Welcome to the 26th Annual SW Test Workshop

Jerry Broz, Ph.D.

SW Test General Chair

June 5-8, 2016

SW-Test Workshop

- **SW Test is a Probe Technology Forum …**
  - Focused Technical Workshop for Wafer Test Professionals
  - Practical solutions to real problems
  - Balanced mixture of semiconductor manufacturer, and supplier as well as collaborative presentations

- **Informal Conference …**
  - Friendly workshop format focused on technical exchange
  - Great social activities to facilitate networking and informal discussions
  - Meet new people, talk about probe and technology, and **have some fun !**

- **SW Test pursues a "Green Initiative" …**
  - Downloadable eProceedings and enviro-friendly practices

Twenty-Six Years
of Probe Technology

Many thanks to all of the 8000+ attendees

from around the world !

SW Test Workshop - June 5-8, 2016

SW Test 2016 e-Proceedings ?

www.swtest.org

Password for Sunday = redwood
Password for Monday = bluespruce

- **SW Test Team continues to be focused on a green initiative.**

- **Each day of the workshop will be available for download in a password protected file.**
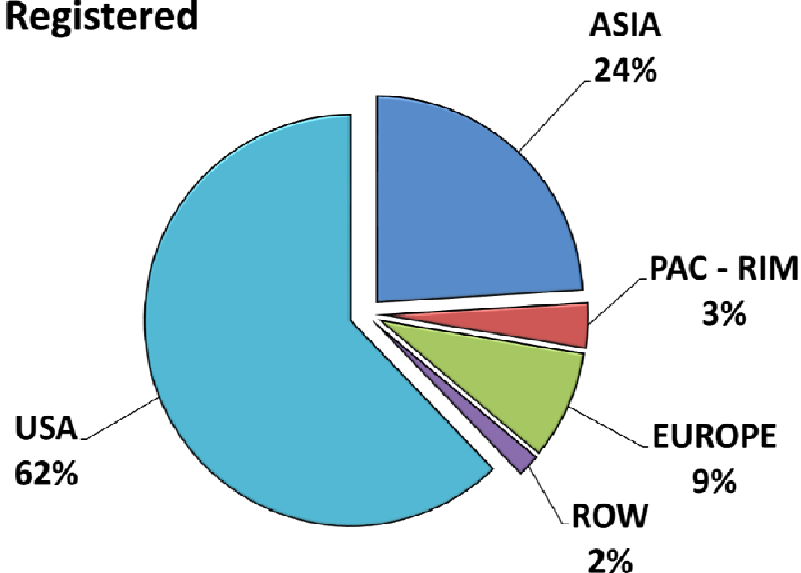
   http://www.swtest.org
   WiFi Password = aragon2016

- **WiFi will be available during the entire workshop to allow access to website for download.**

- **The daily PDF file password will be announced through the day.**
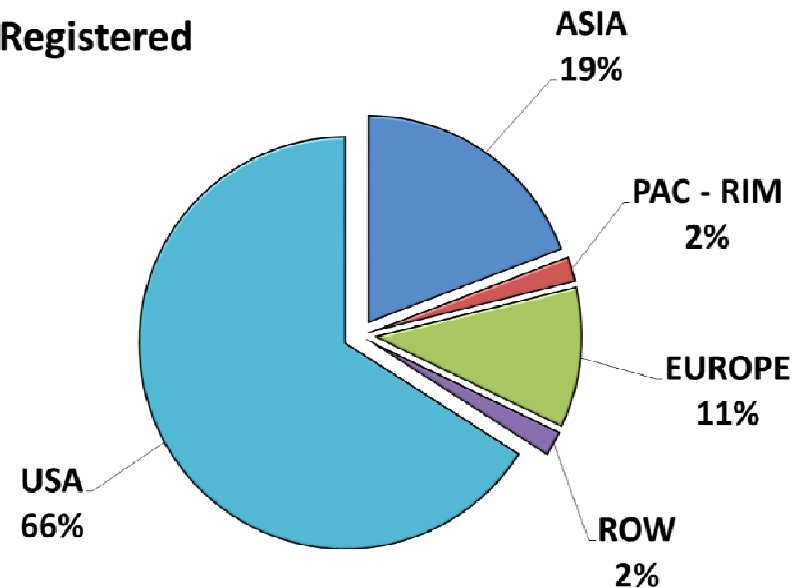
Attendance in 2016 is Strong !

2016
400 Registered

ASIA
24%

PAC - RIM
3%

EUROPE
9%

ROW
2%

USA
62%

2015
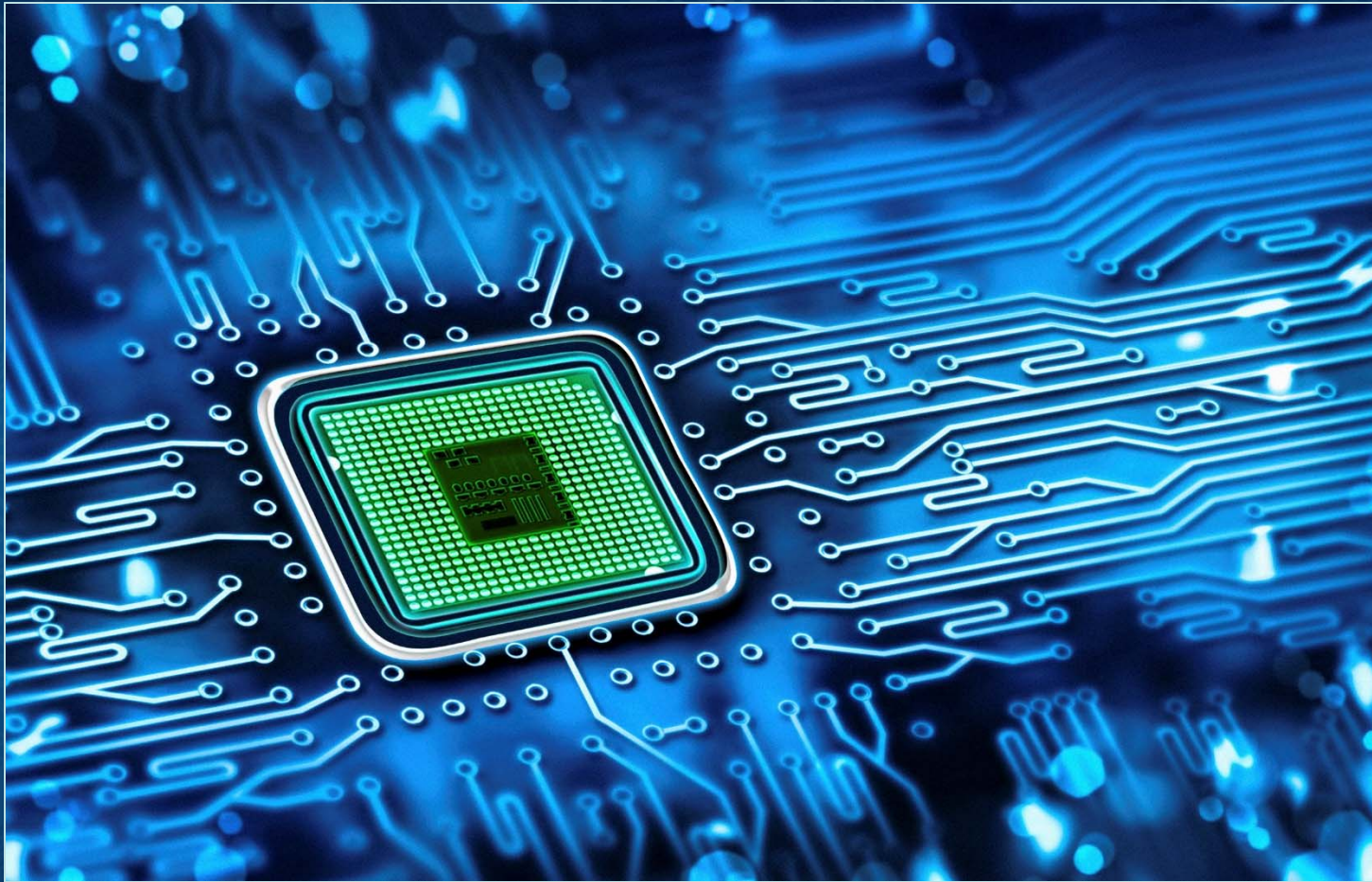**364 Registered**

ASIA
19%

PAC - RIM
2%

EUROPE
11%

ROW
2%

USA
66%

19 out of 32 Podium Presentations
have at least one international author !

