SPECIAL REPORT

Next Generation Military Grade Memory and Storage Solutions

Next Generation Storage Solutions in Defence

21st Century Data Storage in an Age of Net Centric Collaboration

Flash Memory and DRAM Meet Constraints of Moore's Law

Confronting Pentagon Weakness in IT Acquisition

Memory for the Future

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Foreword

DATA STORAGE for mobile computer devices for use in the military is a rapidly changing field of high complexity. This is the topic of this Special Report.

The opening article looks at the significant development in memory since NAND Flash memory was introduced in 1989. However, as collecting data on the battlefield is becoming increasingly more critical to gain a tactical advantage, new means of storage have had to be found. One of the solutions is Resistive Random Access Memory (RRAM), which is more stable than NAND Flash, with much longer life, speed and better latency – a perfect fit for the defence industry. However, cost is an issue, so it could be some time before RRAM is embraced wholly by defence procurers. There are other developments taking place in storage, among which is 3D XPoint, which are examined in the article.

The second piece looks from a military perspective at how the needs and demands of the military for updated memory storage and data handling and retrieval systems are evolving. Nowadays, the war fighter on the ground or analysing data for situation awareness or targeting will judge military capabilities by the features available to him or her on a new smart phone or tablet.

The third article reviews changes in the semi conductor industry in DRAM and NAND memory storage. Memory technology is changing fast but the technology is bumping up against the constraints of ever reducing size in nano technology.

The challenge for every department of defence is to prepare to fight the next conflict and win with the latest appropriate technology. However, the acquisition process in the United States, for example, has become mired in bureaucratic acquisition procedures and Congressional gridlock. The politics of the acquisition process could be said to be jeopardising technology adoption.

The future is always a tough call to write about. This is especially true in the field of semi conductors, where disruptive change can and does take place within a 3-month period, rendering past assumptions part of history. The final article looks at the challenge facing researchers working to improve memory storage and retrieval. It also summarises the complexity of the issues that need to be weighed up when deciding which data storage system to use for which defence platform.

Mary Dub
Editor

***Mary Dub** has written about international security in the United States, Europe, Africa and the Middle East as a television broadcaster and journalist and has a Masters degree in War Studies from King's College, London.*

NEXT GENERATION MILITARY GRADE MEMORY AND STORAGE SOLUTIONS

Next Generation Storage Solutions in Defence

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THE UK electronic systems industry contributes an estimated £80 Billion to the UK economy and employs an estimated 850,000 people. The UK Defence Sector is a leading high-technology manufacturing and service provider for the UK, generating £22.1 billion per year for the UK economy.

It is estimated by 2020 there will be 50 billion connected devices generating 40 Trillion GBs of data. Looking at electronics systems specifically designed for use in the defence sector, it is easy to see that the ability to record vast amounts of data brings with it huge operational and competitive advantages to both the sub-system manufacturers and technology users on the front line. As the defence sector continues to transition to the digital era the importance of selecting the correct memory technology has never been more important.

Specialist memory distributors, Jactron, have helped provide a wide variety of defence applications on Air, Land and Sea. Since 1989, we have supported manufacturers and prime contractors with memory solutions that can be found embedded within systems supporting C⁴ISR, mission, simulation, training and condition based monitoring activity across the globe.

This report aims to provide a non-biased overview on what the future may hold for memory technology. Using our experience we will look at how memory has evolved and the considerations that need to be factored into the decision making process when selecting data storage components.

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Memory and data storage has come a long way since the early days of computing, but have the principles of memory and storage changed? Not really. Yes everything is smaller, quicker, more durable and secure, but we are still seeing a need to source legacy memory, even 2MB Linear Flash PCMCIA cards in certain applications are still required.

There will always be a trade-off between speed and storage and the challenge for manufacturers is to come up with a solution for both. There has been no real significant new development in memory since NAND Flash memory was introduced to the world in 1989 but for this to be filtered into military applications takes how long exactly? No one really has a sure fire answer. It really depends on the type of technology being used, the storage requirement, the end user requirement or even the entry into service date. The real issue is how Primes and OEMs can integrate today's new memory and storage into existing systems quickly, effectively and with minimal downtime. Compliance, specifications, cost and benefits all need to be considered before upgrading to new memory and storage.

Collecting data on the battlefield is becoming increasingly more critical to gain a tactical advantage. Satellite imagery, communications, targeting all require one thing in common – memory and the ability to store encrypted data in a secure, robust environment in varying temperatures. So how do today's military requirements align with the market?

Technology Readiness

Since its introduction to the world, NAND Flash memory has long been the staple of all storage devices currently available. It has only been over the last 15 years that we have seen NAND Flash at a level of technology readiness within the military. Although we see new kit being displayed at global trade shows every year, how much of this new equipment currently uses NAND Flash? Anything that has artificial intelligence or stores

There has been no real significant new development in memory since NAND Flash memory was introduced to the world in 1989

data is 99% likely to have NAND Flash technology which is nigh on 25 years old!

Due to the need for proven technology in the defence arena, new memory and storage solutions technology has taken years to filter down into military applications as the OEMs and supply chain develop new equipment. The telecoms industry however is quick to embrace new technologies as the regulation and certification is less stringent.

