Semiconductor and Semiconductor Equipment

Secular/Cyclical Backdrop Entering 2022

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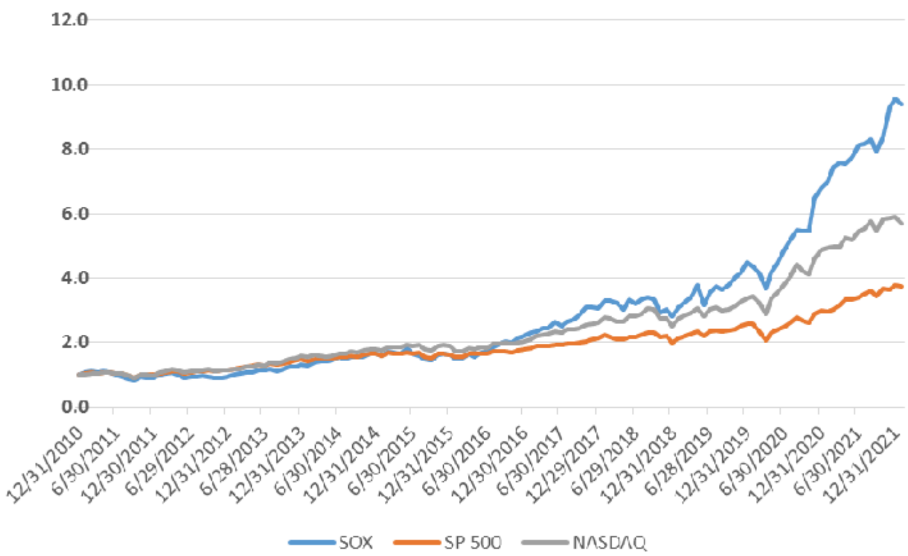
Semiconductor/Semicap Stocks Have Outperformed the Market over the Past 1,3,5,10 Years

Three Full Semiconductor Cycles Over The Past 10 Years



Annual Stock Returns (CAGR%)	3-year	5-year	10-year
SOX (Semi) Index	**47%**	**33%**	**26%**
Semicap Equipment	**66%**	**41%**	**29%**
SP500 Index	22%	16%	14%
NASDAQ Composite Index	30%	22%	19%

*Pricing as of 01/11/2022 close

Source: Bloomberg Finance L.P.

- **Drivers of the Strong Stock Performance**
  - **Realization that semiconductors are the foundational building block for all innovation in the tech sector – applications/devices/appliances are getting more intelligent and requiring higher levels of semiconductor $ content**
  - **Emergence of new semiconductor drivers: cloud datacenter, EV, IoT, AI/Deep learning**
  - **Lower cyclicality in the industry driven by end-market diversification and disciplined supply growth**
  - **Lower cyclicality drives more focus on profitability/free cash flow expansion – strong capital return to shareholders**
  - **Industry consolidation (M&A) to drive diversification, R&D scale, and enhanced profitability and capital returns**
  - **Near term: Positive Y/Y inflection in semi company revenues in 2H20 and expectations of industry growth through 2022…and potentially into 2023**
  - **We expect long-term positive fundamental trends to continue**

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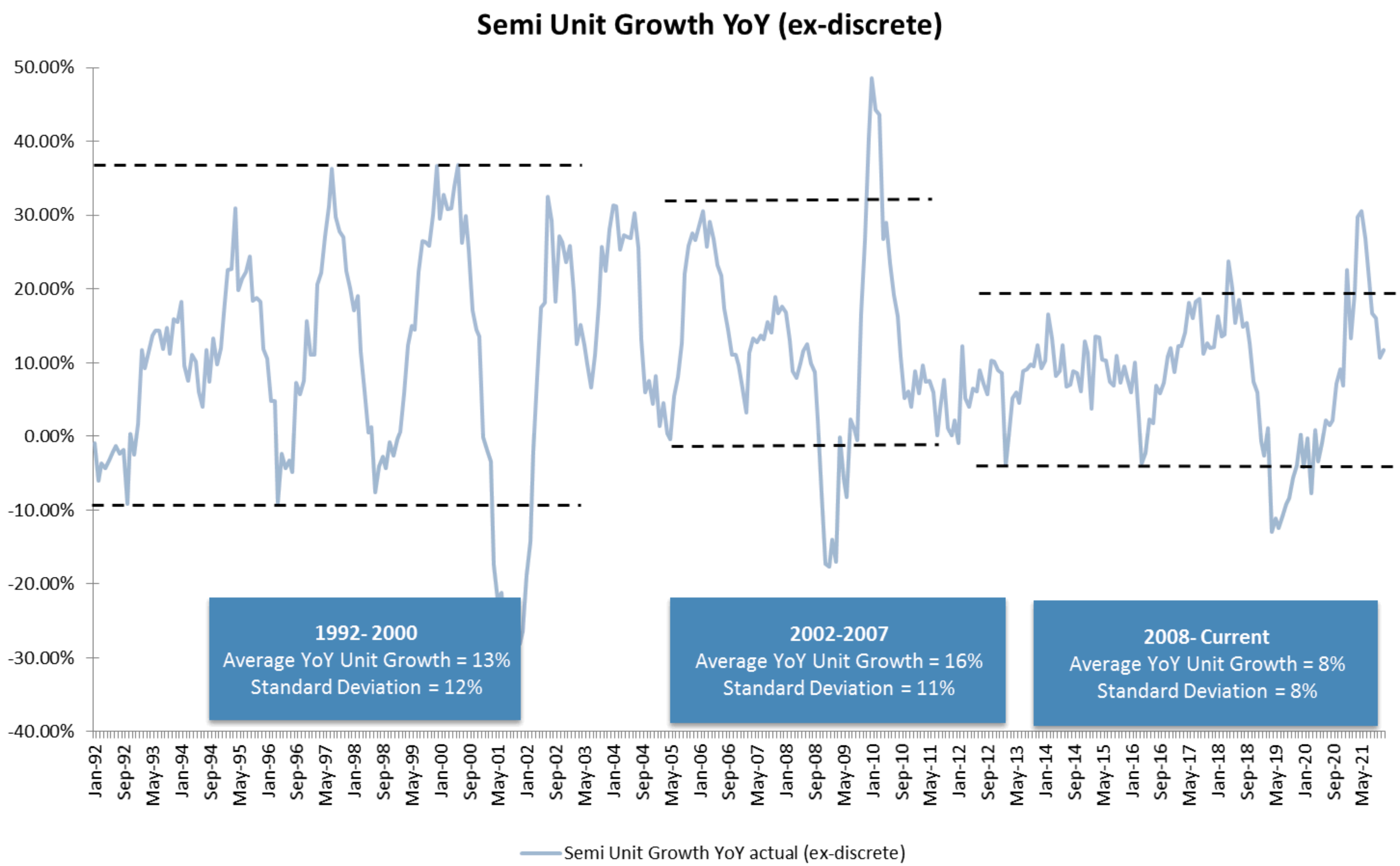
Semis in More Stable Growth Phase – Focus on Market Leadership, Strong Product Cycles, Margin/Free Cash Flow Expansion, and Capital Allocation



Source: WSTS, J.P. Morgan estimates.

