1. Product Sectors of the NEMI, SIA, and IPC Roadmaps

TWGs (*see Table 2*) forecast trends for numerous technology and infrastructure areas (*see Table 3*), and contrast technology trends with anticipated product needs. Composed of experts from OEMs, EMS providers, suppliers, government agencies, universities and related consortia/trade associations, the TWGs predict the evolution of technology and/or business practices, identify gaps and "showstoppers" in the existing technology and/or infrastructure, and develop recommendations for their respective areas.

Digital Silicon Technology
• Semiconductor devices (digital)
Business Processes/Technologies
• Product lifecycle information management
Design Technologies
• Environmentally conscious electronics
• Modeling, simulation & design tools
• *Thermal management*
Manufacturing Technologies
• Board assembly
• Final assembly
• Test, inspection & measurement
Component/Subsystem Technologies
• Connectors
• Displays
• Energy storage systems
• Interconnect substrates – ceramic
• Interconnect substrates – organic
• Mass data storage
• Optoelectronics
• Packaging
• Passive components
• RF components

Table 2. Technology, Infrastructure and Business Practice Areas

What Areas are Covered?

For each roadmapping cycle, NEMI determines technology, infrastructure and business practice areas according to what is happening in industry and what changes are expected to have the greatest effect on electronics manufacturing.

The 2002 roadmap covers 18 technology and business process topics. Addressing the shifts in each of these areas, along with the related technology gaps and business needs, benefits the entire electronics industry. By helping organizations focus resources on areas of greatest need, the roadmap improves technology development and deployment for greater manufacturing productivity.

How Has the Process Evolved?

Since the first roadmap in 1994, NEMI has enjoyed increasingly greater support and participation from industry. This effort reaches beyond the NEMI membership to involve a broad spectrum of organizations in the critical task of defining industry needs.

Earlier roadmaps dealt exclusively with technology needs. However, recognizing that good business practices can be as critical to a company's success as technology, NEMI continues to expand its focus to address business practices along with technology needs.

Parameter	Metric	2003	2005	2007	2013
RF section cost (for a given function)	Relative to costs in 2000	0.7	0.35	0.17	0.05
Number of freq bands		2	4	6	6
Number of Antennas (Diversity)		1	2	2	3
Number of Modulation formats		2	4	5	5
Data transmission rate (peak)?	kb/s	14	160	1500	11,000
Transmit Peak-to-Average Ratio (worst)	dB	4 dB	5 dB	5 dB	4 dB
Talk time	minutes	90	120	160	200
Battery Voltage	V	3.3	2.7	1.5	1.2
RF section area	mm^2	1800	1200	800	500
RF component thickness	mm	2.5	1.5	1.5.MEMs	1.0,MEMS
From Portable emulator:					
Average Component I/O Density	I/O per cm^2	70	80	100	140
Max Component I/O Density**	I/O per cm^2	280	320	350	450
I/O per Component, avg.	#	3.6	4.0	4.4	5.0
Package I/O Pitch (Perimeter)	mm	0.5	0.5	0.5	0.5
Package I/O Pitch (Area array)	mm	0.5	0.4	0.25	0.2
Max I/O per package	I/O per pkg	256	288	312	360
Flip Chip I/O Pitch (Area)	mm	0.25	0.25	0.20	0.10
Substrate Lines and Spaces	microns	60	35	30	20

Table 3. Cellular handset: Key Attribute Needs

The 2002 roadmap features, for the first time, a chapter on connectors. There is also a new chapter on product lifecycle information management, which combines the topics of enterprise information technology, supply chain management and factory information systems. In addition, the 2002 roadmap provides extended situation analysis and benchmarking for RF components, optoelectronics, displays, mass data storage, energy storage systems, connectors and modeling, simulation and design tools.

