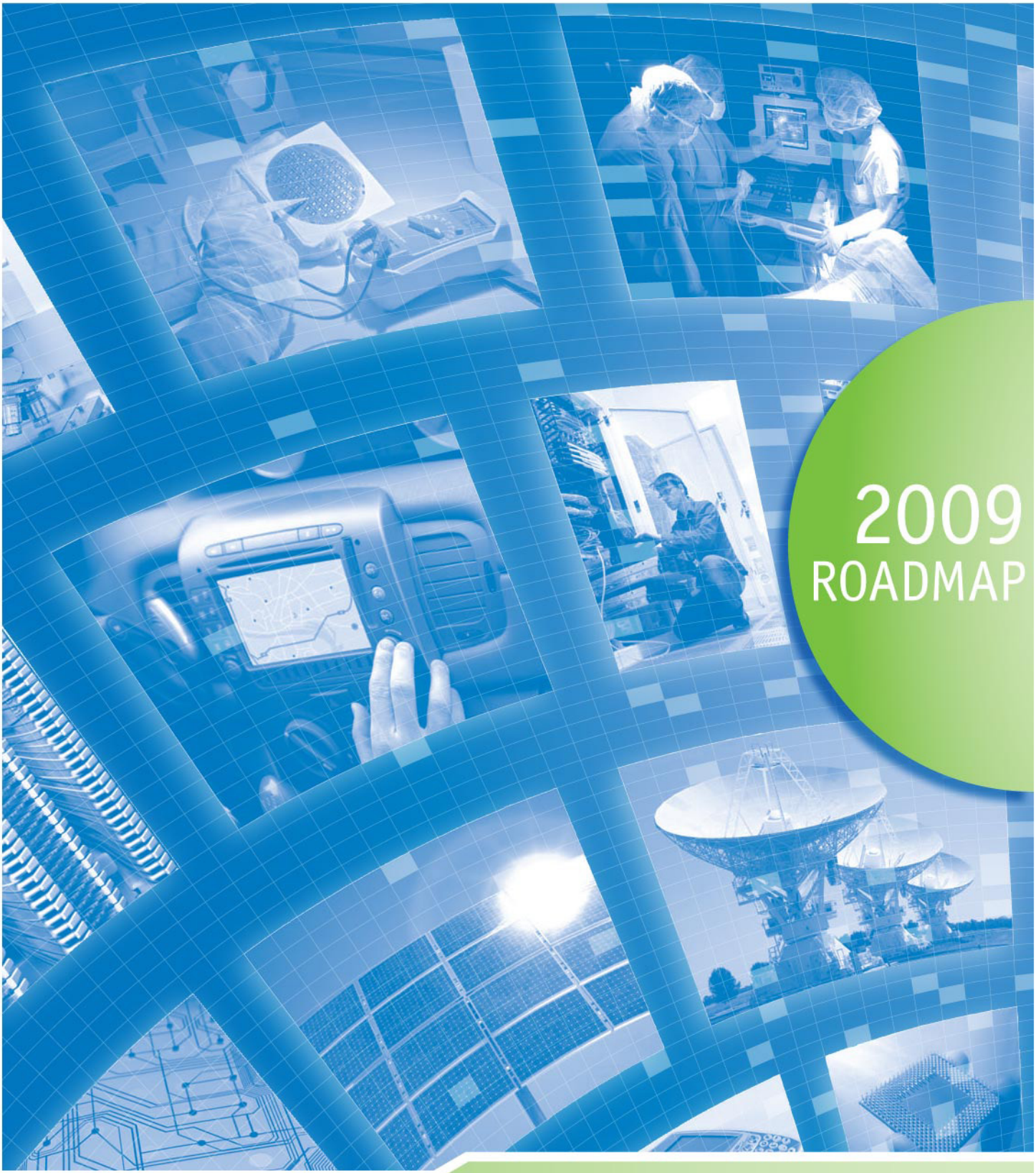


2009 ROADMAP

Advancing manufacturing technology

iNEMI®

International Electronics Manufacturing Initiative

EXECUTIVE SUMMARY

OVERVIEW

SITUATION ANALYSIS

BUSINESS

As the electronics industry matures, many product segments are entering the commodity phase of the life cycle. Accordingly, breakthrough technology is no longer sufficient to insure business success. Customers are demanding the right solution at the right cost from winning enterprises. It is difficult to forecast the impact of the major economic downturn on the industry during the next two years; however, it is likely that some technology deployment timetables will be impacted. The electronics industry is completing 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). There has been a dramatic movement of manufacturing and manufacturing support to China from North America, Europe and other Asian countries because of: 1) a low-cost, highly skilled workforce; and 2) a massive market opportunity. Security concerns and rising transportation costs have recently had the effect of slowing down this movement in some segments. The increasing scope of outsourced operations requires loosely coupled business processes spanning multiple companies.

