

CONNECTOR MARKET:

- **\$39B Worldwide:** \approx 6.5%/yr Growth/Cyclical Track Record.
- **Split:** Test/Burn-in Sockets <10%, Production Connectors & Sockets = >90%. These are two distinctly different markets, with different customers & players.
- **Metallic Connectors:** (Cu, Brass, PhBr, BeCu), **Fiber Optic Connectors:** (Glass, POF), **Electronic:** \leq 5v **Electrical:** \geq 12v.
- **Major Markets:** Computer, Comm, Auto. Mil-Aero, Industrial, Consumer, Appliance, Medical, Instrumentation, Other.
- **True Connectors:** *Separable* Mechanical & Electrical Connection:
 - ⇒ **Level 0** = On-Chip, (Sub-Micron on-chip Al/Cu Interconnects)
 - ⇒ **Level 1** = Chip-to-Package (Wire Bond, C4)
 - ⇒ **Level 2** = Chip Pkg to Board (DIMM Socket)
 - ⇒ **Level 3** = PC Board (PCIe)
 - ⇒ **Level 4** = Board-to-Board, Chassis/Subsystem (Backplane Connector)
 - ⇒ **Level 5** = IO Panel (USB)
 - ⇒ **Level 6** = Intersystem (Ethernet Cable)

Level 0 & 1 (ULSI, SiP, SoC) impact Packaging & Interconnect. Net Result: Fewer Discrete Connectors/Function, but More Functions, Applications & Systems. This = Connector Growth @ ~ 1/3 less than ICs.

KEY POINTS ABOUT THIS MARKET:

- 100s of small to mid-sized companies.
- Tyco, Molex, Amphenol, FCI, Delphi, Yazaki, JST, Foxconn. \geq \$1B in Sales.
- Top 10 between 50% & 55% of TAM.
- Industry Consolidation will Continue. Most recent Major: FCI/Bain Capital
- Globalization of the Supply Chain is increasing.
- Mfg Footprint is Shifting to Asia to Support OEM/EMS Assembly.
- Market ~ 60% Standards-Based, 40% Application-Specific.
- Key Dynamics for the Future:

- ⇒ Growth (Volatility?) in Developing World: China, Other Asia, India?
- ⇒ North American & EU Market & Mfg Infrastructure vs. Current Trends.
- ⇒ Semiconductor & Electronic Packaging Developments.
- ⇒ Wireless Technology vs. Cables. Other Technology Breakthroughs.
- ⇒ Market-Specific Issues. (Computer, Telecom, Automotive)

PRODUCT CHARACTERISTICS:

- **Contacts:** Metallic Pin-and-Socket, Spring, Blade, Card-Edge or Fiber-Optic.
- **Housings:** Injection, Insert Molded Plastics, Metal
- **System Requirements:** Electrical-to-Electronic, Tighter Mechanical Specs & Reliability, Application-Specific Requirements, Design-For-Automation & Environmental Regulations.
- **Key Processes:** Machining, Stamping, Plating, Molding, Automated (or Bench) Assembly, Packaging of Small, Precision Parts.
- **Supply Chain:**
 - ⇒ Electronic Materials, Metals & Plastic Resins.
 - ⇒ Stamping, Plating, Tool & Die, Molding & Assembly Suppliers
 - ⇒ Suppliers of Mfg Automation, Packaging Equip, Test & Analysis.
 - ⇒ Suppliers of Modeling, Simulation & CAD Software.

⇒ **Connector Mfg = Discrete Assembly Process of small, precision metal & plastic parts.**

⇒ **Integrated Mfg Developments include Insert Molding.**

⇒ **Connector mfg process is different than the batch processes used in IC mfg. The discrete approach provides Design Flexibility in Connector Products.**

KEY TRENDS & ROADBLOCKS:

- **Discrete Connector Miniaturization has Limits:** ~ 0.3mm or 12 mil Contact Pitch. Smaller Contacts become are fragile, cross-talk increases, etc. Trade-offs: Area Arrays vs. Linear Connector Pin Fields, Serial vs. Parallel Interfaces.
- **Beyond These Limits:** BGA, μ BGA, MEMS, 3D Packaging. Use of μ Springs, μ Connectors.
- **Connector Roadmap is Evolutionary:** Few paradigm shifts or showstoppers.
- **Lead-Free Assembly:** Biggest Change 2005-2007. (see below)
- **Si IC Technology:** (Moore's Law) continues to drive creation (and elimination) of applications.
- **Fiber Optics:** Evolutionary encroachment into Cu World: Intel Si Lasers? EOICs?
- **Other Trends:** Continued Miniaturization , SiP, 20 Gbps Barrier? Wireless/Cable less
- **Power Density:** Peak Power is an issue in some applications. Si Developments will Mitigate.

