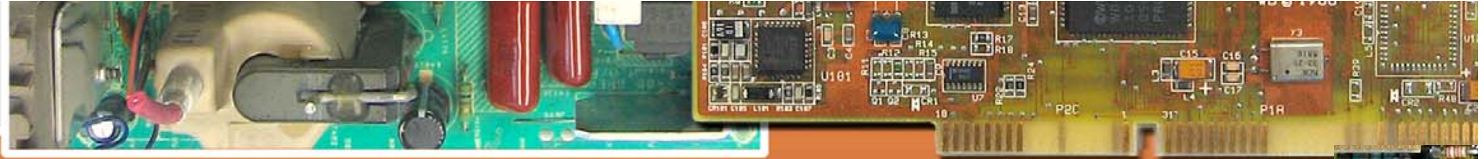
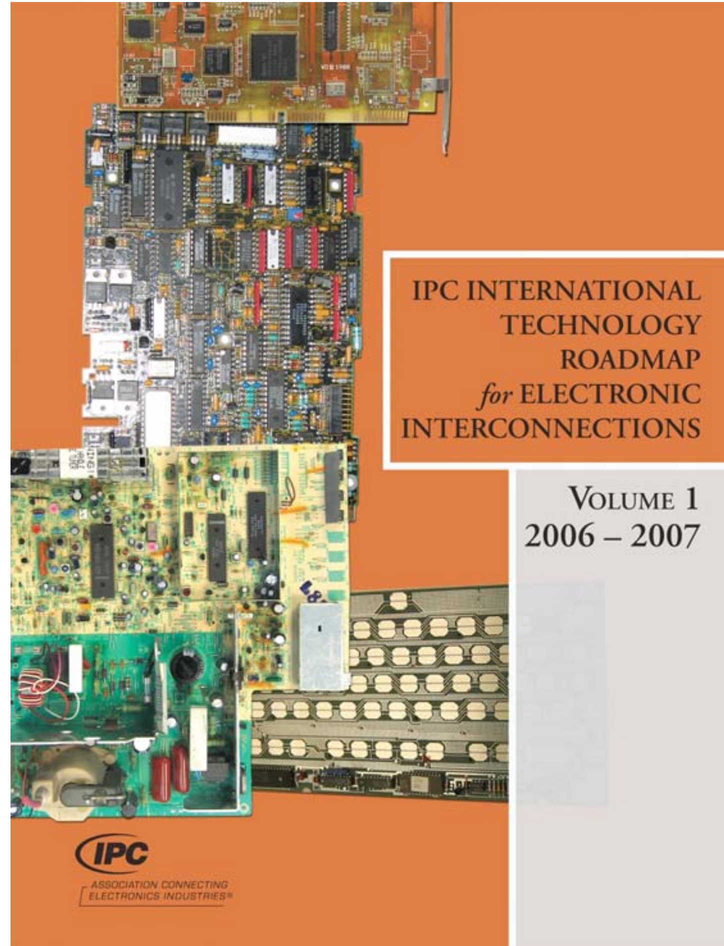
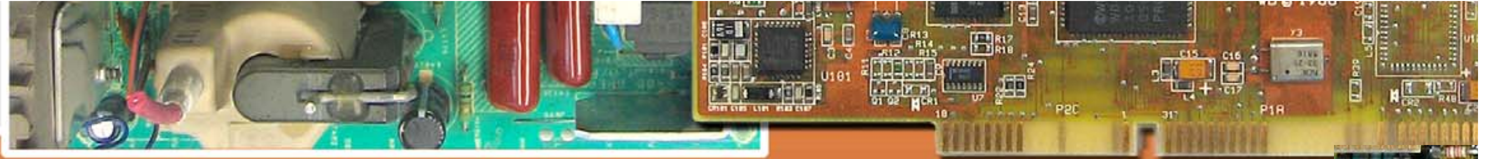


IPC International Technology Roadmap for Electronic Interconnections 2006 - 2007



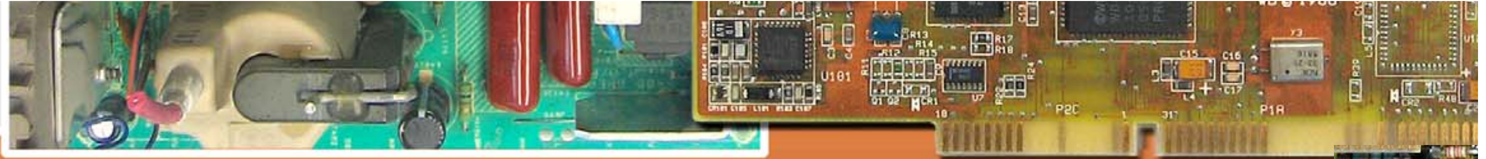
Preparing for the next generation



Roadmap mission

To guide manufacturing, process, material, equipment, and product, research and development, in order to establish leadership in electronic interconnection technology;

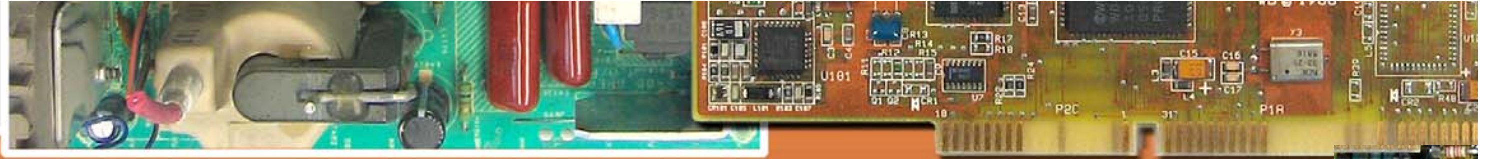
Integrate the development in the electronic industry with partners in academia and government; and excel in the global market by implementing these developments and continuously improving customer satisfaction.



Focus of the IPC Roadmap

- Electronic interconnections include the processes for fabrication of the interconnection structure and materials plus the attachment mounting the assembly of electronic components.

- This International Technology Roadmap is intended to provide the vision, and direction for product development, process development and services required to satisfy the short term, near term and long term requirements for electronic interconnections



Driving Forces

60's – 70's - Main Frames

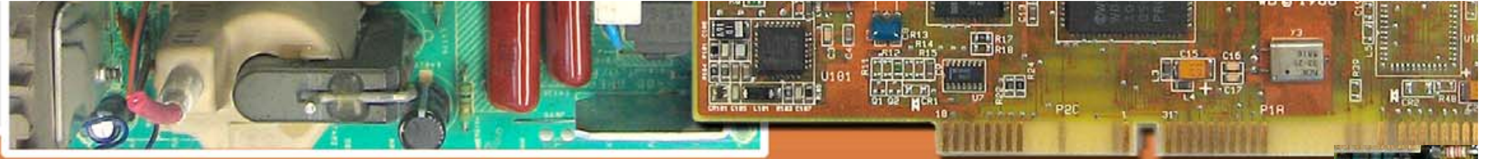
70's – 80's - Personal Computers

80's – 90's - Hand Held

90's – High Speed data and RF

Today – Packaging / Silicon

Future – Optoelectronics?
– Enhanced copper performance?