REGULATORY

Two European Union (EU) Directives, RoHS (Restriction on use of certain Hazardous Substances) and WEEE (Waste from Electrical and Electronic Equipment), which are governing the material content and end-of-life management of electronic products, were implemented on July 1, 2006 and August 13, 2005, respectively. The European Union, End of Life Vehicle (ELV) Directive was recently amended to expand the ban on lead in electronics for vehicles and spare parts which are type approved after December 31, 2010. Legislation impacting the design and recycling of electronic products is being enacted throughout the world, including China. Industry is struggling to keep up with the ever expanding portfolio of regulations that span from local to regional requirements.

- Environmental legislation in various product segments requires 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. The list of banned materials is likely to expand over time.
- A number of "High Reliability" product manufacturers utilized Pb (the element lead) exemptions under the EU RoHS creating a dual supply chain for components. A number of leading "High Reliability" firms are now providing Pb-free products to customers, except those who ban them.
- A regulatory challenge for the medical electronics market is receiving prompt approval of new technology.

- Environmental changes are now being made for market advantage, as well as meeting regulations. This can complicate supply chain transitions as phase-in dates are more widely varied based on business needs of specific firms.

MARKET

The boundaries among computers, communications and entertainment products have blurred. Large, flat panel displays continue to experience growth both in number and size virtually eliminating CRT (Cathode Ray Tube) displays for many applications. Wireless products are now widely used in the office, at home and on the person; and digital cameras, MP3 players, GPS (Global Positioning System) are merged into cellular phones. Home and office functionality is being added to automotive products. RFID (Radio Frequency Identification) systems are being used for security and increased efficiency of commerce. The needs of the telecommunication and data communication infrastructures are converging. With the move to all digital communications and storage we see the convergence of a number of markets:

- Medical-Consumer
- Automotive-Entertainment
- Communication-Entertainment
- Computing-Entertainment

Prismark Partners predicts market growth as follows:

- Worldwide production of computers and office equipment reached $446Bn in 2007 and is expected to grow at an average rate of 3.8% per year to reach $559Bn in 2013. This is the largest segment of the $1.3Trn electronics industry, accounting for about 35% of overall production, and is driven by business and individual consumer spending.
- Global production of communications equipment reached $176Bn in 2007, representing about 14% of the electronics industry. This segment is expected to increase at an average rate of 5.7% per year to reach $246Bn in 2013. Most growth over the next five years will be attributed to data-related equipment.
- Portable and consumer electronics production reached $300Bn in 2007, following several years of exceptional growth. Growth, however, is expected to slow significantly through 2013 due to market saturation in key product segments, decreasing average selling prices and deteriorating economic conditions.
- Medical electronics equipment production reached $66Bn in 2007, accounting for about 5% of the global electronics industry. This market is expected to continue to increase at an average rate of 4.1% per year to reach $84Bn in 2013. Medical electronics' focus is shifting towards diagnostics/prevention rather than therapy.
- The automotive electronics industry accounted for about 6% of global electronics production and reached $79Bn in 2007. The sector is expected to experience modest growth through 2013, increasing at a CAAGR (Compounded Average Annual Growth Rate) of about 3.1% per year due to an increase in average electronic module penetration per car in a slow-growing vehicle sales environment.
- In 2007, 6.5Bn SiPs were assembled. By 2012, this number is expected to reach 12.7Bn, growing at an average rate of about 14% per year.

TECHNOLOGY

As projected in the 2007 Roadmap, the shift to measuring microprocessor performance by throughput rather than frequency has led to widespread use of multi-core processors. A consequence of the expected demise of the traditional scaling of semiconductors is the increased need for improved cooling and operating junction temperature reduction due to large leakage currents. The consumer's demand for thin multifunctional products has led to increased pressure on alternative high density packaging technologies. During the next five years high-density 3D packaging of complete functional blocks will become the major technology challenge in the industry.

