CROSSBAR – ReRAM Memory

Venture Capital Investment Report

Kaiden Gilbert: 21317009

14th September 2018	**Exit Valuation: $293.27M**	**IRR: 25%**

CROSSBAR – Data is the new air! In fact, It's Everywhere!

Wherever you go, data is available at all times. Crossbar is a pioneer is its field, revolutionising data storage through its emerging ReRAM technology.

THE STORY SO FAR

- **The Company:** In conjunction with collaborative engagements, Crossbar is the leader in patented filament-based non-volatile ReRAM technology – Resistive Random Access Memory – suited for end-use application in gigabyte (GB) silicon storage, which is geometrically smaller (denser), boasts lower power consumptions with more robust reliability and performance metrics relative to incumbent data storage solutions, including NAND Flash memory.

- **The Market:** NAND Flash currently dominates the non-volatile memory (NVM) market, with it being the preferred storage technology used in laptops, tablets and mobile phones. Because of the proliferation of data consumption over the past decade, memory storage use is continuing to grow exponentially, sparking a drive for innovation throughout the semiconductor industry. This organic growth is being driven by: the explosion of data in cloud storage; continued proliferation of storage hungry features in mobile devices; innovation in automotive electronics; and, greater connectivity in devices. By the end of 2018, the global semiconductor industry is forecasted to be valued at US$477 billion, with growth continuing at a 12.2% CAGR.

- **The Opportunity:** It's widely recognised that the current 2D & 3D NAND Flash memory technology has a diminishing ability to meet market demand with scaling into denser memory cells. The semiconductor industry is screaming out for a solution that boasts scalability, has fast read speed with reliable yields, and can evolve in line with future needs for larger storage in smaller geometries. We're seeing a shift in trajectory from cloud players paying closer attention to silicon storage. Whilst the current solution, Hard Drives, provide great retention and recovery, they're power hungry, produce excessive heat and boast inferior latency to ReRAM technology.

- **The Solution – Enter Crossbar ReRAM:** Crossbar has developed a scalable filament-based ReRAM memory cell with proven scalability below 10nm lithography (currently at 40nm), a breakthrough in ReRAM technology. Crossbars ReRAM boasts 1000 times faster write performance, 100 times lower read latency and 20 times better energy efficiency than the current incumbent NAND Flash solution.

- **The Strategy:** Crossbar is actively growing its ecosystem of hardware and software partners to help re-shape how new ReRAM-centric architectures can usher in the new wave of world transformation – positioned for an exit with further licensing agreements and/or a potential acquisition target.

TABLE OF CONTENTS

INVESTMENT THESIS

- **Growth momentum in cloud storage and mobile devices:** The continued growth momentum in the semiconductor industry, driven by, IoT, smartphones, PC's, tablets and automotive electronics is providing staggering growth in the amount of data being generated and stored daily, expanding the need for enhanced data storage capacity. The cloud data centres that were previously comprised of racks of hard drives are being replaced by new Solid State Drives (SSD's) containing non-volatile memory (NVM) like NAND Flash memory (2D & 3D), providing an opportunity for NVM hopefuls, including Crossbar, to capture market share.

- **Incumbent NAND Flash technology scalability is stagnating:** The current mainstream non-volatile technologies – dominated by 2D and 3D Flash memory – have stagnated in their ability to continue reducing memory cell geometries to meet a growing demand of smaller devices, while maintaining future storage needs (physical storage capacity). In essence, the architecture of NAND flash memory cells doesn't allow a reliable way to effectively provide a higher density cell without sacrificing retention and reliability in performance. And with a proliferation of demand for data storage capacity, cloud storage players are beginning to look elsewhere for a viable solution in NVM.

- **Crossbar ReRAM a viable solution for Storage Class Memory:** Crossbar is developing their unique filamentary-based ReRAM technology, providing a unique solution the current incumbent memories (NAND Flash). Accordingly, Crossbar ReRAM can be architected with a page size of 2K Bytes (NAND page size ~8-32Kbyte) to reduce code execution, with read latencies of 20 nanoseconds (NAND read latency ~50-75 ns) producing ReRAM speeds comparable to DRAM. Remarkably, Crossbar ReRAM doesn't sacrifice data retention and reliability in achieving DRAM like speeds, boasting 10 years of data retention with a cycling endurance of 10k cycles – far superior relative to NAND data retention of 1 year with a cycling endurance of only ~1K-3K cycles. Simply put, Crossbar ReRAM offers a solution that's a fast, tuneable, low power and erase-free memory storage cell, without sacrificing data-retention and endurance.

- **Leadership – A rich heritage of memory innovation:** Based in Santa Clara, California, Crossbars management and R&D teams include some of the world's most renowned technologist, with decades of experience in the semiconductor industry, more specifically, in developing, manufacturing and marketing memory technologies for commercialisation and licencing.

- **Crossbar position for Strategic Acquisition Target:** We believe that with the M&A trends of larger semiconductor vendors, especially in the non-volatile memory space, showing an increased tendency to target acquiring IP instead of in-house R&D, Crossbar is primed for a strategic exit once it achieves its 10nm scalability milestone in the medium term to long term.

SEMICONDUCTOR MARKET OVERVIEW

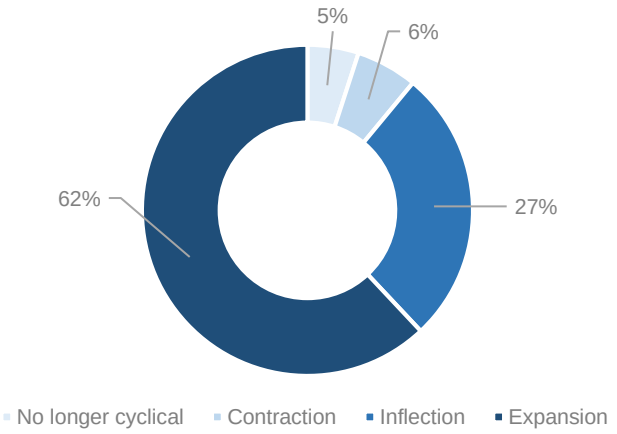
The semiconductor industry in 2017 surprised everyone. High-voltage revenues amongst some of the largest semiconductor players led to record-breaking performances industry-wide, leaving the question on everyone's mind: can 2017 levels of growth be sustained? Many executives from leading semiconductor companies have publicly recognized the unlikelihood of sustaining current compounded annual growth rates (CAGR) over the long term, some even underpinning 2017 as an anomaly. However, one thing for sure is that the consensus for a correction in the semiconductor industry, in the short-term, isn't indicative of prospects, rather optimism is continuing to foster momentum in the demand for larger data storage capacities.

Are we entering a "new wave" semiconductor industry?

Whilst over the past decade growth has been dominated by personal computing & handsets, semiconductor executive consensus believes we're at or even past the inflection point where by the industry can diversify into revolutionary new technology segments, such as Internet of Things (IOT), Artificial Intelligence (AI), and Automotive Electronics. A detailed industry survey conducted by KPMG concluded that 62% of semiconductor executives think the industry in 2018 has moved into an early multi-year expansion phase (Exhibit 1) on the back of a convergence in semiconductor end markets such as software, technology and automotive electronics (KMPG 2018).

Exhibit 1: KMPG survey of industry executive growth sentiment

Source: KPMG 2018



On a broader basis IHS is forecasting total semiconductor industry revenue in 2018 to grow by 7.1%, with semiconductor memory technology spearheading growth momentum by 12.2% ending 2018 (IHS Markit 2018). These growth rates for 2018 are attributable to the "new wave" of technology segments; wireless communication is positioned to benefit from next generation handsets incorporating AI capability, increase battery life & biometrics; automotive electronics are continuing to innovate by focusing on advanced safety features; while consumer electronics are absorbing benefits from increased internet connectivity; and global data processing is forecasted to grow with an increase in servers supporting the surge in demand for cloud computing and storage, and in turn, non-volatile memory storage.

Semiconductor industry set to continue harnessing 1H18 momentum into 2019

According to the Semiconductor Industry Association (SIA), the semiconductor industry has continued to marshal robust performance figures, reaching $117.9 billion of sales during in 2Q18 (an increase of 6% over 1Q18) and year-to-year by more than 20% for 15 consecutive months (SIA 2018). As a sum of parts, the World Semiconductor Trade Statistics (WSTS) believes the global semiconductor industry is healthy and is expected to capatilise on the all-time high valuation of US$412.2 billion in 2017, with forecast consensus expecting further growth to continue ending 2018 valued at US$477 billion (WSTS 2018). Of this growth, we're expecting the greatest contribution across memory integrated circuits, with analog IC's, discretes and

optoelectronics expected to also contribute to global semiconductor growth in 2H2018 (Exhibit 2). However, they have adopted the consensus and forecasted a significant "slowdown" in global semiconductor growth post-2018, with total year-on-year growth to lag from 15.7% in 2018 down to 5.2% in 2019 (Exhibit 3) – Memory again is the biggest contributor to this correction, decreasing from 30.5% in 2018 to 4.6% YoY in 2019 (SIA 2018).