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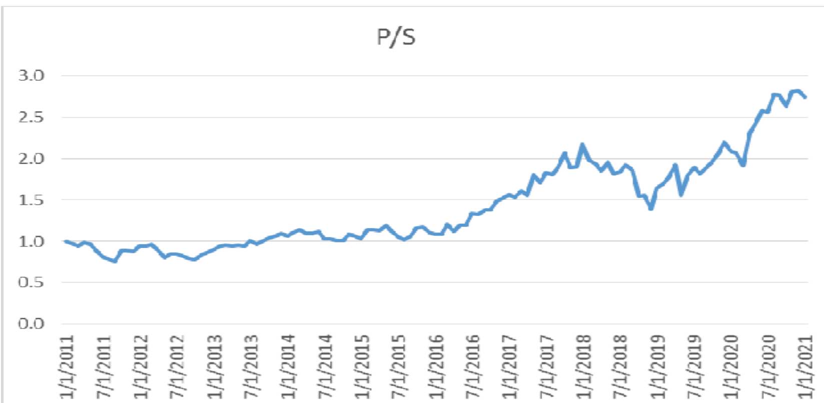
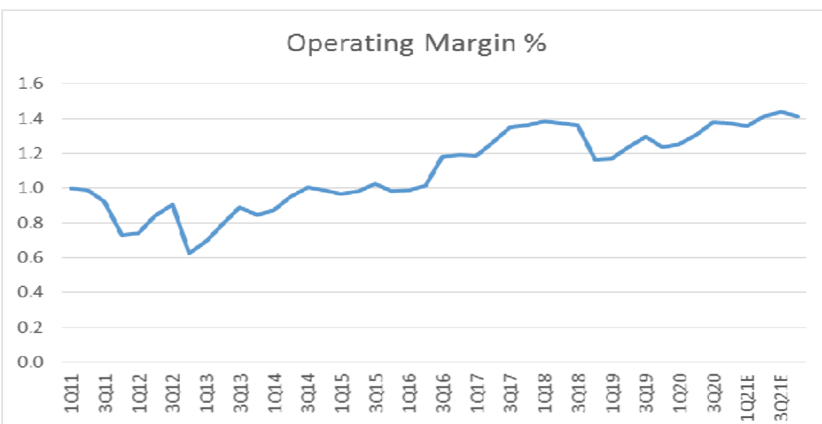
Valuation Multiples Have Expanded on Lower Cyclicality and Focus on Profitability Expansion

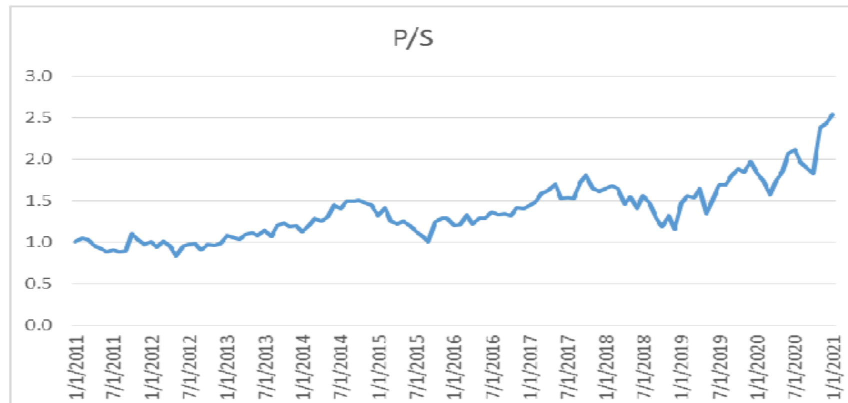
- End-market diversification and lower industry cyclicality drive more focus on profitability and free cash flow
- As operating margins and free cash flow margins have expanded, companies have put in place strong capital return programs – driving higher valuation multiples (see charts below)
- Industry consolidation has driven valuation multiples higher over time as well

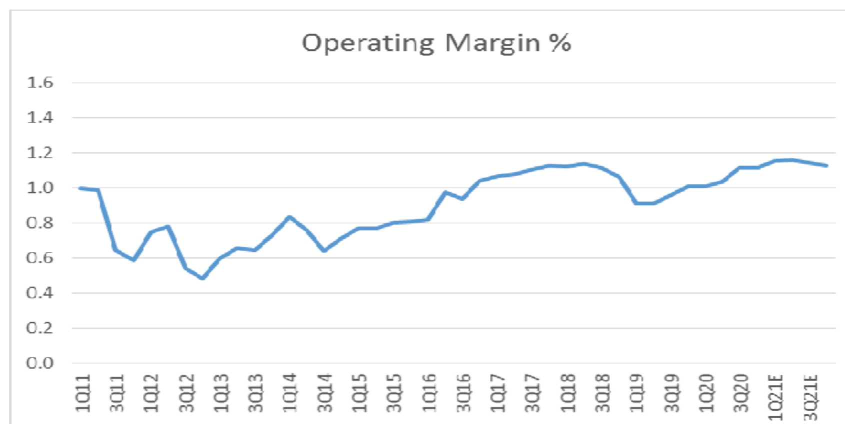
Semiconductor Average (Indexed to 1)





Semiconductor Capital Equipment Average (Indexed to 1)





Source: J.P. Morgan estimates, Bloomberg Finance L.P. and Company reports.

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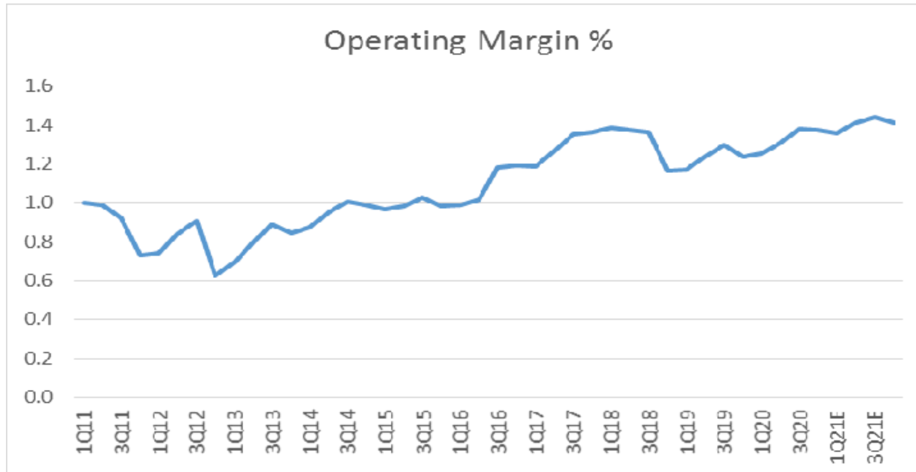
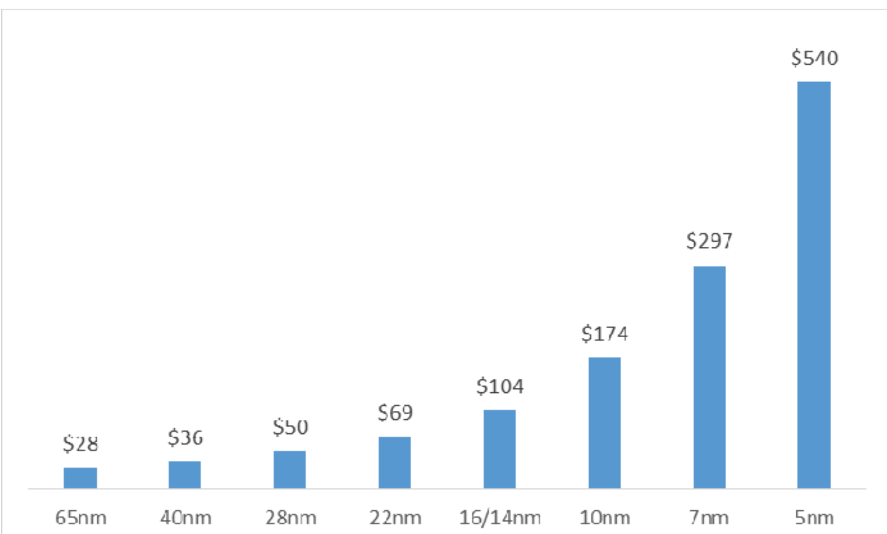
Strong Focus by the Semiconductor Industry on Profitability and FCF Expansion, as Design and Manufacturing Intensity Continues to Rise

