

The End of EDA Toward System Design

Raúl Camposano

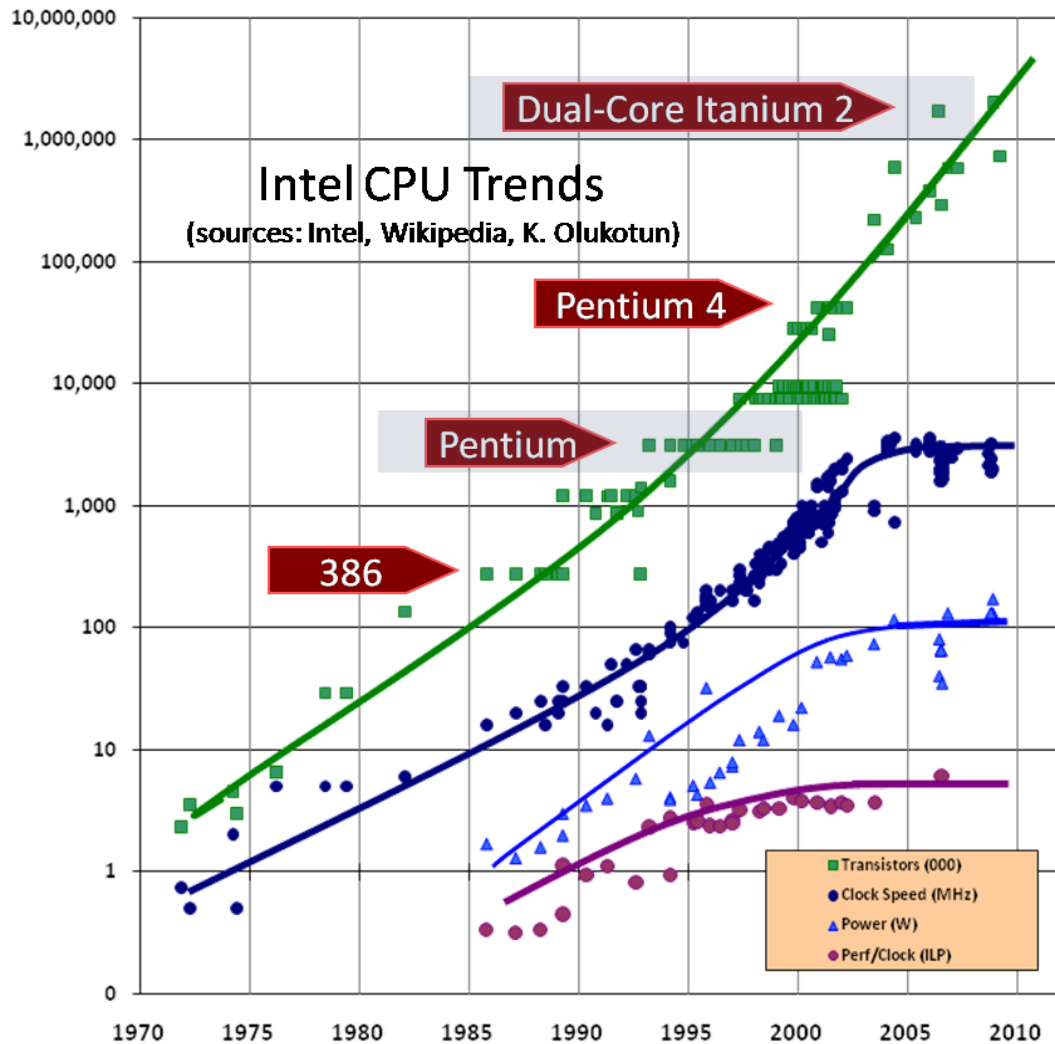
November, 2014

The End of EDA

What we may be witnessing is not just the commoditization of electronics, or the passing of a particular period of electronic design / EDA, but the end of electronic design / EDA as such: that is, the end point of a technological evolution and the universalization of the use of electronics as the final form of intelligence in everything ^[1].

[1] Paraphrasing Francis Fukuyama's essay "The End of History?" The National Interest, 1989

The Free Lunch is (largely...) Over



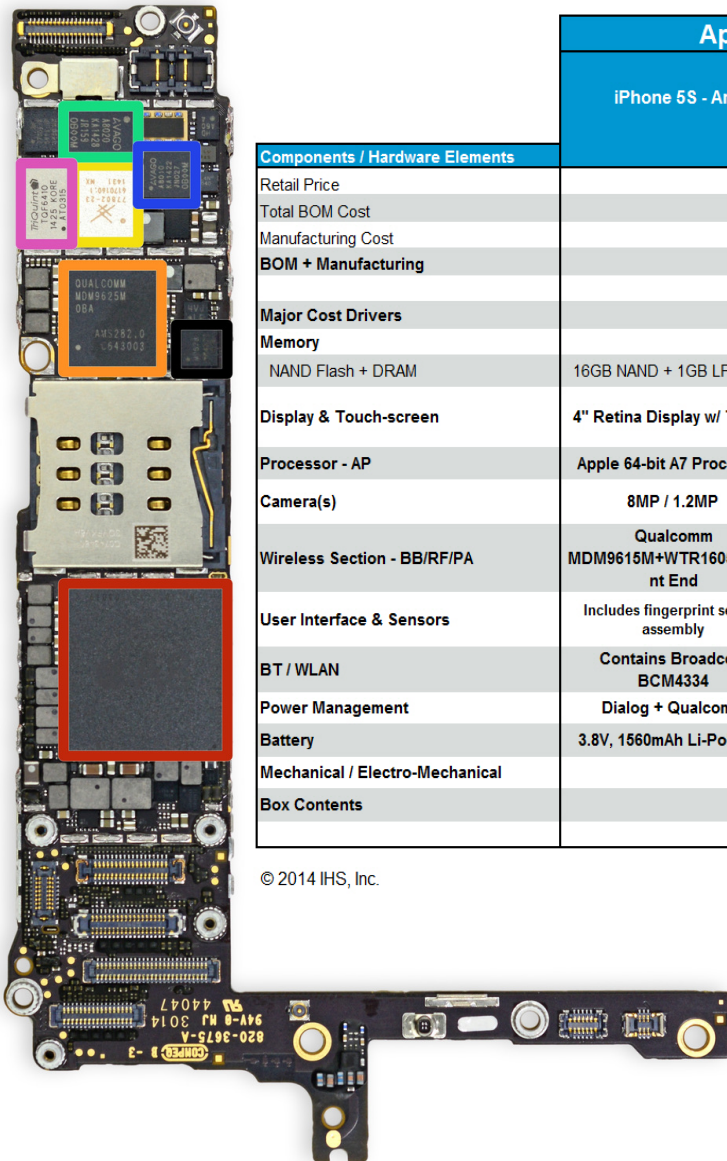
2014
Fastest i7 3.6/4.0GHz, 150W
Fastest Xeon 3.4/3.7GHz, 155W

Intel CPU Introductions (graph updated August 2009; article text original from December 2004)

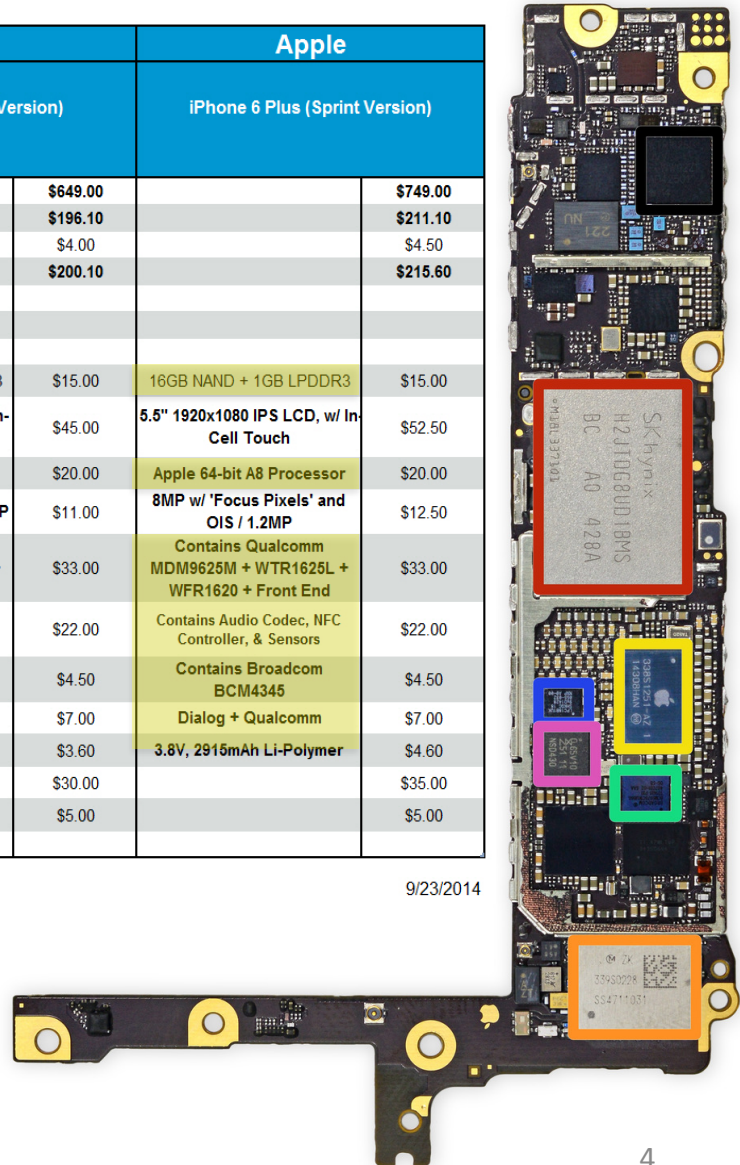
Source: The Free Lunch Is Over: A Fundamental Turn Toward Concurrency in Software



Preliminary Apple iPhone 6 & 6 Plus Teardown Estimates



Components / Hardware Elements	Apple		Apple		Apple	
	iPhone 5S - Analysis Oct 2013		iPhone 6 (Sprint Version)		iPhone 6 Plus (Sprint Version)	
Retail Price		\$649.00		\$649.00		\$749.00
Total BOM Cost		\$190.85		\$196.10		\$211.10
Manufacturing Cost		\$4.00		\$4.00		\$4.50
BOM + Manufacturing		\$194.85		\$200.10		\$215.60
Major Cost Drivers						
Memory						
NAND Flash + DRAM	16GB NAND + 1GB LPDDR3	\$18.30	16GB NAND + 1GB LPDDR3	\$15.00	16GB NAND + 1GB LPDDR3	\$15.00
Display & Touch-screen						
4" Retina Display w/ Touch	\$41.00		4.7" 1334x750 IPS LCD, w/ In-Cell Touch	\$45.00	5.5" 1920x1080 IPS LCD, w/ In-Cell Touch	\$52.50
Processor - AP						
Apple 64-bit A7 Processor	\$17.00		Apple 64-bit A8 Processor	\$20.00	Apple 64-bit A8 Processor	\$20.00
Camera(s)						
8MP / 1.2MP	\$14.80		8MP w/ 'Focus Pixels' / 1.2MP	\$11.00	8MP w/ 'Focus Pixels' and OIS / 1.2MP	\$12.50
Wireless Section - BB/RF/PA						
Qualcomm MDM9615M+WTR1605L+Front End	\$28.50		Contains Qualcomm MDM9625M + WTR1625L + WFR1620 + Front End	\$33.00	Contains Qualcomm MDM9625M + WTR1625L + WFR1620 + Front End	\$33.00
User Interface & Sensors						
Includes fingerprint sensor assembly	\$22.00		Contains Audio Codec, NFC Controller, & Sensors	\$22.00	Contains Audio Codec, NFC Controller, & Sensors	\$22.00
BT / WLAN						
Contains Broadcom BCM4334	\$4.50		Contains Broadcom BCM4345	\$4.50	Contains Broadcom BCM4345	\$4.50
Power Management						
Dialog + Qualcomm	\$6.25		Dialog + Qualcomm	\$7.00	Dialog + Qualcomm	\$7.00
Battery						
3.8V, 1560mAh Li-Polymer	\$3.50		3.8V, 1810mAh Li-Polymer	\$3.60	3.8V, 2915mAh Li-Polymer	\$4.60
Mechanical / Electro-Mechanical						
	\$30.00			\$30.00		\$35.00
Box Contents						
	\$5.00			\$5.00		\$5.00



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9/23/2014

Electronics \$ 91

Other \$120

SW >\$42 per Device



Sept. 2014—1,300,000

June 2014 - 1,200,000

October 2013 - 1,000,000 (475,000 native to iPad)