- RF (Radio Frequency) System-in-Package (SiP) applications have become the technology driver for small components, packaging, assembly processes and for high density substrates.
- Application of MEMS (Micro-Electro-Mechanical Systems) technology is making new capabilities feasible in a number of old and new markets such as microphones, crystal replacement, displays, servo control for mass data storage, optical and RF switches.
- A number of alternative approaches to today's established data storage technologies will develop over the next decade. These include magnetic random access memory (MRAM), probe-based, molecular, fluorescent multilayer optical, near-field optical and 3-D holographic storage components and systems.

HIGHLIGHTED NEEDS

Significant needs and trends in Design Technologies, Manufacturing Technologies, and Component/Subsystem Technologies were identified in the 2009 iNEMI Roadmap efforts. They are already affecting electronics manufacturing and the way we do business.

INFORMATION MANAGEMENT

Data and product traceability and security are increasingly an issue for the electronics industry. Counterfeit products from components to systems need to be eliminated. Data traceability is needed for high reliability products, environmental conformance and medical regulations.

DESIGN TECHNOLOGIES

Design and simulation tools are a roadblock to more rapid introduction of new materials and technologies by OEMs in a number of rapidly developing areas:

- Predictive tools for determining delamination of new materials.
- Thermal management for 3D packages with stacked die.
- Co-design of mechanical, thermal, bio and electrical performance of the entire chip, package and associated heat removal structures.
- Design tools for emerging technologies like embedded components and nano-materials.
- Integrated design and simulation tools (circuit, EM, thermal, mechanical, manufacturing, etc.) for higher functionality in mixed-mode wireless chips and modules.

Commercial design tools for manufacturability, test and assembly are needed by the EMS firms to increase manufacturing productivity and reduce costs.

MANUFACTURING TECHNOLOGIES

With research and development (R&D) responsibility shifting from OEMs to the ODMs and EMS companies; government, academia and industry consortia need to formulate new ways to adopt and develop emerging technologies (such as nanotechnology) into the manufacturing process. These new approaches will have to be consistent with viable business and funding models (see Strategic Concerns) required to create new industrial infrastructures. Specific manufacturing development targets include:

- Process development to accelerate miniaturization.
- Advanced assembly processes that support 3-dimensional structures and low temperature processing.
- Product traceability.
- Reliability evaluation of through silicon via (TSV) technology.
- Improved equipment accuracy for assembling stacked die, PoPs, SIPs, etc.
- Lower testing costs, particularly for new non-digital technologies.

COMPONENT/SUBSYSTEM TECHNOLOGIES

- Higher thermally conductive materials, such as carbon nanotubes, carbon fiber, aluminum nitride and even diamond, to cool optical and electronic devices.
- In-circuit test technologies that can be incorporated into the build process.
- Low cost, high density, high performance PCB substrate technology.
- Lower dielectric constant materials to improve the performance of high-speed digital systems.
- New technologies and materials for next generation optical storage devices.
- New photovoltaic and LED materials with greater efficiency.

PARADIGM SHIFTS

Many of the Technology Working Groups identified paradigm shifts that are taking place now and potential paradigm shifts that might occur in the future. 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 need for continuous introduction of complex, multifunctional new products to address the converging markets (first identified in 2004) has continued to favor the development of functional, modular components or SiP. This paradigm shift in the design approach increases the flexibility, shortens the product design cycle and places the test burden on the producers of the modules.

The standard platform movement that is developing in the telecom market is helping to address the disrupting and disaggregating of both the design chain and the supply chain. This movement could accelerate the introduction of new functions by making them easier to do. Telecom, computing, IT and military sectors are affected.

The board assembly roadmap is predicting another migration to lower temperature and lower cost lead-free solder materials in 2011-2017.

Other paradigm shifts identified in the 2009 iNEMI Roadmap include:

- Optical Interconnects at the board level are still viewed as being outside the roadmap time frame.
- Data rates on PCBs are now well above 1 Gbps.
- Increased use of touch screens, particularly capacitive.
- MEMs oscillators are replacing quartz crystals.
- Emergence of photovoltaics.
- Energy efficient lighting is becoming an important market segment.
- Flip chip finally is an alternative to wire bonding.
- Printed electronics moving from R&D into initial applications.
- Packaging materials changing over the next decade (again).
- Wafer level packaging is coming of age.
- ODMs emerging for designing cell phones, GPS, etc.
- High density PCBs will use discrete devices only down to 0201 format.
- High Density Interconnect Substrates (SiPs or Organic Packages) will use embedded passives or 01005 discretes based on size constraints.
- The next two years will be a period of rapid evaluation of alternative materials for connector housings and cable insulation to find replacements for brominated/chlorinated flame retardants and PVC.

