NEMI Optoelectronic Substrates Project (Status Report)

Jack Fisher - Project Leader

The optoelectronics industry is moving at a rapid pace and new ideas and processes occur almost every week. The printed wiring board is one of the components that may impact or be impacted by the optoelectronic momentum. To enable the optoelectronic industry to meet it's cost and performance targets the PWB must be able to carry both electrons and photons in the same substrate. The NEMI Optoelectronic Substrate team will investigate the use of optical waveguides in or on PWB's.

Initial investigation by the committee determined that the OEM's were not planning to use optoelectronics in their next generation machines.

The OEM's felt that optoelectronics was at least two generations away from implementation in product that effect the revenue stream

The OEM's were all working on internal analysis's of optoelectronic solutions and were all interested in participating in a NEMI technology analysis activity.

There are numerous estimates of how far copper can be pushed to increase data rates. The estimates range from 2.5 Gb/s to 40 Gb/s.

Inititatives

Cost/performance modeling of optical wave guides vs. copper conductors Inititative

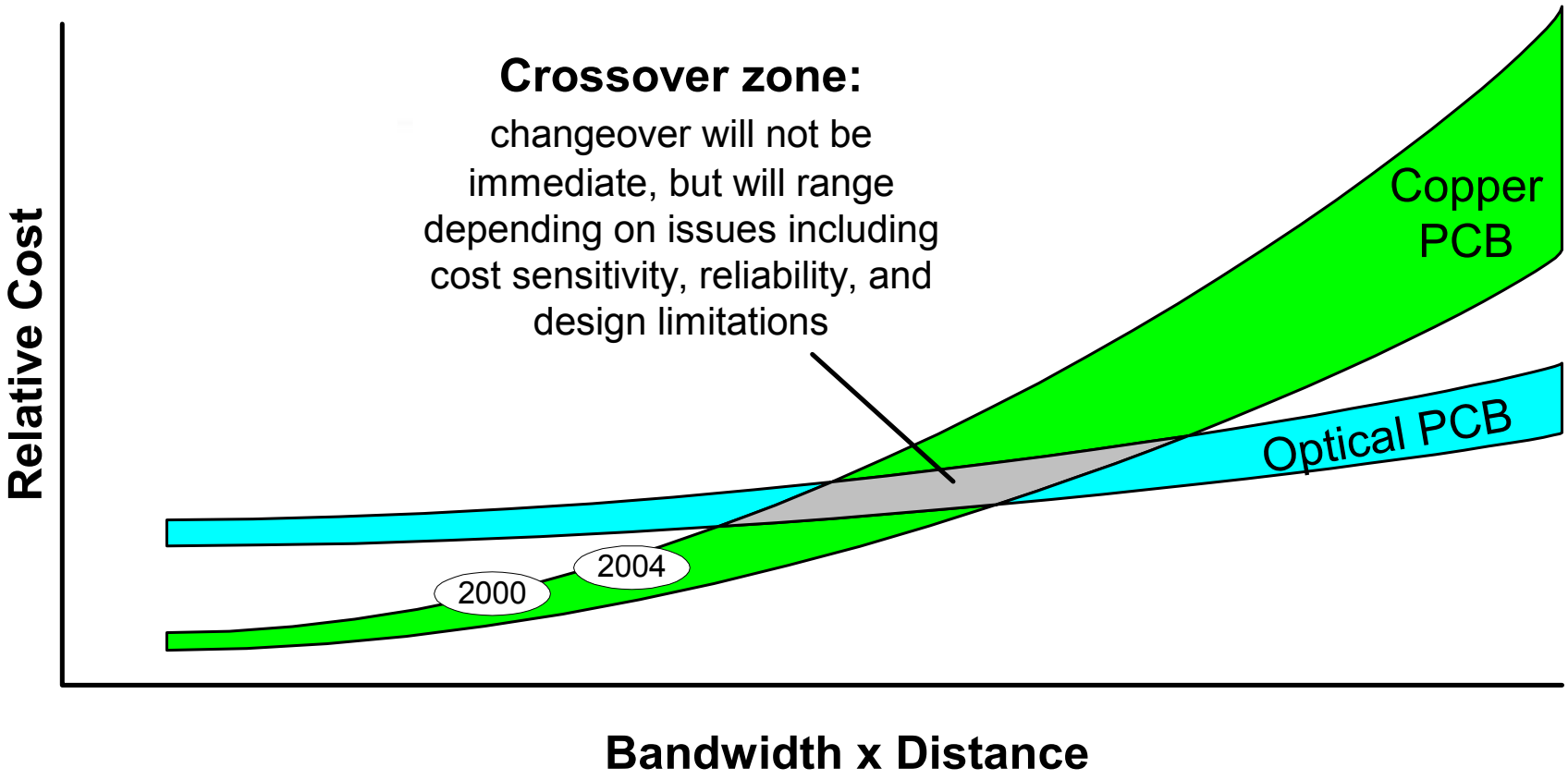
Objective:
Develop a cost model for a “copper” telecom industry backplane and then model potential designs for equivalent optoelectronic backplanes. The goal is to determine a bandwidth crossover point between copper and opto. Currently the team is using a backplane as the primary focus of the activity. Copper and optoelectronic transmitters and receivers may also need to be included which also may allow an analysis of chip carrier technology to be included in the project.