Si IC Technology Controls much of the Destiny of Connectors. Others include IC Packaging, Mainstream Printed Circuit Board Technology Wireless Interconnect, and System Packaging. All are also Si-Dependent.

KEY TRENDS & ROADBLOCKS CONT:

- **Paradigms are more Business/Market Related:** e.g. Outsourcing, Offshoring, ROI vs. Prod. Life Cycles:
 - ⇒ **Offshore Mfg. vs. Domestic Mfg Infrastructure** – China, Other Asia. (China with $\geq 16\%$ /year growth. US & EU $\leq 3.5\%$).
 - ⇒ **Erosion of Home Markets** - New Strategies (High Tech, High Mix/Low Vol?).
 - ⇒ **Materials and Process Technologies** - Are Evolving. Mixed Bag: Scarcities of some capabilities in Emerging Markets. The Reverse May Happen in the Future.
 - ⇒ **If and when PCBs & Electronic Packaging go 'Micro':** Connectors will also.
 - ⇒ **Rest of World:** India (Infrastructure?), Vietnam, Other A-P are growth possibilities in mfg.
 - ⇒ **China Flexible Bench Assembly:** Replaced Western Automation.
 - ⇒ **Re-Automation:** Will happen in China as labor costs rise.
 - ⇒ **Environmental Regulations:** RoHS/WEEE, are being met with few disruptions. **REACH** will be new, but hopefully lesser challenge.

Connector's Future seems Evolutionary. Globalization of the Supply Chain & Markets will be the most significant Challenge facing this Industry through 2011.

ENVIRONMENTAL REGULATIONS:

- **RoHS, or Directive 2002-95-EC:** Limits use of hazardous materials in electronic products. These materials include Pb, Cd, Hg, Hexavalent Chrome, PBBs [Polybrominated Biphenyl Ether] and PBDEs [Polybrominated Diphenyl Ether]. Connectors have gone through the RoHS/WEEE redesign/materials substitution cycle without major problems. They are, for the most part, RoHS/WEEE Compliant. Major connector suppliers have focused a lot of internal resources to meet this requirement.
 - ⇒ **Exemptions:** Subject to exemptions documented in RoHS, including use Sn-Pb in electronic component applications, compliant pin [e.g. backplane] connection systems, in other connector applications including flexible etched circuitry and fine pitch Sn whisker-resistant coatings, military applications, etc.
 - ⇒ **RoHS (Pb-Free) Was The Most Significant Challenge for the Connector Industry as a whole 2005-07.**
 - ⇒ **Status:** This challenge has been met w/ 80% of total production Compliance at an estimated cost of \$60-100M. 20-30% of product & technical engineering resources were devoted to meeting this challenge.
- **Ongoing Issues:**

- ⇒ **Long Term Reliability Data Doesn't Exist.**
- ⇒ **Sn Whiskers (plating control issue that major suppliers have mastered).**
- ⇒ **There are Ongoing & Different Regional Regulatory Regimes: EU REACH, China RoHS.**
- ⇒ **Future Possibilities: Brominated Flame Retardants, Halogen-Free.**

INEMI EMULATOR APPLICATIONS & TIME LINE:

• SUMMARY BY TYPE

Table summarizes key types, applications, requirements, etc. Most barriers are overcome by design advances, including x-linkages to other technologies: printed circuits, flexible etched circuitry and fiber optics:

CONNECTOR TYPE SUMMARY

CONNECTOR TYPES	APPLICATIONS	REQUIREMENTS	EMULATORS	TRANSITIONS*	WHEN
Electronics					
• Test & Burn-In	IC Test, Emulation	Density, Speed, Cycle Life	Digital Si, SiP	Wafer-Scale Test	2011
• IC Sockets	LGA, PGA Socketing	# of Pins, GHz	Office/Computer	IO #, BGA, mBGA/Direct Attach	2009
• Submin/FEC Connectors	Mobile, Handheld	Miniaturization, SFF Packaging	Mobile Systems	SiP, SoC Integration	2000+
• Stacking Connectors	Mobile, Other	Mated Ht, Density, Perf.	All	3D Circuitry, SiP/SoC Integration	2007
• PCB Connectors	All	SMT, Cost, Performance	All	Density, Gb Speed, SoC	2011+
• Backplane	Telco, Computer	Density, 1-20Gbps Speed	Office/Telecom	Density, Speed, EO	2005+
• IO Connectors	All	Panel Mount, Cycle Life	All	Wireless IO	2005+
• Fiber Optic Connectors	Telco, Computer, Other	Applied Cost, Performance	Office/Telecom	Cost, Speed, Optical ICs	2011+
Other Connectors					
• Cable Assemblies	All	Strain Relief, Cost/Performance	All	Bluetooth, WiFi	2005
• Premises Wiring	LANs, telecom	Wire Mgt, Standards	Office	WiFi/WiMax, Fiber/10GbE	2006+
• Telecom/CATV	CO, Base Station, Cable	Severe Environment, RF, EO	Office/Telecom	Hybrid Fiber/Coax, μ Wave, Wireless	2000+
• Mil-Aerospace	Aircraft, Missile, Comm.	Reliability, Severe Environment	Mil-Aero	COTS	2005+
• Automotive	Cars & Trucks	12-44V, high current	Auto	New Wiring, HEV/Fuel Cell	2006
• Application Specific	Medical, other	Reliability, Perf, Unique Designs	Auto, CE, Med, Oth.	Industry Stds/Multiple Source	2000+

When competing or disruptive technologies are mainstream. FEC=Flexible Etched Circuitry, SFF=Small Form Factor, SiP=System-in-Package, SoC=System-on-Chip, WiFi/WiMax=802.11-15, CO=Central Office, COTS=Commercial-Off-The-Shelf

CORE COMPETENCIES:

- At the heart of connector design and manufacturing processes are a set of proven core technologies. These competencies have many years of experience behind them. They can be characterized as to Critical Issues:
 - ⇒ **Metallurgy/Metal Forming:** No Critical Issues. Eventually, size limits of conventional stamped contacts will require Si bench/chemical milling processes.
 - ⇒ **Plating:** No Critical Issues. Sn solder plating has been implemented, Selective Au is advanced. Plating is an Issue in the Developing World.
 - ⇒ **Contact Physics:** No Critical Issues. Mistakes are Made. Z-Axis Interconnects pose some problems, as do Socketing BGAs (Solder Ball Plasticity).
 - ⇒ **Materials & Molding:** No Critical Issues. Thermal issues are emerging but will be solved. Insert Molding Technology is Now Significant. There may some supply chain & future Environmental Issues.
 - ⇒ **Assembly/Packaging:** No Critical Issues. Offshore Learning Curve. Odd-Shape Placement 'OK'.
 - ⇒ **Mechanical/Electrical Design:** No Critical Issues. Design tools are adequate.
 - ⇒ **Design for Manufacturability/Assembly:** Issue is Design for Global Mfg.
 - ⇒ **Global Logistics/Supply Chain:** Issue for Smaller Mfrs. & the Supply Chain. Multinationals mastered.
 - ⇒ **Environmental Regulations:** REACH, other Regulations May Become an Issue. Impact of RoHS on Connectors was costly but mostly successful. Long Term questions on Reliability Remain.

Connector design and manufacturing requires these core capabilities. Rarely do key industry design initiatives - usually backed by major OEMs or consortia - stray from the comfort zones promulgated by these Technologies.

MANUFACTURING TRENDS:

- **Modular Assembly:** Automatic In-Process Material Handling [in higher labor cost countries]. Stand-Alone Operator-Assisted Bench [in lower labor cost countries], Re-toolable Process Stations.
- **State-Of-The-Art Metal Forming:** [both Tool Materials and Design] - In-Line with Assembly.
- **Tight Tolerance Stack-Ups:** Traditional Assembly Methods will become Obsolete. Solution: Critical Contact Forming and Insertion will be controlled by Adaptive Servo Controls. Measurements taken On The Fly will automatically alter the stations' setup. Measurements can be Direct [sensing critical component features/dimensions], or Indirect [monitoring equipment/tool characteristics].
- **Marking and Packaging:** Integrate Connector Component Flow Seamlessly into OEM/CM Production Control Systems. Web-Based access to Networked Machines for Remote Diagnostics, Preventive Maintenance. Emergence of Automated Quality MIS, correlating Component Quality with Machine Performance and Yields.