STRATEGIC CONCERNS

The restructuring of the electronics industry over the last decade from vertically integrated OEMs to a multi-firm supply chain has resulted in a disparity in R&D needs versus available resources. Critical needs for research and development exist in the middle part of the supply chain (IC assembly services, passive components and EMS assembly) as illustrated in Figure 1, and yet these are the firms least capable of providing the resources. A partial solution has been the development of vertical teams to develop critical new technology while sharing the costs.

VALUE CREATION IN THE SUPPLY CHAIN

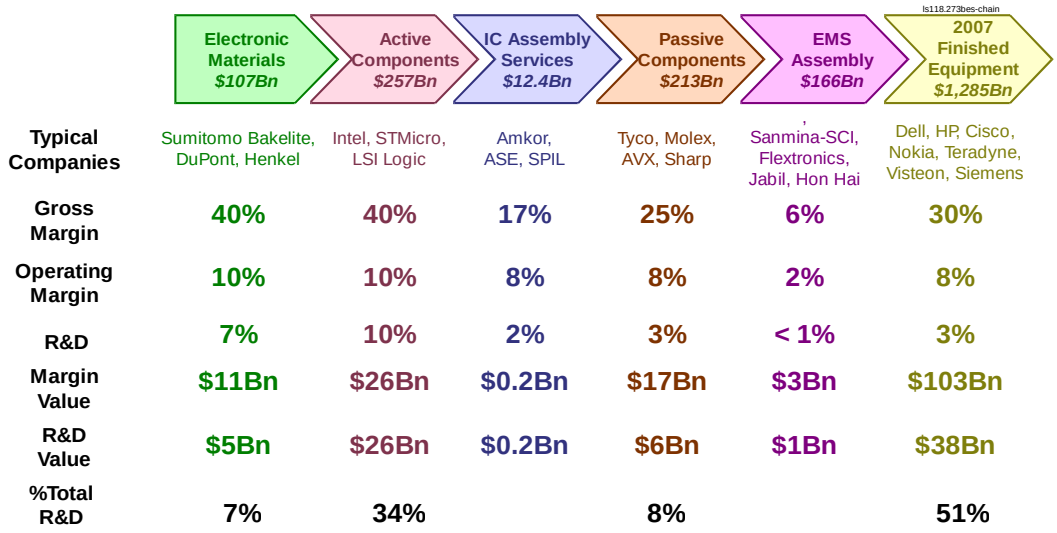


Figure 1. Value Creation in the Supply Chain
(*Courtesy of Prismark Partners*)

Other strategic concerns include:

- With manufacturing R&D responsibility transitioning to the EMS companies in low cost geographies, government, academia and industry consortia will need to formulate ways to adopt and develop emerging technologies (such as nanotechnology) into the board assembly process and higher functional units, within the global outsourcing environment.
- Consumers are increasingly concerned about the impacts that electronics products may exert regarding safety, energy usage and environmental impact. These concerns need to be addressed proactively by the industry.
- Harmonization of environmental regulations for electronic products must be driven through international standardization.
- The mechanisms for cooperation between industries, and among researchers working in all advanced technologies, must be strengthened. Cooperation among OEMs, ODMs, EMS firms and component suppliers is needed to focus on the right technology and to find a way to deploy it in a timely manner.
- As lines blur between semiconductor back-end and assembly and packaging, cooperation is needed to insure a viable technical and business model.
- Disruptive technology offers opportunity for innovation. In order to ensure success, the supply chain must be willing to invest with a long-term perspective in mind.