Exhibit 2: Worldwide Memory IC Sales (US$M)

Source: Wolrd Semiconductor Trade Statistics 2018

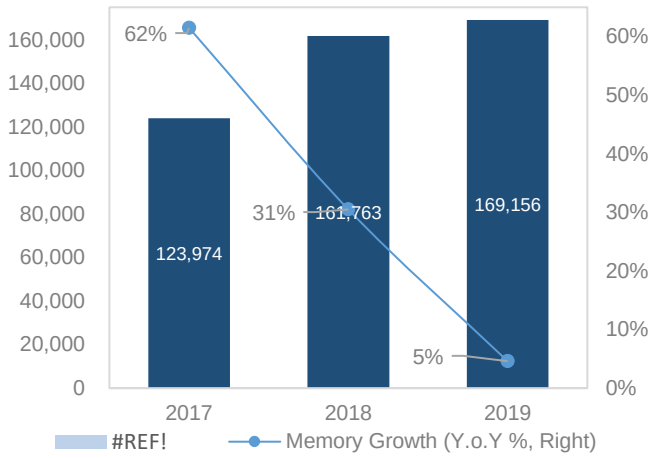
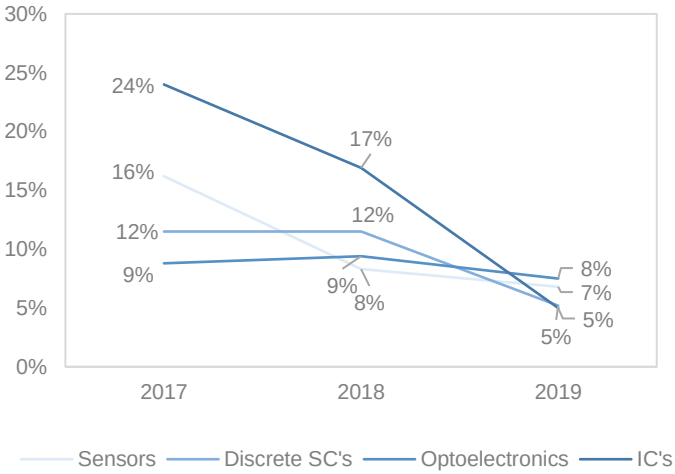


Exhibit 3: Semiconductor Year-on-Year Growth (Segmented)

Source: World Semiconductor Trade Statistics 2018

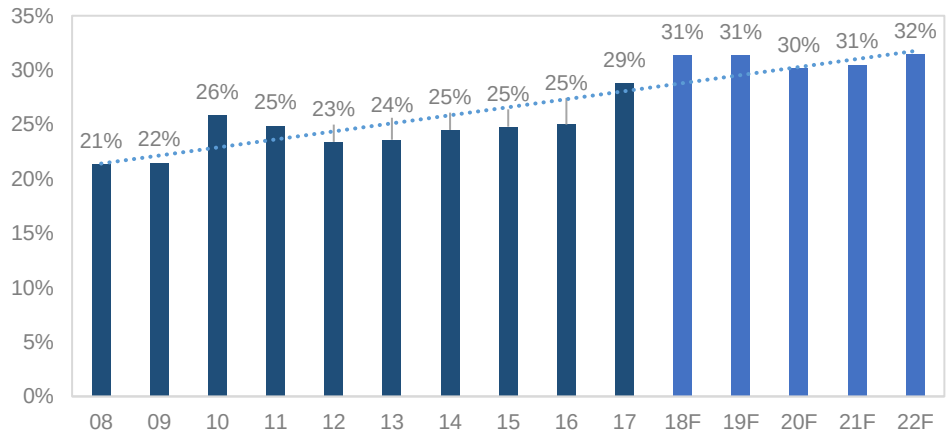


Looking over the horizon through to 2021 – what's driving IC demand?

To fully grasp this growth story in the semiconductor industry, more specifically, the integrated circuit market, we need to understand the global end-use application of IC's. More so in developed economies, the integrated circuit market has traditionally been closely linked to the performance of the electronic system market. As a result, the IC market is expected to be injected with stimulus for growth as the electronic system market expands (Exhibit 4) on the back of a growing number of end-use application and subsequent digital content.

Exhibit 4: % of Electronic System Content in Semiconductors

Source: IC Insights 2018



Accordingly, we've identified that Internet-capable converging technologies alongside the surging mobile electronic systems will keep demand for IC's robust through to 2021:

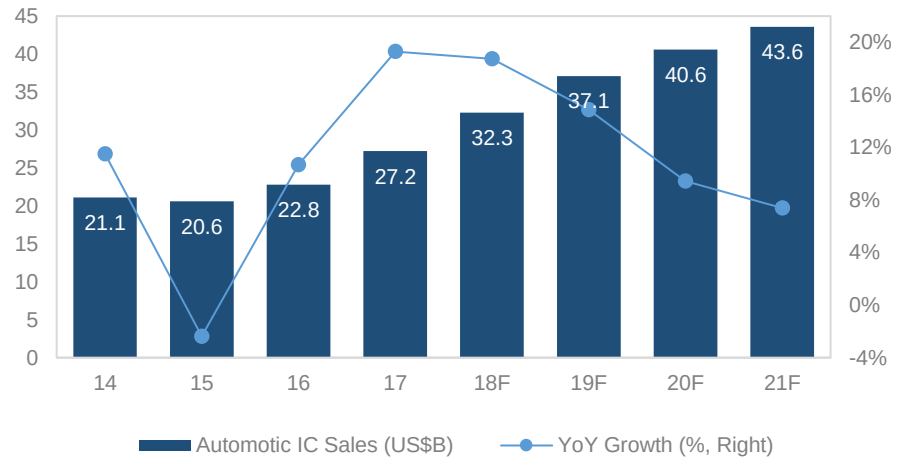
- **Personal Computing:** Even though demand in recent years for Tablet PC's has softened, the computing segment made up of both tablet and traditional PC's still dominates the IC market in terms of market share.

- **Emergence of Internet of Things:** The explosion of machine learning in recent times, along with the increased momentum in global interconnection via the internet will undoubtedly fuel the need for greater memory and storage capabilities with no slowdown in sight. Now days, organizations use IoT devices to collect real time data and assist in business decision making. But this collected data needs to be processed and appropriately formatted on storage systems (what was previously racks of hard drives, is being replaced by non-volatile memory SSDs'). As a result, IC Insights forecasts IoT to expand market share of IC sales by an a CAGR of 13.2% by 2021 – roughly 70% faster than the total IC market growth (IC Insights 2018).

- **Automotive Electronics:** Consumer demand and the increase presence of government mandates for the electrical systems in autonomous electronics that improve the vehicles performance, safety and luxury is expected to, alongside the memory components within them, grow by 18.5% in 2018 to a record high $32.3 billion. Additionally, the automotive IC market accounts for only 7.5% of the overall IC market currently in 2018, however, is forecasted to increase to 9.2% by 2023 (IC Insights 2018). The evolution of embedded flash memory technology for Multipoint Control Units (MCU) is expected to capture roughly 23% of the automotive growth throughout to 2021. Overall, due to the average memory capacity cars poised to grow from 35Gb in 2018 to 60Gb in 2025, IC insights are forecasting an increase in demand for automotive IC's, stimulating automotive IC sales growth to $43.6 billion in 2021 representing a CAGR of 12.5% (Exhibit 5) (IC Insights 2018).

Exhibit 5: Automotive IC Sales Forecast (Billions)

Source: IC Insights 2018



- **Mass Adoption of Smartphones:** The global cellphone market has overtaken the personal computing industry in the overall consumption of integrated circuits over recent years (Exhibit 7) – driven primarily by the rapid expansion of the smartphone segment. After some consolidation in growth in 2017, with IC insights forecasting the worldwide smartphone industry to contract again throughout the remainder of 2018 before mounting another growth story in 2019 and beyond. According to data reconciled by the International Data Corporation (IDC), the lucrative smartphone industry is projected to post shipment totals of 1.462 billion units in 2018, which is a drop of 0.2% from 2017-unit shipments of 1.465 billion, before growing again at a compounded annual growth rate of 2.5% until 2022 with worldwide shipment volumes reaching upwards to 1.654 billion (Exhibit 6) (IDC 2018).

Exhibit 6: Smartphone Shipments (Millions) – 3G, 4G & 5G

Source: IDC 2018

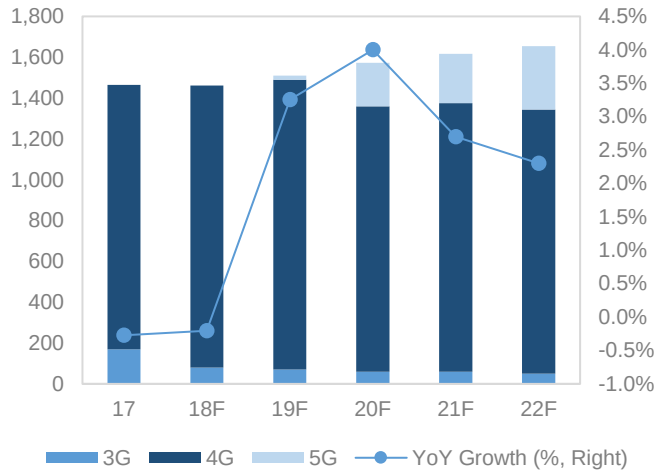
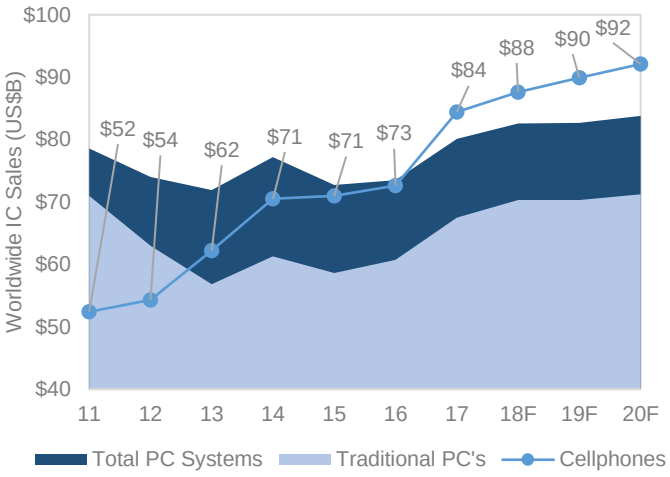


Exhibit 7: Cellphone Consumption of IC's Surpasses PC's

Source: IC Insights 2018



IC Insights are attributing this growth to a turnaround in consumption of smartphones from a disappointing 2017. China, who consume roughly 30% of the worlds smartphone units, experienced a 4.9% year-on-year decline in its smartphone market with further contractions forecasted to continue for the remainder of 2018 before flattening and consolidating smartphone growth in 2019 (IC Insights 2018). However, it isn't China who have the memory semiconductor industry restless, it's India. India have been in the headlines for all the right reasons as manufacturing continues to ramp-up regardless of their dependence on Chinese components. The manufacturing boom in India is only beginning, with the gradual build up in local production volumes catching the attention of many larger players in the industry.

