

J.P. Morgan Semiconductor and Semiconductor Capital Equipment: 2020 Outlook

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J.P. Morgan Semiconductor Universe Comp Sheet

JPM Rating	Market Cap	1/10/20 Price	Non-GAAP EPS		P/E		Revenue		P/S		EV/Sales		Consensus Non-GAAP EPS		Consensus Sales		Consensus P/E		Consensus P/S		
			C19E	C20E	C19E	C20E	C19E	C20E	C19E	C20E	C19E	C20E	C19E	C20E	C19E	C20E	C19E	C20E	C19E	C20E	
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PC Semiconductors																					
INTC	OW	\$261,281	\$58.94	\$4.60	\$5.00	12.8	11.8	\$70,956	\$72,925	3.7	3.6	3.8	3.7	\$4.61	\$4.68	\$70,977	\$72,197	12.8	12.6	3.7	3.6
NVDA	OW	\$150,990	\$244.32	\$5.56	\$7.50	44.0	32.6	\$10,762	\$12,875	14.0	11.7	13.2	11.1	\$5.27	\$7.06	\$10,516	\$12,652	46.3	34.6	14.4	11.9
AMD	N	\$53,800	\$48.17	\$0.61	\$0.98	79.0	49.1	\$6,704	\$8,125	8.0	6.6	8.0	6.6	\$0.62	\$1.09	\$6,714	\$8,550	77.6	44.1	8.0	6.3
Memory																					
MU	OW	\$63,980	\$56.67	\$3.82	\$3.02	14.8	18.8	\$20,637	\$22,002	3.1	2.9	3.0	2.8	\$3.35	\$3.05	\$20,254	\$21,528	16.9	18.6	3.2	3.0
WDC	N	\$20,110	\$67.94	\$1.21	\$3.92	56.1	17.3	\$15,509	\$17,302	1.3	1.2	1.8	1.6	\$1.25	\$4.61	\$15,564	\$17,198	54.3	14.7	1.3	1.2
Enterprise/Networking/Datacenter Semiconductors																					
XLNX	UW	\$25,392	\$99.47	\$3.90	\$3.31	25.5	30.1	\$3,237	\$3,371	7.8	7.5	7.4	7.1	\$3.80	\$3.65	\$3,237	\$3,431	26.2	27.2	7.8	7.4
MRVL	OW	\$17,707	\$26.50	\$0.65	\$0.93	41.1	28.6	\$2,666	\$3,031	6.6	5.8	7.3	6.4	\$0.68	\$0.88	\$2,703	\$3,029	38.9	30.1	6.6	5.8
AVGO	OW	\$124,476	\$299.22	\$20.92	\$23.99	14.3	12.5	\$22,892	\$25,265	5.4	4.9	6.6	6.0	\$21.17	\$23.69	\$22,749	\$25,350	14.1	12.6	5.5	4.9
MLNX	NR	\$6,745	\$118.89	\$6.48	N/A	18.3	N/A	\$1,286	N/A	5.2	N/A	4.6	N/A	\$6.50	\$7.20	\$1,285	\$1,405	18.3	16.5	5.2	4.8
IPHI	OW	\$3,681	\$80.86	\$1.58	\$2.10	51.0	38.5	\$363	\$445	10.2	8.3	10.3	8.4	\$1.58	\$2.09	\$363	\$455	51.2	38.7	10.1	8.1
Mobile Devices																					
SWKS	N	\$20,678	\$120.08	\$5.99	\$6.95	20.0	17.3	\$3,285	\$3,595	6.3	5.8	5.9	5.4	\$5.99	\$6.74	\$3,285	\$3,534	20.0	17.8	6.3	5.9
QRVO	OW	\$13,546	\$113.42	\$5.77	\$6.69	19.7	16.9	\$3,113	\$3,409	4.4	4.0	4.4	4.0	\$5.77	\$6.33	\$3,115	\$3,331	19.7	17.9	4.3	4.1
KN	UW	\$1,959	\$20.87	\$1.12	\$1.26	18.6	16.5	\$858	\$909	2.3	2.2	2.4	2.2	\$1.12	\$1.29	\$858	\$906	18.6	16.2	2.3	2.2
Analog/Microcontrollers																					
TXN	OW	\$123,500	\$130.00	\$5.12	\$4.92	25.4	26.4	\$14,233	\$13,755	8.7	9.0	8.6	8.9	\$5.27	\$5.06	\$14,241	\$14,098	24.7	25.7	8.7	8.8
ADI	N	\$44,177	\$118.57	\$4.81	\$4.85	24.7	24.4	\$5,750	\$5,756	7.7	7.7	8.4	8.4	\$4.92	\$4.98	\$5,832	\$5,784	24.1	23.8	7.6	7.6
NXPI	N	\$36,755	\$129.64	\$7.58	\$8.60	17.1	15.1	\$8,846	\$9,370	4.2	3.9	4.7	4.4	\$7.61	\$8.45	\$8,854	\$9,354	17.0	15.3	4.2	3.9
MCHP	OW	\$28,295	\$110.83	\$5.54	\$6.10	20.0	18.2	\$5,248	\$5,416	5.4	5.2	6.9	6.7	\$5.58	\$6.07	\$5,268	\$5,513	19.9	18.3	5.4	5.1
MXIM	OW	\$16,864	\$61.45	\$2.13	\$2.62	28.8	23.4	\$2,177	\$2,353	7.7	7.2	7.3	6.8	\$2.14	\$2.42	\$2,177	\$2,298	28.7	25.4	7.7	7.3
MXL	N	\$1,490	\$20.88	\$0.79	\$0.82	26.3	25.4	\$317	\$321	4.7	4.6	5.2	5.2	\$0.79	\$0.82	\$317	\$319	26.4	25.6	4.7	4.7
Diversified/Consumer/Standard Components/Other																					
ON	N	\$10,088	\$24.58	\$1.50	\$1.60	16.4	15.4	\$5,491	\$5,675	1.8	1.8	2.4	2.3	\$1.51	\$1.60	\$5,492	\$5,709	16.2	15.4	1.8	1.8
MTSI	UW	\$1,753	\$26.41	N/A	\$0.46	N/A	57.3	\$464	\$491	3.8	3.6	4.9	4.6	(\$0.56)	\$0.38	\$457	\$484	(47.3)	69.0	3.8	3.6
VSH	N	\$3,112	\$21.46	\$1.32	\$1.15	16.2	18.6	\$2,659	\$2,610	1.2	1.2	1.1	1.1	\$1.31	\$1.10	\$2,659	\$2,552	16.4	19.6	1.2	1.2
CY	NR	\$9,085	\$23.40	\$1.11	N/A	21.0	N/A	\$2,216	N/A	4.1	N/A	4.1	N/A	\$1.11	\$1.25	\$2,210	\$2,347	21.2	18.7	4.1	3.9
Semiconductor Capital Equipment																					
AMAT	OW	\$57,229	\$61.47	\$3.16	\$4.18	19.5	14.7	\$14,955	\$17,275	3.8	3.3	3.9	3.4	\$3.12	\$3.80	\$14,842	\$16,497	19.7	16.2	3.9	3.5
LRCX	OW	\$44,352	\$294.34	\$14.30	\$17.96	20.6	16.4	\$9,466	\$10,748	4.7	4.1	4.4	3.9	\$14.34	\$14.34	\$9,473	\$10,506	20.5	20.5	4.7	4.2
KLAC	OW	\$27,704	\$173.01	\$8.60	\$10.30	20.1	16.8	\$5,244	\$5,725	5.3	4.8	5.5	5.1	\$8.62	\$8.62	\$5,253	\$5,711	20.1	20.1	5.3	4.9
Large Cap Semi Average																					
						28.3	21.2			7.1	6.6							20.8	19.9	7.1	6.7
Small-Mid Cap Semi Average						25.3	27.4			4.4	3.8							17.0	26.9	4.4	3.9
Semi Group Average (ex-outliers)						23.0	23.7			5.4	5.1							18.9	23.4	5.4	5.0
SOX Index		1,866	88	107	21.2	17.4			5.2	4.6								21.2	17.4	5.2	4.6
S&P500		3,265	174	193	18.7	16.9			2.3	2.2								18.7	16.9	2.3	2.2

Source: Company reports, Bloomberg, J.P. Morgan estimates.

Note: Pricing as of 1/10/2020 close.

