IEEE SCV CPMT Seminar
Packaging:
The Core of Competitive Advantage
March 28, 2013
Sunnyvale, CA
Presented by
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Senior Technical Advisor
ASE Fellow
ASE Group
CPMT Distinguished Lecturer
ASE GROUP
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ASE Manufacturing Sites
Assembly, Materials & Test
ASE Worldwide Locations
Suzhou, China (ASEN)
Shanghai, China (Material)
Shanghai, China (A&T)
Kunshan, China
Penang, Malaysia
ASE Weihai, China
Paju, Korea
Takahata, Japan
ISE Labs
Fremont, California
Austin, Texas
Singapore
ChungLi, Taiwan
Kaohsiung, Taiwan
Waterloo, Belgium
Vienna, Austria
Yokohama, Japan
Shanghai, China
San Jose /
Santa Clara, CA
Irvine, CA
San Diego, CA
Tempe, Arizona
Austin, Texas
Boston, Massachusetts
Sales and Representative Offices
IC Service
System Service

Packaging & Us

- What is changing?
- What has not changed?
- How should we invest our time and energy to evolve with our changing world?

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Outline

- The Big Picture
- Changes: Business, Market, Technology
- Situation Analysis
- Packaging DNA- Re-inventions & Innovations
- Smart Product Business Opportunities
- CPMT Professionals
- Wrap-Up

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The CPMT Profession

ASE GROUP

"The transition from agriculture to manufacturing is still the route to higher productivity and rising living standard for developing economies. In advanced economies, manufactured goods stand as the tangible expression of innovation and competitiveness………… We see that a new era of innovation and opportunities promises to inspire a new generation of manufacturing professionals"

Manufacturing the Future: The next era of global growth & innovation
McKinsey Report November 2012

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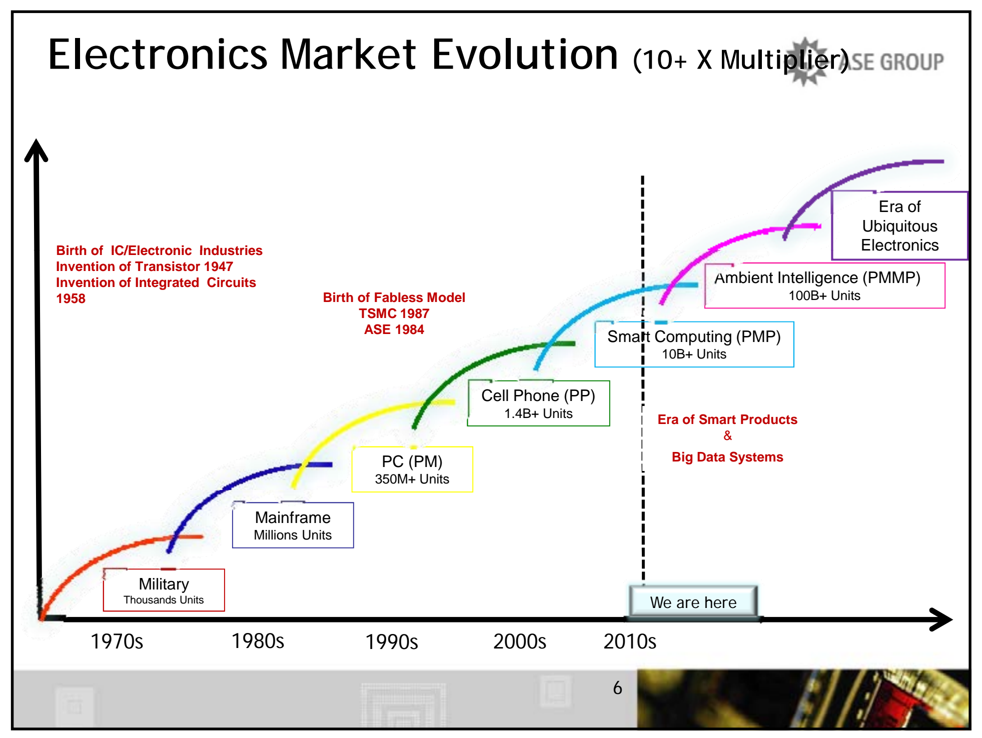
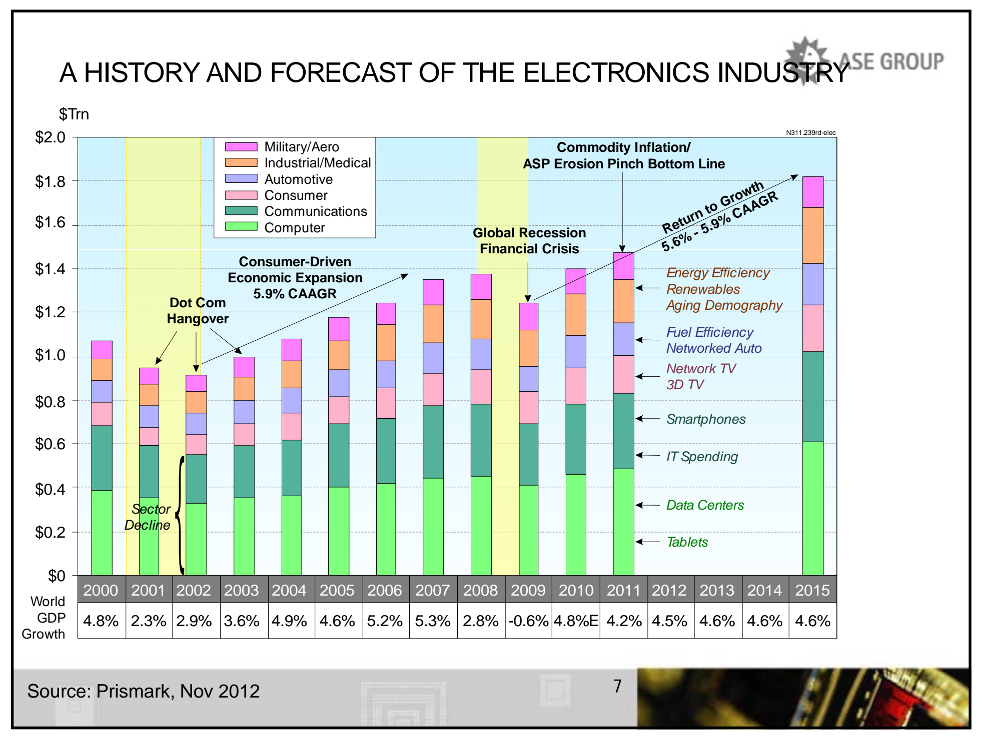
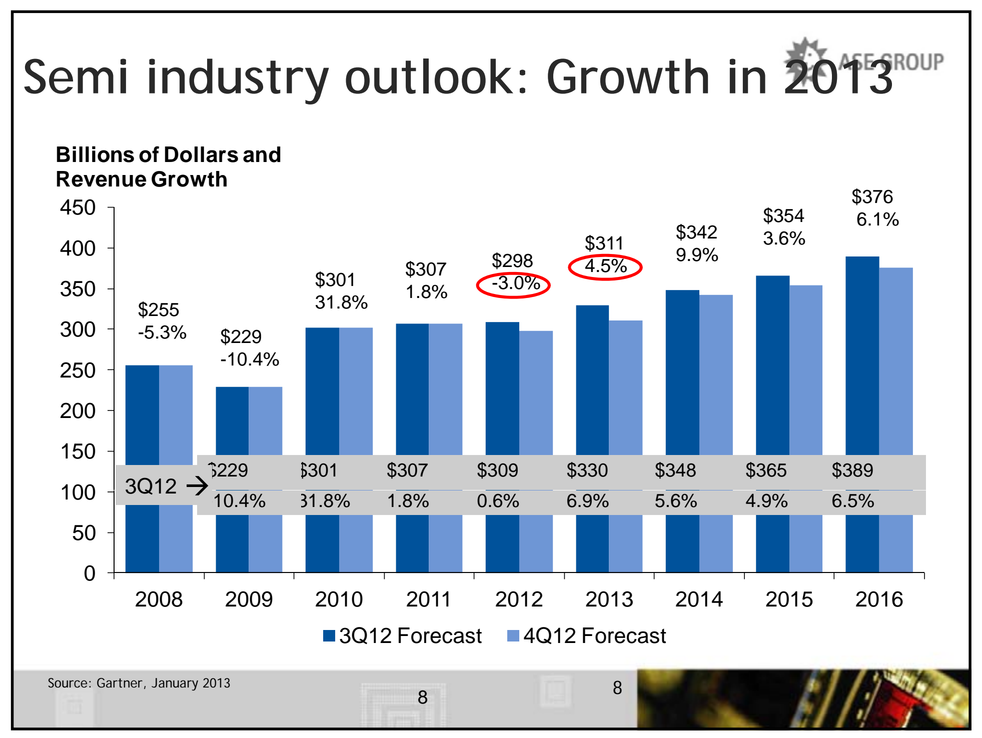
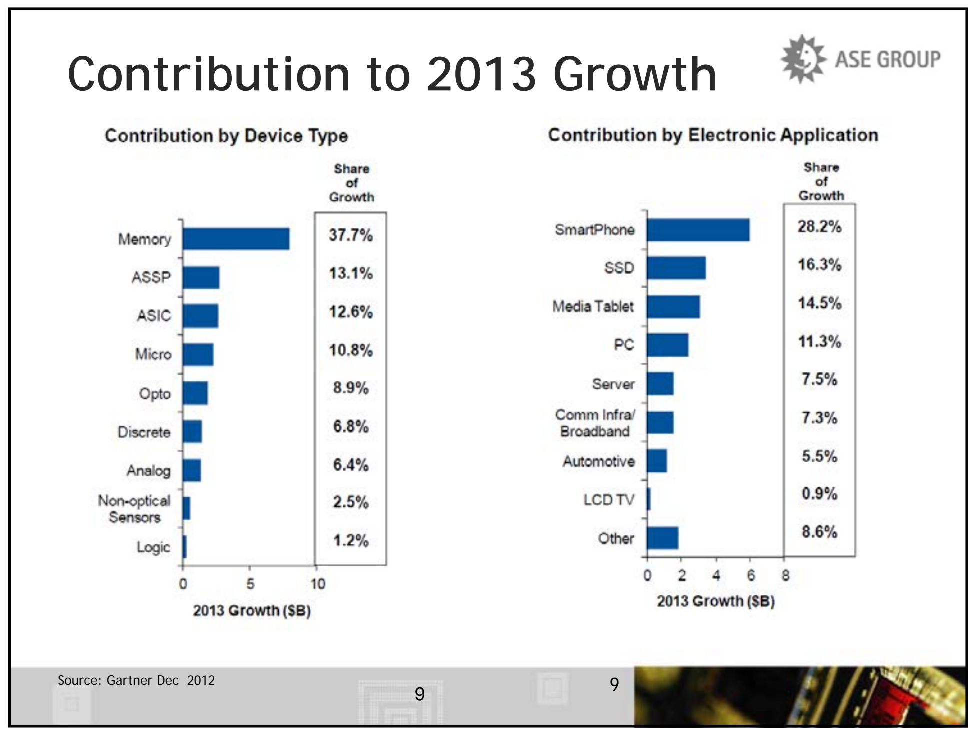
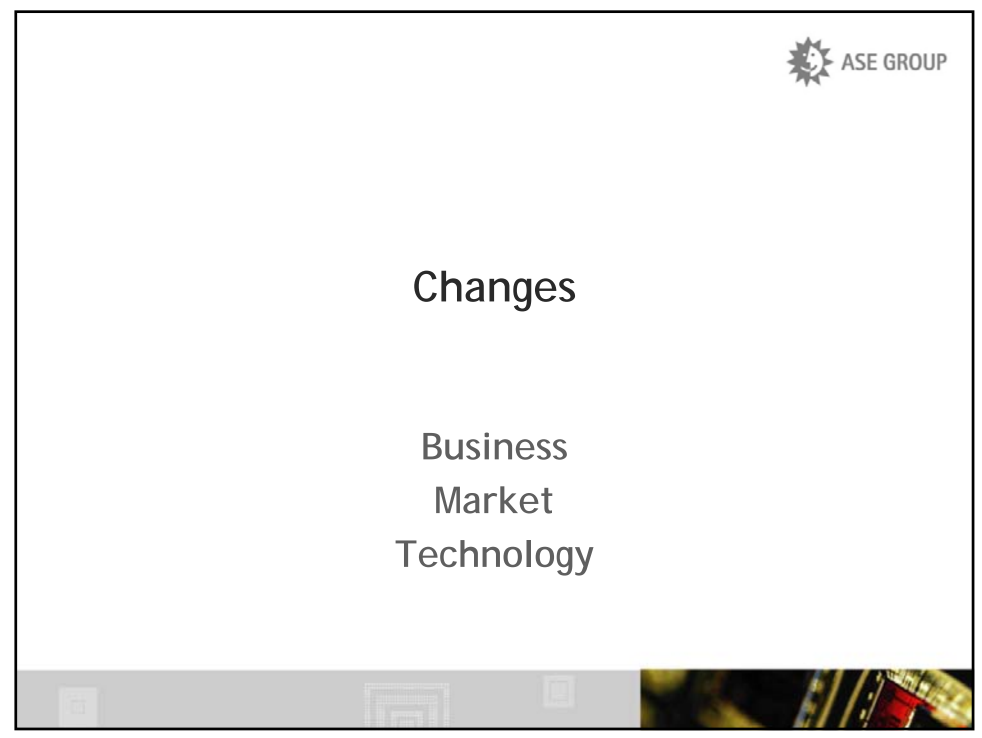
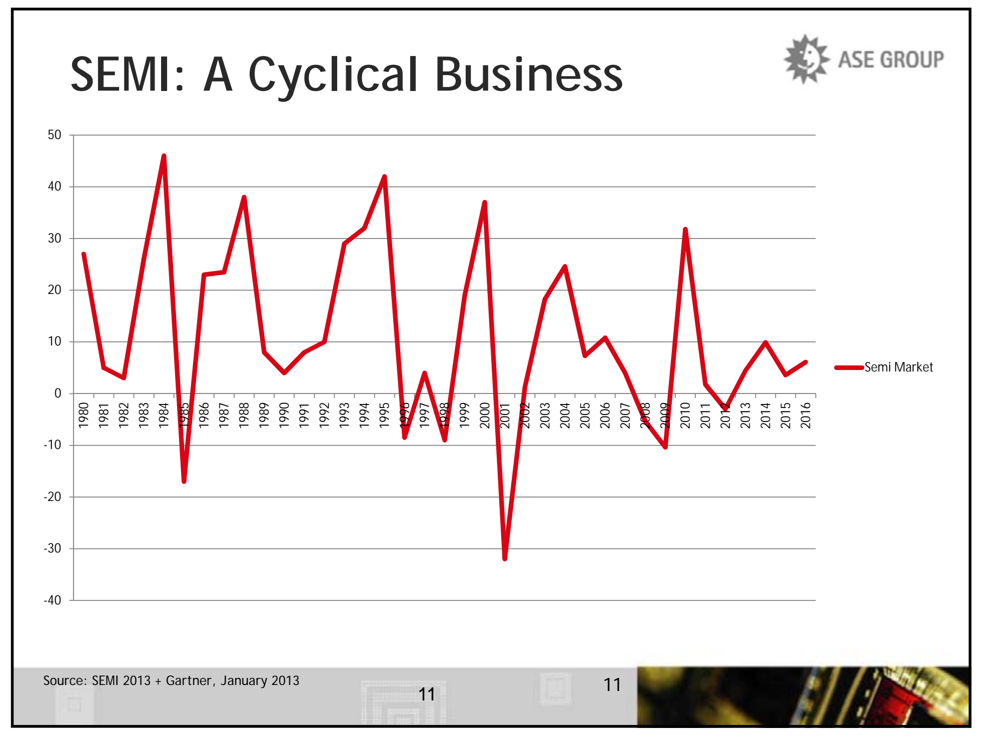