Think military midlife upgrades – this is when we typically see new components and equipment being added retrospectively and integrated into military hardware. Frequently, memory and storage is seen as an afterthought as the requirement of the end user often changes. There are specifications for military components which include wiring, packaging, materials and memory, all of which need to be taken into consideration when selecting the right build of materials (BOM) memory and data storage.

Military requirements often demand high security, power protection, varied operating temperatures, shock or vibration proof factors, and a higher quality build of materials specification. There is an extreme difference between commercial of the Shelf (COTS) storage and industrial grade, especially if the end user is the military. In MIL terms, our industrial offerings are still considered COTS. However, certain types of memory and storage can be customised to become more durable, secure, reliable and faster at the point of manufacture, rather than an afterthought.

From the early origins of Computing in the military – think Alan Turing (who is considered by many as the father of modern computing) and his Enigma code breaking machine, to modern day computing memory, the storage of data has evolved dramatically.

The explosion of connected devices and digital services is generating massive amounts of new data. For this data to be useful, it must be stored and analysed very quickly. So as memory with planar NAND is nearing its practical scaling limits delivering to those requirements has become more difficult with each generation. So is NAND about to enter its next stage of evolution? There are many types of memory currently in development, but we have focused on several which, in our opinion, are the most relevant and are at a state of manufacturing readiness.

The Future – 3D NAND?

Composed of a controller and NAND Flash memory, it is only the largest companies who can devote sufficient research and development resources to propel the SSD market forward through real innovation. Typically these companies reside in Asia.

Companies that manufacture their own NAND Flash memory are at the vanguard of SSD development, and very few can offer the breadth of expertise exercised by well-known household brands such as Samsung, Toshiba, Micron/Intel and Hewlett Packard. Whilst Samsung now focus on consumer products Toshiba, Micron and HP are still major players in the defence arena.

These companies have the capability to design and manufacture NAND memory, which makes up the bulk of the cost of an SSD. They also develop the associated controller and firmware that manages how the SSD interacts with the system.

The problem with NAND Flash has been one of cost. Since the development of NAND, the drive has been for SSDs to be priced on a par with their magnetic drive cousins but over the years the price has been reduced by 2 factors; die geometry and cell layering.

3D NAND technology uses an innovative process architecture to provide three times the capacity of planar NAND technologies, while providing better performance and reliability for some applications. Micron are the first to employ floating gate cell technology in 3D NAND—a proven cell technology that enables better performance, quality, and reliability. They stack 32 storage tiers to achieve the highest-capacity NAND die available today: 256Gb multilevel cell (MLC) and 384Gb triple-level cell (TLC) 3D NAND.

This vertical approach allows them to expand the size of each 3D NAND cell—the lithography is actually larger than their latest planar NAND. The larger NAND cells improve both performance and endurance to the point where they expect their MLC 3D NAND parts will meet or exceed the endurance rates of their 20nm NAND—and their TLC 3D NAND will satisfy demanding data centre storage applications.

According to Micron, 3D NAND will;

1. **Pack in More Capacity.** Up to three times the capacity of existing NAND products – enough to enable 3.5TB gum stick-sized SSDs or more than 10TB in standard 2.5-inch SSDs.
2. **Boost Performance.** Achieve significantly higher read/write bandwidth and I/O speeds, as well as improved random read performance, thanks to 3D NAND's fast 4K read mode.
3. **Save Power.** Power consumption will be reduced significantly in standby mode thanks to 3D NAND's new sleep mode features that cut power to inactive NAND die (even when other die in the same package are active).

There are many more important considerations in the selection of industrial-grade SSDs. To truly be considered industrial-grade, SSDs must:

- Be SLC NAND Flash-based
- Offer advanced Flash management
- Integrate power-fail corruption mitigation technologies
- Be backed with extensive design and reliability testing
- Have a fixed BOM
- Ensure supply longevity

There's every reason to consider solid-state drives (SSDs) as the primary storage medium for PCs and laptops used in military applications. The benefit of SSDs over traditional spinning drives is immense. No moving parts enables smaller form factors to be created, while the intrinsic speed of SSDs far outstrip that of even the fastest mechanical spinners. No moving parts equals less downtime and more reliability in the field. The lack of moving parts is also a massive boost when copying or writing small files, as SSDs can be hundreds of times faster than traditional drives at these tasks. If you need to speed up a PC, one of the cheapest ways to do this is to invest in an SSD. However, not all SSDs are created equal.