Semi/Semicaps – Remain Positive on the Group...Continue To Accumulate...Our Top Picks Are Broadcom (AVGO) and KLA (KLAC)

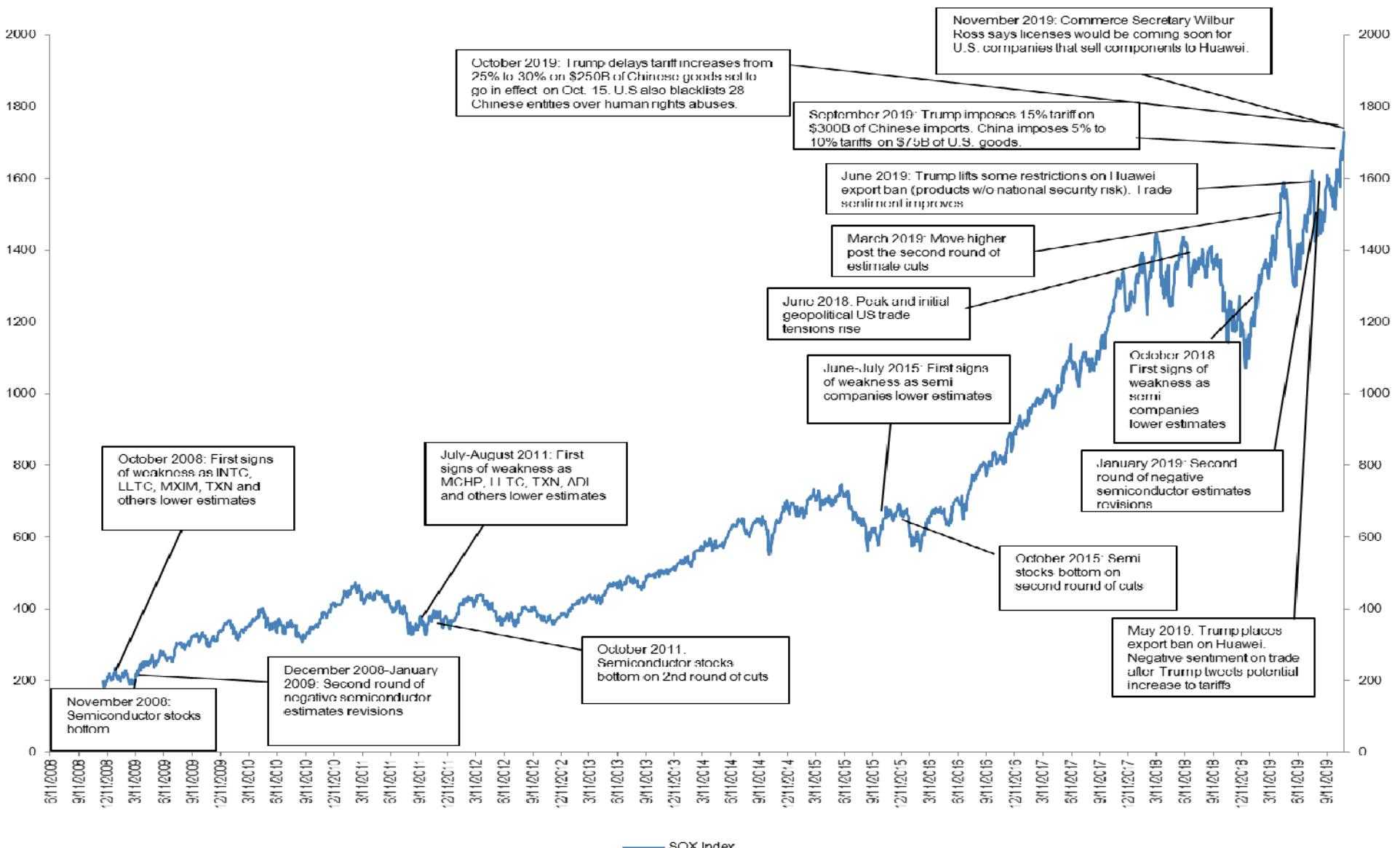
- We believe the semiconductor industry has entered a more stable and less cyclical growth phase characterized by low- to mid-single-digit annual revenue growth and high-single-digit unit growth
 - With the industry generally driving high-single-digit Y/Y unit growth, the entire value chain is able to better predict silicon consumption requirements, better respond to perturbations in supply/demand and more efficiently plan manufacturing output
 - As a result, volatility in semiconductor supply/demand and semiconductor equipment spending has muted significantly
 - Compare this to 10 years ago, when unit growth rates were +15% Y/Y – small perturbations in supply/demand would drive significant swings in inventory, shipments, capacity planning and equipment spending
 - **Bottom line: the current environment is likely more stable and less cyclical for semiconductor and semiconductor capital equipment suppliers**
 - In a maturing industry, we believe the market will focus on market leadership/scale, operating margin and free cash flow margin expansion and increasing payout ratios
- After a 2019 where we forecast semi industry revenue (ex-memory) to be down 6% (ex-memory) and down 20+% in wafer fab equipment (WFE) spending with memory down ~40% in semicaps as suppliers remain disciplined & focused on profitability, we estimate semi industry growth and semiconductor equipment spending both up mid-single-digits % in 2020.
- The market started discounting weak industry trends back in June 2018, and most of our stocks were down 25% by December...YTD the group is outperforming (SOX up ~55% YTD) as market discounts improved supply/demand trends in 1H20- But China drives volatility.
 - We anticipate continued volatility in stocks on US/China trade conflict - semiconductors/sempcap equipment significant bargaining leverage
 - Assuming no further deterioration of US/China trade conflict or resolution, we see stocks continuing to outperform in 2020
- Cyclical supply-side fundamentals still appear healthy, but continued demand weakness in China/Industrial and Auto. However, recent signs of stabilization: Supply-side metrics such as distribution inventories/lead times are still within normal ranges and continued weakness in Industrial/Auto end-markets due to macro uncertainty, trade tensions.
- Record consolidation (M&A) wave should continue in the medium term: Focus on scale, diversification, margin and FCF expansion
- Semis large-cap top pick: AVGO; we also favor MRVL, TXN, INTC, NVDA, MCHP, MU & QRVO – semis small-cap top pick: IPHI
 - Given continued volatility and potential trade concerns – we focus on market leadership, strong US-based exposure to cloud spending trends, strong product cycles, diversification and margin/free cash flow expansion with increasing payout ratios.
- Memory capex discipline should drive improved profitability in 2020. Semi capital equipment fundamentals to follow: top pick KLAC (OW). KLA's top-line performance is outperforming relative to industry peers on strong product cycles and robust Foundry/Logic spending. KLAC dominates the semiconductor process control equipment market with >4x more market share than their #2 competitor. We are also OW LRCX & AMAT.

We See Mid-Single-Digit % Semi Revenue Decline (ex-memory) in 2019 After ~8% Growth in 2018...Expect Semi Stocks To Outperform Amidst Volatility on US/China Trade

- Following >20% semiconductor revenue growth in 2017, growth in 2018 was strong again (mid-teens % or ~8% ex. memory). However, growth decelerated in 2H18, exacerbated by trade tensions, slowdown in China Industrial/Auto/White goods production, cloud datacenter digestion....
 - We believe stocks bottomed in late 2018, early 2019 at down ~25-27% from peak in June (similar to ~30% average peak/trough decline in prior down cycles)....however volatility has increased on China/US trade conflict...recent concerns on global growth
 - **Sustainable move higher in stocks typically occurs after the second/third round of estimate cuts** ...this has been a consistent pattern over the past three downturns, this cycle earnings revisions has been extended given the impact of Tariffs on pushing out industry recovery from 4Q19 to 1H20..... **semiconductor stocks are significantly outperforming in 2019 with the SOX index up 55% YTD (vs. S&P at 26%) and the market is discounting Y/Y industry positive inflection in 1H20 ... We anticipated and got a retest in the SOX back to ~1400 level, but, assuming no further meaningful breakdown in trade discussions, we anticipate semi stocks moving higher through the remainder of the year and into 2020...forward EPS estimates have gotten cut by 15-25% and in-line with prior downcycles.... Early 2020 view is industry +4%-7% Growth**
- M&A could continue to drive stock outperformance, and we expect the trend to continue through 2019 and beyond
- We model aggregate end market demand to be sub-seasonal through 4Q19, however, we expect datacenters to continue to be strong through the remainder of the year and into 2020 on cloud spending reacceleration. Over the longer term, we expect automotive and industrial to grow strongly on increased content opportunities.
 - Expect global GDP growth of 2.5% in 2020 – below 2019 (2.6%) – JPM economists are not forecasting a recession in '20
 - Automotive markets should continue benefitting from healthy content gains, while Industrial could be at or below seasonal on Asia softness due to macro/trade uncertainty – **net neutral for TXN, ADI, ON, CY, MXIM, and NXPI**
 - Computing end market mixed, with PC CPU shortages holding back shipments, expected re-acceleration in datacenter in 2H19 – **net positive for INTC, NVDA, MU, AMD**
 - In the handset end market, we expect overall smartphone unit shipments to be down mid-single-digit % and expect companies that demonstrate dollar content gains to perform better given the challenging environment. We expect 5G has become a positive catalyst and demand should be solid in 2020 and over the next few years – **net positive for AVGO, QRVO and SWKS**
 - Outside of Huawei, Comm equipment (wireless/wireline) fundamentals picking up momentum on expectations of earlier 5G deployments in Korea/North America/China – **positive for ADI, NXPI, MRVL, IPHI, MTSI, XLNX and QRVO**
 - Cloud networking/optical trends healthy and ramping strongly with strength in datacenter driven by 200G/400G upgrade cycle in cloud and hyperscale – **positive for AVGO, IPHI and MXL**

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Current Down Cycle Similar To Prior Three Cycles: Stocks Usually Positively Discount Recovery After 2nd or 3rd of Round of Estimate Cuts