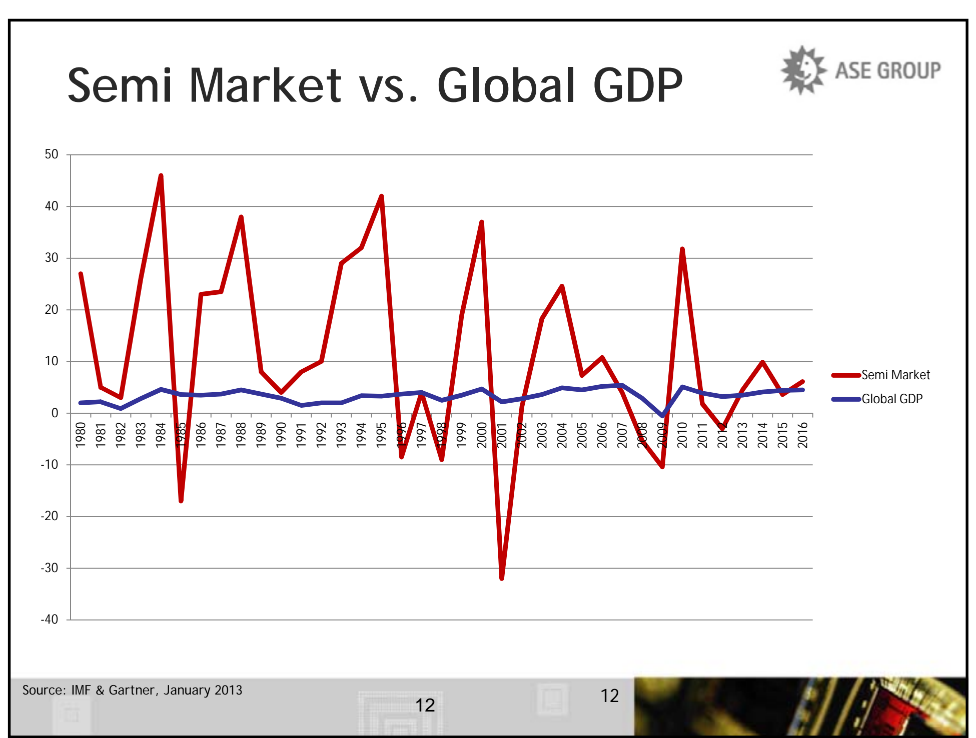

A HISTORY AND FORECAST OF THE ELECTRONICS INDUSTRY
ASE GROUP
$Trn
Military/Aero
Industrial/Medical
Automotive
Consumer
Communications
Computer
Commodity Inflation/
ASP Erosion Pinch Bottom Line
Global Recession
Financial Crisis
Return to Growth
5.6% - 5.9% CAAGR
Consumer-Driven
Economic Expansion
5.9% CAAGR
Dot Com
Hangover
Sector
Decline
Energy Efficiency
Renewables
Aging Demography
Fuel Efficiency
Networked Auto
Network TV
3D TV
Smartphones
IT Spending
Data Centers
Tablets
World GDP Growth
2000 4.8%
2001 2.3%
2002 2.9%
2003 3.6%
2004 4.9%
2005 4.6%
2006 5.2%
2007 5.3%
2008 2.8%
2009 -0.6%
2010 4.8%E
2011 4.2%
2012 4.5%
2013 4.6%
2014 4.6%
2015 4.6%
Source: Prismark, Nov 2012
7


Semi industry outlook: Growth in 2013
ASE GROUP
Billions of Dollars and
Revenue Growth
2008 $255 -5.3%
2009 $229 -10.4%
2010 $301 31.8%
2011 $307 1.8%
2012 $298 -3.0%
2013 $311 4.5%
2014 $342 9.9%
2015 $354 3.6%
2016 $376 6.1%
3Q12
$229 10.4%
$301 31.8%
$307 1.8%
$309 0.6%
$330 6.9%
$348 5.6%
$365 4.9%
$389 6.5%
3Q12 Forecast
4Q12 Forecast
Source: Gartner, January 2013
8

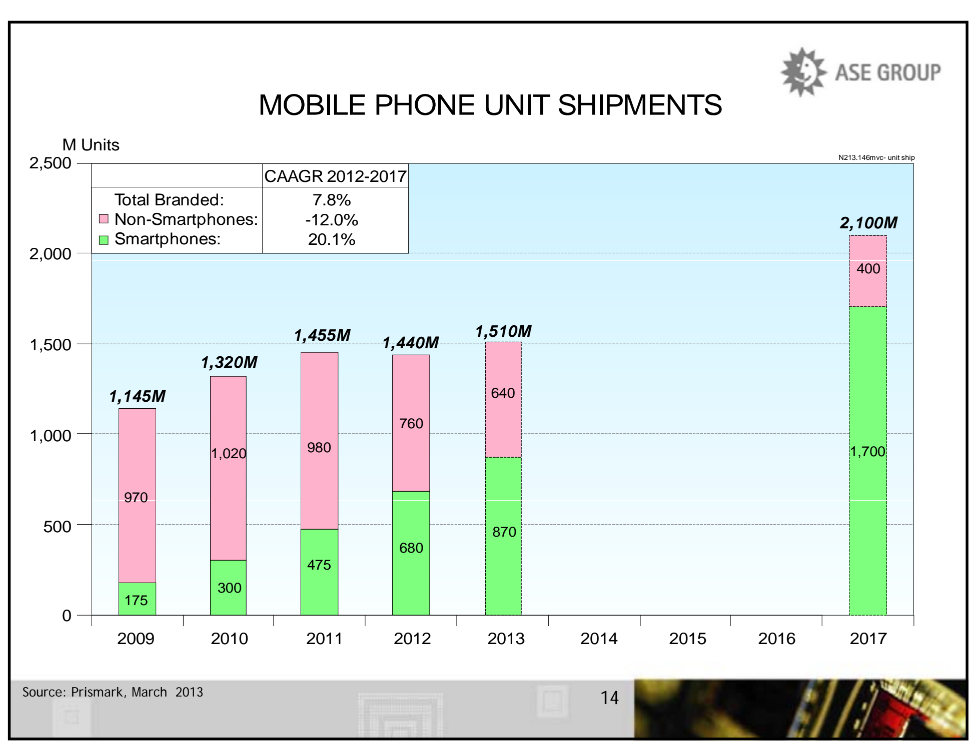

Contribution to 2013 Growth
ASE GROUP
Contribution by Device Type
Share of Growth
Memory 37.7%
ASSP 13.1%
ASIC 12.6%
Micro 10.8%
Opto 8.9%
Discrete 6.8%
Analog 6.4%
Non-optical Sensors 2.5%
Logic 1.2%
0 5 10
2013 Growth ($B)
Contribution by Electronic Application
Share of Growth
SmartPhone 28.2%
SSD 16.3%
Media Tablet 14.5%
PC 11.3%
Server 7.5%
Comm Infra/ Broadband 7.3%
Automotive 5.5%
LCD TV 0.9%
Other 8.6%
0 2 4 6 8
2013 Growth ($B)
Source: Gartner Dec 2012
9
9

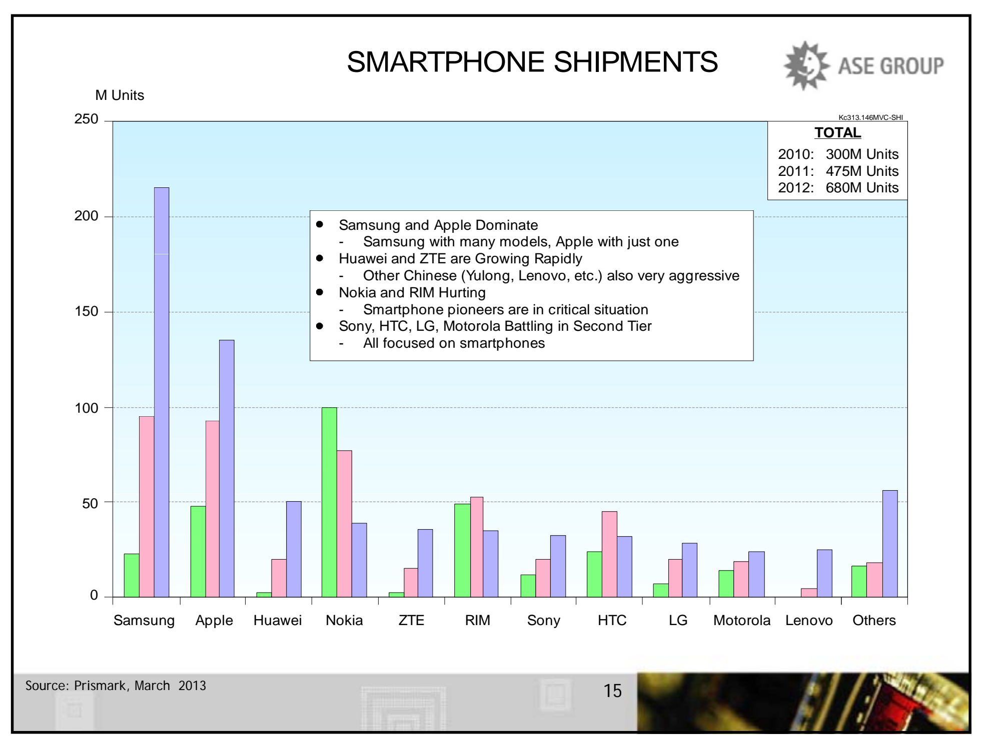

ASE GROUP
Changes
Business
Market
Technology

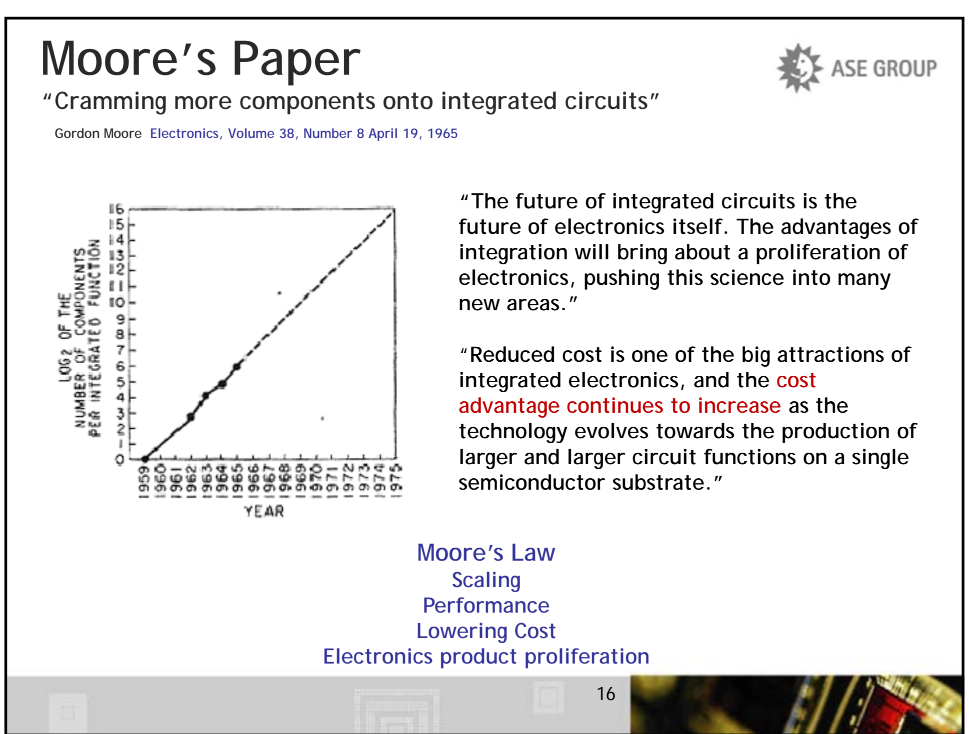

SEMI: A Cyclical Business
ASE GROUP
50
40
30
20
10
0
-10
-20
-30
-40
1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016
Semi Market
Source: SEMI 2013 + Gartner, January 2013
11
11