As with previous roadmaps, NEMI coordinated with other roadmapping organizations to synchronize timelines, agree on and refine product sector definitions, identify common elements, facilitate cross-functional groups, and coordinate roadmapping schedules. Direct links with other roadmaps and other organizations include SIA (semiconductors), IPC (interconnection substrates), the Optoelectronics Industry Development Association (OIDA; optoelectronics and optical storage), the Information Storage Industry Consortium (INSIC; magnetic and optical storage), the US Display Consortium (USDC; displays), the Supply Chain Council (SCC; product lifecycle information management), and the International Microelectronics Packaging Society (IMAPS; ceramic substrates). (*see Figure 1*)

II. HIGHLIGHTS OF THE 2002 NEMI TECHNOLOGY ROADMAP

Situation Analysis

Business

As the electronics industry matures, it inevitably will enter the commodity phase of the life cycle. In this period, break-through technology may no longer be sufficient to insure business success. Customers will demand and get the right solution at the right cost from winning enterprises. This drives a whole series of business behavior that is quite different from the past.

Segments of the electronics industry continue to be in the middle of a major re-structuring, moving the center of manufacturing competence from the OEMs (Original Equipment Manufacturers) to the EMS (Electronics Manufacturing Services) providers and ODMs (Original Design Manufacturers).

- Business models across the electronics industry are changing leading to significant shifts in roles and responsibilities across the supply chain.