Semiconductor Market Landscape

2015F Top 20 Semiconductor Sales Leaders
($M, Including Foundries)

2015F Rank	2014 Rank	Company	Headquarters	2014 Tot Semi	2015F Tot Semi	2015/2014 % Change	2015F @ 2014 Exch. Rates	2015/2014 % Change
1	1	Intel	U.S.	51,400	50,305	-2%	50,305	-2%
2	2	Samsung	South Korea	37,810	41,606	10%	44,776	18%
3	3	TSMC*	Taiwan	24,975	26,562	6%	27,798	11%
4	6	SK Hynix	South Korea	16,286	16,917	4%	18,206	12%
5	4	Qualcomm**	U.S.	19,291	15,632	-19%	15,632	-19%
6	5	Micron	U.S.	16,720	14,816	-11%	14,816	-11%
7	7	TI	U.S.	12,166	12,112	0%	12,112	0%
8	8	Toshiba	Japan	11,040	9,734	-12%	11,143	1%
9	9	Broadcom**	U.S.	8,428	8,421	0%	8,421	0%
10	15	Avago**	Singapore	5,644	6,961	23%	6,961	23%
11	13	Infineon (1)	Europe	5,938	6,898	16%	8,245	39%
12	10	ST	Europe	7,384	6,840	-7%	6,840	-7%
13	12	MediaTek**	Taiwan	7,032	6,504	-8%	6,807	-3%
14	17	Sony	Japan	5,292	5,885	11%	6,737	27%
15	14	NXP	Europe	5,647	5,790	3%	5,790	3%
16	11	Renesas	Japan	7,307	5,664	-22%	6,484	-11%
17	20	GlobalFoundries*(2)	U.S.	4,355	4,990	15%	4,990	15%
18	19	Nvidia**	U.S.	4,382	4,628	6%	4,628	6%
19	21	UMC*	Taiwan	4,331	4,474	3%	4,682	8%
20	18	Freescale	U.S.	4,548	4,410	-3%	4,410	-3%
—	—	Top 20 Total	—	259,976	259,149	0%	269,783	4%

*Foundry   **Fabless   (1) Includes $1.1B of International Rectifier sales in 2015.
(2) Includes $700M of IBM's semi sales in 2H15.

Merger "Fever" in 2016 (18 mergers) !

2015F Top 10 Post-Merger IDM Semiconductor Sales Leaders ($M)

2015F Rank	Company	Headquarters	2014 Tot IC	2014 Tot O-S-D	2014 Tot Semi	2015 Tot IC	2015 Tot O-S-D	2015 Tot Semi	2015/2014 % Change
1	Intel	U.S.	51,400	0	51,400	50,305	0	50,305	-2%
2	Samsung	South Korea	35,759	2,051	37,810	39,366	2,240	41,606	10%
3	SK Hynix	South Korea	15,798	488	16,286	16,437	480	16,917	4%
4	Micron	U.S.	16,720	0	16,720	14,816	0	14,816	-11%
5	TI	U.S.	11,431	735	12,166	11,370	742	12,112	0%
6	NXP/Freescale*	Europe	7,718	2,477	10,195	7,775	2,425	10,200	0%
7	Toshiba	Japan	9,385	1,655	11,040	8,469	1,265	9,734	-12%
8	Infineon/IR*	Europe	4,380	2,696	7,076	4,131	2,746	6,877	-3%
9	ST	Europe	5,468	1,916	7,384	5,020	1,820	6,840	-7%
10	Sony	Japan	1,122	4,170	5,292	840	5,045	5,885	11%
—	Top 10 Total		159,181	16,188	175,369	158,529	16,763	175,292	0%

*Includes both companies' sales for all of 2014 and 2015.

2015F Top 10 Post-Merger Fabless Semiconductor Sales Leaders ($M)

2015F Rank	Company	Headquarters	2014 Tot IC	2014 Tot O-S-D	2014 Tot Semi	2015F Tot IC	2015F Tot O-S-D	2015F Tot Semi	2015/2014 % Change
1	Qualcomm/CSR*	U.S.	20,066	0	20,066	16,032	0	16,032	-20%
2	Avago/Broadcom*	Singapore	12,957	1,115	14,072	13,922	1,460	15,382	9%
3	MediaTek	Taiwan	7,032	0	7,032	6,504	0	6,504	-8%
4	Nvidia	U.S.	4,382	0	4,382	4,628	0	4,628	6%
5	AMD	U.S.	5,506	0	5,506	3,988	0	3,988	-28%
6	HiSilicon	China	3,220	0	3,220	3,830	0	3,830	19%
7	Apple/TSMC	U.S.	1,460	0	1,460	3,085	0	3,085	111%
8	Marvell	U.S.	3,733	0	3,733	2,875	0	2,875	-23%
9	Xilinx	U.S.	2,429	0	2,429	2,175	0	2,175	-10%
10	Spreadtrum	China	1,340	0	1,340	1,880	0	1,880	40%
—	Top 10 Total		62,125	1,115	63,240	58,919	1,460	60,379	-5%

*Includes both companies' sales for all of 2014 and 2015.

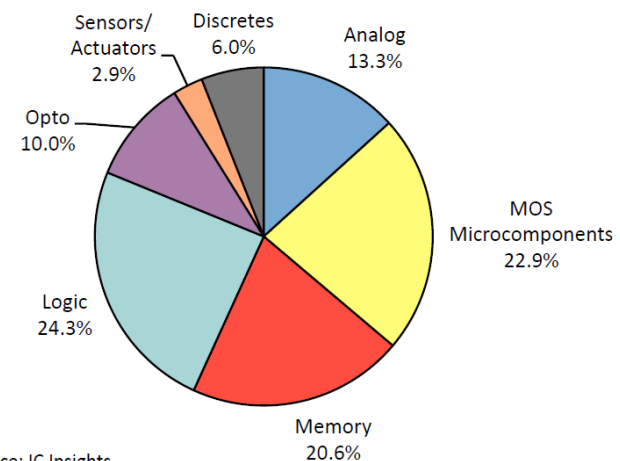Source: Company reports, IC Insights' *Strategic Reviews* database

Overall Semi Industry Trending

Product Category	2015	2016F
Cellphone App MPUs	8%	10%
Signal Conversion	14%	10%
32-bit MCU	13%	8%
Display Drivers	10%	6%
General Purpose Logic	9%	6%
NAND Flash	2%	6%
Wired Comm—App-Specific Analog	12%	6%
Wired Comm—Spcl Purpose Logic	0%	6%
Wireless Comm—App-Specific Analog	9%	6%
Auto—App-Specific Analog	-1%	5%
Auto—Spcl Purpose Logic	-7%	5%
Power Management Analog	2%	5%
PLDs	-10%	3%
Wireless Comm—Spcl Purpose Logic	-5%	3%
Amplifiers/Comparators	-4%	2%
Computer and Peripherals—Spcl Purpose Logic	1%	2%
Industrial/Other—App-Specific Analog	-15%	2%
Std PC, Server, etc. MPUs*	-2%	2%
Tablet MPUs	-10%	2%
Total IC Market	**-1%**	**2%**

| Product Category	2015	2016F
Interface	-1%	1%
Computer—App-Specific Analog	-3%	-2%
Consumer—App-Specific Analog	-3%	-2%
Consumer—Special Purpose Logic	-10%	-2%
4-/8-bit MCU	-12%	-3%
DSP	-7%	-4%
16-bit MCU	-10%	-5%
EEPROM/ROM/EPROM/Other	-11%	-5%
Standard Cell	-9%	-6%
DRAM	-3%	-8%
Industrial/Other—Spcl Purpose Logic	-15%	-9%
NOR Flash	-23%	-11%
SRAM	-20%	-13%
Gate Array	-29%	-20%

*Includes embedded processors but does not include graphics processors.