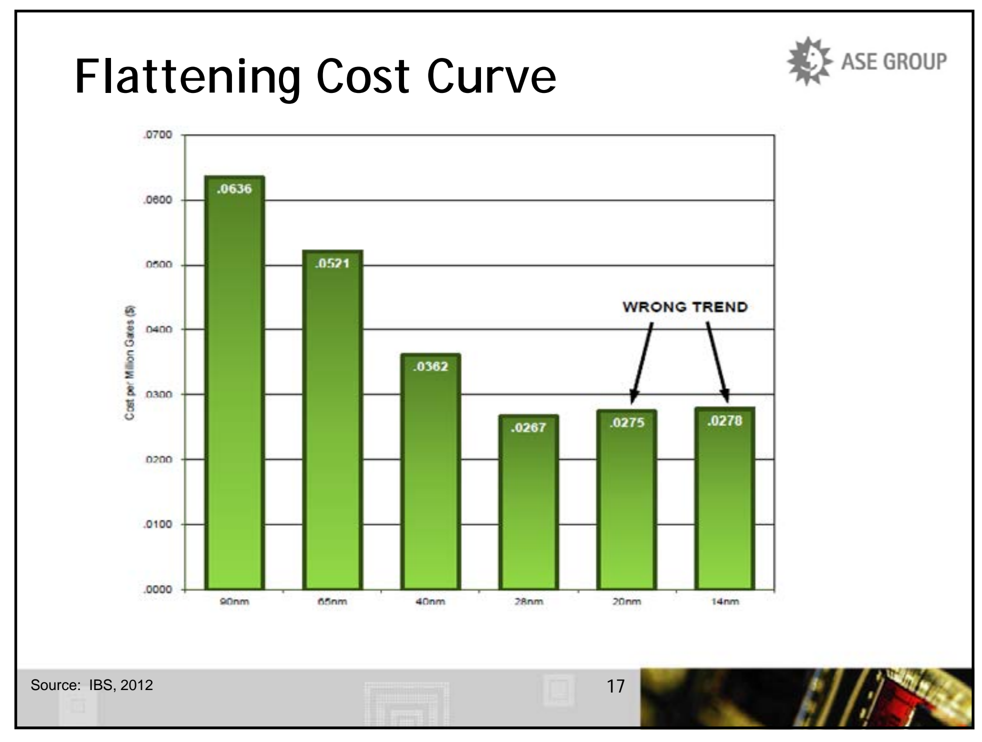

Semi Market vs. Global GDP
ASE GROUP
50
40
30
20
10
0
-10
-20
-30
-40
1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016
Semi Market
Global GDP
Source: IMF & Gartner, January 2013
12
12

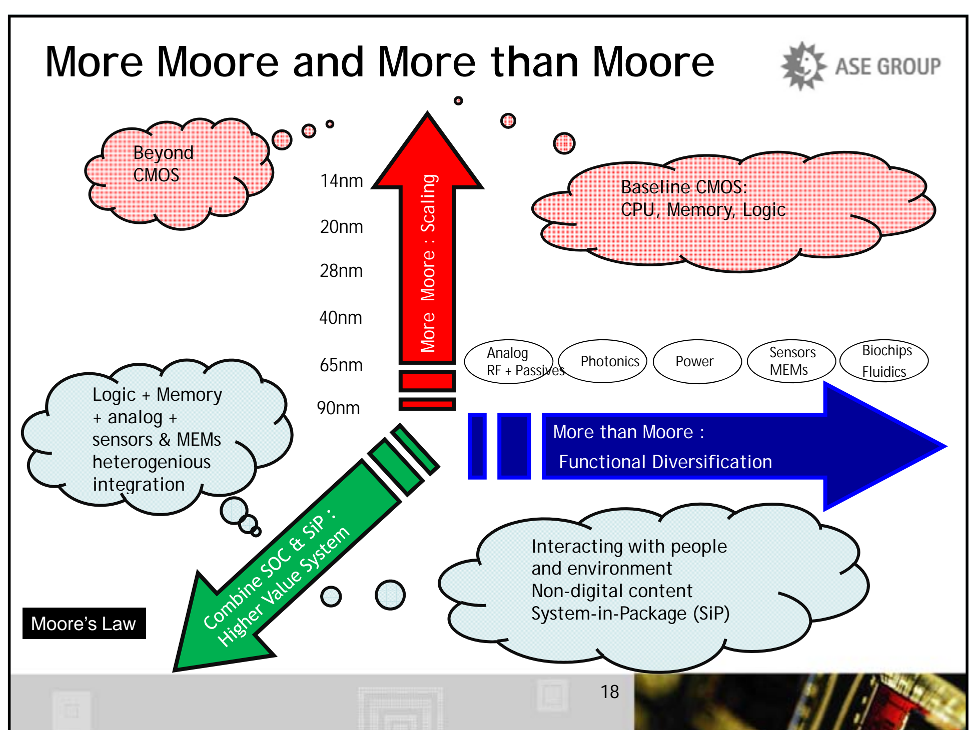
Smart phones at play!
ASE GROUP
LIVE
#nbcpolitics
THE SECOND ★ INAUGURATION OF ★
BARACK OBAMA
© NBC


ASE GROUP
MOBILE PHONE UNIT SHIPMENTS
M Units
CAAGR 2012-2017
Total Branded: 7.8%
Non-Smartphones: -12.0%
Smartphones: 20.1%
2,500
2,000
1,500
1,000
500
0
1,145M
970
175
1,320M
1,020
300
1,455M
980
475
1,440M
760
680
1,510M
640
870
2,100M
400
1,700
2009
2010
2011
2012
2013
2014
2015
2016
2017
Source: Prismark, March 2013
14


SMARTPHONE SHIPMENTS
ASE GROUP
M Units
250
200
150
100
50
0
TOTAL
2010: 300M Units
2011: 475M Units
2012: 680M Units
• Samsung and Apple Dominate
- Samsung with many models, Apple with just one
• Huawei and ZTE are Growing Rapidly
- Other Chinese (Yulong, Lenovo, etc.) also very aggressive
• Nokia and RIM Hurting
- Smartphone pioneers are in critical situation
• Sony, HTC, LG, Motorola Battling in Second Tier
- All focused on smartphones
Samsung
Apple
Huawei
Nokia
ZTE
RIM
Sony
HTC
LG
Motorola
Lenovo
Others
Source: Prismark, March 2013
15


Moore's Paper
ASE GROUP
"Cramming more components onto integrated circuits"
Gordon Moore Electronics, Volume 38, Number 8 April 19, 1965
LOG2 OF THE NUMBER OF COMPONENTS PER INTEGRATED FUNCTION
YEAR
"The future of integrated circuits is the future of electronics itself. The advantages of integration will bring about a proliferation of electronics, pushing this science into many new areas."
"Reduced cost is one of the big attractions of integrated electronics, and the cost advantage continues to increase as the technology evolves towards the production of larger and larger circuit functions on a single semiconductor substrate."
Moore's Law
Scaling
Performance
Lowering Cost
Electronics product proliferation
16


Flattening Cost Curve
ASE GROUP
.0700
.0600
.0500
.0400
.0300
.0200
.0100
.0000
.0636
.0521
.0362
.0267
.0275
.0278
WRONG TREND
90nm
65nm
40nm
28nm
20nm
14nm
Source: IBS, 2012
17


More Moore and More than Moore
ASE GROUP
Beyond CMOS
14nm
20nm
28nm
40nm
65nm
90nm
More Moore : Scaling
Baseline CMOS: CPU, Memory, Logic
Analog RF + Passives
Photonics
Power
Sensors MEMs
Biochips Fluidics
Logic + Memory + analog + sensors & MEMs heterogenious integration
More than Moore : Functional Diversification
Combine SOC & SiP : Higher Value System
Interacting with people and environment
Non-digital content
System-in-Package (SiP)
Moore's Law
18

Situation Analysis

- Business - Growth aligning with global GDP
  - Slow semi growth + escalating capex + extreme technology driving consolidation
  - Dynamic consumer business = two players dominating across landscape
  - Electronics in every business: Consumer, aerospace, industry, home, health
  - Full product technology integration co-exists with delineated supply chain
- Market - Fast Changes
  - Consumers want more & more functionality - MEMs, Sensors, & more.
  - Product cost expectations are given
  - Smart Phone/Tablet superseded PC as the Market Driver
  - Big Data driving data center & network systems
- Technologies - Inflection Point
  - More Moore scaling continues. CPI at 14 nm FinFET in 2014 ?
  - Scaling is stalling in power, in bandwidth, & in cost per gate
  - More than Moore integration with 2.5D and more?
- Future has arrived
  - Customization in Mass Production
  - Heterogeneous Integration - nodes, technology, function, business, region

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Packaging DNA

History

- For 40+ years, semi industry has lowered cost 9 orders of magnitude through scaling & Moore's Law
- Packaging has been a crucial technology enabler without the Moore's Law scaling advantage

Present

- With the burgeoning mobile and smart phone era, the packaging industry is experiencing a flowering of new package innovations and reinvention of traditional packages.
- Packaging is leading the charge for 'More than Moore' integration

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Packaging DNA 2013

- For 40 years, our Packaging DNA was:
  - Wire bond with Au wire
  - Flip Chip solder bump
- In last couple of years, we have introduced new DNA:
  - Au & Cu Wire bond
  - Flip Chip Cu Pillar
  - Wafer level Packaging: WLCSP + WL fanout
  - Embedded technologies
  - 2.5 D Interposer - TSV
  - 3D Packaging
  - Packaging for MEMs, Sensor, and Power
  - Heterogeneous integration
- And more on the way……

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Gold vs. Copper Wire:
Copper is ~30% of the market in 2012

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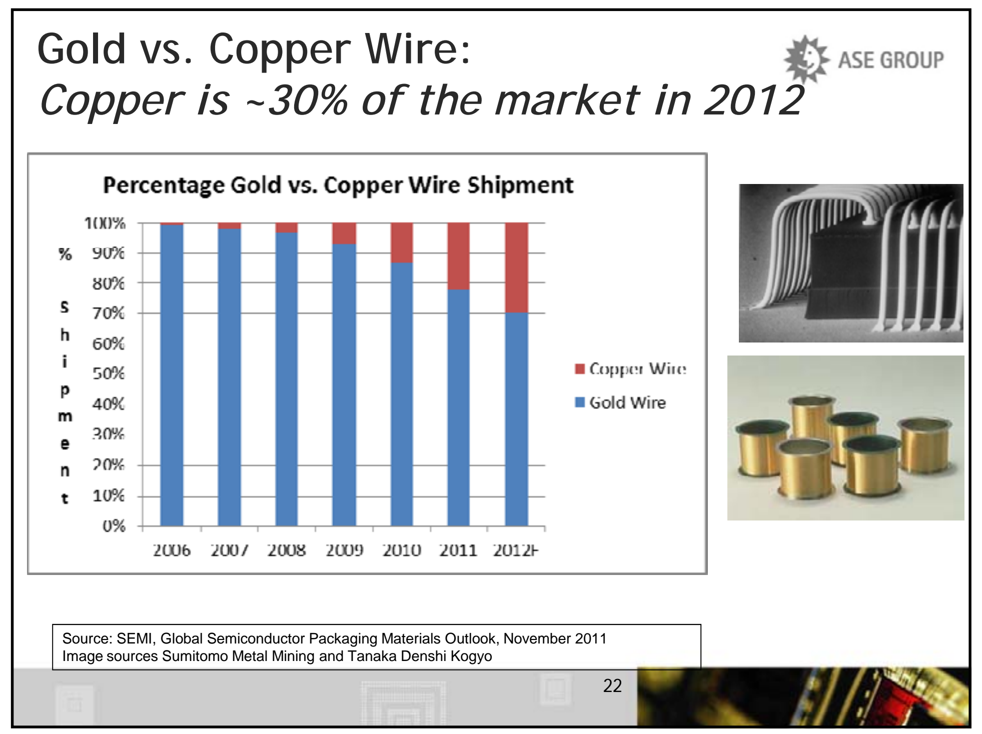