Activities:
In light of the OEM's not booking optoelectronics as part of their next generation equipment it was decided to do a business analysis of copper vs. optoelectronics

The product to be analyzed will be a communications industry backplane.

Optical Backplane Cost

Cost-performance is the key driver; we need an industry metric to compare optical vs. Cu-based, e.g. $/(Gb/s/channel/m)



- Jack Fisher
- Bruce Booth

Status:

- Bi-monthly telecons
- Very good participation
  - Several OEM's
  - Several fabricators / Contract assemblers
  - Several material suppliers

Team Members

iNEMI	Cookson	Macdermid	Solectron
Agilent	Cray	Merix	Teradyne
Alcatel	Dow Corning	Nortel	Univ. of Maryland
Bell Labs Lucent	IBM	Optical Crosslinks	U.S. Connect
Celestica	Infineon	Park Nelco	
Cisco	Intel	Promex	
Cortrec	Motorola	Rohm Haas	

Sub-groups

Optical: Peter Arrowsmith, Celestica

- To do a business model you need:
  - A modeling tool
    - PCB cost model
    - Component assembly model tool
  - Select optoelectronic technology alternatives
    - Fiber
    - Waveguide
    - Polymer appliqué
    - Etc

- Develop and agree on sensitivities (materials, components, process, etc.)
  - Opto sensitivities
  - Copper sensitivities

- Develop and agree on architectures
  - Opto architectures
  - Copper architectures

Difficult because it is often proprietary information

Cost Models

Two cost models have been developed:

- Backplane cost model
  - Technical Cost Model (activity based + engineering relationships) : Adam Singer, Cookson
- Assembly cost model
  - Sequential process cost of ownership model: Peter Sandborn, U. of Maryland

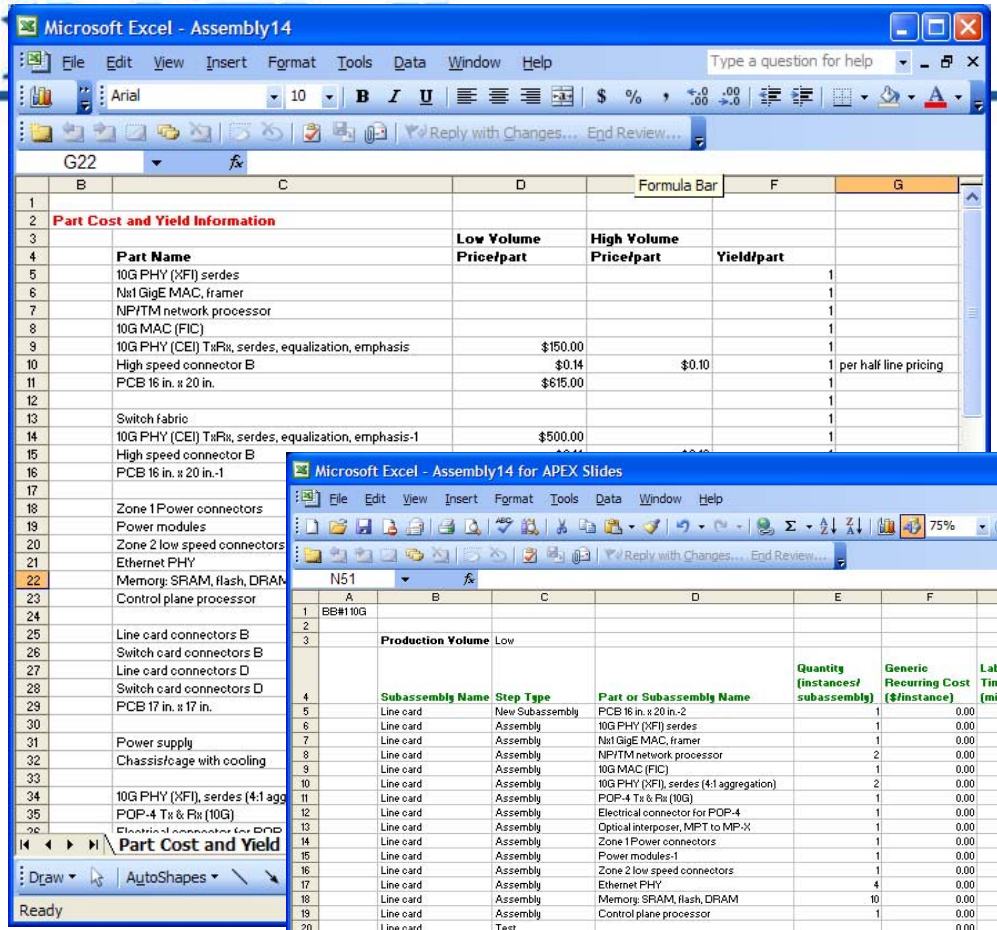
Assembly Cost Modeling Approach

- Sequential process model – the sequence of process steps is important because modeling recurring functional test (and possibly rework is important)
- Supports system physical hierarchical – parts -> subassemblies -> assemblies, etc.
- Distinguishes between mature and immature processes and parts
- Relative costs – more interested in accurately modeling cost differences between technology options rather than absolute costs

Assembly Cost Modeling Inputs

- Part data
  - Procurement cost and yield at assembly
- Assembly process data
  - Generic processing steps with labor, material, tooling, and capital equipment contributions
  - Recurring functional test steps (additionally characterized by fault coverage)
  - Rework steps

Assembly Cost Model


Microsoft Excel - Assembly14

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Arial 10

Reply with Changes... End Review...