Apple Press Info

Press Releases

Product Images & Info

App Store Sales Top \$10 Billion in 2013

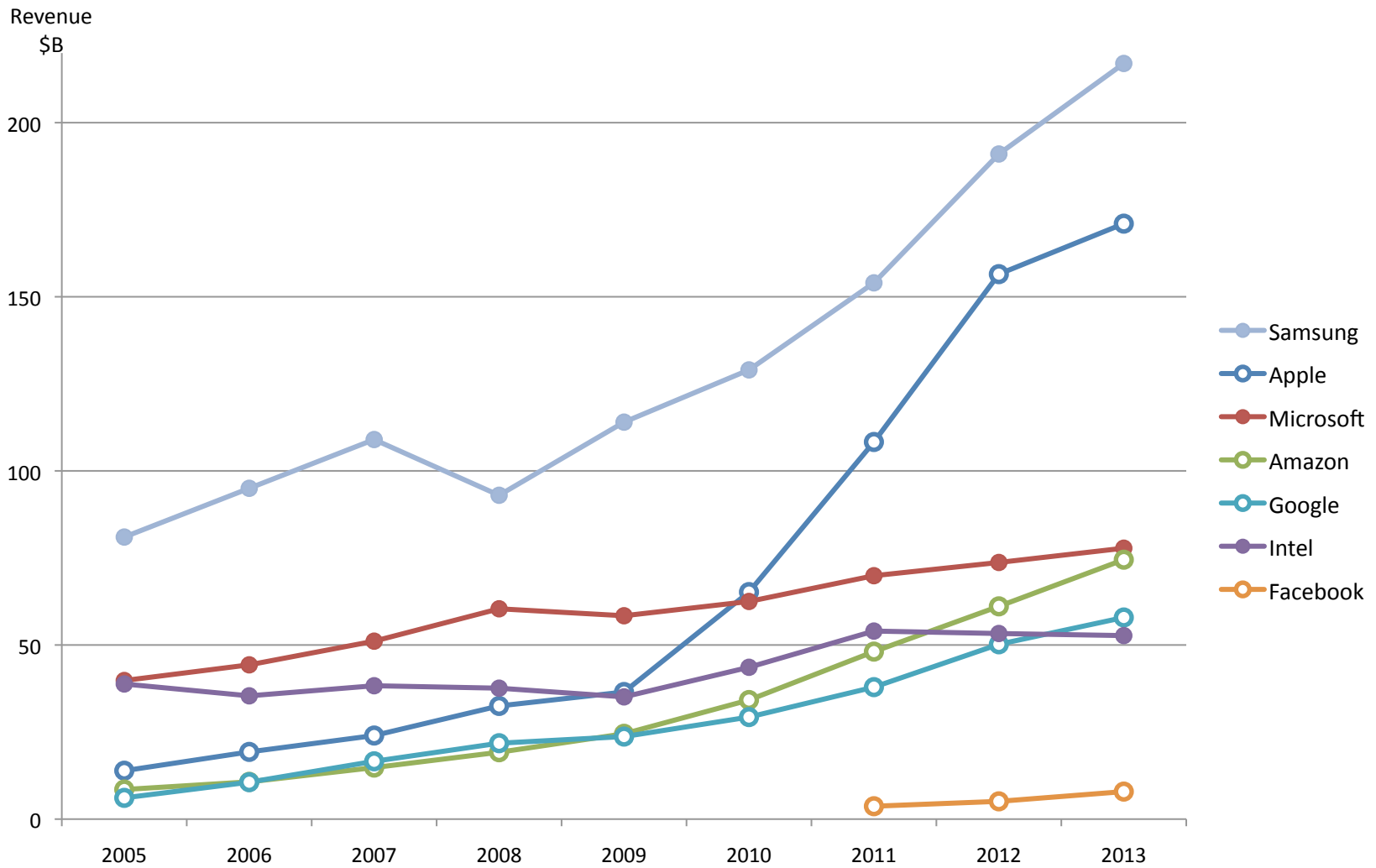
Record-Breaking December with Over \$1 Billion in Sales

CUPERTINO, California—January 7, 2014—Apple® today announced that customers spent over \$10 billion on the App Store™ in 2013, including over \$1 billion in December alone. App Store customers downloaded almost three billion apps in December making it the most successful month in App Store history. Apple's incredible developers have now earned \$15 billion on the App Store.

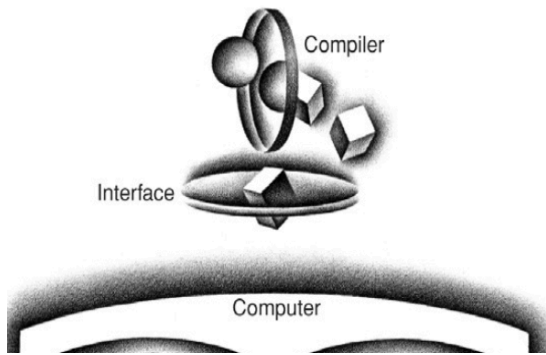
CNET > Tech Industry > Apple's 2013 by the numbers: 150M iPhones, 71M iPads

**Apple's 2013 by the numbers:
150M iPhones. 71M iPads
16.5 million Macs sold**

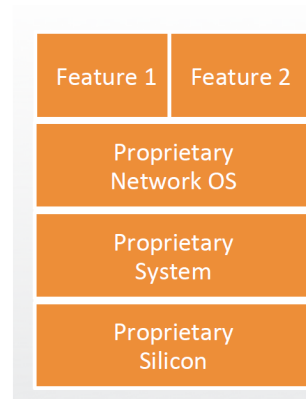
Systems Companies Capturing Value



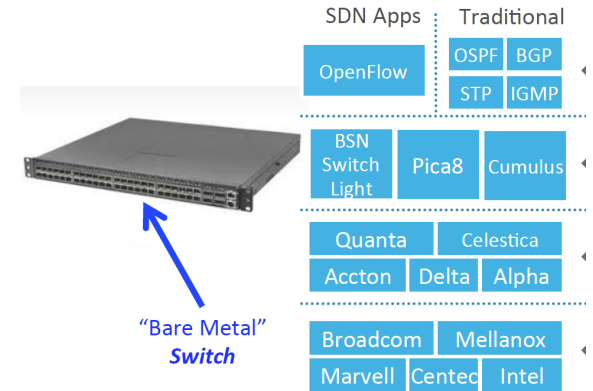
HW vs. SW



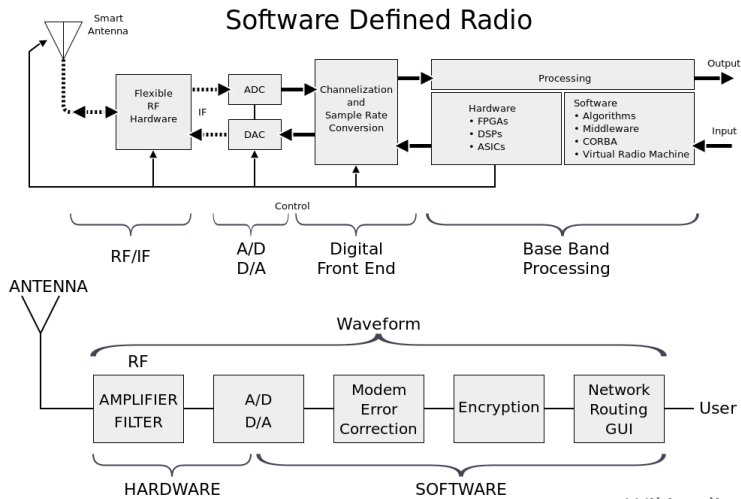
Patterson / Hennessy – The HW / SW Interface



No vertical integration – just like how we buy our servers

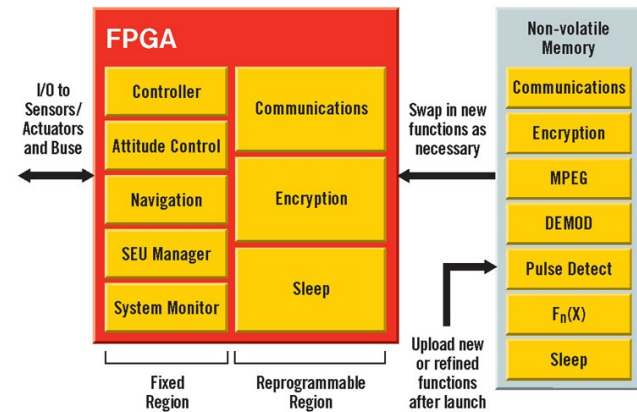


Big Switch Networks



Wikipedia

Software-Defined Satellite

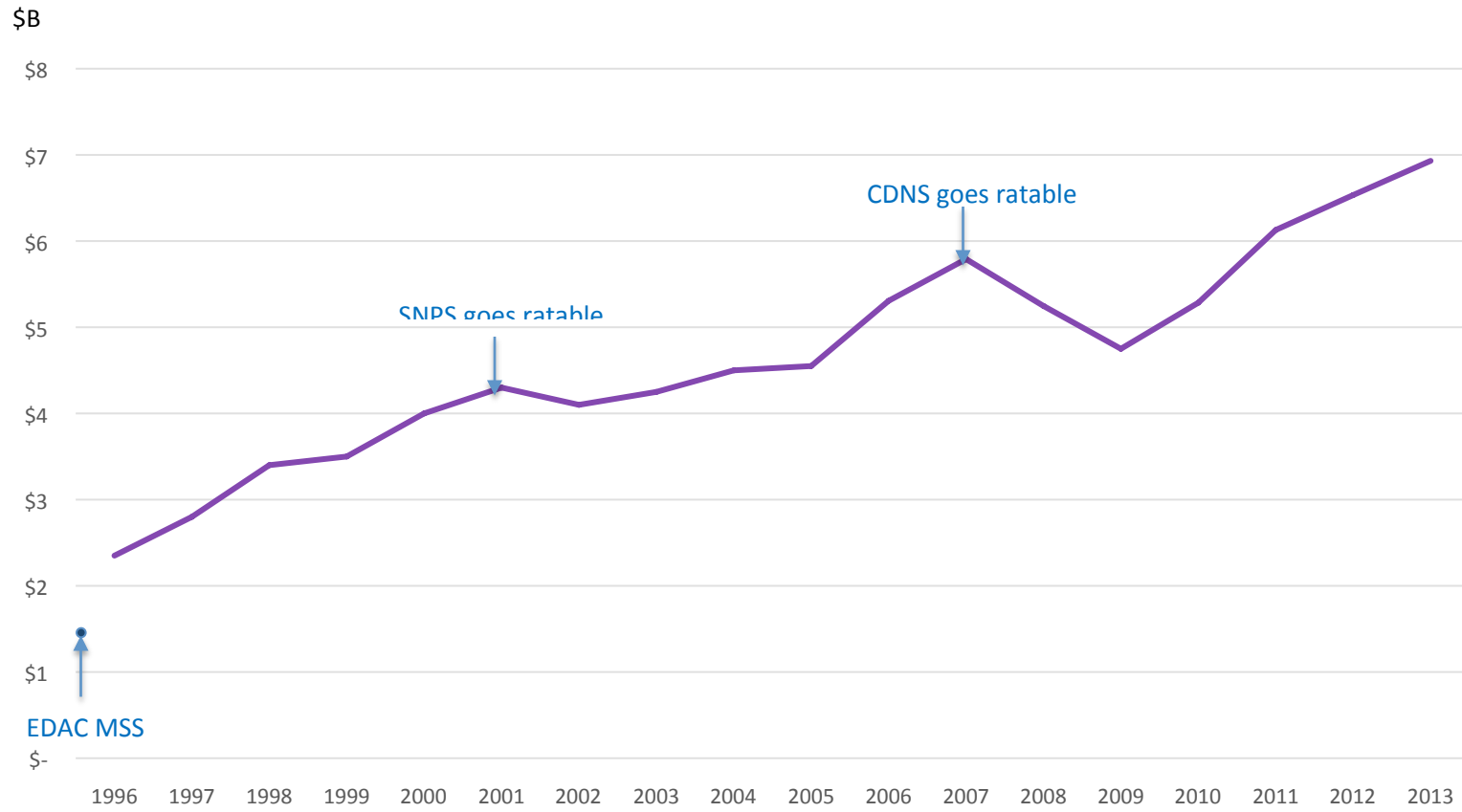


Xilinx

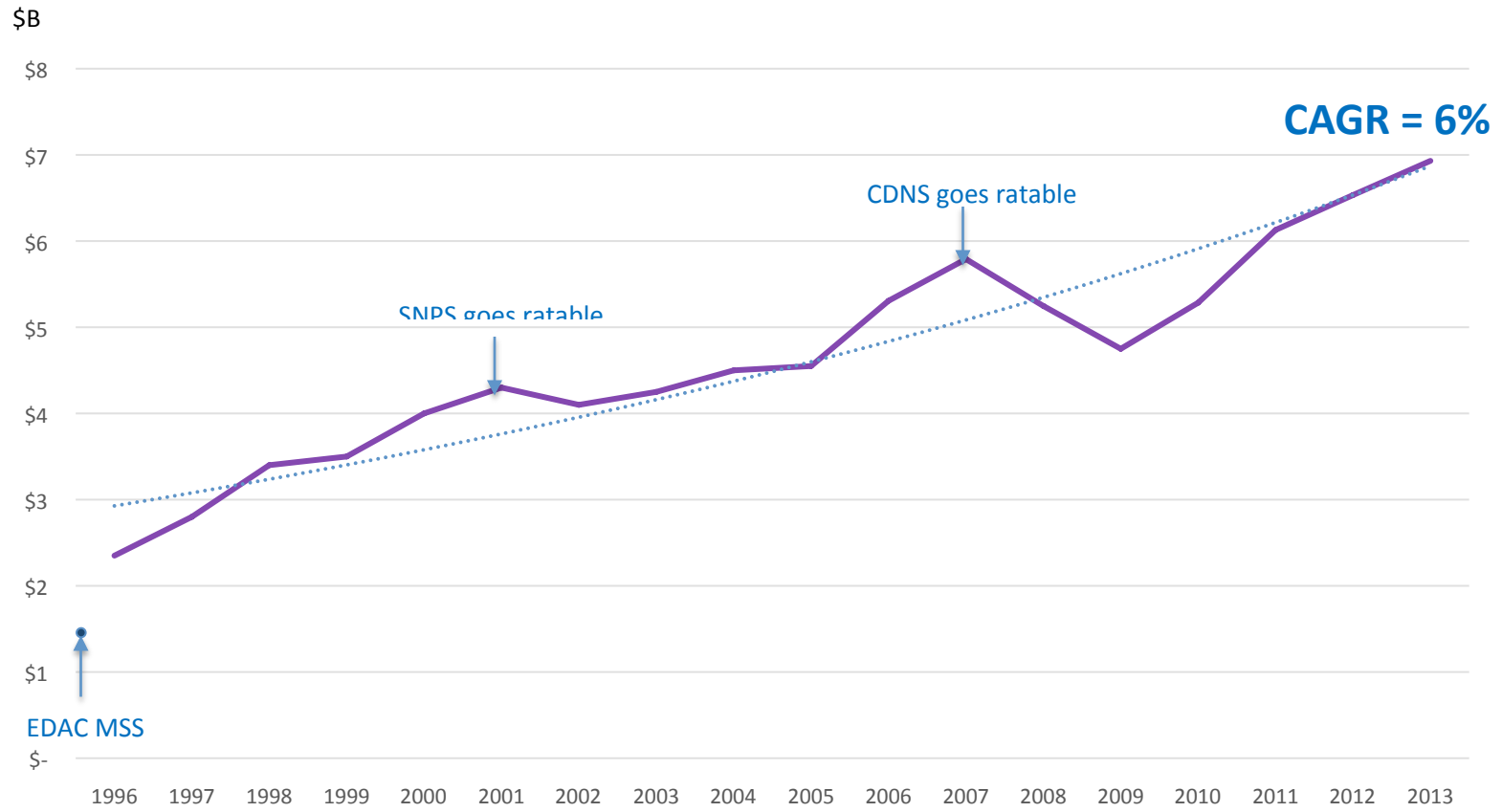
EDA also Evolved into (mostly) SW

- Gen 1 1960-1980
 - CALMA, Computervision, Applicon, Zuken
 - Customized Workstation + Artwork Editing SW
- DMV 1981-1988
 - Daisy, Mentor, Valid
 - Still substantial focus on Hardware sales
- Gen 3 1988
 - Cadence (88 ECAD +SDA), Mentor, Synopsys (Optimal Solutions 86)
 - Software