Another major catalyst associated with the smartphone industry is the introduction of 5G smartphones into shipments. Even though it could still be over a year away before 5G smartphones become commercially available, the devices will feature larger AMOLED bezel-less displays, virtual reality capabilities, complex & advanced camera functions, and overall increased requirement for speed, performance and memory storage. IDC has forecasted that by 2020, the 5G smartphones will account for roughly 7% of all smartphone shipments, with it reaching upwards of 18% in 2022 (IDC 2018) – substantial upside in demand for the memory semiconductor industry to come.

Has Global GDP Growth become a reliable indicator for IC Market Growth?

Interestingly, we've seen a relationship beginning to form between the direction of global GDP growth and the worldwide integrated circuit market growth in recent years – correlation of 0.95 for 2016-2018 with the tight relationship forecasted to remain close at 0.95 through to 2020 (IC Insights) at the least (Exhibit 8). Such a relationship development isn't abnormal considering the drastic changes the semiconductor industry has experienced of late. As the IC market begins to mature and firms such as Samsung and Intel begin to consolidate market share and stabilize their capex as a percent of sales ratio (Exhibit 9), we'd expect the market to become less cyclical leading to less volatility in the longer term. However, we'd expect to see a slowdown in world-wide integrated circuit growth rates in line with a GDP growth slowdown as we begin see centrals banks worldwide transition away from quantitative easing - reducing their balance sheets and steadily raising interest rates to pilot a soft landing from a sustained period of economic prosperity.

Exhibit 8: GDP Growth vs WW IC Market Growth (%)

Source: IC Insights 2018, World Bank, Analyst Calculations - (2017 IC growth exludes DRAM & NRAD)

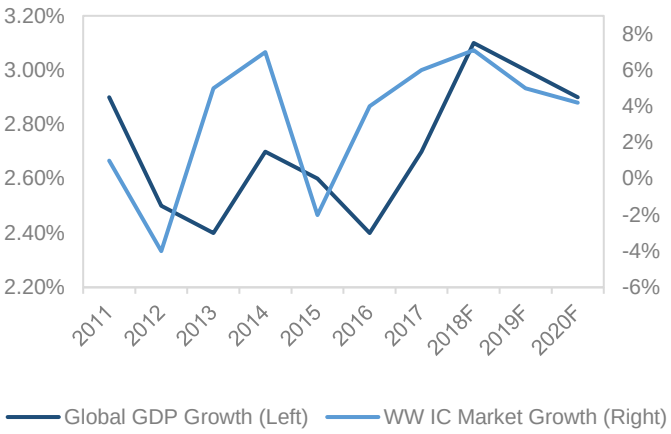
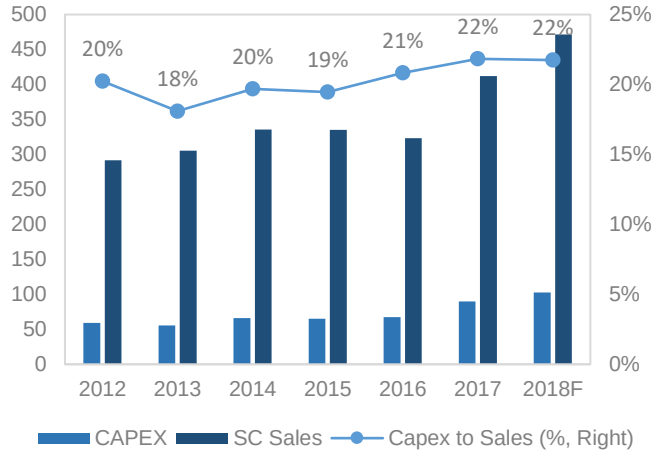


Exhibit 9: Semiconductor CAPEX to Sales Ratio (%)

Source; SIA 2018

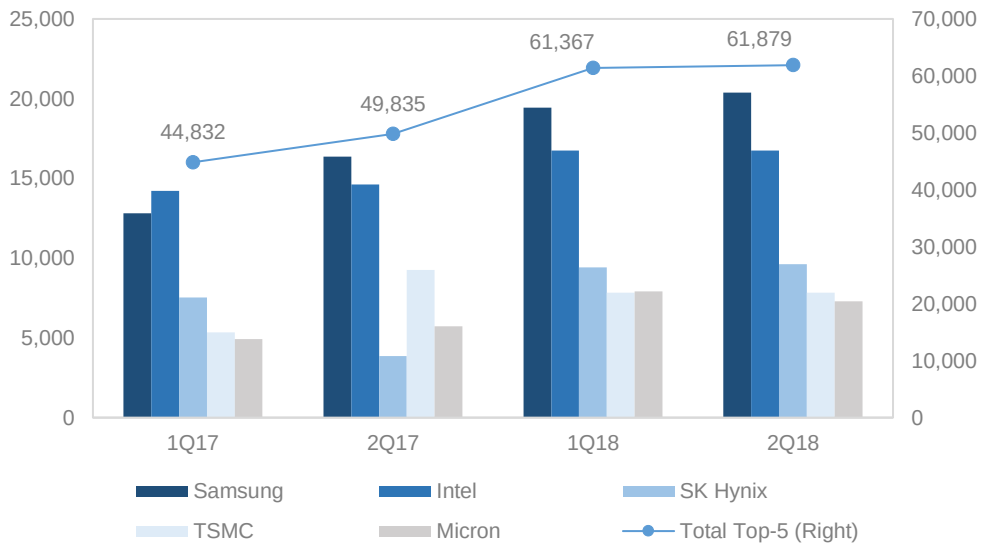


Semiconductor Manufacturing Landscape – Samsung taking reign

Over the past few years we've seen major consolidation in semiconductor suppliers, a result of which is the top-15 worldwide semiconductor (IC and OSD – optoelectronic, sensor and discrete) sales surging by 24% in 1H18, spearheaded by the sales of memory integrated circuits (IC Insights 2018). In 2017, the semiconductor industry experienced a changing of the guard in 1Q17 when Samsung stripped Intel as the number one ranked semiconductor supplier (Exhibit 10) – a mantle Intel had held since 1993. With continuous momentum coming from strong DRAM and NAND flash markets over 2017 and 1H2018, Samsung were able to surpass Intel semiconductor sales from 1% more in 1H2017 to a staggering 22% more semiconductor sales in 1H2018. With this the IC insights 2018 McClean Report is forecasting that memory device sales will represent 84% of Samsung semiconductor sales come end of 2018. Thus, moving forward it's not unrealistic to expect further consolidation in the supply chain, the larger players in the market (top-5) forecasted to ramp their consolidation efforts in China for the rest of 2018 and moving into 2019 (IC Insights 2018).

Exhibit 10: Market Share of Worldwide IC Sales by Top-5 Suppliers (US$B)

Source; IC Insights 2018



NON-VOLATILE MEMORY – A DEEPER LOOK

Dynamic Random-Access Memory (DRAM) – Too expensive!

The DRAM memory is super-fast and boasts exceptional endurance, as a result is suited for usage in fast **system memory** (computer program & systems). The memory cells of DRAM work by coupling a transistor with a capacitor that stores charge to be read when determining the logic state of a memory cell. However, DRAM is a volatile memory, as the cells must be refreshed (read and written back) every 60 milliseconds due to the continuous leaking of storage charge from the capacitor. The issue with DRAM in the current environment is whilst it's capable of fast switching speeds, the DRAM technology is volatile (low data retention) and too expensive for widespread use in systems.

NAND Flash Memory– Scaling limitations!

Unlike DRAM, NAND Flash programmable memory is inexpensive due to its higher bit capacity and expectation capacity, best suiting it for lower-cost, non-volatile **silicon storage** (silicon oxide circuits). In sharp contrast to DRAM (which needs to be powered on to continuously retain data), NAND Flash can retain its data even when powered off, making the technology useful for storage for portable devices (Solid State Drives, Tablets & Smartphones). However, the main appeal is the small cell size of NAND Flash that results in lower costs ($/Gb), making it more economically feasible end-use applications.

However, the biggest issue facing the current NAND Flash Memory technology is scalability in achieving higher densities to meet demand for smaller cell geometries in end-use applications. Because the structural system is sensitive to fluctuations in the charge density (as charge density is caused by electrons becoming trapped in an oxide-floating gate interface), the loss of a single electron can lead to a loss of retention (the shining feature of NAND Flash). So as NAND Flash manufactures begin packing the floating gate transistors into a lesser space to increase density, you can expect the closer proximity to increase in cell-to-cell interference – inherently leading to an increase in the corruption of stored data within the cells. Therefore, the demand for NAND Flash technology to accommodate expanding memory requirements in cloud storage, smartphones and solid-state drives will only exacerbate loss of retention and thus, reliability of NAND Flash memory at smaller cell geometries.

STORAGE CLASS MEMORY – The Hierarchy Disruptor

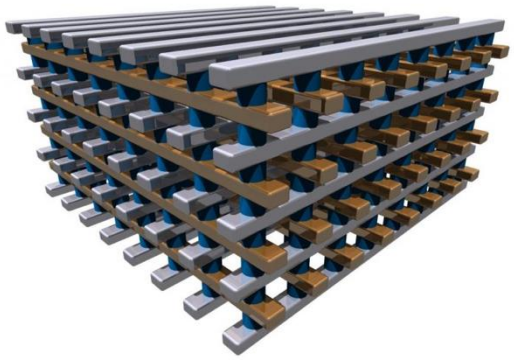
Storage Class Memory (ReRAM) – A unique solution to data storage?

The term "Storage Class Memory" (SCM) encapsulates a class of emerging technologies, like ReRAM, that are anticipated to penetrate the semiconductor memory marker in the coming decade. The potential recognised in SCM's ability to disrupt DRAM and NAND Flash as the universal standard for memory in datacenter, laptops and smartphones is underpinned by the unique characteristics displayed by the technology. SCM cannot be categorised as either DRAM or NAND Flash; it's slower and denser then DRAM, but faster than its NAND Flash counterpart while maintaining storage persistence.

Structurally, ReRAM is a memory technology based on a three-layer structure (3D); the two outer layers of electrode materials and the inner layer formed by a dielectric material. Most ReRAM cells currently consist of a switching material "sandwiched" between the two electrode materials, which are then arranged into a cell matrix to form what we call a memory array (Exhibit 11). Accordingly, an electronic voltage is applied to the ReRAM memory cell resulting in a change in resistance – here forms the name "Resistive Random-Access Memory". This resistance will establish the "1" (On) and "0" (Off) states, which we call the switching mechanism.