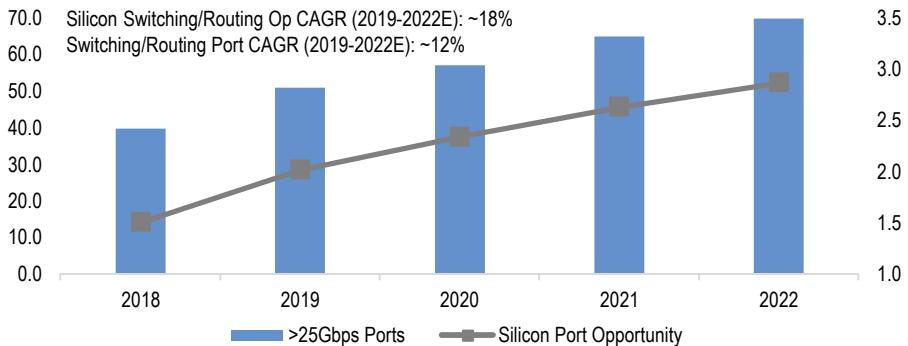


Strong Data Center Fundamentals Led by Cloud Service Provider Spending: Solid Setup for AVGO, INTC, MU, NVDA, WDC, NVDA, MLNX, and IPHI

- Look for companies levered to data center trends to outperform in 2020 across COMPUTE, NETWORKING and STORAGE/MEMORY

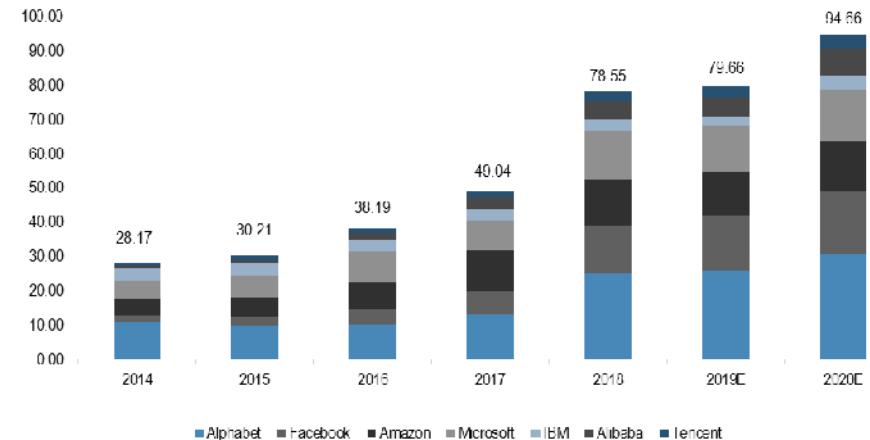
- Cloud Service Provider Spending (top 7) grew by >55% in 2018 and is expected to grow 1% and 19%, respectively, for 2019 and 2020
- Cloud services revenues continue growing >40%+ Y/Y
- Over the next 5 years, CIOs should grow spending on public cloud by 4x
- Early stages of Intel Cascade Lake and AMD EPYC 2 (with increased memory channels) – OW INTC, MU
- Silicon switch ports to grow >23% in 2020 – OW AVGO, IPHI
- PAM4 (50Gb speeds per switch port) networking upgrade already underway and to ramp through 2020 – benefit to optical / networking levered companies – OW AVGO and IPHI
- Fast growing Artificial Intelligence workloads not just about GPU: seeing broad adoption of FPGAs and ASICs for AI/Deep Learning applications – \$9B market (training) by 2020 – OW NVDA and AVGO
- DRAM memory content in a cloud server is 50% higher than traditional enterprise server – OW MU

Data Center Switch Port Growth and Switch Silicon Opportunity (2018-2022E)



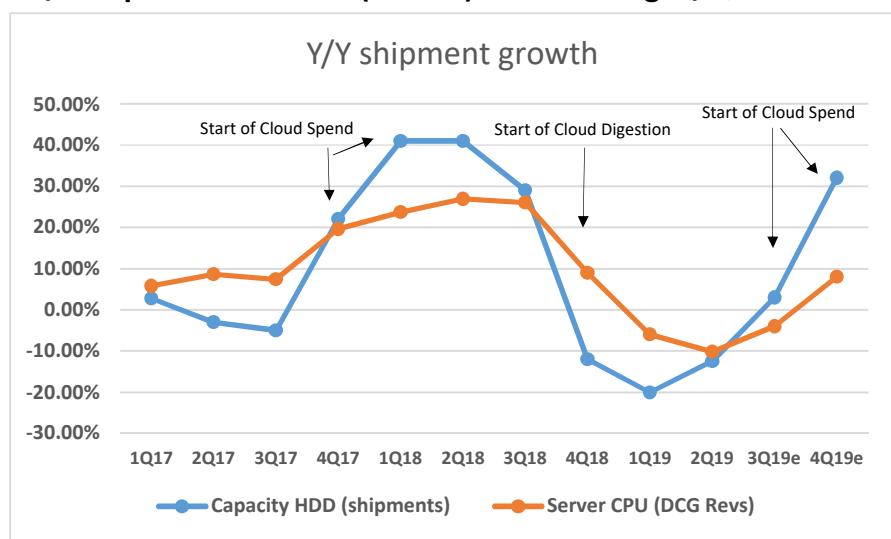
Source: Company reports, IDC and J.P. Morgan estimates.

Cloud Service Provider Spending – Top 7 CSPs (2014-2020E)



Source: Company reports, IDC and J.P. Morgan estimates.

HDD Y/Y shipment inflection (arrows) drives strong Q/Q in HDD and CPU



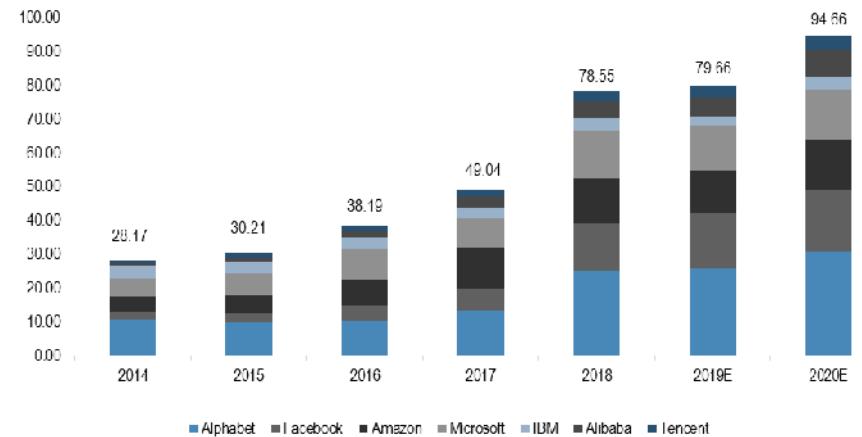
Source: Company reports, IDC and J.P. Morgan estimates.

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Broadcom (AVGO): Driving Strong Cloud Networking Upgrade Starting This Year, Strong Custom ASIC (custom chip) Pipeline.....

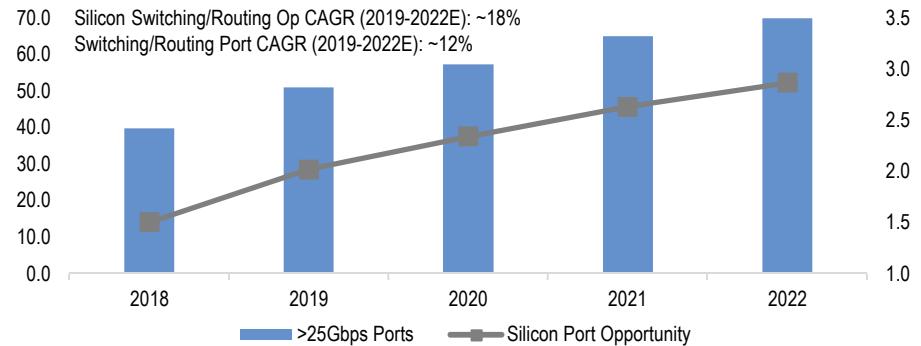
- **Still viewed as an Apple iPhone Supplier (non-core business)....market not appreciating the diversification of the business....>25% of total revenues are now exposed to cloud datacenter**
- **Category Killer in Cloud Datacenter Networking....>85% share of merchant and ASIC switching silicon opportunity ~\$2.5B-\$3B per year growing 10-12% Y/Y**
 - Tomahawk 3 (50G PAM4 per port) production ramp started 2H18 – significant upgrade cycle in 2020
 - Tomahawk 4 (50G PAM4 per port) sampling now
 - Not only leader in switch/routing – but also NIC, PHY, optical silicon as well to support the switch silicon
- **Category Killer in Artificial Intelligence Custom Processor Chips to Customers like Google (TPU1/2 and TPU3 beg. in 2019), Fujitsu, Intel, and several others...\$1-\$2B opportunity per year (from zero base in 2016)**
- **Strong cloud infrastructure spending not only benefits Broadcom's leadership in switching/routing, but also its leadership in enterprise/cloud storage silicon – Enterprise SSD Controllers, HDD capacity cloud drive controllers, Storage HBA, Storage Systems connectivity**
- **Dividend raised to \$13 (from \$10.60 prior, or +23% Y/Y) and strong FCF of the combined company implies annual dividend rising to ~\$14.25+ next year....>10% growth going forward....\$15+ in F21**
- **Post SYMC, may focus more on stock repurchases versus deleveraging once reach ~2x net leverage level**

Cloud Service Provider Spending – Top 7 CSPs (2014-2020E)



Source: J.P. Morgan estimates.