EDA



EDA

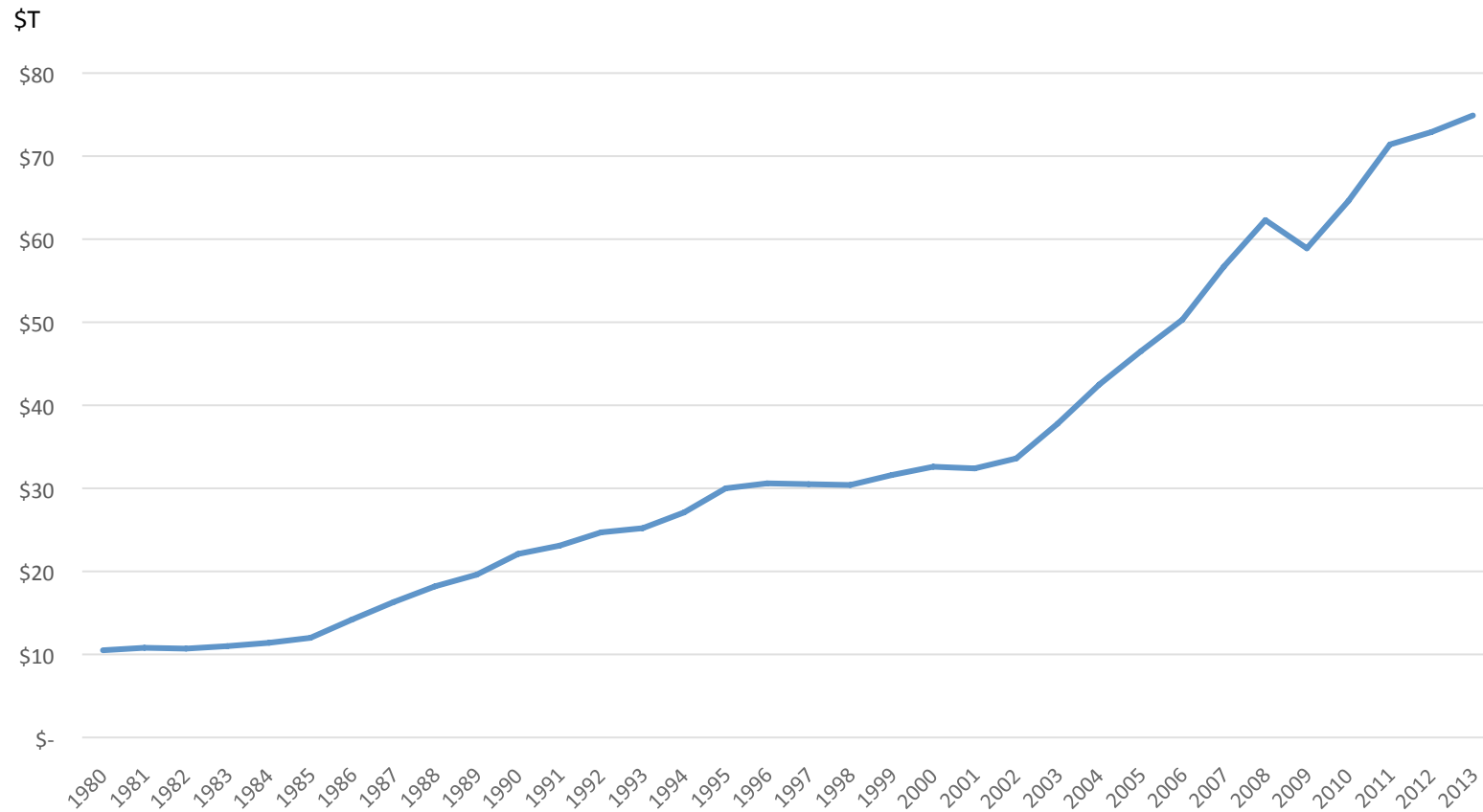


Buffet's Valuation Indicator



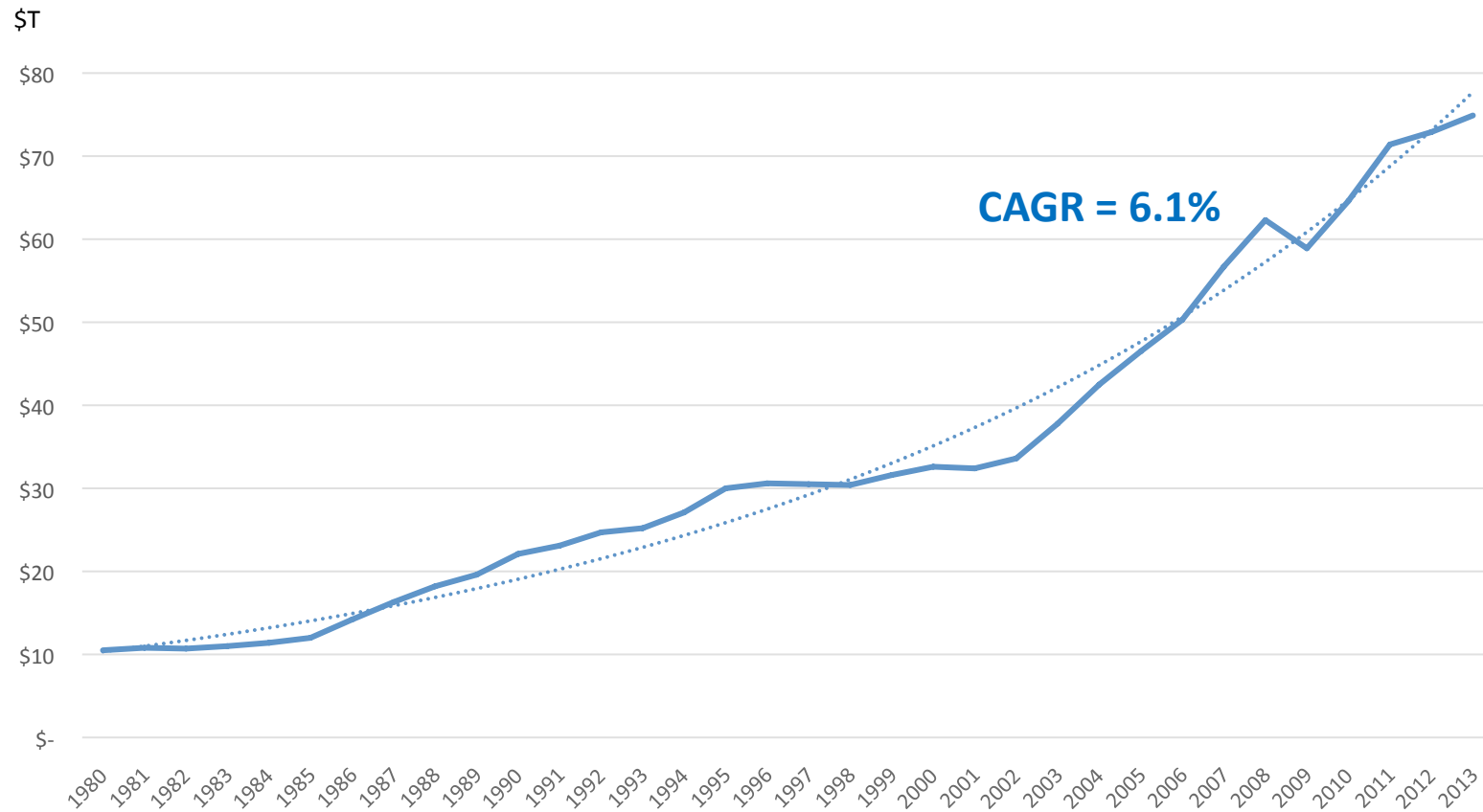
Source: Board of Governors of the Federal Reserve System and U.S. Bureau of Economic Analysis