The roadmap may be thought about as four different sections

Components

PCB manufacturing

Assembly of PCB's

Infrastructure and support

Multi-dimensional Approach

MARKET SECTORS

- Auto
- Computer
- Military
- Telecommunications
- Education/Retail
- Consumer
- Industrial
- Instrumentation

PERFORMANCE SECTORS

- Harsh Environment
- Portables
- High Performance
- Low Cost, High Volume
- Cost & Performance Sensitive

TECHNOLOGY SECTORS

- Commodity
- Leading Edge
- State of the Art

Performance Sectors

Technology Sectors

Market Sectors

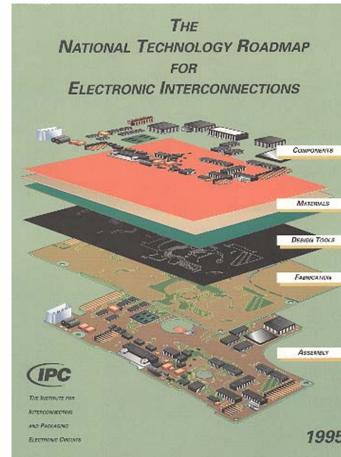
Technology Planning is Multidimensional

History of IPC Roadmapping

1993

Base Element First National Technology Roadmap Survey
Established IPC as a National Roadmapping entity
9 Business Segments
151 R&D Tasks
Identified Potential Showstoppers
- Lack of coordinated technology integration into manufacturing
- No single common set of needs between industry, government and academia
- Lack of process controls
- Poor customer/supplier relationships

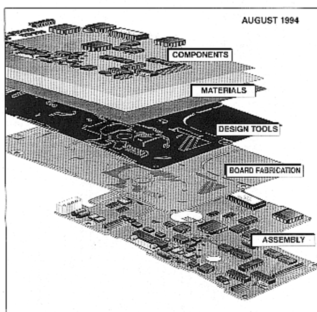
4 year outlook
Led to the creation of ITRI



1995

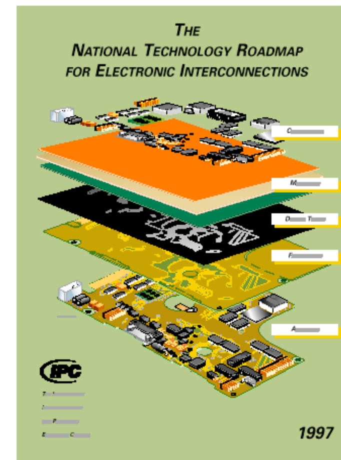
Base Element - OEM Input - 8 Emulators
Nationally Integrated, NEMI, SIA, MCC, SIA
Presented to U.S. Congress - June 1995
15 Year Outlook
Focus on Revenue Center of Gravity
- Conventional
- Leading Edge

Initiated the 1996 Worldwide Benchmark



1994

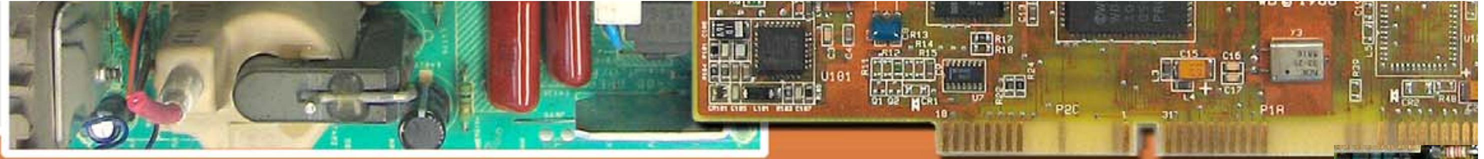
Base Element - Survey
10 Business Segments (EH&S)
162 R&D Tasks
4 Year Outlook
Established ITRI Priorities



1997

Base Element - OEM Input - 20 Emulators
Nationally Integrated
Added Chapters
- Ceramic Interconnections
- Backplanes
- Connectors

Added State of the Art focus



IPC International Technology Roadmap for Electronic Interconnections 2006 - 2007

2002 - 2003

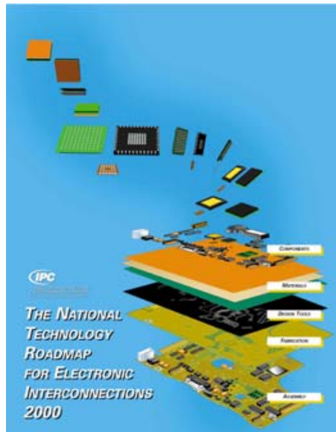
Base Element - OEM Input

Internationally Integrated

8 Product Sectors

Added information

- **Embedded Passives**
- **Optoelectronics**
- **Backplanes**



2000 – 2001

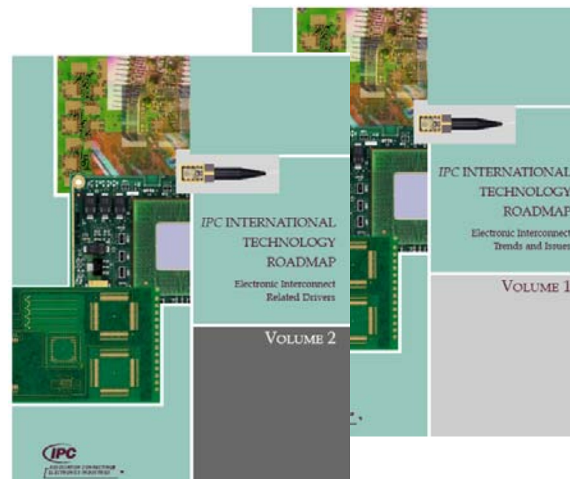
Base Element - OEM Input -

Nationally Integrated

11 Product Sectors

Added Chapters

- **Component Manufacturing**
- **Packaging**
- **Optoelectronic**
- **Reliability**



2004 - 2005

Base Element - OEM Input

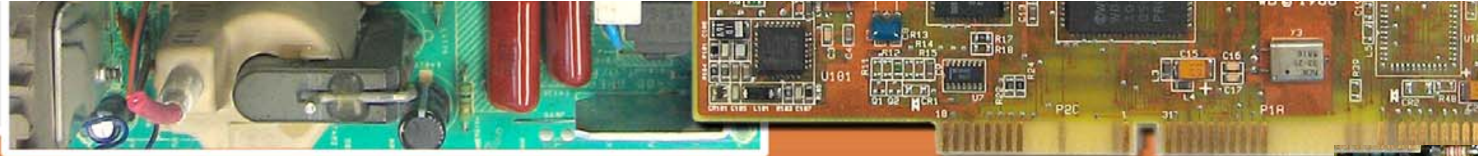
Internationally Integrated

8 Product Sectors

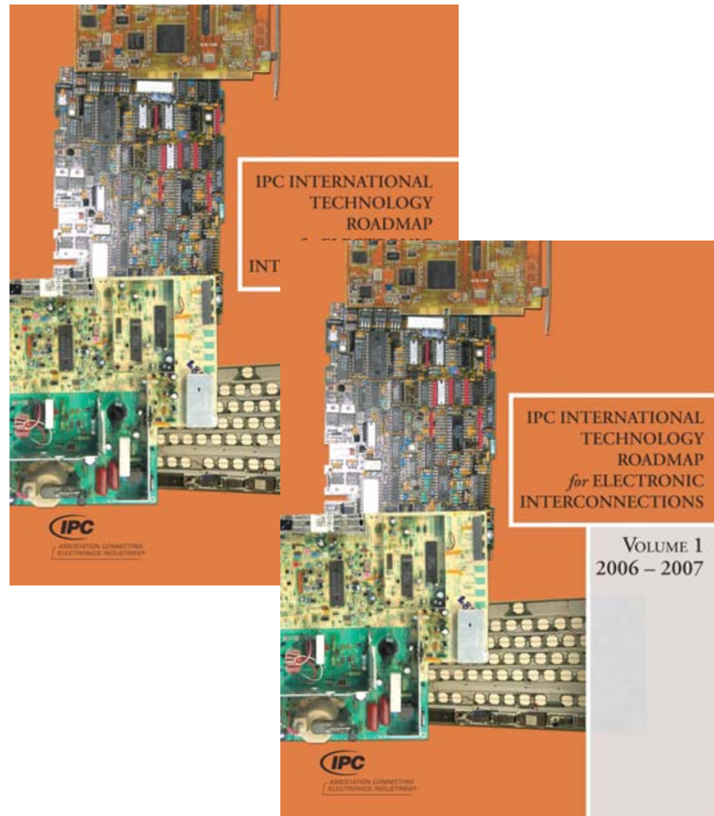
Added information

- **Embedded Passives**
- **E- Test**
- **Optoelectronics**
- **Reliability roadmap**