Semiconductor Industry Operating Margins



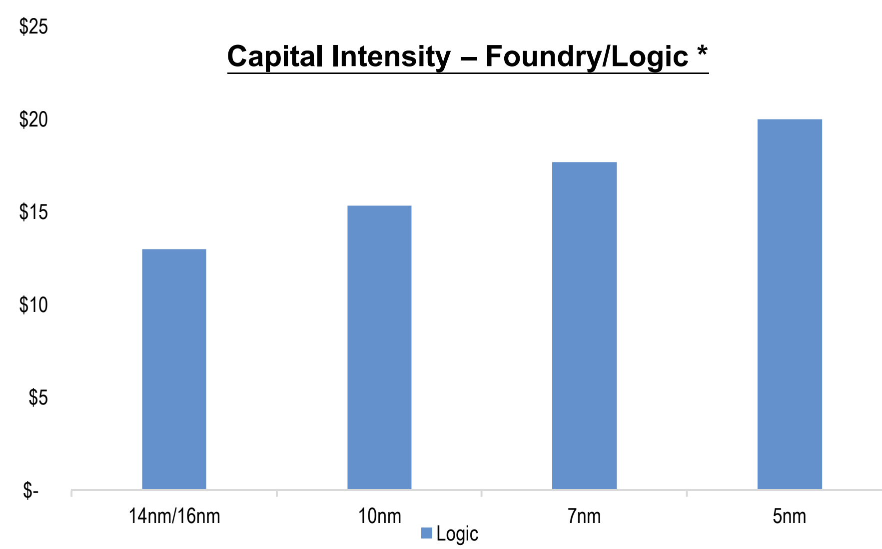
Source: J.P. Morgan estimates, Bloomberg Finance L.P. and Company reports.

Chip Design Costs ($M)



Source: IBS, McKinsey

Capital Intensity – Foundry/Logic *



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

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

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Cyclical Focus – Current Cycle 2022 and 2023

Cyclical Dynamics Over the Past 10 Years have been DEMAND driven….NOT Supply driven

- **The last three down-cycles (2010/2011, 2015/2016, and 2018/2019) have been DEMAND driven Not Supply driven as the value chain (supply-side) has become more disciplined on supply expansion:**
  - **2010/2011: Auto/consumer/PC slowdown**
  - **2015/2016: China, PC, Communications infrastructure slowdown**
  - **2018/2019: China/US trade war and tariffs, weak industrial and smartphone demand (ahead of 5G upgrade cycle)**
- **2022: We anticipate another strong year for the semiconductor industry with revenues growing 10%+ and out-year EPS estimates being revised higher by 15-20% over the next few quarters, following six consecutive quarters of positive EPS revisions. Conclusion- <u>Cyclical Dynamics Strong In 2022</u>**
- **2023: Although supply will expand through 2023, manufactures will be disciplined on adding capacity and there remain bottlenecks (equipment lead-times/component shortages, potential continued COVID-19 disruptions, delays in localization efforts/subsidies)….current macro-demand outlook for 2023 remains constructive….if we assume seasonal trends (conservative) going forward, we can continue to see positive Y/Y industry revenue growth well into 2023…….**
  - **Similar to prior cycles, a potential down turn in 2023 would have to be demand driven….but much harder to predict demand inflections….**
  - **Supply-side dynamics may overshoot demand in 2023, but this will create a 1-2 quarter industry slowdown if demand remains strong, <u>but not the classical 4-6 quarter down-cycle</u>….**

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Only 40-50% Through the Current Up-Cycle; Tight Supply Drives Multiple Qtrs of Strength

- We estimate that the industry is only 40-50% through the current up-cycle (remember last cycle positive Y/Y trend was 10 quarters long). It will likely take another 4-6 quarters for supply to catch up with demand and inventories across the value chain to get back to normalized levels
  - Companies are shipping 20-30% BELOW current end-market demand
  - Equipment lead times 9-12 months (equipment order to production output)
  - It will likely take 3-4 quarters for supply to catch up with end-market demand…..and then another 1-2 quarters for value-chain inventory replenishment

- Classical inventory analysis is potentially misleading as it doesn't take into account significant unfulfilled backlog…… Also, rising input costs and raw materials buffers make historical comparisons more difficult and potentially over estimating unit production output……

- More importantly – Need to focus on both sides of the equation: Semiconductor inventories in the value chain versus product inventories at point of consumption

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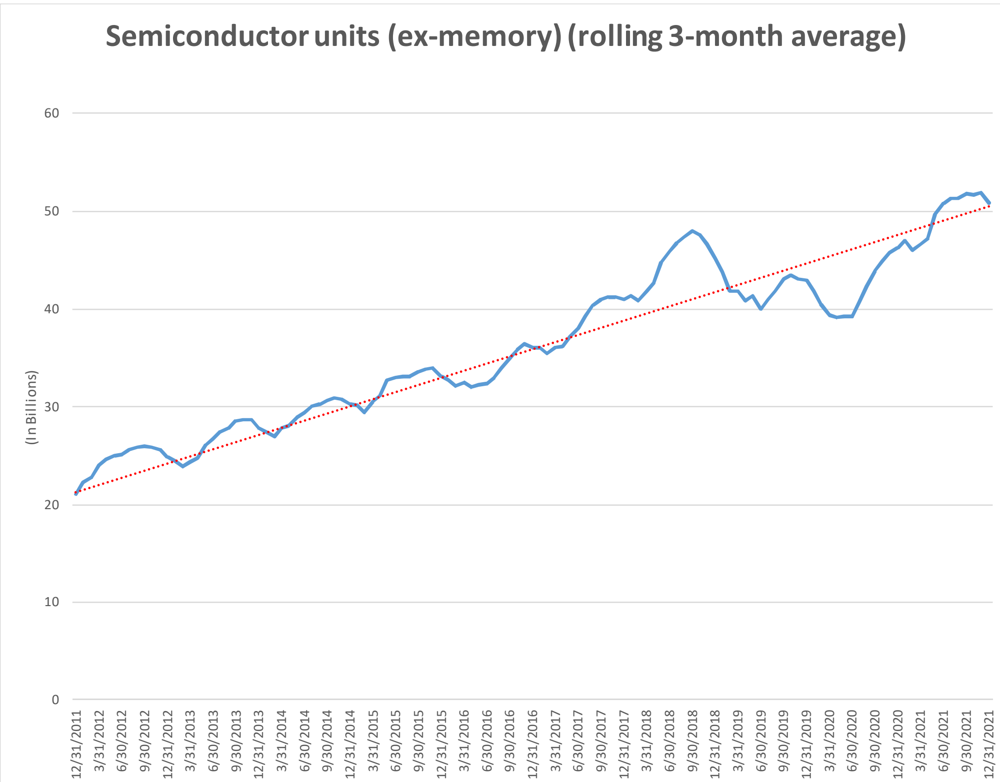
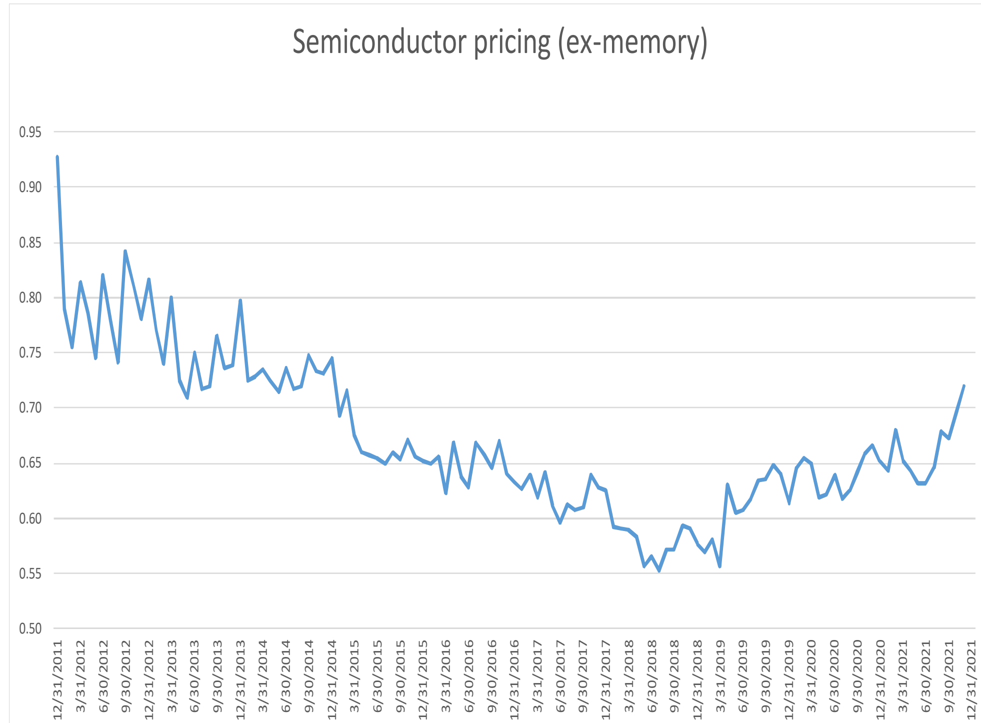
Industry Unit Shipments In-Line With Historical Trend…..But Pricing is UP