Gross World Product



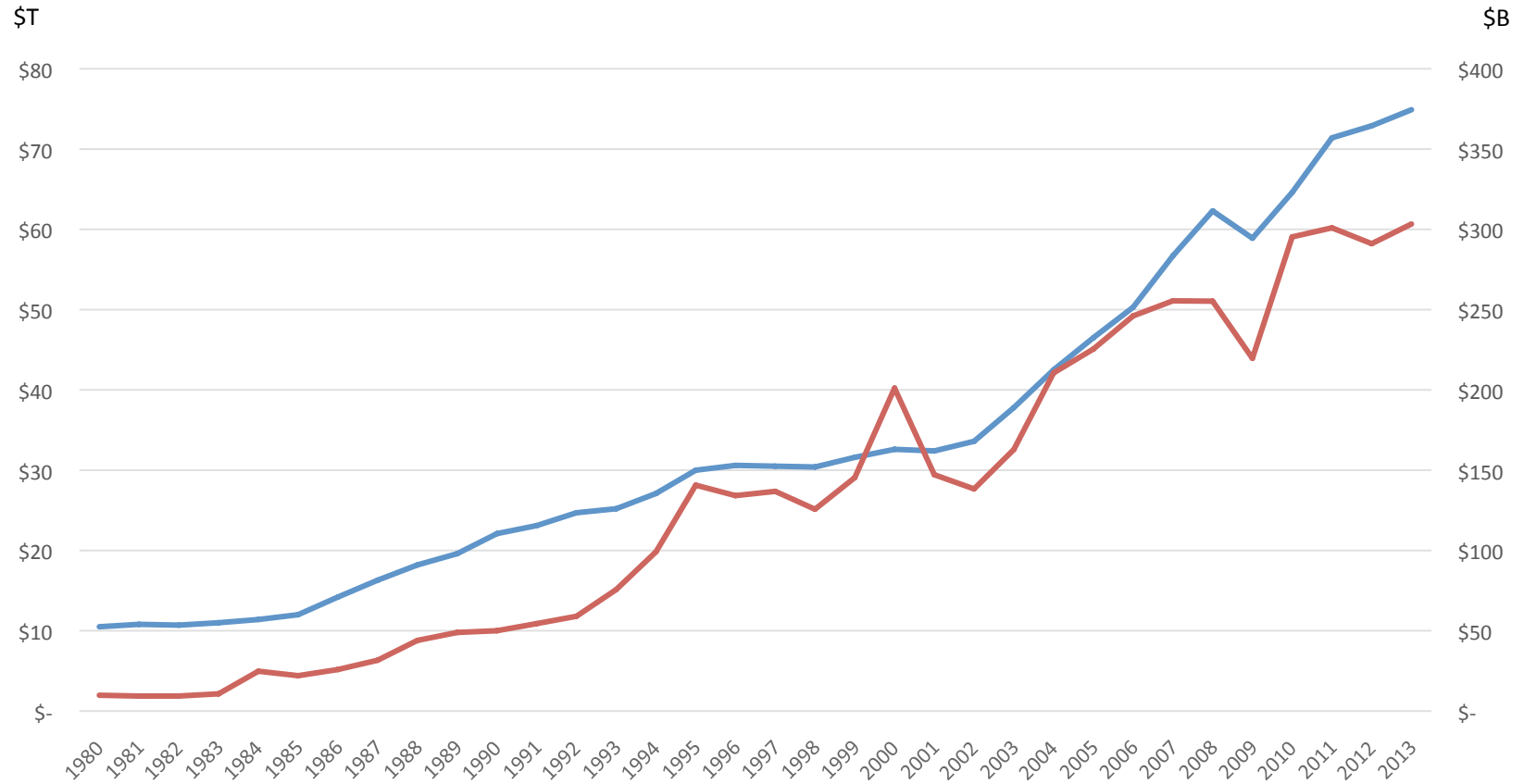
Source: World Bank

Gross World Product



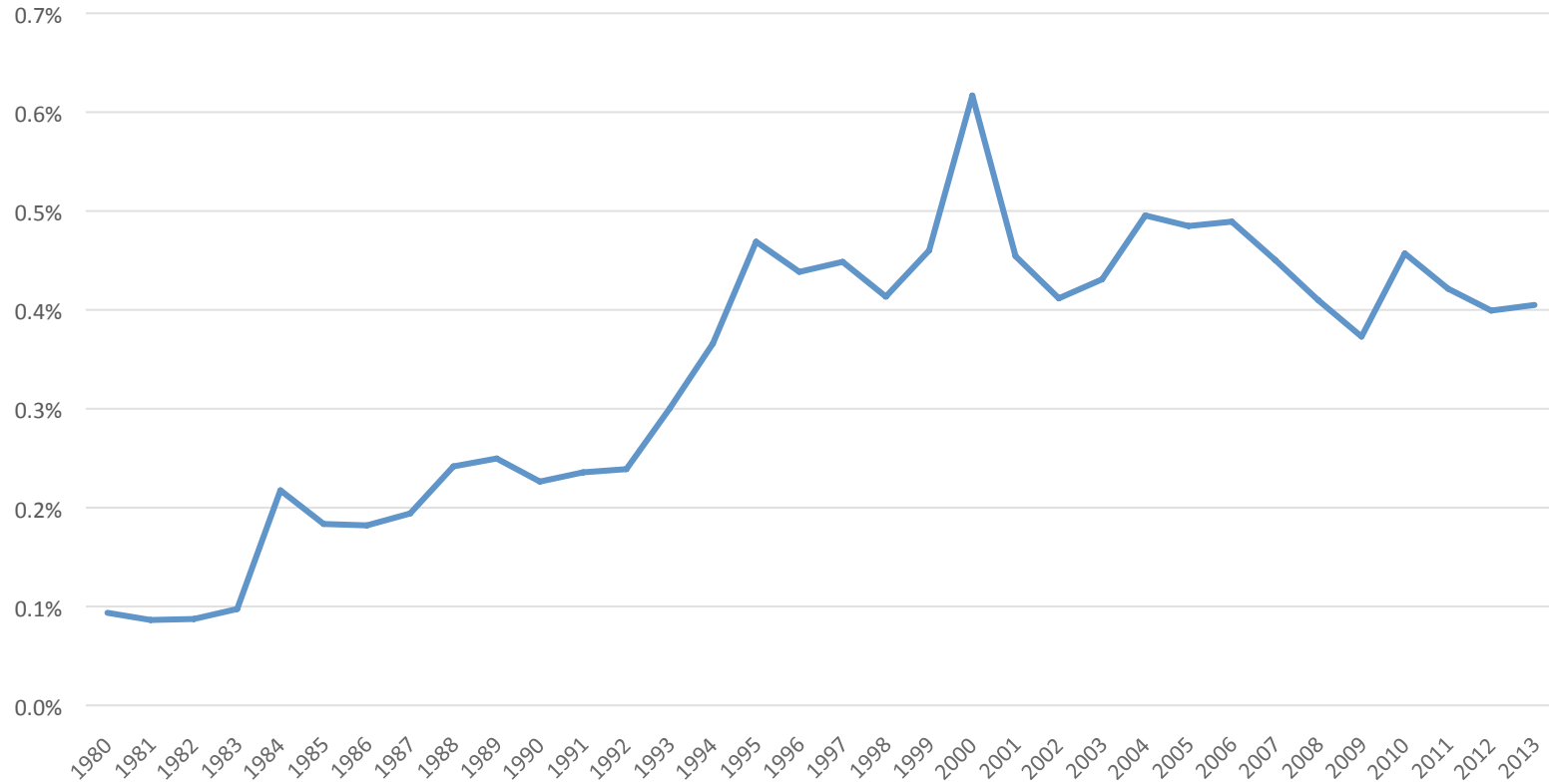
Source: World Bank

Semiconductors

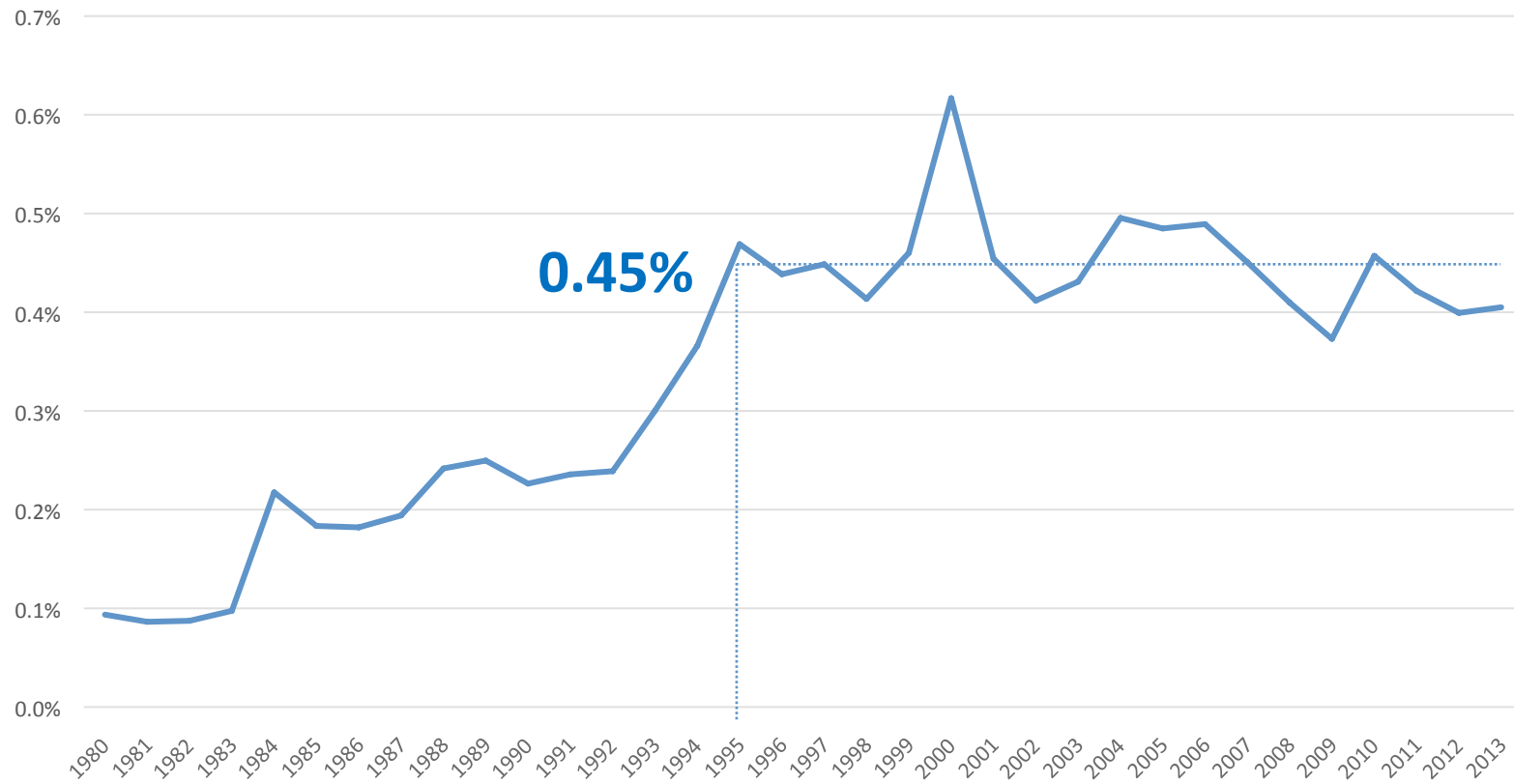


Source: SIA

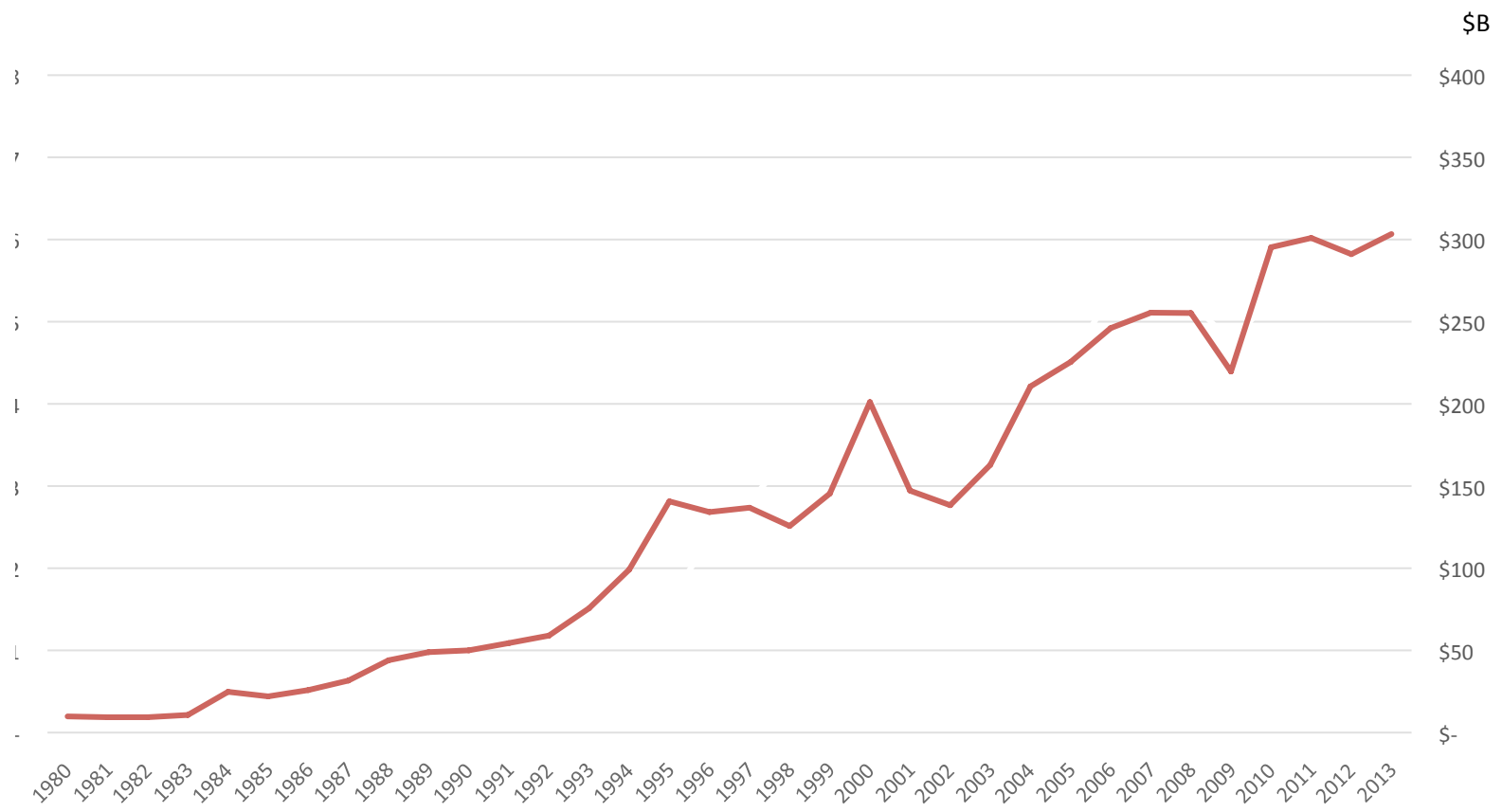
Semi / WDC



Semi / WDC

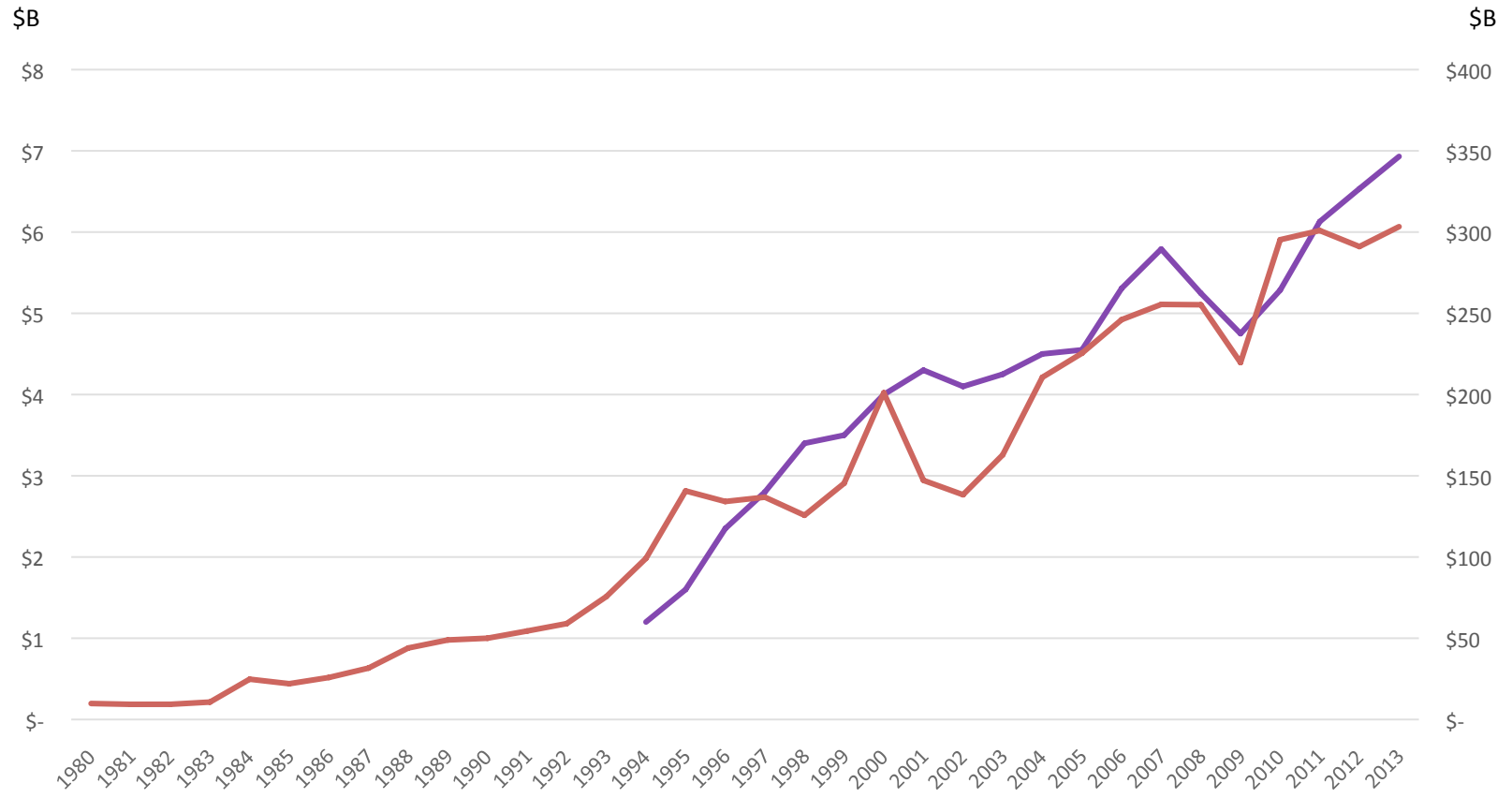


EDA



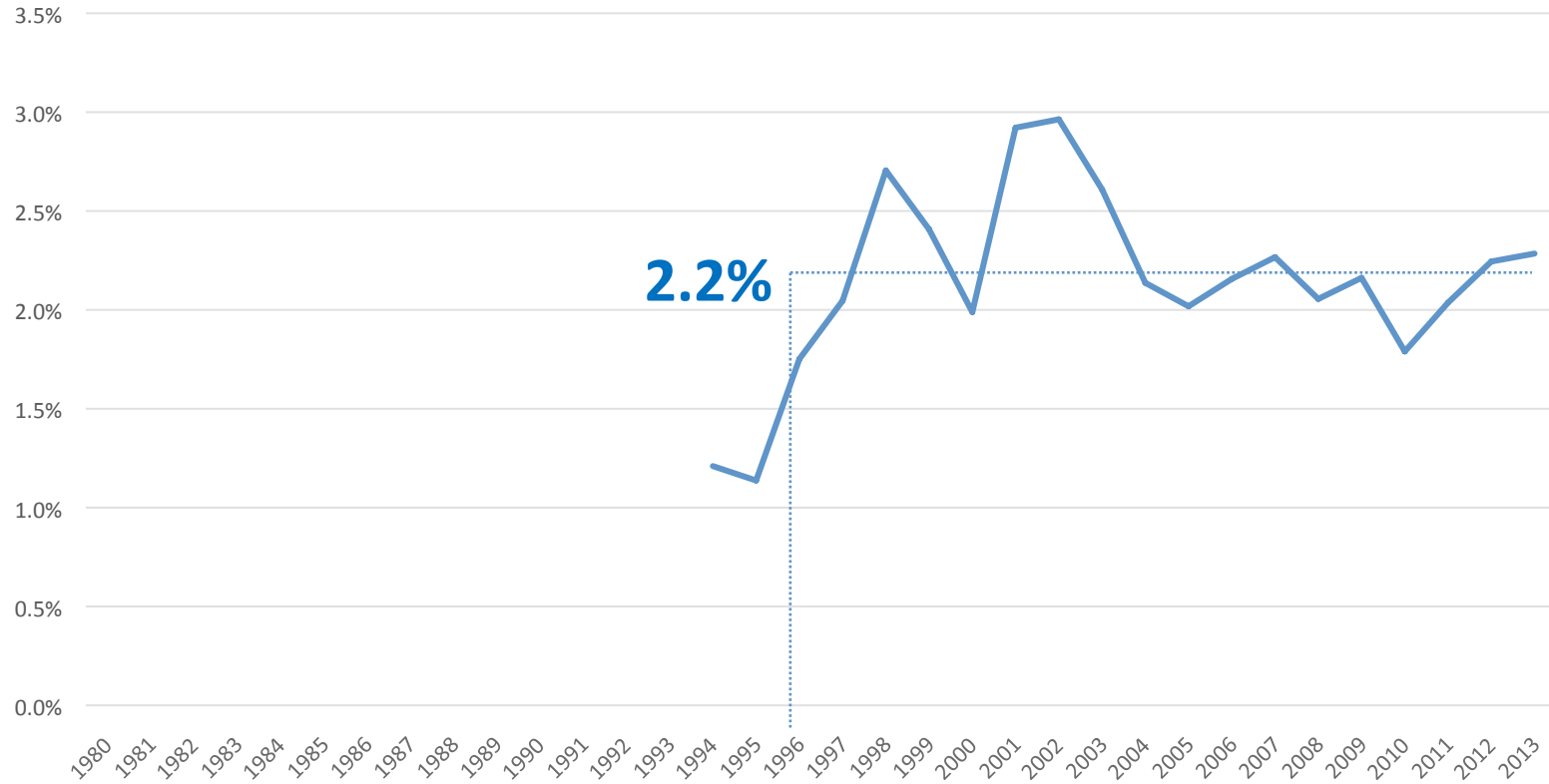
Source: EDAC

EDA



Source: EDAC

EDA / Semi



Traditional EDA Revenue Is Stagnant

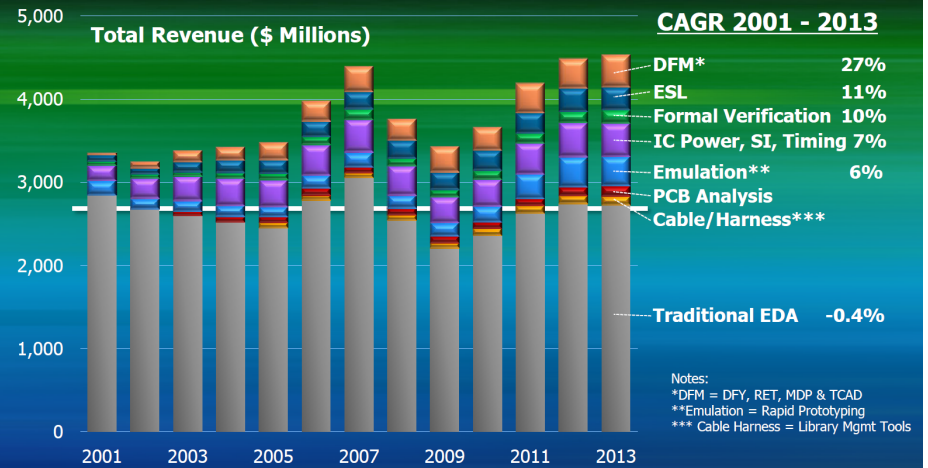


Source: EDAC Market Statistics Services and Mentor Graphics Analysis & Estimate (2013)

8 WCR, DAC June 2014

Mentor
Graphics

New Methodologies Drive EDA Revenue Growth



