

# 4DS Memory (ASX:4DS)

Initiation Research Report

28 August 2018

Highly Speculative

Target Price: Not Rated

## KEY FACTS

Closing Price \$0.12

Report Date 28<sup>th</sup> August 2018

Company Website [www.4DS.com.au](http://www.4DS.com.au)

Analyst Kaiden Gilbert

## COMPANY STATISTICS

12 Month High \$0.130

12 Month Low \$0.026

Market Cap (A\$Mil) 110.92m

Issued Shares 964.56m

Issued Options 122m

Cash (A\$Mil) A\$3m

## MAJOR SHAREHOLDERS (%)

Board and Management 15%

Top 20 33%

Ordinary Shareholders 52%

## 4DS SHARE PRICE (YTD)



## 4DS – FROM LAB TO FAB

We see 4DS releasing a positive announcement in September pertaining to the successful fabrication of a megabit chip with fully functioning memory. However, due to the early stage & speculative nature of 4DS, we're not setting a target price.

## INVESTMENT THESIS

- **Growth momentum in cloud storage and mobile devices:** The continued growth momentum of IoT, smartphones, PC's, tablets and automotive electronics is driving 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 4DS, to capture market share.
- **4DS's unique solution using ReRAM on the cusp of production:** 4DS is developing their unique Interface Switching ReRAM (non-filamentary) technology, providing a unique solution the current incumbent memories (NAND Flash). ReRAM scales better, has lower power consumption, greater endurance & reliability and speed & performance comparable to DRAM. After already ticking off development milestones of (i) achieving circuitry linewidth (resolution) of 40 nanometres (nm), (ii) possessing read speed comparable to DRAM at ~50 nanosecond (1000 times faster than NAND Flash), (iii) a 97% yield, (iv) boasting sufficient data retention without sacrificing speed and endurance, 4DS (with the aid of IMEC) is primed for production.
- **Strategic partnerships with Western Digital and IMEC:** The Joint Development Agreement (JDA) with a global storage behemoth, HGST (subsidiary of US\$17bn NASDAQ listed Western Digital), will provide 4DS with the resources and technical expertise required to expedite the development and eventual commercialisation of 4DS's ReRAM memory. Likewise, the collaboration with IMEC will fast-track the fabrication of a megabit 4DS Interface Switching chip with a fully functional memory.
- **Intellectual property catching the attention of acquirers:** The recent consolidation within large semiconductor manufactures including, Samsung, Intel and SK Hynix, as seen these large memory makers shift their battleplans from manufacturing innovative memory technologies to owning intellectual property. This presents 4DS with the potential opportunity to have their intellectual property acquired. We believe with their extensive due diligence, Western Digital will take the front seat as a potential acquirer.
- **Astute and experienced management team:** 4DS boasts a world-class team of memory specialist, material scientists and test engineers who are experienced in founding, building and jockeying start-up tech companies for a strategic exit.

## SEMICONDUCTOR MARKET OVERVIEW

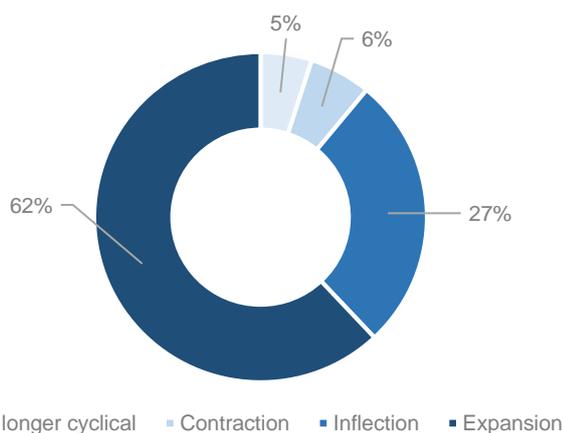
The semiconductor industry in 2017 surprised everyone. High-voltage revenues amongst some of the largest semiconductor players led to record-breaking performances industry-wide, leaving the question on everyone's mind: can 2017 levels of growth be sustained? Many executives from leading semiconductor 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.

Exhibit 1: KPMG survey of industry executive growth sentiment

Source: KPMG



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. 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

Worldwide, 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. As a sum of parts, the global semiconductor industry is healthy and is expected to capitilise 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. 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, we've 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% in 2019 (year-on-year).