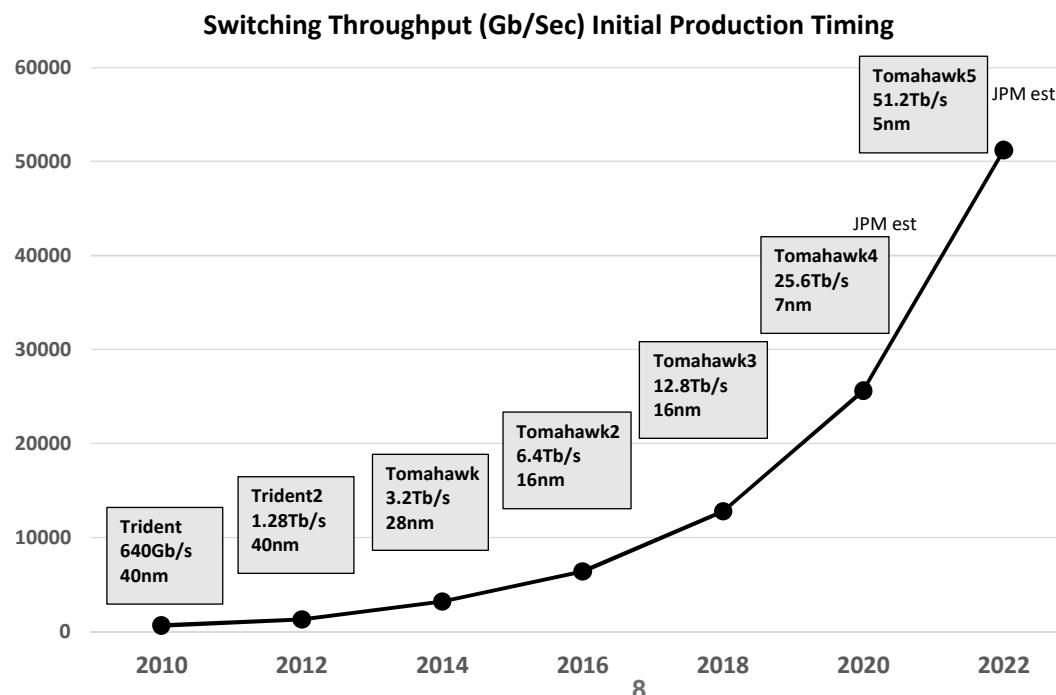
Data Center Switch Port Growth and Switch Silicon Opportunity (2018-2022E)



Broadcom (AVGO): Google to Become \$1B ASIC Customer for Broadcom in the Next 12-18 Months
– AI/Deep Learning, Smart NICs, Google Home Platform.....Continues to Drive Moore's Law Performance In Its Flagship Datacenter Switching Family.....

- We believe Broadcom's custom ASIC business with Google will become a \$800M-\$1B business for Broadcom (from \$50-\$75M in 2017) over the next 12-18 months. TPU1, TPU2, TPU3, TPU4 all done by AVGO....ASIC wins on SmartNIC, switching, and Google home platforms as well.....
- Google should be the same size or greater than Broadcom's current large ASIC customer, Apple at \$800M per year
- Drives diversification of the business, customer base, and continues to drive double-digit Y/Y profile in Broadcom's cloud datacenter franchise (>25% of total company revenues)

Broadcom Drives Moore's Law Performance in Switching (2x increase in switching throughput every 2 years)



Broadcom Infrastructure Software Segment – Focused on Mission Critical, Driving 65-70% EBIT Margins....Longer Term Total Company 60% EBITDA Margins and 50% FCF margins....

- **Broadcom should continue to build-out its Infrastructure Software Business focused on mission critical applications:**
 - SAN Storage (switching/HBA/Software/Silicon)- Brocade, Emulex, LSI
 - Mainframe Software (transaction processing) – CA
 - Enterprise Security Software - Symantec
 - Leader in endpoint protection, web gateway, data loss prevention (DLP)
 - Potential LT synergies with silicon leadership (already engaged on security acceleration ASIC silicon with Facebook and Microsoft). Stingray silicon SmartNIC platform focused on security.
- **Feedback from large customers of the Infrastructure Software Segment:**
 - SAN Storage, Mainframe, Enterprise security ARE MISSION CRITICAL APPLICATIONS
 - See stable spending trend for these applications going forward
 - On Symantec:
 - Proven scalability (100k's endpoint protection)
 - Proven scalability across on-prem/hybrid/cloud architectures
 - More confidence on AVGO mgmt. driving LT roadmaps and required R&D investments
- Brocade/CA already driving 70% EBITDA margins and SYMC to drive 65%+ EBITDA margins post synergies.....LT can see total Broadcom driving ~58-60% EBITDA margins, 50% FCF margins and DD% earnings and FCF/share growth

RF Semiconductors: 5G Complexity Benefits RF Market Leaders QRVO, AVGO and SWKS

■ Adoption of 5G set to reaccelerate RF market growth

- Ramp of 5G to meaningful increase RF market opportunity primarily on new sub-6 GHz content, will millimeter wave also additive over the next few years
 - ~\$6-\$7 of incremental sub-6 GHz content
 - >>\$10 of incremental mm wave content
- Complexity challenges in advanced 4G and 5G leading to use of highly integrated modules
- Anticipate double-digit % market growth CAGR through 2022 with potential upside

■ Qorvo, Skyworks and Broadcom remain well-ahead of the competition

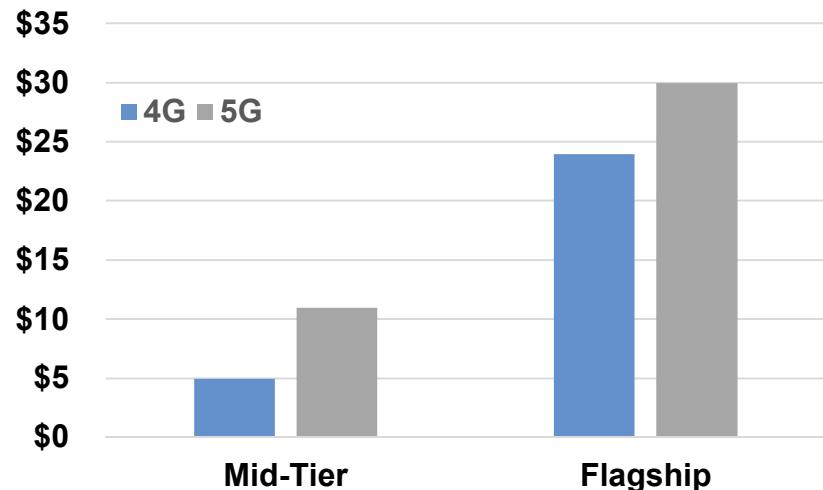
- Core base component expertise (PAs, switches, premium filters, etc.)
- Years of experience building highly integrated modules
- Use of substandard RF could result in poor performance and impact form factor, including impact on signal integrity (i.e. dropped calls), reduced battery life and worse overall user experience
- We maintain our view of QRVO, SWKS and AVGO being key beneficiaries of the 5G ramp as the companies are uniquely positioned to deliver the highest performing RF
- Non-Mobile businesses of QRVO and SWKS set to resume double-digit % revenue growth
- Driving strong gross, operating and free cash margin expansion
- Supportive of further upside in shares over the next 18-24 months

Content per Unit Growth and RF TAM Growth

	CAGR (2019-2022E)
Smartphone Unit Growth Framework	0-2%
Average RF Content Per Device Growth	~10%
RF Market Growth	10-12%

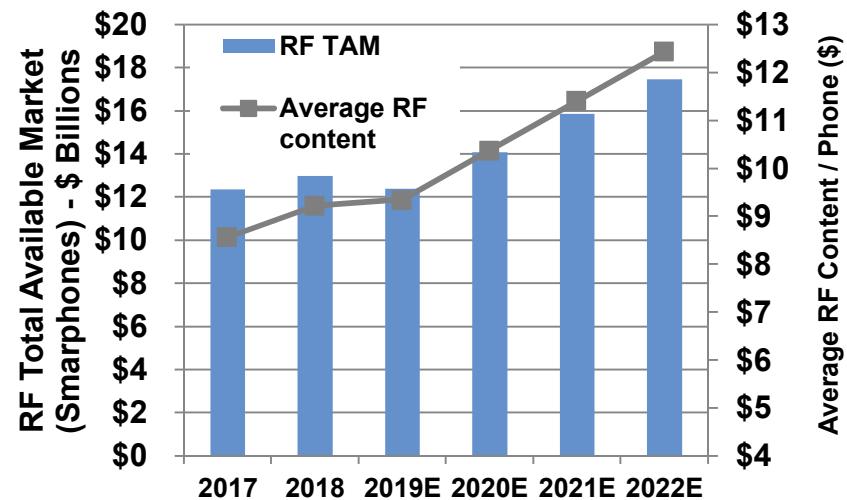
Source: J.P. Morgan estimates.