Notes:
 *DFM = DFY, RET, MDP & TCAD
 **Emulation = Rapid Prototyping
 *** Cable Harness = Library Mgmt Tools

Source: EDAC Market Statistics Services and Mentor Graphics Analysis & Estimate (2013)

9 WCR, DAC June 2014

Mentor
Graphics

6%



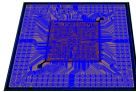
Software

SDK, IDE, compiler,
debugger, build,
source control...



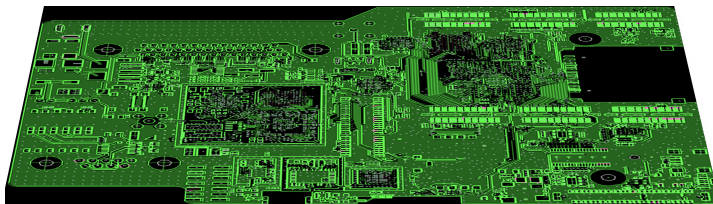
Die

EDA



Package

MCM, EM,
Thermal, Mechanical



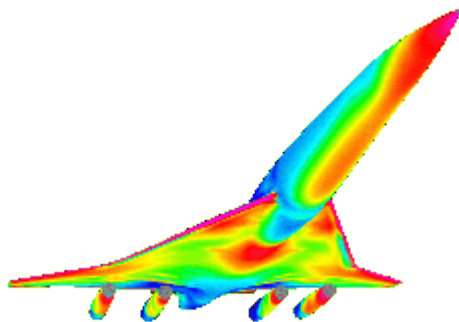
Board
Connector

PCB, EM,
Thermal, Mechanical



Sub-System

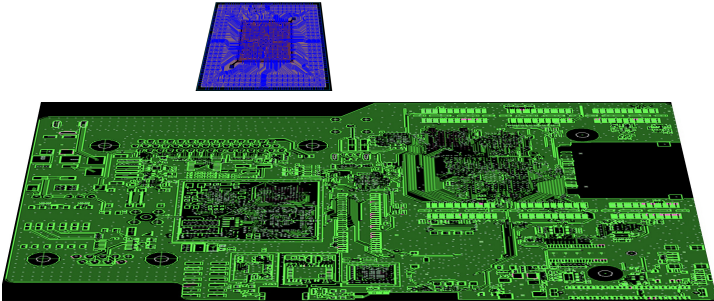
Mechanical,
Thermal, EM



System

Mechanical, CFD,
Thermal, EM

Ergonomics, sustainability, CO₂ emissions ...