Exhibit 11: ReRAM memory cell

Source: Crossbar 2018



Incumbent technology reaching physical limits – Enter ReRAM?

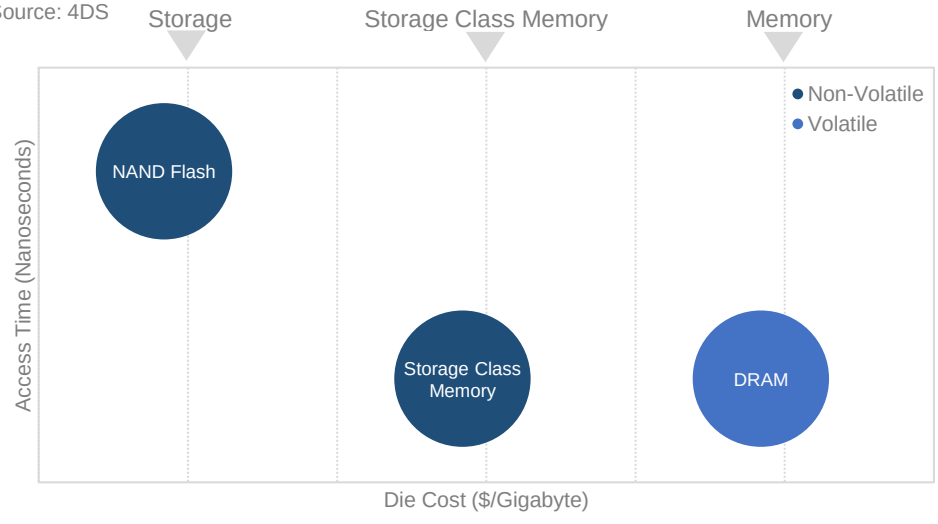
We cannot simply just replace DRAM with SCM, empirical research indicates that simply switching memory technology from DRAM to SCM will dramatically increase the average transfer latency of a cache block, and with memory latency being an important element in workloads of datacenters, the increase will directly manifest into end-to-end degradation of overall performance. Therefore, there is substantial demand for innovation in the field of these Storage Class Memory technologies to not replace but use SCM's for its capacity and lower costs while trying to reach speeds comparable to DRAM, not to outperform DRAM.

However, ReRAM has substantial potential for a NAND Flash replacement. Compared to NAND Flash, ReRAM has been tested to deliver 100 times lower read latency and 1000 times faster write performance with approximately 20 times lower power consumption to Flash. But perhaps the most important advantage is the potential for ReRAM to provide massive amounts of storage in a small amount of space.

Even though the ideal Storage Class Memory technology holds both characteristic of DRAM (speed & endurance) and NAND Flash (cost & retention), realistically this utopia may never come to rise. More accurate opportunities with the emergence of new Storage Class Memory will weigh closer to either a space close to DRAM (need lower cost (Higher Density) System Memory with same speed) or the space close to NAND Flash (willing to pay a little more for faster Silicon Storage with the same retention), with each technology prioritising different systems in respect to data retention, speed & endurance:

Exhibit 12: Storage Class Memory exhibits both DRAM & NAND Flash features

Source: 4DS



Storage Class Memory's come in a plethora of densities and performance grades (Exhibit 12). When SCM weighs towards the space closer to NAND Flash, retention becomes priority, with opportunity arising when SCM can reach higher speeds than NAND Flash without sacrificing retention - system companies will be more than willing to pay a higher price per gigabyte. Conversely, speed is the dominant priority within the DRAM space for SCM's. By reaching an endurance as close as possible to DRAM (without sacrificing speed), SCM's can provide a unique opportunity to reduce the need for more expensive DRAM in lower-end systems worldwide.

CROSSBAR MEMORY– Business Overview

Headquartered in Santa Clara, California, Crossbar was founded in 2010 with a simplistic philosophy: The light bulb. The car. The telephone. All these inventions had profound impacts on the world and people's lives. So, what's next? Crossbars' co-founders – George Minassian & Sung Hyun Jo – envisioned a "new wave" of inventions dominated by innovations including, natural human-machine interfaces, autonomous cars, artificial intelligence (AI) and a mass adoption of cloud storage - all requiring a ubiquitous access to data. This is when Crossbar ReRAM was born.

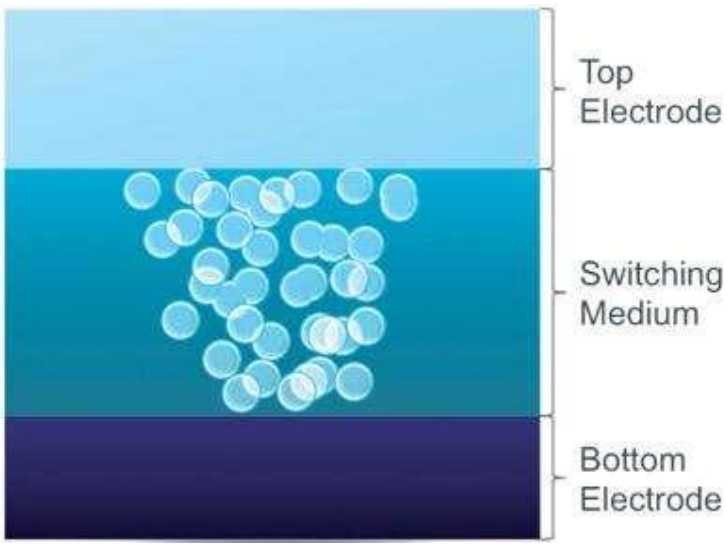
Crossbar is a pioneer in the emerging Story Class Memory (SSM) space. Their radically different approach to the non-volatile memory ReRAM (NVRRAM), is a unique ReRAM memory technology that can be integrated (embedded) inside a system-on-chip or developed, produced and commercialised as a standalone memory chip. Currently, Crossbar ReRAM has two intellectual property (IP) cores licensed for 40nm circuitry linewidth (resolution) with a truly revolutionary 2x (between 20nm & 29nm) nanometer process node IP cores under development. As a result, it has become obvious in a semiconductor industry - where the physics of scalability haven't been in its favor - that Crossbar ReRAM going to continue to play an important role in enabling a new world (Crossbar Memory 2018).

How does Crossbar ReRAM work?

Crossbar ReRAM memory technology is underpinned by a silicon-based switching material that acts as the host material sandwiched between two electrodes (Exhibit 13). Thanks to Crossbar's patented in-built selector, these cells can then be arranged into a cell matrix to form an extremely dense 3D memory array without occupying additional silicon area – providing the architecture to potentially develop the cells below 10nm. The actual ReRAM memory cell functions when a voltage is applied to the cell causing resistance to change, establishing the "On" and "Off" states referred to as the resistive switching mechanism (Crossbar Memory 2018).

Exhibit 13: Architecture of Crossbar ReRAM Memory Cell

Source: Crossbar 2018



SCM Requirements – Crossbar ReRAM ticks all the boxes

Crossbar ReRAM has ticked all the boxes for commercialization; Its' ReRAM reaches read speeds comparable to DRAM; has robust data retention & endurance, and most importantly, its technology allows for efficient scalability. Crossbar has ticked all the boxes required to attract licensing & acquisition attention from larger memory players:

- ✓ **Circuitry linewidth (Resolution):** Crossbar are continuing to come good on their scalability promises. Achieving a benchmark 40nm resolution (with functioning 2x nm IP cores in development), proves their capability to scale down memory cells to meet a changing storage landscape.

- ✓ **Capable of speed comparable to DRAM:** Successfully achieved read speeds for its filamentary ReRAM comparable to that of DRAM (roughly 50 nanoseconds). The comparison to NAND Flash is attractive, as Flash memory can only achieve read speeds of approximately 50,000 nanoseconds, nearly 1000x slower! But it's the near-zero errors that wins the gold medal; other emerging storage technologies like Intel & Microns 3D Xpoint can achieve similar read speeds but require a significant amount more error correction.

- ✓ **Cycling endurance suitable for Storage Class Memory:** Crossbar has achieved the minimum requirement of 400 for the number of switching cycles in a linear endurance test with flying colours. Demonstrated at IEDM in late 2014, Crossbar ReRAM boasted a write cycle endurance greater than 100M cycles (the switching between "on" and "off" states).

- ✓ **Power Consumption:** The ability of Crossbar ReRAM to simplify the overall management of data write and reads, allows the cell to reduce the number of background memory operations (SSD controller, DRAM usage, read and write) in data storage, improving programming performance and power consumption by delivering a 20x improvement to NAND flash – achieving a 64pJ/cell program energy.

Crossbar ReRAM products:

All Crossbar ReRAM technology can be stacked in 3D and as a result, deliver higher density storage on a single chip. It's simplicity, stickability and CMOS compatibility (allows the technology to be adopted in future generations), make the intellectual property a desired product for many memory storage companies seeking a solution to their storage needs. Crossbars products available for licensing are:

- **P SERIES:** Crossbars P SERIES intellectual property cores focus on embedded NVM applications in end-use applications including: IoT, wearable electronics, tablets, smartphones, artificial intelligence, automotive electronics and consumer electronics. The P SERIES IP core is versatile, it can be integrated at the same process nodes of Field Programmable Gate Arrays (FPGA), System-on-Chip (SoC) and micro-controllers (MCU) or even used purely as a stand-alone chip – The P SERIES provides companies with plenty of options. The P SERIES is available for licensing at 40nm with further scaling potential available below 10nm (Crossbar Memory 2018).

- **T SERIES:** Crossbars T SERIES IP core focuses on providing a memory storage solution for current high-density (large storage in small geometries) and low-latency memory applications such as artificial intelligence, mobile computing and data center storage. The T SERIES data integrity exceeds the current incumbent NAND Flash NVM solution, allowing companies – depending on their business model – to utilize the IP as hard macros that can be integrated into FPGA or SoC devices, supporting densities from 1Gbyte to 1 Terabyte (Crossbar Memory 2018).

- **CUSTOM ReRAM:** Crossbars ReRAM technology portfolio allows for the IP to be tunable, customising key attributes to provide solutions for unique memory storage requirements. Companies can ask for specific requirements, allowing Crossbar to optimize different key attributes, such as, memory size, data retention, access speed (read/write speed), endurance and latency to suit the clients' needs (Crossbar Memory 2018).