Source: SEMI, Global Semiconductor Packaging Materials Outlook, November 2011
Image sources Sumitomo Metal Mining and Tanaka Denshi Kogyo

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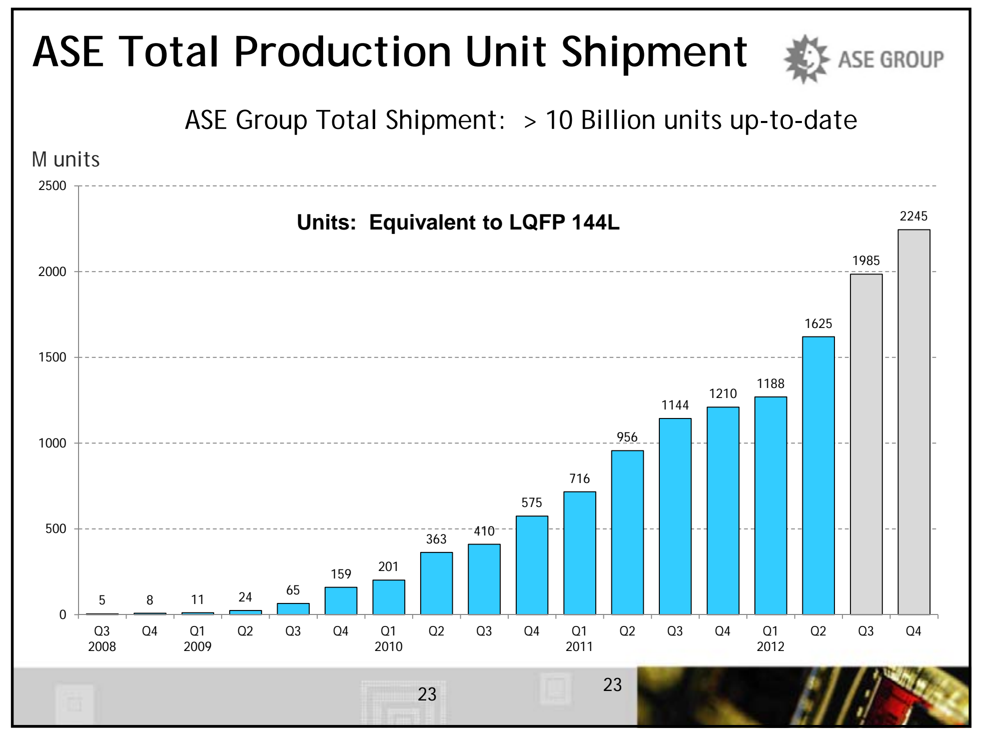
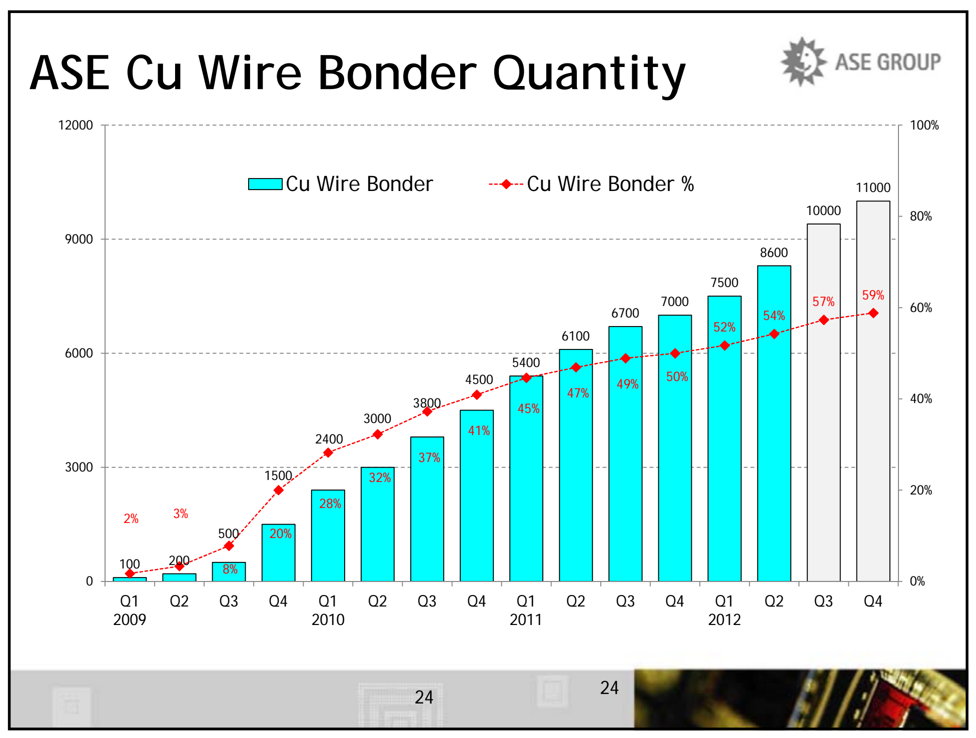
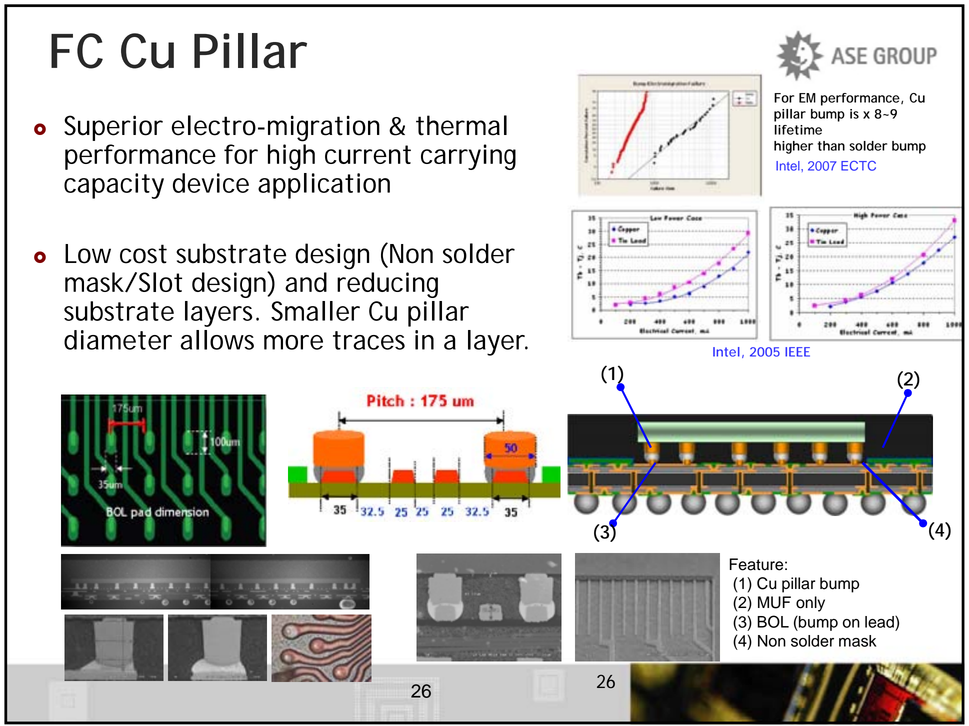
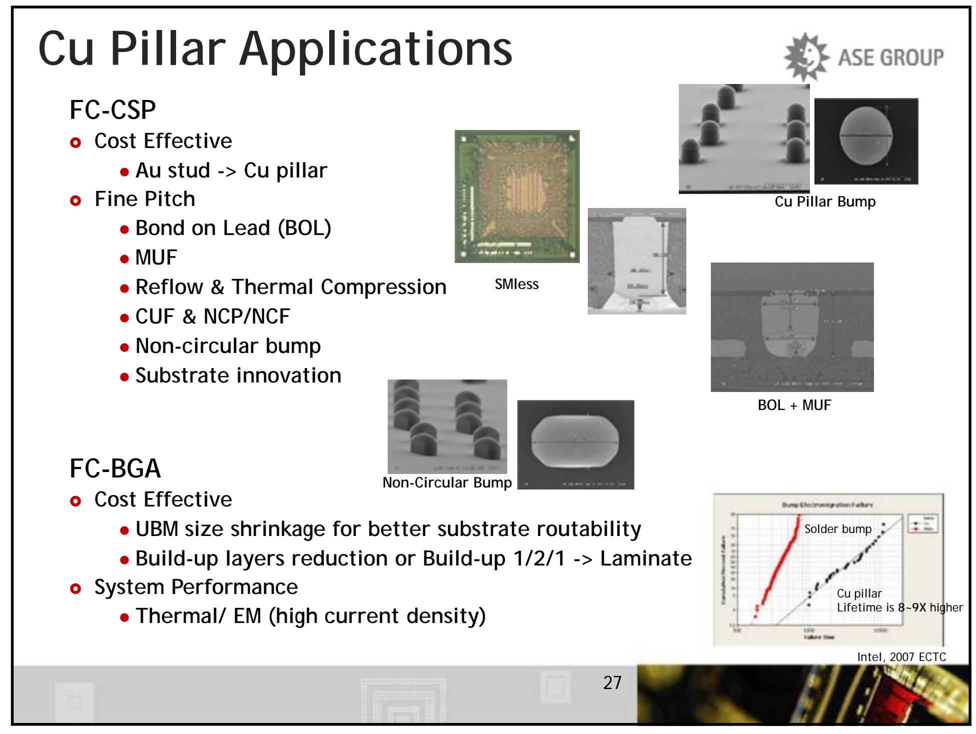
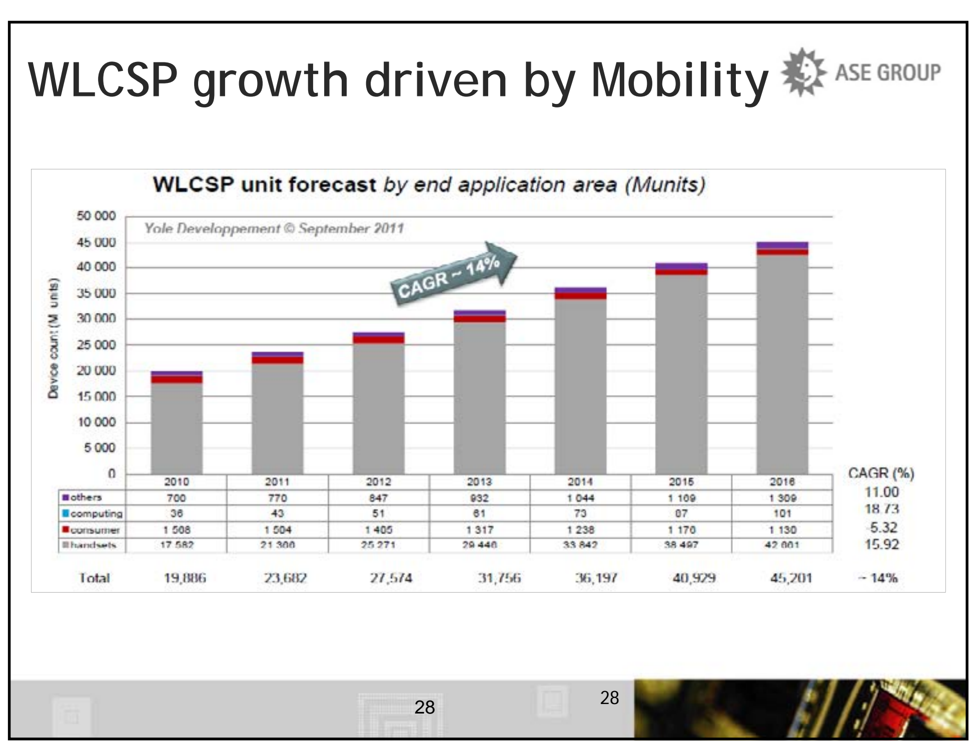

ASE Total Production Unit Shipment
ASE GROUP
ASE Group Total Shipment: > 10 Billion units up-to-date
M units
Units: Equivalent to LQFP 144L
0
500
1000
1500
2000
2500
5
8
11
24
65
159
201
363
410
575
716
956
1144
1210
1188
1625
1985
2245
Q3 2008
Q4
Q1 2009
Q2
Q3
Q4
Q1 2010
Q2
Q3
Q4
Q1 2011
Q2
Q3
Q4
Q1 2012
Q2
Q3
Q4
23


ASE Cu Wire Bonder Quantity
ASE GROUP
Cu Wire Bonder
Cu Wire Bonder %
0
3000
6000
9000
12000
0%
20%
40%
60%
80%
100%
100
200
500
1500
2400
3000
3800
4500
5400
6100
6700
7000
7500
8600
10000
11000
2%
3%
8%
20%
28%
32%
37%
41%
45%
47%
49%
50%
52%
54%
57%
59%
Q1 2009
Q2
Q3
Q4
Q1 2010
Q2
Q3
Q4
Q1 2011
Q2
Q3
Q4
Q1 2012
Q2
Q3
Q4
24