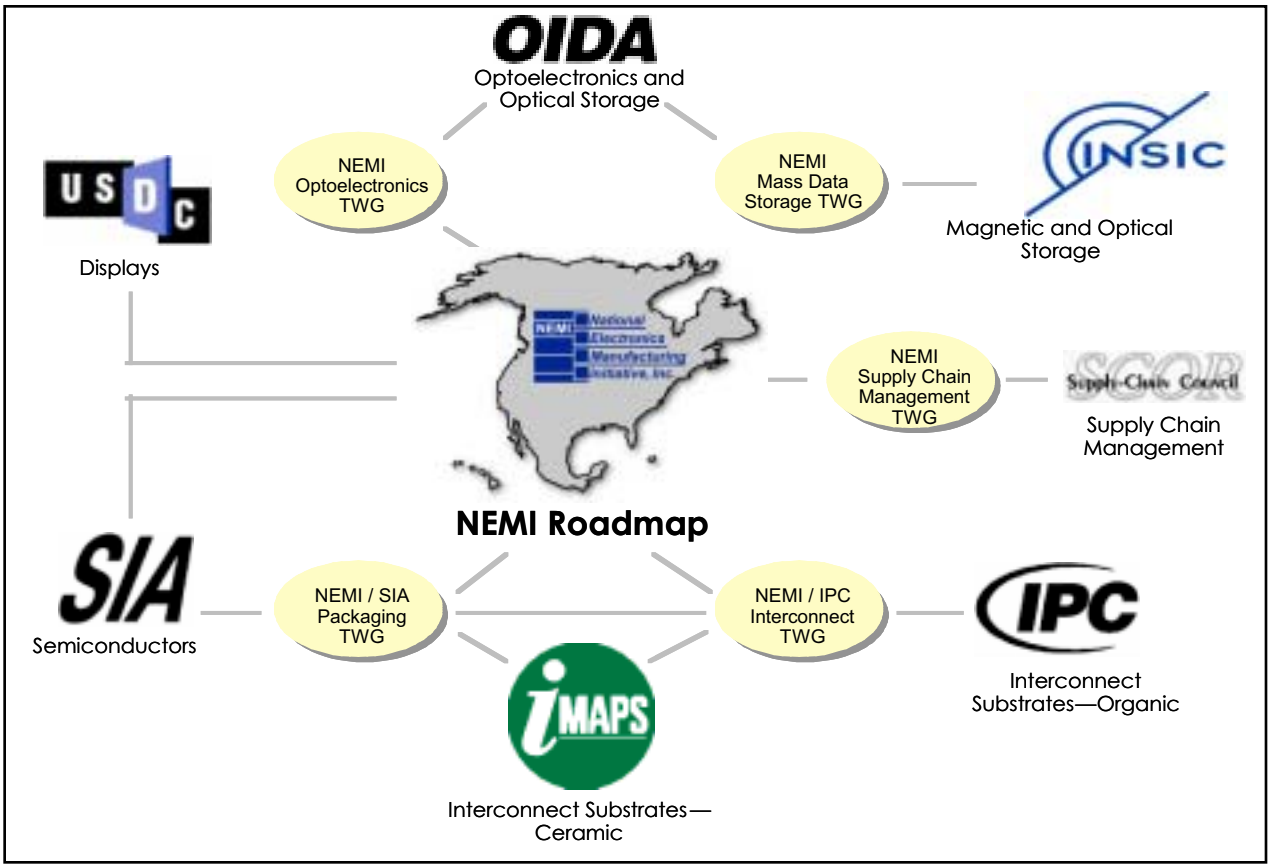

Figure 1. Linkages with other Electronic Roadmapping Activities

- Supply Chain Management (SCM) offers the potential to increase productivity.
- The increasing scope of outsourced operations requires loosely coupled business processes spanning multiple companies.
- EMSs are reporting 2001-2 revenues that are down 40-50% from 2000.
- There has been a movement of manufacturing to China from both the United States and South East Asia: a low-cost, highly skilled workforce, and a massive market opportunity.

Regulatory

Legislation impacting the design and recycling of electronic products is under discussion throughout the world. Two directives, RoHS (Restriction on use of certain Hazardous Substances) and WEEE (Waste from Electrical and Electronic Equipment), which will govern the material content and end-of-life management of electronic products, are in the final legislative stage in the European Union. These directives must be implemented by 2006 and 2004 respectively.

- Environmental legislation in various product segments will require the electronics industry to share detailed material content data of their products and components.
- To meet regional legislative requirements, manufacturers must remove environmental "Materials of Concern," such as lead and bromine.
- The electronics industry is facing end-of-life or producer responsibility legislation.

Market

During the past two years sales of electronics products have declined, and the decrease is generally predicted to continue through much of 2003 as the markets work off excess inventories while demand for new products develops. The inventory surplus has highlighted a continuing need for improved supply chain management.

- The use of Cell Phones for web access is forecast to exceed the use of personal computers for web access by 2005-6.
- PC growth is forecast to be stalled through 2003.
- The optical equipment market is forecast to shrink to $40B in 2005 from $85B in 2000 because optoelectronics broadband technical capabilities have outpaced demand.
- The LCD industry will invest $40B in manufacturing capacity for displays over the next several years to keep up with demand.
- Wireless networking and automotive entertainment are emerging as volume drivers.
- Wireless networking will grow to 2B units by 2006-2007.

Technology

It is no longer clear that the rate of advancement predicted by Moore's Law will be sustained over the long term. Improving design productivity and reusing the designs are the key solutions for this issue. Increasing packaging costs could also slow the traditional learning curve of the semiconductor industry.

- Growth in silicon device size is slowing, and the rate of reduction in feature size will resume on a three-year cycle, its historical rate.
- LCD and plasma displays are starting to encroach on the CRT market, while OLED (Organic LED) has the promise of providing thin, lightweight – even roll-up – display technology that could compete with LCDs.
- New applications of MEMS technology are making new capabilities feasible in a number of old and new markets such as: displays; servo control for mass data storage, optical switches, laser tuning; rf components, passives; and micro-batteries.
- Manufacturing ramp-ups continue to accelerate in the portable and consumer segments. Release to peak production is only three to six months, with production end at 18 months or sooner.
- System in Package (SiP) has emerged as the fastest growing packaging technology although still representing a relatively small percentage of the unit volume.

Highlighted Needs

Several significant needs and trends in Design Technologies, Manufacturing Technologies, and Component/Subsystem Technologies have been identified from the 2002 NEMI Roadmap efforts. These trends and needs are already impacting electronics manufacturing and the way we do business.