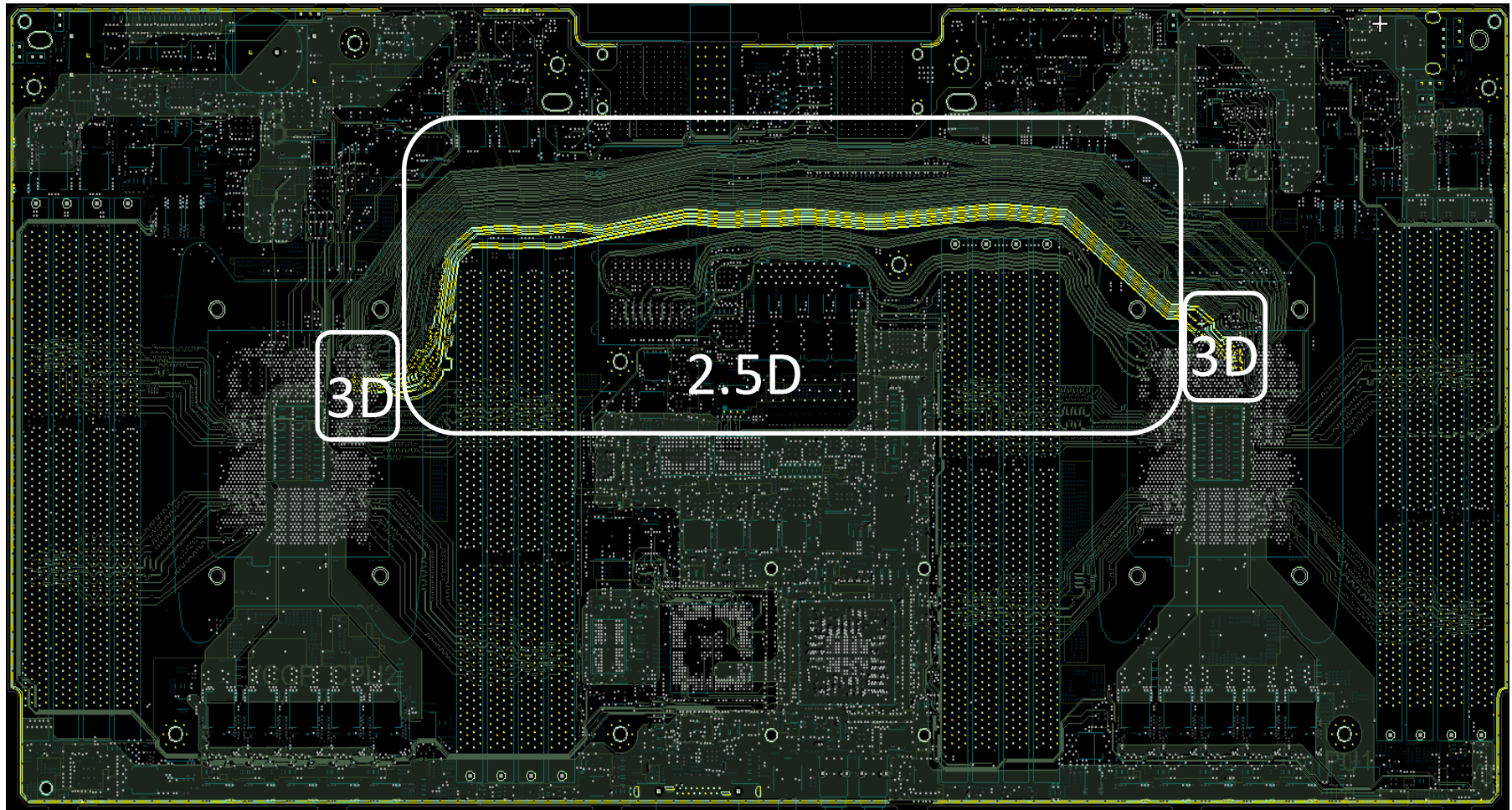
Package

MCM, EM

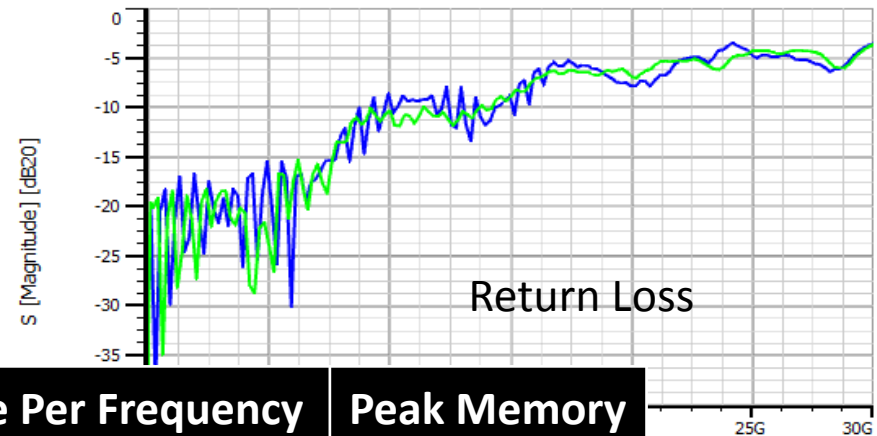
Board
Connector

PCB, EM

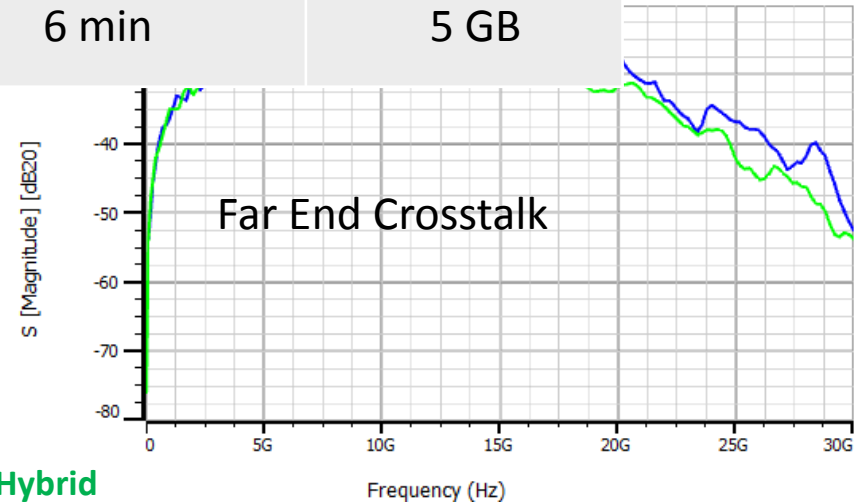
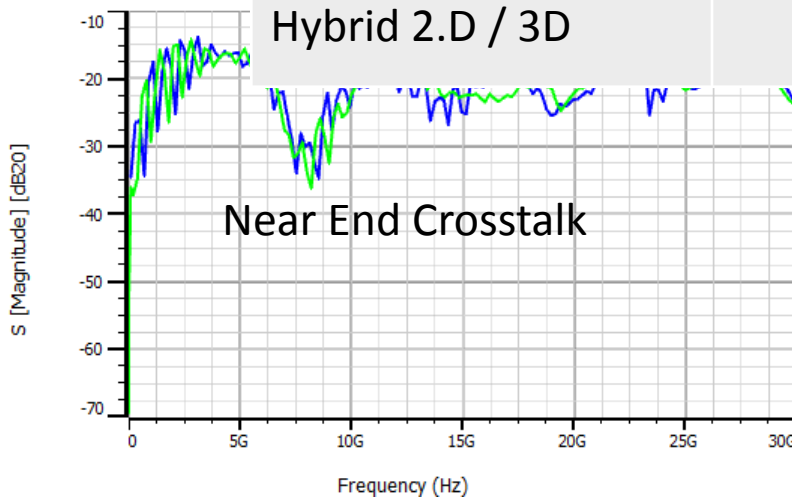
Hybrid Electromagnetic Simulation



Hybrid Mode

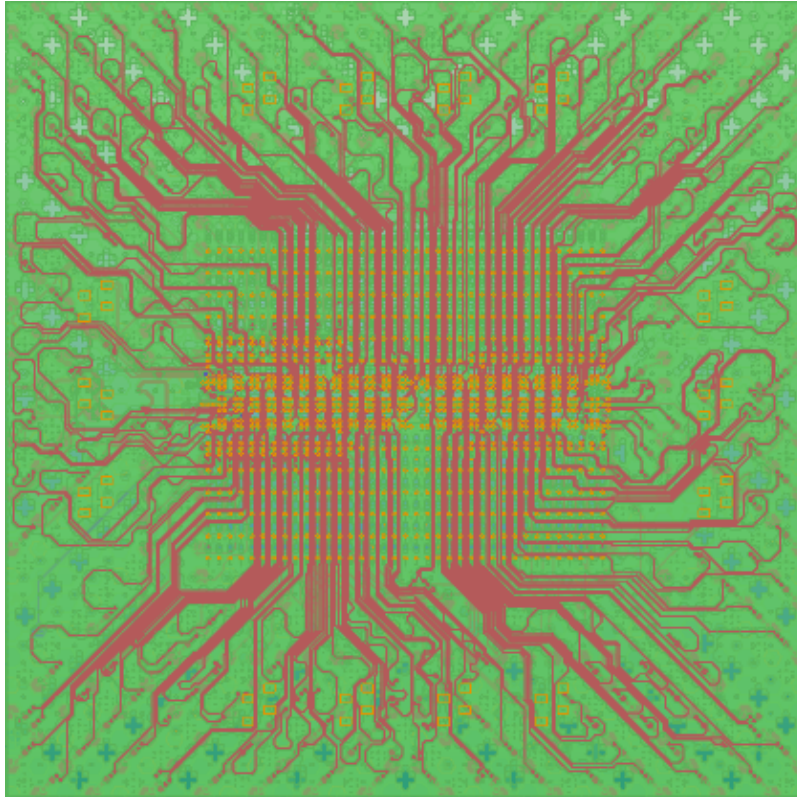


Method	Time Per Frequency	Peak Memory
Full 3D	61 min	50 GB
Hybrid 2.D / 3D	6 min	5 GB



Hybrid
3D

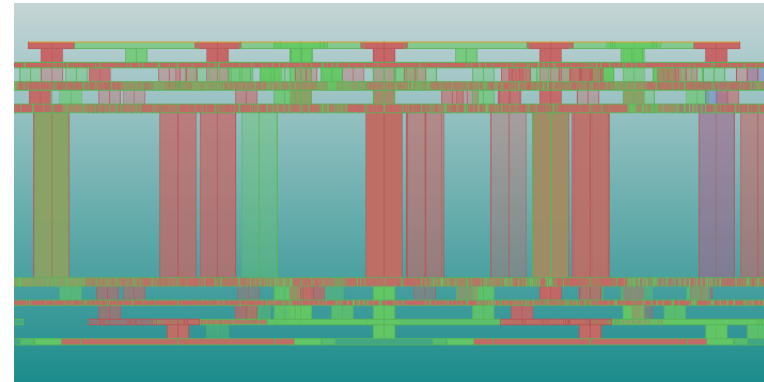
Parallelism in EM Simulation



Layers: 8 Nets: 320 Ports: 1000

IBM Challenge Problem

- Capacitance, Inductance of all nets
- S-parameter extraction of 20 nets



Layer Name	Layer Type	Cond. Material	Diel. Material	Thickness	Elevation
1 TOP	CONDUCTOR	COPPER	AIR	0.629921	28.818851
2 DIEEL_1	DIELECTRIC	COPPER	ABF GX13	1.29921	28.18893
3 FC3	CONDUCTOR	COPPER	ABF GX13	0.511811	26.88972
4 DIEEL_2	DIELECTRIC	COPPER	ABF GX13	1.29921	26.377909
5 FC2	CONDUCTOR	COPPER	ABF GX13	0.826772	25.078699
6 DIEEL_3	DIELECTRIC	COPPER	ABF GX13	1.29921	24.251927
7 FC1	CONDUCTOR	COPPER	ABF GX13	0.826772	22.952717
8 DIEEL_4	DIELECTRIC	COPPER	BT 679FG	15.748	22.125945
9 BC1	CONDUCTOR	COPPER	BT 679FG	0.826772	6.377945
10 DIEEL_5	DIELECTRIC	COPPER	ABF GX13	1.29921	5.551173
11 BC2	CONDUCTOR	COPPER	ABF GX13	0.511811	4.251963
12 DIEEL_6	DIELECTRIC	COPPER	ABF GX13	1.29921	3.740152
13 BC3	CONDUCTOR	COPPER	ABF GX13	0.511811	2.440942
14 DIEEL_7	DIELECTRIC	COPPER	ABF GX13	1.29921	1.929131
15 BOTTOM	CONDUCTOR	COPPER	ABF GX13	0.629921	0.629921

Capacitance Extraction of All Nets

Computation	Time	Speedup
MS&S 8 cores	235 min	6x
RHS 80 machines	7.3 min	32x
Test Case upload	0.7 min	
Result download	1.0 min	

Peak Memory: 5.5 GB

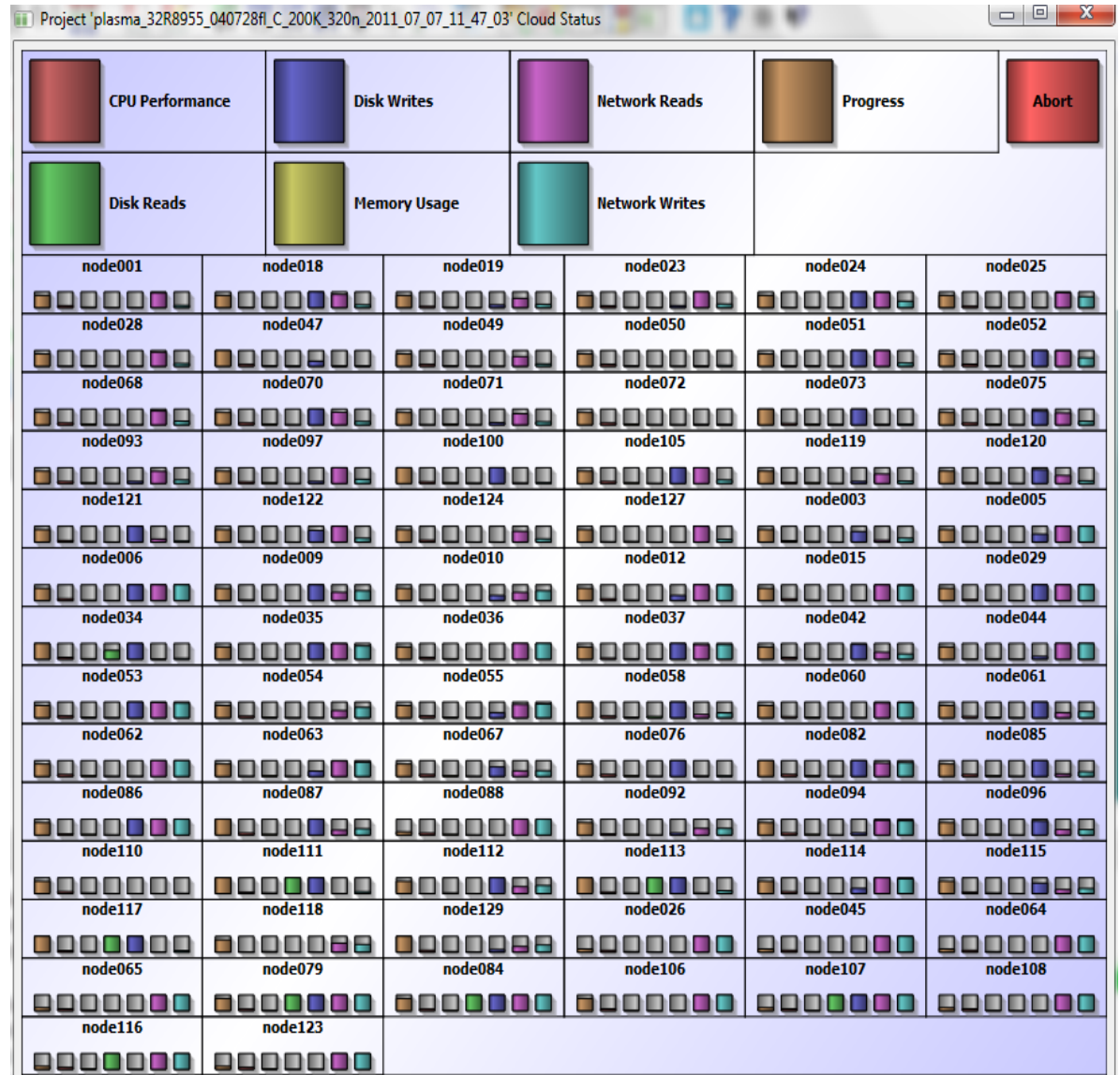
RHS

Setup time = 1.8 min (serial)

$$p = (235 - 1.8) / 235 = 0.99234$$

$$\text{Max Speedup}_{N=80} = \frac{1}{(1-p) + \frac{p}{n}} = 50x$$

$$\text{Max Speedup}_{n=\infty} = \frac{1}{(1-p) + \frac{p}{n}} = 131x$$



Inductance Extraction of All Ports

Computation	Time	Speedup
MS&S 8 cores	2741 min	6x
RHS 125 machines	50 min	55x
Test Case upload	1.0 min	
Result download	3.0 min	