CROSSBAR STRATEGY – Develop an arsenal of IP

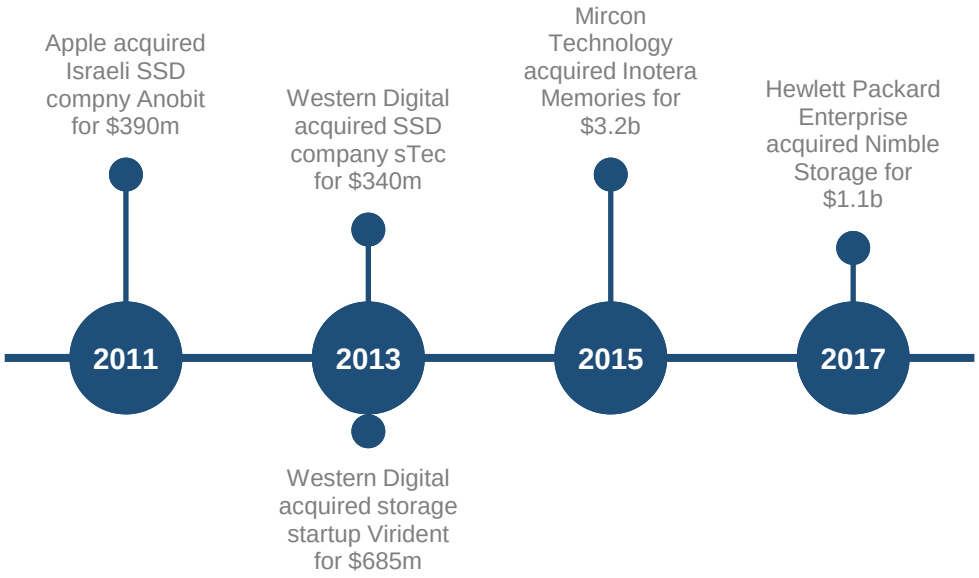
Becoming a new memory maker is unrealistic, and rest assured Crossbar understand this. Crossbar remain disillusioned with the fact that joining the short list of high-volume high-density memory markets is cost prohibitive for anyone outside of the well-established suppliers like Samsung, Intel and SK Hynix.

Crossbar ReRAM recognize that the current consolidation of the semiconductor industry by the likes of Samsung (wide-sweeping consolidation in 2017), Intel and SK Hynix (consolidation of China in 2018) provide opportunity for start-up technology companies to exit by becoming "noticed" and subsequently, license IP or better yet, be an acquisition target. Therefore, the battleground shifts from manufacturing to intellectual property. This isn't easy, the established global memory markers need concrete proof that a developer like Crossbar can make the proclaimed best high-density memory, which is difficult given the resources required to develop this technology. Fortunately, in a dynamic industry like the semiconductor industry, there is always a need for niche memory products tailor to specific needs that are somewhere between DRAM and NAND.

As a result, we've seen a number for high-valued acquisitions over the past decade (Exhibit 14), with further consolidation only to prompt large scale players in the semiconductor industry to seek acquiring or licensing intellectual property rather than focusing resources on developing themselves.

Exhibit 14: Key intellectual property acquisitions over the past-decade

Source: 4DS Investor Presentation 2018



Short-to-Medium term strategy – Licensing agreements

Crossbar ReRAM has 290 patents currently filed, with 145 patents already issued. Presently, Crossbar has IP cores licensed for 40nm ready, with further potential to port to 28nm process nodes, enabling higher density and more tightly integrated memory devices. Currently, the licensing strategy for Crossbar is to license its technology to system-on-chip (SoC) and memory companies as an off-the-shelf or even custom IP cores to fit a niche. Crossbar has two running high-end licensing agreements:

- **Semiconductor Manufacturing International Corp (SMIC):** On the 11th March 2016, Crossbar (licensor) announced it will provide China's leading silicon storage foundry with intellectual property to license to customers under the terms of a strategic partnership. The licencing deal will enable the customers of SMIC (licensee) to integrate Crossbars NVRRAM 3D blocks based upon the 40nm CMOS manufacturing process into system-on-chips and microcontrollers.

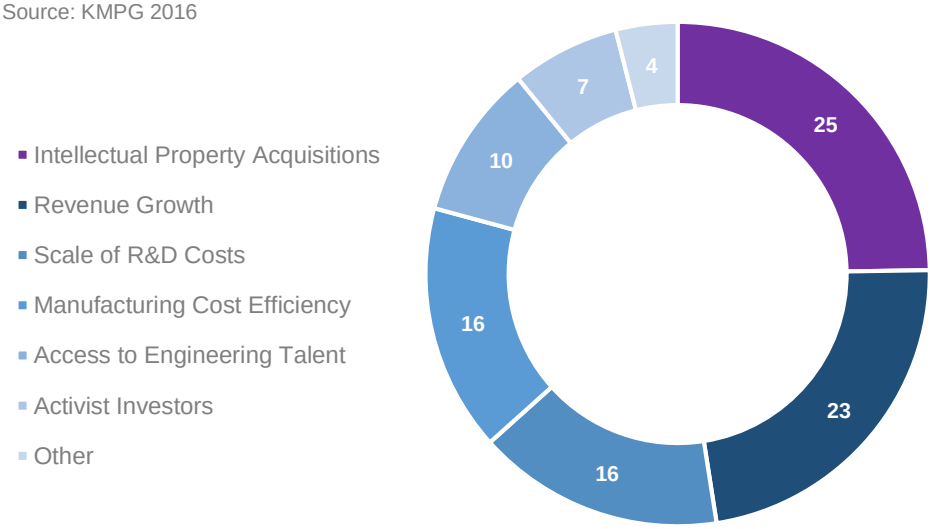
- **Microsemi Corporation:** On the 16th May 2018, Crossbar (licensor) announced a strategic collaboration with Microsemi (licensee) to integrate ReRAM technology into their products, in which Microsemi will licence Crossbar's ReRAM core intellectual property. As part of the agreement, Crossbar announced there would be continued collaboration with Microsemi in R&D and the application of the ReRAM technology in Microsemi's next generation products.

Long term strategy – strategic acquisition of intellectual property

It's not surprising that insights leveraged from KPMG's Global Semiconductor Outlook (2018) survey indicate that acquisitions, mergers and joint ventures for intellectual property is the second most important strategic priority for industry leaders – diversifying into new business areas is the top priority). Mergers, acquisitions and joint ventures are integral for leading chipmakers such as Samsung, Intel and SK Hynix to stay ahead in todays hyper connected and rapidly changing digitalized world, as a result, over half (51%) of the surveyed CEO's predicted the aggregate valuation for M&A deals for the rest of 2018 to increase (KMPG 2018). The key driver of this M&A activity according to one-quarter of respondents in KMPG's Global Semiconductor Outlook (2016) is the need to acquire intellectual property (Exhibit 15). The rising cost of in-house R&D has led to larger developers integrating a make versus buy mentality into their decision-making process, as more and more companies seek greater return on investment (ROI) through the strategic acquisition of IP versus allocating investment capital to developing in-house technology (KMPG 2016).

Exhibit 15: What is the key M&A driver in the semiconductor industry?

Source: KMPG 2016

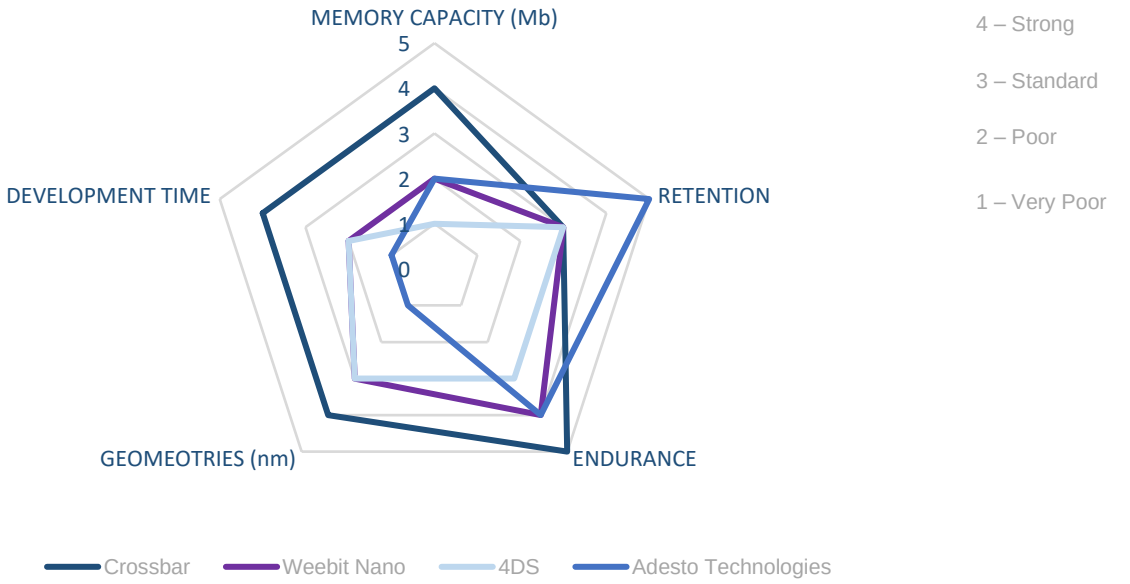


We believe that Crossbar can capitalize on the semiconductor industries movement towards the acquisition of intellectual property as a potential target. With Crossbar currently being the pioneer in ReRAM technology development, it isn't unrealistic to assume that the key development and manufacturer players in the industry haven't noticed the profound impact ReRAM technology when considering new end-application markets beyond the traditional PC, including, IoT, AI, cloud storage and autonomous vehicles.

CROSSBAR COMPETITIVE POSITIONING

Competitive Positioning of Crossbar and its Competitors in Non-Volatile Memory Industry

Source: Analyst Calculations, Public Information from Companies



Memory Capacity:

In terms of memory capacity Crossbars ReRAM has proven to be a superior technology. Crossbar has successfully fabricated an embedded 8-Mbit array within its 28nm cell compared to its competition; Weebit Nano has fabricated a 1-Mbit array within its 40nm cell; Adesto Technologies has proven a 512Kb (0.512 Mbit) array at 130nm cell geometries; while lastly, 4DS hasn't yet proven its memory capacity, but expecting results mid-September 2018.