Design Technologies

- Design and simulation tools and testing are the main roadblocks to more widespread use of embedded passives for size reduction.
- The size reduction of discrete devices has hit a wall at 0201 package size, with many facilities having difficulty maintaining optical recognition.
- The extension of Moore's Law beyond 2005 will require new packaging technologies to reduce the cost of packaging.
- Co-design of mechanical, thermal, and electrical performance of the entire chip, package, and associated heat removal structures is one of the key crosscut challenges.
- Simulation tools are needed by 2005 for optoelectronics and nano-electronics.
- New materials, components, and processes need to be developed, qualified, and introduced in 2002-2006 to enhance recycleability, improve energy efficiency, and reduce ecological impact.

- New efficient methods need to be developed and implemented for data exchange of environmental attributes to meet the requirements of European and Japanese regulations on Electronics and Automotive products.

Manufacturing Technologies

- The component underfill process has provided faster flow times, but difficulties exist with reworkable and pre-applied underfill for standard SMT operations.
- For board assembly of optoelectronics to be competitive in North America, it is important to develop low temperature soldering and automated fiber handling and assembly.
- Board assembly will be challenged with providing material control and identification standards during the transition between lead free and eutectic materials and throughout the product life cycle.
- Cost Improvements are needed to make flexible automation viable.

Component/Subsystem Technologies

- In-circuit test technologies that can be incorporated into the build process.
- Cost and performance models that help highlight the benefits of embedded passives.
- Industry standards, design guidelines and tools for ceramic interconnection substrates.
- Faster improvements in RF filter technology to meet the cost/performance demands of both the Portable and the Large Business Systems Product Sectors.
- Faster improvement in Analog-to-Digital Converter (ADC) technology to meet the implementation of digital linearizers in Portable units.
- Faster improvement in antenna design and development to meet the implementation needs of portable units like software defined radios, dual-band, and dual-mode radios.
- Assembly processes and equipment that support integrating electronics and optics into single packages.
- Technologies that support effective hybrid integration of components into lower cost, smaller, higher functioning subsystems.
- Improved coordination of R&D activities so that technical exchange of non-proprietary information is effective.
- A set of integrated design and simulation tools (circuit, EM (electromagnetic), thermal, mechanical, manufacturing, etc.) to facilitate the trend toward higher functionality in mixed-mode wireless chips and modules.
- Improved optoelectronic subcomponents and materials that allow automation will be the key to expanding the market.
- Low cost high volume optical connectors to expand optical broadband communications to the board and component level. The time line depends on broadband market development and termination costs.

Paradigm Shifts

All of the Technology Working Groups attempted to identify paradigm shifts that are taking place now and potential paradigm shifts that might occur in the future. We believe this information is critical for infrastructure providers to identify where non-linear changes may occur in the future. These changes provide both opportunities and risks for individual firms.

The non-linear development of low cost digital computing, memory, and storage during the last decade has not only exceeded the needs for personal computing, but also has created the market for digital music, video, and photography. These applications impact both the home, mobile and business markets. Uncertainty remains as to what combinations of functionality the consumer and worker want in products, and where they will want to use these products and services. Cost effective broadband transmission is now the gating technology for the introduction of new products and solutions. The home and mobile markets present particularly strong opportunities for rapid growth of new transmission technologies including Bluetooth and WiFi/802.11/3G for wireless applications and optoelectronics for stationary applications.

The need for rapid introduction of complex, multifunctional new products to address this emerging market, has favored the development of functional, modular components or System in Package (SiP) for the Portable Product Sector and portions of the Consumer and Office Systems Product Sectors. This paradigm shift in the design approach increases the flexibility and shortens the product design cycle, and places the test burden on the producers of the modules. It allows for product upgrading at the modular level. It reduces the barriers to market entry to start up firms. Key module developments have been RF modules such as for Bluetooth and GSM, which solve the black magic of RF design. The SiP has enabled OEMs to maintain their size / weight reduction roadmaps while integrating more features and functions through system package integration. The SiP will change the dynamics of the supply chain.