G22

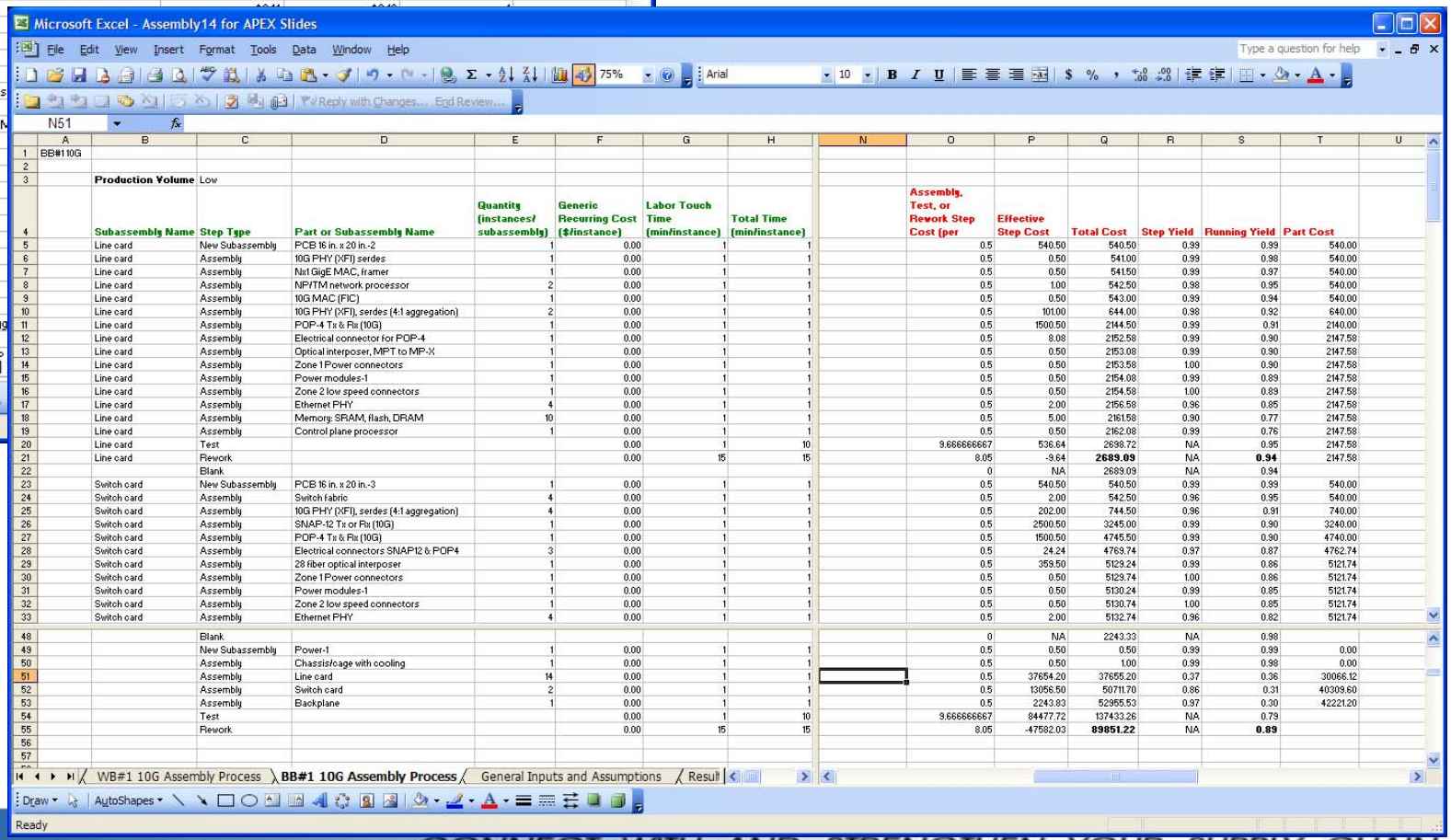
Formula Bar

	B	C	D	F	G
1					
2		**Part Cost and Yield Information**			
3			**Low Volume**	**High Volume**	
4		**Part Name**	**Price/part**	**Price/part**	**Yield/part**
5		10G PHY (XFI) serdes			1
6		Nx1 GigE MAC, framer			1
7		NP/TM network processor			1
8		10G MAC (FIC)			1
9		10G PHY (CEI) TxRx, serdes, equalization, emphasis	$150.00		1
10		High speed connector B	$0.14	$0.10	1 per half line pricing
11		PCB 16 in. x 20 in.	$615.00		1
12					1
13		Switch fabric			1
14		10G PHY (CEI) TxRx, serdes, equalization, emphasis-1	$500.00		1
15		High speed connector B			
16		PCB 16 in. x 20 in.-1			
17					
18		Zone 1 Power connectors			
19		Power modules			
20		Zone 2 low speed connectors			
21		Ethernet PHY			
22		Memory: SRAM, flash, DRAM			
23		Control plane processor			
24					
25		Line card connectors B			
26		Switch card connectors B			
27		Line card connectors D			
28		Switch card connectors D			
29		PCB 17 in. x 17 in.			
30					
31		Power supply			
32		Chassis/cage with cooling			
33					
34		10G PHY (XFI), serdes (4:1 agg			
35		POP-4 Tx & Rx (10G)			