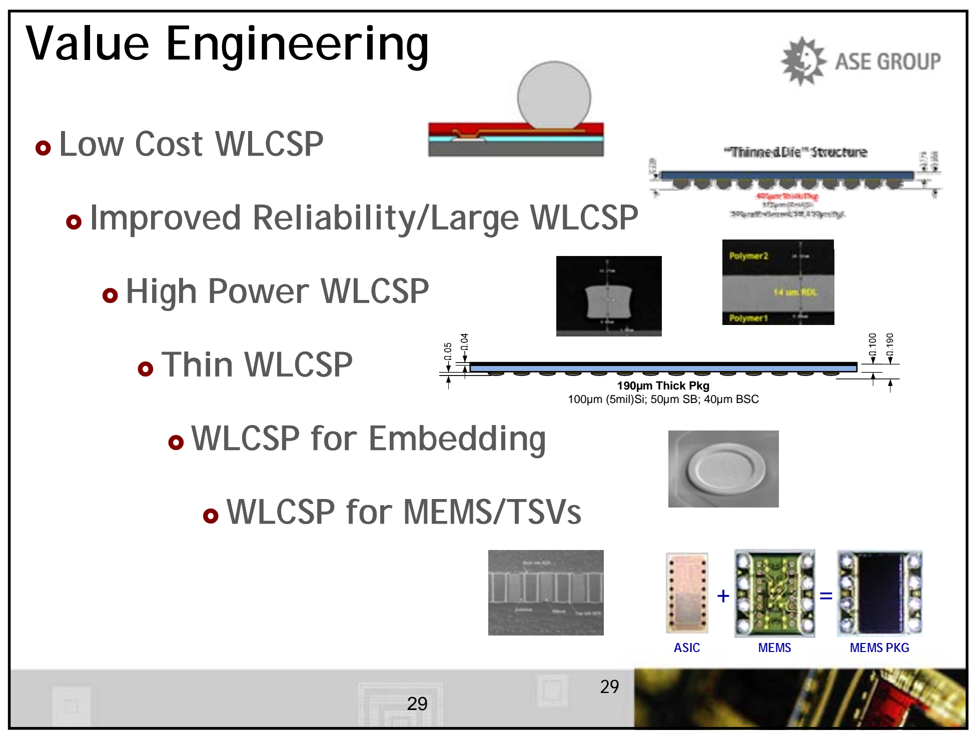
ASE GROUP
McDonald's
BILLIONS AND BILLIONS SERVED
And billions of $$ saved!
25
25

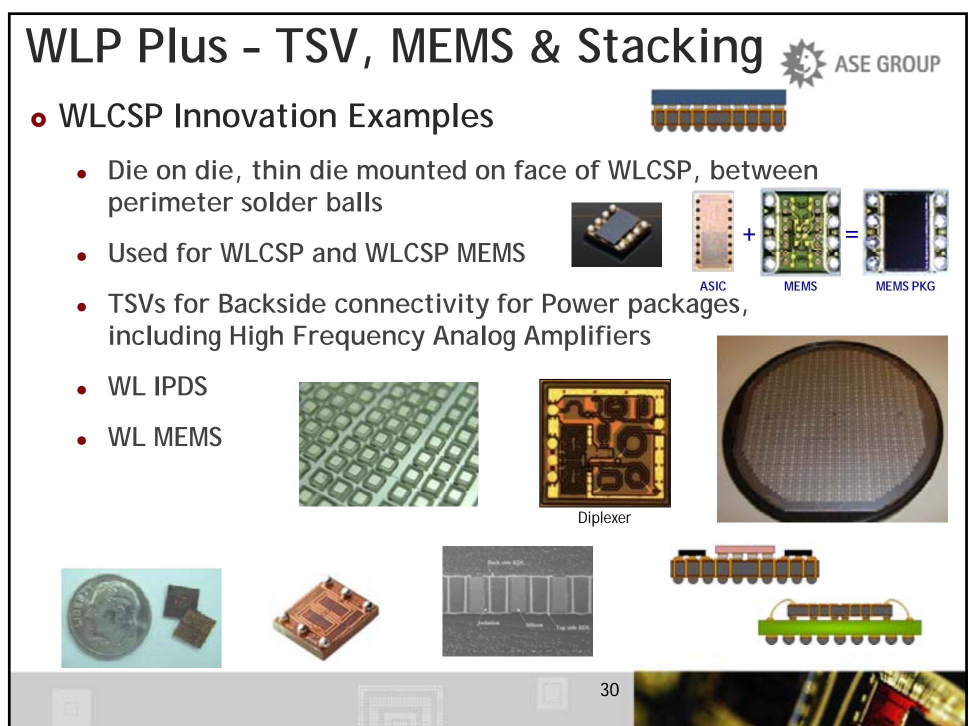

FC Cu Pillar
ASE GROUP
Superior electro-migration & thermal performance for high current carrying capacity device application
Low cost substrate design (Non solder mask/Slot design) and reducing substrate layers. Smaller Cu pillar diameter allows more traces in a layer.
For EM performance, Cu pillar bump is x 8~9 lifetime higher than solder bump
Intel, 2007 ECTC
Intel, 2005 IEEE
175um
100um
35um
BOL pad dimension
Pitch : 175 um
50
35
32.5
25
25
25
32.5
35
(1)
(2)
(3)
(4)
Feature:
(1) Cu pillar bump
(2) MUF only
(3) BOL (bump on lead)
(4) Non solder mask
26
26

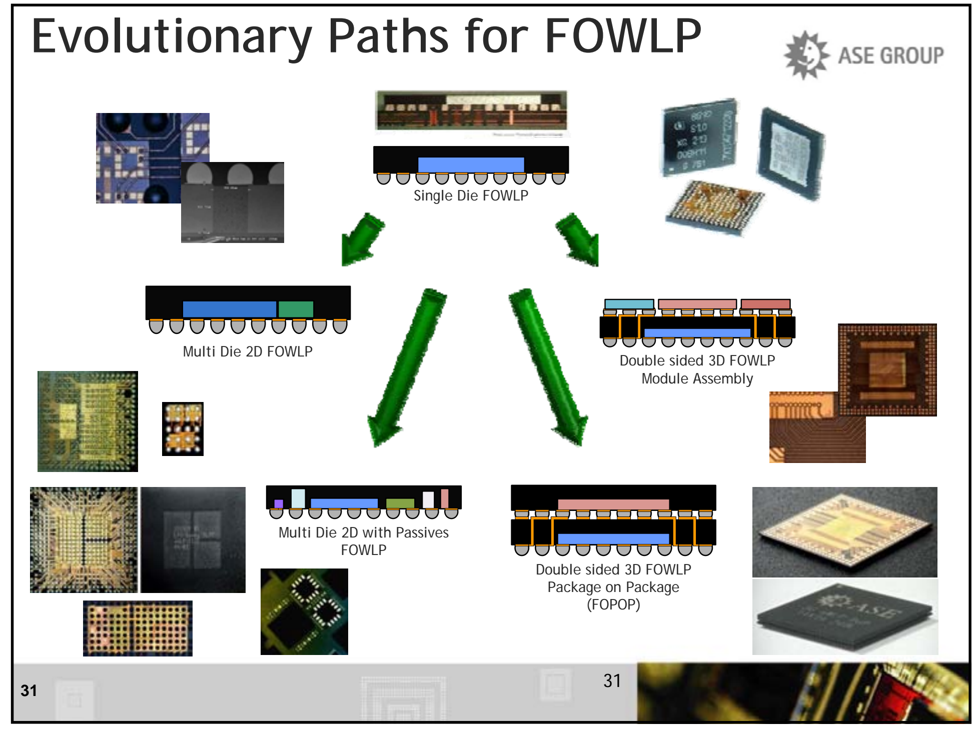


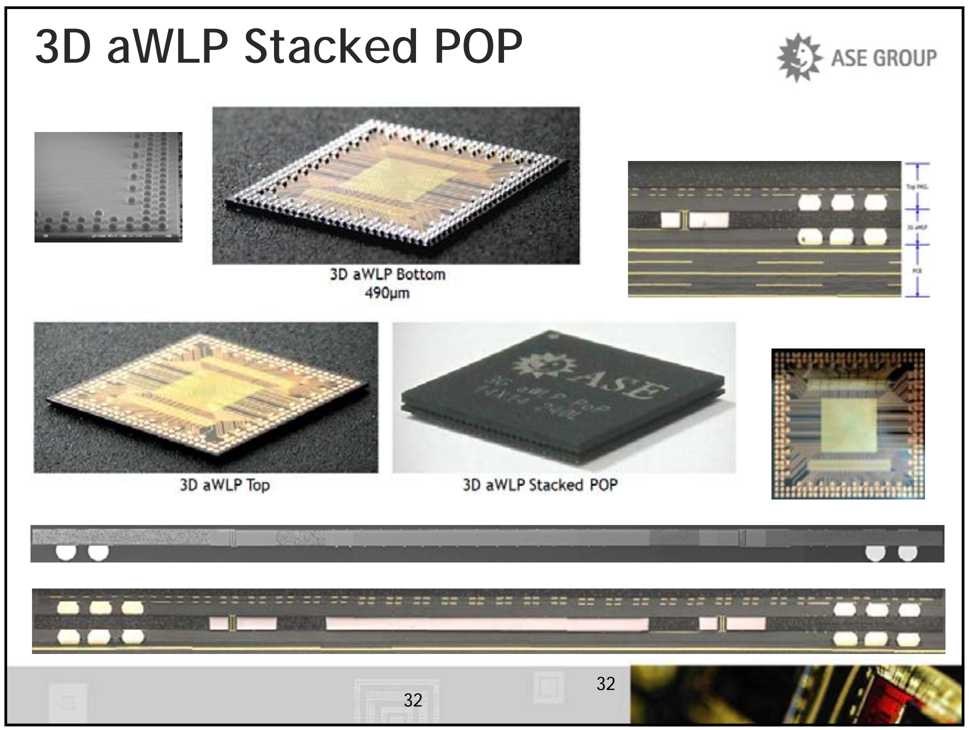


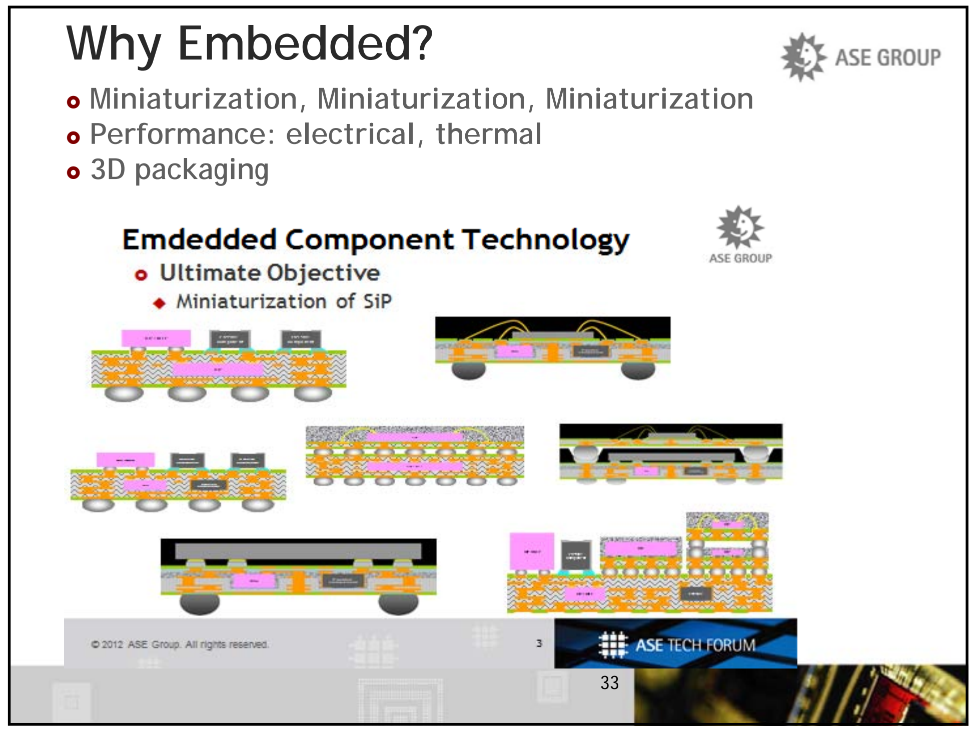
	2010	2011	2012	2013	2014	2015	2016	CAGR (%)
others	700	770	847	932	1 044	1 109	1 309	11.00
computing	36	43	51	61	73	87	101	18.73
consumer	1 508	1 504	1 405	1 317	1 238	1 170	1 130	-5.32
handsets	17 582	21 300	25 271	29 446	33 842	38 497	42 001	15.92
Total	19,886	23,682	27,574	31,756	36,197	40,929	45,201	~ 14%


Value Engineering
ASE GROUP
Low Cost WLCSP
Improved Reliability/Large WLCSP
High Power WLCSP
Thin WLCSP
WLCSP for Embedding
WLCSP for MEMS/TSVs
"Thinned Die" Structure
Polymer2
14 um RDL
Polymer1
190µm Thick Pkg
100µm (5mil)Si; 50µm SB; 40µm BSC
ASIC
MEMS
MEMS PKG
29