Preparing for the next generation



IPC International Technology Roadmap for Electronic Interconnections 2006 - 2007



2006 / 2007

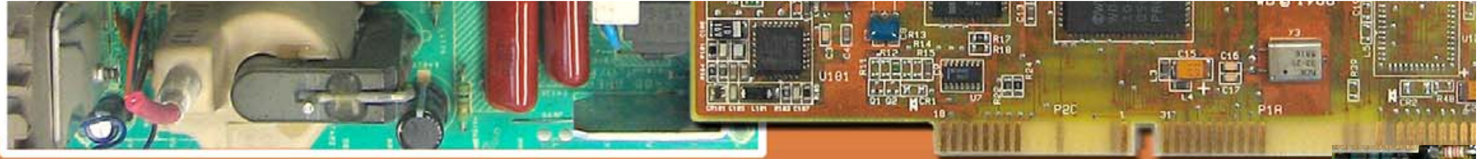
Base Element - OEM Input

Internationally Integrated

8 Product Sectors

Added information

- **Factory environment**
- **Design**
- **Equipment**
- **Reliability roadmap**



Who uses the IPC Roadmap?

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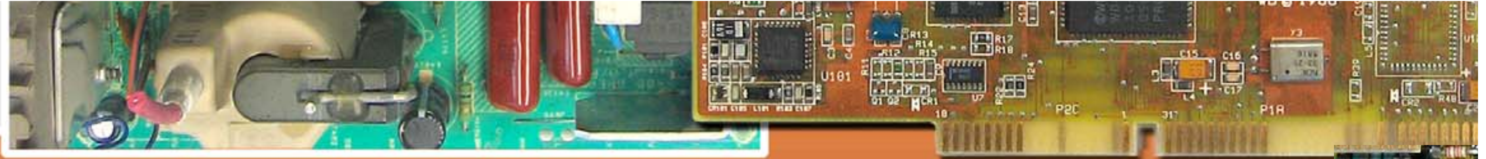
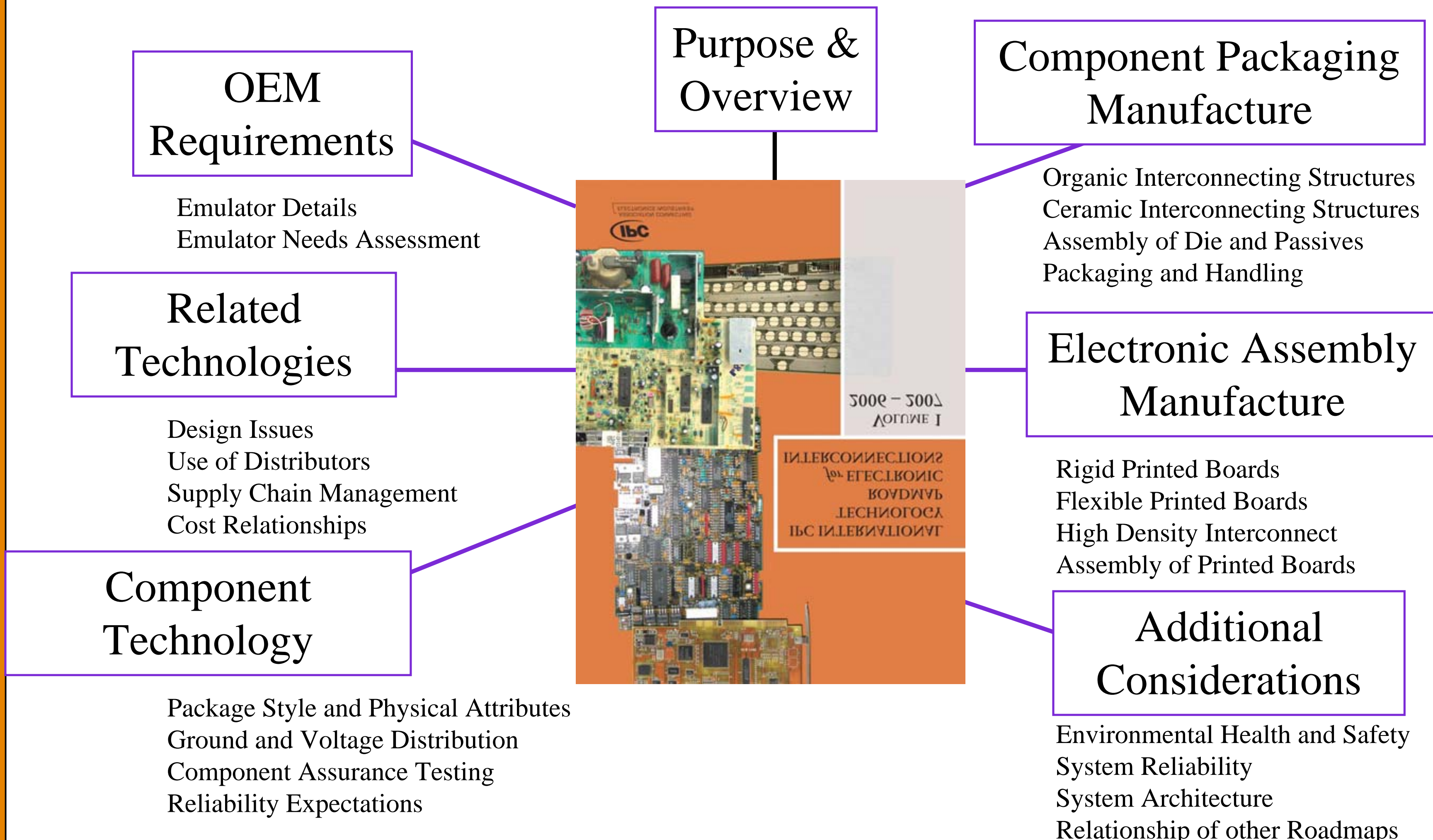
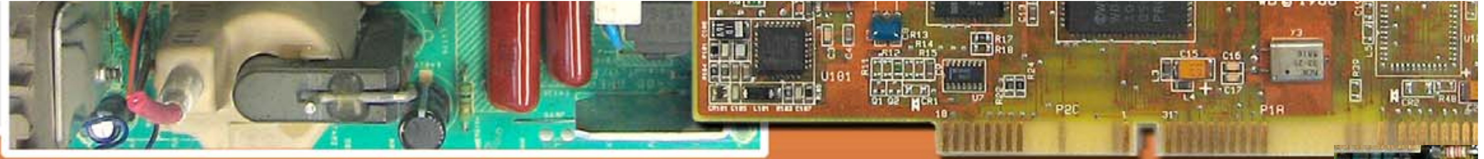


What makes the IPC Roadmap different?