Semiconductor Unit Shipments Over The Past 10 Years



Source: WSTS/SIA

Semiconductor Unit Pricing Over The Past 10 Years



Source: WSTS/SIA

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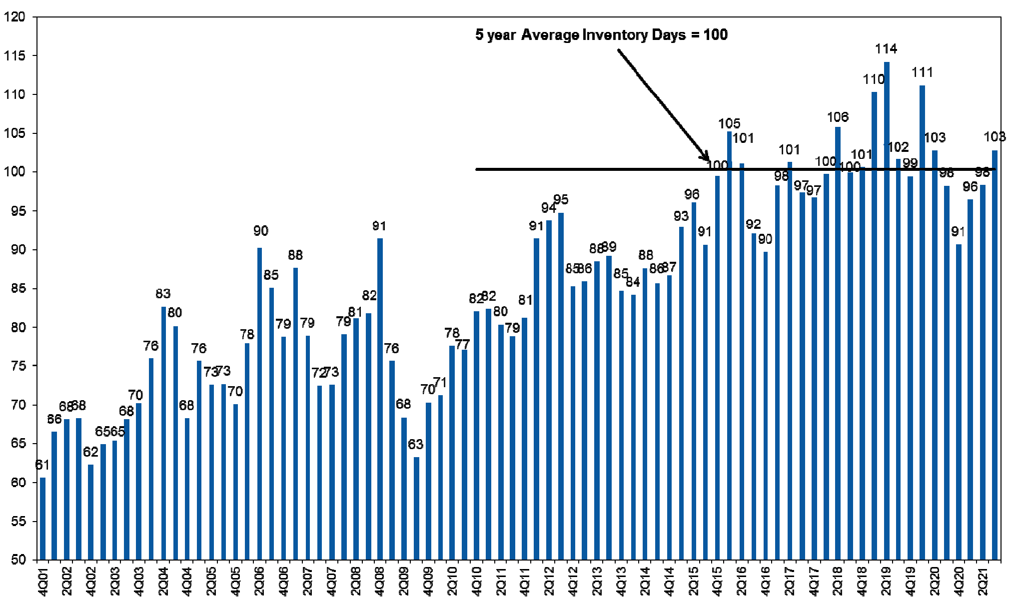
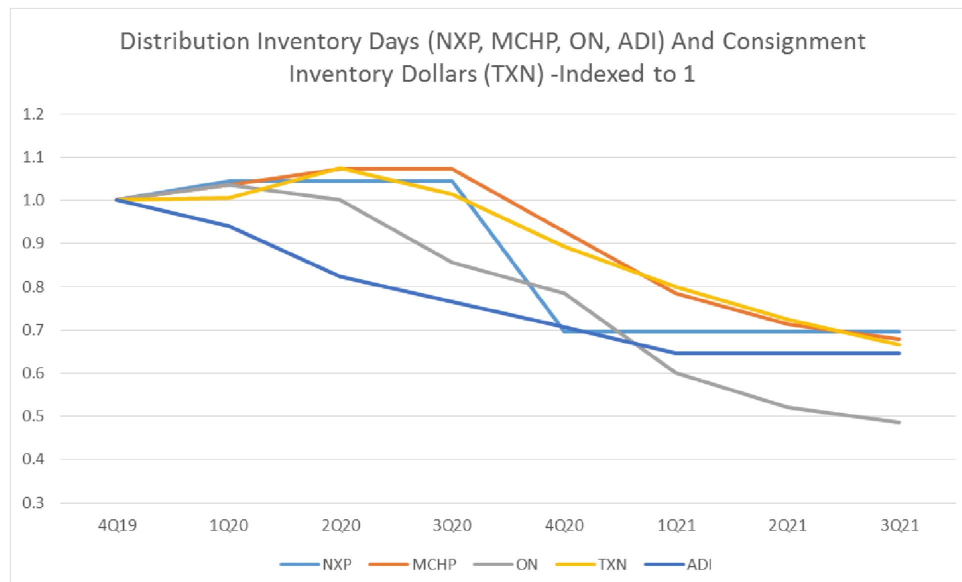
Inventories in the Channel and at Direct Customers Remain at Low Levels

- **Semi days of inventory in-line with historical trends:** 103 days in 3Q21, slightly above the 5-year average of 100 days up from prior quarter. **True inventory metrics (calculated in days/weeks) we believe are potentially LOWER than actual reported results as they don't take into account the un-fulfilled shipment backlog that was requested to be shipped in the current quarter. Also, 10%+ Y/Y cost increases implies that not all of the $ value step up in inventories is due to unit/production growth.**
- **Overall channel/customer inventories are at/near historic lows, and lead times are continuing to get stretched out. Distribution/channel inventories remaining 30-50% below pre-COVID 19 levels (with signs of heading lower) and direct customer inventories (as measured by consignment/finished goods) at 15-35% below.**

Days of Inventory, JPM Semi Universe



Source: Company reports and J.P. Morgan estimates



Source: Company reports and J.P. Morgan estimates

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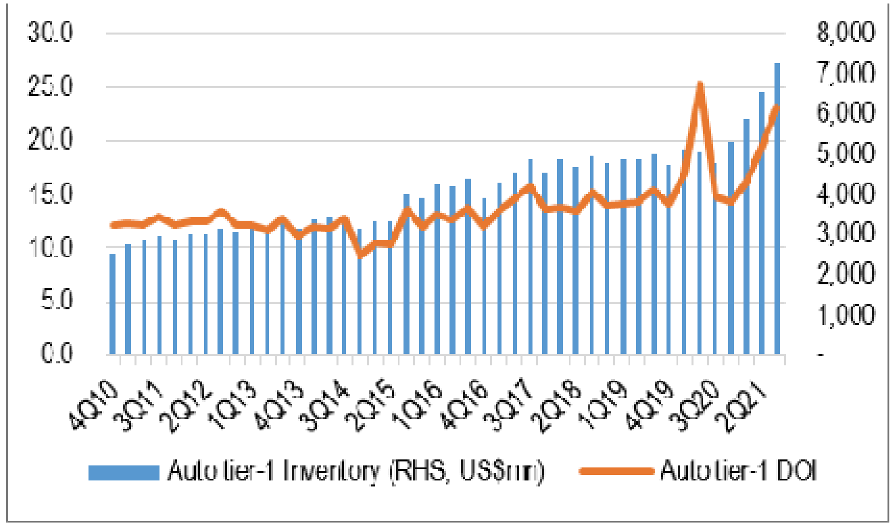
Semi /Customer Inventories Need to Be looked at Alongside End Market Inventories and Demand– Auto Mkt Example