Data Retention:

Crossbars competitive positioning in relation its technologies data retention is strong. Even though Adesto Technologies boast a 40Y @ 125°C retention capability, Crossbar ReRAM's 10Y @ 85°C data retention is still significant when considering the small geometries that the cells can scale down to (proven 28nm). Accordingly, Weebit Nano may have a retention of 10Y @ > room temperature, but its only proven at a cell geometry of 40nm. Again, with 4DS, there has been no public information on their data retention capabilities but were assuming they'd be like Crossbar and Weebit (10Y).

Endurance:

Crossbars competitive positioning is strongest in the technology's endurance capabilities. Crossbar has a write cycling endurance (total number of write cycles) of 10^6 compared to its competition; Weebit Nano has cycling endurance of 10^5 ; Adesto Technologies of 10^5 ; and 4DS of 10^3 .

Cell Geometries (nm):

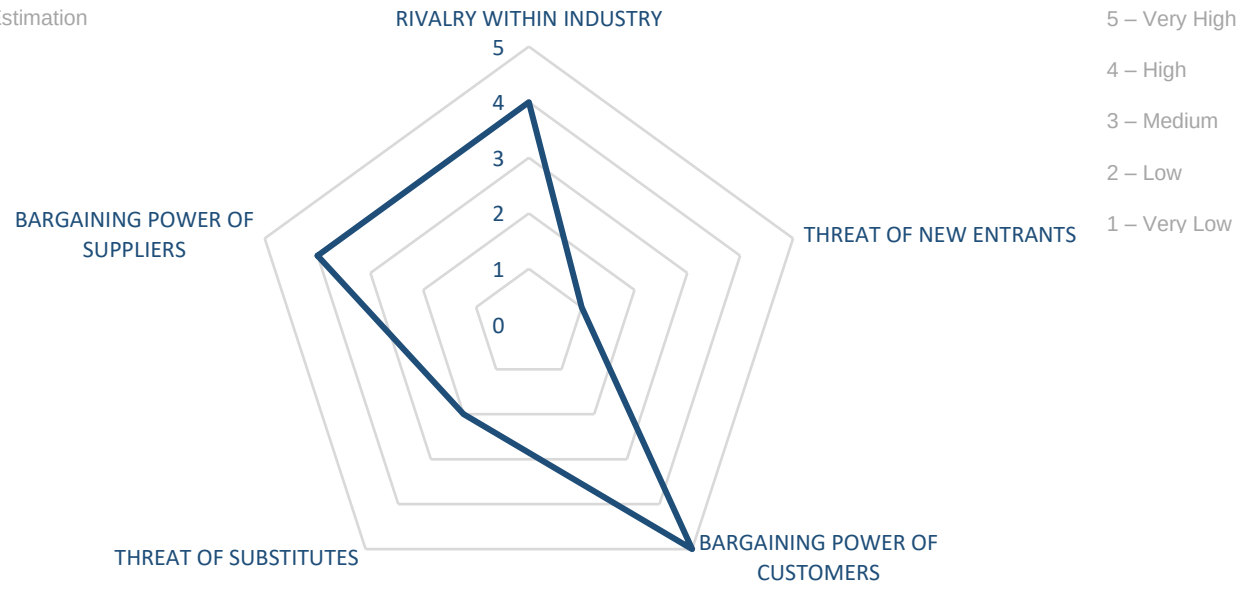
To be competitive in the non-volatile memory industry, the technology needs to be scalable to smaller cell geometries. Crossbar is the pioneer in the space. Crossbars competitive positioning is very strong, with proven fabrication of 28nm functioning chips, where as both Weebit Nano and 4DS have only proven functionality at 40nm, and Adesto Technologies at only 130nm.

Development Time:

Development time measures the time it takes for a company to successfully develop & commercialize a 28nm chip. Crossbars embedded 28nm ReRAM chips time to market is set for 2021-2022. Weebit Nano & 4DS have only just completed their 40nm chips so were predicting 2024 at the earliest before their 28nm technologies become commercially viable. Lastly, Adesto argues 55nm is their targeted sweet spot, focusing resources on fabricating 55nm chips rather than 28nm.

Porter Five Forces for the Non-Volatile Memory Industry

Source: Analyst Estimation



Rivalry within industry (High): Competition **is high** in the non-volatile memory industry (NVM) as developers are jockeying for the dominant position in the new world of persistent memories. The NVM industry has become a plethora of acronyms with companies competing on differentiation like chip performance (speed, reliability & features, power consumption and life expectancy; 4DS (Non-Filamentary ReRAM), Avalanche (SST-MRAM), Weebit Nano (Filamentary ReRAM), Adesto Technologies (CBRAM) and Micron & Intel (3D Xpoint NVRAM) – all, alongside Crossbar, vying for NVM supremacy.

Threat of new entrants (Very Low): The threat of new entrants is **very low**. This is a result of the very high barriers of entry into the non-volatile memory industry. The key barriers are underpinned by; substantial start-up capital investment to get research and development off the ground; growing difficulties in finding qualified human capital (engineers, developers, designers etc.) for each stage of the value chain; profound economies of scale, placing new entrants at a cost disadvantage; and finally, the combination of a consolidation of NVM providers with partnerships and the adjacent growth in cross licensing has resulted in the market power of incumbents like ReRAM, NAND and DRAM to solidify.

Bargaining power of customers (Very High): The bargaining power of customers is **very high** in the NVM. The major buyers in the industry deal in large volumes and the chips are sold primarily only from business-to-business. In addition, these same buyers pose backward integration threats, with Samsung, Intel, Micron and SK Hynix manufacturing their own chips. As a result, the major buyers have a significant leverage on what they buy, for what price and or what quantity.

Threat of substitutes (Low): The threat of substitutes in the non-volatile memory industry is **low**, making it very attractive for Crossbar's competitive positioning. With Crossbar ReRAM pioneering the development of storage class memory to fill the niche void between DRAM and NAND, providing both scalability and cost efficiency, there has been no emergence of substitute technologies challenging the underlying functionality of ReRAM.

Bargaining power of suppliers (High): The market is characterized by a large volume of suppliers that is then dominated by a small number of larger players. This diffusion of the supply chain risk spread across many companies allows the larger companies to have substitutes from suppliers and developers– like Crossbar. As a result, the **high** bargaining of suppliers is a threat to Crossbars competitive positioning.

MANAGAMENT – The Four Jockeys of the Crossbar Stallion

**All Information on Directors and Management is courtesy of Crossbar Inc.*

GEORGE MINASSIAN, PH. D - *Chief Executive Officer and Co-Founder*

Dr. George Minassian has been a co-founder and CEO of Crossbar since 2010. A seasoned veteran of the semiconductor memory industry, Dr. Minassian brings Crossbar 25 years of experience in systems, logic design, new business development, and product development. Over his extensive career, Dr. Minassian has a proven track record of developing commercially successful, leading-edge products (Crossbar 2018).

Previous Experience/Skillset in Industry:

- **From 1999-2002,** Dr Minassian was a director for a microprocessor leading company, Advanced Micro Devices, where he spearheaded the Wireless Engineering department and developed the industry's first CMOS rf process.
- **From 2002 to 2010,** Dr. Minassian lead the innovation for Flash memory solutions in his role at Spansion as vice president of System and Software Engineering - he led the $1.2 billion Flash Memory business targeting the cellular wireless market segment (Crossbar 2018).

SUNG HYUN JO, PH. D - *Chief Technology Officer and Co-Founder*

Dr. Sung Hyun Jo has been with Crossbar since 2010, where he leads the company's Device Engineering and Advanced Technology teams as Chief Technology Officer. He brings to Crossbar over 10 years of experience in nanoelectronics, advanced semiconductor processing and a track record of award winning research and development (Crossbar 2018).

Previous Experience/Skillset in Industry:

Dr. Sung Hyun Jo's expertise is in the emerging non-volatile memory space, specifically, programmable logics and neuromorphic systems based around ReRAM technology. He developed the 3D stackable high density crossbar memory array, which has now become integral for Crossbars' ReRAM technology scalability. Interestingly, Dr. Sung Hyun Jo has over 80 issued pending patents (Crossbar 2018).

SUNDAR NARAYANAN, PH. D - *Vice President of Technology*

Dr. Sundar Narayanan has been vice president of Technology at Crossbar since October 2012 and oversees the development of the company's Resistive Memory technology. He brings Crossbar over 15 years of industry experience in technology development specializing in prototyping, commercialization, technology transfer, yield enhancement and Low Rate Initial Production. Like Dr. Sung Hyun Jo, Dr. Sundar Narayanan has 14 issued U.S. and international patents (Crossbar 2018).

Previous Experience/Skillset in Industry:

In 2011 as head of Engineering at SVTC Technologies, he developed and spearheaded the technology development process, taking ideas from prototypes to the validated processes and finally, to Specialty Production across multiple device platforms in emerging memories, such as CMOS and NVMs (including PCM, CBRAM, MRAM) (Crossbar 2018).

HAGOP NAZARIAN - *Vice President of Engineering and Co-Founder*

Hagop Nazarian is vice president of engineering and co-founder of Crossbar. He has over 25 years of semiconductor industry experience in leading new product and technology initiatives, directing design engineering teams, and in R&D Device and Reliability engineering (Crossbar 2018).

Previous Experience/Skillset in Industry:

Prior to 2010, Mr. Nazarian was VP at Spansion, Design Engineering department, where he and his design teams designed 65nm and 45nm MirrorBit NOR products. Additionally, as the director of NAND Flash Design at Micron Technology, he formed the first NAND design team that successfully developed 2Gbit - 16Gbit SLC and MLC NAND products on 90nm, 70nm and 50nm technology nodes (Crossbar 2018).