Part Cost and Yield

Draw AutoShapes

Ready


Microsoft Excel - Assembly14 for APEX Slides

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Reply with Changes... End Review...

N51

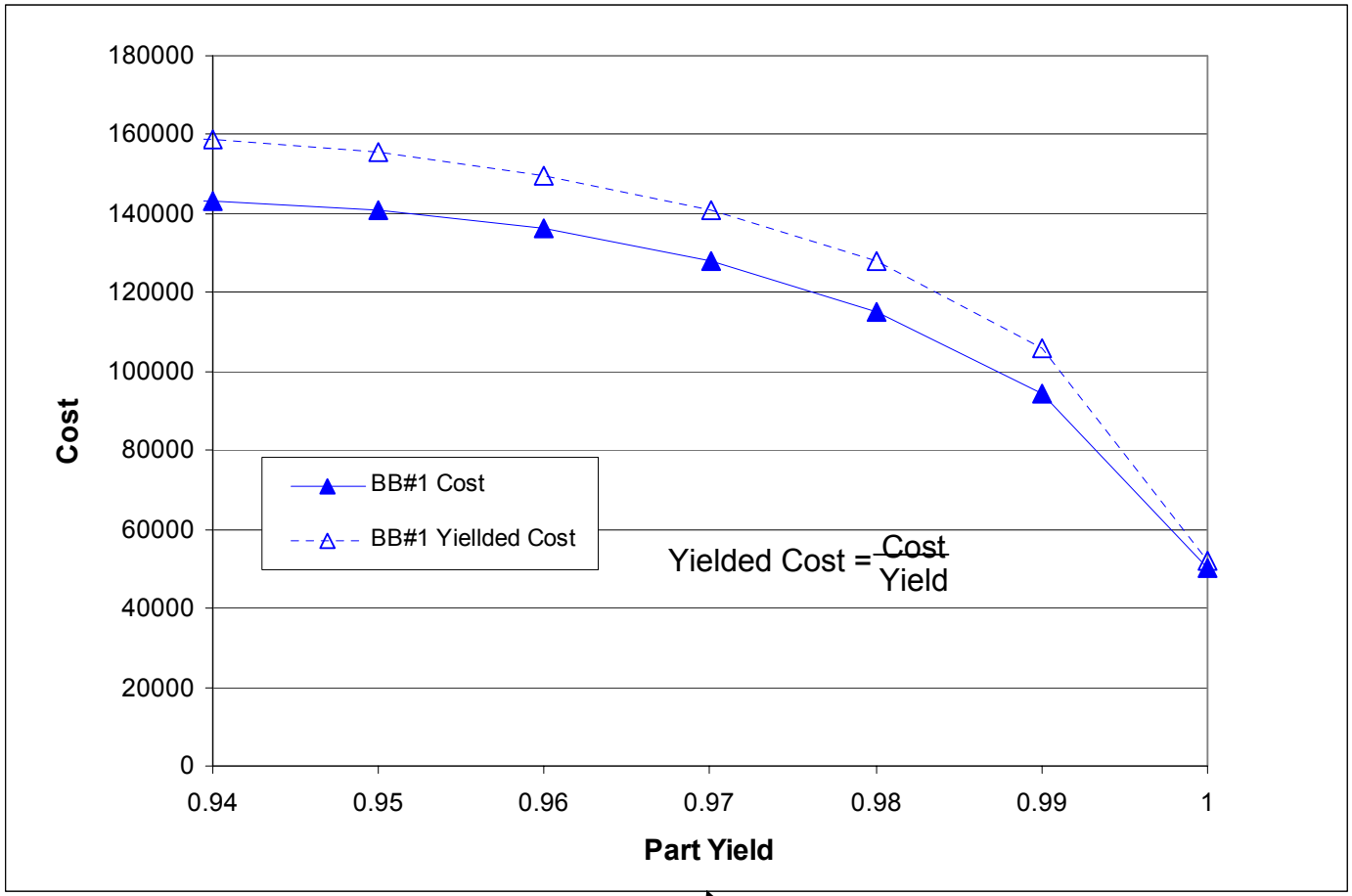
	A	B	C	D	E	F	G	H	N	O	P	Q	R	S	T	U
1	BB#1 10G															
2																
3		**Production Volume**	Low													
4	**Subassembly Name**	**Step Type**	**Part or Subassembly Name**		**Quantity (instances/ subassembly)**	**Generic Recurring Cost ($/instance)**	**Labor Touch Time (min/instance)**	**Total Time (min/instance)**		**Assembly, Test, or Rework Step Cost (per**	**Effective Step Cost**	**Total Cost**	**Step Yield**	**Running Yield**	**Part Cost**	
5	Line card	New Subassembly	PCB 16 in. x 20 in.-2		1	0.00	1	1		0.5	540.50	540.50	0.99	0.99	540.00	
6	Line card	Assembly	10G PHY (XFI) serdes		1	0.00	1	1		0.5	0.50	541.00	0.99	0.98	540.00	
7	Line card	Assembly	Nx1 GigE MAC, framer		1	0.00	1	1		0.5	0.50	541.50	0.99	0.97	540.00	
8	Line card	Assembly	NP/TM network processor		2	0.00	1	1		0.5	1.00	542.50	0.98	0.95	540.00	
9	Line card	Assembly	10G MAC (FIC)		1	0.00	1	1		0.5	0.50	543.00	0.99	0.94	540.00	
10	Line card	Assembly	10G PHY (XFI), serdes (4:1 aggregation)		2	0.00	1	1		0.5	101.00	644.00	0.98	0.92	640.00	
11	Line card	Assembly	POP-4 Tx & Rx (10G)		1	0.00	1	1		0.5	1500.50	2144.50	0.99	0.91	2140.00	
12	Line card	Assembly	Electrical connector for POP-4		1	0.00	1	1		0.5	8.08	2152.58	0.99	0.90	2147.58	
13	Line card	Assembly	Optical interposer, MPT to MP-X		1	0.00	1	1		0.5	0.50	2153.08	0.99	0.90	2147.58	
14	Line card	Assembly	Zone 1 Power connectors		1	0.00	1	1		0.5	0.50	2153.58	1.00	0.90	2147.58	
15	Line card	Assembly	Power modules-1		1	0.00	1	1		0.5	0.50	2154.08	0.99	0.89	2147.58	
16	Line card	Assembly	Zone 2 low speed connectors		1	0.00	1	1		0.5	0.50	2154.58	1.00	0.89	2147.58	
17	Line card	Assembly	Ethernet PHY		4	0.00	1	1		0.5	2.00	2156.58	0.96	0.85	2147.58	
18	Line card	Assembly	Memory: SRAM, flash, DRAM		10	0.00	1	1		0.5	5.00	2161.58	0.90	0.77	2147.58	