RF Content Growth Within Smartphone Tiers *



Source: J.P. Morgan estimates. * sub-6 GHz

RF Market Size and RF Content per Unit Growth Framework



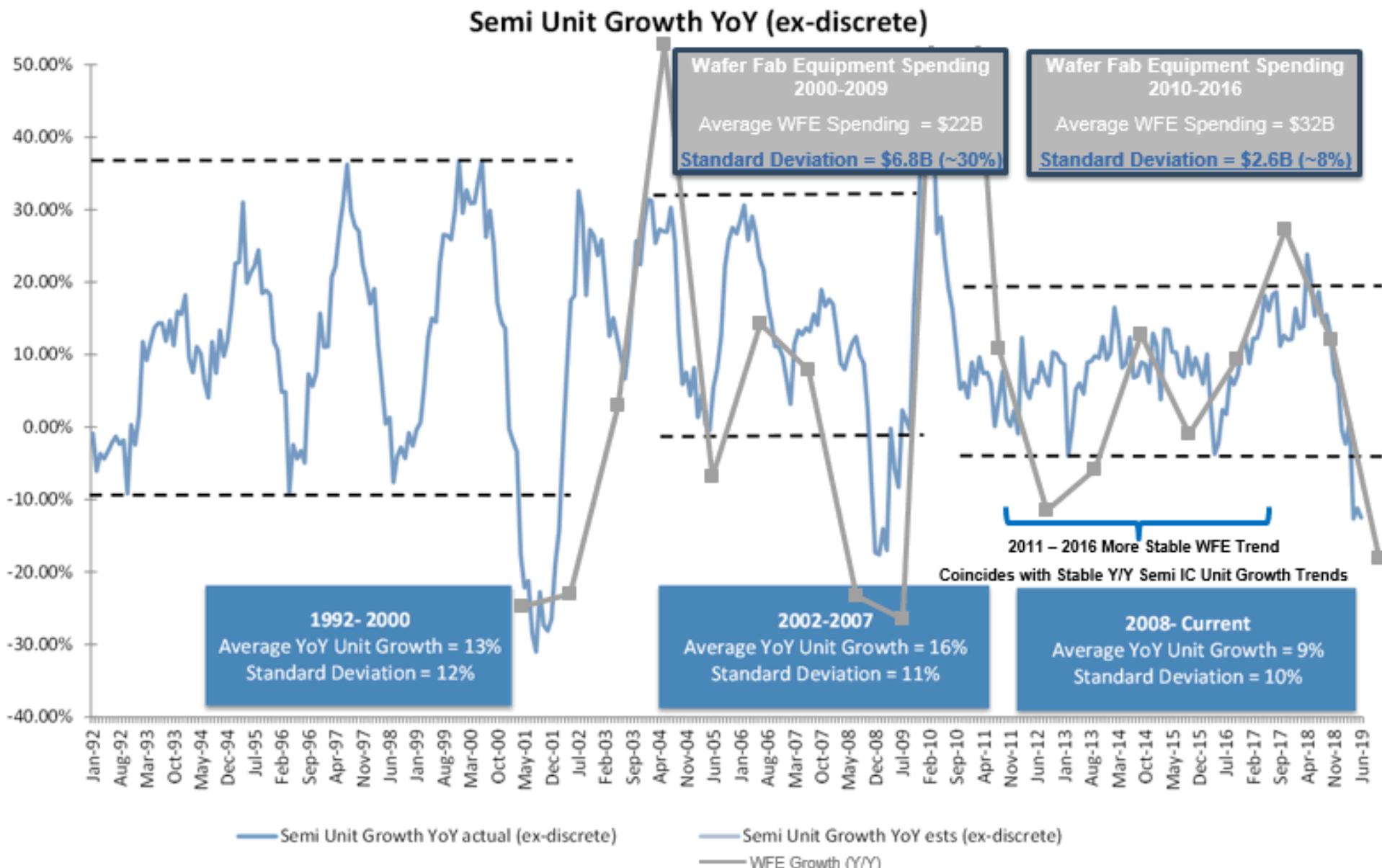
Source: J.P. Morgan estimates.

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Semiconductor Capital Equipment: Remain OW LRCX, KLAC and AMAT

- **Following a down wafer fab equipment (WFE) in 2019, we expect spending in 2020 to increase by mid-single-digits %:**
 - The semiconductor industry has entered a more stable and less cyclical growth phase, which should drive a more predictable trend of semi unit growth and therefore capex growth and semicap equipment revenue growth
 - The current Moore's Law-driven equipment spending cycle adds to the predictability and a growth vector to equipment spending
 - Rising capital intensity is associated with next-generation manufacturing technology inflections such as FinFET, 3D NAND, lower-resistance interconnects, multiple-patterning, and integrated packaging
 - Memory spending (DRAM and NAND) down by ~40% in 2019 as memory makers aim for S/D balance and continued profitability → We expect Memory spending to increase by mid-single-digits in 2020 with NAND inflecting by mid-year and DRAM inflecting in 2H20
 - Foundry/Logic spending in CY19 exiting the year strong and we see continued broad-based growth in CY20 led by investments at the leading edge (7nm/5nm Foundry and 10nm/7nm Logic) with lagging edge remaining strong
 - Domestic China semi manufacturers have begun to fill pilot lines with slight upside to prior estimates and we see continued strong investments in China in 2020 as domestic manufacturers continue to come up the learning curve
 - **We expect wafer fab equipment (WFE) spending to return to growth (mid-single-digits %) in 2020 as memory fundamentals improve and on broad-based demand for compute, networking, acceleration, 5G, etc. that is driving continued strength in Foundry/Logic.**
- We anticipate companies under coverage to drive revenue growth better than WFE spending in 2020 on market share gains, SAM expansion, and solid service revenue growth
- Despite industry headwinds, semicap companies are more profitable than in past downturns, with annualized earnings power exiting 2020 of ~\$20 for LRCX, ~\$12 for KLAC and ~\$4 for AMAT, which implies 25+% upside in the stocks
- **KLAC is our top semicap pick, as a diversified leader poised to benefit from new technology migration and positive exposure to EUV lithography adoption**

Steady Semiconductor Unit Growth Environment Has Led to Similarly Muted Wafer Fab Equipment (WFE) Spending Cycles



Source: WSTS, Gartner and J.P. Morgan estimates.

Total Capex Spending by Semi Manufacturers (2013-2020E)

Company	2013	YoY%	2014	YoY%	2015	YoY%	2016	YoY%	2017	YoY%	2018E	YoY%	2019E	YoY%	2020E	YoY%
IDM																
Intel	\$10,711	-2.6%	\$10,105	-5.7%	\$7,326	-27.5%	\$8,025	9.5%	\$9,300	15.9%	\$11,900	28.0%	\$14,250	19.7%	\$14,500	1.8%
Texas Instruments	\$507	2.4%	\$410	-19.1%	\$551	34.4%	\$531	-3.6%	\$550	3.6%	\$1,130	105.5%	\$925	-18.1%	\$1,000	8.1%
Others	\$3,408	-40.3%	\$3,514	3.1%	\$3,983	13.4%	\$3,612	-9.3%	\$5,100	41.2%	\$4,850	-4.9%	\$4,775	-1.5%	\$4,950	3.7%
Total	\$14,626	-15.0%	\$14,029	-4.1%	\$11,860	-15.5%	\$12,168	2.6%	\$14,950	22.9%	\$17,880	19.6%	\$19,950	11.6%	\$20,450	2.5%
% of Total Capex	29%		26%		22%		20%		17%		19%		23%		23%	
MEMORY																
Samsung Memory	\$6,930	20.1%	\$9,700	40.0%	\$10,320	6.4%	\$9,100	-11.8%	\$19,700	116.5%	\$18,000	-8.6%	\$15,750	-12.5%	\$16,000	1.6%
SK hynix	\$3,300	-6.8%	\$4,800	45.5%	\$4,900	2.1%	\$5,400	10.2%	\$8,500	57.4%	\$15,200	78.8%	\$11,300	-25.7%	\$10,435	-7.7%
Nanya/Inotera *	\$485	127.3%	\$809	66.8%	\$1,955	141.7%	\$1,580	-19.2%	\$1,100	-30.4%	\$675	-38.6%	\$250	-63.0%	\$350	40.0%
Micron + IM JV	\$1,620	-14.7%	\$3,140	93.8%	\$4,200	33.8%	\$5,150	22.6%	\$5,500	6.8%	\$9,150	66.4%	\$7,800	-14.8%	\$6,000	-23.1%
Intel Memory	\$0	NM	\$0	NM	\$0	NM	\$1,600	NM	\$2,500	56.3%	\$3,300	32.0%	\$1,750	-47.0%	\$2,000	14.3%
Toshiba Mem+WD	\$2,150	6.4%	\$2,500	16.3%	\$3,500	40.0%	\$4,000	14.3%	\$5,000	25.0%	\$5,000	0.0%	\$4,000	-20.0%	\$4,000	0.0%
Others, inc. Domestic China	\$654	6.4%	\$679	3.8%	\$320	-52.9%	\$450	40.6%	\$3,825	750.0%	\$4,625	20.9%	\$3,625	-21.6%	\$5,125	41.4%
Total	\$15,139	7.7%	\$21,628	42.9%	\$25,195	16.5%	\$27,280	8.3%	\$46,125	69.1%	\$55,950	21.3%	\$44,475	-20.5%	\$43,910	-1.3%
% of Total Capex	30%		40%		47%		46%		54%		60%		50%		49%	
FOUNDRY																
TSMC	\$9,690	16.7%	\$9,522	-1.7%	\$8,123	-14.7%	\$10,200	25.6%	\$10,900	6.9%	\$10,500	-3.7%	\$14,000	33.3%	\$14,000	0.0%
Globalfoundries	\$4,000	5.3%	\$3,500	-12.5%	\$2,500	-28.6%	\$1,500	-40.0%	\$2,500	66.7%	\$2,500	0.0%	\$1,500	-40.0%	\$2,500	66.7%
Samsung Logic	\$4,660	-34.4%	\$2,848	-38.9%	\$3,108	9.1%	\$2,286	-26.4%	\$6,600	188.7%	\$3,250	-50.8%	\$4,300	32.3%	\$4,000	-7.0%
Others	\$1,879	-16.5%	\$2,436	29.6%	\$3,245	33.2%	\$6,325	94.9%	\$4,900	-22.5%	\$3,450	-29.6%	\$3,950	14.5%	\$3,950	0.0%
Total	\$20,229	-5.7%	\$18,306	-9.5%	\$16,976	-7.3%	\$20,311	19.6%	\$24,900	22.6%	\$19,700	-20.9%	\$23,750	20.6%	\$24,450	2.9%
% of Total Capex	40%		34%		31%		34%		29%		21%		27%		28%	
Total	\$49,994	-5.2%	\$53,963	7.9%	\$54,031	0.1%	\$59,759	10.6%	\$85,975	43.9%	\$93,530	8.8%	\$88,175	-5.7%	\$88,810	0.7%