- Interconnect & assembly technology only
- Operational level detail
- Emulator analysis and Comparison
- Two points of reference data for each time frame
  - RCG / SoA

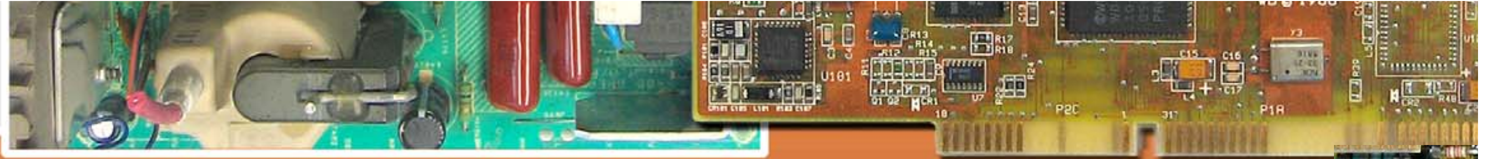
Organization of the 2006-2007 Roadmap





Accomplishments of IPC Roadmaps

- Created ITRI
- DuPont Shipley Consortia
- NCMS PCB & Embedded Passives Consortia
- Prioritized Industry R&D Activity
- Prioritized New and Improved Standards – HDI, Electronic Design, and now Optoelectronics
- Established a Working Agenda for Congress
- Worldwide Acceptance
- Encouraged international vision and participation



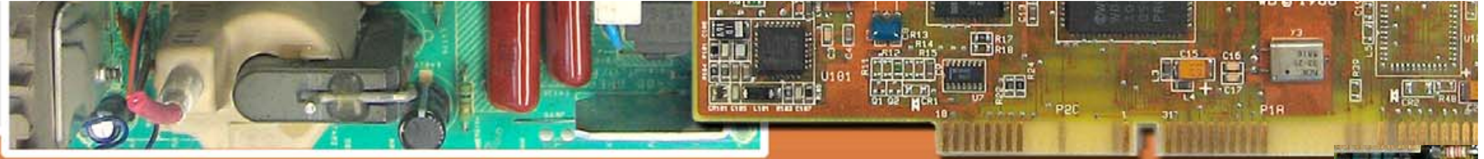
Internationalizing the IPC National Technical Roadmap

European Input – Michael Weinhold, EIPC

Japan Input - Hisao Kasuga
- Aki Shibata
- Henry Utsunomiya

Hong Kong - S.L.Law

China – Huawei Technologies

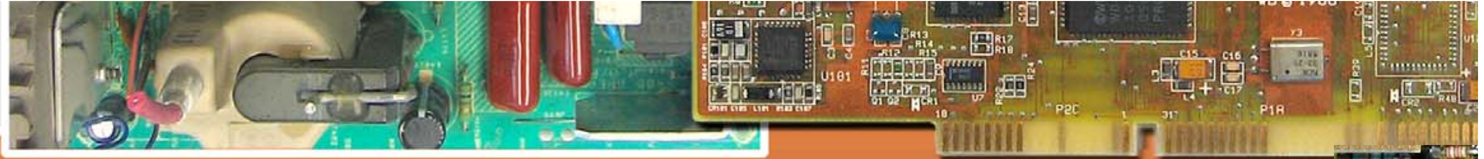


What's new for 2006 - 2007

Focus group concept

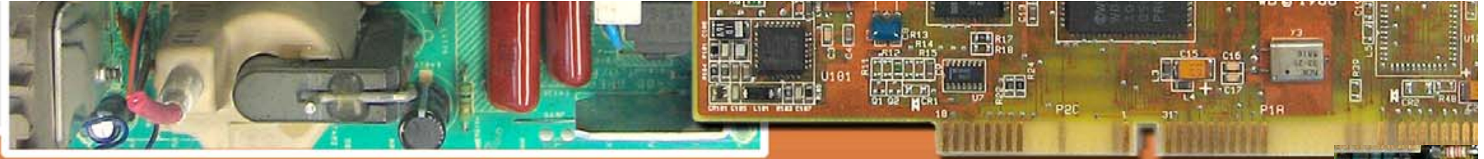
10 Very successful focused meetings

- Packaging
- Design
- Flex
- Reliability
- Factory environment
- Equipment
- Materials
- Optoelectronic assembly
- $PCQR^2$



• Detail Validation for Printed Boards

Figure A6-2: PCQR² Test Modules



- **PCQR² Test Panel Sample Section**

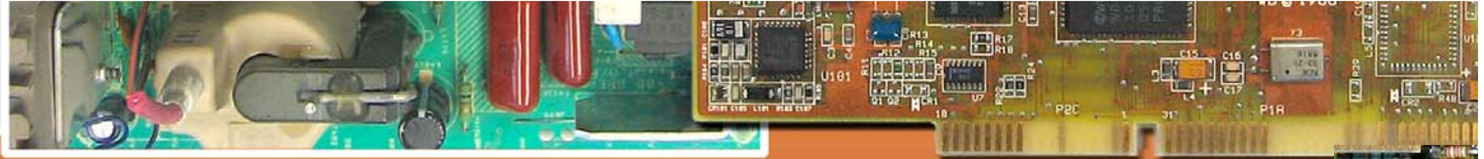
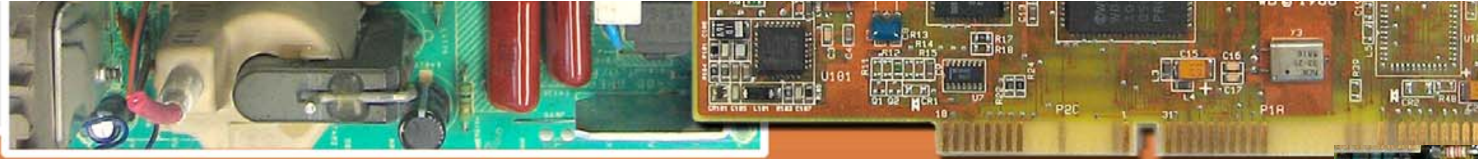


Figure A6-3: PCQR² Database Submissions by Geographic Region

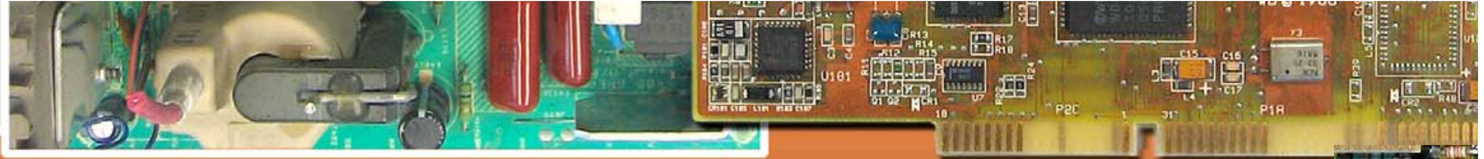


What's new for 2006 - 2007

Reliability section updated

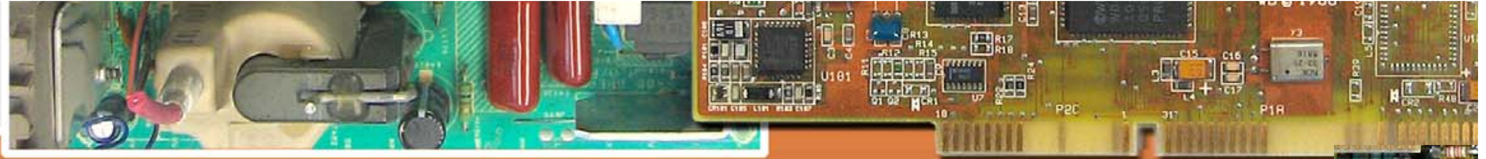
Optoelectronic substrate assembly completely revised

New section on Printable Electronics



Product Emulators – 2006 - 2007

- E-1 Electronic games
- E-2 Low Cost Electronics
- E-3 Hand-held / Wireless Electronics
- E-4 Mid Range Electronics
- E-5 High Performance Electronics
- E-6 RF and Microwave Electronics
- E-7 Harsh Environments/Aerospace
- E-8 Harsh Environments/Auto Electronics



Component Packaging

In the 2006-2007 packaging is still the main technology driver. Packaging I/O density and new package configurations continue to be the most significant driver of PCB technology