Source: IC Insights

(2015 Semiconductor Market, $353.7 Billion)

Analog 13.3%
MOS Microcomponents 22.9%
Memory 20.6%
Logic 24.3%
Opto 10.0%
Sensors/Actuators 2.9%
Discretes 6.0%

Source: IC Insights

Worldwide IC Overview - End Market

Worldwide semiconductor consumption market by region, 2003–2014
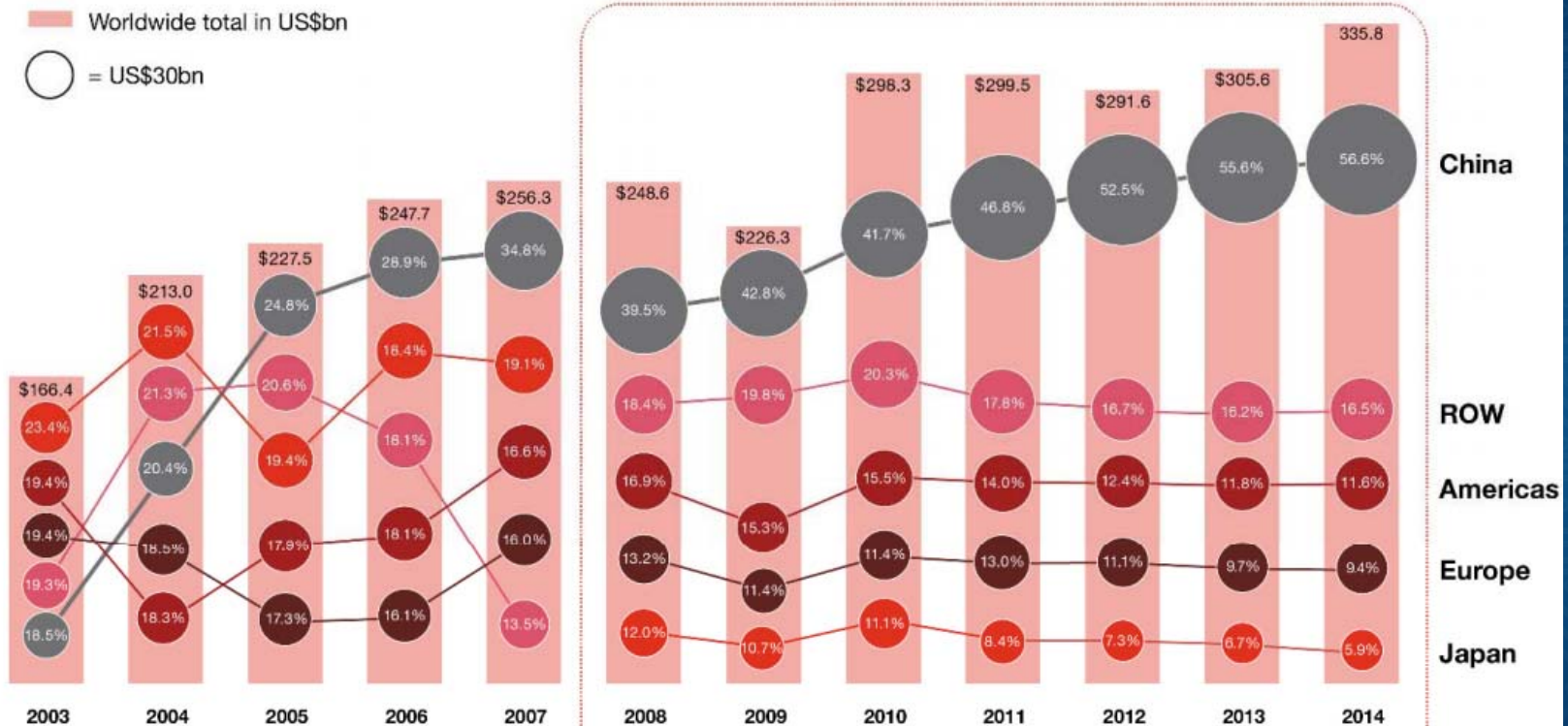
WW Wafer Capacity – Taiwan becomes No. 1 !

Wafer Capacity at Dec-2015 – by Geographic Region
(Monthly Installed Capacity in 200mm-equivalents)
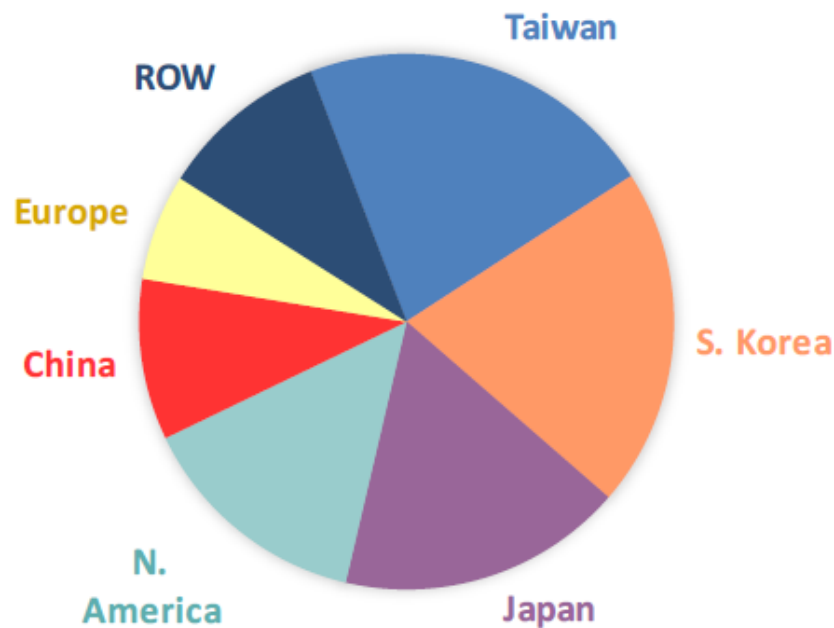
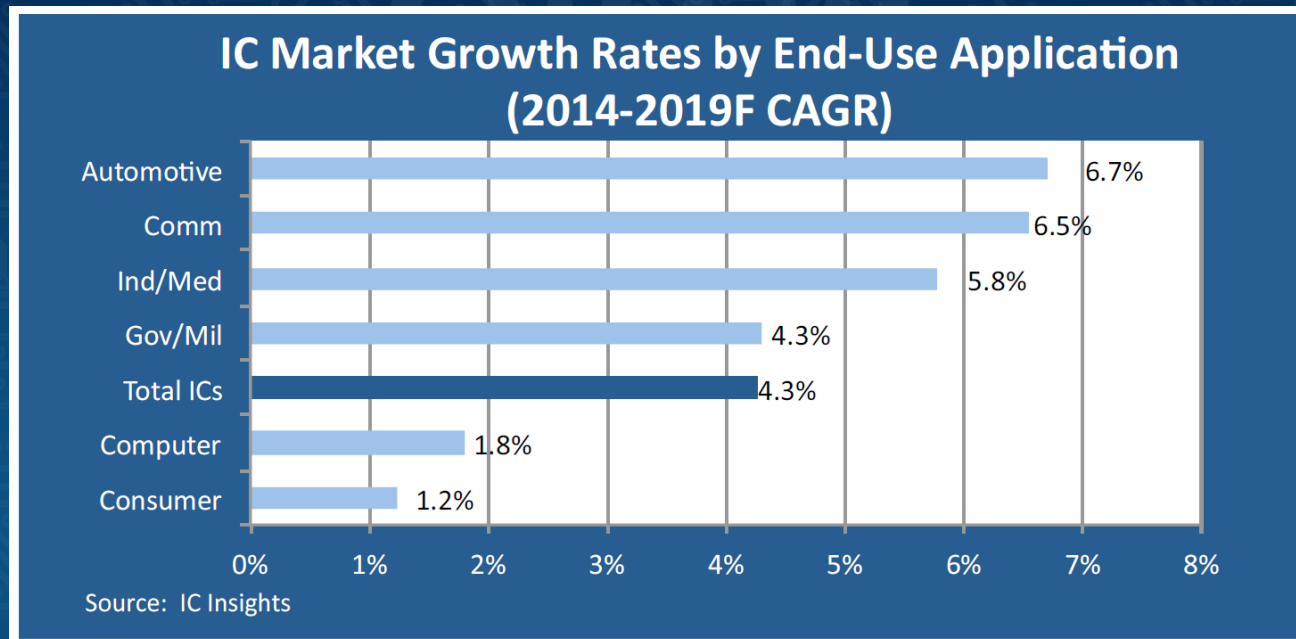| Region	Installed Capacity (K w/m)	% of Worldwide Total
Taiwan	3,547	21.7%
S. Korea	3,357	20.5%
Japan	2,824	17.3%
N. America	2,320	14.2%
China	1,591	9.7%
Europe	1,046	6.4%
ROW	1,665	10.2%
TOTAL	16,350	100%