- **High Auto OEM chip inventories (Raw Materials) ~1.7x higher versus pre-COVID-19 is being skewed by chip pricing increases, increasing $ semi content per vehicle, auto OEM focus on mid/high-end production (higher $ content), and EV penetration (2x semi content)…..Cannot make a judgement on level of inventory (Units) without looking at END-MKT INVENTORIES**
- **If you look at absolute automotive vehicle inventories or DOI at dealerships or rental car fleets – Dealership vehicle inventories are still 3X LOWER versus pre-COVID-19 levels and rental car fleet size is 20-25% lower versus pre-COVID-19 levels ……STILL IMPLIES TIGHT CHIP SUPPLY ENVIRONMENT GOING FORWARD**

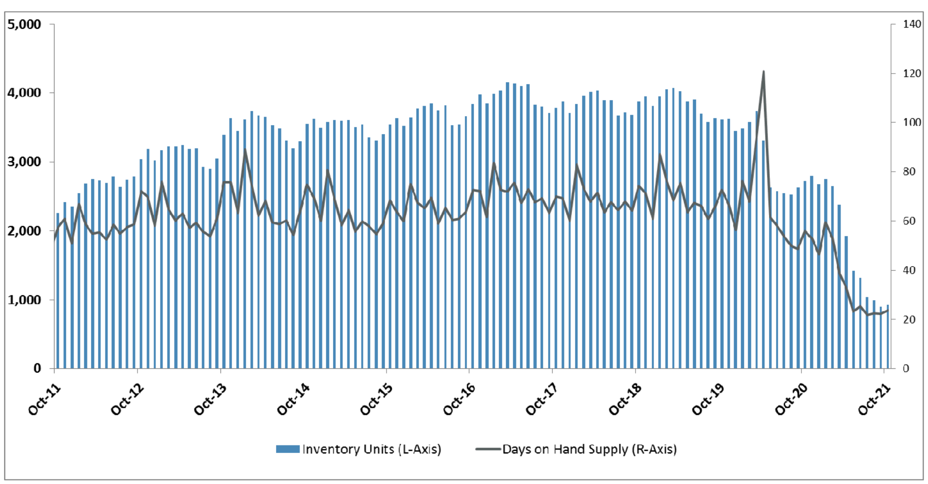
Auto OEM Raw Materials Inventory 1.7x Higher Versus Historical…..But Trend Still Lags Dealership Inventories Which are 3x Below Historical and Rental Car Fleets Which are 25% Below Historical…….



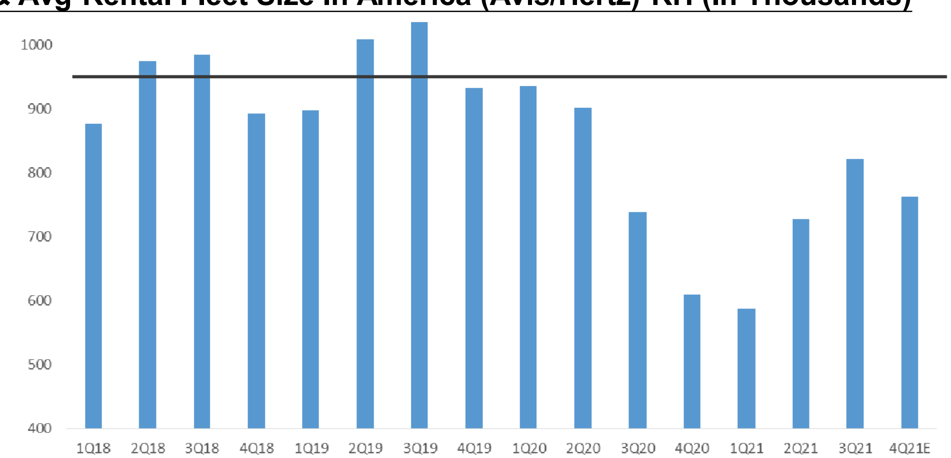
Auto OEM Raw Materials Inventory

Source: Company Reports

End Mkt Inventories: New Vehicles in Inventory on U.S Dealer Lots (LH) & Avg Rental Fleet Size In America (Avis/Hertz) RH (In Thousands)



Source: Autodata



Source: Company Reports and J.P. Morgan estimates

We Anticipate the Market Continuing to Discount an Improving Economic Backdrop in 2021 and 2022 with Strong Demand Drivers in Place

- **Global GDP growth of 5.8% in CY21E (+6% in Q4, +3% in Q1), 4.3% in CY22E**
- **Semi industry growth of 24% in CY21E, 10%+ in CY22E**
- **Cloud/hyperscale capex spending growth of 19% in CY21E (top 4 CSPs)**
  - **Up 30% in CY22E**
- **PC shipments up 11% in CY21E after 11% growth in CY20, flat to down 2% in CY22E**
- **5G smartphone unit shipment growth of >100% in CY21E, up ~40% in CY22E**
  - **Total smartphone shipments up ~3% Y/Y in CY21E and up ~2% in CY22E**
- **5G base station deployment growth of 35% in CY21E, 20-22% in CY22E led by global 5G deployment ex China (up ~40% Y/Y in 2022)**
- **Global light vehicle production up ~1% in CY21E, +9% in CY22E, up 10% in CY23E**
  - **EV production up 80% in 2021, up 25-30% in 2022 and 2023 (25% of the mix)**

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

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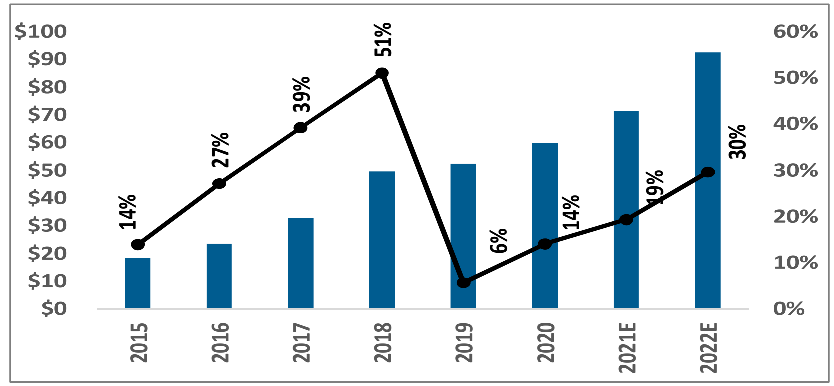
Strong Data Center Spending – Driving Strong Demand for Compute, Networking, and Memory/Storage Semiconductors - $60B+ Semiconductor Market Opportunity

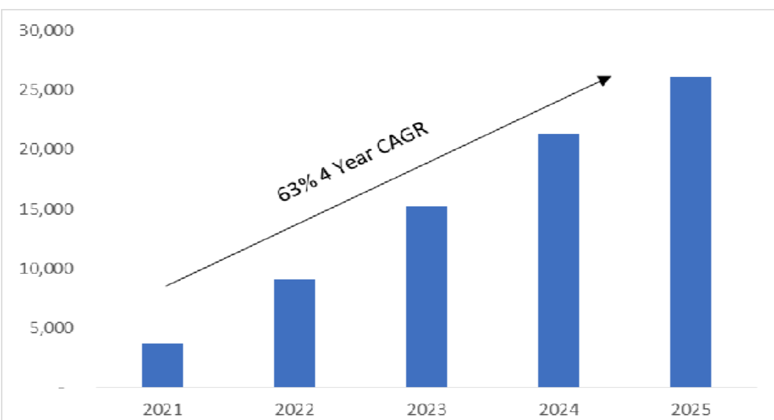
- **Look for companies levered to data center trends to continue to outperform in 2022 across COMPUTE, NETWORKING and STORAGE/MEMORY**
- Cloud Service Provider Spending (top 4) grew 19% in 2021. **We expect cloud spending momentum to be sustained into 2022 at 30% Y/Y (after 2H21 spending inflection).**
  - Cloud services revenue should continue to grow >40%+ Y/Y
  - Over the next 5 years, CIOs should grow spending on public cloud by 4x
  - Early ramp of new processors by Intel, AMD, NVIDIA, and ARM-Adopters
  - Silicon switch ports (>25Gbps) projected to grow 17% CAGR
  - DRAM memory content in a cloud server is 50% higher than traditional enterprise server
  - Datacenter compute acceleration growing >20% CAGR, driven by higher complexity workloads (AI/Deep Learning, Analytics, etc.)