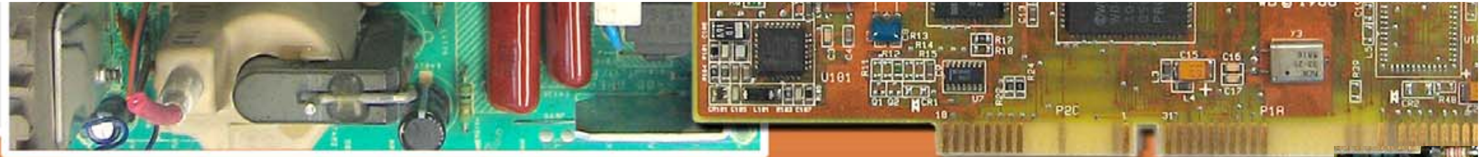


Table C1-2: Substrate Design Feature Characteristics

DESIGN FEATURES	CONVENTIONAL	LEADING EDGE	STATE-OF-THE-ART
Lines & Spaces (µm)	100 - 250	50 – 100	< 25
Via Diameter (µm; as drilled)	>250	100 - 200	50
(Conductive) Layer Count	1 - 2	2 - 20	>20
Dielectric Thickness (µm)	25 - 100	12 -25	12
Conductor Thickness (µm)	18 -36	10 -17	8 - 9
Adhesive	Yes	Adhesiveless	Adhesiveless
Minimum Annular Ring =(pad diameter-hole diameter) x 1/2 (µm)	200	50	None (landless via)

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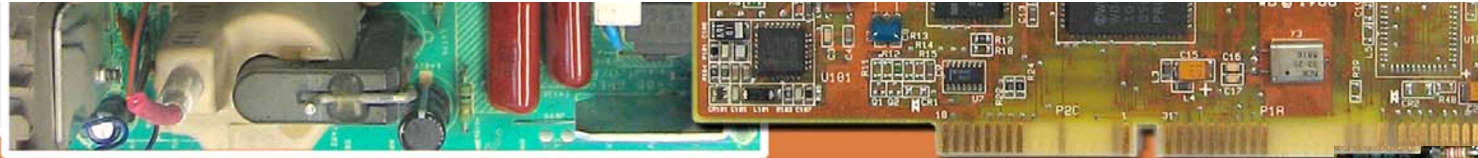


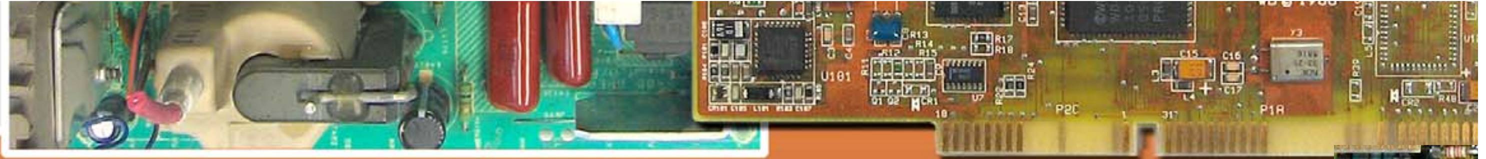
IPC International Technology Roadmap for Electronic Interconnections 2006 - 2007

Table C1-6: Mechanical Hole Formation

ATTRIBUTE	CURRENT 2006-2007		NEAR TERM 2008-2009		MID TERM 2010-2011		LONG TERM 2012-2016	
	RCG	SoA	RCG	SoA	RCG	SoA	RCG	SoA
Via Size Min (μm)	200	150	150	125	125	110	100	80
Aspect Ratio	8:1	12:1	11:1	15:1	15:1	20:1	18:1	23:1
Via Pitch (μm)	600	400	500	300	450	250	350	200

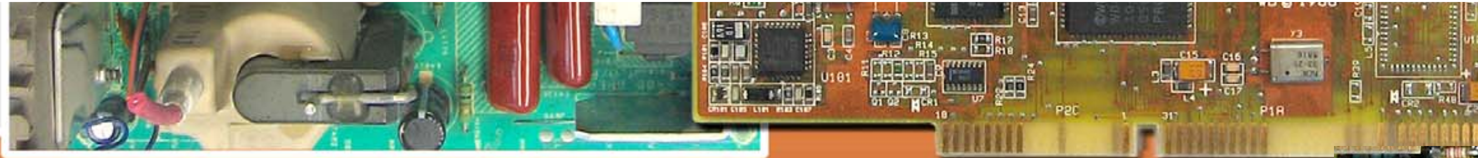
Table C1-7: Non-mechanical Hole Formation

ATTRIBUTE	CURRENT 2006-2007		NEAR TERM 2008-2009		MID TERM 2010-2011		LONG TERM 2012-2016	
	RCG	SoA	RCG	SoA	RCG	SoA	RCG	SoA
Via Size Min (μm)	125	60	120	50	100	40	75	30
Aspect Ratio (Depth:Diam)	1:2	1:1	1.5:1	.90:1	1.25	.80:1	1:1	.75:1
Via Pitch (μm)	300	200	250	175	225	150	200	125



PCB Manufacturing Technology

The challenge to PCB manufacturers continues to be density and layer count. Connect density has not slowed down and is not forecasted to slow. Layer count, especially in the larger boards continues to show an increase.



IPC International Technology Roadmap for Electronic Interconnections 2006 - 2007

Table D1-3: Innerlayer Imaging for 35 µm copper foil

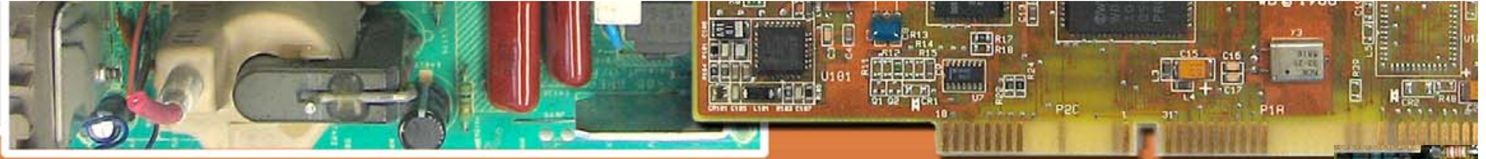
ATTRIBUTE	CURRENT 2006-2007		NEAR TERM 2008-2009		MID TERM 2010-2011		LONG TERM 2012-2016	
	RCG	SoA	RCG	SoA	RCG	SoA	RCG	SoA
Feature Size (µm)	60	40	50	35	40	25	35	20
Tolerance (µm)	20	7	15	5	12	4	12	3
Defect Size as % of Image	20	15	15	12	15	10	12	10

RCG = Conventional (practiced by 95% of the industry)
SoA = State of the art (practiced by 5% of the industry)
Tolerance is taken to mean plus or minus 3 sigma standard deviation.

Table D1-9: Mechanical Hole Formation in 1.5 mm board thickness

Attribute	CURRENT 2006-2007		NEAR TERM 2008-2009		MID TERM 2010-2011		LONG TERM 2012-2016	
	RCG	SoA	RCG	SoA	RCG	SoA	RCG	SoA
Via size min (µm)	250	150	230	150	225	125	212	125
Aspect ratio	6:1	10:1	7:1	10:1	7:1	12:1	8:1	12:1
Via pitch (µm)	500	300	450	250	400	225	400	200

RCG = Conventional (practiced by 95% of the industry)
SoA = State of the art (practiced by 5% of the industry)



Electronic Manufacturing Assembly

Products will continue to be a through hole and surface mount mix. Assembly will be driven by multi-chip package designs with an increasing number of I/O's to support power requirements and bandwidth. Array pitches will continue decrease to new levels. Thermal issues will become critical.

MEMs is still a niche technology with wireless becoming widely used.