Source: IC Insights

Slowed Growth is the 2016 Forecast

- **Worldwide semiconductor market is forecasted to be up 1.4% to US$341 billion in 2016, and up to 3.1% to US$352 billion in 2017.**

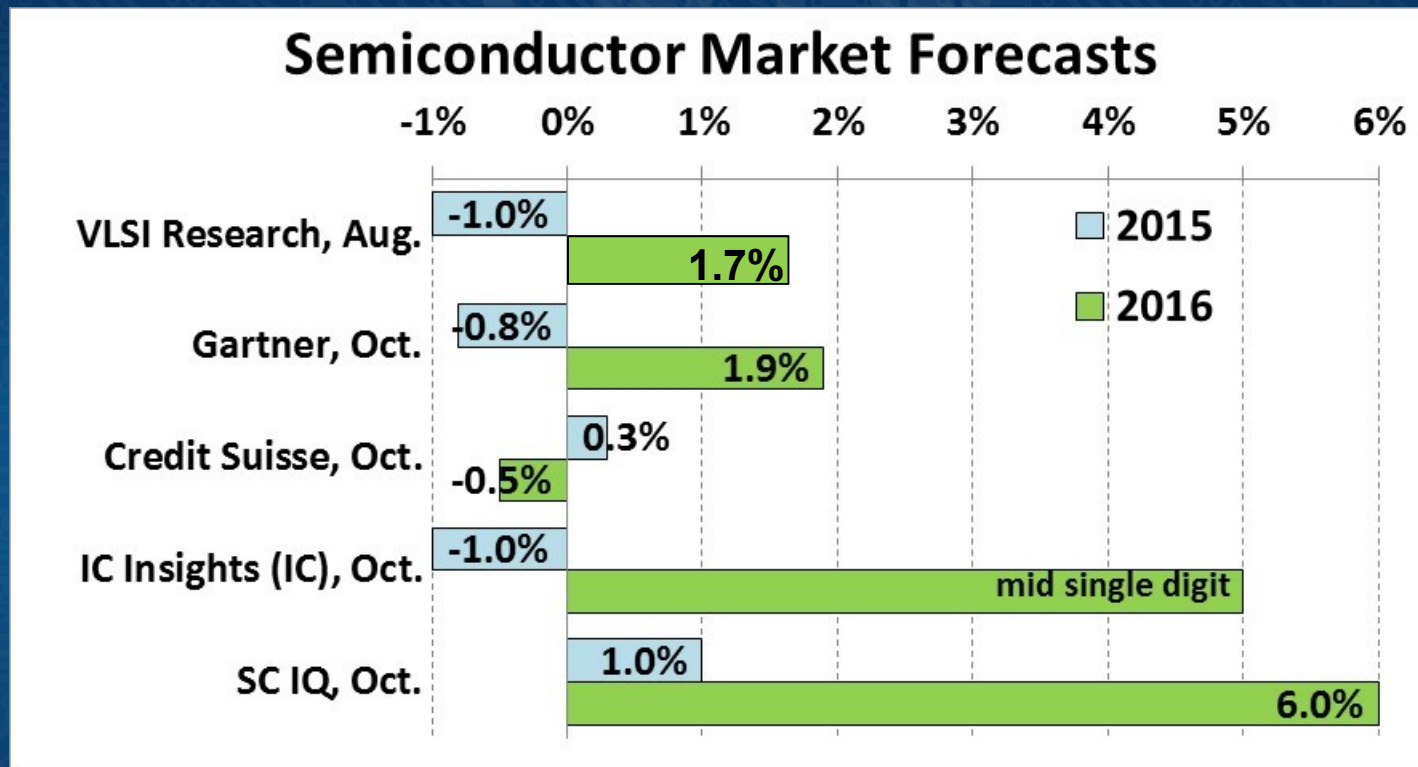| Autumn 2015	Amounts in US$M				Year on Year Growth in %			
	2014	2015	2016	2017	2014	2015	2016	2017
Americas	69,324	68,930	70,516	73,072	12.7	-0.6	2.3	3.6
Europe	37,459	34,388	34,355	35,331	7.4	-8.2	-0.1	2.8
Japan	34,830	31,251	31,564	32,203	0.1	-10.3	1.0	2.0
Asia Pacific	194,230	201,823	204,576	210,990	11.4	3.9	1.4	3.1
Total World - $M	335,843	336,392	341,011	351,596	9.9	0.2	1.4	3.1
Discrete Semiconductors	20,170	18,794	18,902	19,584	10.8	-6.8	0.6	3.6
Optoelectronics	29,868	33,493	35,269	36,895	8.3	12.1	5.3	4.6
Sensors	8,502	8,789	9,024	9,366	5.8	3.4	2.7	3.8
Integrated Circuits	277,302	275,316	277,816	285,752	10.1	-0.7	0.9	2.9
Analog	44,365	45,483	47,027	48,953	10.6	2.5	3.4	4.1
Micro	62,072	61,170	63,047	64,474	5.8	-1.5	3.1	2.3
Logic	91,633	90,212	91,753	93,785	6.6	-1.6	1.7	2.2
Memory	79,232	78,450	75,989	78,539	18.2	-1.0	-3.1	3.4
Total Products - $M	335,843	336,392	341,011	351,596	9.9	0.2	1.4	3.1

WSTS tabulates its semi-annual industry forecast by convening an extensive group of global semiconductor companies that provide accurate and timely indicators of semiconductor trends.

Projected IC Growth by Application

IC Market Growth Rates by End-Use Application (2014-2019F CAGR)

Application	CAGR
Automotive	6.7%
Comm	6.5%
Ind/Med	5.8%
Gov/Mil	4.3%
Total ICs	4.3%
Computer	1.8%
Consumer	1.2%

Source: IC Insights

- **Automotive, Comm, Ind Medical and Gov / Mil Products have most demanding test conditions.**

- **Automotive IC market is forecast to grow at ~7% in 2016 !**
  - Analog ICs (44%) and MCUs (30%) largest IC product categories in automotive market.
  - Automotive memory to increase while memory market (as a whole) is expected to decline.
  - Growth in automotive market IC product categories is expected in the Asia Pacific region.