KEY RECOMMENDATIONS

STANDARDS DEVELOPMENT

The need for standards development has been identified in a number of areas. Many participants believe that the lack of standards is significantly slowing the implementation of technology and growth of markets:

- Collaborative standards for data exchange.
- Develop standardized final assembly process definitions and metrics.
- Develop and adopt standards and guidelines for ceramic interconnection substrates.
- Develop a broad agreement on the mechanism required to provide an open architecture for best-in-class test integration.

iNEMI TECHNICAL PROJECTS

Four environmental projects have been proposed in the roadmap:

- Non-Competitive LCAs (Life Cycle Assessments) for ICT (Information and Communications Technology) Products based on a building block approach using assembly emulators/evaluators for weight and class, number of devices by class; agreed upon by industry.
- PVC Replacement Alternatives.
    - LCA comparing PVC versus PVC-free cables.
    - Technical evaluation of alternatives.
- Establish market for postconsumer plastics as feedstock for "Green" products (e.g., polycarbonate, ABS).
- Establish new electronic applications for postconsumer blended plastics (e.g., housings for power supplies).

DESIGN

The increasing OEM focus on time-to-market and the complexity of emerging technology will require significant development and investment in design tool infrastructure. The following areas need increased research and development:

- Co-design of mechanical, thermal and electrical performance of the entire chip, package and associated heat removal structures.
- Simulation tools for nano devices and materials.
- Integrated design and simulation tools for RF modules and devices.
- Electronics-manufacturing simulation and modeling tools for the designer.
- Cost effective, improved thermal management.
- New capability to close the gap between chip and substrate interconnect density.

MANUFACTURING TECHNOLOGY

Two major strategic needs generate the recommendations in manufacturing technology: the miniaturization of the product and the need for simplified, next generation assembly processes:

- The development of new approaches to organic substrate fabrication that address needs for dramatic increases in density, reduced process variability, improved electrical performance and significant reductions in cost.
- Manufacturing processes for dealing with warpage and thin format products
    - Wafer
    - Package

  - PWB
- 3D Package Stacking Development
  - Assembly
  - Cooling
  - Reliability
- Low Temperature Assembly
  - Tactical (Soldering)
  - Strategic (Opportunities from "room temperature" processing)
- Development of viable rework processes for Pb-free soldering

MATERIALS DEVELOPMENT

- A combination of materials and fabrication research is needed to support the development of monolithically integrated optics and electronics that take advantage of the electronics infrastructure.
- Low cost, higher thermal conductivity, packaging materials, such as adhesives, thermal pastes and thermal spreaders.
- Next generation of solder materials to replace the high cost/high temperature silver containing alloys.
- New interconnect technologies deploying nano-materials to support decreased pitch and increased interconnect frequencies.
- High-performance laminates that are competitively priced.
- Clearer specifications for new materials which are supported by a broad base of customers, to increase market size and reduce the risk for materials R&D.
- Reliability testing methodologies for new materials.
- Development of LED and Photovoltaic materials to produce high-efficiency materials.

ENERGY AND THE ENVIRONMENT

iNEMI's environmental TWG has chosen to focus on electronics as a solution to climate change. To harvest this potential, the iNEMI roadmapping team has identified a number of electronics-enabled solutions that offer the collective potential of reducing greenhouse gas emission by a billion tons.

- Develop and implement good scientific methodologies to assess true environmental impacts of materials and potential trade-offs of alternatives.
- Evaluate the viability of alternative materials prior to implementation. At the recent iNEMI Sustainability Summit, it was recommended to evaluate PVC replacement alternatives in a two step project:
  1. LCA comparing PVC versus PVC-free cables
  2. Technical evaluation of alternatives
- Industry must be more involved in policy making on material restrictions so that policy makers understand trade-offs inherent in material substitution.
- Support research and development to create a sustainable infrastructure and viable recycled materials market for use in new products and other applications.