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

Source: World Semiconductor Trade Statistics

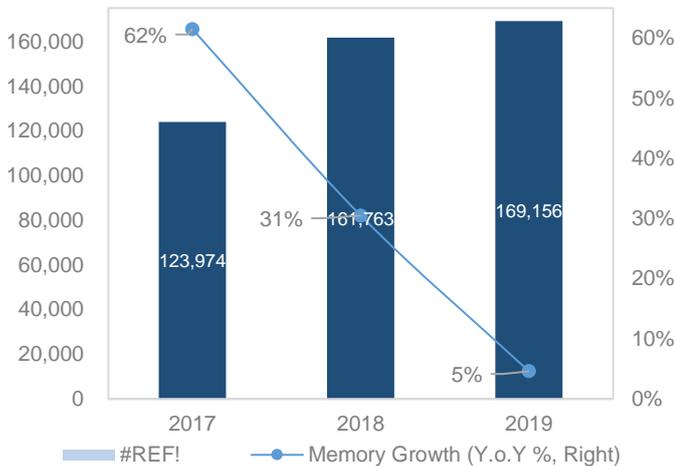
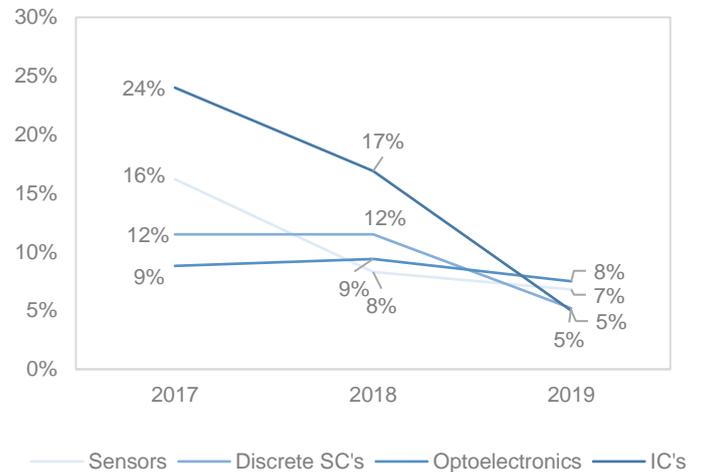


Exhibit 3: Semiconductor Year-on-Year Growth (Segmented)

Source: World Semiconductor Trade Statistics

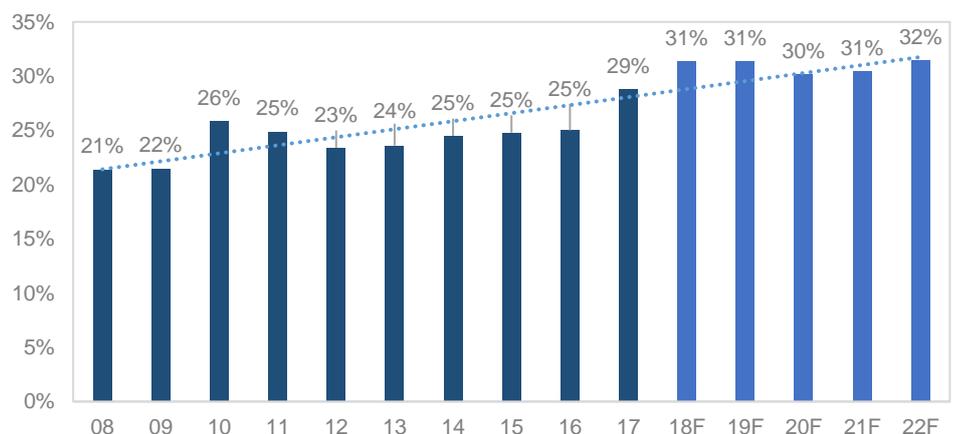


### Looking over the horizon through to 2021 – what's driving IC demand?

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



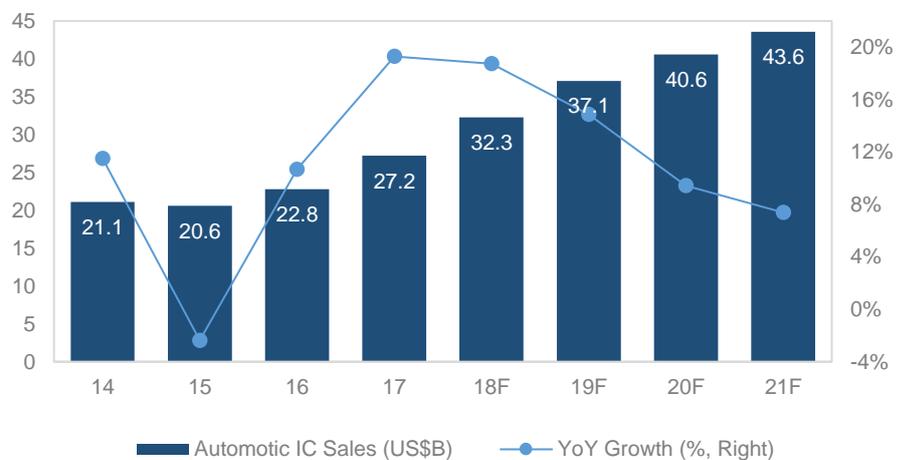
Accordingly, we've identified that Internet-capable converging technologies alongside the surging mobile electronic systems will keep demand for IC's robust through to 2021:

- **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, IoT is forecasted 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.
- **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 – according the IC insights. 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, we're 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)

Exhibit 5: Automotive IC Sales Forecast (Billions)