Overall Industry Expectations for 2016

Semiconductor Market Forecasts

	-1%	0%	1%	2%	3%	4%	5%	6%

VLSI Research, Aug.
- 2015: -1.0%
- 2016: 1.7%

Gartner, Oct.
- 2015: -0.8%
- 2016: 1.9%

Credit Suisse, Oct.
- 2015: 0.3%
- 2016: -0.5%

IC Insights (IC), Oct.
- 2015: -1.0%
- 2016: mid single digit

SC IQ, Oct.
- 2015: 1.0%
- 2016: 6.0%

Legend: ☐ 2015 ☐ 2016

WW semiconductor market is forecasted to be up <u>1.5 to 2% in 2016</u>

Total Units Expected to Exceed 1 Trillion (10^{12})

Tracking Semiconductor Unit Growth
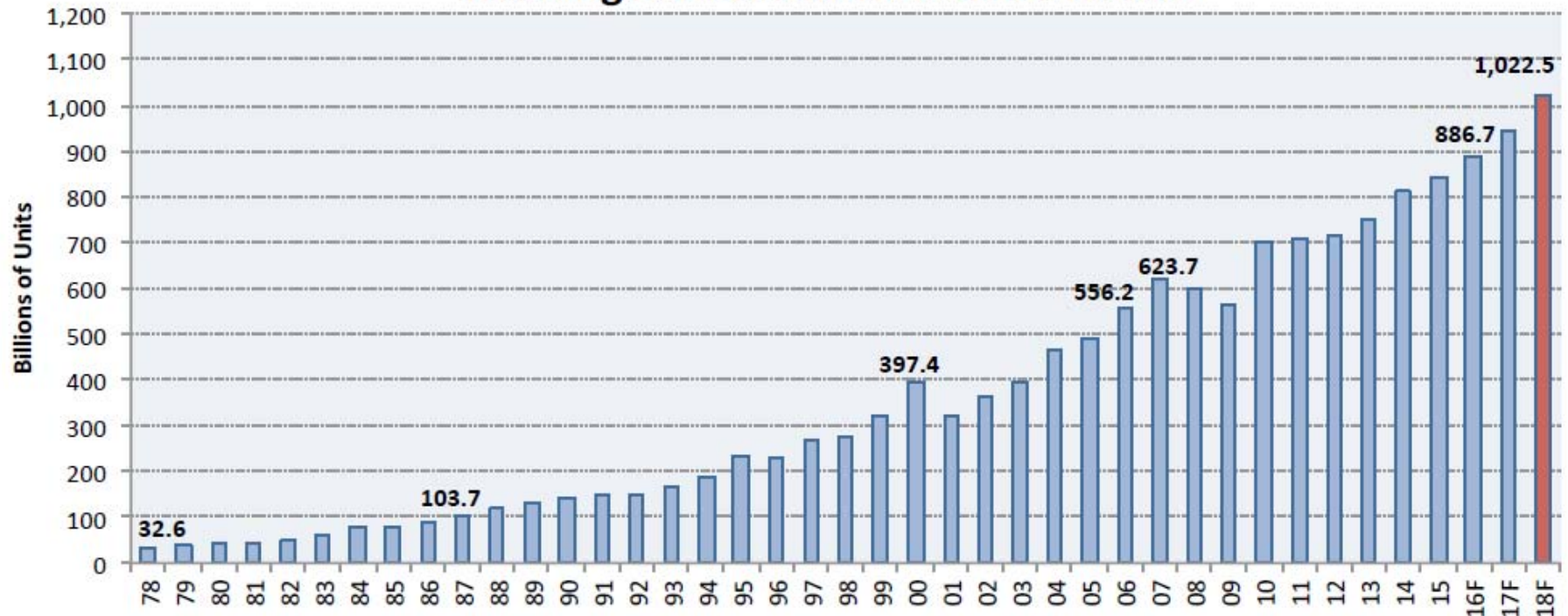
Source: IC Insights

Total Units Expected to Exceed 1 Trillion (10^{12})

1 trillion = 1,000,000,000,000

- The United States has not existed for a trillion seconds

- Western Civilization has not been around for a trillion seconds

- 1 trillion seconds (or 31,688) years ago Neanderthals stalked the plains of Europe
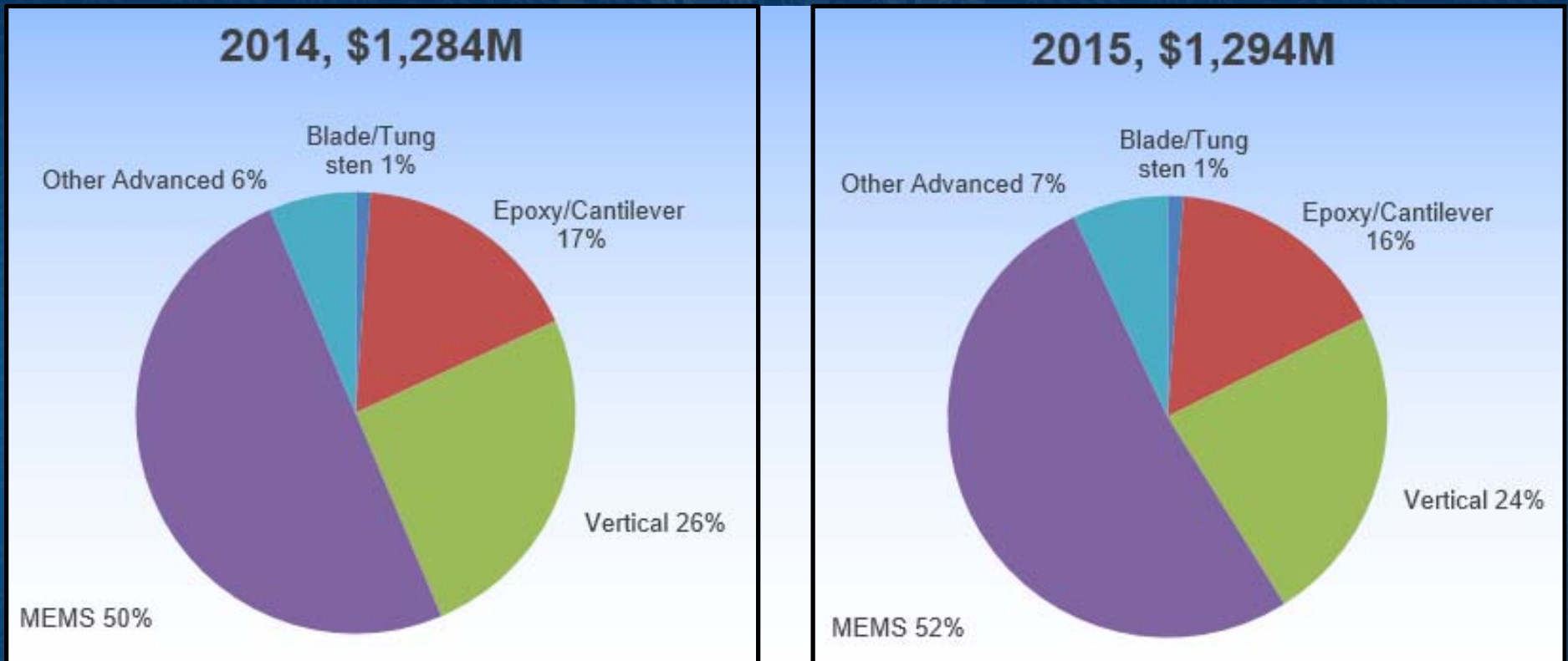
Probe Card Revenues
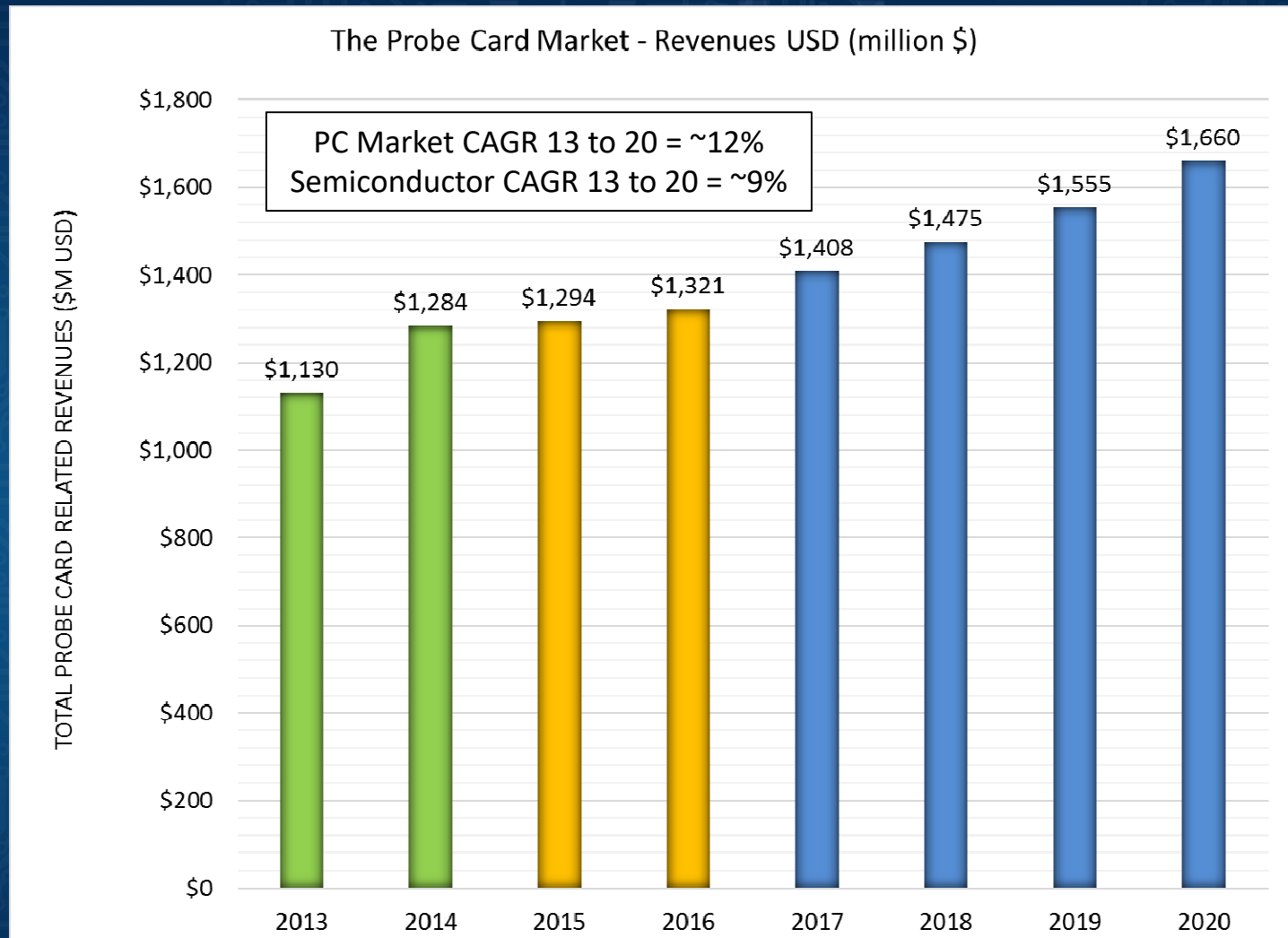
The Probe Card Market - Revenues USD (million $)