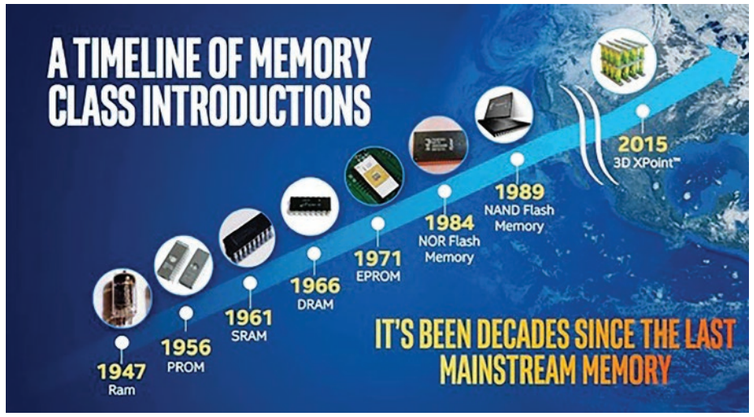
New Technologies

Similar technologies from the other Flash manufacturers are now coming to market and 3D NAND is only one of the developments. There is a possibility that in 2016 Hewlett Packard may release a new product called 'Memristor', which is much more stable than NAND Flash, with much longer life, speed and better latency. Known as RRAM (Resistive Random Access Memory) this could become the next evolution in memory. The concepts around RRAM are not new – they've been around since the 1960s but have only gained significant interest in the last 10 years as a successor to current memory technology. As applications push for faster and higher performance and lower power draw in smaller packages, memory companies are scouting RRAM's abilities to beat Flash's performance as Flash is nearing its scaling limits. The idea is simple; to combine all of the benefits of both DRAM and MRAM and create a form of memory which will not be dependent on power. RRAM is expected to deliver write performance up to 20 times faster than NAND Flash memory, with 20 times less power consumption and 10 times more durability – a perfect fit for the defence industry.

However, the stumbling block for RRAM is cost per bit as the performance increases are not strong enough against Flash to overcome the cost increase to RRAM. RRAM will happen but up against 3D V NAND, there will be fierce competition. So the transition into the defence market may be in for its next evolutionary step. For smaller handheld items within defence, the new technology transition could be quicker than it is currently. It would be churlish to ignore other potential memory developments such as; T-RAM, Z-RAM, CBRAM, NRAM, SONOS, Ferroelectric, Racetrack, Millipede and FJG. These memory types have their own unique operating properties, different methods of manufacture and are in various stages of development. Ultimately the defence industry will be driven by consumer demand and who can get their product to market, quicker and cheaper than the competition. However, some of the memory listed above may never find its way into the consumer market and may be focused on the industrial market, specialist applications or may drop at the first hurdle - only time will tell. Beta Max v VHS, Blue Ray v HD DVD - there are many analogies across various industries as to what is best but ultimately it comes down to fit, form, function, availability and price.

3D XPoint

The sluggish speed of data storage compared to the pace at which processors can work has become a significant bottleneck in the capabilities of computers. Several large computing and chip companies have invested heavily in promising new data storage technologies, but none has yet



SOURCE; WWW.INTEL.COM

RRAM is expected to deliver write performance up to 20 times faster than NAND Flash memory, with 20 times less power consumption and 10 times more durability – a perfect fit for the defence industry

borne fruit, until now. The innovation is called 3D XPoint, and is the invention of Intel and Micron.

This new memory technology is now in production, and is up to 1,000 times faster than the NAND Flash storage used in memory cards and computers' solid state drives (SSDs). Storage capacity is claimed to be similar to Flash memory and durability is improved. Intel is marketing it as the first new class of "mainstream memory" since 1989 which saw the introduction of NAND Flash memory.

One of the key advantages over RAM is that 3D XPoint retains data when the power is switched off – which could be critical in military applications if there is a sudden power loss or applications need to be turned on or off quickly to preserve battery

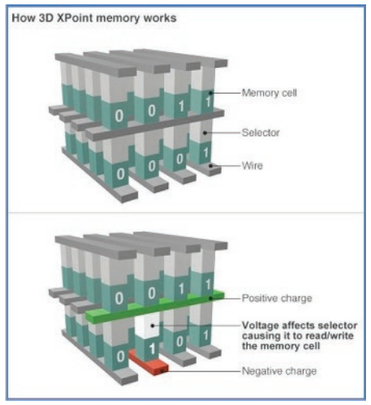
SOURCE; WWW.INTEL.COM

life in, say, handheld GPS units or field radios. Rather than pitch it as a replacement for either Flash storage or RAM, the company suggests it will be used alongside them to hold certain data "closer" to a processor so that it can be accessed more quickly than previously.

But why do we need faster storage? For example; the Flash storage in a smartphone and PC seems more than fast enough to view and record photos and videos. But there are other situations where using today's storage slows things down or introduces constraints. So-called "big data" tasks are a particular issue. Another example is the possible need to stream 8K ultra-high definition video clips, satellite imagery or UAV streaming from the battlefield without experiencing lags for C4ISR applications. Likewise in the military simulation market the ability to access bigger storage files more quickly could transform simulation training to a more user-friendly and realistic experience. No doubt training and simulation providers are monitoring these developments extremely closely for the next generation of equipment.

So, What's the Big Advantage Over Flash Memory?

SSD's are up to 1,000 X slower than 3D XPoint, but are cheaper to buy so does it come down to price or performance for the military? However, there is still some confusion as to where 3D XPoint will sit. The manufacturers see it to co-exist as a new memory layer between NAND and DRAM. There is still some debate as to whether SSDs and 3D XPoint will be competitors or XPoint will be used in future SSDs. Performance would win,



SOURCE; INTEL & MICRON

in theory, every time as 3D XPoint does away with the need to use the transistors at the heart of NAND chips. Because of its speed, it's possible it can function as main memory as well as storage because it's non-volatile. The new memory could potentially be used as the sole memory technology in a computer or in conjunction with traditional DRAM as well. Will 3DXPoint replace SSDs? Certainly not in the short term for the military; longer term maybe, if or when the new technology is proven.