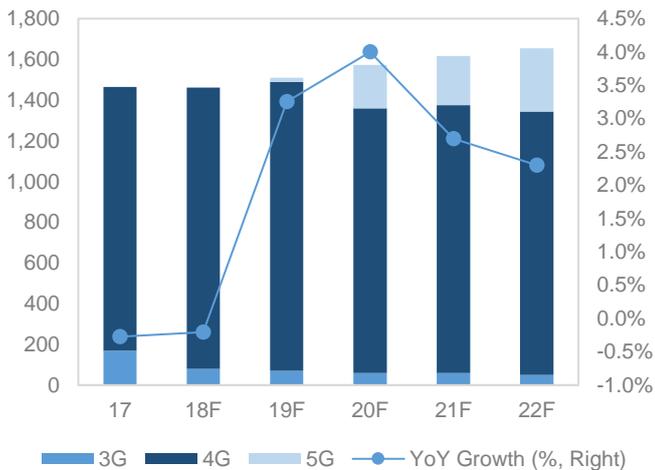
Source: IC Insights 2018



- **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, the worldwide smartphone industry is forecasted 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).

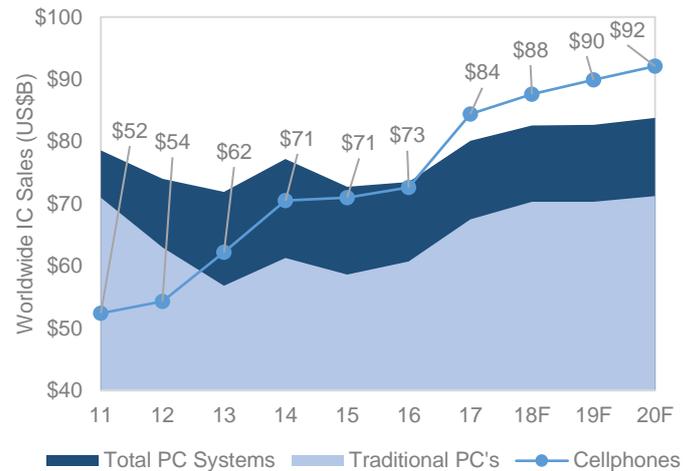
## Exhibit 6: Smartphone Shipments (Millions) – 3G, 4G & 5G

Source: IDC 2018



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

Source: IC Insights



We're 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 it's smartphone market with further contractions forecasted to continue for the remainder of 2018 before flattening and consolidating smartphone growth in 2019. 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 – substantial upside in demand for the memory semiconductor industry to come.

### Has Global GDP Growth become a reliable indicator for WW 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 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 central 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, World Bank - (2017 IC growth excludes DRAM & NRAM)

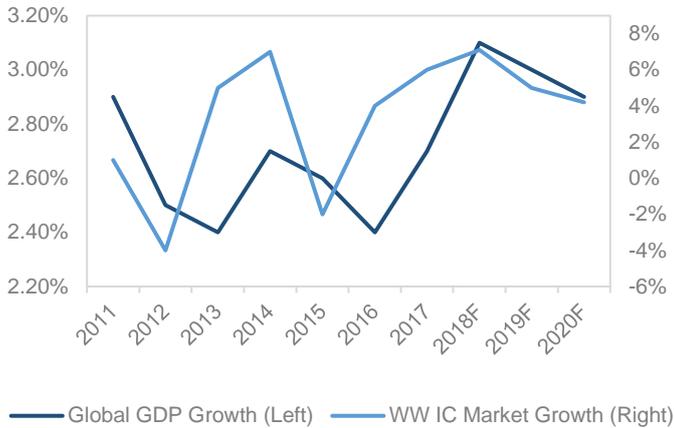
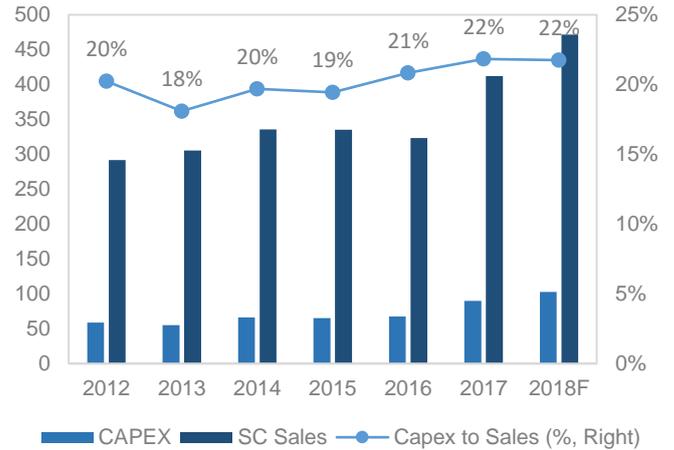


Exhibit 9: Semiconductor CAPEX to Sales Ratio (%)