PC Market CAGR 13 to 20 = ~12%
Semiconductor CAGR 13 to 20 = ~9%

2013: $1,130
2014: $1,284
2015: $1,294
2016: $1,321
2017: $1,408
2018: $1,475
2019: $1,555
2020: $1,660

Y-axis: TOTAL PROBE CARD RELATED REVENUES ($M USD)

Thanks to John West and Risto Puhakka!

J. Broz

Revenue by Technology

2014, $1,284M

- Other Advanced 6%
- Blade/Tungsten 1%
- Epoxy/Cantilever 17%
- Vertical 26%
- MEMS 50%

2015, $1,294M

- Other Advanced 7%
- Blade/Tungsten 1%
- Epoxy/Cantilever 16%
- Vertical 24%
- MEMS 52%

Thanks to John West and Risto Puhakka!

Top Probe Card Vendors

Top 10 Semiconductor Probe Card Vendors 2015
Revenues in $M, Calendar Year (excludes service and spares)

Rank 2015	Rank 2014	Company	2014	2015	% Change
1	(1)	FormFactor, Inc.	269	282	**4.8%**
2	(2)	Micronics Japan Co., Ltd.	220	230	**4.5%**
3	(3)	Technoprobe	105	119	**13.3%**
4	(4)	Japan Electronic Materials	95	102	**7.4%**
5	(5)	MPI Corporation	83	77	**-7.2%**
6	(7)	Cascade Microtech	52	65	**25.0%**
7	(9)	SV TCL	43	45	**4.7%**
8	(10)	Will Technology	36	38	**5.6%**
9	(6)	Korea Instrument	56	37	**-33.9%**
10	(8)	Microfriend	51	33	**-35.3%**
		Other	274	266	**-2.9%**
		Semiconductor Probe Cards	1284	1294	**0.8%**

Thanks to John West and Risto Puhakka!

J. Broz

SW Test Workshop - June 5-8, 2016

26th Annual SW Test Workshop

- **Technical Program for 2016**
  - Technical Tutorial on Sunday
  - Nine Focused Technical Sessions across three days
  - 32 Podium Presentations and a Panel Discussion

- **Products / Services EXPO**
  - 42 full size booths … SOLD OUT !
  - EXPO does not compete with Technical Program

- **Corporate Support Program … MANY THANKS !**

Platinum Sponsors

Gold and Silver Sponsors

Gold Sponsors

GOLD SPONSOR	GOLD SPONSOR	GOLD SPONSOR
STAr Technologies	SV TCL — An SV Probe Company	SYNERGIE CAD PROBE

Silver Sponsors

SILVER SPONSOR	SILVER SPONSOR	SILVER SPONSOR	SILVER SPONSOR
Acme Technology, Inc. — Quality Probe Needle Solutions	TEL	PacTech	ADVANCED PROBING SYSTEMS Inc

"We're not in it for the money …"

- **SW Test Team has worked closely with the RBI staff such that every attendee has free parking, in-room internet, no resort fees, WiFi access during the workshop, and the best on-site conference room rate for this level of property.**

- **SW Test Executive Team …**
  - Jerry Broz, Ph.D., General Chair and Sr. Member IEEE
  - Rey Rincon, Freescale Semiconductor, Technical Program Chair
  - Maddie Harwood, CEM Inc., Finance Chair & Registration Coordinator

"Who's Really to Blame …"

- **Program Committee …**
  - John Caldwell (Micron Technology)
  - Darren James (Rudolph Technologies)
  - Gary Maier (IBM)
  - Patrick Mui (JEM America)

- **Steering Committee …**
  - Gunther Boehm (FeinMetall GmbH)
  - Michael Huebner, Ph.D. (FormFactor)
  - Amy Leong (Formfactor)
  - Clark Liu (PTI)
  - Mark Ojeda (Spansion)
  - Fred Taber (Taber Consulting)
  - Joey Wu (MPI)
  - Karen Armendariz (Celadon Systems)
  - Stevan Hunter, Ph.D. (ON Semi / BYU Idaho)
  - Al Wegleitner (Texas Instruments)
  - Sang Kyu (SK) Yoo (Samsung Electronics – Korea

SW Test is organized, coordinated, and executed through the efforts of your colleagues.

Technical Program / Agenda

- **Sunday, June 3**

  – Technical Tutorial by ON Semiconductor (US and Philippines)

  - **Tutorial on the Effects of Probe Marks on Wirebonding**
    – Stevan Hunter, Ph.D., Priscila Brown, and Rachel Wynder
  - **Analysis for Pre-Mature Worn-out of Vertical Probe Needle**
    – Wiljelm Carl K. Olalia
  - **Understanding the Probe Damage Risk thru Determination of Minimum Bond Pad Opening**
    – Wiljelm Carl K. Olalia
  - **Reducing Probe Needle Damage on Bond Pad Using Six Sigma Methodology**
    – Glenn T. Placido

  – Keynote Presentation by Friedrich Taenzler, Ph.D. (TI)

Keynote Speaker

Friedrich Taenzler, Ph.D.