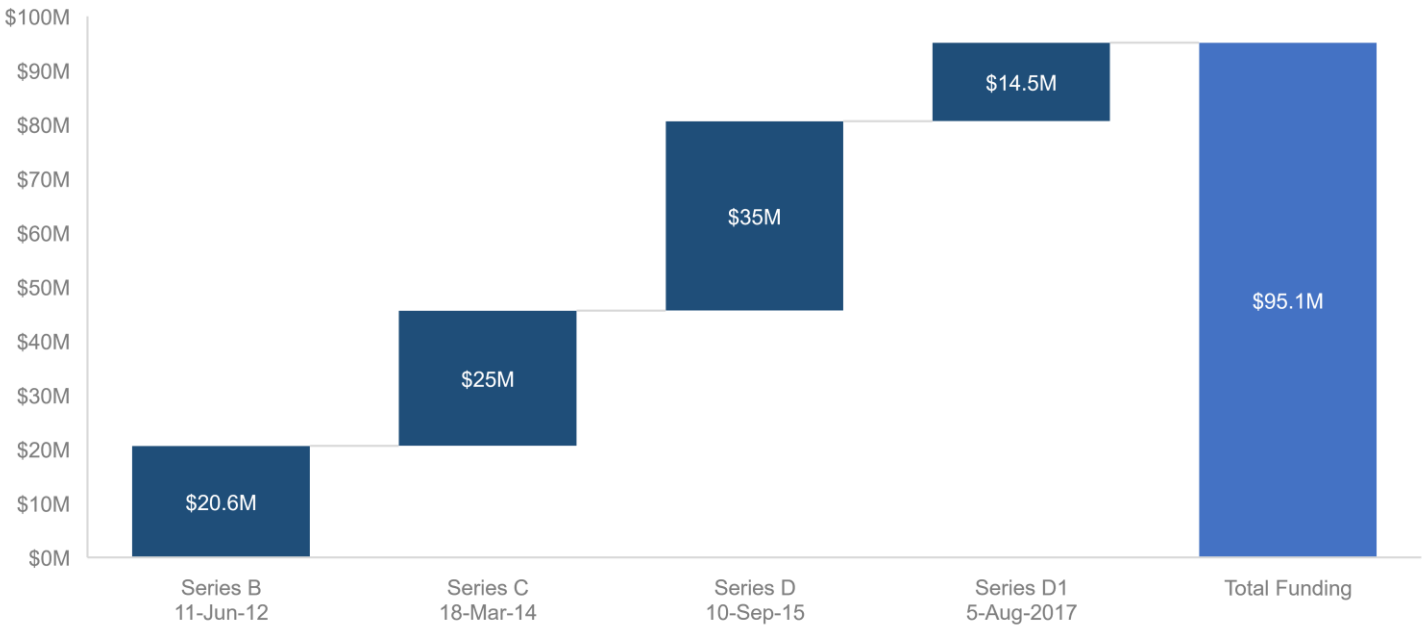
Likewise, his time at Cypress Semiconductor as design manager resulted in his team designing Cypress's first CPLDs Flash based product line. Hagop has also worked at Xicor as a senior designer and R&D device engineer developing non-volatile EEPROM memory cell technologies, and products (Crossbar 2018).

Mr. Nazarian has 95 issued patents and 12 patents pending. His patents are related to NAND, NOR, MRAM, ReRAM technologies, (Crossbar 2018).

FUNDING HISTORY OF CROSSBAR INC

Exhibit 16: Crossbar Funding Sources Since Inception in 2010

Source: Pitchbook, Craft



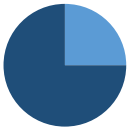
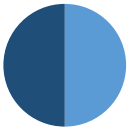
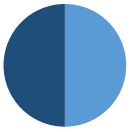
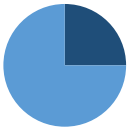
Crossbar Inc has transitioned into later staged venture capital funding to fund its research and development of smaller geometries for its ReRAM technology cells (Exhibit 16). The Series A & B funding was an early-stage funding round (Crossbar wasn't producing any licensing revenue), whereas Series C, D, D1 & D2 were all funded with Crossbar generating some source of licensing revenue from its intellectual property. The next round of funding will provide adequate capital for Crossbar to experiment with the fabrication of 1x nodes (between 0-10nm cell geometries) for its embedded ReRAM technology, propelling ReRAM and storage class memory into a new era of memory storage.

CROSSBAR INVESTMENT RISKS

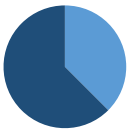
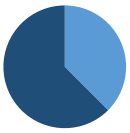
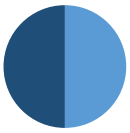
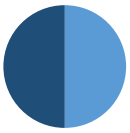
PROBABILITY	IMPACT: LOW	IMPACT: MODERATE	IMPACT: HIGH	IMPACT: VERY HIGH
IMPROBABLE		C1	C2, M2	
POSSIBLE	M1	M3	C3	
PROBABLE				

** 'C' = Company Specific Risk & 'M' = Industry/Market Specific Risk*

Company Specific Risks

Company Risks	Likelihood	Impact	Description
Termination of Partnership with SMIC or Mobiveil Inc. (C1)	**Improbable** 	**Moderate** 	The partnerships with SMIC and Mobiveil have proven to be extremely valuable for Crossbar Inc. The ability to work with industry leading manufacturers to research, develop and fabricate ReRAM cells onto chips has bolstered technological progress. If either of these partnerships cease, it would stagnate advancements in scaling Crossbar ReRAM towards 1x nodes (10nm cells). Only a moderate impact as we believe Crossbar wouldn't have too much trouble finding another strategic partnership.
Reliance on Key Personal (C2)	**Improbable** 	**High** 	Much of Crossbars success (or failure) will depend on the ability of the management team to stay on focus. You cannot always guarantee that a talented management team will always succeed, however, we believe the treasure trove of experience Crossbars management team has in the semiconductor industry and research & development will hold the project in good stead. As a result, even though the impact will be high, the probability of Crossbar management hindering the development and commercialisation of the ReRAM technology is low.
Commercialisation Risk (C3)	**Possible** 	**High** 	Although Crossbar has demonstrated its ability to licence its ReRAM technology onto 40nm nodes, there is no guarantee they will be able to successfully commercialise 28nm or even 10nm nodes in the future. If this becomes a problem, Crossbar ReRAM will stagnate in revolutionising the storage class memory industry and consequently lose attractiveness for a potential strategic acquisition of its IP.

Industry/Market Specific Risks

Industry/Market Risks	Likelihood	Impact	Description
Other Emerging Technologies (M1)	**Possible** 	**Low-Moderate** 	In addition to Crossbars filament switching ReRAM, numerous alternative technologies are under development, including interface switching ReRAM, PCM, FeRAM, MRAM and CeRAM to just name a few, some of what the industry has recognised as viable technologies. Even though the alternative technologies don't target Crossbars niche, if developed and commercialised, they would still pose a moderate threat.
Extension of current incumbent technologies lifespan (NAND Flash) (M2)	**Improbable** 	**High** 	The somewhat recent introduction of 3D NAND, most notably Intel and Microns 3D Xpoint, has prolonged the lifespan of NAND Flash for a least a few years. Coupled with the developed of TLC and MLC, NAND Flash cells now have increase memory cell capacity, thus, its not beyond the possibility that the industry will continue to innovate with NAND Flash further prolonging the economic lifespan. This has a high impact as it would push the need for alternative technologies like ReRAM for another few years at the least.
SCM Technical Hurdles (M3)	**Possible** 	**Moderate** 	Much like Micron & Intels 3D Xpoint, Crossbars ReRAM could face technical hurdles with lower than expected cell endurance and slower read & write speeds than initially anticipated with commercialised – especially with scaling cell geometries down to 10nm. This can be mitigated with further capital spending on R&D but will be extremely costly for Crossbar if the technology in the industry isn't yet sufficient.

VALUATION

Venture Capital Method

The Venture Capital Method (VCM) is widely accepted as pragmatic and doesn't have any theoretical justification like the traditional DCF or Multiple Valuations. Nevertheless, the VCM is broadly used in practice. The primary goal of a VC fund is to receive a return for their investment over a time period – a harvest year typically is 3 to 8 years from vintage. The first, and arguably, the biggest question VC funds need to ask is: "How much will we be able to sell our stake in the company in a liquidity event?".

Having this viewpoint is very logical in sense, as investing in start-ups (at different rounds) is not a liquid investment like typical equity investing, the only way to capitalise paper gain is to sell your stake in the company, hopefully at a higher value than at vintage.

Plausible Potential Exit Value for Crossbar – Using VCM

When determining the plausible exit value for Crossbar, we needed to understand that the $1M investment in Crossbar would be a late-stage investment. Typically, late-stage investors will conduct a more thorough analysis of the company's market share, market size and revenues generated to calculate a more concise exit valuation. Later-stage investors demand smaller multiples of 3x-5x Cash-on-Cash returns (Berkery 2008) as the risk of a revenue generating start-up with a proven product is lower. However, the issue with Crossbar is their tendency to not disclose any of their financial information including, revenues, authorized stock issued, and stock price issued. As a result, we have had to make assumptions based on available public information in regard to stock price of authorized shares issued throughout the funding stages.

Assumptions made for Potential Exit Valuation

- **Post-Money Valuation:** We calculated the post-money valuation using Crossbar's last round of funding on the 5th of August 2017 of $95.1M as the pre-money valuation. When adding the new equity raised from our $1M Series D2 funding round we calculated a subjective post-money valuation of $96.1M.

- **Ownership:** The ownership stake in Crossbar again is highly subjective and was based of very little publicly available information. However, according to information from Pitchbook, Crossbars first round of funding authorized shares at $0.37, so for the sake of consistency, we kept all authorized shares issued at $0.37 with no preference shares being issued (unrealistic). This means with our $1M investment we'd expect a 1.04% stake in Crossbar.

- **Expected Harvest Date:** A rule of thumb for Venture Capital Funds is to aim to hold the investment for only 3 to 8 years. As a result, in our base case calculation of the potential exit valuation, we used a median 5-year harvest date.

- **Discount Rate:** Our assumption of a discount rate of 25% was derived from the later-stage nature of a $1M Crossbar Series D2 funding. Typically, later staged VC funds apply discount rates of 25% to 35% to investment opportunities as they require lower required returns (Desache 2014).