19	Line card	Assembly	Control plane processor		1	0.00	1	1		0.5	0.50	2162.08	0.99	0.76	2147.58	
20	Line card	Test				0.00	1	10		9.666666667	536.64	2698.72	NA	0.95	2147.58	
21	Line card	Rework				0.00	15	15		8.05	-9.64	**2689.09**	NA	**0.94**	2147.58	
22		Blank								0	NA	2689.09	NA	0.94		
23	Switch card	New Subassembly	PCB 16 in. x 20 in.-3		1	0.00	1	1		0.5	540.50	540.50	0.99	0.99	540.00	
24	Switch card	Assembly	Switch fabric		4	0.00	1	1		0.5	2.00	542.50	0.96	0.95	540.00	
25	Switch card	Assembly	10G PHY (XFI), serdes (4:1 aggregation)		4	0.00	1	1		0.5	202.00	744.50	0.96	0.91	740.00	
26	Switch card	Assembly	SNAP-12 Tx or Rx (10G)		1	0.00	1	1		0.5	2500.50	3245.00	0.99	0.90	3240.00	
27	Switch card	Assembly	POP-4 Tx & Rx (10G)		1	0.00	1	1		0.5	1500.50	4745.50	0.99	0.90	4740.00	
28	Switch card	Assembly	Electrical connectors SNAP12 & POP4		3	0.00	1	1		0.5	24.24	4769.74	0.97	0.87	4762.74	
29	Switch card	Assembly	28 fiber optical interposer		1	0.00	1	1		0.5	359.50	5129.24	0.99	0.86	5121.74	
30	Switch card	Assembly	Zone 1 Power connectors		1	0.00	1	1		0.5	0.50	5129.74	1.00	0.86	5121.74	
31	Switch card	Assembly	Power modules-1		1	0.00	1	1		0.5	0.50	5130.24	0.99	0.85	5121.74	
32	Switch card	Assembly	Zone 2 low speed connectors		1	0.00	1	1		0.5	0.50	5130.74	1.00	0.85	5121.74	
33	Switch card	Assembly	Ethernet PHY		4	0.00	1	1		0.5	2.00	5132.74	0.96	0.82	5121.74	
48		Blank								0	NA	2243.33	NA	0.98		
49		New Subassembly	Power-1		1	0.00	1	1		0.5	0.50	0.50	0.99	0.99	0.00	
50		Assembly	Chassis/cage with cooling		1	0.00	1	1		0.5	0.50	1.00	0.99	0.98	0.00	
51		Assembly	Line card		14	0.00	1	1		0.5	37654.20	37655.20	0.37	0.36	30066.12	
52		Assembly	Switch card		2	0.00	1	1		0.5	13056.50	50711.70	0.86	0.31	40309.60	
53		Assembly	Backplane		1	0.00	1	1		0.5	2243.83	52955.53	0.97	0.30	42221.20	
54		Test				0.00	1	10		9.666666667	84477.72	137433.26	NA	0.79		
55		Rework				0.00	15	15		8.05	-47582.03	**89851.22**	NA	**0.89**		
56																
57																