Other paradigm shifts, identified in the 2002 NEMI Roadmap include:

- EMS providers are expanding their capabilities so they can supply cradle-to-grave design, sourcing,

- Supply Chain management is emerging as a key enhancer of productivity. This change presents significant opportunities to lower costs and compete globally.
- System in a Package (SIP) architectures (based on both organic and ceramic materials) have been developed and are now in full production. This same architecture, with capability for buried cavities and channels, allows for MEMS device construction with a variety of new applications in Fuel Cells and Life Sciences (DNA/Blood testing).
- The number of metal levels on Integrated Circuits will grow to 15 during the ten-year period of the Roadmap.
- The pace at which silicon technology generations are introduced, has decelerated
- Automotive products are moving to 42 volt systems and are encompassing home and office conveniences during this roadmap cycle.
- MEMS devices are finding their way into more areas of use and will continue to expand as costs and packaging technology evolves.

Emerging or potential paradigm shifts, identified in the 2002 NEMI Roadmap include:

- In Supply Chain Management, the focus will move from functional expertise to "Integrated Response Management". Also, "Build to Forecast" will move even more strongly to "Build to Order" or "Configure to Order."
- New IT and business models are giving rise to highly leveraged or virtual manufacturing enterprises. The Internet enables small, highly leveraged companies to compete in many markets, head to head with traditional, larger companies.
- Multichip RF modules will be replaced by integrated RFICs in many portable communication products.
- Organic LEDs are emerging as alternatives for LCDs allowing the potential for flexible displays and reel-to-reel processing.
- Nanotechnology has the potential to be a very disruptive technology during the period covered by this roadmap.

- Energy Storage Systems technologies that may present an opportunity for North American manufacturing are fuel cells and high power batteries for hybrid electric vehicles.

Accomplishments

The 2002 NEMI Roadmap activity accomplished the

- Provided extended Situation Analysis/Benc marking Reports on: RF Components, Opt electronics, Displays, Mass Data Storage, Ener Storage Systems, Connectors, and Modelin Simulation, and Design Tools.
- Combined three existing TWGs (EIT - Enterpri Information Technology, FIS - Facto Information Systems and SCM - Supply Cha Management) into a new TWG (PLIM - Produ Lifecycle Information Management) to facilita identification and integration of needs.
- Discussed business issues in each chapter – aid by suggested questions from NEMI's Busine Leadership Team.
- Maintained strong linkages with all oth national Roadmaps: SIA, IPC, IMAPS, USD NSIC, OIDA.
- Strengthened validation of previous NE Roadmap predictions.
- Included Emulator Tables in each Product Sect chapter, comparing the 2000 quantifi predictions with this year's predictions.

III. HOW THE NEMI ROADMAPPING PROCES BENEFITS THE ELECTRONICS INDUSTRY IN CHINA

As General Dwight D. Eisenhower was fond of sayin "It's not the Plan (that is created) but the Planni (process) that provides maximum insight". Those wh participate in the Roadmap creation get a broad view of th supply chain landscape from customers, competitors, an suppliers. Roadmaps can become "self fulfillin prophecies" as many within Industry focus on th identified challenges and benchmark their compan against the user needs. The NEMI roadmap proce enables participants to understand and exploit ne business opportunities within the manufacturing supp chain, improve the probability of providing the "rig solution at right time," and improve return on investme based on providing timely and needed solution.

Most of the global firms that participate in the NE Roadmapping process also participate in electroni manufacturing in China. This strong linkage between th NEMI Roadmapping Process and the Chinese electroni supply chain serves to insure that the Chinese electroni infrastructure is also identifying the global user needs. W hope that as the Chinese infrastructure grows that th linkage will continue to grow and become more direct.

References

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