If the 3D XPoint is so Fast, Why Not Just Use it to Replace RAM Altogether?

RAM's speed advantage over traditional storage has long made it the chip of choice to funnel data directly into processors. However, because it is relatively expensive to produce, computer makers tend to restrict how much they include. Each megabyte of 3D XPoint will certainly be significantly cheaper than the equivalent amount of RAM. And the new technology has the added advantage of being non-volatile, meaning it does not "forget" information when the power is switched off.

But, unfortunately it is still not quite as fast as RAM, and some – but not all – applications need the extra speed the older technology provides, which is all too pertinent in legacy military programmes. So until 3D XPoint becomes as fast as RAM we may not see it in the defence arena any time soon or not at all. However 3D XPoint is being driven by Intel and Micron, arguably two of the largest and respected technology companies in the world, so we need to keep abreast of their developments. Most military applications are not necessarily speed dependant so may not have the need for such technology. Yes speed is important but is it the underlying factor for defence applications? Security, reliability and cost also matter. Ask a soldier in the field; What would you prefer?

A piece of kit that works most of the time and is really fast or it's a bit slower but never lets you down. We know what the answer would be.

3D XPoint instead of RAM or Flash?

Online gaming companies might want to substitute 3D XPoint for RAM. But how can this be transferred into the military simulation market? In theory, this could be fairly easy and the benefits could be – quicker response times (smoother graphics) and the ability to hold more data and scenarios for training – i.e. a larger more comprehensive virtual battlefield. Remember, all simulation is computer-based so gaming companies who have expertise in producing military games may have a competitive edge embracing this new technology. No doubt they will be keen to get their hands on 3D XPoint to see how it operates. However, this may not be for some time as Intel and Micron will almost certainly focus on pushing 3D XPoint to the commercial managers in the first instance. This makes a lot of sense both commercially and practically. Firstly, it is unproven technology and no one knows how it is really going to operate in commercial applications (smartphones, tablets etc.) It may fall at the first hurdle and be removed. This is unlikely given the time and money spent on research and development. Secondly, the manufacturers would want to recoup as much money as fast as they can and the quickest way is into the commercial market.

Intel and Micron spent more than a decade researching 3D XPoint before it was ready to go into production and invested millions to ensure the technology will be the benchmark for years to come. No doubt with their vast resources in R&D this will be the first of a long list of new 3D XPoint product lines. Many users have already experienced faster switch-on times on new computers thanks to such files being kept on SSDs rather than disk drives. A similar performance leap would be experienced by adopting 3D XPoint.

But how long will it take? Months, maybe years? No one can really say. How will the new technology be supported by manufacturers? The demand will be high for some time, that much is clear, whichever new technology wins the race. As to when 3D XPoint will make it into the defence market, if ever, remains to be seen, as it will come down to demand initially in the consumer market and price to manufacture, which will over time decline. In addition, the critical point from a military perspective is how quickly can design engineers incorporate the new technology into the current and next generation of equipment.

There are, of course, pros and cons of 3D XPoint. While undoubtedly a big step forward, there are drawbacks such as;

- **Cost** – 3D XPoint is higher so this won't be replacing NAND any time soon and the chips cost less than the manufacture of RAM
- **Speed** – The chips are faster than NAND, but slower than RAM.

So What Else Does the Future Hold for Memory in the Defence Sector?

It may be pertinent to mention the move away from SLC (single layer cell), since this will undoubtedly affect the defence market. We should not be surprised to see SLC almost totally disappear to be replaced by pSLC. (Pseudo-SLC), perhaps in the next 5-10 years. Pseudo SLC is using MLC NAND as single cell, so emulating SLC. It improves significantly on MLC issues such

In the military simulation market the ability to access bigger storage files more quickly could transform simulation training to a more user-friendly and realistic experience

as endurance and speed, whilst coming some way toward the specifications of SLC. It makes no sense for Flash manufacturers to produce such small volumes of SLC, when most designers will be happy with pseudo, as it provides design flexibility and improved longevity.

However, all these new technologies are still very much in their infancy and have not yet matured enough to start implementing into consumer products let alone future defence applications. It will take years before we even start to see the next generation of memory on the frontline, as the testing and certification process is long and arduous, for good reason.

Conformal Coatings are also going through change and these can be dictated by the MIL standards. Acrylic, Epoxy, Silicone, Polyurethane or Urethane and Paraxylyene, to name a few, all have pros and cons and different attributes. Coatings will always evolve and, like all things bound for the military, will require extensive testing to ensure longevity and performance for the harshest of environments and operating conditions.