Cloud Service Provider Spending – Top 4 CSPs (2015-2022E)



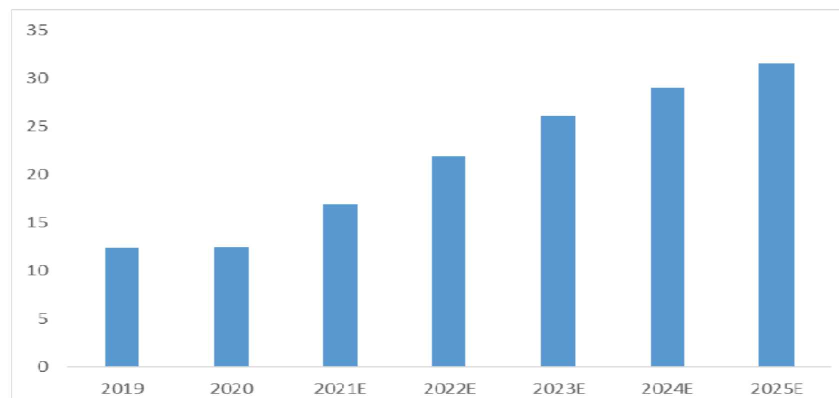
Source: : Dell'Oro and J.P. Morgan estimates.

Data Center 200G/400G/800G Switch Port Growth (63% CAGR 2021-2025)



Source: Dell'Oro

Cloud Computing Growth - Worldwide Accelerated Server Revenue($B) (20% CAGR 2021-2025)

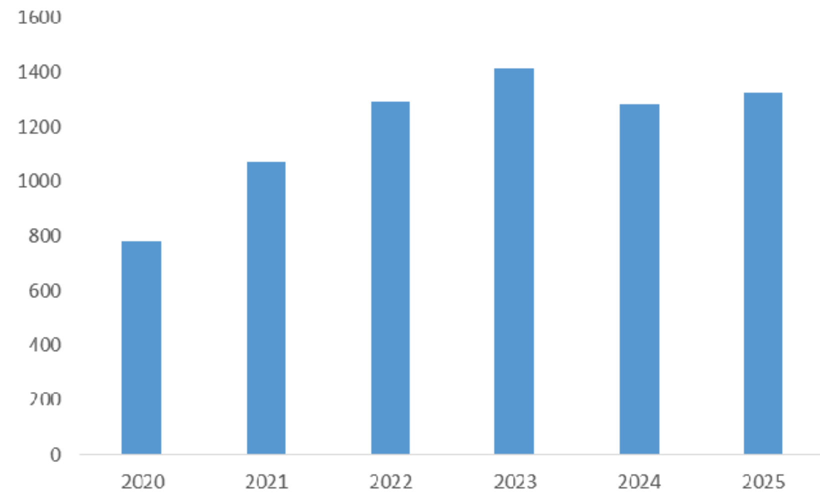


Source: IDC and J.P. Morgan estimates

5G Wireless Infrastructure: Anticipate Strong Growth in 2022 and 2023

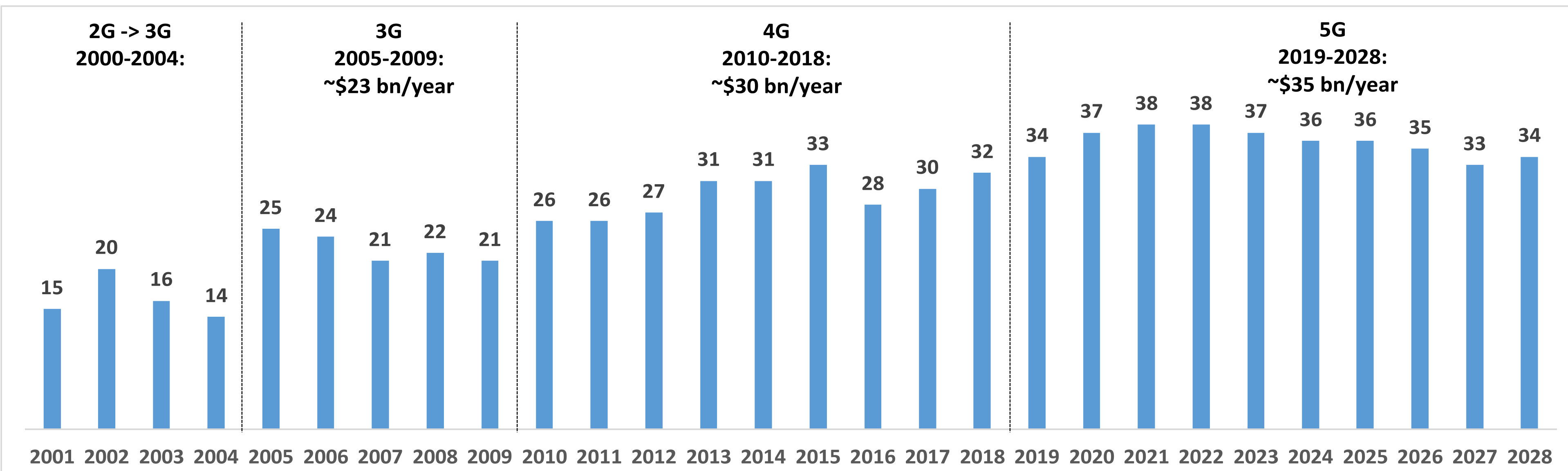
- **5G Basestation Deployments – Growing by more than 22% CAGR (2020-2023E)**
- 5G Basestation global deployments up 35% Y/Y in 2021 and 20-22% Y/Y in 2022
- **$4B digital semiconductor SAM, $1B RF/Analog SAM**
- 5G deployments accelerate outside of China (up 40% Y/Y)- Continued momentum in North America activity and follow by Europe

5G Basestation Deployments (2020E -2025E)



Source: IDC and J.P. Morgan estimates.

Carrier Infrastructure Spending



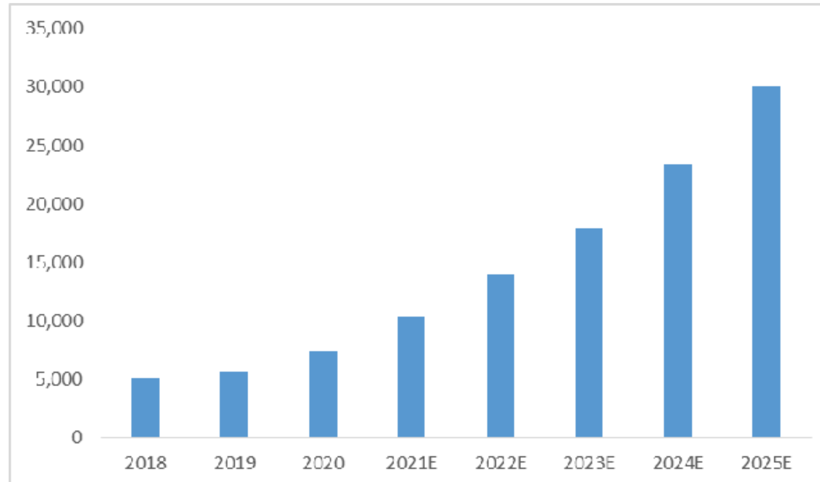
Source: Altman Vilandrie, CTIA, ExteNet

Automotive Market Opportunities – ADAS/Autonomous Driving and xEV Driving Significant $$ Content Growth in Leading Edge and Analog/Power Semis