Source: Semiconductor Industry Association

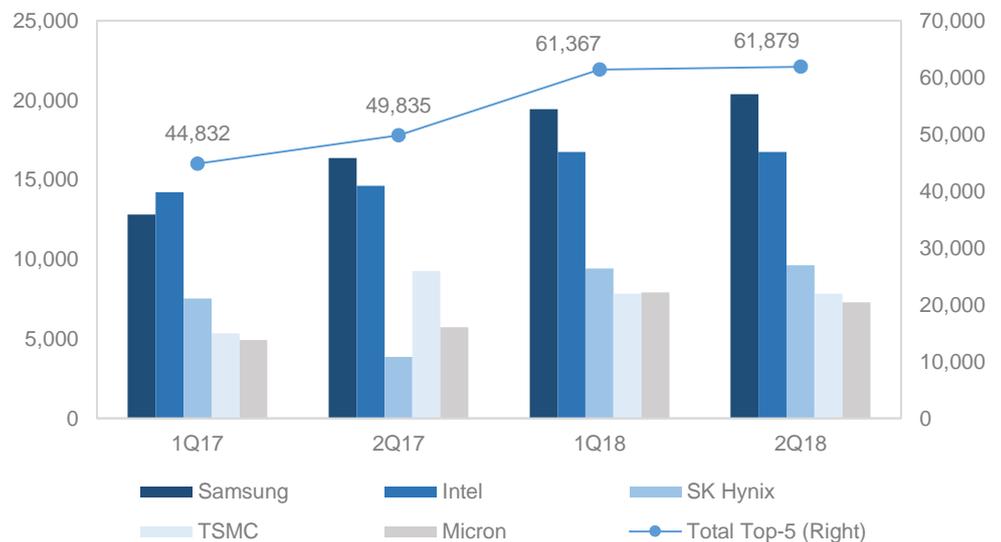


### Semiconductor Competitive Landscape – Samsung taking reign

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. 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! 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.

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

Source: IC Insights



## 4DS MEMORY BUSINESS OVERVIEW

At its core 4DS is in the development of intellectual property pertaining to the emerging non-volatile storage class memory known as “Resistive Random-Access Memory” or ReRAM. It’s understood that ReRAM if successfully developed and further then, commercialised, has the potential to displace the current mainstream technologies – dominated by the goliath NAND Flash memory. 4DS has secured 20 patents for its intellectual property (technology and materials deposition process).

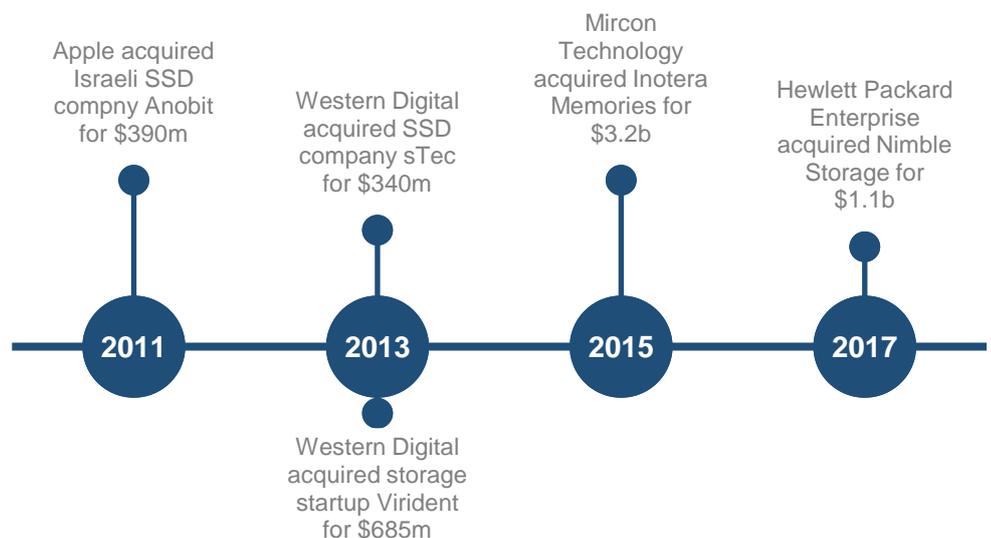
4DS has been developing its own unique solution in displacing the current NAND Flash memory market. Its Metal Oxide Hetero Junction Operation (MOHJO) technology is an interface switching ReRAM (non-filamentary) technology that in comparison to the current incumbent solutions to storage (2D & 3D NAND Flash memory), scales better (smaller geometries at higher density), has a lower power consumption, greater cycling endurance, 1000x read speed and greater reliability.

### Business Model and Strategy – The acquisition of 4DS intellectual property

Becoming a new memory maker is unrealistic, and rest assured 4DS understand this. 4DS 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. Then where to go for 4DS?

4DS 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, acquired. Therefore, the battleground shifts from manufacturing to intellectual property. This isn’t easy, the established global memory makers need concrete proof that a developer like 4DS can make the proclaimed best high-density memory, which is difficult given the resources required to develop said 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 11), with further consolidation only to prompt large scale players in the semiconductor industry to seek acquiring intellectual property rather than focusing resources on developing themselves.

Exhibit 11: Key intellectual property acquisitions over the past-decade



## Joint Development & Collaborative Agreements

Currently, 4DS is engaged in a joint-development with a global storage leader, HGST Netherlands B.V (renewed on the 21st May 2018). The scope of HGST's work is to mainly focus on material improvements, cell evaluation objectives and scaling objectives, which includes the testing of endurance and data retention. Overall, the entry into a joint development agreement with HGST allows 4DS to harness resources that will expedite the development, and if successful, the commercialization of 4DS's unique technology.