Ideally the wish list for next generation of storage will consist of the follow attributes;

- Cheap to build and fixed BOM
- Holds over 10TB of data
- Faster than RAM
- Consumes little power
- Has no loss of data
- Survives extreme temperatures

Ethical Issues

What about the ethical points to consider? Recently Jactron were asked to provide memory for a military application. The only suitable memory available under the specification required by the OEM was made in Japan. Given Japan's ethical stance on providing technology into military applications, the OEM was unable to source the required part. In addition, Jactron have also been asked to provide memory for a critical weapons application, but the manufacturer would not accept the component we offered as it was manufactured overseas and not in the UK. Now the OEM has no memory solution and thus, a redesign which will cost time and money and certainly a delay to the programme. So designers of these systems need to consider the ethical, compliance and security issues from the outset. This is an area where Jactron can save time and money by advising and recommending suitable solutions.

Summary

As the next generation of memory enters into the market it will be a good number of years before we will see this filter into the military, primarily in a test and evaluation capacity. There is no doubt from industry that the next generation of memory and embedded storage is here and has made a giant leap forward – probably the biggest since 1989. The question industry has to ask itself is how quickly can we incorporate this new technology into applications destined for the military as a retrofit, upgrade or new product development? Ultimately, the requirement will be driven by the customer and the OEMs – the companies with the R&D muscle to drive these changes. DRAM sales have continued to grow during 2015, predominantly for servers and big data centres.

However, we mustn't forgot the ethical issues which must be taken into consideration when supplying parts for military bound hardware, so these conversations need to be held and sometimes awkward questions need to be asked from the outset.

About Jactron

For over 25 years Jactron has been providing specialist memory and storage solutions for high performance applications and are considered number one for our customer service and product knowledge. Jactron is the industrial division of Simms International plc, who are one of the leading distributors of memory solutions in the UK. Jactron are focused on delivering memory and storage solutions to the Aerospace, Defence, Energy, Marine, Medical, Telecommunications and Transportation industries.

We offer impartial technical advice for the products we distribute on behalf of some of the world's leading manufacturers which include Innodisk, PRETEC, ATP and APRO, ensuring that our customers receive the appropriate solution for their application.

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21st Century Data Storage in an Age of Net Centric Collaboration

Mary Dub, *Editor*

"In Iraq, U.S. forces who recovered computers used by al-Qaida consistently found Google Maps information on them. Insurgents were using the same databases as U.S. forces to view streets, consider get-away routes and plan ambushes. The discoveries showed how one kind of U.S. tactical advantage was eroding. We will derive our future advantage from the ability to store, access and analyze unique data, and deliver those resources through our networks to the point of need, better and faster than our enemies."
Armed Forces Journal 2012[1]

A fighting force that cannot keep up with the commercial world cannot keep up with the technologies used by its adversaries

21ST CENTURY warfare is based on the premise that western forces can establish information dominance. This means, as the quote from the article says, that we can store, access and analyse unique data faster than our enemies. This is a major challenge to western forces against a cunning enemy often trained in computer science at good universities using all the available methods of the best in 2015 consumer electronics. The challenge for western military is to ensure that the speed and agility of today's enemy can be challenged by the tactical edge delivered by the capability to move data to and from the last tactical mile, that is, the dismounted soldier on the ground.[2]

Establishing Tactical Edge on the Battlefield

Unfortunately, soldiers on the battlefield are routinely horrified at the gap between what they can do at home with their smartphones and what they can do with military-supplied comms gear in the field. A fighting force that cannot keep up with the commercial world cannot keep up with the technologies used by its adversaries. A second driver of network evolution is the advent of Big Data. The US Department of Defense has invested in satellites, planes, helicopters and unmanned platforms and pursued an incredible range of high-technology sensors to deliver data to enhance situational awareness. But in virtually every instance, the network required to move these vast amounts of Big Data has been a lesser concern. Programs such as Gorgon Stare, Blue Devil 2 and ARGUS are beginning to produce hyper-scale data on the order of one petabyte a day. No network can move all of the data collected, and no analytic tool can ingest it. Currently, the best that can be done is about 10 terabytes an hour, leaving about two-thirds of the collected data unreviewed.[3]

USAF Netcentric Collaborative Targeting

As an illustration of the complexity of the data storage and access required for analysing data, the funding request for Network Centric Collaborative Targeting (NCCT) is an example of the requirements. This is a shortened summary of the demands. There is a need for technologies and sub-nodal analysis tools to horizontally and/or vertically integrate network collaborative Intelligence, Surveillance and Reconnaissance (ISR) sensor systems within and across intelligence disciplines. This includes Signals Intelligence to Signals Intelligence (SIGINT-SIGINT) correlation and Ground Moving Target Indicator to Signals Intelligence (GMTI-SIGINT) correlation. Also, we need to determine which nodes of the adversary's Command, Control, Communications, Computers, Intelligence (C4I) network to engage or protect to achieve desired effects, and model execution plans to determine the need to disrupt or monitor the required network aim-points in order to redirect activities based on changing battlefield conditions.[4]

NEXT GENERATION MILITARY GRADE MEMORY AND STORAGE SOLUTIONS

Lockheed Martin Allies with Cleversafe

To facilitate the complexity of handling not just Big Data, but Large Data including Full Motion Video, Lockheed Martin has linked with Cleversafe to provide secure, distributed storage cloud offerings to enhance the performance of Active Archive, Data Security, Still Imagery, Full Motion Video (FMV), SharePoint Storage Enhancement, and Distributed Computing. "Our alliance allows Lockheed Martin and Cleversafe to deliver Mission On Demand™ Storage Clouds to our customers around the globe, meeting their growing need to store massive amounts of data being collected," said Bob Eastman, Vice President at Lockheed Martin's IS&GS-National Information Systems.[5,6]