WB#1 10G Assembly Process | BB#1 10G Assembly Process | General Inputs and Assumptions | Result

Draw AutoShapes

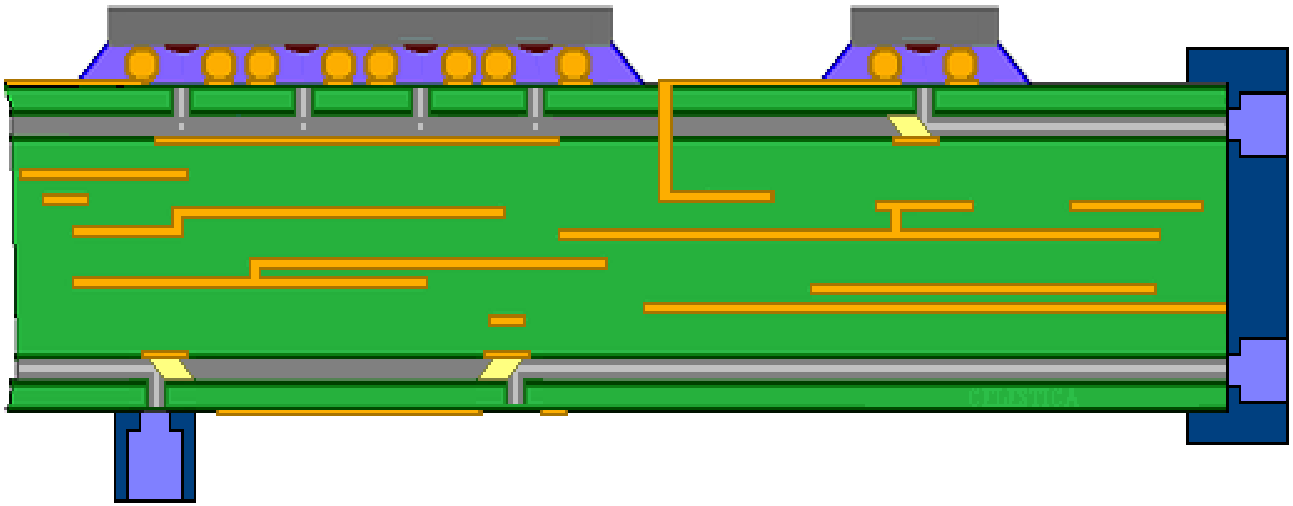
Ready

Example Preliminary Assembly Cost Results for Optical Black Box (BB#1)



BOM Costs:
BB#1 = $42,221 (current low volume)