Auto Semiconductor Opportunity

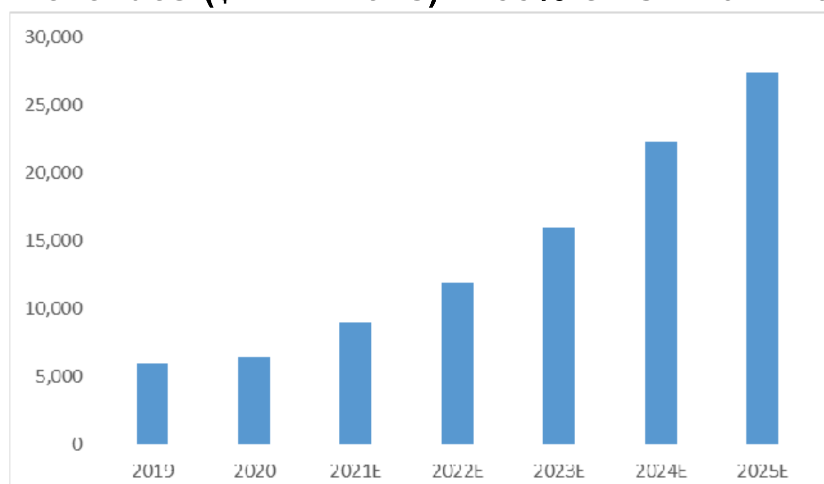
- **Automotive should be a large driver of leading edge silicon SOC demand as ADAS/autonomous driving capabilities continue to penetration new model vehicles**
- **Additionally, the strong adoption of xEV cars (with enhanced ADAS/autonomous capabilities) is driving strong penetration – xEV CAGR is ~30% (2021-2025E), and dollar content in xEV is 1.8-2x HIGHER versus conventional internal combustion engine (ICE)**
- **Overall dollar content per vehicle is accelerating from 5-7% CAGR through 2018, to 10-12% CAGR 2018-2025E, driven by**
  - **More high-end processors per car (domain-based architecture and Autonomous compute intelligence)**
  - **More power semis/battery management for xEV**

xEV Auto Production Outlook (Units in 000s) ~30% CAGR 2021-2025E



Source: IHS and J.P. Morgan estimates

ADAS / Autonomous (HPC) Semiconductor Revenues ($ in Millions) ~ 35% CAGR 2021-2025E



Source: Gartner

Custom Chip (ASIC) Market Experiencing a Resurgence in Activity as Large OEMs, Cloud and Hyperscalers Look to Differentiate at the Silicon Level – $10-12B Oppty

- **Demand is rising for custom ASICs, because many of the large OEMs/CSPs/Hyperscalers are looking for more differentiation, better performance, lower power consumption and overall lower cost of ownership versus off-the-shelf chip solutions (or ASSPs) – Broadcom (#1 35% share high-end ASIC mkt) and Marvell (#2 15% share high-end ASIC mkt should continue to dominate this opportunity**
- **These same customers do not have the capabilities to do large complex system-on-a-chip (SOC) designs, nor do they have the broad IP portfolio of on-chip design blocks, like high speed SERDES capabilities or high speed memory interface technology. They need to engage with semiconductor companies that have the IP and chip design expertise.**
- **The digital custom ASIC market is a ~$10-$12B per year market opportunity growing at a 12-15% CAGR :**
  - **Cloud/Hyperscale ASICS (AI processors, SmartNICs, Security/Video processors, Networking/Storage acceleration)**
  - **Telco/service provider equipment OEMs (5G basestation modem, 5G digital front end, 5G MIMO/Beamforming)**

Snapshot of High Profile Custom ASIC Programs: AVGO/MRVL

ASIC Customers	Programs	Technology	Status
Cloud Titan A	AI Chip	28nm Technology	Deployed
Cloud Titan A	AI Chip	16nm Technology	Deployed
Cloud Titan A	AI Chip	16nm Technology	Deployed
Cloud Titan A	AI Chip	7nm Technology	Deploying Now High Vol
Cloud Titan A	AI Chip	5nm Technology	2H 2022
Cloud Titan A	AI Chip	3nm Technology	Won, In Development
Cloud Titan A	VCU Chip	12nm Technology	Ramping
Cloud Titan A	Switching	7nm technology	2021
Cloud Titan B	DPU	16nm technology	2020/2021
Cloud Titan B	Video	7nm technology	2021/2022
Cloud Titan B	Storage	16nm technology	2021
Cloud Titan B	Security	7nmnm technology	2021
Cloud Titan C	Security	7nm technology	2020/2021
Cloud Titan C	DPU	7nm technology	2022
Cloud Titan C	Compute	5nm technology	ARM Server Processor
Tier-1 US Service provider	Compute	16nm Technology	SmartNIC
Clout Titan D	Compute	16nm Technology	SmartNIC
Compute OEM	AI Chip	7nm technology	AI acceleration
AI Semi Company	AI Chip	7nm technology	AI acceleration
AI Semi Company	AI Chip	5nm Technology	AI acceleration
5G Networking OEMs	Networking	7nm/5nm Technology	5G Basestation/Radio

Source: J.P. Morgan Research

New ASIC Programs for Broadcom/Marvell

- **Broadcom 7nm/5nm/3nm win on TPU platform**
- **Broadcom 5nm win multiple AI platforms**
- **Broadcom 7nm win Video acceleration**
- **Broadcom 7nm/5nm multiple DPU wins**
- **Broadcom – 60+, 7nm/5nm/3nm programs**
- **Marvell – 5nm multiple cloud networking ASICs**
- **Marvell – 5nm win multiple AI platforms**
- **Marvell - 5nm Auto compute ASIC**
- **Marvell – 5nm multiple 5G (BTS/Radio) ASICs**
- **Marvell – 35+, 5nm programs designs underway**

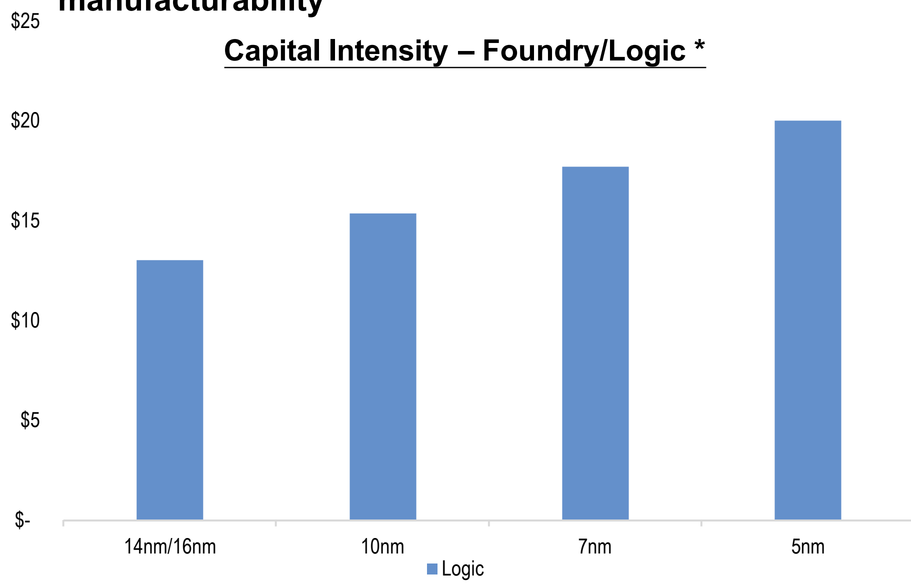
Source: J.P. Morgan Research

Capital Intensity Increasing Across Device Types – Positive for Semi Equipment

Capital Intensity Increasing Across Device Types

- **Since bottoming in 2013 at 9%, WFE intensity has grown to 15% in 2021…..WFE growth has outgrown semi industry growth by 600-700 basis points per year on increasing capital intensity. We anticipate 300-500 bps per year WFE outperformance going forward.**
- **Require increasing capex to drive bit growth for both DRAM and NAND (see charts on right)**
- **Capital intensity increasing for Foundry/Logic even as EUV has begun ramping; 5nm capital intensity >50% higher than 14nm/16nm**
- **Time-to-market, complexity, new materials driving strong focus on yield, defect density, reliability and manufacturability**