Peak Memory: 14 GB

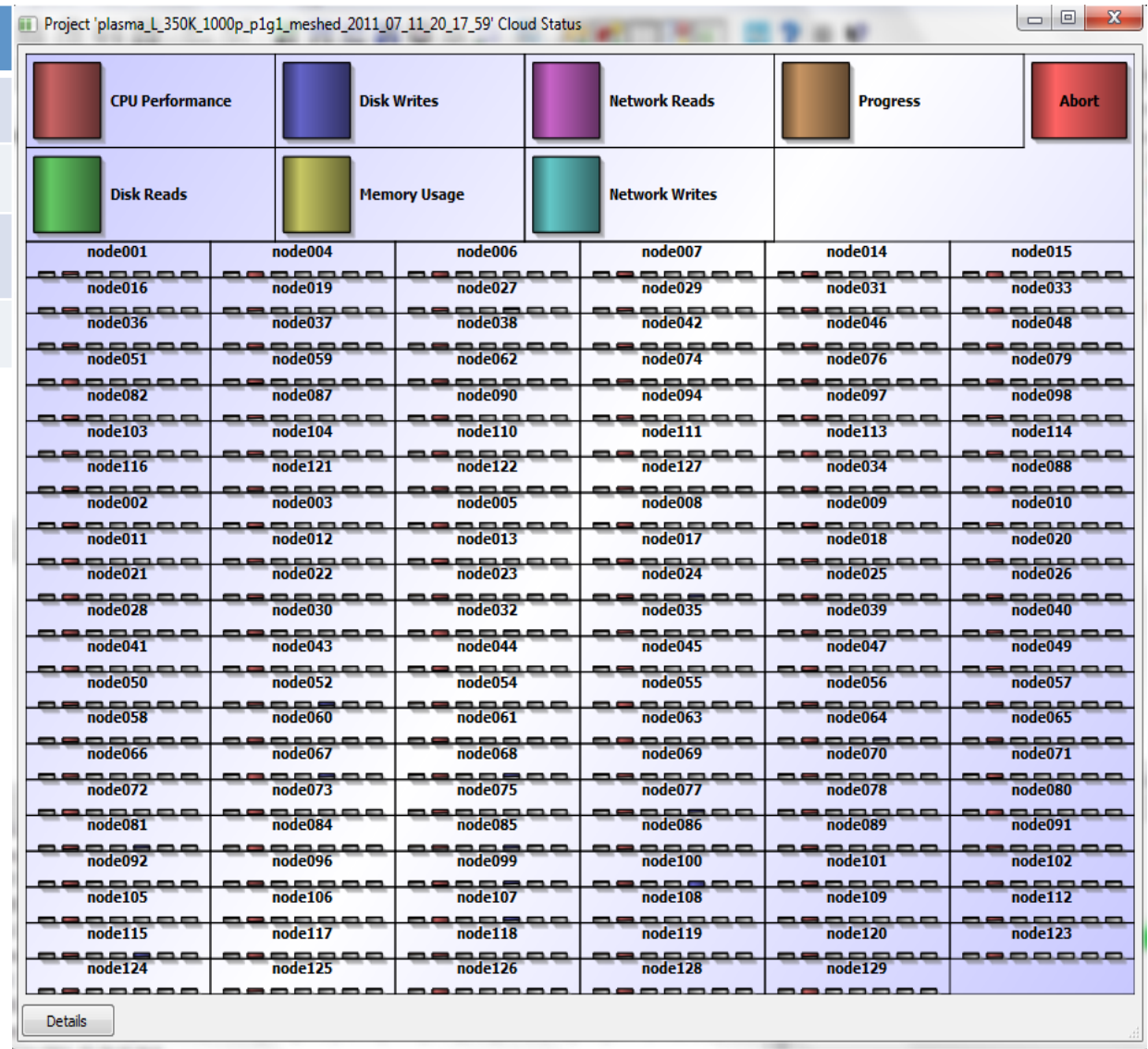
RHS

Setup time: = 28 min (serial)

$$p = (2741 - 28) / 2741 = 0.98978$$

$$\text{Max Speedup}_{n=125} = \frac{1}{(1-p) + \frac{p}{n}} = 55x$$

$$\text{Max Speedup}_{n=\infty} = \frac{1}{(1-p) + \frac{p}{n}} = 98x$$



S-Parameters

Computation	Time	Speedup
MS&S 8 cores	5954 min	6x
RHS 5 machines Freq 25x5 machines	70 min	3.4x 25x
Test Case upload	1.0 min	
Result download	5.0 min	

Peak Memory: 11 GB

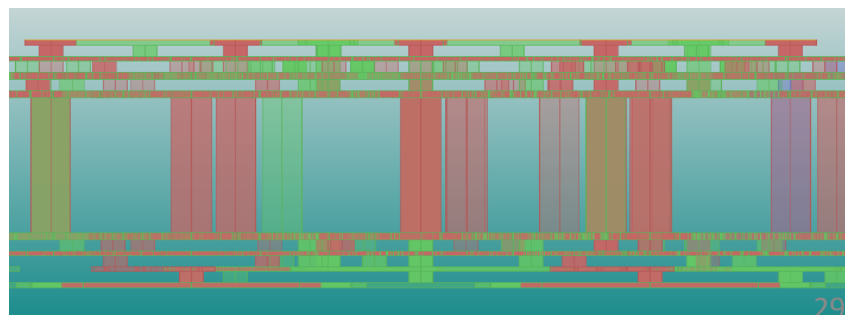
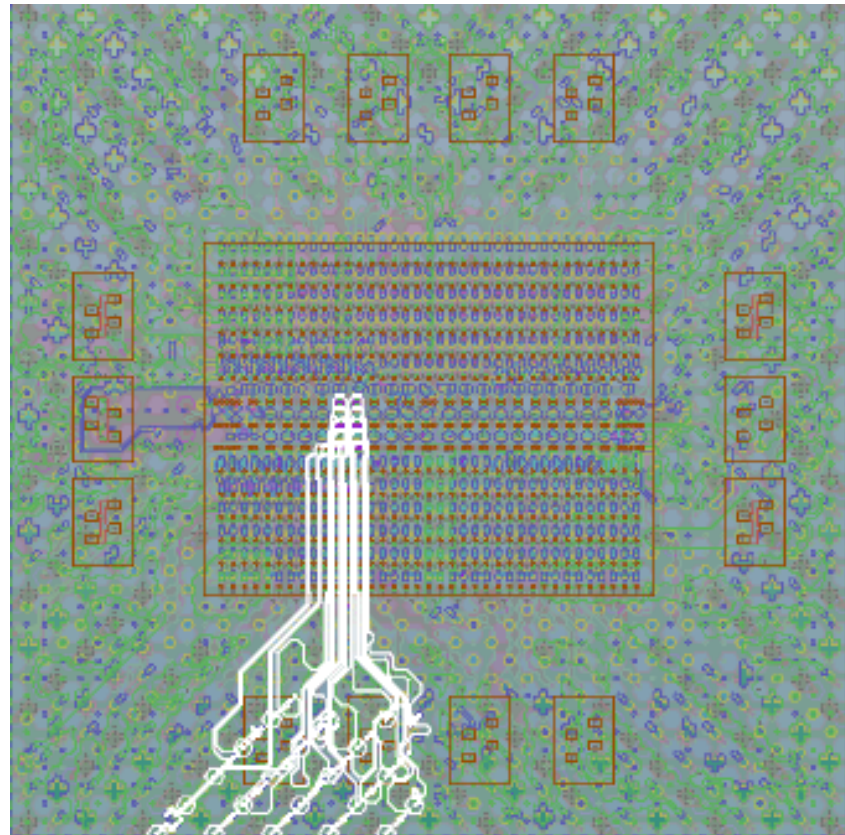
RHS

Setup time = 11.5 min (serial)

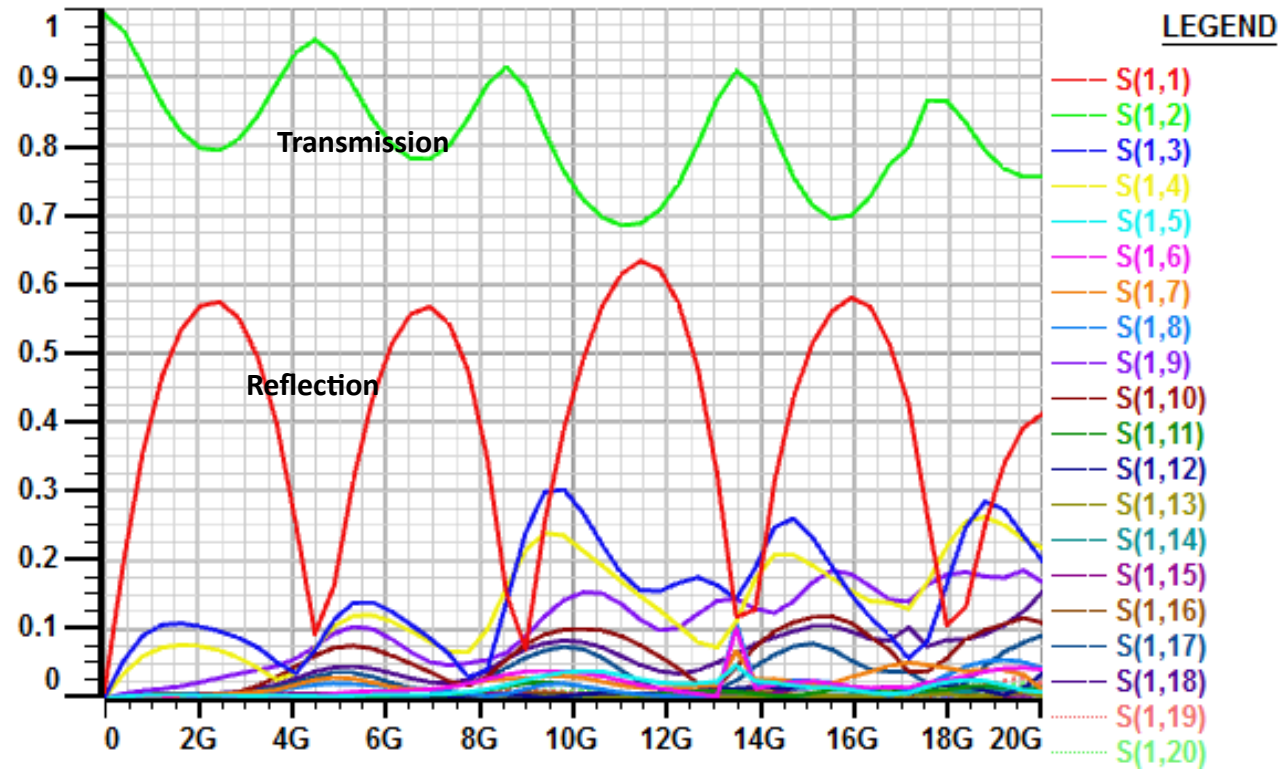
$p = (119 - 11.5) / 119 = 0.8067$

$$\text{Max Speedup}_{n=5} = \frac{1}{(1-p) + \frac{p}{n}} = 3.6x$$

$$\text{Max Speedup}_{n=\infty} = \frac{1}{(1-p) + \frac{p}{n}} = 10.3x$$



S-Parameters



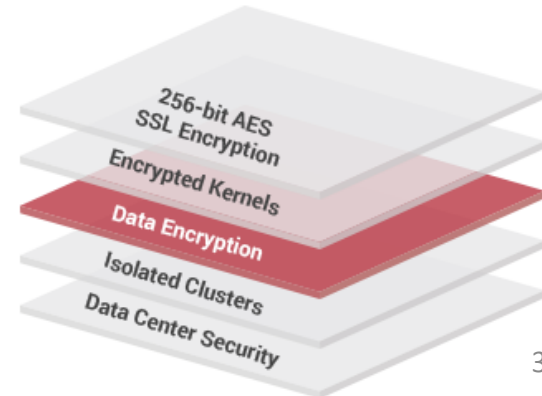
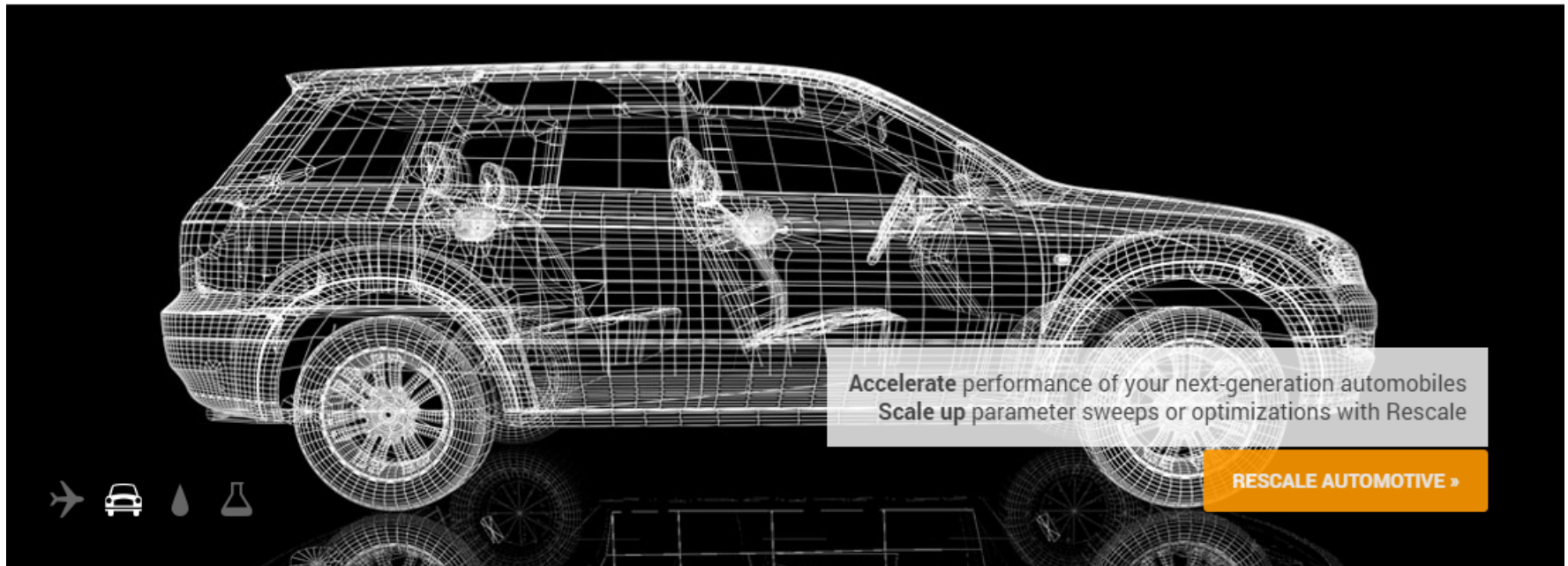
Simulation in the Cloud







































































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Simulation Software

 Abaqus FEA	 Ansys	 ANSYS CFX	 ANSYS Fluent	 ANSYS HSS	 MSC Nastran	 NAMD	 NASA CFL3D	 NASA FUN3D	 Numecc FINE/Marine
 ANSYS Maxwell	 ANSYS Mechanical	 ASCA	 AutoDock Vina	 AVL Fire	 Numecc FINE/Turbo	 NWChem	 NX Nastran	 OpenEye OMEGA	 OpenEye ROCS
 Blast	 Blender	 BOXERMesh	 Cabalix	 Calypso	 OpenFOAM	 OVERFLOW	 PTC Creo Simulate	 PyFR	 R
 CASE	 CPD+	 CONVERGE	 DOCK	 ESI PAM-CRASH	 RadTherm	 Ricardo Vectra	 Ricardo Ware	 Schrodinger Glide	 STAR-CD+
 ESI VA One	 ESI VPS	 Fire Dynamics Simulator	 FLO-3D	 Gamses	 SU2	 System Modeler	 VRAND Genesis	 WRF	 XFlow
 Gerris	 Gromacs	 Homer	 LAMMPS	 LS-DYNA	 DAKOTA	 HEEDS	 Mathematica	 MATLAB	 NOMAD
 Mesa	 MentalRay	 Missile Dancem	 Modeller	 MSC Marc	 Octave	 SciPy	 User-provided Software		



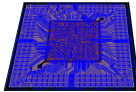
Software

SDK, IDE, compiler,
debugger, build,
source control...