Assumed to be the same for every part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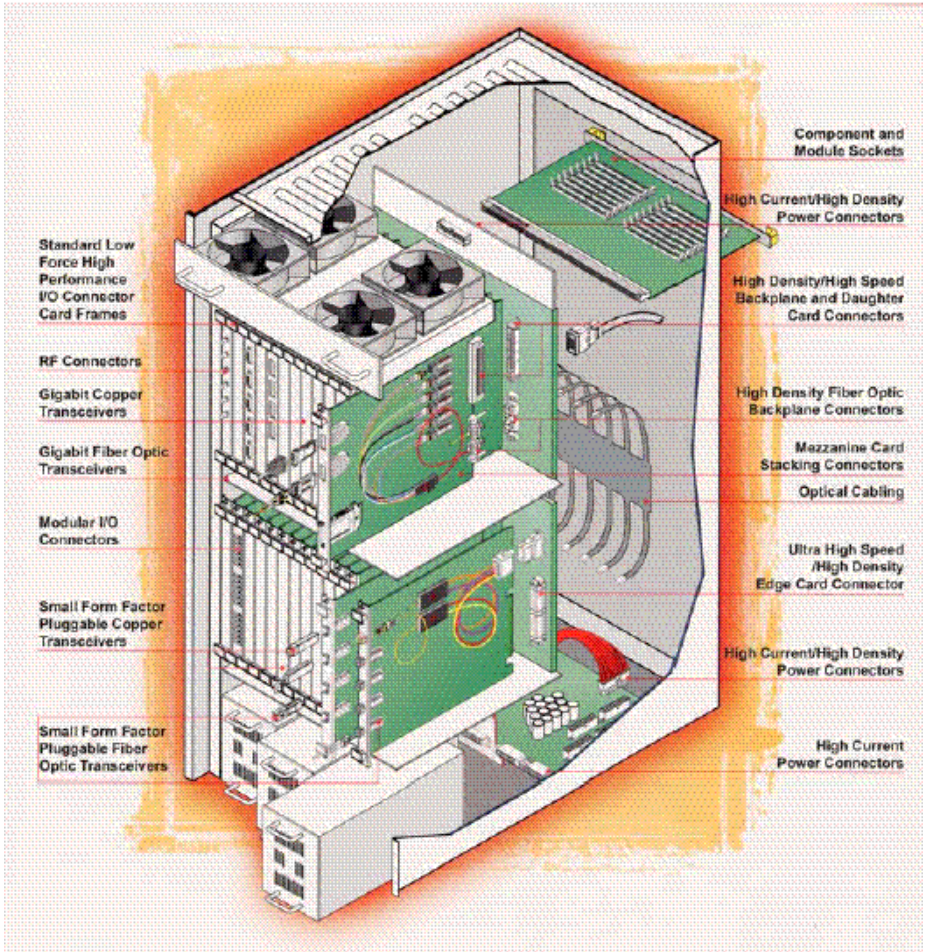
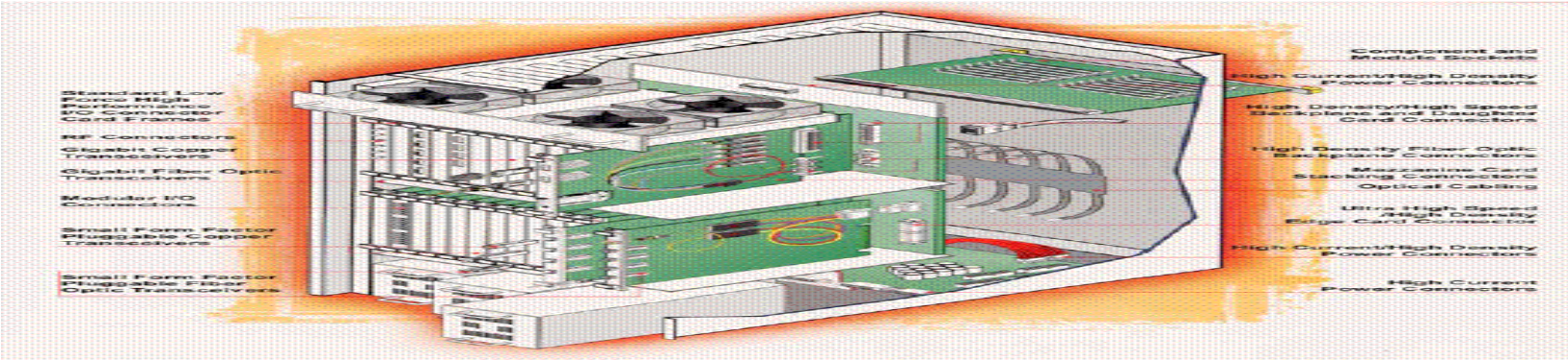
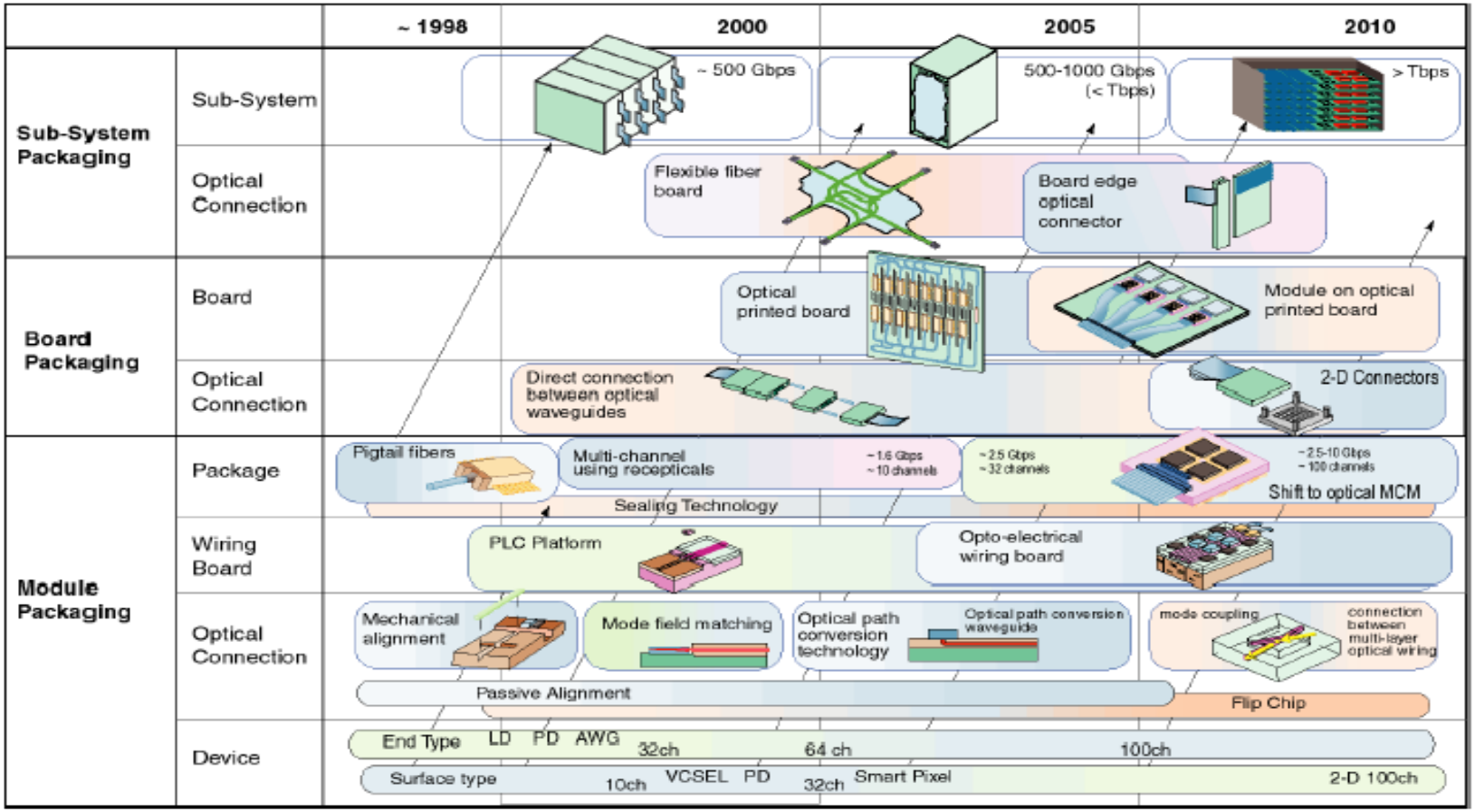
Generic Copper Backplane Bandwidth Technology Roadmap