In June 2017, 4DS announced a collaborative agreement with IMEC, Belgium, which has the potential to substantially accelerate the development roadmap moving forward. IMEC is recognized to sit amongst the top semiconductor R&D institutes worldwide, with expertise focusing on memory technologies including DRAM, NAND Flash, SRAM, SST-MRAM and the emerging ReRam. The collaborative agreement between 4DS and IMEC will focus on expanding 4DS's memory technology from a laboratory R&D environment in the Silicon Valley into an environment with a Complementary Metal Oxide Semiconductor (CMOS) production environment to manufacture integrated circuits. As a result, by collaborating with IMEC, 4DS will potentially manufacture Mb-sized interface switching ReRam memories at 300mm wafer – 300mm wafers are the current required wafer size for the future production of Gb and Tb SCM chips for memory and storage used in data centers, smartphones & personal computers.

## A DEEPER LOOK INTO THE DRAM AND NAND FLASH MEMORY

### Dynamic Random-Access Memory (DRAM) – Too expensive for widespread use!

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; 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, as 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.

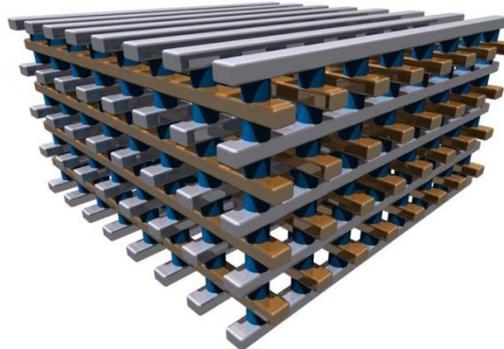
## STORAGE CLASS MEMORY – THE HIERARCHY DISRUPTOR

### Storage Class Memory (ReRAM) – A unique solution to the rise in data storage?

The term “Storage Class Memory” (SCM) encapsulates a class of emerging technologies, like ReRAM, that are anticipated to penetrate the semiconductor memory market 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 than 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 12). 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 12: ReRAM memory cell



Source: Crossbar Memory

### Incumbent technology reaching physical limits – Enter ReRAM?

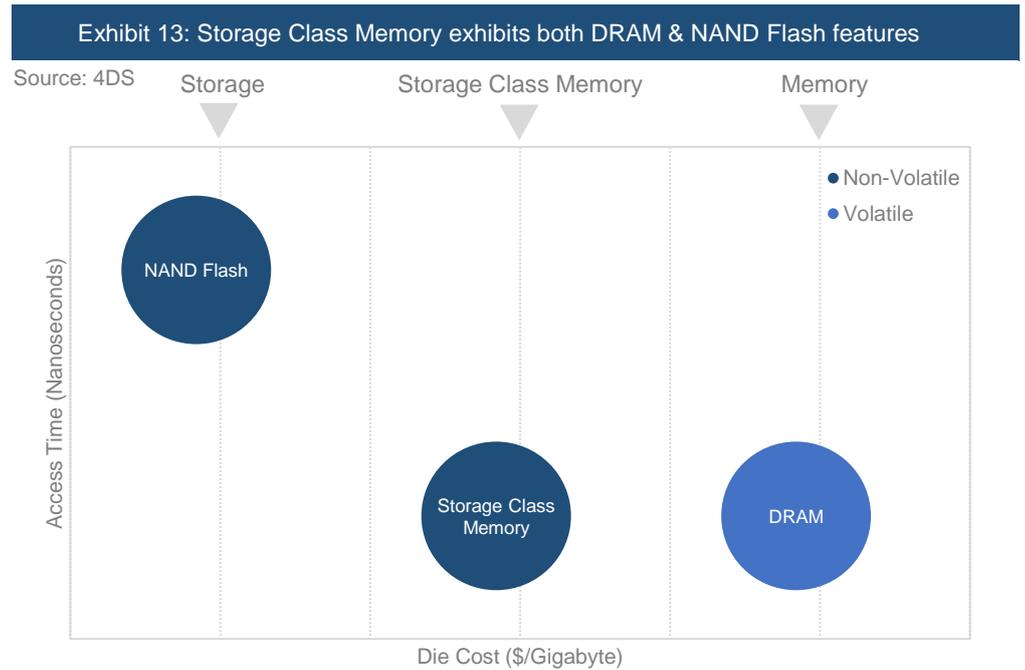
We cannot simply just replace DRAM with SCM, empirical research indicates that simply switching memory technology from DRAM to SCM will dramatically increase the average transfer latency of a cache block, and with memory latency being an important element in workloads of datacenters, the increase will 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 characteristics 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:

Storage Class Memory's come in a plethora of densities and performance grades (Exhibit 13). 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.