Optoelectronic assembly continues to evolve and grow

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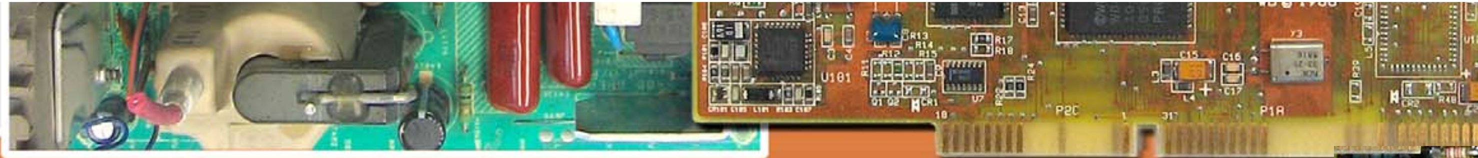
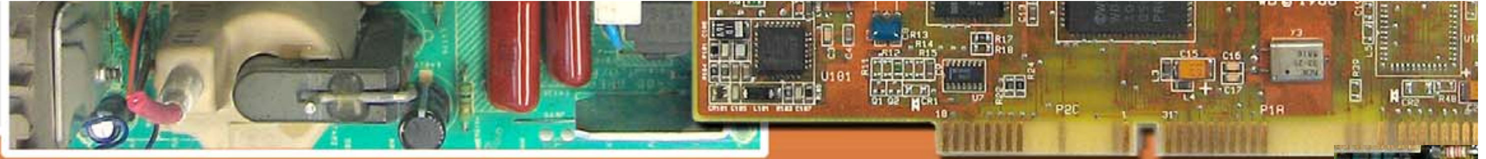


IPC International Technology Roadmap for Electronic Interconnections 2006 - 2007

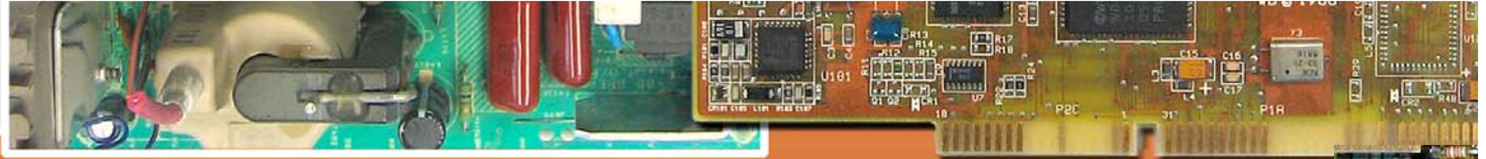
Table E1-5: Manufacturing Evolution

Assembly Issues	CURRENT 2006 - 2007		NEAR TERM 2008 - 2009		MID TERM 2010 - 2011		LONG TERM 2012 - 2016	
	RCG	SoA	RCG	SoA	RCG	SoA	RCG	SoA
Components	0.8 mm CSPs	0.4 mm CSPs	0.65 mm CSPs	0.3 mm CSPs	0.5 mm CSPs	0.2 mm CSPs	0.3 mm CSPs	0.2 mm CSPs
Joining Surfaces/Substrates	Sn/Pb	Lead free Alloys	Sn/Pb	Lead free Alloys	Lead Free	Industry standard	Lead Free	Industry standard
Placement Accuracy	± 0.03 mm	± 0.01 mm	± 0.01 mm	±0.005 mm	±0.005 mm	±0.003 mm	±0.003 mm	0.002 mm
Attachment Techniques	Inerted wave and reflow	Site specific assembly	Reflow and Laser	Robotic Laser	Reflow and Laser	Robotic Laser	Reflow and Laser	Robotic Laser
Rework	Manual	Robotic: Program	Robotic assisted	Robot test linked	Robotic assisted	Robot test linked	Robotic assisted	Robot test linked
Cleaning	No clean and aqueous	Benign solutions	Aqueous cleaning	Benign solutions	Aqueous cleaning	Benign solutions	Aqueous cleaning	Benign solutions



Environmental topics

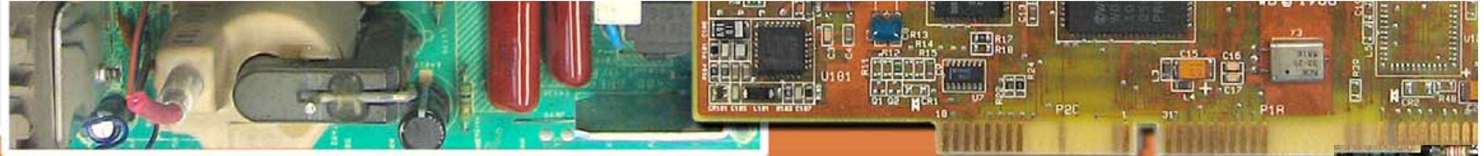
Environmental regulations changing from domestic regulations, increasingly to global regulations. A new trend of international "market driven" environmental initiatives focusing on materials. The highest priority issues are those relating to RoHS compliance, reducing the burden associated with exchanging materials composition information. Regulations governing the environmental impacts of manufacturing, including the use, storage, transportation, and disposal of hazardous materials, continue to exert a significant influence on the manufacturing process.



Design issues

Design and simulation tools are the main roadblocks to more rapid introduction of new technologies in a number of rapidly developing areas:

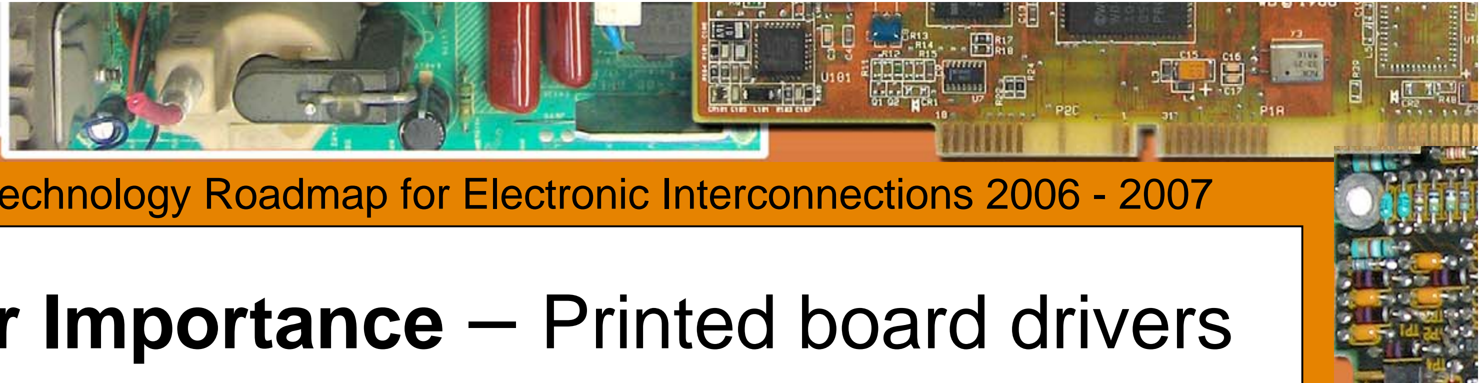
- **Mechanics and Reliability Modeling**
- **Thermal and Thermo-fluid Simulation**
- **Improved design tools for emerging technologies like embedded passives and optoelectronic PCB's**