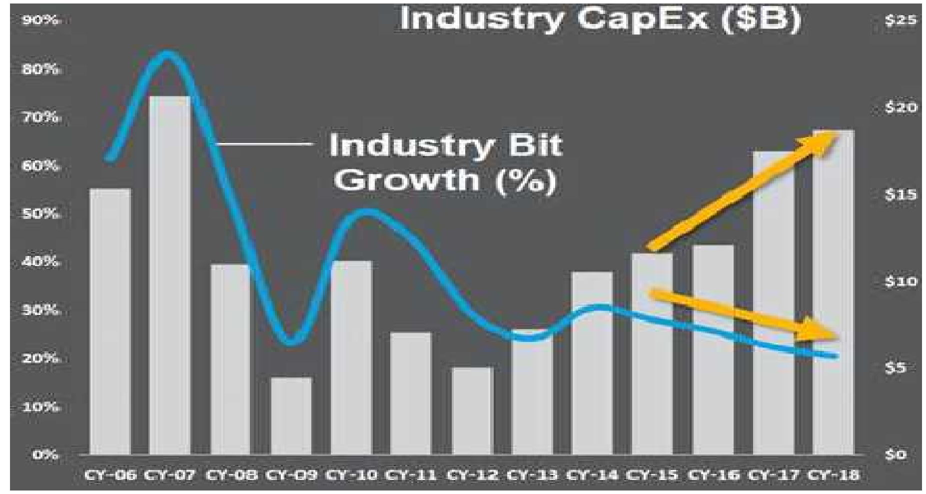
Capital Intensity – Foundry/Logic *



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

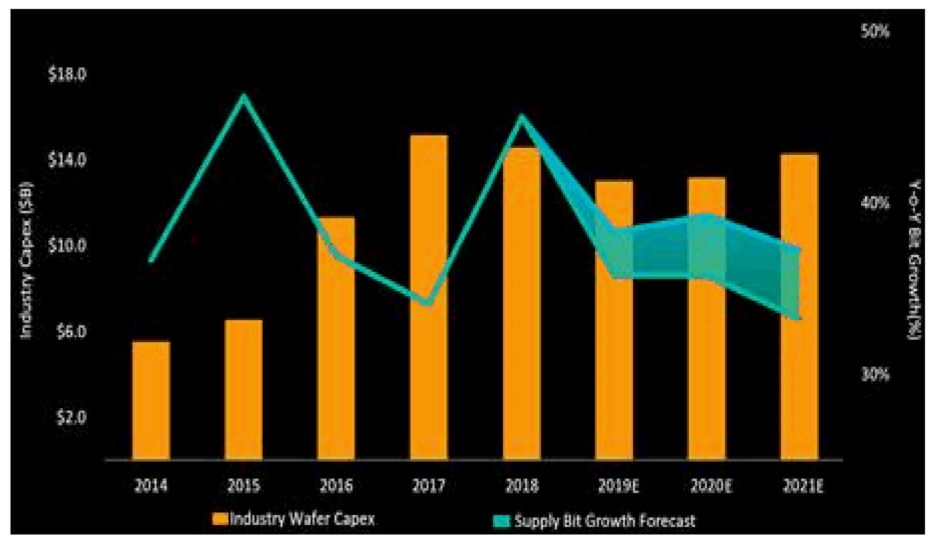
* $B of WFE required for 100k wafer starts per month (WSPM) greenfield capacity

DRAM Capex vs. Bit Growth



Source: Micron, May 2018 Analyst Day

NAND Capex vs. Bit Growth



Source: Western Digital, December 2018 Analyst Day
Forward Insights, 2018, WDC. 2019-2021 Projection

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Summary – Growth and Cyclical Trends Remain Positive Through 2022 Our Top Picks Are Broadcom (AVGO), Marvell (MRVL), 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 15-20 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
- **We continue to see a constructive fundamental setup for semi industry revenues exiting 2021 and into 2022, as we are still in the early innings of a prolonged multi-quarter upcycle, and in addition to strong demand trends, we believe our companies will continue to exert strong pricing power amidst a tight supply environment. We see semi industry revenue up ~24% Y/Y in 2021. We see another 10%+ growth in semi revenues in CY22. In semiconductor equipment, we see spending up 40%+ Y/Y in 2021, led by continued Foundry/Logic strength and memory recovery and another 10%+ in CY22**
- **Supply constraints across all end markets…we see multiple quarters of strength for the semi suppliers.** Channel/customer inventories are at historic lows, and lead times are continuing to get stretched out. We believe end-demand is trending ~20-30% above semi companies' ability supply, and we estimate it will take another 3-4 quarters for the situation to normalize. Given the strong demand environment, combined with supply tightness, we anticipate revenue/EPS expansion into 2022 and perhaps into 2023
- **Expect continued industry consolidation (M&A):** Focus on scale, diversification, and margin and FCF expansion
- **Promising outlook for foundry/ memory in 2021/2022 demand and capex spending driving strong semi equipment fundamentals**
- **Gov't incentives for US domestic manufacturing capability a positive – innovation and assurance of supply base**
- **Semis large-cap top pick: AVGO and MRVL; we also favor ADI, INTC, GFS, NVDA, MCHP, MU**
  - Given continued volatility and potential cyclical concerns, we focus on market leadership, strong US-based exposure to cloud/5G infrastructure spending trends, strong product cycles, diversification, and margin/free cash flow expansion with increasing payout ratios
- **Semi capital equipment fundamentals strong and likely to continue into 2022 and beyond: 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 ~4.5x more market share than their #2 competitor. We are also OW LRCX & AMAT

Disclosures

Companies Discussed in This Report (all prices in this report as of market close on 11 January 2022)
Broadcom Inc(AVGO/$622.05/OW), KLA Corporation(KLAC/$425.61/OW), Marvell Technology Inc(MRVL/$86.23/OW)

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Initiated coverage Nov 01, 2010. All share prices are as of market close on the previous business day.

Date	Rating	Price ($)	Price Target ($)
15-Mar-19	OW	268.20	365
14-Jun-19	OW	281.61	350
13-Dec-19	OW	327.80	380
13-Mar-20	OW	218.78	340
05-Jun-20	OW	308.89	365
04-Sep-20	OW	352.09	420
11-Dec-20	OW	410.04	500
05-Mar-21	OW	443.59	570
04-Jun-21	OW	464.80	585
03-Sep-21	OW	491.90	600
06-Dec-21	OW	558.12	655
10-Dec-21	OW	583.42	700

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KLA Corporation (KLAC, KLAC US) Price Chart

Source: Bloomberg Finance L.P. and J.P. Morgan; price data adjusted for stock splits and dividends.
Initiated coverage Nov 07, 2002. All share prices are as of market close on the previous business day.

Date	Rating	Price ($)	Price Target ($)
07-Mar-19	OW	114.50	160
06-Aug-19	OW	126.46	180
31-Oct-19	OW	172.96	200
05-Feb-20	OW	178.80	210
04-Aug-20	OW	207.65	250
29-Oct-20	OW	190.55	260
04-Feb-21	OW	286.30	335
30-Apr-21	OW	326.36	400
30-Jul-21	OW	319.43	410
28-Oct-21	OW	340.57	460

Marvell Technology Inc (MRVL, MRVL US) Price Chart

Source: Bloomberg Finance L.P. and J.P. Morgan; price data adjusted for stock splits and dividends.
Initiated coverage Oct 22, 2002. All share prices are as of market close on the previous business day.

Date	Rating	Price ($)	Price Target ($)
07-Feb-19	OW	19.04	24
31-May-19	OW	22.19	27
04-Dec-19	OW	25.16	31
29-May-20	OW	29.97	36
28-Aug-20	OW	35.91	40
09-Oct-20	OW	42.75	50
29-Oct-20	NR	39.53	--
08-Jun-21	OW	48.27	66
27-Aug-21	OW	63.24	74
29-Nov-21	OW	71.99	85
03-Dec-21	OW	71.03	100

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