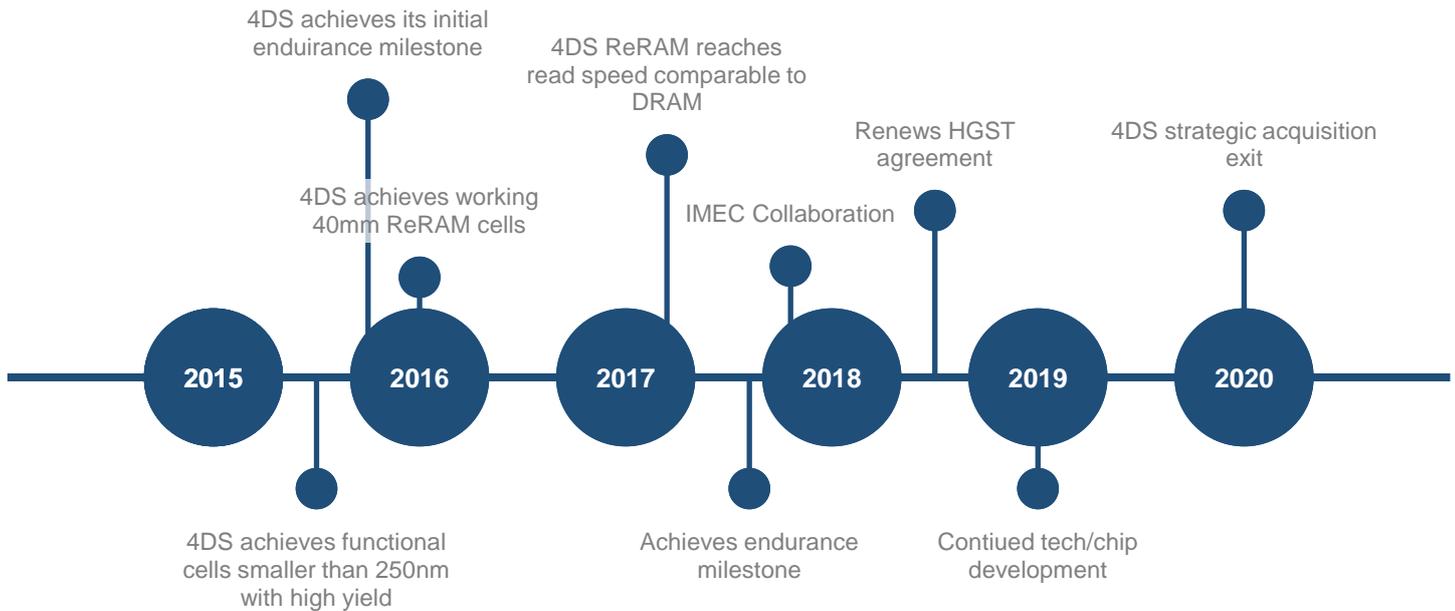
## 4DS'S INNOVATION – MOHJO MEMORY CELL TECHNOLOGY

4DS's memory functions much like the most ReRAM developments, however, at the heart of 4DS's memory is the MOHJO hetero junction. Even though the filamentary switching mechanisms (Exhibit 14) used in ReRAM have evolved substantially over the past-decade to a point of being able to compete with NAND Flash in end-use applications, the mechanism still needs to overcome some shortcomings. The filamentary switching mechanism still lacks control; the filament in the switch mechanism acts as a kind of circuit between the two electrode materials but are somewhat random and difficult to control. Secondly, endurance in the traditional filamentary switching mechanism is hampered due to the need for forming and reforming filaments. And lastly, cells are continuing to get smaller, but the filamentary current is the same resulting in larger current densities – the issue of this is the restriction in the ability to scale down in size.

4DS avoids the issue of scalability all together. The MOHJO hetero junction doesn't rely on the formation of the actual filament. The MOHJO switching system reduces its resistance to form the "on" and "off" states – giving it an advantage over normal switching technology. By operating without filaments, 4DS's memory technology is allows the switching current to scale inline with smaller cell geometries – well suited for gigabyte silicon storage in smartphone and cloud storage.

## THE 4DS ROADMAP SO FAR – A STORY OF WHEN, NOT IF

Source: 4DS



### SCM REQUIREMENTS – 4DS ARE TICKING ALL THE BOXES?

4DS's ReRAM is starting to tick all the boxes. With ReRAM reaching read speeds comparable to DRAM, and retention tests producing sufficient results, 4DS is delivering most of the parameters needed to begin the development of a Megabit chip:

- ✓ **Circuitry linewidth (Resolution):** 4DS are continuing to come good on their scalability promises, achieving the benchmark 40nm resolution proving 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 non-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:** 4DS achieved the minimum requirement of 400 for the number of switching cycles in a linear endurance test with flying colours. Out of more than 1,000 memory cells tested, 97% passed the minimum required number, with 4DS demonstrating can further optimise endurance to a point where cells are achieving more than 20,000 state changes per cell.
- ✓ **Data Retention without sacrificing speed and endurance:** 4DS's MOHJO is back with a vengeance, confidently announcing that their data retention is enough for storage class memory without the need to sacrifice its advancements in 50ns speed and impressive cycling endurance. IMECs collaboration reiterates this confidence as they can now focus on the Megabit chip development.