- **Emulator Importance** – Design drivers

Table A4-8A: E-7 Harsh Environments/Aerospace Design Factors

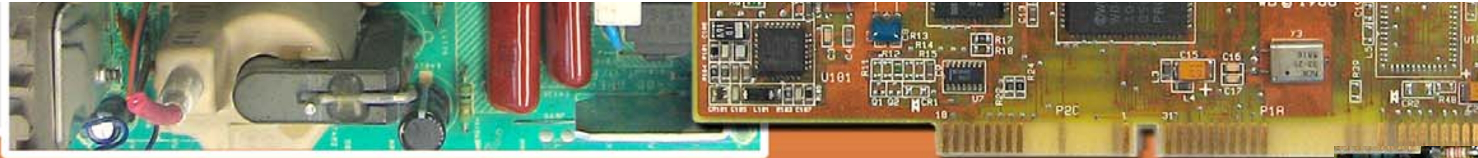
Technical Driver	Metric Measure	CURRENT 2006–2007		NEAR TERM 2008–2009		MID TERM 2010–2011		LONG TERM 2012–2016	
Design Factors		RCG	SoA	RCG	SoA	RCG	SoA	RCG	SoA
On Chip Rise Time	Nanoseconds	0.35	0.32	0.29	0.23	0.16	0.14	0.14	0.12
On Chip Frequency	MHz	875	1167	1167	1750	1167	1750	1750	3500
Min. Device Voltage	Volts	4.0	1.8	1.8	1.2	1.6	1.0	1.2	0.8
Voltage Levels	Avg levels	4	3	4	2	3	2	2	2
Frequency (Chip to Bd)	MHz	700	900	1000	1200	1600	1900	1900	2200
Thermal Dissipation	Watts avg/max	20/70	25/90	20/80	30/100	25/100	30/120	35/150	40/150
EMC Susceptibility	Design Yes/No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Operation Hours/Life Expectancy	Cycles per day/ Number years	1/10	1/20	1/10	1/20	1/10	1/20	1/10	1/20
Operating Range	Min/Max °C	-55/125	-55/125	-55/140	-55/150	-55/140	-55/150	-55/150	-55/150
Max. Board Temp	°C	65	75	70	80	75	85	110	120



- **Emulator Importance** – Printed board drivers

Table A4-8B: E-7 Harsh Environments/Aerospace Printed Board Technology Factors

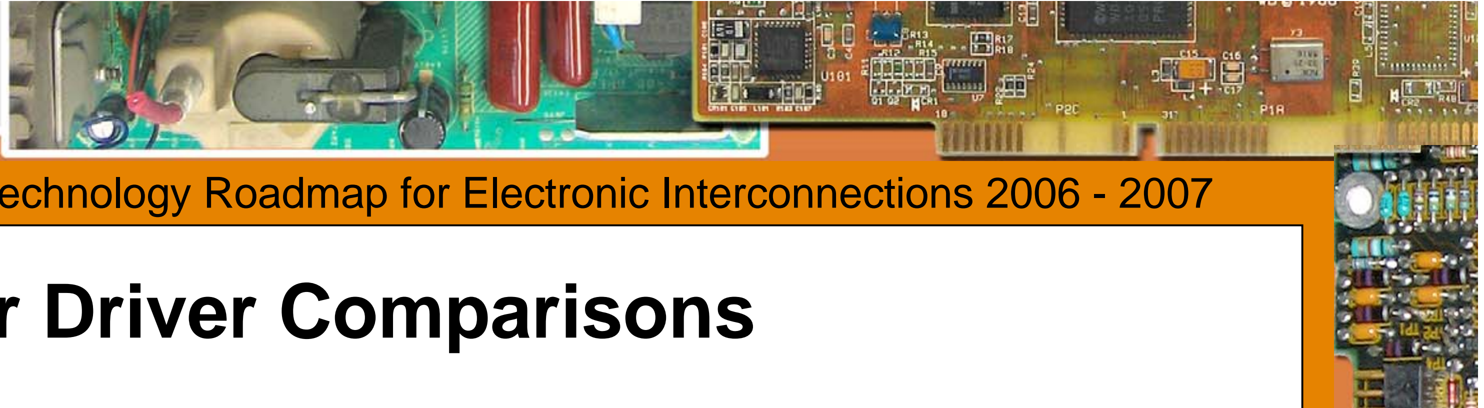
Technical Driver	Metric Measure	CURRENT 2006–2007		NEAR TERM 2008–2009		MID TERM 2010–2011		LONG TERM 2012–2016	
Printed Board Technology Factors		RCG	SoA	RCG	SoA	RCG	SoA	RCG	SoA
Materials	Mat'l type code	MOD FR-4	BT Epoxy	MOD FR-4	BT Epoxy	MOD FR-4	BT Epoxy	BT Epoxy	BT Epoxy
Board Size-Area	sq cm	250	200	230	180	230	180	220	150
Thickness-Cond. Area	mm	1.75	1.5	1.5	1.2	1.5	1.2	1.5	1.2
Layer count	Avg. layers	6	12	8	14	10	16	14	20
Line width/space	Min. internal µm	100/100	100/85	100/85	75/75	75/75	50/75	50/75	25/50
Min. hole Dia.-thru Via	Min./µm	200	200	200	200	150	150	150	125
Min. hole Dia.-buried/blind	Min./µm	150	40	150	40	150	40	40	40
Min. microvia-buried/blind	Min./µm	125	100	125	100	125	100	125	100
Land diameter value (compute as area cm sq)	Add to Hole µm	150	200	150	180	150	150	100	100
Hole Qty-Mechanical (compute as area cm sq)	Avg./board	2578	1867	2288	1869	2600	1900	2700	2000
Hole Qty-Microvia	Avg./board	3222	5333	3813	6231	5200	7600	5500	8000
Plane Keepout Zone	Plus to Hole Dia	450	400	375	350	350	300	350	300
Soldermask Registration	Microns to DTP	125	100	100	75	75	50	75	50
Aspect Ratio Micro Via	Max Ratio	0.7:1	0.9:1	0.7:1	0.9:1	0.8:1	1.0:1	0.8:1	1.0:1
Aspect Ratio Drilled	Max Ratio	5:1	8:1	5:1	10:1	5:1	10:1	5:1	10:1



- **Emulator Importance** – Assembly drivers

Table A4-8C: E-7 Harsh Environments/Aerospace Board Assembly Technology Factors

Technical Driver	Metric Measure	CURRENT 2006–2007		NEAR TERM 2008–2009		MID TERM 2010–2011		LONG TERM 2012–2016	
Board Assembly Technology Factors		RCG	SoA	RCG	SoA	RCG	SoA	RCG	SoA
Leads/component	Avg. leads	23	20	23	18	25	24	30	28
I/O pitch Array Packages	Minimum mm	1.0	0.75	0.80	0.65	0.80	0.65	0.65	0.5
Max. # leads/component	I/O count	540	660	650	750	700	800	800	900
Solder joints primary side (joints/cm sq)	# joints	4700	5200	5200	6000	5600	6500	6000	7000
Solder joints secondary side	# joints	3160	3480	3300	4000	4000	4600	4500	5000
# discretes	Total parts	280	410	330	520	300	400	320	450
Max. array components	Total parts	32	23	40	35	60	50	75	60
Max. peripheral components	Total parts	32	23	35	30	40	35	50	42
Test Density	Nodal Access	180	220	210	240	245	290	245	290
Assembly Complexity	Type two sided	2Z	2Z	2Z	2Z	2Z	2Z	2Z	2Z

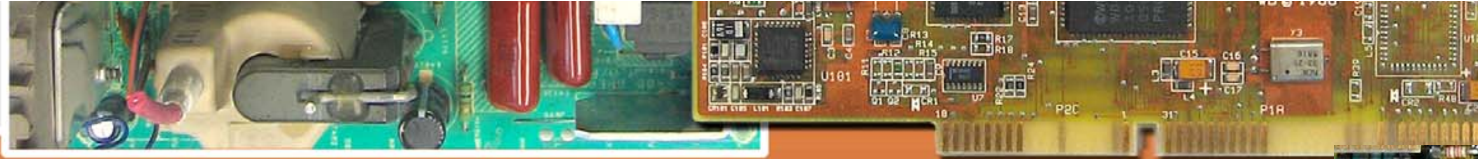


• Emulator Driver Comparisons

Table 12: Usable Board Area (cm^2)