RF-Engineering Manager
Texas Instruments, Inc.
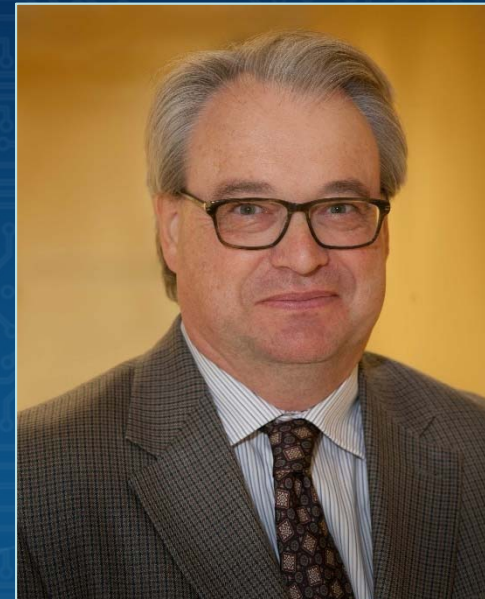
Test and Validation in an Analog and Embedded Environment

Challenges, Limitations, and Future in Test Development Process

SW Test Workshop - June 5-8, 2016

Technical Program / Agenda

- **Monday, June 6**
  - Registration and Breakfast
  - Test Strategy Innovations
  - Lasers Drilling
    - Lunch (Aragon Lawn)
  - Testing Challenges and Solutions
  - Bumps and Arrays
  - SW Test EXPO 2016 w/ Dinner at Reception Stations
    - Networking at La-Taberna Bar
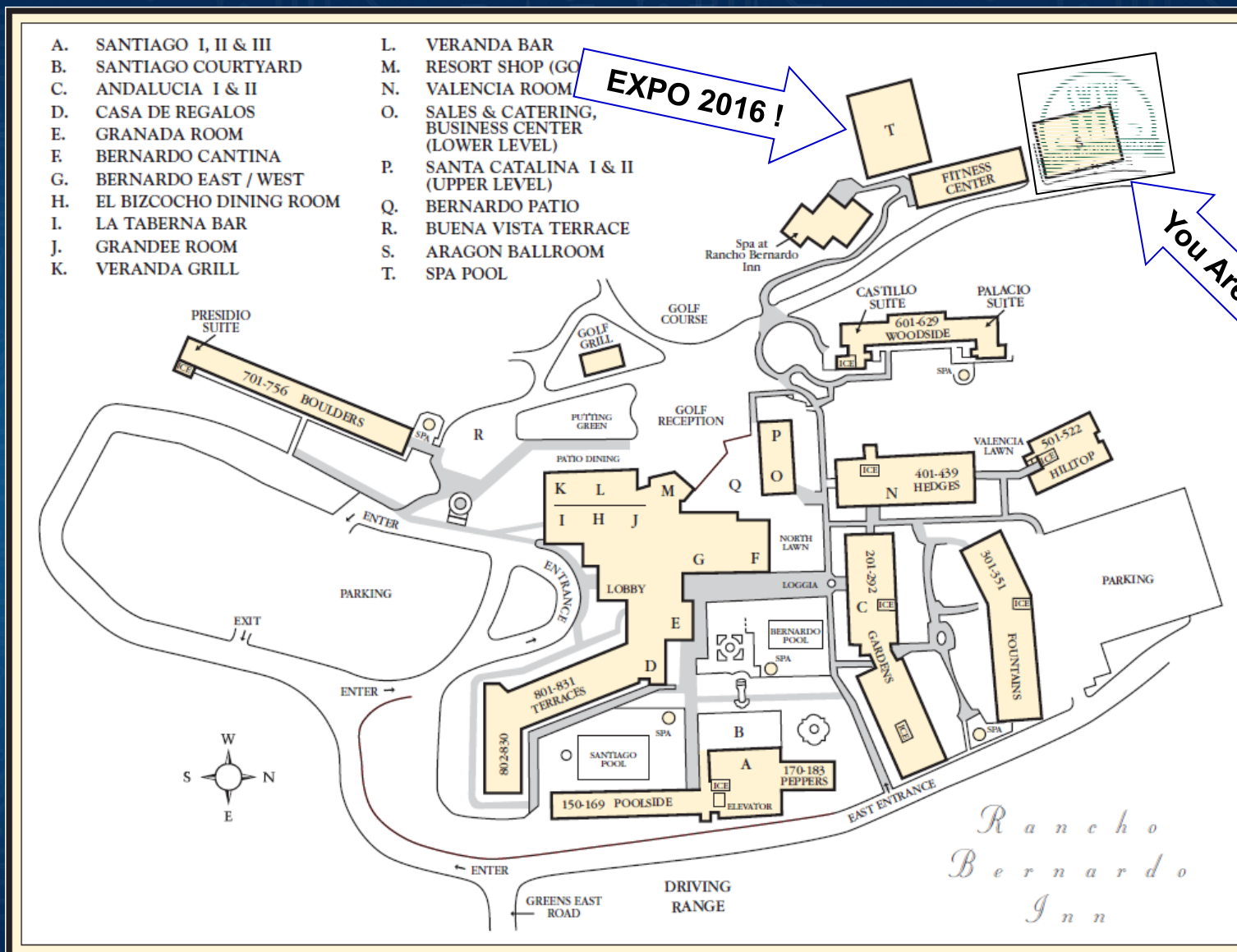   - Hospitality Suites for even more networking

Rancho Bernardo 2016

You Are Here !

SW Test 2017
June 4 to 7, 2017
Rancho Bernardo Inn
San Diego, CA

SW Test Workshop - June 5-8, 2016

Map of the Area

SW Test Workshop - June 5-8, 2016

SW Test EXPO 2016

- Advantest
- AEHR TEST SYSTEMS
- Cascade Microtech, Inc.
- Celadon Systems
- Complete Probe Solutions Inc.
- Daeduck Electronics, Co, LTD
- Feinmetal GmbH
- Ferrotec (USA) Corp.
- FormFactor, Inc. … PLATINUM
- Harbor Electronics, Inc. … PLATINUM
- Heraeus Deutschland GmbH
- Hitachi Chemical Co, Ltd.
- Integrated Technology Corporation
- Integrated Test Corporation
- International Test Solutions, Inc … PLATINUM
- Intest Corporation
- IWIN Co.,Ltd.
- JEM America Corp. … PLATINUM
- Kita USA Inc
- Korea Instrument
- MarTek, Inc.

- LEENO Industrial Inc.
- Micronics Japan Co., LTD. … PLATINUM
- MPI Corporation … PLATINUM
- NTK Technologies
- OptTek Systems, Inc.
- Oxford Lasers
- PacTech USA … SILVER
- Plastronics
- Prober.com
- R & D Altanova … PLATINUM
- Rika Denshi America, Inc.
- Rudolph Technologies
- Specialty Coating Systems
- STAr Technologies, Inc … GOLD
- SV TCL - SV Probe … GOLD
- Synergie CAD Probe … GOLD
- T.I.P.S. Messtechnik GmbH
- TechnoProbe … PLATINUM
- Teradyne GSO … PLATINUM
- Tokyo Electron Laboratory … SILVER
- Vermont Microtechnologies

SW Test EXPO 2016
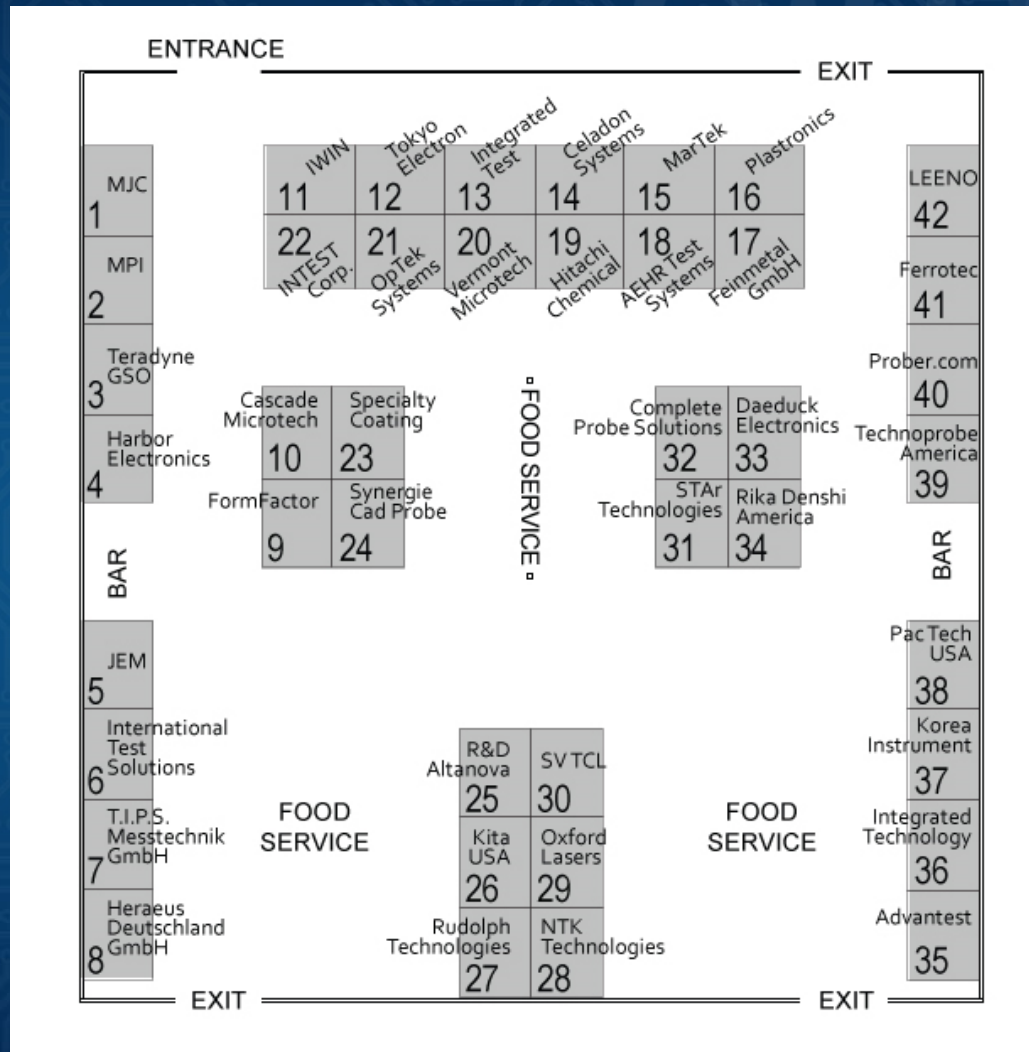
- **QR codes on the backside of the badges**
  - First and Last Name
  - Organization
  - Email Address