WLP Plus – TSV, MEMS & Stacking
ASE GROUP
WLCSP Innovation Examples
Die on die, thin die mounted on face of WLCSP, between perimeter solder balls
Used for WLCSP and WLCSP MEMS
TSVs for Backside connectivity for Power packages, including High Frequency Analog Amplifiers
WL IPDS
WL MEMS
ASIC
MEMS
MEMS PKG
Diplexer
30


Evolutionary Paths for FOWLP
ASE GROUP
Single Die FOWLP
Multi Die 2D FOWLP
Double sided 3D FOWLP
Module Assembly
Multi Die 2D with Passives
FOWLP
Double sided 3D FOWLP
Package on Package
(FOPOP)
31
31


3D aWLP Stacked POP
ASE GROUP
3D aWLP Bottom
490μm
3D aWLP Top
3D aWLP Stacked POP
32
32


Why Embedded?
ASE GROUP
Miniaturization, Miniaturization, Miniaturization
Performance: electrical, thermal
3D packaging
Emdedded Component Technology
ASE GROUP
Ultimate Objective
Miniaturization of SiP
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3
ASE TECH FORUM
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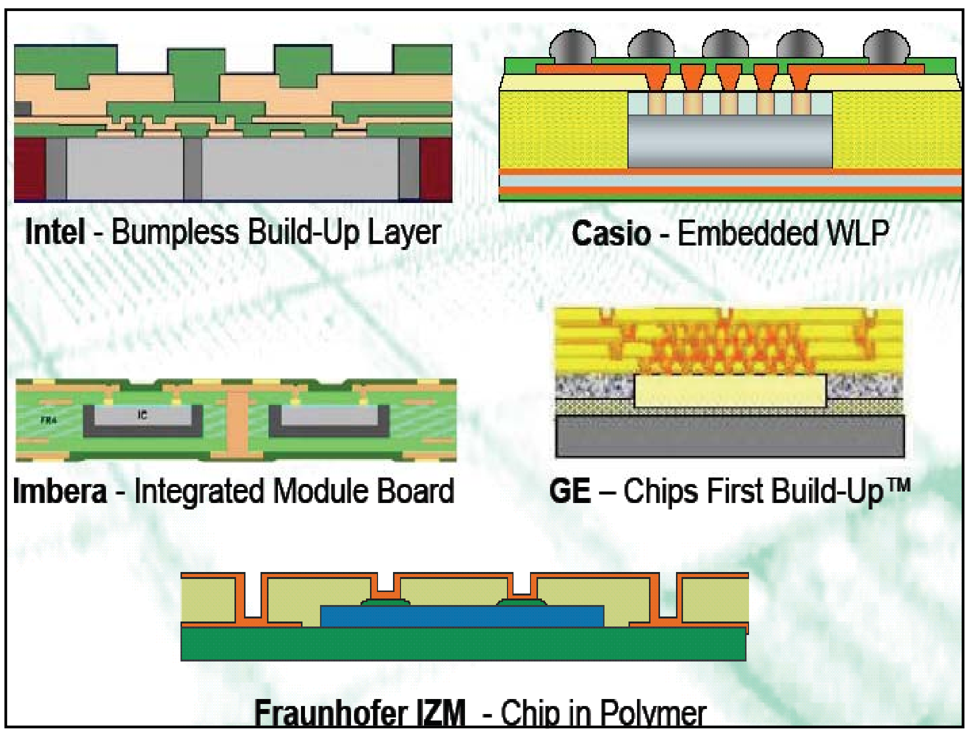
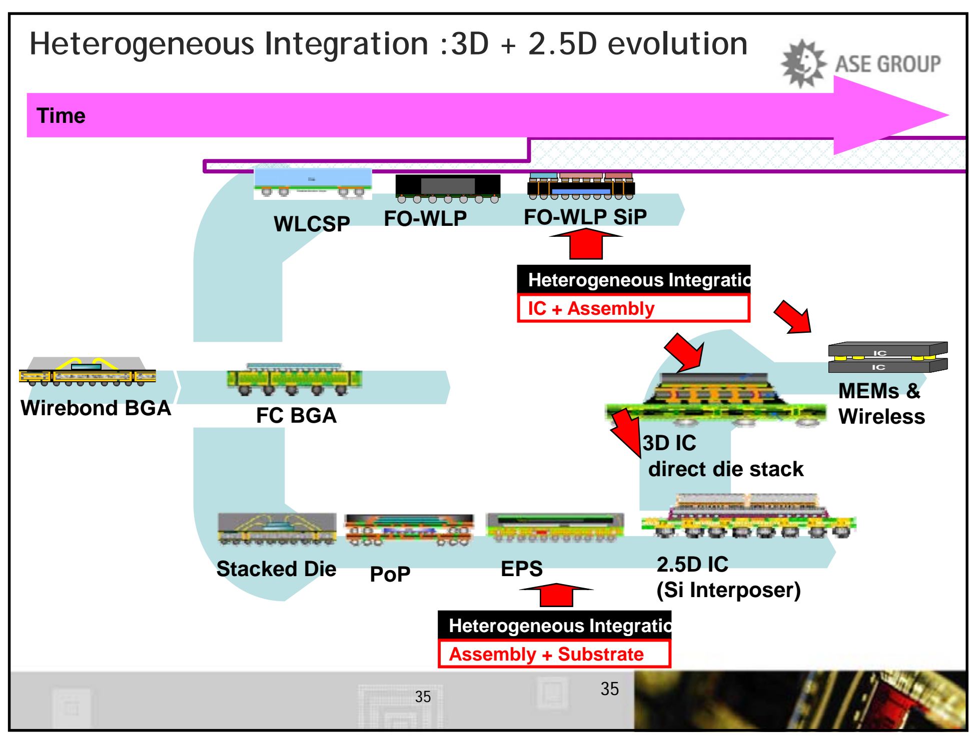
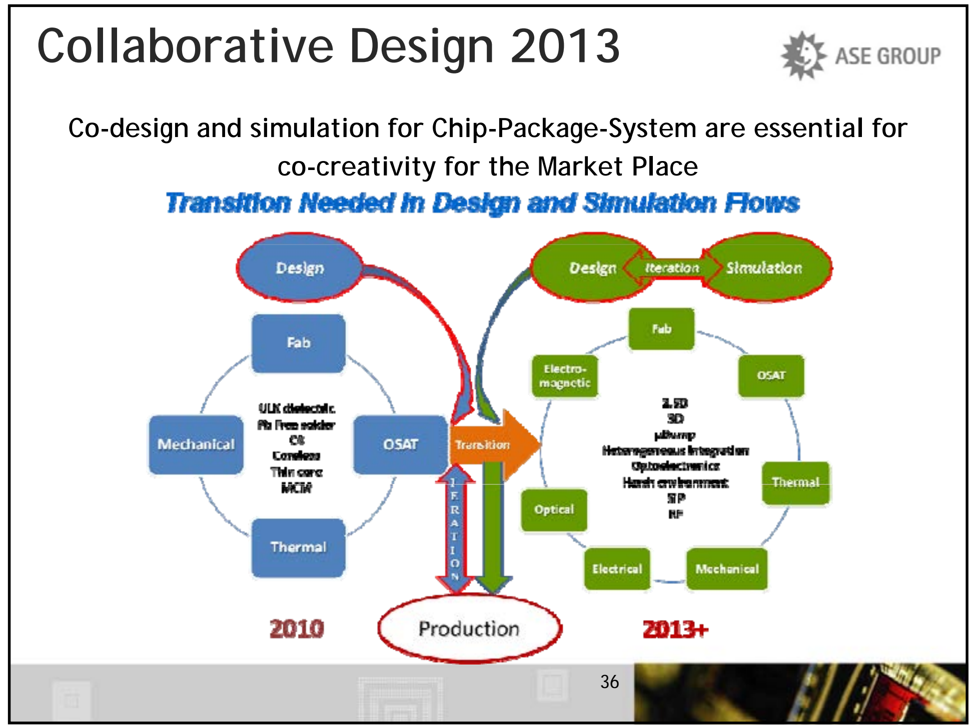

Intel - Bumpless Build-Up Layer
Casio - Embedded WLP
Imbera - Integrated Module Board
GE – Chips First Build-Up™
Fraunhofer IZM - Chip in Polymer



Heterogeneous Integration :3D + 2.5D evolution
ASE GROUP
Time
WLCSP
FO-WLP
FO-WLP SiP
Heterogeneous Integratio
IC + Assembly
Wirebond BGA
FC BGA
MEMs &
Wireless
3D IC
direct die stack
Stacked Die
PoP
EPS
2.5D IC
(Si Interposer)
Heterogeneous Integratio
Assembly + Substrate
35



Collaborative Design 2013
ASE GROUP
Co-design and simulation for Chip-Package-System are essential for
co-creativity for the Market Place
Transition Needed In Design and Simulation Flows
Design
Fab
Mechanical
OSAT
Thermal
ULK dielectric
Pb Free solder
CE
Coreless
Thin core
MCM
Transition
ITERATION
Design
Iteration
Simulation
Fab
Electro-magnetic
OSAT
Thermal
Optical
Electrical
Mechanical
2.5D
3D
µBump
Heterogeneous Integration
Optoelectronics
Harsh environment
SIP
RF
2010
Production
2013+
36

Roles in Collaborative Engineering

- Product Architect & Packaging Architect
  - Product integration Architecture & Design - Performance, Cost & schedule
  - Source multi diverse die devices for package integration
- Device Designer in Fabless and/or Fablite IDMs
  - Supply multi die device products
  - Co-design ecosystem
- Assembly & Packaging Engineer
  - Co-design ecosystem model - heterogeneous and multi foundry products
  - Assembly materials & processes
- Interposer foundry & substrate supplier
  - Co design and co-processing participation
- Material & Equipment Supplier Partnership
  - Optimal materials and equipment for HVM