Handling Zettabytes of Information

The scale of the storage issue for government agencies like the US Department of Defense is huge. According to IDC (International Data Corp), the total amount of digital information created and replicated surpassed 4.4 zettabytes (a zettabyte is 1,000 exabytes) in 2013. The size of the digital universe is more than doubling every two years, and is expected to grow to almost 44 zettabytes in 2020[7]. At the petabyte-scale, data integrity suffers when system size is 10 billion times larger than the bit error rate of hard drive data. Data availability suffers when hundreds of drives fail every day and require a week to rebuild. And another salient issue is that data security suffers with millions of devices and multiple copies in multiple locations. Cleversafe's software platform uses an innovative approach for cost-effectively storing large volumes of unstructured data while ensuring security, availability and reliability. Cleversafe's storage technology uses Information Dispersal Algorithms to separate data into unrecognizable "slices" that are distributed via network connections to storage nodes locally or across the world.

Memory and Storage Concerns

Standing back from the issues around the scale of data, the fundamental question is what is the data for and how is it going to be analysed and used? Without knowing the answer to these questions it is impossible to assess the appropriate storage method. There are secondary priorities that can become first order priorities if they are not addressed effectively. These are security from a range of threats from everything from cyber attack, to power failure, to seizure by the enemy, to insider threats, to failure to scale, to latency and the need for encryption in many forms. There are also the stringent demands of interoperability when working with allies in coalition. The criteria that should be attached to choosing one method of storage over another are neither simple nor straightforward.

Flash Memory and DRAM Meet Constraints of Moore's Law

Don McBarnet, *Defence Technology Writer*

Despite many strengths, Flash does have a limiting weakness – while its speed and random read access is far superior to traditional hard drives, in heavy use, longevity is reduced

TAKING A snapshot of data storage technologies is a picture of a consumer-driven industry changing at a rapid pace producing disruptive change in handheld technology, computing practice and ways of warfare. The pace of change is breath-taking. Gordon Moore, co-founder of Intel and Fairchild Semiconductor observed that the number of transistors in a circuit doubled every two years. However, that trend is changing. The constraint is now one of size. Returning to Flash, which is a form of EEPROM (electrically-erasable programmable read-only memory). Flash is a non-volatile memory type. This means that it does not require power to maintain stored data integrity, so a system can be turned off – or lose power – without losing data. Flash has low power demands and it is rugged; it is more resistant to the high-g (gravitational acceleration) bumps and drops mobile computing devices often receive in use. This rugged nature allows the drives to maintain function through these events, which saves data. Flash is solid state storage, storing data using electricity in surface-mounted chips on a printed circuit board (PCB) and offers fast retrieval, developed in 1984 by Dr. Fujio Masuoka while he was working at Toshiba in Japan[8]. NOR and NAND flash are named after the technology of the floating gates of the memory cells that hold data. Despite many strengths, Flash does have a limiting weakness – while its speed and random read access is far superior to traditional hard drives, in heavy use, longevity is reduced. This reduction is due to flash's relatively limited tolerance for write-erase cycles.[9]

DRAM Data Storage

DRAM or dynamic random access memory is a type of memory that is typically used for data or program code that a computer processor needs to function. DRAM is a common type of random access memory (RAM) used in personal computers (PCs), workstations and servers. Random access allows the PC processor to access any part of the memory directly rather than having to proceed sequentially from a starting point.[10]

The Operation of Moore's Law: The Search for Smaller, Faster, More Effective

The competitive drive by integrated circuit manufacturing companies like Intel, Micron and Samsung to develop and gain market advantage from technological leadership is producing change. Toshiba and other major manufacturers of planar floating gate NAND flash are setting those engineering efforts aside and focusing development on 3D NAND, also known as vertical charge trap or floating gate flash, and other 3D memories. Scott Nelson, vice president in charge of Toshiba's memory business, said planar or 2D NAND flash will continue to be sold because there are still many "lower density" applications for it. But the economics of shrinking the node below 15nm don't make sense. In 2013, Samsung became the first to introduce a vertical TLC (Thin Layer Chromatography) "V-NAND", a 32-layer cell structure based on Charge Trap Flash (CTF) technology and vertical interconnect process technology to link the cell array. By applying the latter technologies, Samsung's 3D V-NAND can provide over twice the scaling compared to its 20nm-class planar NAND flash.[11]

Santa Clara, California Flash Memory Summit

This issue was discussed at length in California at the Santa Clara Flash Memory Summit 2015 . The critical issue is that 2D planar NAND is limited by the shrink factor. 10 nm (or 9 nm) would be the last node (TLC), but this risks cell-to-cell interference. This is why Samsung and others are producing V-NAND. This, according to Samsung, provides up to twice the endurance of planar NAND.[13] V-NAND decreases its electric field because its cells are slightly larger, and employs CTF-based insulators eliminating the risk of cell-to-cell interference, resulting in superior retention performance. According to *Market Realist*, com Samsung V-NAND provides up to twice the endurance of planar NAND[13]. In comparison between 3-bit and 2-bit, Samsung 3-bit V-NAND shows endurance similar to that of 2-bit planar NAND, and even better performance in heavy workloads. V-NAND also shows a sustained P/E (Program-erase) cycle for longer periods of time.[14]