Using these assumptions, we derived a potential exit valuation of $293,273,926 ($293M), with a 1.04% equity stake resulting in proceeds of $3,051,758 and a Cash-On-Cash return of 3.05x (in-line with what we would expect for late-stage funding).

Exhibit 17: Crossbar Exit Valuation

Crossbar Post-Money Valuation

	Total Value ($)	Per Share	# Shares	% of Total
Series A				
Pre-Money Valuation	$95,100,000	$0.37	257,027,027	99.0%
New Equity Raised	$1,000,000	$0.37	2,702,703	1.0%
Post-Money Valuation	**$96,100,000**	**$0.37**	**259,729,730**	**100.0%**

Venture Capital Deal Valuation

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Post-Money Valuation	$96,100,000					
Expected Harvest Date	5 Years					5
Discount Rate	25%					25%
Potential Exit Value						**$293,273,926**
Investor 1 Ownership						1.0%
Investor 1 Equity Value						$3,051,758
Total Proceeds to Investor	($1,000,000)	-	-	-	-	$3,051,758
Required IRR	**25%**					
Cash-on-Cash (CoC)	**3.05x**					

We also conducted a sensitivity analysis (Exhibit 18) to illustrate how our required IRR would increase/decrease as the harvest year expands/contracts from 5-years adjacent to the discount rates increasing/decreasing according to perceived investment risk. As illustrated as the Harvest Year expands out to 7-Years the required IRR to invest in in Crossbars Series D2 funding round increases irrespective of changes in discount rate. Likewise, as the discount rate increases to 35% the required IRR increases irrespective of the Harvest Year, this indicates that as the perceived risk in Crossbar increases we are demanding a higher IRR to compensate.

Exhibit 18: Sensitivity Analysis of Required IRR

Discount Rate \ Harvest Year (Years to Exit)	Year 3	Year 4	Year 5	Year 6	Year 7
15%	9%	12%	15%	18%	22%
20%	12%	16%	20%	24%	29%
25%	14%	20%	25%	31%	37%
30%	17%	23%	30%	37%	44%
35%	20%	27%	35%	43%	52%

Why not DCF?

When conducting a Discounted Cash Flow (DCF) Valuation an analyst follows a few simplified steps to value a company:

1. Project the future revenues and costs of the company.
2. Convert revenues and costs into a net operating cash flow.
3. Assume the net operating cash flows are paid out in dividends (it is more accurate to use actual projected dividends).
4. Project the timing of capital expenditures.
5. create a projected year-by-year cash flow schedule for company.
6. Estimate the cost of capital.
7. Discount the cash flows to find equity value of company.

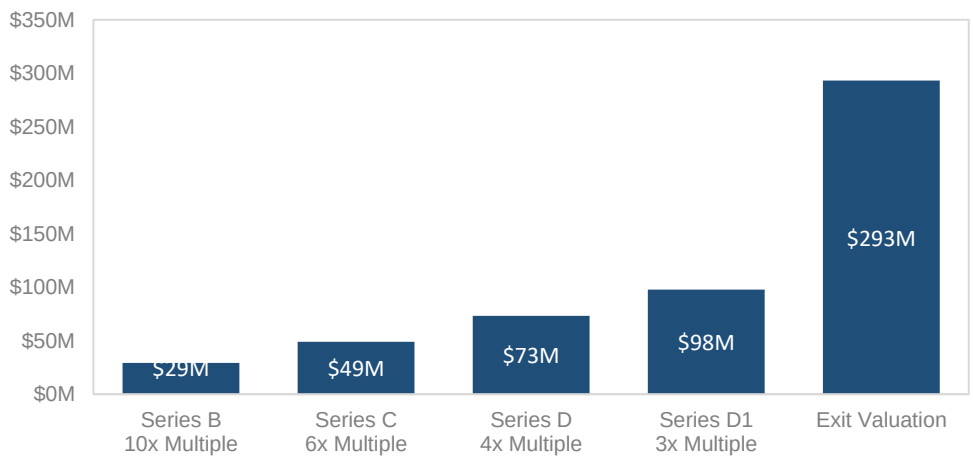
Even though this analysis is straight forward, its primarily used **for established companies – not start-ups like Crossbar.** The companies usually have been running for some time with revenues and costs being able to be sourced from historical dates with ease (Crossbar doesn't disclose financials. The market of these companies also can be generally estimated, making it easier to make assumptions regarding the future market share and thus performance of said company. Most importantly, analysts can use comparable companies to estimate the WACC of the company for an accurate discounted valuation. This sort of analysis isn't plausible for start-up companies. There are far too many variables involved when valuing a start-up tech company like Crossbar. For example, the ReRAM market may end being a flop as it's only an emerging technology there is no guarantee it is going to cement its place. Because of these variables, using a DCF doesn't make practical sense.

Justification for accuracy of our Crossbar Exit Valuation

When justifying the accuracy of our Crossbar exit valuation we constructed a proxy benchmark. Using our Exit Valuation of $293M we worked backwards to see if the valuation was inline with what other VC funds were calculating the exit valuation as at different funding rounds. To do this we used the industry recognised required CoC return multiple typically required at different stages of investment: Series B (10x), Series C (6x), Series D (4x) and Series D1 (3x) (Berkey 2008). As we can see in Exhibit (99), by reverse engineering the exit valuation the implied valuation of Crossbar at the differing funding stages is roughly in line with the actual historical post-money valuation, meaning our valuation of $293 isn't improbable and its accuracy is justified.

Exhibit 19: Valuation Calculations using CoC Multiples

Source: Analyst Calculations



REFERENCES

4DS 2018, *Investor Presentation*, 01 Feb 2018. Available from: http://www.4dsmemory.com/media/files/Jim-Open-Briefing-ASX.pdf. [18 August 2018].

Berkeley 2018, *Raising Venture Capital – For Serious Entrepreneurs*, 01 Feb 2008. Available from: http://library.globalchalet.net/Authors/Startup%20Collection/%5BBerkery,%202008%5D%20Raising%20Venture%20Capital%20for%20the%20Serious%20Entrepreneur.pdf. [10 September 2018].

Crossbar 2018, *Crossbar Fact Sheet*, 28 August 2018. Available from: https://www.crossbar inc.com/assets/resources/fact-sheets/Crossbar-Fact-Sheet.pdf. [22 August 2018].

IC Insights 2018, *Automotive IC Market on Pace for Third Consecutive Record Growth Year*, 31 May 2018. Available from: http://www.icinsights.com/news/bulletins/Automotive-IC-Market-On-Pace-For-Third-Consecutive-Record-Growth-Year/. [26 August 2018].

IC Insights 2018, *Global GDP Impact on Worldwide IC Market Growth Forecast to Rise*, 31 July 2018. Available from: http://www.icinsights.com/news/bulletins/Global-GDP-Impact-On-Worldwide-IC-Market-Growth-Forecast-To-Rise/. [23 August 2018].

IC Insights 2018, *Global GDP Impact on Worldwide IC Market Growth Forecast to Rise*, 31 July 2018. Available from: http://www.icinsights.com/news/bulletins/Global-GDP-Impact-On-Worldwide-IC-Market-Growth-Forecast-To-Rise/. [19 August 2018].

IC Insights 2018, *Semi Content in Electronic Systems Forecast to Reach 31.4% in 2018*, 18 July 2018. Available from: http://www.icinsights.com/news/bulletins/Semi-Content-In-Electronic-Systems-Forecast-To-Reach-314-In-2018/. [26 August 2018].

IC Insights 2018, *Seven Top15 1H18 Semi Suppliers Register 20 Gains*, 20 August 2018. Available from: http://www.icinsights.com/news/bulletins/Seven-Top15-1H18-Semi-Suppliers-Register-20-Gains-/. [23 August 2018].

IDC 2018, *Worldwide Smartphone Volumes Will Remain Down in 2018 Before Returning to Growth in 2019 and Beyond*, 31 May 2018. Available from: https://www.idc.com/getdoc.jsp?containerId=prUS43856818. [19 August 2018].

IHS Markit 2018, *Global Semiconductor Market Trends*, 01 May 2018. Available from: http://theconfab.com/wp-content/uploads/P-18-Len-Jelinek.pdf. [23 August 2018].

Intel 2015, *3D Xpoint Investor Presentation*, 07 August 2015. Available from: https://www.intelsalestraining.com/infographics/memory/3DXPointc.pdf . [3 September 2018].

KPMG 2016, *2016 KPMG Global Semiconductor Industry Outlook*, 01 February 2016. Available from: https://home.kpmg.com/content/dam/kpmg/pdf/2016/06/kpmg-semiconductor-rd-efficiency-2016-web.pdf. [19 August 2018].

KPMG 2018, *2018 KPMG Global Semiconductor Industry Outlook*, 01 February 2018. Available from: https://assets.kpmg.com/content/dam/kpmg/us/pdf/2018/02/kpmg-semiconductor-outlook-2018-web.pdf. [19 August 2018].

Pitchbook 2018, *1Q 2018 VC Valuations*, 31 March 2018. Available from: https://files.pitchbook.com/website/files/pdf/PitchBook_1Q_2018_VC_Valuations_Report.pdf. [10 September 2018].

SIA 2018, *Semiconductor Industry Association Mid-Year Publication*, 03 Aug 2018. Available from: https://www.semiconductors.org/news/2018/08/03/global_sales_report_2017/mid_year_global_semiconductor_sales_up_20.4_percent_compared_to_2017/. [24 August 2018].

WeeBit Nano 2018, *Investor Presentation*, 28 August 2018. Available from: https://weebit-nano.com/wp-content/uploads/2018/09/Investor-Presentation-Aug-2018.pdf. [3 September 2018].

WeeBit Nano 2018, *Investor Presentation*, 8 May 2018. Available from: https://weebit-nano.com/wp-content/uploads/2018/05/may-presentation.pdf. [3 September 2018].

WSTS 2018, *World Semiconductor Trade Statistics August 2018 Press Release*, 16 Aug 2018. Available from: https://www.wsts.org/esraCMS/extension/media/f/WST/3613/WSTS-nr-2018_08.pdf. [24 August 2018].

Report Disclaimer

This report is published for educational purposes the information and opinions contained in this have been obtained from public sources and are believed by the analyst to be reliable, but we make no representation as to the accuracy or completeness of such information.