## COMPETITIVE POSITIONING – 4DS WORKING THAT MOHJO

Over the past half a decade 4DS has built a robust technology targeting the void between the two current goliaths in the memory market, DRAM and NAND Flash memories. Centered on the emerging non-volatile storage class memory, ReRAM, 4DS has utilized extensive research & development to solidify its position as a real disruption in the semiconductor memory market. Becoming one of Australia's only storage class memory developers to get into a position to disrupt the status quo is a testament to the management, development and engineer team, with this achievement compounding to potentially secure a strategic takeover of intellectual property from larger scaled players in the market.

### 4DS's MOHJO provides a differential characteristic

4DS's memory technology capabilities separates them from many of the other competitors in the market and continues to be a strength driving global attention to its non-filamentary ReRAM technology. Interface switching ReRAM has key advantages over other emerging technologies, but the filamentary based ReRAM cells developed by the likes of Crossbar, Adesto Technologies and Panasonic, face challenges due to the electrical currents required to read and write will stay roughly the same as the memory cell geometries shrink. 4DS's interface switching ReRAM (non-filamentary) is a differentiating factor as the memory cell architecture allows for scaling efficiencies as a result of not relying on a filamentary layer to switch. Therefore. In comparison to its peers, 4DS exhibits a robust competitive positioning amongst rivals in the industry.

Company	Exchange Code	NVM Type	Market Cap	Target Market
4DS Memory	ASX: 4DS	Non-Filamentary ReRAM	114.46M	SCM – Smartphones, Cloud Storage, Automotive Electronics
Crossbar	Private	Filamentary ReRAM	N/A (Private)	IoT, SSD's and Wearable Electronics
Adesto Technologies	NASDAQ: IOTS	Filamentary ReRAM	166.83M	IoT, Wearable Electronics
Weebit Nano	ASX: WBT	Filamentary ReRAM	79.98M	IoT, Wearable Electronics

### Astute and experienced management jockeying the 4DS story

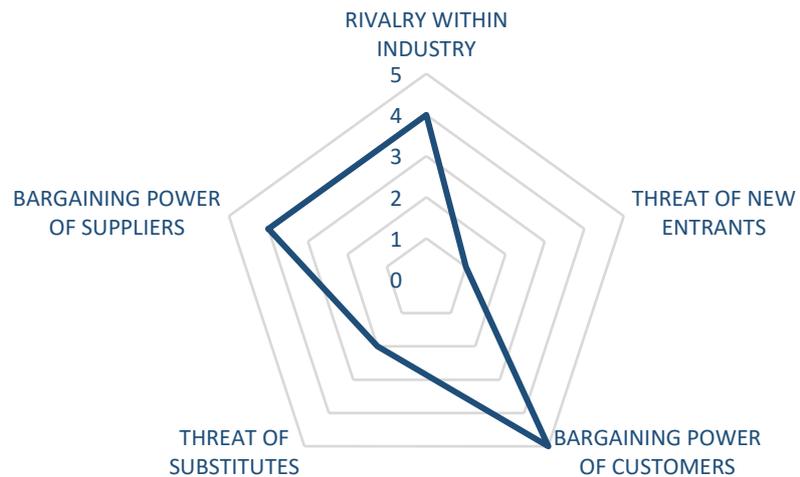
Strong and experienced management has been the cornerstone of the company's success, allowing them to foster and drive the innovation required to parry the risk of obsolescence in the dynamic non-volatile memory industry. Likewise, management has substantial experience in not only in the space of innovation but have also demonstrated the ability to successfully build and exit similar projects in the past, placing 4DS's in a robust position to properly progress towards the end goal of a strategic acquisition of its intellectual property.

### Foundations already laid for future strategic action

Given 4DS' development agreement with HGS, whose parent company Western digital has publicly made clear their preference for 3D ReRAM, while the likes of SK Hynix, Panasonic, SMIC and Samsung have all also jumped on board opting for 3D ReRAM as their future technology of choice. However, 4DS' JDA with Western Digital provides the greatest competitive boost, as the NADFAQ-listed behemoth is renowned for strategically investing in emerging technologies, and with due diligence into 4DS and its patents already been conducted, 4DS must have attracted more than just attention from the industry.

## PORTER FIVE FORCES ANALYSIS

### Porter Five Forces for 4DS in Semiconductor Memory Industry



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

**Threat of new entrants (Very Low):** The threat of new entrants is **very low** as barriers to entry in the semiconductor memories industry are high. The start-up resources are high requiring significant investment to get research and development off the ground, while finding qualified human capital (engineers, developers, designers etc.) has proven to be difficult. Additionally, maintaining competitive technology amongst strong competition requires further investment in innovation to halt the risk of obsolescence. As a result, it's becoming substantially harder for new entrants to break into the rapidly changing semiconductor memory industry.

**Bargaining power of customers (Very High):** The bargaining power of customers is **very high** in the semiconductor memory industry providing a threat to 4DS's competitive positioning. The major buyers in the industry deal in large volumes and the chips are sold primarily only from business-to-business. In addition, these buyers' 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 semiconductor memories industry is **low**, making it very attractive for 4DS's competitive positioning. There are no real other substitutes in storage class memory market what 4DS is targeting. In terms of the non-volatile memory ReRAM, there isn't a sure substitute for the void in the market the technology provides – scalability & cost efficiency.