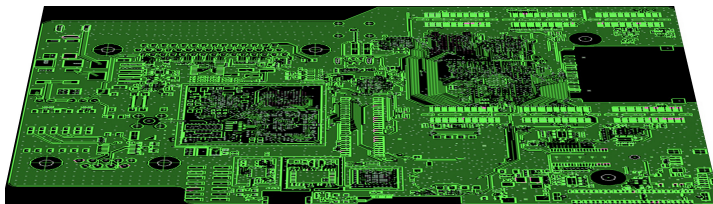
Die

EDA



Package

MCM, EM,
Thermal, Mechanical



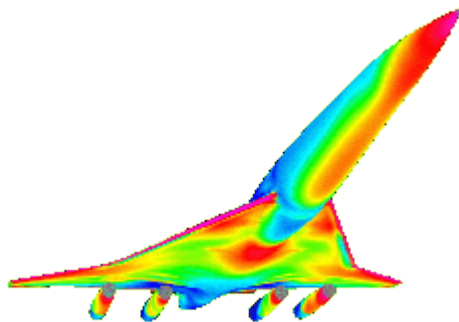
Board
Connector

PCB, EM,
Thermal, Mechanical



Sub-System

Mechanical,
Thermal, EM



System

Mechanical, CFD,
Thermal, EM

Ergonomics, sustainability, CO₂ emissions ...

Software

Rank 2013	Rank 2012	Vendor	2013 Revenue	2012 Revenue	2012-2013 Growth Rate (%)
1	1	Microsoft	65.7	62.0	6.0
2	3	Oracle	29.6	28.7	3.4
3	2	IBM	29.1	28.7	1.4
4	4	SAP	18.5	16.9	9.5
5	5	Symantec	6.4	6.4	-0.8
6	6	EMC	5.6	5.4	4.9
7	7	HP	4.9	5.0	-2.7
8	9	VMware	4.8	4.2	14.1
9	8	CA Technologies	4.2	4.3	-2.6
10	12	Salesforce.com	3.8	2.9	33.3
		Others	234.6	224.0	4.7
		Total	407.3	388.5	4.8

Top 10 Worldwide Software Vendors, Worldwide, 2012-2013 (Billions of Dollars)

Source: Gartner (March 2014)

CAD / Simulation

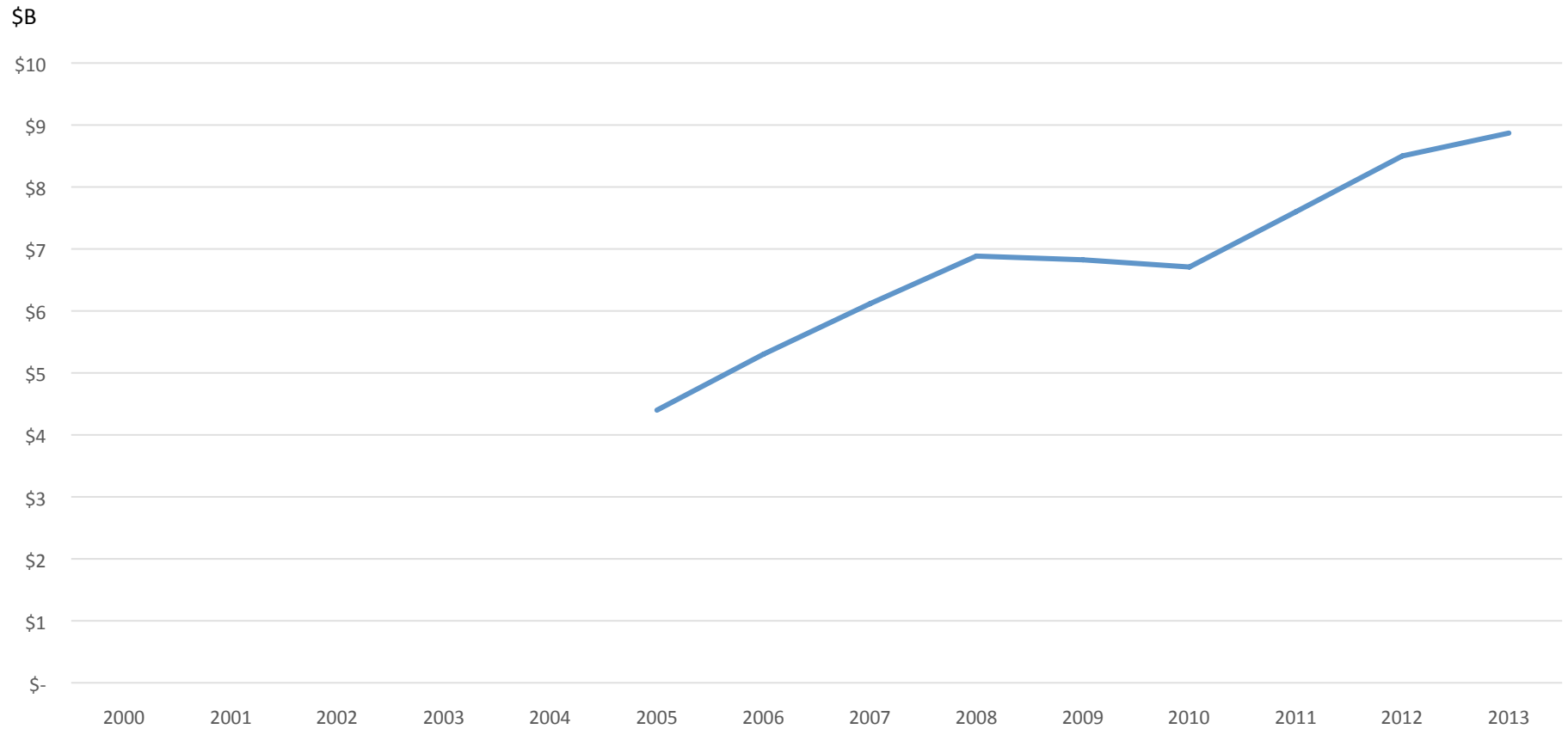
\$B

Rank 2013	Rank 2012	Vendor	2013 Revenue	2012 Revenue	2012-2013 Growth Rate (%)
1	1	Dassault Systèmes	2.6	2.5	1.8
2	2	Autodesk	2.3	2.2	4.1
3	3	Siemens PLM	1.8	1.7	7.5
4	4	PTC	1.3	1.3	3.0
5	5	Ansys	.86	.80	7.9
Total			8.9	8.5	4.7

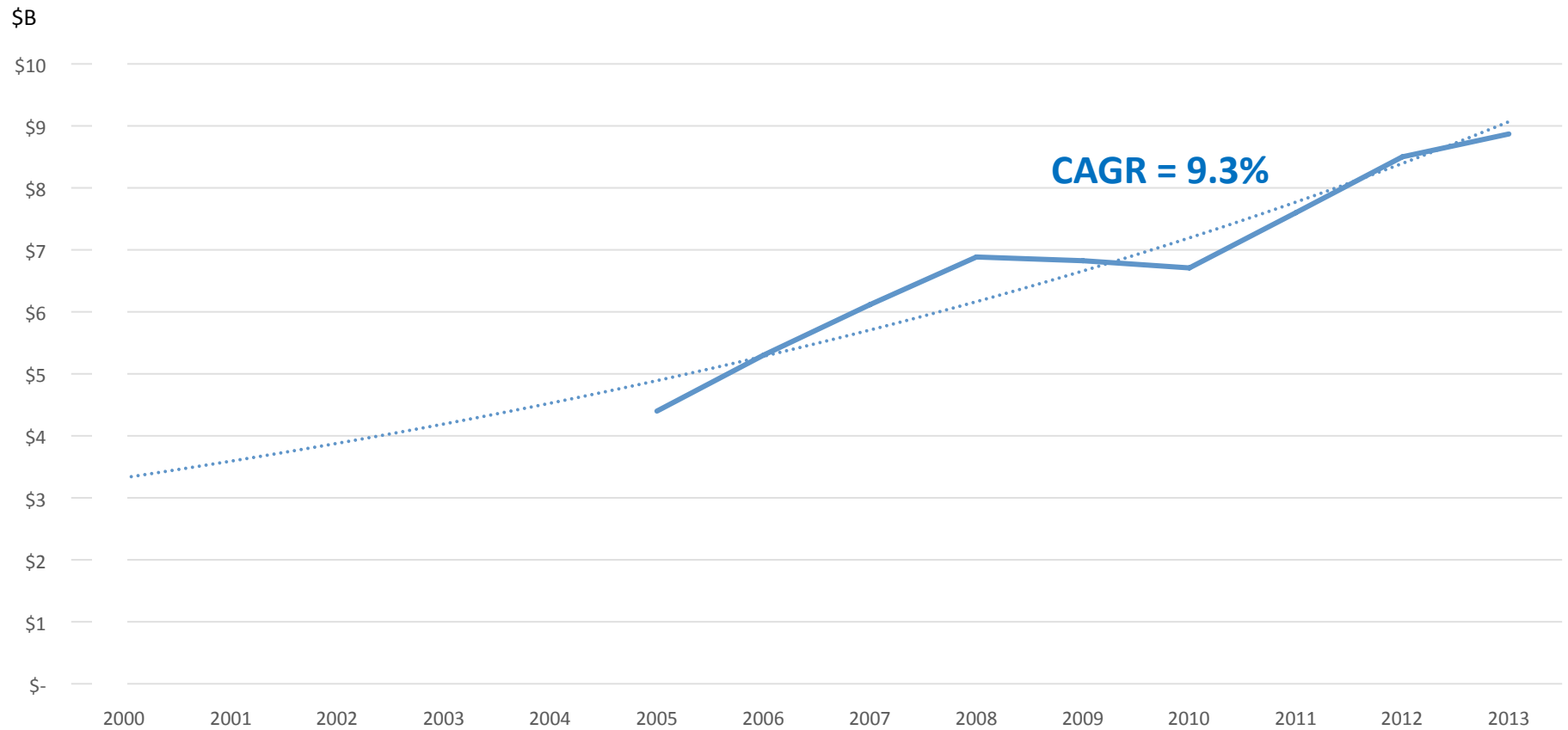
Top 5 Worldwide CAD Vendors, Worldwide, 2012-2013 (Billions of Dollars)

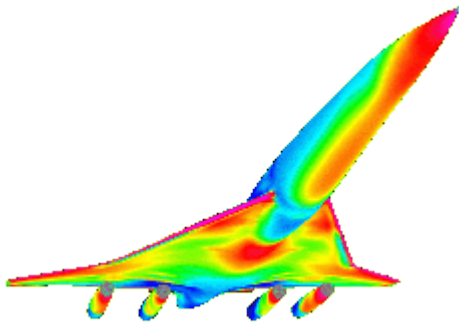
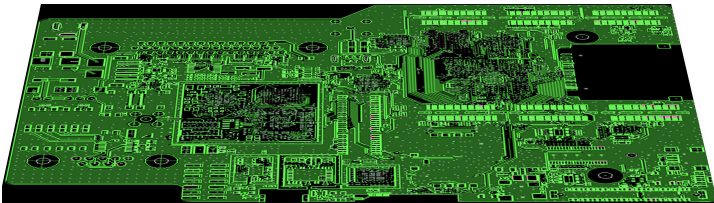
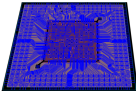
Sources: JPR, Schnittger, Public Co.

CAD / Simulation



CAD / Simulation





Software
Application Development Software
\$9 / \$407B
2.2%

Die
Package
EDA
\$6.2 / \$303B
2.0%

Board Connector
\$0.8 / \$80B
1.0%

Sub-System
CAD
>\$9 / >2T ?
<0.5%

System



Summary

- Semiconductors and EDA have been growing at the pace of GWP since 1996
- Cost, complexity and functionality continue to migrate to SW and system
- EDA and CAD are poised for contact, leading to system design