Micron Profits from 16-nm Planar NAND and Follows with 3D V-NAND

16-nm planar NAND is considered to be the world's smallest planar NAND lithography.[15] The physical dimension of NAND is its lithography. By employing this technology, Micron can manufacture planar NAND drives with the lowest cost-per-GB prevalent in this space. 16-nm TLC NAND flash memory is thought to strengthen Micron's portfolio from a cost perspective in the retail and consumer segments. Management stated that many channel customers have bought its TLC NAND for SSDs, consumer drives, and memory cards. But Intel/Micron 3D NAND products are making their entry into the market in the second half of 2015.

Intel and Micron's 3D XPoint

Intel and Micron are developing a 32-layer 3D NAND flash based on a floating gate memory cell; they also recently announced a resistive RAM (RRAM) memory called 3D XPoint[16]. The 128Gbit chip, based on the new 3D XPoint technology, increases performance and resilience by up to 1,000 times over planar NAND. Intel and Micron said their 3D NAND would hold 256Gbits (32GB) or 384Gbits (48GB) per chip depending on whether it is produced in two-bit per cell or three bit per cell technology. Micron's and Intel's 32-layer 3D NAND will focus on cutting costs and increasing capacities, while their new 3D XPoint RAM will replace some DRAM and NAND flash for high-performance applications, such as big data analytics. Intel and Micron heralded 3D XPoint RAM as "the first new class of memory since 1989," referring to floating gate NAND.

Confronting Pentagon Weakness in IT Acquisition

Don McBarnet, *Defence Technology Writer*

DoD Cloud Computing Goal:
"Implement cloud computing as the means to deliver the most innovative, efficient, and secure information and IT services in support of the Department's mission, anywhere, anytime, on any authorized device."
The US Department of Defense, Cloud Computing Strategy[17]

The Joint Information Environment is a robust and resilient enterprise that delivers faster, better informed collaboration and decisions enabled by secure, seamless access to information regardless of computing device or location

WHILE THE pace of change in world computing is responding to Moore's Law and its constraints, the US Pentagon is on another time plane, not of its own making or choosing. But it is going slowly, very slowly. Congressional challenge to funding bills has not made the process any faster. As a result, the Department of Defense has been analysing this issue of speed. And here speed is measured in months, but is really years. According to a Defense Science Board analysis of 32 major automated information system acquisitions, the average time to deliver an initial DOD program capability is *91 months*, once funding is approved. This is two to three times the average industry IT refresh cycle time, making it difficult to keep pace with user needs and technology evolution.[18] But they know this and are aware of the problem. They are also committed to change. The Department of Defense has begun this transformation by establishing a set of initiatives that are aimed at achieving improved mission effectiveness and cyber security in a reengineered information infrastructure. The result of this new effort will be the Joint Information Environment, or JIE. The Joint Information Environment is a robust and resilient enterprise that delivers faster, better informed collaboration and decisions enabled by secure, seamless access to information regardless of computing device or location. The new strategy is based on Efficiency, Agility, and Innovation.[19] This move will embrace a cultural shift, changing from a focus on the acquisition of materiel solutions to the acquisition and consumption of cloud services.

Department of Defense Energy Use Demands and Cost

While Congressional approval of budget is always the first hurdle to a project, another issue is central to Department of Defense choice of software for its data storage and retrieval systems energy consumption. The Department of Defense (DOD) is the single largest energy consumer in the nation. As the largest owner of federal data centres, with 772, the DOD has more than twice as many centres as any other agency. By consolidating some of its data centres, DOD could have a significant positive impact on energy savings for the federal government.[20] And the consequence of these savings would be to use more commercial cloud computing, subject to important national security considerations. The DOD is implementing the use of cloud computing as part of its savings effort.[21] Of course, United States and Department of Defense levels of encryption would have to be adhered to.

The Energy Cost versus Modernisation Dilemma

According to the Federal Energy Management Program (FEMP), a data centre can consume as much as 100 times the energy of a typical office building. As server power becomes more concentrated and servers become more energy-efficient, one impact is that, in many cases, power and cooling capacity will be the primary constraints to the expansion of computational capacity within a data centre. Server hardware would no longer be the primary cost component of a data centre. This represents a significant shift in data centre economics that threatens to overwhelm the advances in chip efficiency that have driven the growth of digital information during the past 30 years.[22]

NEXT GENERATION MILITARY GRADE MEMORY AND STORAGE SOLUTIONS

Commercial Cloud Use and milCloud

In 2015, the Department of Defense is moving its storage facilities to the cloud to lower costs, improve technology and upgrade security, according to Acting Chief Information Officer Terry Halvorsen.[23] According to the National Institute of Standards and Technology, cloud computing is a model for enabling on-demand network access to a shared pool of configurable computing resources – networks, servers, storage, applications and services. This move to commercial cloud computing represents a significant change in policy, so Terry Halvorsen is committed to alerting industry: "Industry needs some consistency, so I've got to … let industry know ahead of time [what we need]," and when a baseline changes.[24] What is milCloud? MilCloud is said to offer an integrated suite of capabilities that can make the development, deployment and maintenance of secure DOD applications more agile. And of course, defining security is a central conundrum. The definition of security is evolving: "I think [relatively sensitive data] is a much smaller portion of our data than we think it is," Halvorsen added. The process is rough and ready and Halvorsen is using a process called 'kluging' – a computer jargon word for inelegantly patching together systems to make them workable.