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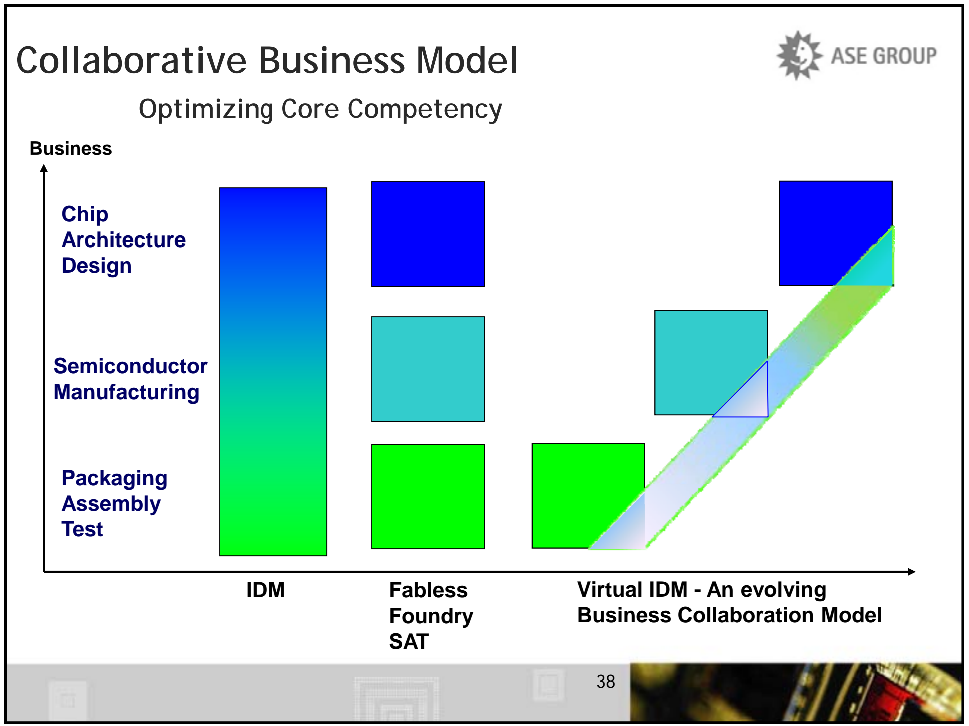
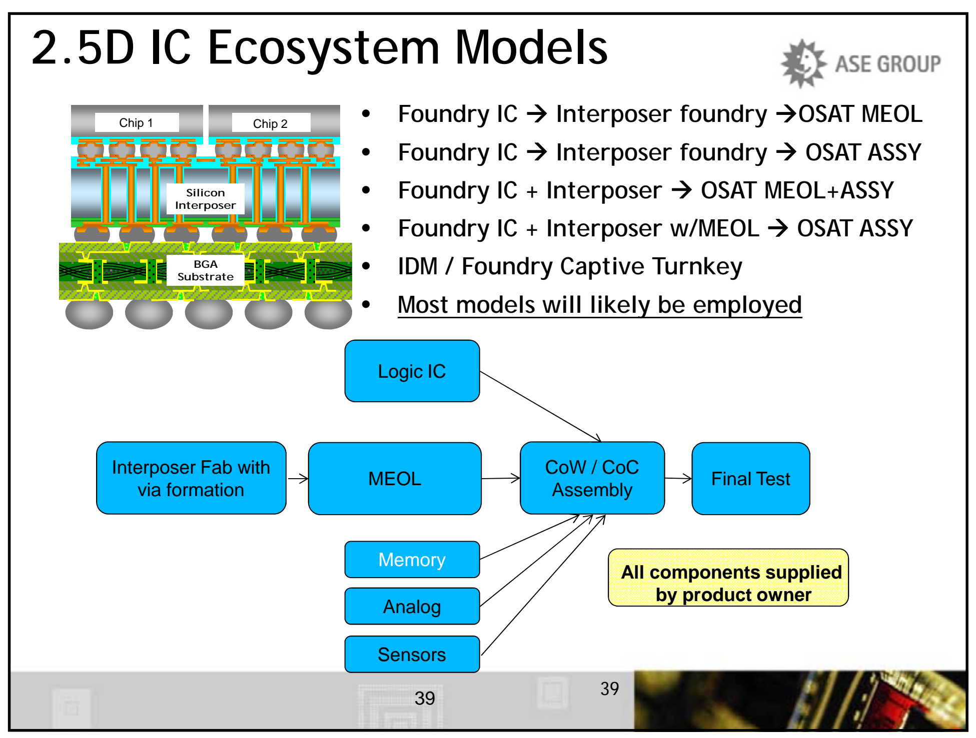
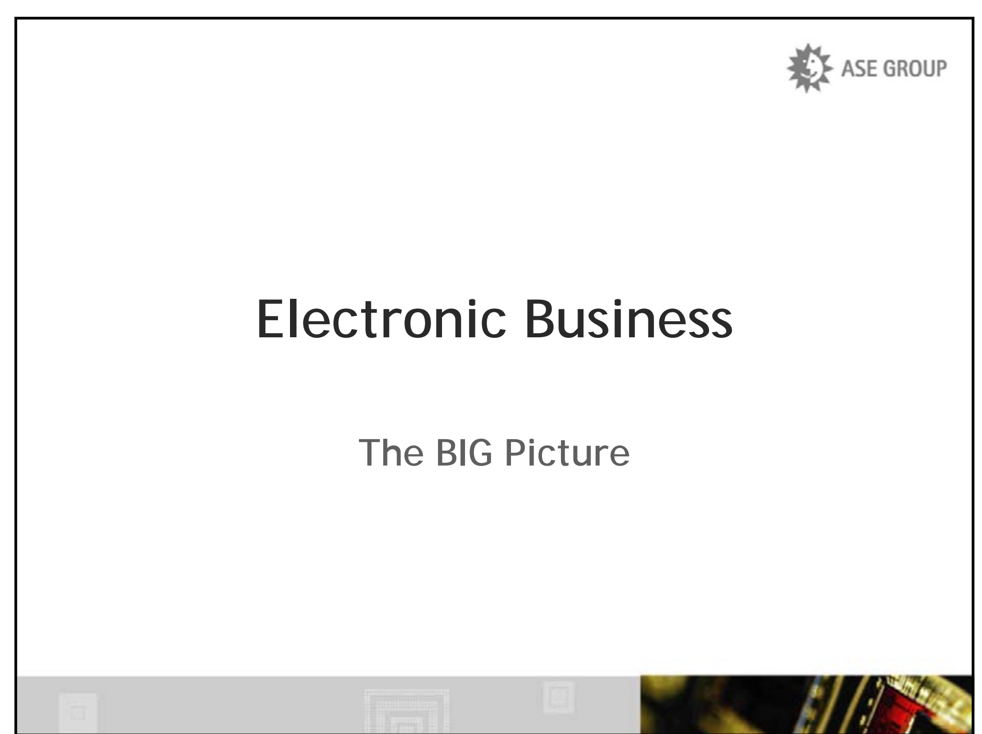
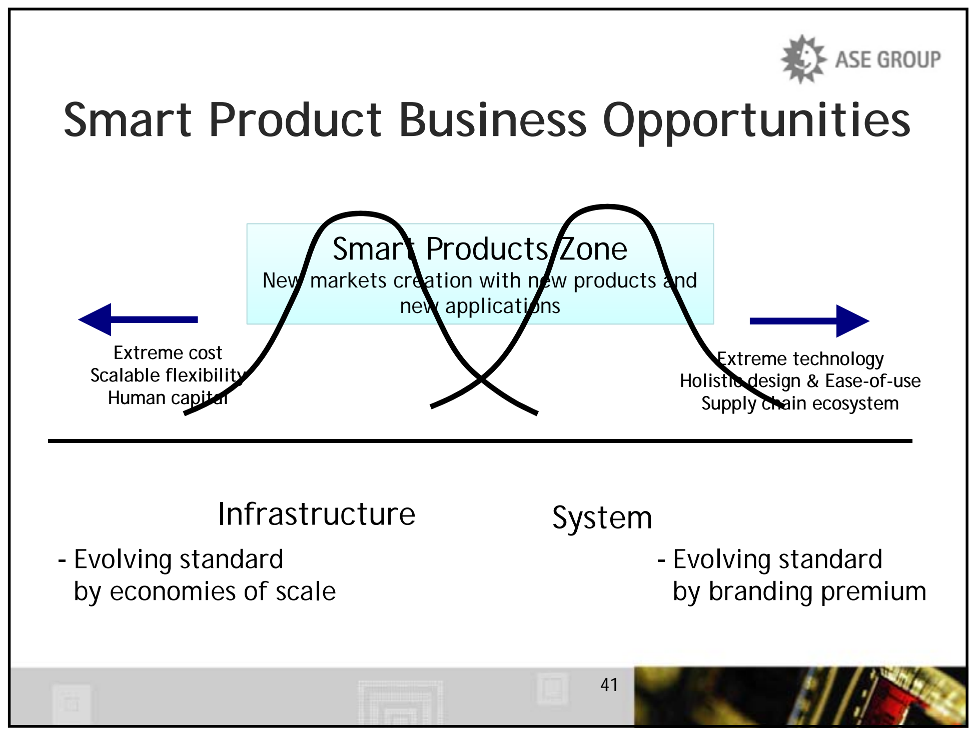
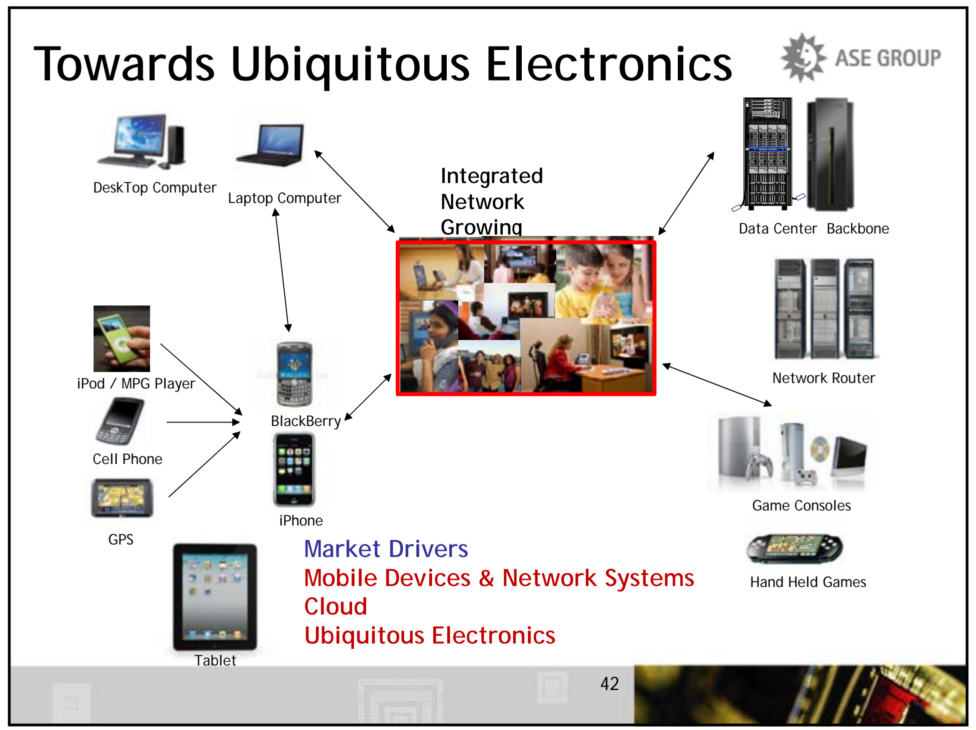


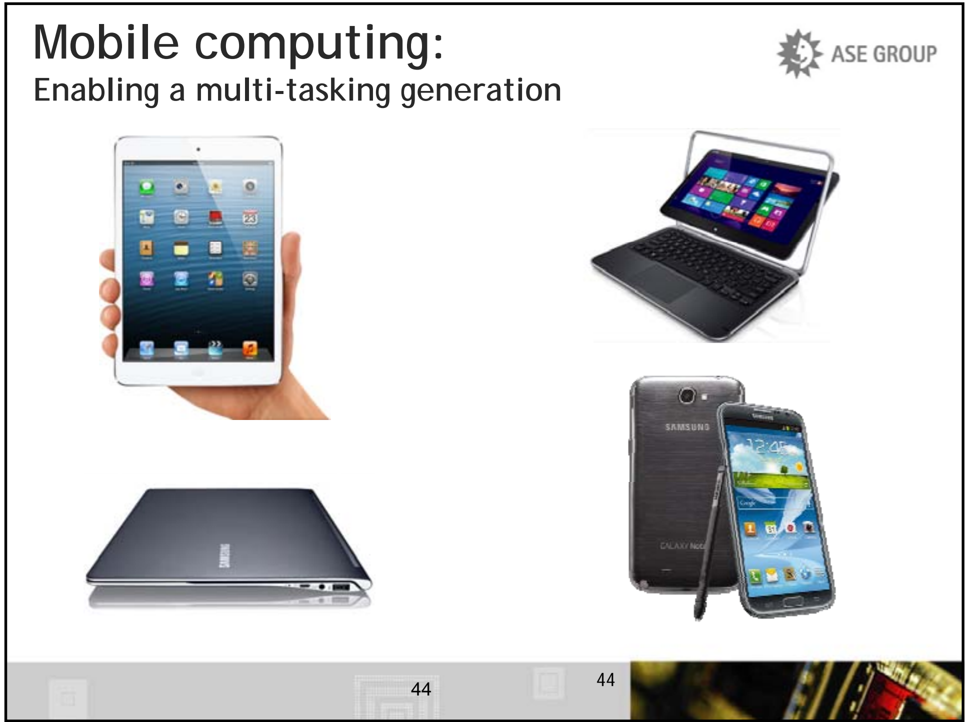

2.5D IC Ecosystem Models
ASE GROUP
Chip 1
Chip 2
Silicon Interposer
BGA Substrate
• Foundry IC → Interposer foundry →OSAT MEOL
• Foundry IC → Interposer foundry → OSAT ASSY
• Foundry IC + Interposer → OSAT MEOL+ASSY
• Foundry IC + Interposer w/MEOL → OSAT ASSY
• IDM / Foundry Captive Turnkey
• Most models will likely be employed
Logic IC
Interposer Fab with via formation
MEOL
CoW / CoC Assembly
Final Test
Memory
Analog
Sensors
All components supplied by product owner
39

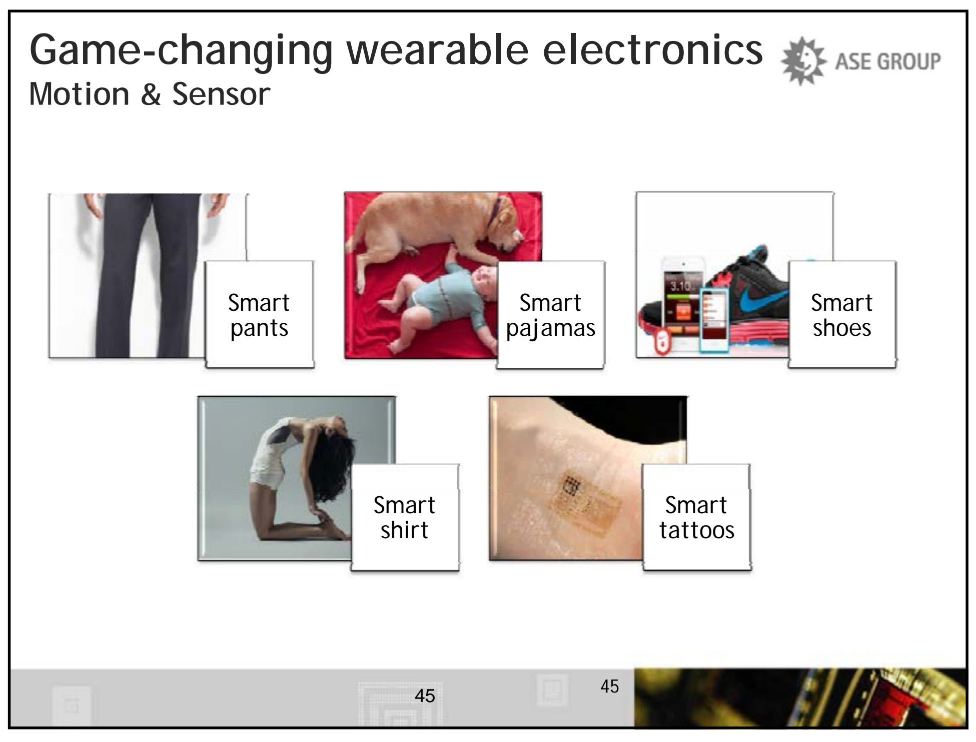

ASE GROUP
Electronic Business
The BIG Picture


ASE GROUP
Smart Product Business Opportunities
Smart Products Zone
New markets creation with new products and new applications
Extreme cost
Scalable flexibility
Human capital
Extreme technology
Holistic design & Ease-of-use
Supply chain ecosystem
Infrastructure
- Evolving standard
by economies of scale
System
- Evolving standard
by branding premium
41