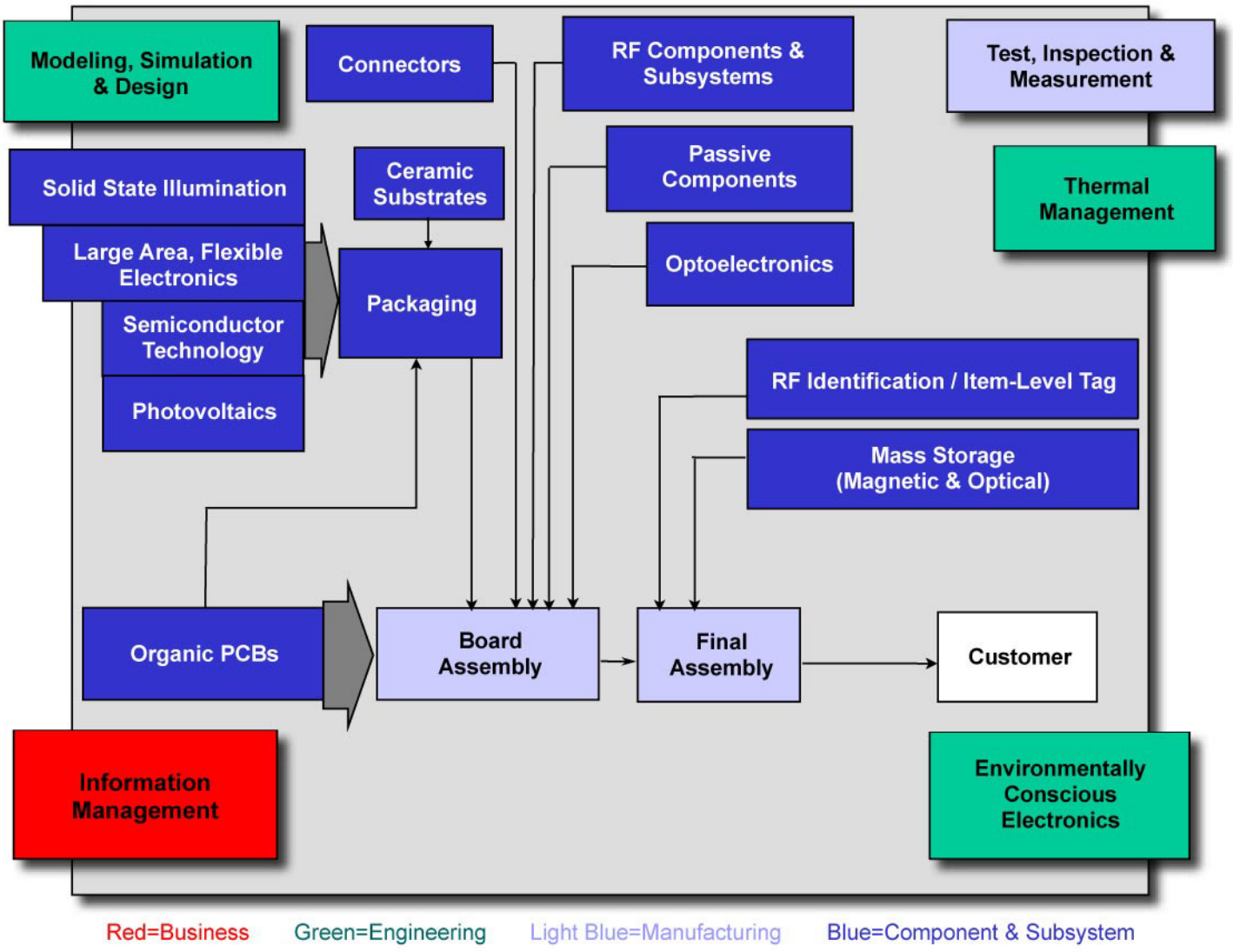
2009 iNEMI Roadmapping Process

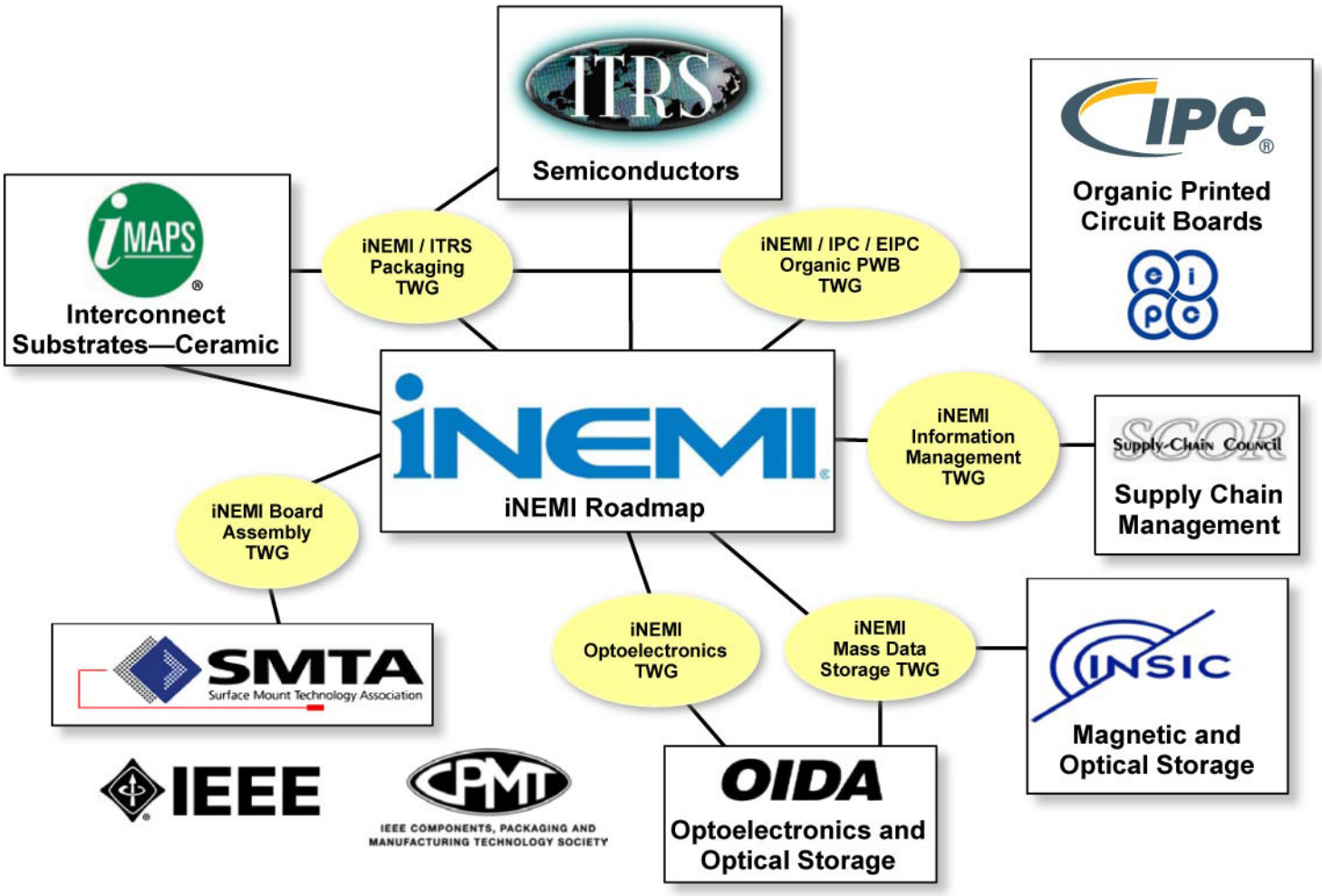
The 2009 Roadmap was developed by 20 Technology Working Groups (TWGs), in response to inputs from representatives of OEMs in five Product Emulator Groups (PEGs). The PEGs and TWGs are defined below. These groups included more than 550 individuals from over 250 corporations, consortia, government agencies and universities, located in approximately 18 countries on four continents.

2009 Product Emulator Groups (PEGs)

Industry Sector	Product Characteristics
Automotive	Products that must operate in an automotive environment
Medical	Products that must be highly reliable and, in some cases, support life-critical applications
Consumer / Portable	Produced in high volumes, cost is the primary driver; hand-held, battery-powered products are also driven by size and weight reduction
Office / Large Business Systems	Driven by the need for maximum performance over a wide range of cost targets
Netcom (Network / Datacom / Telecom)	Products that serve the networking, datacom and telecom markets and cover a wide range of cost and performance targets

2009 Technology Working Groups (TWGs)




ITRS
Semiconductors
IPC
Organic Printed Circuit Boards
iMAPS
Interconnect Substrates—Ceramic
iNEMI / ITRS Packaging TWG
iNEMI / IPC / EIPC Organic PWB TWG
iNEMI
iNEMI Roadmap
iNEMI Information Management TWG
SCOR
Supply-Chain Council
Supply Chain Management
iNEMI Board Assembly TWG
SMTA
Surface Mount Technology Association
iNEMI Optoelectronics TWG
iNEMI Mass Data Storage TWG
INSIC
Magnetic and Optical Storage
IEEE
CPMT
IEEE COMPONENTS, PACKAGING AND MANUFACTURING TECHNOLOGY SOCIETY
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