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Memory for the Future

Mary Dub, *Editor*

Storage and retrieval of data for the defence industry will always be against a backdrop of a wily and skilful enemy who will be using the same or similar devices, but perhaps in a different or more effective way

WRITING ABOUT the future, even the short-term future in the field of semi conductors is high risk. Why? Because technological change drives manufacturing industry competition for the consumer market which drives government policy. And in this field, the level of innovation in the consumer market frequently leads defence ministries acquisition.

What is New Now in Industry?

NAND flash was invented by Toshiba Corporation in 1984 and, while its architecture has been rapidly evolving over the years, its planar structure remained largely unchanged. However, the Korean corporation, Samsung Electronics, plans to concentrate on expansion of production capacities used to make its 3D V-NAND memory.[25] According to Samsung, V-NAND also applies innovative Charge Trap Flash (CTF) technology, which prevents data corruption caused by cell-to-cell interference. So the synergy of both structural and material innovations leads to improved speed, power efficiency and endurance. Samsung says that V-NAND does not need to go through a complex program algorithm to write data, and this enables the memory to write data up to two times faster than traditional 2D planar NAND flash memory.

However, other changes are afoot – HP is developing Memristor.

What is Memristor and How Does it Take Technology Forward?

According to Martin Fink, HP Chief Technology Officer and Director of HP Labs, some see Memristor as the new step forward[26]. Memristor is put forward as a possible replacement for both DRAM and Flash. How would Memristor work? Instead of using electrons, Memristor stores data using ions. Applying a charge to a Memristor moves these ions a tiny distance, resulting in a large, measurable change in resistance that remains the same even when power is lost. Unlike the ephemeral behaviour of electrons, ions actually stay where Memristor puts them. HP believes that they can be as fast as DRAM and as cheap as Flash while using vastly less energy than either. HP says that chipmakers believe they can make interconnects smaller than 10nm wide. Fink says HP researchers believe Memristors can follow suit. 3-D manufacturing is relatively easy: Memristor grids can be stacked several levels high with existing patterning, deposition and etch techniques. Storing multiple bits per cell is also eminently feasible. Again, according to HP, if all these elements are added together, incredible bit density can be achieved.

Leaving Memristor on one side, some also see possibilities in two other technologies that may be technically and commercially viable in the next decade. These are spin-transfer torque RAM (STT-RAM) and phase-change memory (PCM). I will leave to the future the development and evaluation of these two new techniques.

Cleversafe's Innovations

Lockheed Martin's ally, Cleversafe, pioneers REST. I will leave the description to Cleversafe. The second half of storage is retrieval. This is what REST does. The REST API works in a way that is similar to retrieving a Universal Resource Locator (URL). But instead of requesting a webpage, the application is referencing an object. Cleversafe says that the REST API access to storage offers several advantages; it tolerates Internet latency, provides for "programmable" storage and efficient global access to large amounts of data. Meeting the Highly Complex Challenge of Delivery of data at a Price

While reviewing development at an electron or ion level, or at a system or system architecture level, it is easy to get side tracked from the purpose at hand which is to deliver data to war fighters to fight and win through information dominance. A conflict always has at least two parties who are pitting their will against each other. Storage and retrieval of data for the defence industry will always be against a backdrop of a wily and skilful enemy who will be using the same or similar devices, but perhaps in a different or more effective way. The aim of storage or memory must always be retrieval for an immediate purpose, which needs to be fulfilled in a timely way. Therefore, there always needs to be an awareness that the delivery can be to remotely located war fighters and support personnel in restricted tactical environments.

Net Centric Connectivity

On operation, there will inevitably be high mobility combined with disconnected or intermittent connectivity, limited bandwidth and long latency. The US Department of Defense is aware that it must be careful not to jeopardize its mission by trading the confidentiality, integrity, and availability of DOD information for desired benefits.[27] Leaving aside for one moment the challenges provided by DRAM or planar or 3-D NAND, the fundamental issue is resolving the level of importance of strong and competing priorities. Federal Government organizations, whether civilian, defense or intelligence agencies, are faced with the conflicting objectives of sharing sensitive information, while at the same time keeping it secure from insider threats and outside attackers. Then there is the policy and commercial imperative of "Cloud first" initiatives.[28] Additionally, there are the numerous security controls from NIST 800-53[29], which must also be implemented. There will never be a simple solution for decision makers about which system or future system will be the best. The endless search for greater smallness and intensity of power in a chip is continuing. And if the data is stored well, retrieved faster, and analysed with insight, the technology will be there to provide the winning edge in conflict.

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