**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 4DS. As a result, this is an unattractive prospect for 4DS's competitive positioning providing a **high** threat.

## DIRECTORS – A GOLD MINE OF EXPERIENCE

*\*All Information on Directors and Management is courtesy of 4DS*

### **James Dorrian (Non-Executive Chairman):**



James Dorrian is the non-executive Chairman of 4DS. He is a former partner at Crosspoint Venture Partners, a Silicon Valley based early stage venture capital firm. He has served as both CEO and Board Member of several Silicon Valley companies and has in depth M&A and IPO experience. Prior to this, Mr Dorrian was the Founder and CEO of Arbor Software and has held management roles with a number of multinational IT companies. He is a founding member of the OLAP Council, an industry consortium for On-Line Analytical Processing. Mr Dorrian holds a Bachelor of Arts in Economics and Communications from Indiana University.

### **Dr Guido Arnout (CEO and Managing Director):**



Guido Arnout is the Chief Executive Officer and Managing Director of 4DS. Prior to joining 4DS in 2013, Dr Arnout has helped guide multiple Silicon Valley companies through commercialisation or sale. He was the founding President and CEO of PowerEscape, which introduced the first tools for the development of low-power software executing on multi-core devices. He was also founding President and CEO of CoWare, which pioneered system-level design tools for hardware-software co-design and the time-based licensing business model. Dr Arnout co-founded the Open SystemC Initiative, an industry consortium to standardise a language for system level design, and as its President submitted the SystemC language to IEEE. He served as VP of Engineering and later senior VP of marketing of CrossCheck Technology. He co-founded and later became VP of Engineering of Silvar-Lisco, the first commercial EDA (electronic design automation) company. Dr Arnout holds a PhD in Electrical Engineering from the University of Leuven in Belgium.

### **Howard Digby (Non-Executive Director):**



Howard Digby is a non-executive Director of 4DS. Mr Digby started his career at IBM and has spent over 25 years managing technology related businesses in the Asia Pacific region, of which 12 years were spent in Hong Kong. More recently, he was with The Economist Group as Regional Managing Director. Prior to this he held senior management roles at Adobe and Gartner where his clients included major semiconductor players including Samsung, Hynix and TSMC. Mr Digby is a non-executive Director of Estrella Resources (ASX:ESR) and is currently an advisor to a number of early stage technology companies. Mr Digby holds a Bachelor of Engineering (Mechanical) (Honours) from The University of Western Australia.

### **David McAuliffe (Executive Director):**



David McAuliffe is an Executive Director of 4DS. He is an experienced board director and entrepreneur who has had over 20 years' experience. During that time he was involved in numerous capital raisings and in-licensing of technologies. He is a founder of several companies in Australia, France and the United Kingdom, many of which have become public companies. Mr McAuliffe holds a Bachelor of Laws (Honours), a Bachelor of Pharmacy and is the President of the Dyslexia-Speld Foundation WA (Inc).

## MANAGEMENT – ASTUTE, PASSIONATE & DRIVEN

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### **Michael Van Buskirk (Chief Engineering Officer):**



Michael Van Buskirk is Chief Engineering Officer at 4DS. Mr Van Buskirk has held executive roles with a number of leading memory companies in Silicon Valley. He was the Chief Technology Officer at Adesto Technologies Corporation, where he initiated and directed its second and third generation CBRAMTM technology to make it suitable for broad market acceptance. He served as the Chief Operating Officer at Innovative Silicon, Inc., where he co-invented and developed its ultra-low voltage Z-RAMTM vertical floating body memory technology. Mr Van Buskirk was the Chief Technology Officer at Spansion, Inc., the flash memory joint venture between Advanced Micro Devices (AMD) and Fujitsu, where he integrated and oversaw the former Fujitsu and AMD flash memory engineering teams. Prior to the establishment of Spansion in 2003, he spent 17 years with AMD where he held senior positions including Vice-President of Engineering, Memory Group. Mr Van Buskirk holds a Bachelor of Science in Electrical Engineering from Oregon State University.

### **Seshubabu Desu, PhD (Chief Technology Officer):**



Seshubabu Desu is Chief Technology Officer at 4DS. Dr Desu is a highly regarded global subject matter expert in thin films, semi processing and non-volatile memories. He was Dean of SUNY Binghamton's Watson School of Engineering, Head of the Electrical and Computer Engineering Department at University of Massachusetts Amherst, and a professor at Virginia Tech Blacksburg. He holds 30 US patents, has written over 240 refereed technical articles and is a Highly Cited Researcher. Dr Desu has co-edited six books and supervised over 30 MS and PhD theses. He is a Fellow of both IEEE and the American Ceramic Society. His previous experience includes being a Group Leader at GE and a Senior Member of Technical Staff at Bell Laboratories. He holds a PhD in Materials Science and Engineering from the University of Illinois at Urbana-Champaign.

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