- **Many Free Readers**
  - iTunes Store
  - Android Store

Technical Program / Agenda

- **Tuesday, June 9**
  - Registration and Continental Breakfast
  - Moving Forward with Space Transformer Technology
  - Power Probing at Temperature
    - Lunch (Aragon Lawn)
  - Probecard Potpourri
  - EXPO 2016 w/ Refreshments will be served
  - "Luck be a Lady Tonight" Casino Night & Social Club

Tuesday Social Celebrates
Las Vegas Style Casino Night

- **Network and Socialize from 6:00 to 9:00PM**

- **Cocktails, Dinner and Gambling, Lounge Singing**

J. Broz

SW Test Workshop - June 5-8, 2016

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Technical Program / Agenda

- **Wednesday, June 10**
    - Registration
    - Moving from x1 to x123 SOIC Improvements
    - Process Improvement
    - Awards and Adjournment
    - Box Lunch (Aragon Lawn)

SW Test Workshop - June 5-8, 2016

Recognition & Awards

- **Most "Inspirational" Presentation**

- **Best Presentation, Tutorial in Nature**

- **Best Data Presented**

- **Best Overall Presentation**

- **Top Two Presentations from SW Test 2016 will be presented at SEMICON West Test Forum, July 12, 2016**
  - SEMI will arrange for complimentary hotel stay for up to three nights
  - SW Test will award a travel grant to each speaker
  - http://www.semiconwest.org/test-forum

SWTW-2015 Awards

Most Inspirational Presentation

Determining Probe's Maximum Allowable Current

Jarek Kister and Amy Leong (FormFactor, USA)
Amer Cassier (Qualcomm - San Diego,CA, USA)

Best Presentation, Tutorial in Nature

An innovative design and implement of vertical probe card for High Speed Loopback (12 Gbps) Application

Morgan Ku, Alex Wei, Seenew Lai, Akey Chen, Anderson Huang,
Steven Wu, Cahris Lin
(MPI Corporation - Zhubei, Taiwan)
Y.S. Kuo and Kenny Tang
(TSMC Corporation - Hsinchu, Taiwan)

SWTW-2015 Awards

Best Data Presentation

Probe Route Optimization and its effects on the efficiency of test

Daniel Fresquez and Rachel Koski
(Texas Instruments - Dallas, TX, USA)

> Nominated for Best ATE Publication of the Year presented at Test Vision 2020 on July 13, 2016

Best Overall Presentation

Experience in Applying Finite Element Analysis for Advanced Probe Card Design and Study

Krzysztof Dabrowiecki and Jorg Behr
(Feinmetall GmbH - Herrenberg, Germany)

> Published in the April 2016 issue of Evaluation Engineering

J. Broz

SW Test Workshop - June 5-8, 2016

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That "Special" Award …

Bill Mann's Poorest Disguised Sales Pitch

*"What happens at SW Test stays at SW Test !!"*

Want to Learn More ?

- **62st IEEE Holm Conference on Electrical Contacts**
  http://www.ieee-holm.org

- **SEMICON West Test Forum 2016**
  http://www.semiconwest.org/test-forum

- **Burn In & Test Strategies Workshop**
  http://www.bitsworkshop.org

- **IS-Test Workshop**
  http://www.is-test.com

- **67th Electronic Components and Technology Conference**
  http://www.ectc.net

- **ProbeCard Insider**
  Technology Blog by Paul Meyer focused on Probe Cards
  http://probecardinsider.com
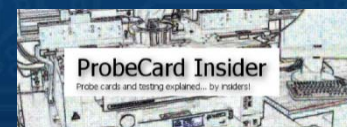
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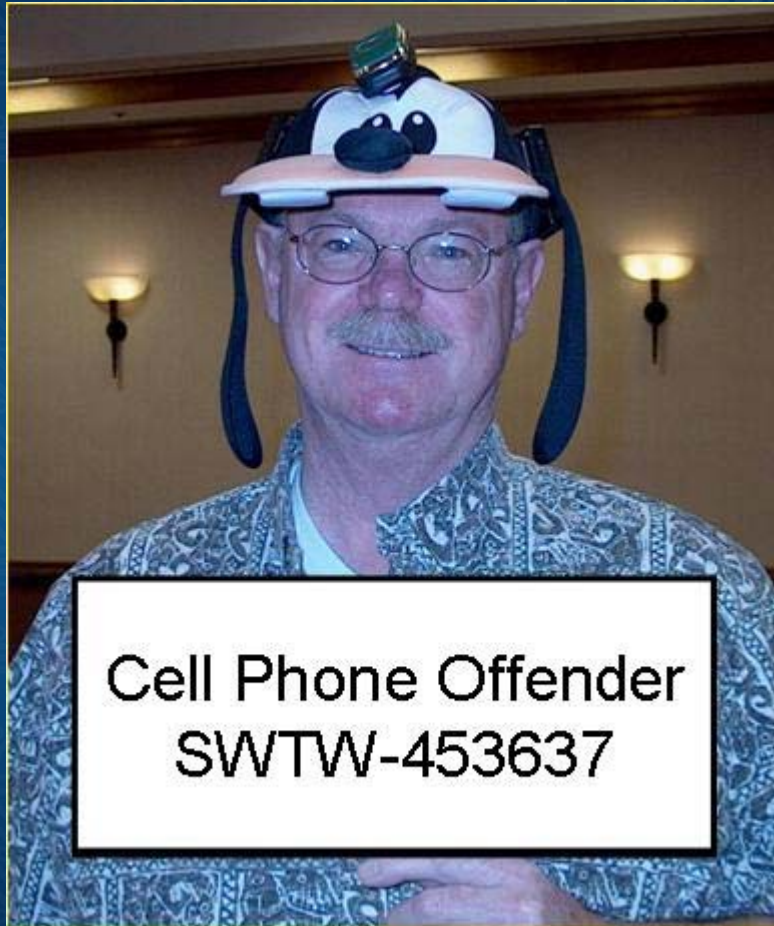
SW Test 2016 e-Proceedings ?

www.swtest.org

Password for Sunday = redwood
Password for Monday = bluespruce

- **SW Test Team continues to be focused on a green initiative.**

- **Each day of the workshop will be available for download in a password protected file.**

  http://www.swtest.org
  WiFi Password = aragon2016

- **WiFi will be available during the entire workshop to allow access to website for download.**

- **The daily PDF file password will be announced through the day.**

Thanks for your Support !

- **Contact the SW Test Team with any questions …**

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