		1 Gbps — 2.5 GBPS — 3.125 Gbps — 4.0 Gbps — 6.125 Gbps — 10 Gbps - 40Gbps					
PCB Technology	Materials	FR-4, Df = 0.020	PPO / CE, Df = 0.015-0.008	BT / APPE, Df = 0.010	PTFE, Df = 0.009 - 0.003	PTFE / Ceramic,	Df = 0.002 - 0.0009
	Processes	Standard processes	Backdrilling — Dual density drilling?				
	Transmission Line Design	Single transmission line, Length management	Differential pair, length, type (Surface microstrip, embedded microstrip, stripline, edge coupled, broadside coupled), location in stack				
	Via Design	Decrease PTH diameter, Remove non-functional pads, Increase anti-pad diameter (Clearance ring)					
	Connector Launch Design	Pad in via or PTH, micro vias, buried vias					
Connector Technology	Teradyne connectors	HDM	VHDM & VHDM L-series	VHDM-HSD	Gbk	GBx	
	ERNI connectors	ERmet	Ermet	Ermet ZD	ERmetZD	Ermet Zero XT	
	Tyco connectors	HM-ZD	Z-Pack HM-ZD MultiGig RT-1	Z-Pack HM-ZD	MultiGig RT-2	MultiGig RT-3	
	FCI	Metral 2000	AirMax VS Metral 4000	AirMax VS	AirMax VS	AirMax	
	Fujitsu	FCN-261Z00x			FCN260D		
	Winchester	Xcell				SIP-1000 I platform	
	Molex	Molex is a Teradyne licensee					
Receiver / Transmitter Signal Conditioning Chip Set	Taps required	None Required	One		Two	Multiple	
	Velio	GigaCore			GigaCore2		
Bus Architecture		Shared Bus ? Point to Point ? Multi point ? Sub type?					


Component and Module Sockets
High Current/High Density Power Connectors
Standard Low Force High Performance I/O Connector Card Frames
High Density/High Speed Backplane and Daughter Card Connectors
RF Connectors
Gigabit Copper Transceivers
High Density Fiber Optic Backplane Connectors
Gigabit Fiber Optic Transceivers
Mezzanine Card Stacking Connectors
Optical Cabling
Modular I/O Connectors
Ultra High Speed /High Density Edge Card Connector
Small Form Factor Pluggable Copper Transceivers
High Current/High Density Power Connectors
Small Form Factor Pluggable Fiber Optic Transceivers
High Current Power Connectors


Compact PCI Power High Performance I/O Connector Card Frames
RF Connectors
Gigabit Copper Transceivers
Gigabit Fiber Optic Transceivers
Module I/O Connectors
Small Form Factor Pluggable Copper Transceivers
Small Form Factor Pluggable Fiber Optic Transceivers
Compact PCI Module Sockets
High Current/High Density Power Connectors
High Density/High Speed Backplane and Daughter Card Connectors
High Density Fiber Optic Backplane Connectors
Mezzanine Card Stacking Connectors Optical Cabling
Ultra High Speed High Density Fiber Card Connectors
High Current/High Density Power Connectors
High Current Power Connectors



Source: Japan Institute of Electronics Packaging & SEMI

- **Electrical “White Box” #1:**
- ATCA/PICMG3.0 backplane, single shelf system
- 10G per link, serial, fixed physical path
- XAUI (4 x 3.125G differential pairs,
- **Optical “Black Box” #1:**
- Identical to “White Box” #1, except optical links will replace the high speed electrical channels
- Fiber based, multi-mode
- 10G optical transceivers XFP
- Note: Optical implementation is not defined in the ATCA Spec
- **Optical Black Box #2:**
- 40G implementation of BB#1,
- Fiber based
- **Optical Black Box #3:**
- Fiber Flexplane.
- **Optical Black Box #4:**
- Organic embedded waveguide in backplane