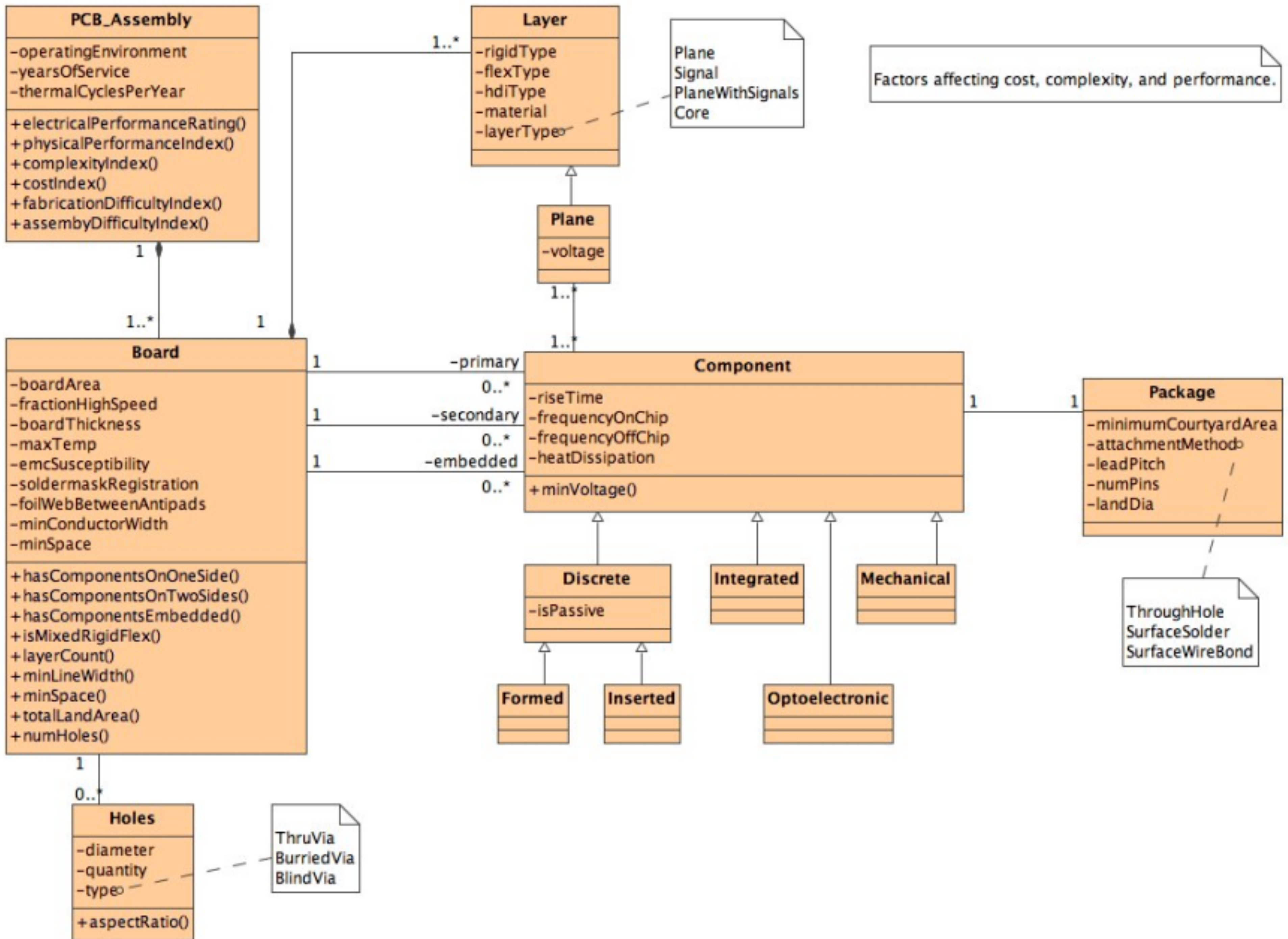
EMULATORS	CURRENT 2006 - 2007		NEAR TERM 2008 - 2009		MID TERM 2010 -2011		LONG TERM 2012 - 2016		Remarks
	RCG	SoA	RCG	SoA	RCG	SoA	RCG	SoA	
E1 Electronic Games	135	85	130	60	125	55	110	50	
E2 Consumer Products	100	40	100	40	100	40	90	35	
E3 Hand-held/Wireless	19	10	19	10	19	10	10	8	Siemens and Nokia Cell Phones 2006
E4 Mid Range Performance	700	600	600	500	600	500	550	400	Intel and Lucent (average) 2006
E5 High Perf.Systems	2000	2400	2200	2600	2400	2800	2500	3000	
E6 RF and Microwave	750	1000	1000	1100	1000	1200	1100	1500	Andrew Corp 2006
E7 Harsh Environment: Aero	250	200	230	180	230	180	220	150	
E8 Harsh Environments:Auto	180	160	160	140	120	100	110	90	
E9 Backplanes	6000	13000	6500	14000	7000	15000	8000	17000	

Usable area excludes card edge connectors, card guide keepouts and other areas that must be free of padstacks or solder joints
Frame of Refence: 100 Square Centimeters = 16 Square Inches (4" x 4")

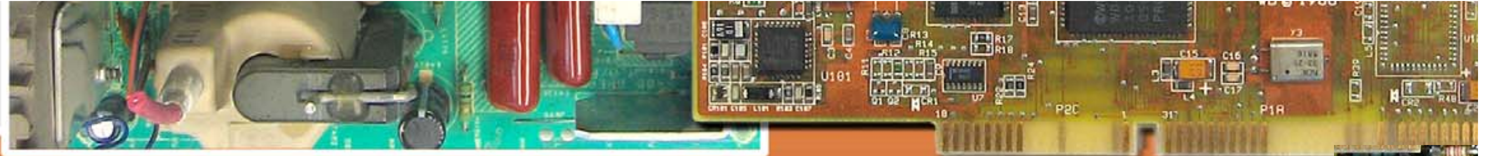


Major Emulator Review

- Added descriptions to drivers
  - EXAMPLE
  - In addition, the following characteristics also apply:
  - I/O explosion; plastic array packages with high I/O count
  - Many systems will make use of daughter board (super component) concepts
  - Connectors will require High I/O and high frequency capabilities
  - HDI and µVia usage will increase with decreasing package pitch
- Discussed inconsistencies
- Evaluated survey from roadmap users
- Developed new methodology for future
- Started data model for XML schema



PCB_Assembly
-operatingEnvironment
-yearsOfService
-thermalCyclesPerYear
+electricalPerformanceRating()
+physicalPerformanceIndex()
+complexityIndex()
+costIndex()
+fabricationDifficultyIndex()
+assembyDifficultyIndex()
Layer
-rigidType
-flexType
-hdiType
-material
-layerType
Plane
Signal
PlaneWithSignals
Core
Factors affecting cost, complexity, and performance.
Plane
-voltage
Board
-boardArea
-fractionHighSpeed
-boardThickness
-maxTemp
-emcSusceptibility
-soldermaskRegistration
-foilWebBetweenAntipads
-minConductorWidth
-minSpace
+hasComponentsOnOneSide()
+hasComponentsOnTwoSides()
+hasComponentsEmbedded()
+isMixedRigidFlex()
+layerCount()
+minLineWidth()
+minSpace()
+totalLandArea()
+numHoles()
-primary
-secondary
-embedded
Component
-riseTime
-frequencyOnChip
-frequencyOffChip
-heatDissipation
+minVoltage()
Package
-minimumCourtyardArea
-attachmentMethod
-leadPitch
-numPins
-landDia
Discrete
-isPassive
Integrated
Mechanical
Formed
Inserted
Optoelectronic
ThroughHole
SurfaceSolder
SurfaceWireBond
Holes
-diameter
-quantity
-type
+aspectRatio()
ThruVia
BurriedVia
BlindVia



- **The 2008/2009 Roadmap**
  - The next roadmap effort is starting
  - Compare things done good or not good
  - Will revisit requests from industry
  - Schedule additional focus meetings
  - Develop a hard copy precise
  - Start software development of XML schema
  - Develop roadmap training sessions