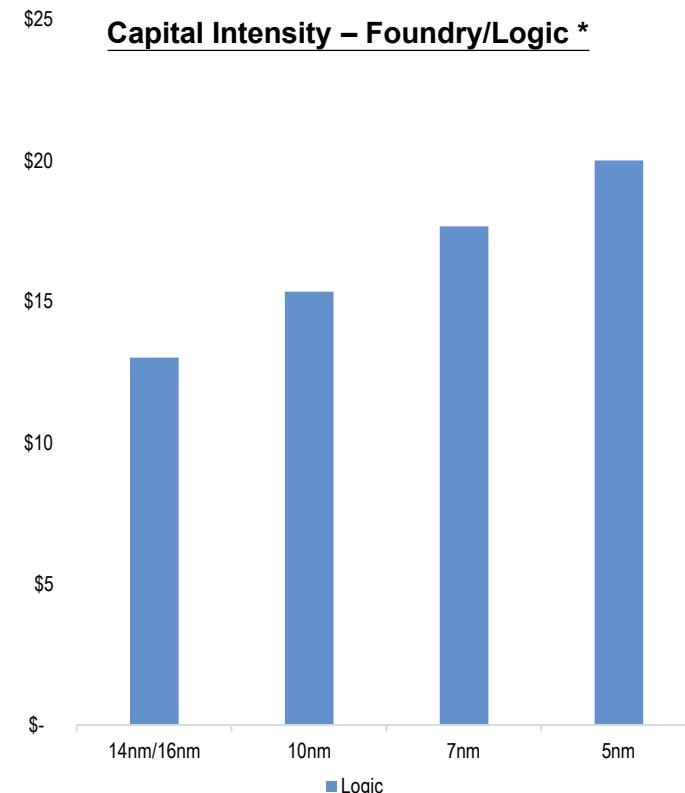
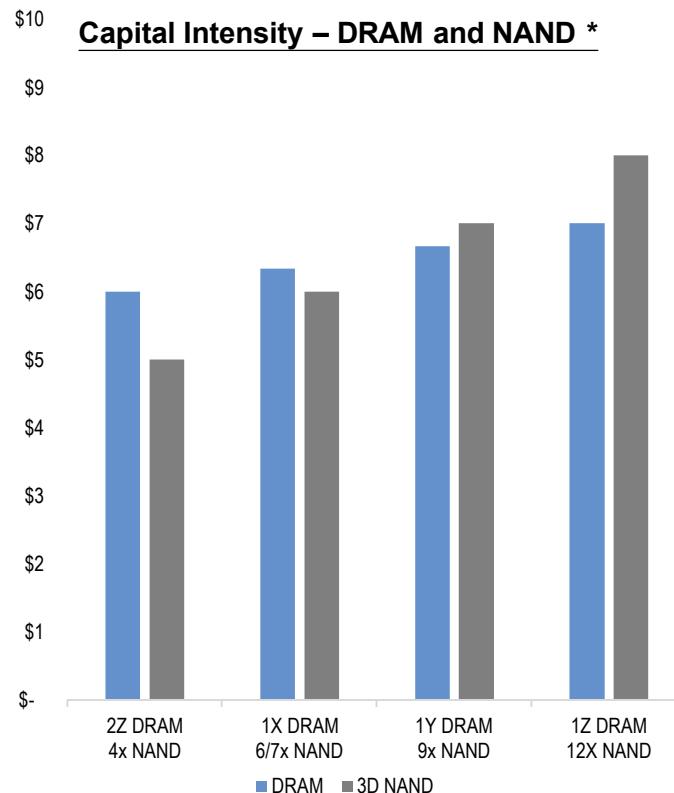
Source: Company reports, J.P. Morgan estimates.

Note: Samsung, and SK Hynix covered by JPM analyst JJ Park; Toshiba covered by JPM analyst Hisashi Moriyama; TSMC, UMC and SMIC covered by JPM analyst Gokul Hariharan. Inotera acquired by Micron on December 6, 2016.

Capital Intensity Increasing Across Device Types – Positive for Semicaps

Capital Intensity Increasing Across Device Types

- Increasing capex to drive bit growth for both DRAM and NAND; NAND capital intensity for 12X layer >50% higher than 4X layer NAND
- Capital intensity increasing for Foundry/Logic even has EUV is begun ramping; 5nm capital intensity >50% higher than 14nm/16nm
- Increasing capital intensity is positive semiconductor equipment companies as spending on equipment will likely have a higher floor and be less cyclical over the next several years



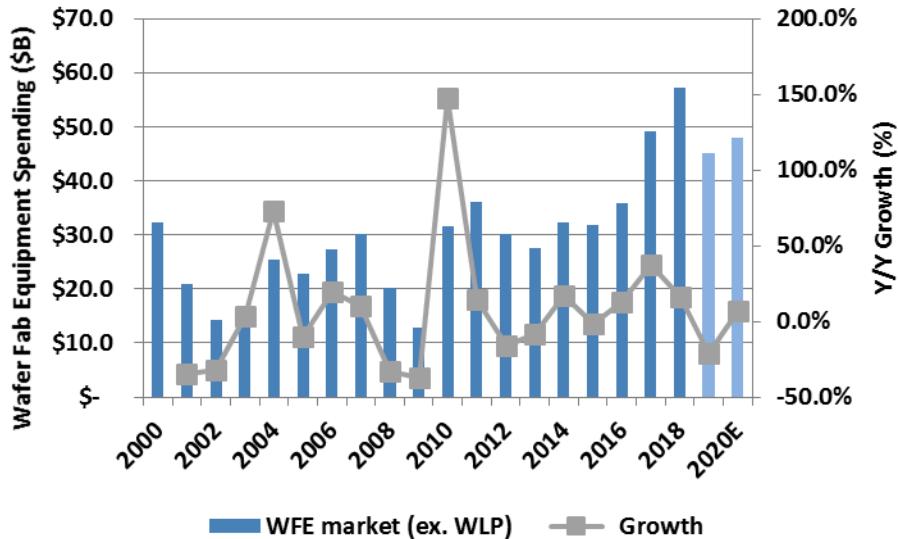
Source: Tokyo Electron SEMICON West 2019, J.P. Morgan Estimates

* \$B of WFE required for 100k wafer starts per month (WSPM) greenfield capacity

Source: Tokyo Electron SEMICON West 2019, J.P. Morgan Estimates

* \$B of WFE required for 100k wafer starts per month (WSPM) greenfield capacity

WFE Forecast and Key Programs for Semiconductor Manufacturers in 2020



Source: Gartner and J.P. Morgan estimates.

* Data excludes wafer level packaging from 2013 (~\$2 billion per year)

We estimate WFE spending to increase by mid-single-digit % in 2020

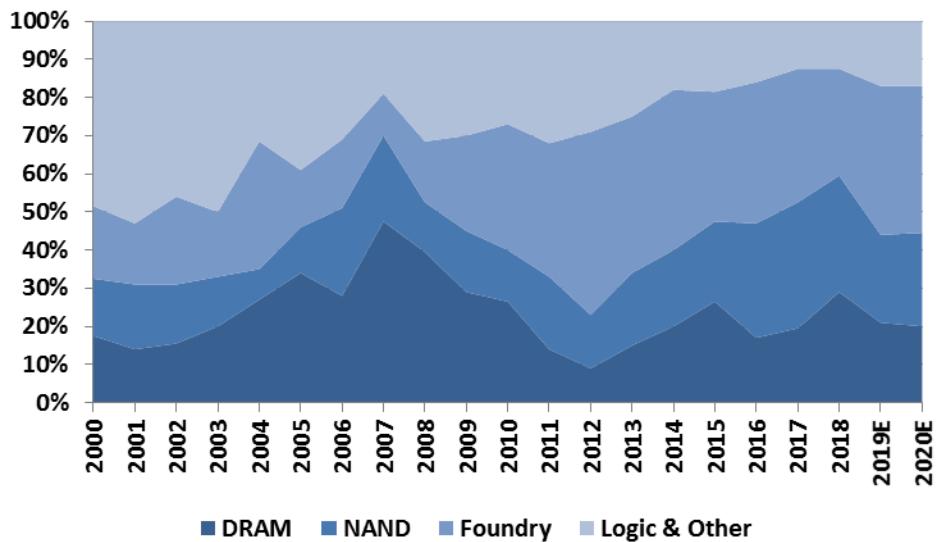
We expect Memory to recover in 2020 on improving S/D fundamentals with Foundry/Logic showing continued strength

Key drivers:

- Memory WFE set to grow, led first by NAND followed by DRAM investments in 2H20
- Continued growth in Foundry/Logic in 2020 overall with the potential for a 'pause' by the leading Foundry early in the year.
 - Broad-based across manufacturers at both leading and lagging edge technology nodes
- Further steady growth in China spending in 2020 as local manufacturers come up the learning curve

Manufacturer	Segment	Technology
China	Foundry	28nm and above (Various)
China	Memory (DRAM)	2Xnm/1Xnm DRAM (Changxin Memory Technologies, Hefei)
China	Memory (NAND)	64 layer 3D NAND (YMTC, Wuhan)
Globalfoundries	Foundry	12nm/14nm FinFET (New York)
Intel	Logic	10nm/7nm/5nm FinFET (Israel, Oregon, Arizona)
Intel	Memory (NAND)	3D NAND, 3D XPoint (Dalian, China)
Micron	Memory (NAND)	3D NAND (Singapore expansion)
Micron	Memory (DRAM)	1Znm DRAM (Taiwan and Hiroshima Japan, expansion)
Samsung	Foundry/Logic	7nm FF(S-3, Hwaseong, South Korea)
Samsung	Memory (NAND)	3D NAND (Pyeongtaek, Korea & Xian, China)
Samsung	Memory (DRAM)	1Z nm DRAM (PyeongtaekK, South Korea)
SK hynix	Memory (NAND)	3D NAND (Cheongju, South Korea)
SK hynix	Memory (DRAM)	1Znm DRAM (Incheon, Korea; Wuxi, China)
SMIC	Foundry	28nm/14nm (China - Various)
Toshiba/WDC	Memory (NAND)	3D NAND (Yokkaichi and Kitakami Japan)
TSMC	Foundry	7nm/5nm FF (Taiwan)
UMC	Foundry	40nm production (China JV)

Source: Industry data and J.P. Morgan estimates.



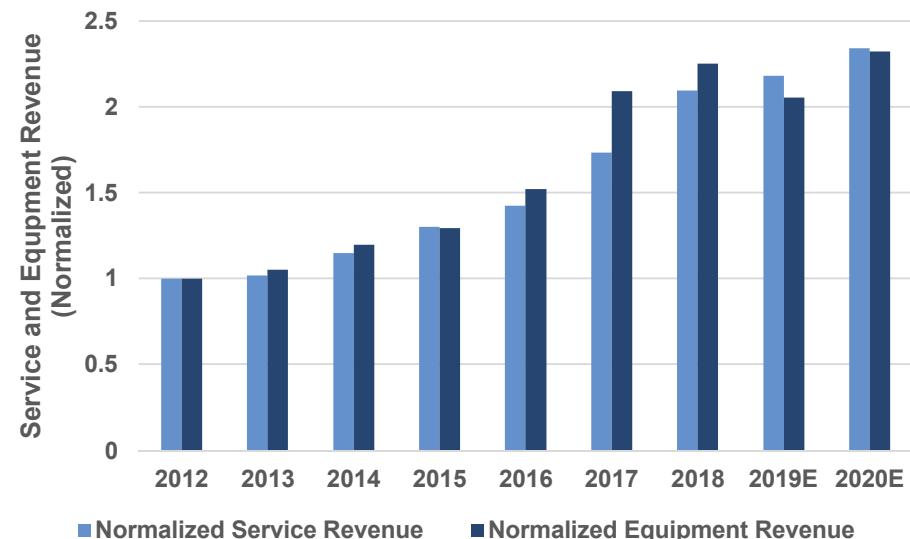
Source: Industry data and J.P. Morgan estimates.

Service / Installed Base Businesses for Applied, KLA and Lam Research Delivering Strong and Relatively Stable Growth With Strong Profitability and Free Cash Flow Generation

Service and Installed Base businesses of AMAT, KLAC and LRCX helping companies outperform relative to WFE spending with strong profitability and cash generation

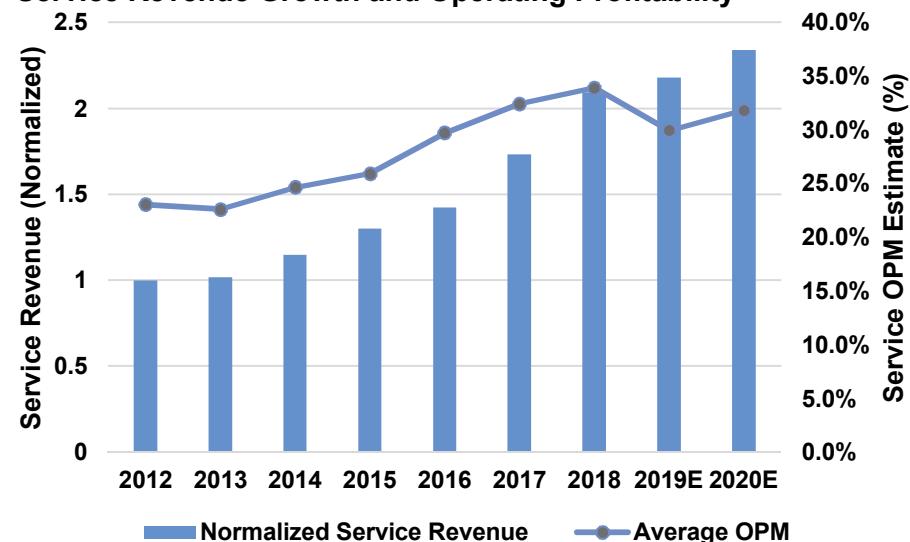
- The service businesses of the large caps under coverage remain underappreciated in our view
- **Growing at double-digit rate since (2014-2020E CAGR)**
- **More stable than equipment sales** and growing in aggregate in 2019 vs. system sales down ~10% on average
- Increasing contribution of **annuity-like long-term service agreements**
- Lower than corporate average gross margin, but generally **accretive** to operating profitability and free cash flow
- Service contribution is an important reason why semiconductor equipment companies under coverage are roughly **4 times more profitable in the recent downturn** compared to the prior downturn in 2012/2013

Service Revenue Growth Vs. Systems Revenue Growth *



Source: Company reports and J.P. Morgan estimates. * Combined AMAT, KLAC and LRCX normalized

Service Revenue Growth and Operating Profitability *



Source: Company Reports and J.P. Morgan estimates.

16 * Combined AMAT, KLAC and LRCX

J.P.Morgan

KLA: The Clear Leader in Semiconductor Process Control with Diversification into Specialty Semiconductors, PCB and FPD

- KLAC maintains its dominant position in the semiconductor process control equipment market, with >4x higher market share than the next two competitors
- Increased diversification with exposure to fast-growing specialty semiconductor markets (Adv. Packaging, Compound Semis, MEMs, etc.) and key enabler of yield and manufacturability solutions for Printed Circuit Board (PCB) and Flat Panel Display (FPD) markets
- Post-ORBK acquisition, KLAC maintains best-in-class margin profile...>60% GMs and >35% OPMs....FCF margins ~28-30%....stable growth services business (25% of revs, 9-11% CAGR)
- Core process control semiconductor business is on pace to GROW in 2019 with WFE down ~20%.
 - Gained share in optical PWI, Gained share (and achieved record revenues) in unpatterned wafer inspection (see report from last year and optical PWI reports from last several years)
 - Growth driven by reticle inspection strong with more growth this year and next (see our KLAC EUV report from last year)
 - Diversification of KLA's business playing out with exposure to non-leading-edge semi process control: new end markets, fast growing niche semi markets and increased service
- \$12/share of annualized earnings power exiting CY20 and \$15 of annualized earnings power in CY23

KLA Accounts for Over 50% of a \$6.4B Semiconductor Process Control Market, > 4X Larger than Its Nearest Competitors

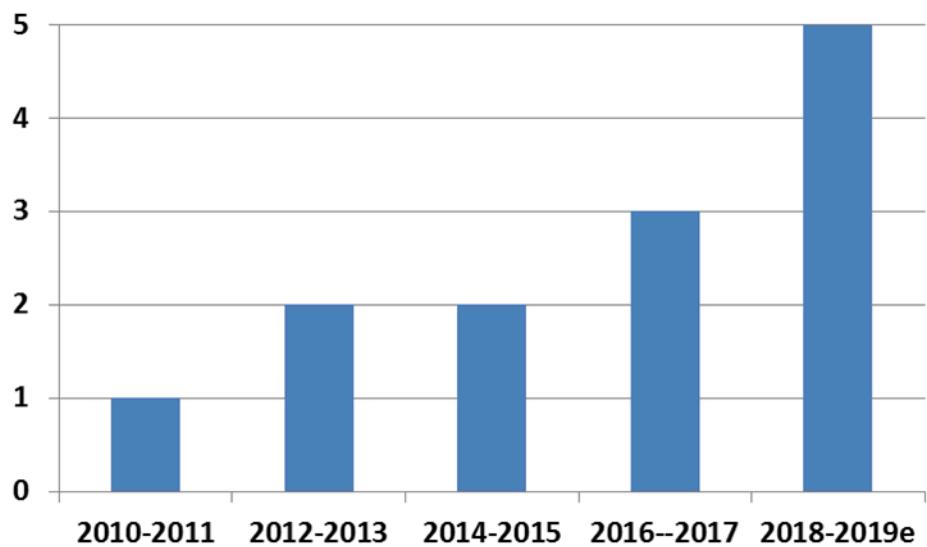
Process Control		2015	2016	2017	2018
1	KLA	2,043.2	2,406.0	2,816.6	3,263.8
	KLAC Share	48.3%	51.2%	51.3%	51.1%
2	Applied Materials	492.9	579.7	651.4	734.9
	AMAT Share	11.7%	12.3%	11.9%	11.5%
3	Hitachi High-Technologies	420.6	500.2	584.2	710.0
	HHT Share	9.9%	10.6%	10.6%	11.1%
	Others	1,273.0	1,216.2	1,434.5	1,684.6
	Others Share	30.1%	25.9%	26.1%	26.3%
	Total	4,229.7	4,702.1	5,486.7	6,393.3
	Total Share	100.0%	100.0%	100.0%	100.0%