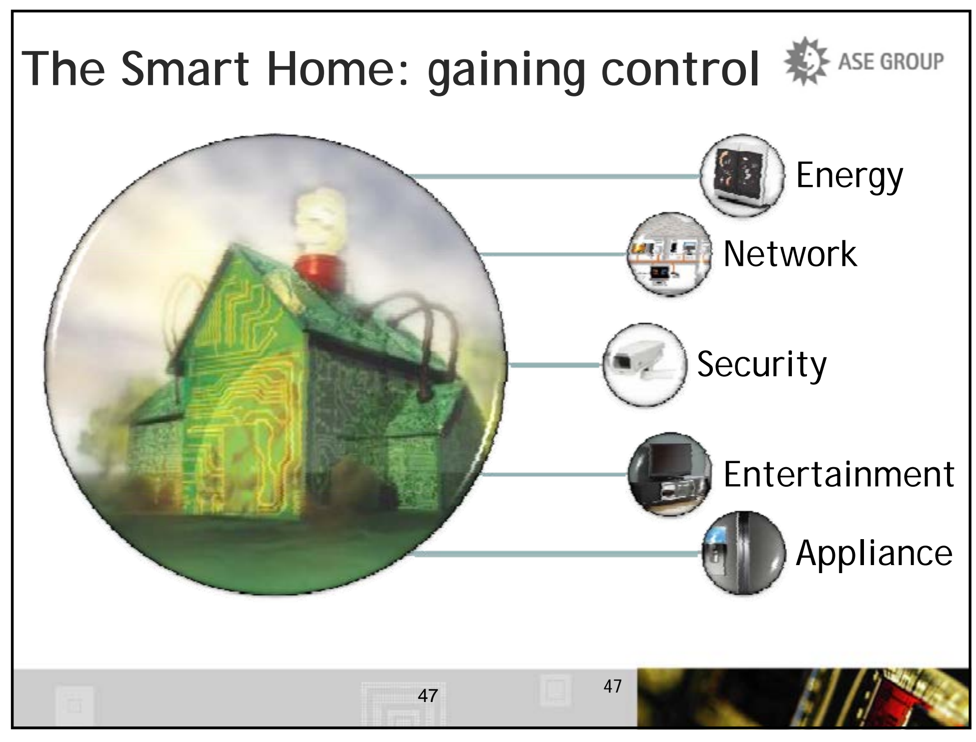

Towards Ubiquitous Electronics
ASE GROUP
DeskTop Computer
Laptop Computer
Integrated
Network
Growing
Data Center Backbone
Network Router
iPod / MPG Player
Cell Phone
GPS
BlackBerry
iPhone
Game Consoles
Hand Held Games
Tablet
Market Drivers
Mobile Devices & Network Systems
Cloud
Ubiquitous Electronics
42

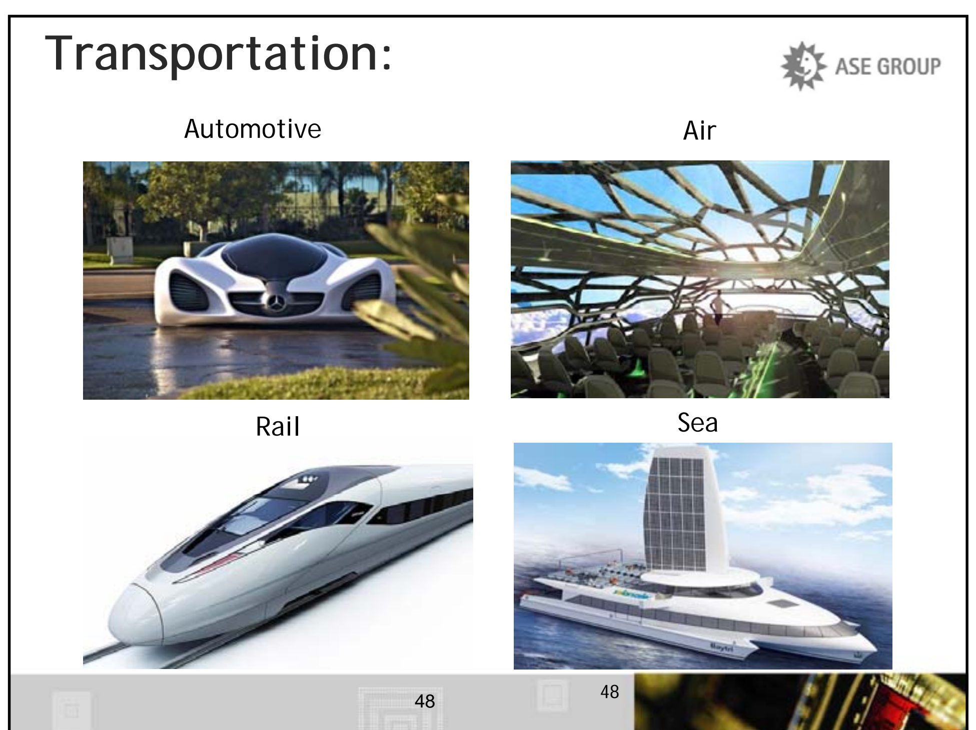
Generation Mobile:
The Personal Nerve Center
ASE GROUP
43
43


Mobile computing:
Enabling a multi-tasking generation
ASE GROUP
44
44


Game-changing wearable electronics
Motion & Sensor
ASE GROUP
Smart pants
Smart pajamas
Smart shoes
Smart shirt
Smart tattoos
45
45

Real-time health in 2013
ASE GROUP
Medical Immediacy
Vital signs
Glucose meters
Blood pressure monitors
Smart inhalers
Detecting & medicating
Healing
46
46


The Smart Home: gaining control
ASE GROUP
Energy
Network
Security
Entertainment
Appliance
47
47


Transportation:
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Automotive
Air
Rail
Sea
48
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Automotive:
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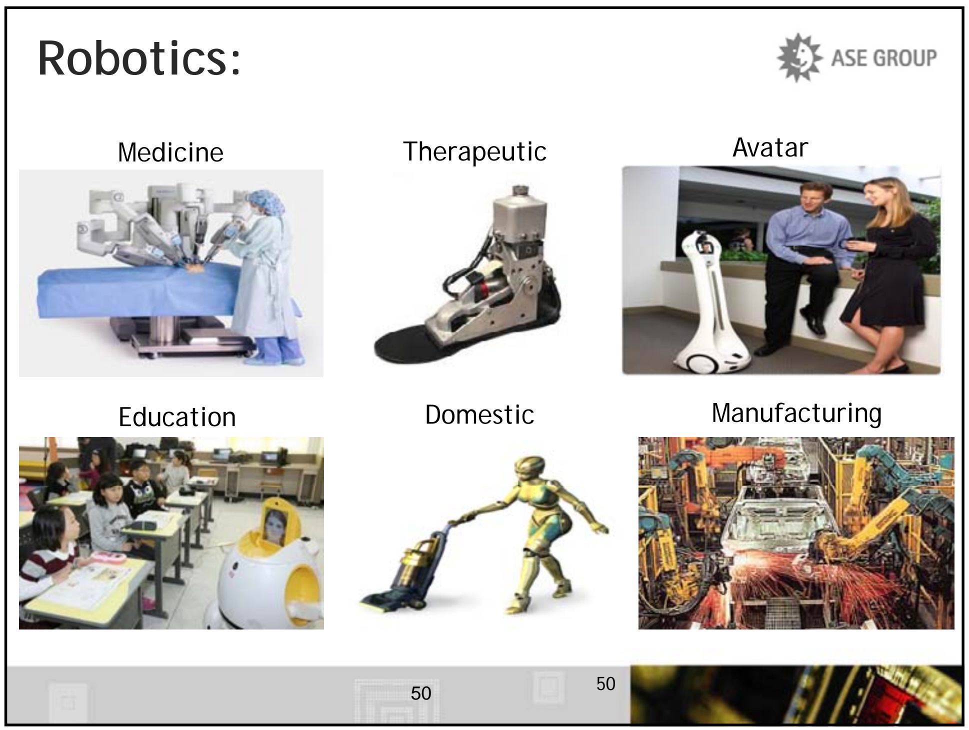
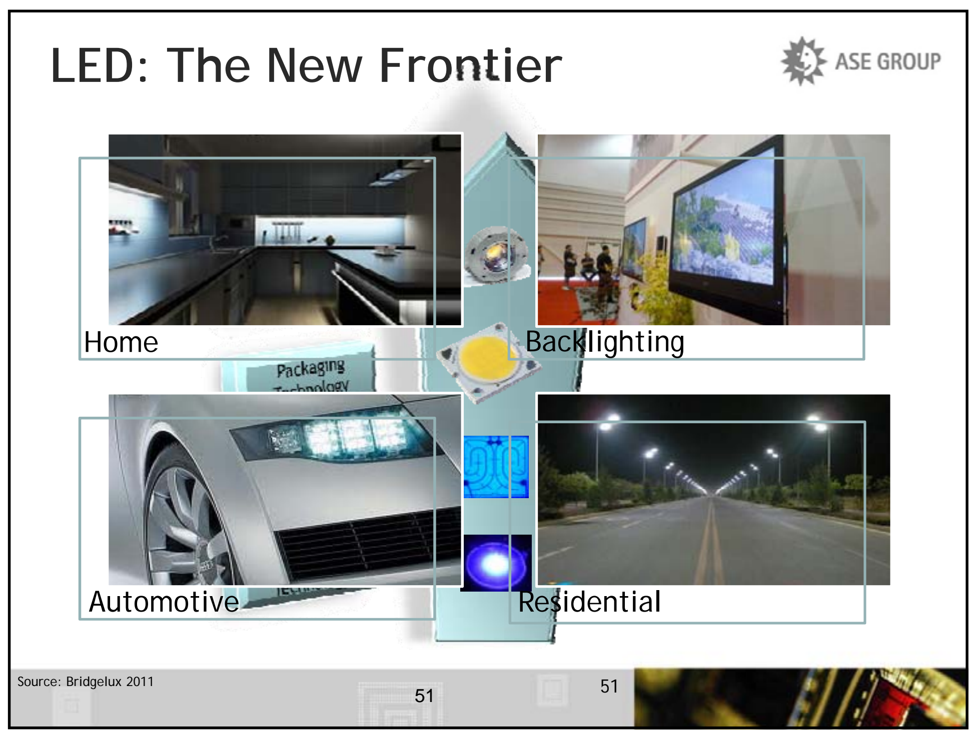
Chassis: braking systems, electronic power steering, active suspension
Body Electronics: Controlling body, seat, door, window, HVAC, lighting + remote
Networking & Communication: CAN, LIN, Flexray, Ethernet, 4G, social media partnerships
Safety: Airbags, electronic stability, collision detection
PASSENGER AIRBAG ON
Integrated Dashboard: augmented reality, infotainment, telematics
Source: Freescale 2012
49
49


Robotics:
ASE GROUP
Medicine
Therapeutic
Avatar
Education
Domestic
Manufacturing
50
50


LED: The New Frontier
ASE GROUP
Home
Backlighting
Packaging
Automotive
Residential
Source: Bridgelux 2011
51
51

The CPMT Profession
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"The transition from agriculture to manufacturing is still the route to higher productivity and rising living standard for developing economies. In advanced economies, manufactured goods stand as the tangible expression of innovation and competitiveness………… We see that a new era of innovation and opportunities promises to inspire a new generation of manufacturing professionals"
Manufacturing the Future: The next era of global growth & innovation
McKinsey Report November 2012
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Re-inventing the CPMT Engineer

- Understand business & market directions, and technology implications
- Mastering core packaging DNA
  - WB, FC, WLP, 2.5D & 3D, embedded, ………..
- Global Network
  - CPMT - Connecting Peers & Mentoring Talent
- Ecosystem Collaboration
  - Design & simulation tools, Materials & HVM equipment
- Practice engineering with both sides of our brain

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Co-Engineering with both sides of brain

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EXPERIENCE =
USABILITY/ANALYTIC + DESIGN/CREATIVE

Left-Brain Functions
Analytic thought
Logic
Language
Science and math

Right-Brain Functions
Holistic thought
Intuition
Creativity
Art and music

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Is collaboration a natural instinct?
For organizations? For individuals?

"With consolidation, competitive advantage shifted to those best at collaboration."

Dan Hutcheson, Jan 2013

"I want to put a Ding in the Universe"

Steve Jobs

Together we shall put our Dings in the Universe

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Summary

- The challenge for the electronics business lies firmly in the areas of technology complexity, business model, and market diversity.
- Packaging technology becomes a crucial enabler and gate. Innovation and re-invention are critical for success.
- CPMT professional stand at the front line of destructive market and technology inflection point.
- The need to reach out & engage in collaborative engineering is becoming paramount.

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Acknowledgement

I want to acknowledge the generous support from many colleagues at ASE Group for this presentation.

I want to thank Patricia Macleod for her great support.

This talk is presented under the auspices of CPMT Society Distinguished Lecturer program.

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