AUTOMATION & RE-AUTOMATION IN DEVELOPING COUNTRIES: Assembly Automation has Five Driving Forces that fashion a Migration Path over the next 10 years. These drivers include:

- ⇒ **Miniaturization:** Higher Contact Insertion Precision and Repeatability will stimulate the need for more Insert Molding. This will drive the finishing of Contact Forming to Post-Plating - In-Line with Assembly.
- ⇒ **Digitalization:** Contact Forming and Insertion will be controlled by Digital Controls. Measurements taken On The Fly will automatically alter Setup.
- ⇒ **Integration of Supply Chain:** From Order to Payment, e.g., Raw Material to Finished Goods, Marking and Packaging will be accomplished to Help Customers Integrate Connector Component Flows Seamlessly into a Production Control System w/o Inventory.
- ⇒ **Availability of Low Cost Labor:** Human Element provides the best “Adaptive Control” and Inspection of Process Steps. The Migration of Assembly Labor to China Continues to Escalate – But Labor Costs are Increasing. As their Manufacturing Infrastructure Improves, Automation Is Happening.

⇒ **Mfg Automation vs. Short, Unpredictable Product Life Cycles:** Connector Manufacturers are squeezed between ever-reducing costs , the Need to Invest in Plant & Equip vs. Short Product Life Cycles. The trend has been to Less Automation, Not More, for ROI considerations. As Labor Costs Rise, This Issue will become Significant.

⇒ **The North American Mfg Infrastructure:** Is under Increasing Stress. Quick-Turn Model Shop/Prototyping and Applic-Specific Production may be Insufficient to satisfy Facilitation. More and More Companies are Rushing to these Remaining Markets to Fill Domestic Plants. Consolidation & Downsizing is in the Offing. The impact of these changes will be felt Throughout the Supply Chain from Electronic Materials, through Stamping, Plating, Tool & Die, Molding & Assembly Equip mfg.

ROADMAP DISCUSSION:

- **Key Drivers for Connectors & Cable:**

- ⇒ IC Technology, Electronic Packaging
- ⇒ Performance (> Signal Frequencies)
- ⇒ Packaging Density (Being offset by Serialization)
- ⇒ Industry Standards (Stds Bodies, Consortia, Defacto-Standards, Licensing Agreements)
- ⇒ Regulatory Issues, possibly as a Hidden Trade Barrier.

OEMs Drive Standards. Connector Industry is an Active Participant. **Future:** More Standards where custom designs have been normal: e.g. Automotive, Medical, Mil/Aerospace, Telecommunications, Applic-Specific Market Segments.

- **Key Areas for Development:**

- ⇒ Advanced Materials & Processes (Thin Web Molding, Designer Alloys, Sn Plating).
- ⇒ Subminiaturization (Etched/Batch Fabricated μ Contacts, Insert Molding, FEC).
- ⇒ Ball Attachment (BGA feet).
- ⇒ 10-40 Gbps Backplanes, High Speed Serial Interfaces & Cables.
- ⇒ BLGA Sockets > 1000 I-O, 1mm pitch.
- ⇒ Next Gen. Memory Sockets (DDR4).
- ⇒ Board/Chassis-Level Optical ICs & Interconnects.
- ⇒ Advances in PCB Technol, responding to Flip Chip, 3DIC, Integrated passives, HD Connectors.

- **Gaps & Show Stoppers:** None Identified that do not have an alternative solution.

- ⇒ Future Developments in Key Connector Markets: Automotive Electronics, Computers, Telecom
- ⇒ Future Impact of SoC on Electronic Packaging & Interconnect.
- ⇒ Conventional Connector Pin Pitches < 10 mils vs. New μ Contact Technologies incl/ MEMS
- ⇒ Wireless Encroachment on IO Standards e.g. Wireless USB
- ⇒ X-Over to Fiber Optics ~ 20-40 Gbps.
- ⇒ Developed World Mfg Infrastructure for High Volume Production.