Source: Gartner and J.P. Morgan; Note: Share may not add up to 100% due to rounding

- We expect KLA to grow core process control faster than the market on SAM and market share gains
- KLA-Tencor bringing innovative products to market
- Process control intensity is rising on increasing manufacturing complexity
- Should help KLA-Tencor build on its industry-leading financial model (>60% GM, >35% OPM, post-Orbotech transaction)

- KLA equipment revenues up 16% Y/Y, in line with WFE equipment growth (Source Gartner)
- Process control equipment revenues set to grow in 2019 (vs. WFE of down ~20%) (Source J.P. Estimates)
- Over 50% market share in process control equipment market
- >4X larger market share than its two nearest competitors

KLA-Tencor Product Platform Launches - 2010 - 2019E



Source: Company Reports

KLA: Diversified Leader in Advanced Silicon / Display / PCB Manufacturability

Through its acquisition of Orbotech, KLA has become a diversified leader in advanced silicon, display and PC manufactureability

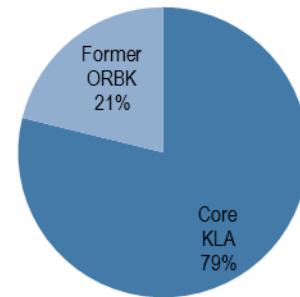
- KLAC is the leading supplier of process control and manufacturability solutions for semiconductor, display and PCB markets
- **Diversified leader** with services accounting for ~25% of revenues and former Orbotech accounting for ~20% of revenues
- PCB and Display (large format and OLED) complexity increasing driving the need for advanced inspection and repair – KLAC is the leader in inspection and report for both markets
- Former ORBK semiconductor segment exposed to advanced packaging, RF, power, MEMS that benefit secular growth trends such as 5G, AI, autonomous driving, etc.
- **Best-in-class margin profile:** >60% GMs, >35% OPM and 28%-30% FCF margin
- **Strong capital returns** with dividend yield outpacing peers on strong cash generation – goal to return 70-75% to shareholders via dividend and share repurchases and we expect KLA to deliver on its \$2 billion share repurchase authorization over the next 6-8 quarters.

Competitive Matrix of Key PCB, FPD and SD Segments

PCB Market	AOI (Automated Optical Inspection)	AOR/AOS (Automated Optical Repair, Shaping)	LDI (Laser Direct Imaging)	UV Drilling	Engineering
Installed base Market participants	#1 Orbotech, CIMS (Camtek), DNS, GigVis, Inspec, Machvision	#1 Orbotech	#1 Orbotech, ORC Imaging, DNS, Ushio/Adtec, Hans Laser	Planned for Flexible PCBs Orbotech, Via Mechanics, Mitsubishi, Electro Scientific Industries	#1 Orbotech
FPD Market					
Installed base Market Participants	AOI (Automated Optical Inspection)	Test	Repair		
#1 Orbotech, ADP, LG, NCB Networks					
Specialty Semi					
Market Participants	Advanced Packaging (Including Etch, PVD and CVD) Orbotech, Lam Research, Applied Materials, AMEC, Evatec	MEMS (Including Etch and PVD) Orbotech, Lam Research, MEMSTAR, Evatec	Power, RF, LED Orbotech, Applied Materials, Evatec Advanced Modular Systems, PlasmaTherm		

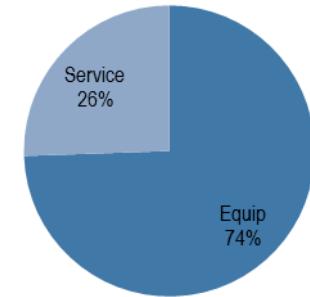
Source: Company reports and J.P. Morgan estimates.

CY20 Core KLA vs. Former ORBK



Source: J.P. Morgan estimates.

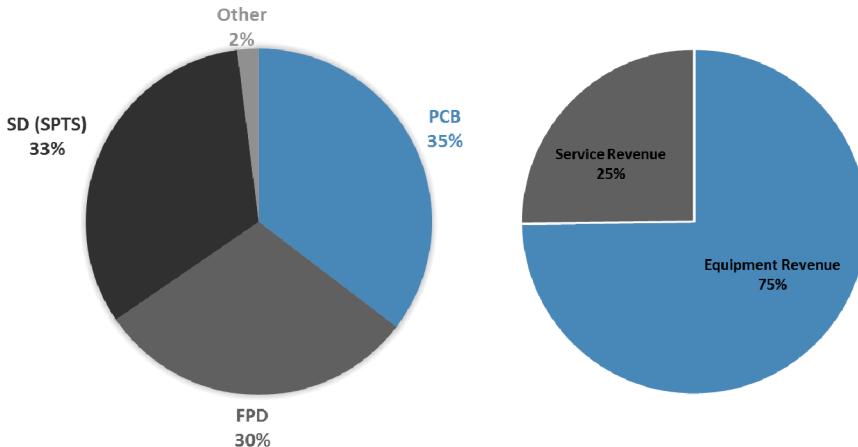
CY20 Rev - Equip vs. Service



Source: J.P. Morgan estimates.

Solid Product Cycles and SAM Expansion of Former Orbotech, Helping to Diversify KLA's End-Market, Customer Exposure

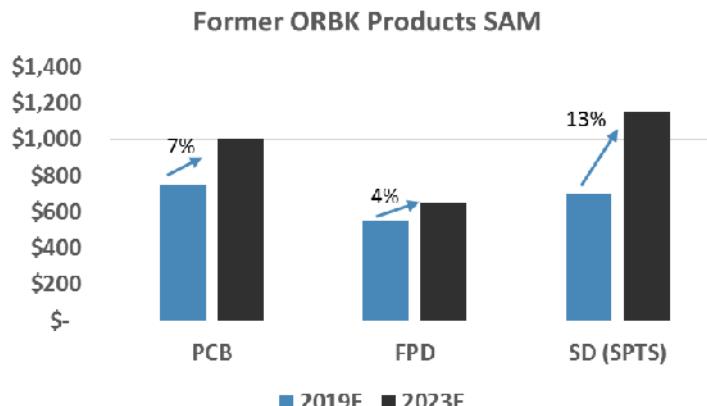
Former Orbotech End-Market Mix, Mix of Equipment vs. Service (2018)



Source: Company Reports

- Solid market share of served markets – ~50% Share of PCB, FPD and ~40% of Semiconductor served markets
- Served markets expanding at a 12% CAGR

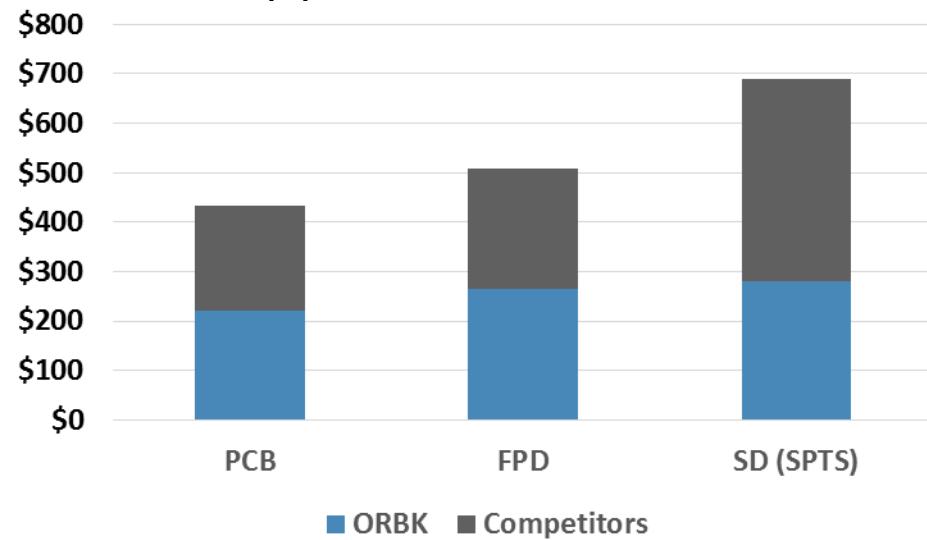
TAM Expansion – PCB, FPD and Semiconductor - \$ Millions



Source: Company Reports

- ORBK revenues up 16% Y/Y in 2018 – strong growth in equipment and service
- Leadership positions in manufacturability solutions (inspection, repair) for PCB and FPD Markets
- Strong position in specialty semi markets: Adv. Packaging, RF, Power, etc.

Orbotech's 2018 Equipment Revenues vs. Estimated 2018 TAM*



Source: Company Reports and J.P. Morgan Estimates

* 2018 TAM calculated by applying expected growth rates per end-market (8% PCB, 13% FPD and 15% Semiconductor Devices)

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